Appendix F | **2024 Edwards Aquifer Authority Reports**

Appendix F1 | **Comal Springs Riffle Beetle Report**

Comal Springs Riffle Beetle Population Assessment

Final Report

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Prepared By:
Matthew R. Pintar
Kyle T. Sullivan
BIO-WEST, Inc.
1405 United Drive, Suite 111
San Marcos, Texas 78666

Prepared For:
Edwards Aquifer Authority
900 East Quincy Street
San Antonio, Texas 78215

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1. Executive summary

Over the past decade, much progress has been made in understanding the biology of the endangered Comal Springs Riffle Beetle (*Heterelmis comalensis*; CSRB). Despite the advances provided by studies of the species in captivity and the wild, there has been little clear evidence of what environmental habitat characteristics affect CSRB abundance and occupancy in natural spring sites. This in turn has limited the ability to use data collected during semiannual biomonitoring to inform on the status of the species. The goal of this project was to conduct a study of the CSRB population across the Comal Springs system to 1) generate an understanding of the environmental habitat variables that relate to CSRB relative abundance and apparent occupancy and 2) develop model-based relative abundance estimates that can be used to inform biological monitoring.

Over a 13-month period from April 2023 to May 2024, five sampling events were conducted at 83 sites across the Comal Springs system. Various measures of site-specific habitat quality, such as water quality, organic material presence, and springflow were directly quantified. Additional local measures of springflow were generated using local discharge measurements from long-term monitoring data and total system springflow from USGS data. Generalized linear mixed effects models were developed for adult and larval CSRB, along with a similar co-occurring but non-spring-endemic species, *Microcylloepus pusillus*, for comparison. The Spring Island area supported the highest relative abundances of CSRB and was also the locality with the overall most stable habitat (consistent springflow), while Spring Run 3 and the Western Shoreline supported lower relative abundances of CSRB. Relative abundances were near-zero in Spring Run 1, where all sampled sites dried during summer 2023, and no CSRB were found in the Upper Spring Run.

Model results indicated that of the examined covariates, local springflow, or springflow attributed to each locality within the system (e.g., Spring Run 1, Spring Run 3, subsections of Spring Island), had the largest positive effect on relative abundance and apparent occupancy of CSRB. The only other covariate with an effect included in the final model was total biofilm coverage of cotton lures, which also had a positive effect for both life stages. These CSRB model results contrast with those of *M. pusillus*, for which there was no response to springflow or biofilm. Although this project included one of the periods of lowest total system springflow during the preceding 30 years, the range of conditions experienced over the course of the project provided environmental variation that informed the model of the effects of springflow on CSRB populations. The model results are perhaps more critical to the understanding of how CSRB are affected by environmental conditions given the potential for future long-term shifts towards lower system-wide flows as anthropogenic effects on the ecosystem grow.

The results of this study and its models have been adapted into a framework that can be used to assess the status of CSRB populations through the biological monitoring program. This framework can determine whether CSRB relative abundances are within historic norms and if observed relative abundances meet expectations based on observed values for environmental covariates. This study emphasizes the need for maintaining adequate springflow across localities to support each CSRB subpopulation. Additional study is needed to measure CSRB responses to higher springflows, assess if there is any true subsurface habitat use, and determine any drivers of lure biofilm.

2. Introduction

The Comal Springs Riffle Beetle, *Heterelmis comalensis* (CSRB; Coleoptera: Elmidae), was initially described as a species endemic to Comal Springs in Comal County, Texas (Bosse et al. 1988). It was later found 28 km away in San Marcos Springs, Hays County (Gibson et al. 2008), but it has not been found in smaller springs throughout the region. Much less is known regarding the smaller, isolated CSRB population in San Marcos Springs and its relationship to the Comal Springs population; only the Comal Springs population is considered here.

CSRB are brachypterous, meaning they have incompletely developed, non-functional wings (Bosse et al. 1988). The loss of wings is likely an adaptation to conserve resources (Zera and Denno 1997) in the stable environmental conditions provided by what historically has been the largest spring complex by discharge in Texas (Brune 2002), and in turn CSRB, as a species, are reliant on this spring system. In 1997, this led to listing CSRB as federally endangered, as the species is threatened by the combination of their limited distribution and increasing human development above the Edwards Aquifer (USFWS 1997). In particular, the species is threatened by excessive human withdrawal of water from the aquifer (USFWS 1997). There is also a recognized risk to the species if groundwater contamination were to occur (Bowles and Arsuffi 1993; USFWS 1997), although evidence for contamination of the aquifer has been minimal (Hutchins 2018). During the drought of record in the 1950s, CSRB presumably survived in hyporheic habitats, but it is unknown how adversely the species was affected or how long it took to recover. A total of 22 ha of surface habitat have been designated as critical habitat – habitat that is essential for a species' conservation – for CSRB in the Comal Springs system (USFWS 2013). A recent review of the species found no need for status change, stating that it remains at risk due to water withdrawals and land use change (USFWS 2024).

Following the listing of CSRB, a biological monitoring program with standardized semiannual sampling was initiated in 2004, and further conservation actions have been taken as part of the Edwards Aquifer Habitat Conservation Plan (EAHCP). An initial field survey (Bowles et al. 2003) did not find clear microhabitat associations of the species, but further work confirmed a spring association of CSRB across small distances (Cooke et al. 2015). A wide range of other studies have been undertaken to understand the species, which along with several unpublished reports and theses (full extent of work summarized in USFWS 2024), include publications on its diet (Nair et al. 2021), microbiome (Mays et al. 2021), response to environmental conditions (Nair et al. 2023), and its life history (Fries 2003, Huston and Gibson 2015, Kosnicki 2022). Life history research has led to the establishment of reproducing captive populations that could be used for reintroduction if a catastrophic event were to occur in the wild (USFWS 2022).

Despite 20 years of CSRB biomonitoring and extensive study of other aspects of its biology, little remains known about environmental factors that affect CSRB habitat occupancy and abundance in the wild. Mark-recapture has proven ineffective (Huston et al. 2015), females are seemingly continuously iteroparous (Kosnicki 2022), and there is a lack of seasonal phenological differences in the presence and abundance of each life stage (Bowles et al. 2003). These factors, along with the potential effects of springflow (drying sites) on CSRB, have made it difficult to study this species using many of the traditional methods used for assessing species occupancy and population size.

Given the challenges of studying wild CSRB populations, planning for a population study was initiated in 2021 under the guidance of the EAHCP Science Committee CSRB working group. The study was designed to assess CSRB across the Comal Springs system using more rigorous and spatially expansive surveys than were used in previous studies and in semiannual biomonitoring, while repeating surveys at the same sites multiple times over the course of one year and quantifying potential environmental covariates. The primary objectives of this study were to 1) generate an understanding of what environmental covariates relate to CSRB abundance and 2) develop model-based relative abundance estimates that can be used to inform biological monitoring.

3. Methods

3.1 Field methods

3.1a Sample sites and schedule

Sampling for CSRB was conducted using cotton lures at 83 sites across the Comal Springs system during a 13-month period beginning in April 2023 and ending in May 2024. We used the cotton lure methodology that was standardized following EAHCP implementation and is a modification of a previous method that utilized a similar-sized piece of cloth but was not folded into a cage. The cotton lure consists of a 15 cm × 15 cm square piece of 200 thread count cloth (60% cotton and 40% polyester) folded by thirds and placed into a 4 cm × 4 cm wire cage made from galvanized wire (Edwards Aquifer Authority 2016). At spring openings that had noticeable springflow, lures were placed just below the substrate—water interface and covered rocks to hold in place and block light from the lure (CSRB avoid light; Cooke et al. 2015).

Lures were left in situ for approximately 30 days (standard since 2004), allowing for colonization and growth of biofilm on each lure, which serves as a food source and potential attractant that encourages colonization of the lures by CSRB. Longer deployment of lures often leads to degraded lures that experience greater/earlier biofilm colonization and in turn fewer CSRB since the lure no longer retains its structure (Huston et al. 2015). Upon retrieval, any lures that were disturbed (e.g., dug up by raccoons or humans, or cloth pulled from the cage by crayfish), exposed to light, experienced heavy sedimentation (historically from heavy precipitation), dried out due to declining water levels, or were otherwise lost, were excluded from analyses.

The sampling schedule was planned so that three of the five sampling periods coincided with spring and fall CSRB biomonitoring (sampling periods 1, 3, and 5; Table 1). The first sampling period occurred when lures were set in April 2023 and retrieved in May 2023. Subsequent sampling periods began approximately two months after the preceding sampling period (Table 1). Lures were set and retrieved over a 2–4-day period.

This study coincided with one of the periods lowest total system springflow in 30 years. Although total system springflow during this study was generally low, it exhibited considerable variation across all of the study periods, with a maximum of 205 cubic feet per second (cfs) in January 2024 and a minimum of 66 cfs in July 2023 (Fig. 1). This variation in flow is important for the interpretation and applicability of results, as the range of conditions experienced during the study inform the models, and the conditions experienced outside of this range necessitate extrapolation of the model, which may not necessarily produce accurate results.

During spring 2023, the decision was made to proceed with this study over concerns about prolonged low-flow conditions because 1) effects of flow on CSRB during low-flow periods are probably more important to understanding CSRB populations than are only conditions within typical historic ranges, especially in the context of climate change, continued land use change, and potential long-term declines in springflow, and 2) there was no way to confidently predict future flows and plan to conduct the study under historically normal conditions. This is further emphasized by the conditions that occurred after the study end, during the nine months from May 2024 through February 2024, which exhibited both lower average springflow than during the study, and perhaps more critically, these months had less variation in springflow than observed during the study period.

Table 1. List of sampling periods with the start and end dates (earliest date lures were set, latest dates lures were retrieved) and the mean 30-day total system springflow over each sampling period.

Sample period	Start date	End Date	Mean 30-day springflow (cfs)
1	10 April 2023	10 May 2023	140
2	5 July 2023	9 August 2023	83
3	23 October 2023	21 November 2023	110
4	29 January 2024	1 March 2024	183
5	15 April 2024	17 May 2024	147

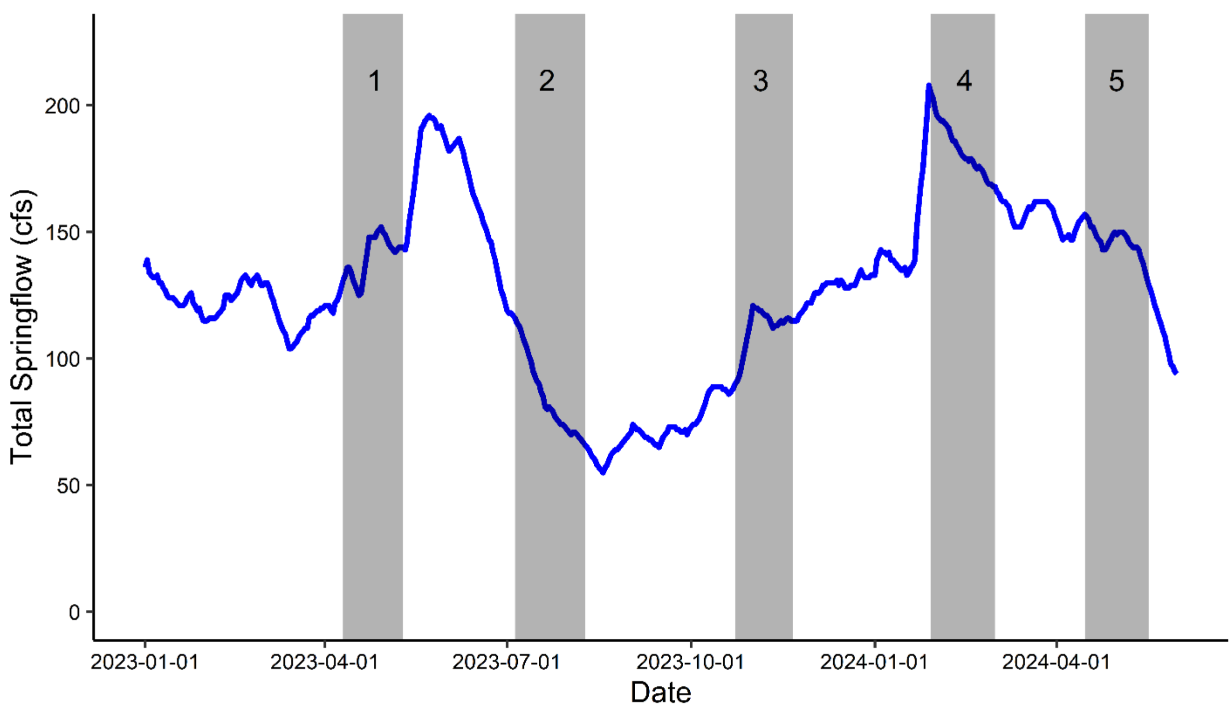


Figure 1. Daily total system springflow from Comal Springs from the start of 2023 through spring 2024 with gray shaded areas representing the five sampling periods (sampling periods 1–5; Table 1).

Initially, 80 sites were selected across five localities in the Comal Springs system. This included the 30 sites used for semiannual biomonitoring, which encompassed ten sites each in these localities: Spring Island, Spring Run 3, and the Western Shoreline. Fifty additional sites were added with ten sites each in these five localities: Spring Island, Spring Run 1, Spring Run 3, Western Shoreline, and the Upper Spring Run area (Fig. 2). Lucas et al. (2016) proposed three CSRB subpopulations based on molecular data: Spring Run 1, Spring Run 3, and Western Shoreline + Spring Island. We planned the sampling design around these subpopulations by balancing availability of active springs and spatial coverage of sites at each locality. Spring Run 2 was excluded because it was expected to have fewer active springs and was considered under recovery from restoration activities. The Upper Spring Run (headwaters) area was added to the study to determine the status of CSRB in that locality since it has not been as extensively studied as the rest of the system.

The additional 50 sites were initially randomly selected from known spring sites mapped by the Texas Parks and Wildlife Department (unpublished data), although their mapped sites were not representative of all active springs. Selected sites were modified when setting the initial group of lures in April 2023 to ensure that lures were set in active spring sites while balancing adequate spatial coverage across each locality and attempting to set lures within close proximity to randomly selected sites. Two additional sites were added in the Upper Spring Run for the final two sampling periods because more sites had active springflow during those sampling periods and we wanted expand the sampling effort to potentially detect CSRB in that locality. Lastly, one of the initial sites at the Western Shoreline was lost due to heavy sedimentation from construction by landowners on the hill above the site; sampling for the remaining two periods was moved to a nearby site (~10 m) that was unaffected by sedimentation.

Upon lure retrieval, lures were inspected and all macroinvertebrates were removed and examined using a microscope. Adult and larval CSRB and *Microcylloepus pusillus* (MIPU) were identified and counted; other spring-associated invertebrates (*Stygoparnus comalensis*, *Stenelmis sexlineata*, *Stygobromus* spp., *Lirceolus* spp.) were counted but are not otherwise considered here because the cotton lure sampling method is not specifically targeted towards these species and their abundances were too low for meaningful analysis. Most of the invertebrates were returned to their spring of origin after enumeration. Some CSRB larvae and less than 50% of adults were preserved in ethanol and transferred to USFWS San Marcos Aquatic Resources Center for genetic analysis; collection restrictions were placed by EAA to limit potential effects on the population study. Given high rates of overdispersion and low rates of recapture (<1%; Huston et al. 2015), it is not expected that this limited removal of CSRB from the system had any impact on subsequent counts.

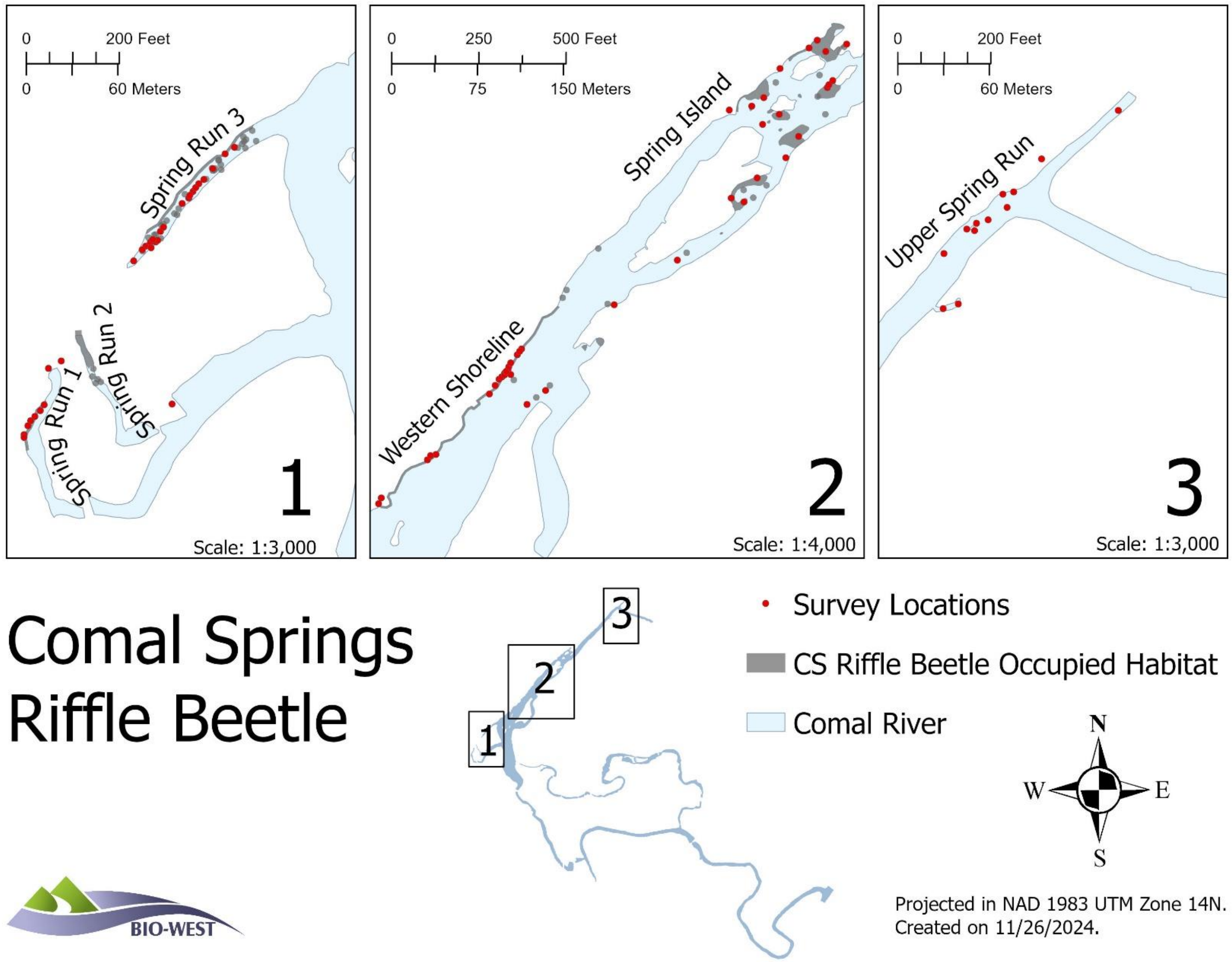


Figure 2. Map of the 83 sample locations (red dots) throughout the Comal Springs with CSRB occupied habitat (gray area; areas where CSRB have been recorded in the past ten years).

3.1b Covariates

At the time of lure set and/or lure retrieval we collected or calculated several spring-level, lure-level, and higher-level (locality or total-system) covariates. Water temperature, dissolved oxygen, conductivity, and pH were measured at lure set and retrieval with a YSI Professional Plus meter. Two measures of depth were collected at both lure set and lure retrieval: water depth was the distance from the water surface to the substrate surface (sometimes negative = substrate above water surface) and lure depth was the distance from the water surface to the lure. Lure depth was always positive when set (underwater), but sometimes negative (above water) when retrieved; any lures above the water when retrieved were excluded. The average substrate size was calculated when lures were set: the percent silt, sand, and boulder/bedrock (anything >256 mm) were estimated and a subsample of all other intermediate size substrate particles were individually measured. We also recorded at both lure set and retrieval whether four categories of organic material were present within the spring area: dead tree wood, dead tree leaves, tree roots, and live macrophytes or bryophytes. Wood, leaves, and roots were combined into an aggregate organic material presence/absence variable.

Site-level springflow (at each lure location) was measured via two methods at both lure set and lure retrieval. A Hach portable velocity meter was used to measure the water velocity (flow) at each terrestrial margin and orifice site, as well as at rocky upwelling sites. Initial (pre-study) investigation into more complex measurements of springflow using multiple recordings over a measured area at terrestrial margin sites using the Hach flow meter did not produce meaningfully different results than a single point measurement. This was likely due to the small area over which there is springflow at each site, the proportionally large area of the Hach probe relative to the lure and most spring openings, and the sensitivity of the probe to slight change in angles in these low-velocity springs. Similarly, during pre-study preparation and examination of sites, it was clear that measurements obtained from the Hach flow meter in upwelling sites were not consistent or reliable due to the influence of both lateral movement of water, proximity of the probe to the spring opening, and force of larger amounts of water impeding our ability to obtain flow measurements at deeper sites that were obviously flowing based on visual observations. Over 90% of flow meter measurements in upwelling sites were, as recorded by the Hach velocity meter, between 0 and 0.09 ft/s (the Hach meter has an accuracy of 0.01 ft/s).

To measure water flux from upwelling sites, a seepage meter was constructed from a circular bucket (diameter = 15 cm, area = 176.7 cm^2) attached to a garden hose with a valve and plastic bag for water collection (Appendix Fig. S1). Water was drained from the bag and air was purged from the system prior to each measurement. The seepage meter bucket was inserted into the substrate to isolate the spring opening, the valve opened, and the bag allowed to fill for 30–60 s. This process was repeated at each site three times within a ten-minute period, and the three measurements ($mL/cm^2/s$) were averaged. To make measurements comparable between the two methods, for 51 of the seepage meter measurements, we also measured the flow of water from each upwelling with the Hach flow meter. Of the 51 measurements, one standard deviation nearly overlapped with 0 (1.64 ± 1.32 cm/s) for the Hach flow meter measurements but was more than two standard deviations from zero when using the seepage meter (0.15 ± 0.06 $mL/cm^2/s$), suggesting the seepage meter effectively isolated water flowing from each spring site and produced a more meaningful number than the flow meter. We then compared the seepage meter flux to the flow meter reading and then converted the flux at each site to a flow measurement based on the linear relationship between these two variables (Appendix Fig. S2; flow = 12.909 × flux – 0.2902).

After each lure was retrieved and invertebrates removed, the lure was spread out on a white background and photographed (Fig. 3). The percent coverage of biofilm on the lures was then visually estimated for each of these colors: black, orange, yellow, purple, and green. Green, which may have been suggestive of light exposure and photosynthesis, only accounted for 5% coverage on a single lure. Total biofilm coverage (all colors summed) was used a final covariate in analyses. A total of 15 lures had their biofilm manually calculated by outlining each color patch and calculating the percentage coverage of each lure, however this procedure was not perfect due to overlap and intergrowth of different biofilm colors. It also took considerably more time and did not meaningfully differ from visual estimation. Lastly, we tried using automated color counting programs, but these tools could not distinguish discoloration from sediment from biofilm. It is also likely that non-visible biofilms cover parts of each lure, but we consider visual discoloration by biofilms to be representative of overall biofilm abundance.

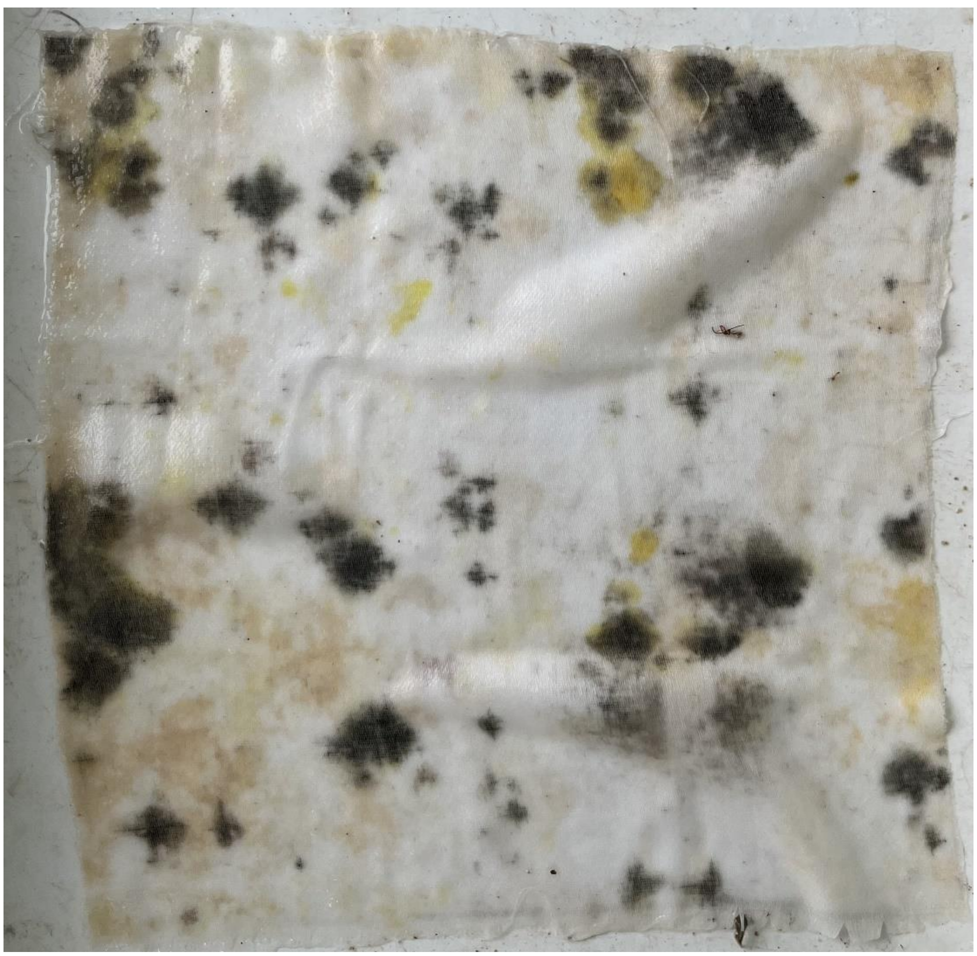


Figure 3. Photograph of one lure after retrieval exhibiting black, yellow, orange, and a small patch of purple biofilm (often blends in with black).

Because biofilm accumulates on lures and then degrades the lures as they remain in the system for longer periods of time, we initially explored using the number of days each lure was set in the system as a covariate. However, such temporal variation is usually observed with data from over longer time spans (10–60 days), and the number of days our lures were set had a much smaller range (26–35 days) with a mean of 30 days and standard deviation of 2.2 days.

We also explored the use of total system covariates such as total system springflow and precipitation, but these were ultimately dropped in favor of localized springflow (see section 3.2b below). Within each locality (Spring Island, Spring Run 1, Spring Run 3, and Western Shoreline), we created spatial groupings (sectors) of sites based on spatial proximity and similarity of sites (Appendix Figs. S3–S5). This was initially done to account for potential spatial autocorrelation in CSRB populations or environmental conditions, but ultimately it was only used to generate measures of local springflow.

For all of the covariates measured or calculated, we visually explored and interpreted the data, incorporated knowledge of the ecology of the Comal Springs system, and used automated model selection on initial generalized linear mixed effects models with the *dredge* function in the 'MuMIn' (Bartoń 2020) package in R (R Core Team 2024) to generate an initial set of final covariates. These final covariates were then included in the final model formulation and refined to achieve final models.

3.2 Statistical methods

The overall goal of this study component was to develop generalized linear mixed effects models (GLMMs) under a Bayesian framework to better understand what environmental factors influence patterns CSRB adult relative abundance and apparent occupancy. Specific objectives included: 1) assess variation of CSRB relative abundance between study sites; 2) quantify the effects of local springflow and biofilm on CSRB relative abundance; 3) derive apparent occupancy probability estimates for objectives 1–2; 4) fit GLMMs for CSRB larvae, and MIPU adults and larvae for comparison; and 5) develop a framework to demonstrate how GLMMs can be used as a tool for the EAHCP Biological Monitoring Program.

Other methods for assessing population sizes were considered during study design and explored in preliminary analyses, but ultimately were excluded because they produced either highly variable population estimates and/or violated statistical assumptions needed to obtain valid results. In particular, *N*-mixture models (Royle 2004) are commonly used in vertebrate surveys to estimate population sizes based on spatially replicated count surveys. However, this study of CSRB populations violated *N*-mixture models in two ways. The CSRB populations within each site were not closed, with the potential for movement to/from sites as well as births and deaths due to the short lifecycle (egg to adult in 6–12 months; USFWS 2024). Additionally, our data, and insect populations in general, tend to be over-dispersed and do not conform to the requirements of *N*-mixture models. Both of these assumptions that are necessary for *N*-mixture models can be relaxed in GLMMs to effectively model CSRB relative abundance.

3.2a Relative abundance model formulation

Patterns in CSRB and MIPU relative abundance were investigated by fitting overdispersed Poisson GLMMs (Breslow 1984). The same model structure was used of each species and life stage and formulated as follows:

$$y_{i,t,j} \sim Poisson(\lambda_{i,t,j}),$$

where $y_{i,t,j}$ is the observed relative abundance (counts/lure) for lure sample *j* during sampling event *t* at site *i*, and was assumed to be the outcome of a Poisson distribution with an expected value of $\lambda_{i,t,j}$. For each GLMM, a log link was used to regress expected values with a linear equation:

$$log(\lambda_{i,t,j}) = \alpha_i + \beta_1 local.springflow_{i,t,j} + \beta_2 total.biofilm_{i,t,j} + \varepsilon_{i,t,j},$$

where α_i is the intercept for site *i*, β_1 is the slope for the effect of 30-day local springflow average (cfs), β_2 is the slope for the effect of total biofilm (%), and $\varepsilon_{i,t,j}$ is an extra-residual term to accommodate additional site-event-sample dispersion. Methods for deriving 30-day local springflow average are described in Section 3.2b.

Site-level intercepts were assumed to be drawn from a Normal distribution with a population-level mean (μ_α) and variance (σ_α^2):

$$\alpha_i \sim Normal(\mu_\alpha, \sigma_\alpha^2)$$

Extra-residual random effects were assumed to be drawn from a Normal distribution with a mean of zero and site-event-sample variance (σ_ε^2):

$$\varepsilon_{i,t,j} \sim Normal(0, \sigma_\varepsilon^2)$$

Since occurrence is also a state variable of interest, apparent occupancy probability was estimated as a derived quantity to assess how it varies between sites and visualize its relationship with environmental covariates. Occupancy was considered apparent because true occupancy is confounded with detection (Kéry et al. 2010). So, like relative abundance, apparent occupancy is an index. Where applicable, estimates of apparent occupancy probability (ψ) were derived directly from relative abundance (λ) estimates using the following 1:1 function:

$$\psi = \Pr(y > 0 \mid \lambda) = 1 - e^{-\lambda},$$

where $e^{-\lambda}$ is the expected probability that relative abundance is equal to zero (Royle and Dorazio 2008).

3.2b Local springflow covariate derivation

Local springflow was derived using spring discharge data from two sources. First, discharge (cfs) data measured from eight stations in Comal Springs were obtained from the EAHCP biological monitoring program (Fig. 4). These data were collected from 2003–2024 in spring and fall of each year. Measurements were also conducted in summer when system-level river discharge decreased to specific low-flow thresholds outlined in the EAHCP (2012). Second, mean daily discharge (cfs) data from the Comal Springs USGS stream gage (#08168710; 1938–2024) were gathered using the R package 'dataRetrieval' (De Cicco et al. 2024).

A linear mixed effects model (LMM) was fit to predict local springflow using the R package 'glmmTMB' (Brooks et al. 2017). Discharge measurements at the eight monitoring stations described above was the response variable and Comal Springs mean daily discharge (hereafter 'total system springflow') on the date of station measurements was the predictor variable. Regression coefficients were estimated for each station by including station as a group-level predictor (i.e., random effects) that allowed their intercepts and slopes to vary randomly. For analysis, total system springflow was centered using the long-term average (1938–2024). Model performance was assessed based on conditional variance explained (R^2) and root mean squared error (RMSE). In addition, 10-fold cross-validation was conducted to evaluate how well the LMM generalizes to out-sample-data ($RMSE_{cv}$) and was estimated by calculating mean (± standard error) predictive accuracy across test folds. All LMM performance statistics and parameter estimates (± standard error) were summarized in a table. Relationships between station discharge and total system springflow were predicted using the R package 'ggeffects' (Lüdecke 2018) and visualized using the R package 'ggplot' (Wickham et al. 2024).

To link local springflow to CSRB lure sample data, a discharge time-series was predicted for stations closest to each site over the study period and 30-day local springflow average was calculated on the date of lure retrieval to approximate springflow conditions for the duration each lure was set. Local springflow at Spring Island was based on stations in closest proximity to each of its four sectors. Lastly, local springflow at Western Shoreline was approximated by subtracting Landa Lake Cable discharge from total springflow (Table 2). While this calculation also includes flow contributions from spring upwellings throughout the lake, it provides a more realistic approximation of springflow conditions at Western Shoreline compared to discharge at Landa Lake Cable exclusively.

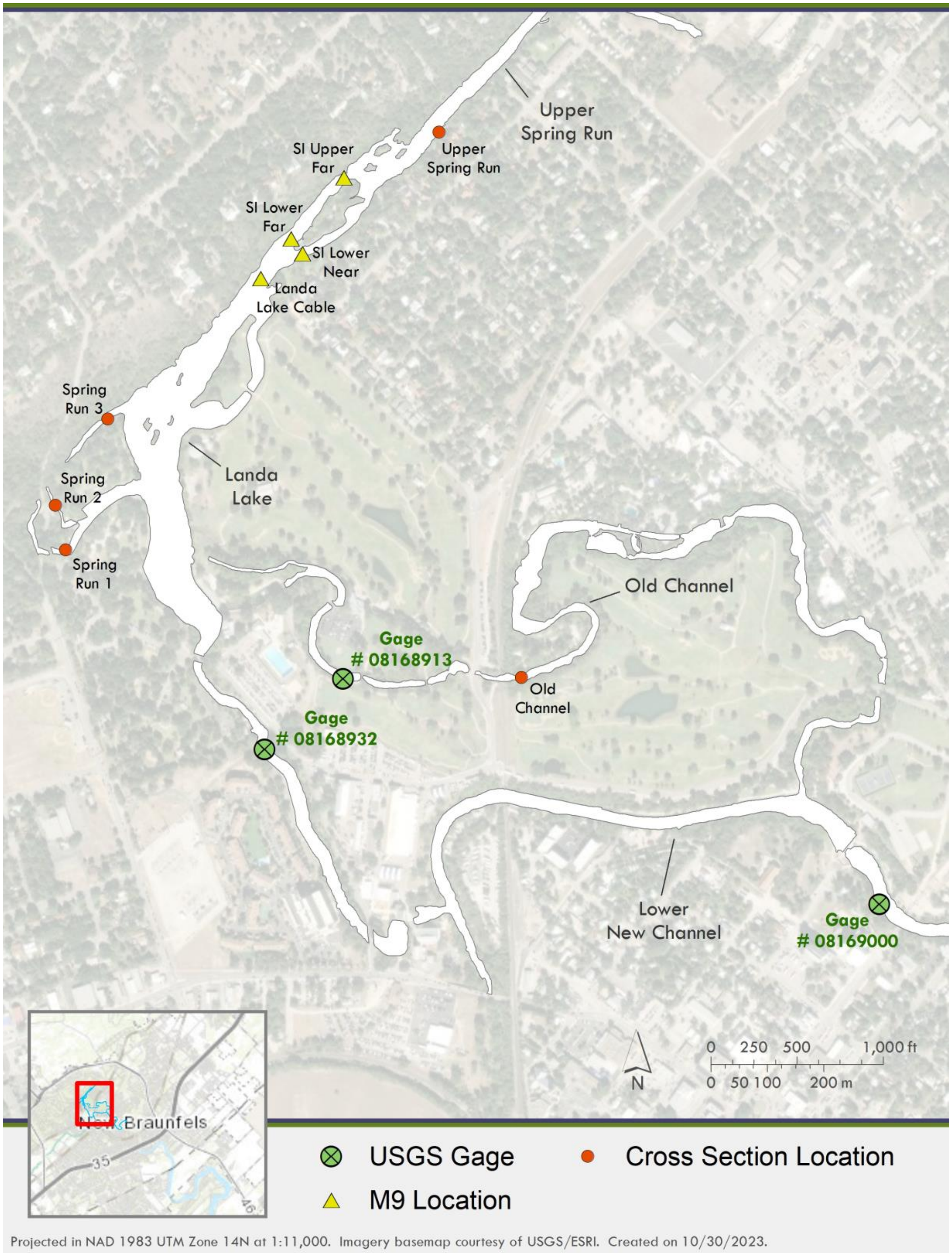


Figure 4. Locations of stations used to local springflow discharge Comal Springs. Cross section springflow measurements were conducted using a HACH FH90 flowmeter and adjustable wading rod. Spring at M9 locations were measured with an acoustic doppler device used by the Edwards Aquifer Authority.

Table 2. Springflow discharge stations used to assess local springflow effects on CSRB relative abundance at each sector per site (see Appendix Figs. S3–S5 for sectors).

Site (sector)	Station
Spring Island (A, D)	Spring Island Lower Near
Spring Island (B, C)	Spring Island Upper Far
Western Shoreline (A–D)	Total Springflow - Landa Lake Cable
Spring Run 3 (A–C)	Spring Run 3
Spring Run 1 (A–C)	Spring Run 1

3.2c Relative abundance model analysis and inference

All GLMMs were analyzed by means of a Bayesian framework with Markov Chain Monte Carlo (MCMC) methods using JAGS called from the R package 'jagsUI' (Kellner 2024). All priors were parameterized to express our current lack of knowledge about each parameter (Hobbs and Hooten 2015). Weakly informative normal prior distributions were used for the population-level mean and slopes for each covariate. Vague uniform prior distributions were used for all variance parameters. Before analysis, total biofilm was centered by its overall mean and 30-day local springflow discharge was centered using site-specific means. Posterior distributions for each parameter were estimated based on the 3rd sample from 80,000 iterations of three chains with a burn-in period of 20,000 iterations per chain. Model convergence was assess based on visual inspection of trace plots, the Gelman-Rubin statistic ($\check{R}$), and density plots for each parameter. Convergence was considered successful if trace plots showed good mixtures of MCMC chains, if $\check{R}$ was less than 1.1 (Gelman and Rubin 1992), and density plots showed similar shapes for each chain.

Multiple methods were used to evaluate model performance. Posterior predictive checks were used to assess consistencies in goodness-of-fit between observed and simulated data. Bayesian *p*-values (B_p) were calculated using the chi-squared discrepancy statistic to estimate the probability that fit of simulated data (χ^2_{sim}) was more extreme than observed data (χ^2_{obs}). Bayesian *p*-values close to zero or one indicated a lack of model fit (Gelman et al. 2013, Hobbs and Hooten 2015). Root mean squared error was also calculated for observed ($RMSE_{obs}$) and simulated ($RMSE_{sim}$) data as an additional measure of posterior predictive accuracy. Further, marginal and conditional R^2 were calculated to quantify variation explained by each model based on methods for GLMMs described by Nakagawa and Schielzeth (2013). Lastly, 10-fold cross validation was conducted to evaluate how the models generalize to out-sample-data. Predictive accuracy across test folds ($RMSE_{cv}$) was estimated using the R package 'jagshelper' (Tyers 2024).

Parameter estimates were based on the median of their posterior distributions and were qualified by uncertainty using 90% Bayesian credible intervals (BCIs). Summaries of all parameter estimates for each model are presented in a table. Site-level intercepts were visualized to assess spatial variation in mean relative abundance on its original scale (counts/lure) and apparent occupancy probability. Lastly, covariate relationships with relative abundance and apparent occupancy were visualized for slopes with

BCIs that did not overlap with zero. All graphical results were built using the R package 'ggplot2' (Wickham et al. 2024).

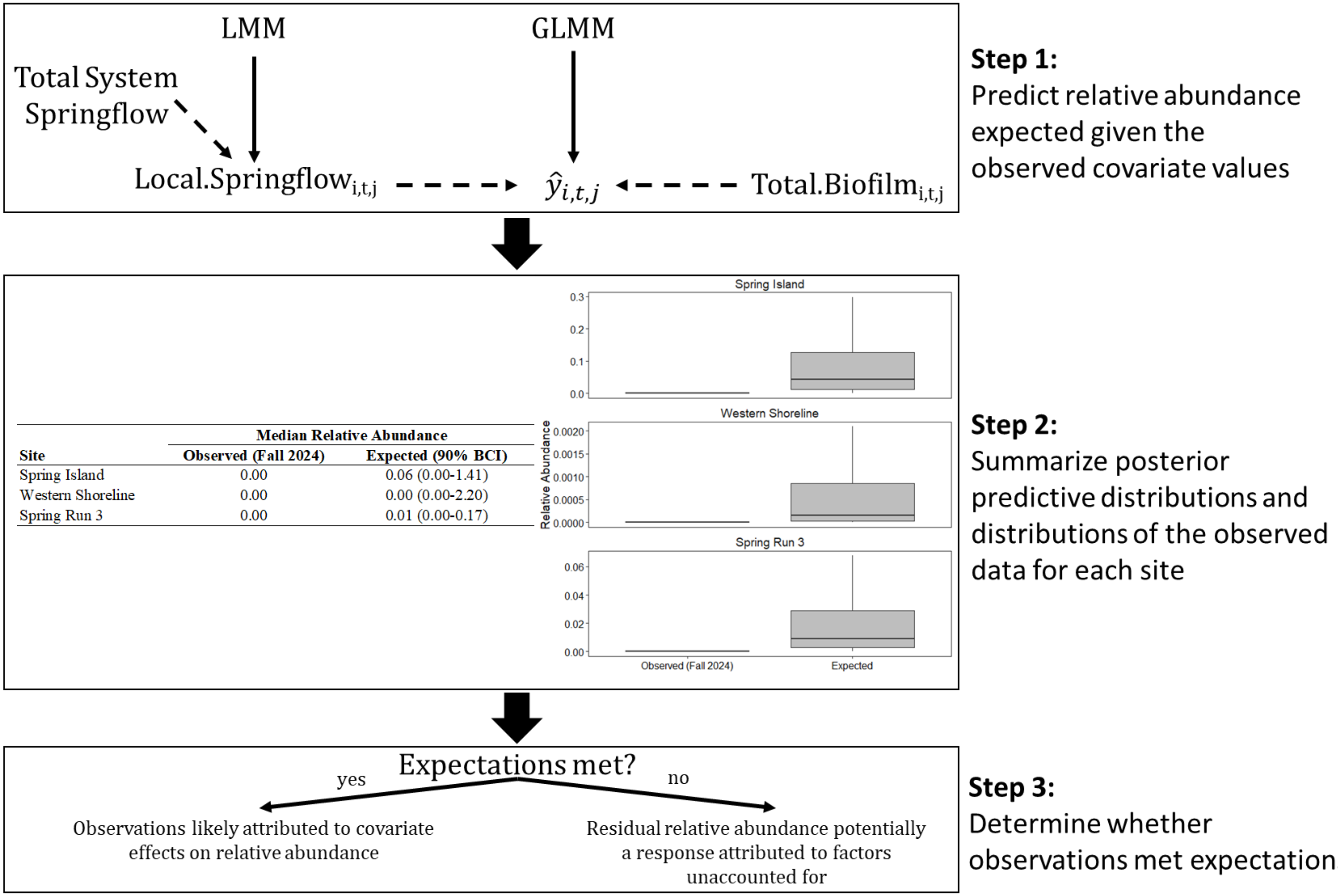
3.3d Framework for biological monitoring applications

The proposed framework aims to demonstrate how the GLMM formulated for this study can be used as a tool for the EAHCP Biological Monitoring Program to assess whether observed relative abundances of CSRB at a given time period met expectations. For CSRB, relative abundance can be used to assess population trends under the following assumptions: 1) relative abundance is a reasonably accurate representation of the population at each site; 2) sampling data are representative of the population – location of samples per monitoring event are selected in a manner that grants inference about each site (including locations not sampled); and 3) the GLMM is a reasonable description of the data, is able to mimic the data with acceptable accuracy, and can adequately generalize to new data.

To exemplify this approach, data collected during the fall 2024 EAHCP monitoring event were used to forecast relative abundance of CSRB adults. Lures were set for 27 days (8 October – 4 November) at Spring Island and 30 days (7 October – 6 November) at Western Shoreline and Spring Run 3 (10 lures in each locality; n = 30 lures total). Mean daily total system springflow during the duration lures were set ranged from 55–74 cfs and total biofilm on the day of lure retrieval ranged from 10–85%. A schematic of the proposed framework is illustrated in Fig. 5 and involves three general steps. For step one, 30-day local springflow average was first derived for each lure sample using the methods described in Section 3.2b. Expected values of each lure sample were then forecasted given their covariate values and the GLMM parameter estimates. Specifically, a posterior forecast distribution was generated by predicting relative abundance from each MCMC posterior sample for site-level intercept and covariate effect sizes (Hobbs and Hooten 2015).

For step two, model fit was first assessed by estimating RMSE (90% BCI) and visually inspecting residuals for fall 2024 predictions. Residual inspections included plotting a histogram and scatterplots for residuals versus predictions and each covariate fit using quantile regression (quantile = 0.5). Observed and expected CSRB adult relative abundance were then summarized at each site for comparison. First, median observed relative abundance was calculated for each site as a measure of population state and was compared to each sites median forecast estimate and its associated 90% BCI. Boxplots were also used to provide visual comparisons between observed relative abundance and posterior forecast distributions for each site. Outliers were omitted from each boxplot to help with interpretability. All residual diagnostic graphs and boxplots were built using the R package 'ggplot2' (Wickham et al. 2024).

Lastly, step three uses results from step two to answer the following question: does the observed data agree with expectations? If the answer was yes, it would be concluded that observations were most likely attributed to covariate effects. If expectations were not met, this would suggest residual relative abundance was potentially a response to other deterministic or stochastic processes not accounted for in the GLMM.



	Median Relative Abundance	
Site	**Observed (Fall 2024)**	**Expected (90% BCI)**
Spring Island	0.00	0.06 (0.00-1.41)
Western Shoreline	0.00	0.00 (0.00-2.20)
Spring Run 3	0.00	0.01 (0.00-0.17)

Figure 5. A schematic of the proposed conceptual framework illustrating how generalized linear mixed effects models can be used as a tool for assessing Comal Springs Riffle Beetle populations under the EAHCP Biological Monitoring program.

4. Results

4.1 Field measurements

4.1a Beetles recorded

Out of a total of 404 lures set during the study, 13 were lost due to disturbance and 38 were dry at the time of retrieval, resulting in 353 lures (samples) with complete data. All dry lures were found during the sampling period 2 (summer 2023) when total system springflow dropped dramatically from the start of the sampling period to the end (Fig. 1). In total, over 600 adults of both CSRB and MIPU were found, with the highest numbers around Spring Island, fewer at Spring Run 3 and the Western Shoreline, and only a single CSRB in Spring Run 1 (Table 3, Fig. 6). No CSRB were found in the Upper Spring Run, which was dropped from analyses, including from MIPU analyses to maintain equivalent comparisons between species.

Table 3. Total number of samples and larval and adult CSRB and MIPU found during the study, excluding all lures that were dry or disturbed.

Locality	Samples	CSRB larvae	CSRB adults	MIPU larvae	MIPU adults
Spring Island	90	93	402	56	330
Spring Run 1	39	0	1	6	5
Spring Run 3	87	27	126	12	154
Upper Spring Run	48	0	0	109	96
Western Shoreline	89	76	101	37	98
Total	353	196	630	220	683

Trends in mean abundance of both life stages of CSRB and MIPU did not show any clear temporal variation in abundance that could be indicative of phenological differences in abundance by season (Appendix Figs. S6–S9). For a thermally stable spring system and a species (CSRB) that primarily occurs in dark microhabitats, it is not surprising to find no phenological variation with season, but this narrow thermal tolerance could threaten the species if conditions were to change (Cooke et al. 2015, Polášková et al. 2022).

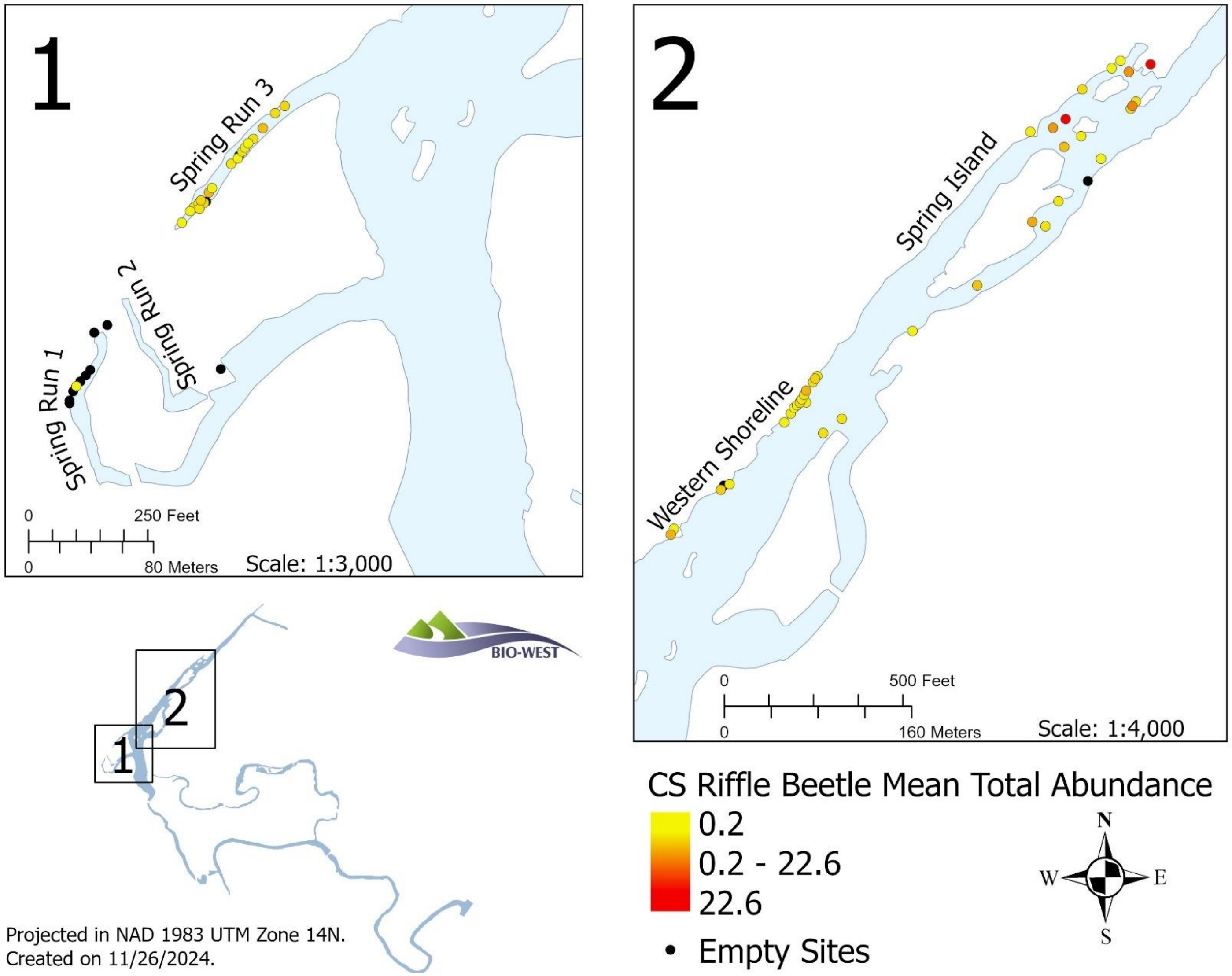


Figure 6. Locations where any individuals either CSRB life stage were observed (empty sites = no CSRB found) and mean total (adults + larvae) CSRB per lure across the duration of the study.

4.1b Covariates

Water quality variables showed little variation across the study and no clear relationships with beetle abundance, as was expected in a stable spring system (Appendix Figs. S10–S12). Some upwelling sites, particularly around Spring Island, exhibited higher dissolved oxygen levels (Appendix Fig. S10), which was likely related to their proximity to aquatic vegetation. At these sites and the microhabitats beetles occupied, obtaining accurate dissolved oxygen measurements of water flowing from the aquifer with a probe that was much larger than the spring openings was nearly impossible.

Conductivity dropped slightly when it rained prior to measurements, but still showed generally little variation across the system (Appendix Fig. S11). Lures were set at depths from just below the water surface (~2 cm) to over 2 m deep (Fig. S13), and CSRB and MIPU were found at sites across those ranges of depths. Substrate varied from sites that were nearly all boulder/bedrock to those that were all silt/sand (Appendix Fig. S14); beetles were found at sites across the range of substrate sizes. While preliminary analyses suggested that higher numbers of beetles may be found in smaller substrate sizes (Fig. 7), this was tied to higher CSRB abundances and smaller substrate sizes at Spring Island sites, which were the most stable (consistently under water and stable springflow) throughout the study.

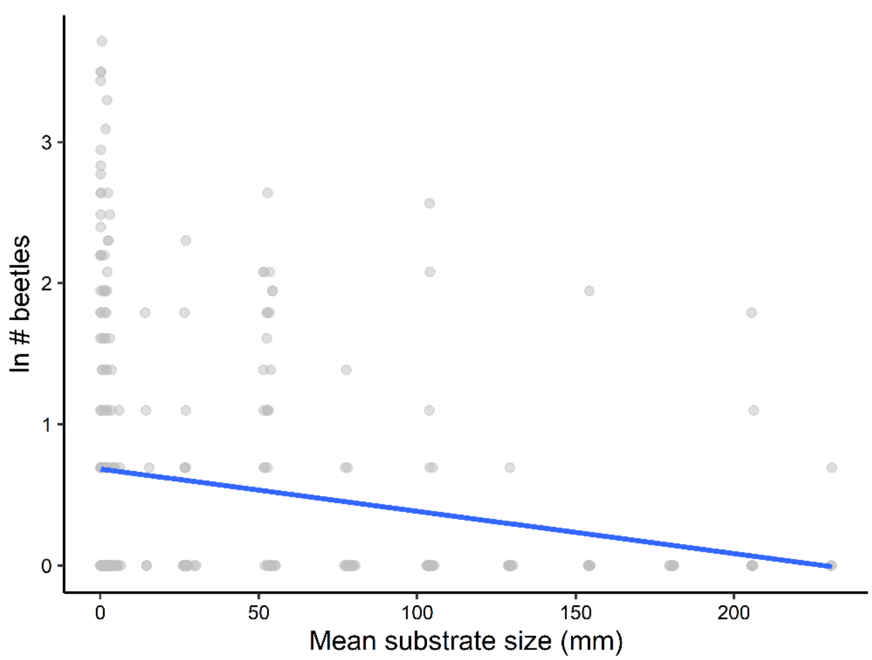


Figure 7. Initial comparison between natural log-transformed adult CSRB abundances and mean substrate size suggested an inverse relationship between the two.

Site-level springflow varied by site and locality across the five sampling periods (Fig. 8), however, there was no clear relationship between site-level springflow and beetle abundance (Appendix Fig. S15). Lures were always set in flowing springs, and beetles were found across the range of site-level flows observed. Initial analyses suggested a possible relationship between total system springflow and beetle abundance, and this was refined into a calculation of local spring flow described in section 4.2. Local springflow also accounted for potential effects of spatial group factors observed in initial data exploration.

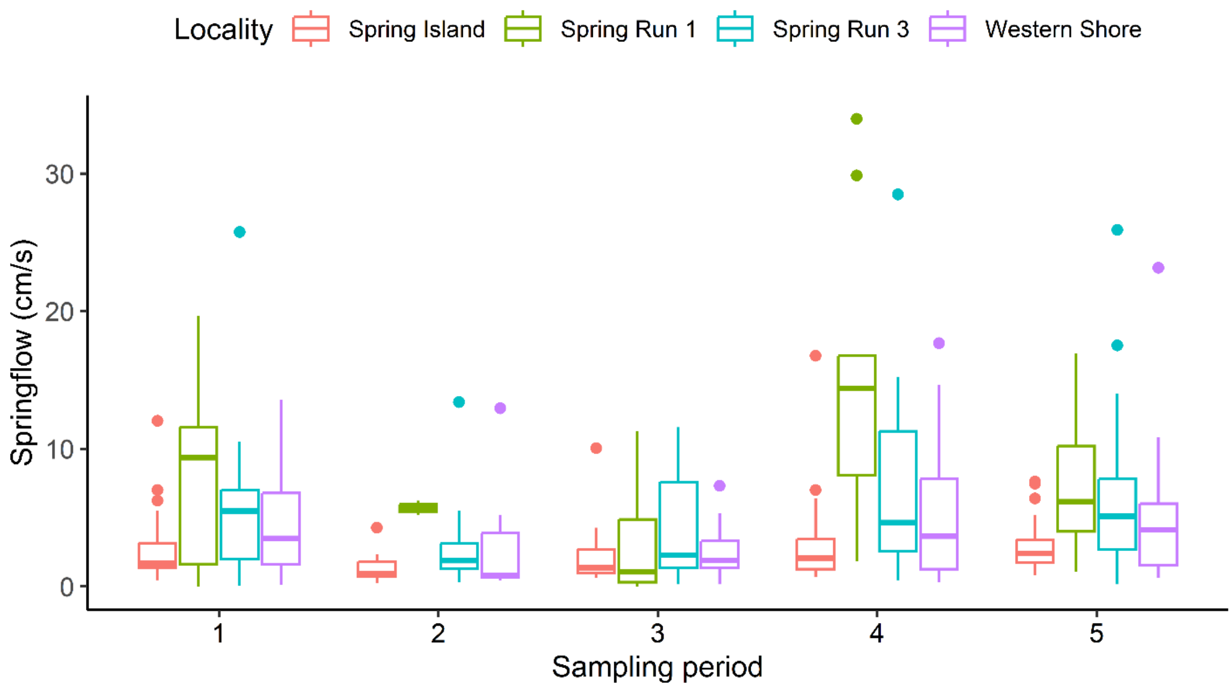


Figure 8. Boxplots of average site-level springflow (mean of starting and ending measurements) set by locality and sampling period.

There was no clear effect of the presence of any organic matter type in the spring area on the abundance of beetles (Appendix Fig. S16). At Spring Island, abundances of both life stages appeared higher when roots were absent, but this pattern was not consistent across other localities. Also at Spring Island, adult abundance trended higher and larval abundance lower when wood was present, but this trend was again not consistent across other localities. Even if beetles are attracted to organic material, any organic material on the spring surface may have no effect on near-surface beetle populations, while organic material deeper within springs that was undetected could have an effect on beetle populations. Organic material presence was excluded from subsequent analyses.

Estimated biofilm coverage on the lures varied widely among samples with no clear temporal or spatial patterns (Appendix Fig. S17). However, initial comparisons suggested a potential positive relationship between biofilm coverage and CSRB abundance (Fig. 9). Biofilm coverage and local springflow were the two covariates included in final analyses (see section 4.3).

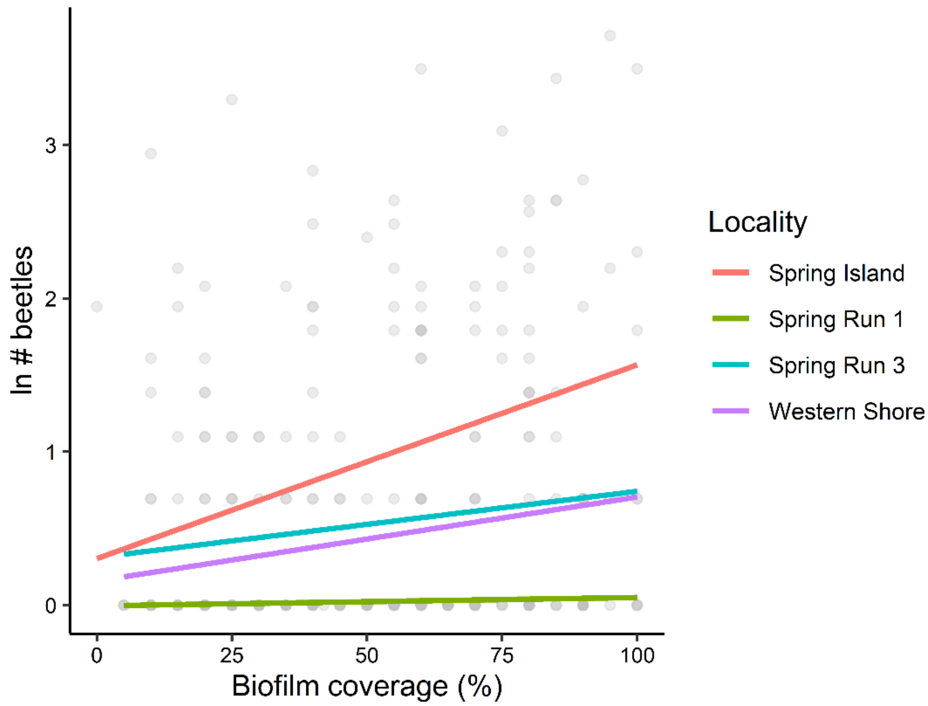


Figure 9. Scatterplot of natural log-transformed adult CSRB abundance and percent biofilm coverage on lures across the four sampling localities.

4.2 Local springflow

From 2003–2024, discharge across the eight monitoring stations ranged from 0–166 cfs (mean = 26 cfs) and mean daily total system springflow ranged from 55–446 cfs (mean = 200 cfs). Long-term (1938–2024) average for total system springflow was 280 cfs. Performance metrics demonstrated the fitted LMM explained a large proportion of variation in the response (conditional R^2 = 0.99), was able to predict training data with high accuracy (RMSE = 3.66 cfs), and generalized to out-of-sample data ($RMSE_{cv}$ = 3.80 ± 0.26) (Table 4). Functional relationships for local discharge at each station are shown in Fig. 10.

Table 4. Summary of parameter estimates, standard errors (SE), and performance metrics for the linear mixed effects model used to predict station-level discharge.

Parameters	Estimate	SE
Fixed effects coefficients		
Intercept	44.59	12.73
Mean-daily total system springflow	0.17	0.04
Random effects standard deviation		
Station intercepts	35.99	-
Station slopes	0.11	-
Predictive Performance		
$R^2_{conditional}$	0.99	-
Residual standard deviation	3.74	-
RMSE	3.66	-
$RMSE_{cv}$	3.80	0.26

Good performance displayed by the LMM supports that it is a reliable quantitative tool for characterizing local springflow conditions at each CSRB study site. This is further illustrated in Fig. 11, which displays a predicted time-series of local springflow at each station from 2001–2024 and demonstrates their agreement with empirical measurements conducted from 2003–2024. Therefore, 30-day local springflow average was calculated on the date of lure retrieval and included as a GLMM covariate (Table 5).

Table 5. Summary statistics for 30-day local springflow average (cfs) during the study duration (April 2023–May 2024) for discharge stations linked to each site.

Site	Station	Mean	Minimum	Maximum
Spring Island	Spring Island Lower Near	16.13	7.11	22.95
Spring Island	Spring Island Upper Far	22.94	13.63	31.02
Western Shoreline	Total Springflow - Landa Lake Cable	75.37	42.45	101.74
Spring Run 3	Spring Run 3	14.38	6.57	20.60
Spring Run 1	Spring Run 1	7.54	0.34	13.03

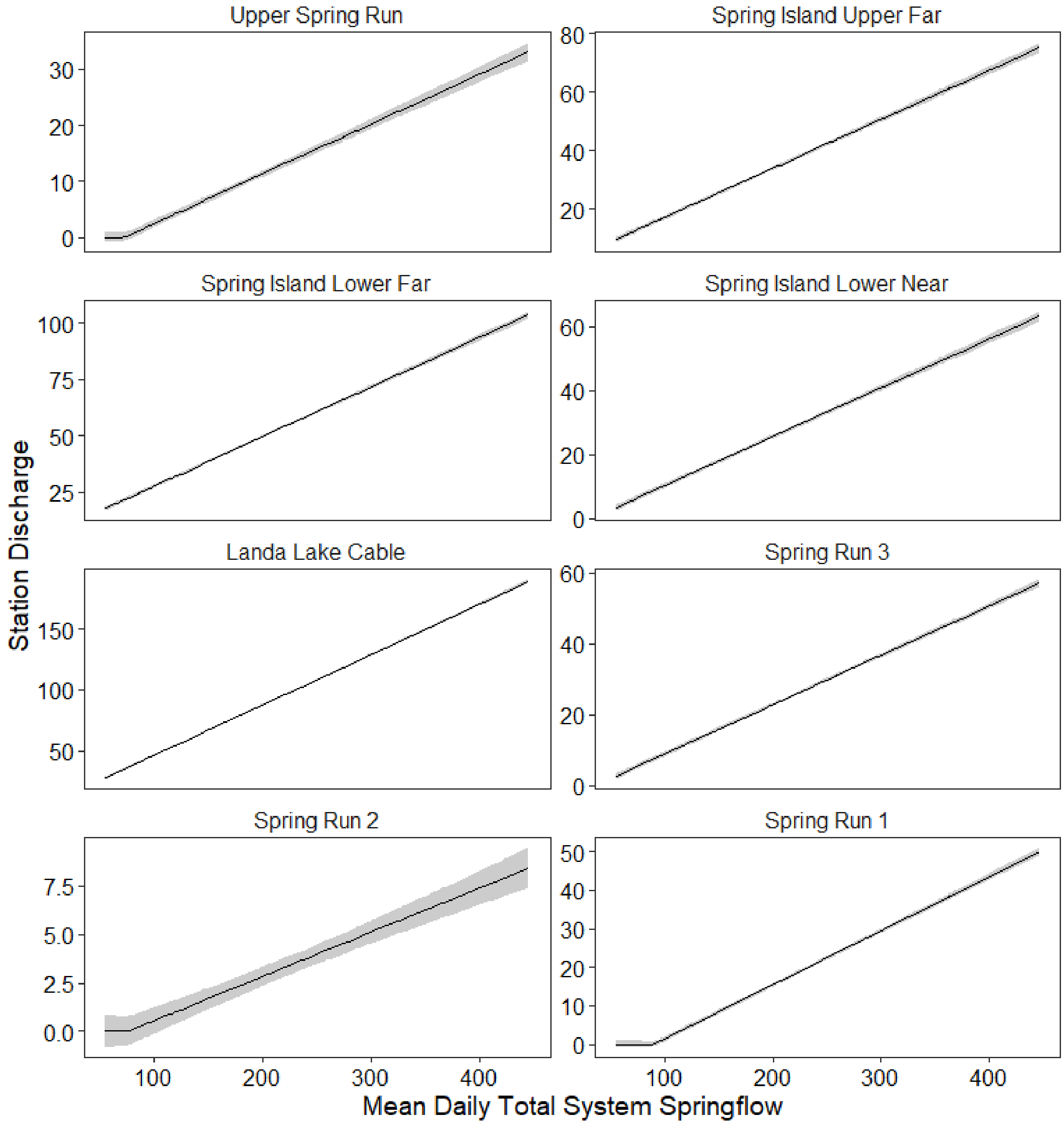


Figure 10. Fitted predictions of discharge (cfs) as a function of mean daily total system springflow (cfs) across at eight stations in Comal Springs. Solid lines and grey polygons represent the line-of-best-fit and ±1 standard error, respectively.

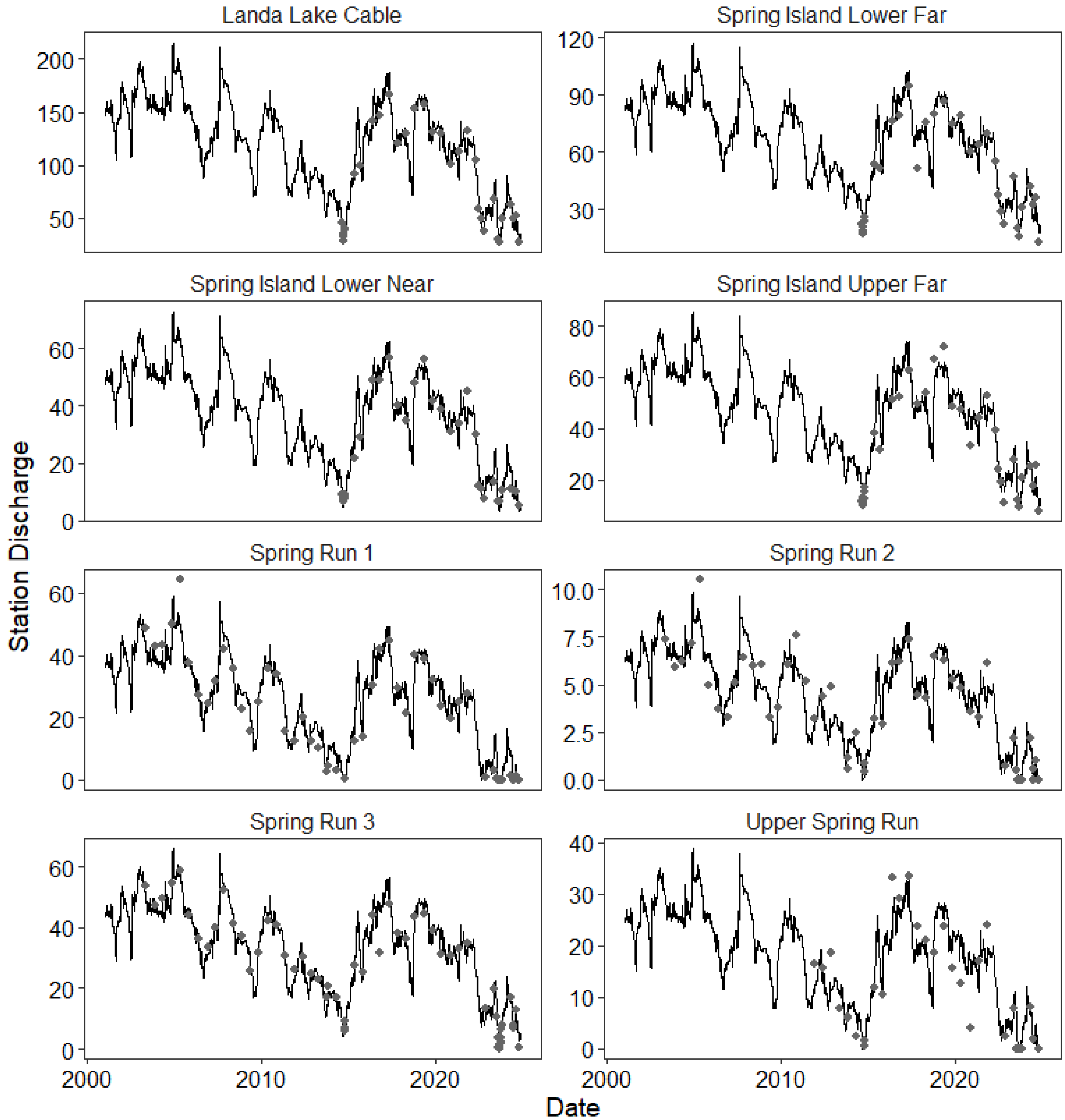


Figure 11. Local springflow time-series from 2001–2024 at eight stations discharge measurement stations in Comal Springs. Solid lines represent LMM predictions per station and grey data points denote observed discharge measurements from 2003–2024.

4.3 Relative abundance

4.3a Model evaluation

All GLMMs converged with trace plots showing adequate mixtures of MCMC chains and Ř less than 1.1 for all parameters monitored. Density plots of marginal posterior distributions also aligned among MCMC chains. Results from all goodness-of-fit assessments revealed adequate fit between model estimates and observed data. Marginal R^2 represents the variation explained by the site-level intercepts and slopes and estimates ranged from 0.64–0.85. Conditional R^2 includes the added variation explained by random effects, which ranged from 0.61–0.93 and explained 0.51–0.62 more variance than marginal R^2. This indicated the random effects components explained a relatively greater amount of variation in relative abundance. Overlap in R^2 90 % BCIs also illustrated uncertainty in differences in proportion of variation explained between GLMMs (Table 6).

Table 6. Estimates (90 % Bayesian credible interval) of performance statistics used to evaluate the goodness-of-fit for generalized linear mixed effects models of relative abundance.

Statistic	CSRB Adults	CSRB Larvae	MIPU Adults	MIPU Larvae
Variation explained				
$R^2_{marginal}$	0.19 (0.06 - 0.39)	0.13 (0.04 - 0.32)	0.18 (0.06 - 0.37)	0.33 (0.14 - 0.57)
$R^2_{conditional}$	0.81 (0.49 - 0.95)	0.64 (0.21 - 0.93)	0.79 (0.47 - 0.94)	0.85 (0.64 - 0.94)
Posterior predictive checks				
B_p (χ^2 discrepancy)	0.45	0.52	0.50	0.51
$RMSE_{obs}$	1.27 (1.07 - 1.52)	0.85 (0.72 - 1.02)	1.27 (1.08 - 1.53)	0.61 (0.49 - 0.76)
$RMSE_{sim}$	1.26 (1.06 - 1.54)	0.84 (0.70 - 1.03)	1.27 (1.07 - 1.54)	0.61 (0.48 - 0.77)
Cross-validation				
$RMSE_{cv}$	4.11	8.90	4.50	1.33

Posterior predictive checks illustrated GLMMs were reasonable descriptions of the observed data. Bayesian *p*-values ranged from 0.45–0.52 and supports that data simulated by each model were consistent with observed data. This was further demonstrated by similar observed and simulated RMSE estimates for each model. Relatively low estimates of RMSE (0.61–1.27) illustrated by posterior predictive checks also supports that the GLMMs predicted relative abundance with good accuracy. That said, cross-validation RMSE was substantially higher relative to posterior predictive checks, ranging from 1.33–8.90. Compared to other RMSE estimates, cross-validation RMSE was about 1.2 times higher for MIPU larvae, 2.5 times higher for CSRB and MIPU adults, and 9.6 times higher for CSRB larvae. Differences in predictive accuracy between these two evaluation procedures indicated some uncertainty in each model's ability to generalize to new data (Table 6).

4.3b Parameter estimates and functional relationships

Average relative abundances represent site-level intercepts on the original response scale (counts/lure), which were used to derive apparent occupancy probability (Table 7). Differences in intercept estimates on the relative abundance scale are described here and apparent occupancy between sites are included in Fig. 12 for comparison. Intercept estimates were zero at Spring Run 1 for each species-life stage combination and was also zero for MIPU larvae at Spring Run 3. Site-level intercept estimates (90% BCI) for CSRB adults were 0.52 (0.32–0.81) at Spring Island, 0.07 (0.03–0.14) at Western Shoreline, and 0.11 (0.06–0.18) at Spring Run 3. Credible intervals for Spring Island did not overlap with other sites, suggesting it is highly probable that average relative abundance was greater at this site relative to others. Intercepts for CSRB larvae, MIPU adults, and MIPU larvae also illustrated greater average relative abundance at Spring Island. However, broad and overlapping credible intervals indicated uncertainty in whether average relative abundance truly differed between sites (Fig. 12).

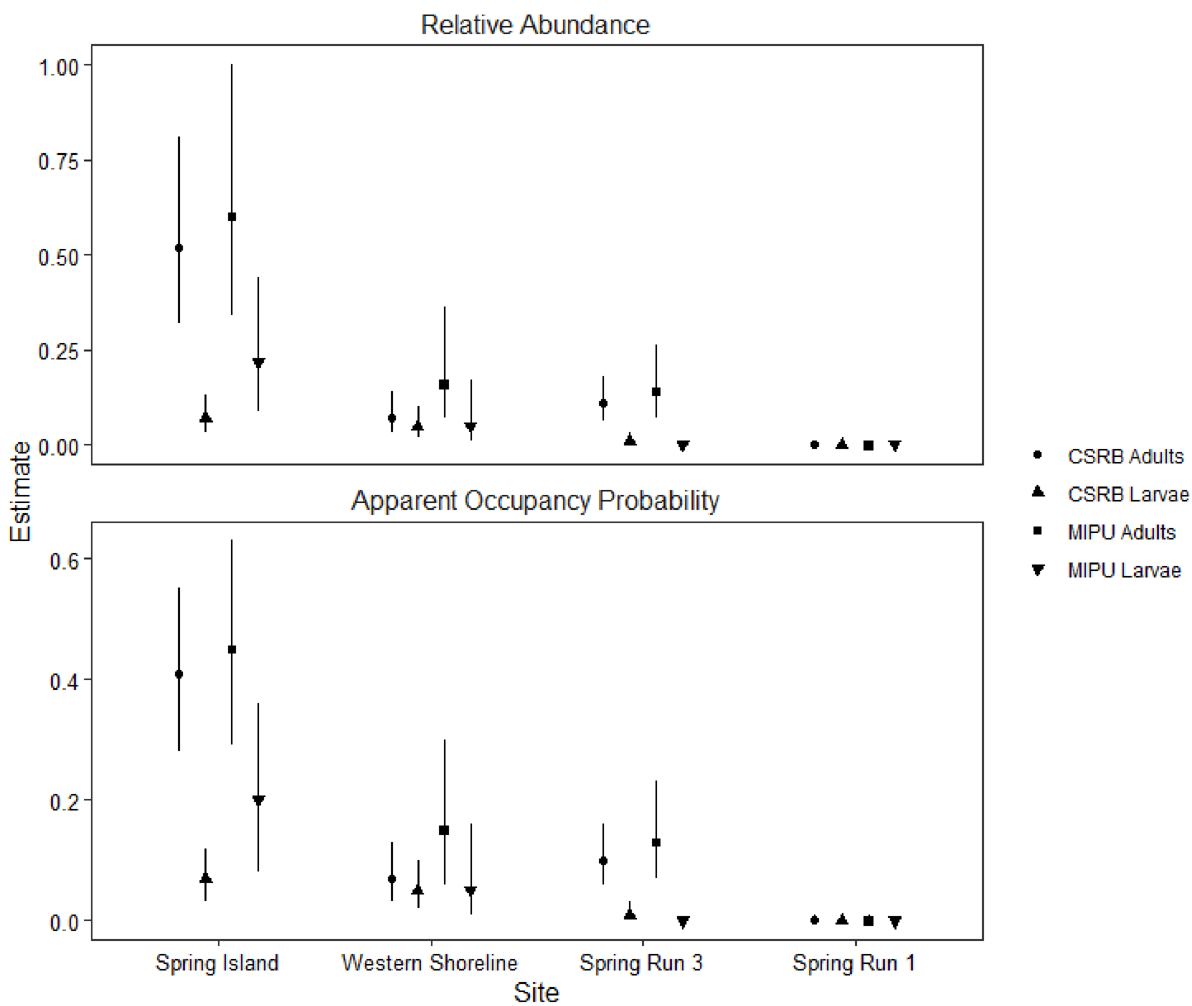


Figure 12. Generalized linear mixed effects model estimates of average relative abundance and apparent occupancy probability at each site. Average relative abundances represent site-level intercepts on the original response scale (counts/lure), which were used to derive apparent occupancy probability. Error bars denote 90 % Bayesian credible intervals.

Table 7. Estimates (Est) and Bayesian credible intervals (BCI) of parameters used to fit generalized linear mixed effects model of relative abundance.

	CSRB Adults		CSRB Larvae		MIPU Adults		MIPU Larvae	
Parameter	**Est**	**BCI**	**Est**	**BCI**	**Est**	**BCI**	**Est**	**BCI**
Intercepts								
Spring Island	-0.65	(-1.13 - -0.22)	-2.68	(-3.44 - -2.04)	-0.50	(-1.08 - 0.00)	-1.52	(-2.44 - -0.81)
Western Shoreline	-2.68	(-3.43 - -2.00)	-3.03	(-3.89 - -2.28)	-1.81	(-2.72 - -1.02)	-2.94	(-4.49 - -1.75)
Spring Run 3	-2.22	(-2.76 - -1.72)	-4.38	(-5.39 - -3.53)	-1.98	(-2.68 - -1.37)	-11.26	(-22.92 - -6.57)
Spring Run 1	-7.62	(-16.57 - -4.59)	-7.06	(-15.44 - -4.38)	-8.01	(-17.02 - -4.79)	-10.70	(-22.55 - -5.81)
Population-level intercept	-3.29	(-8.49 - 0.62)	-4.25	(-8.75 - -1.29)	-3.07	(-8.54 - 1.04)	-6.78	(-14.37 - -1.35)
Covariate Effect Size								
30-day local springflow average	0.14	(0.06 - 0.21)	0.30	(0.22 - 0.40)	0.03	(-0.06 - 0.12)	-0.13	(-0.29 - 0.02)
Percent total biofilm	0.04	(0.03 - 0.05)	0.03	(0.02 - 0.05)	0.01	(0.00 - 0.03)	0.00	(-0.02 - 0.02)
Random effects standard deviation								
Site	4.32	(1.65 - 9.09)	3.01	(0.94 - 8.47)	4.67	(1.84 - 9.17)	6.56	(2.93 - 9.64)
Extra-residual	1.55	(1.33 - 1.82)	1.56	(1.28 - 1.9)	2.02	(1.75 - 2.35)	2.25	(1.75 - 2.98)

For each GLMM, random effects standard deviations were higher for site compared to the extra-residual term. This indicated there were larger differences in relative abundance between sites that weren't accounted for by the model covariates relative to the observation-level. Estimates (90% BCI) of 30-day local springflow average effect size for each CSRB life stage was 0.14 (0.06–0.21) for adults and 0.30 (0.22–0.40) for larvae. Slope estimates for effect size of total biofilm on CSRB relative abundance was 0.04 (0.03–0.05) for adults and 0.03 (0.02–0.05) for juveniles. Bayesian credible intervals for CSRB adult and larvae slopes did not overlap with zero, meaning there was a 0.9 probability that both covariates had a positive non-zero effect on relative abundance. For MIPU, local springflow and total biofilm effect sizes were 0.03 (-0.06–0.12) and 0.01 (0.00–0.03) for adults and -0.13 (-0.29–0.02) and 0.00 (-0.02–0.02) for juveniles, respectively. In contrast to CSRB, the breadth of BCIs for both MIPU life stages failed to reject zero as a plausible effect size by each covariate (Table 7).

Relationships of CSRB relative abundance and apparent occupancy probability are presented for adults and larvae in Fig. 13. Extent of 30-day local springflow averages on the x-axis of each panel encompass the range of discharge magnitudes observed at each site over the study period. Since the effect size of local springflow was fixed across sites, maximum predictions of relative abundance and apparent occupancy probability occurred at Spring Island and Western Shoreline because they exhibited the greatest maximum 30-day local springflow averages. Consequently, as local springflow decreased from its maximum to minimum magnitude, state variables for both life stages were expected to decrease by about 90–100% at Spring Island and Western Shoreline. At Spring Run 3 in contrast, CSRB adult state variables were expected to decrease by about 85% compared to an expected decline near 100% for CSRB larvae. It is also important to note that relative abundance predictions for CSRB larvae at Western Shoreline showed an exponential increase from about 1–139 counts/lure as local springflow increased from 85–100 cfs. Maximum predictions of CSRB larvae at this site were much higher than the observed maximum (14 counts/lure), suggesting the slope estimate of local springflow was not realistic for this life stage (Fig. 13).

Given that total biofilm was quantified as a percentage, its functional relationship with CSRB adults and larvae were more consistent between sites relative to local springflow. Differences in maximum predictions were therefore governed by estimates of each site's intercept. As total biofilm increased from 0–100%, relative abundance and apparent occupancy probability were expected to increase about 97% for both life stages. Lastly, predicted values of relative abundance and apparent occupancy were very similar for all fitted functions except CSRB adults at Spring Island, which illustrated that as relative abundance approached 3.0 counts/lure, apparent occupancy probability approached 1.0 (Fig. 14).

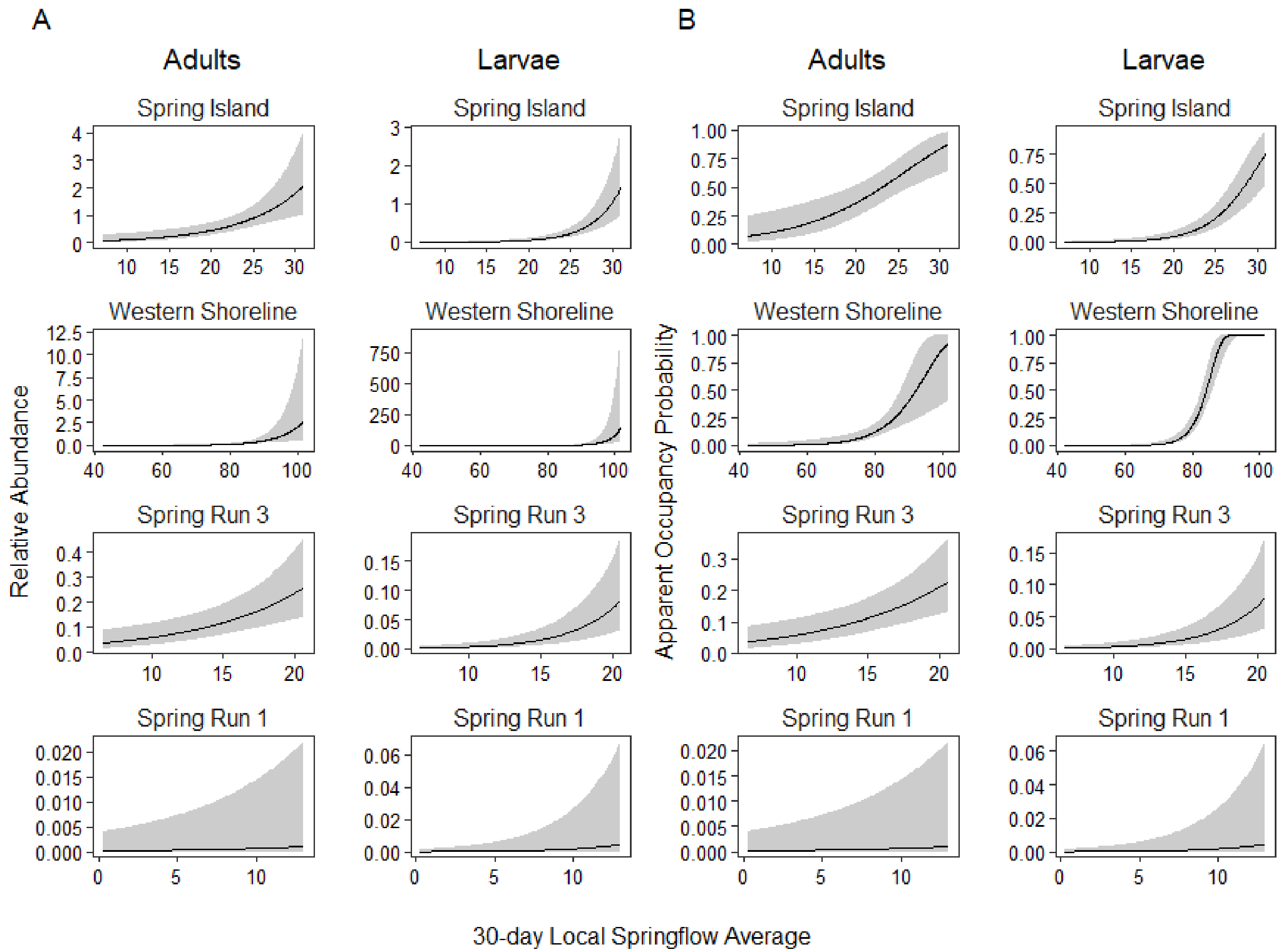


Figure 13. Relative abundance (A) and apparent occupancy probability (B) relationships with **30-day local springflow** average among sites for CSRB adults and larvae. Solid lines represent mean relative abundance predictions by the posterior distributions of each parameter and solid polygons denote 90 % Bayesian credible intervals.

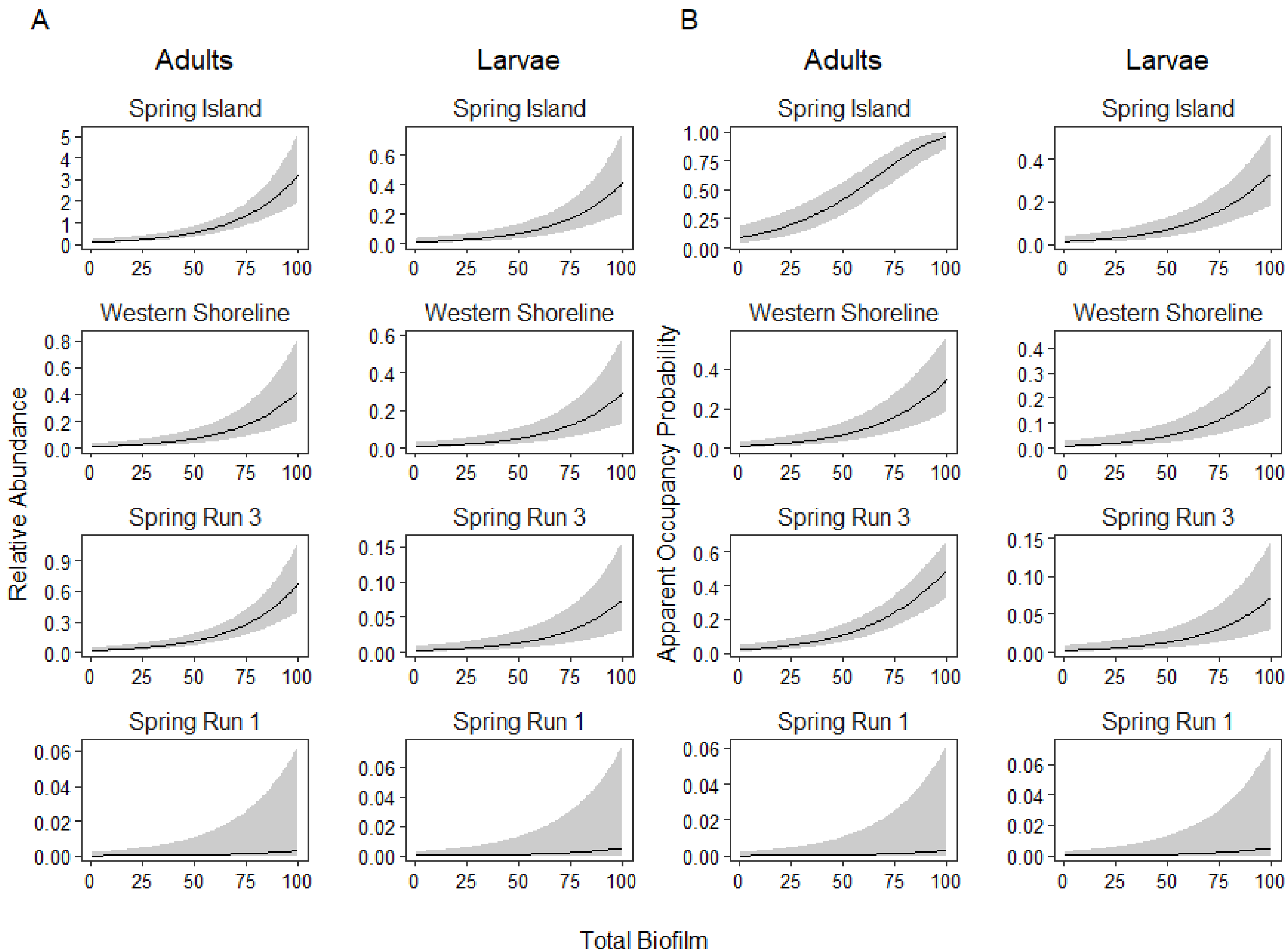


Figure 14. Relative abundance (A) and apparent occupancy probability (B) relationships with **total biofilm** average among sites for CSRB adults and larvae. Solid lines represent mean relative abundance predictions by the posterior distributions of each parameter and solid polygons denote 90 % Bayesian credible intervals.

4.3c Framework for biological monitoring applications

In fall 2024, 30-day local springflow average was 4.4–10.7 cfs at Spring Island, 31.0 cfs at Western Shoreline, and 3.7 cfs at Spring Run 3. Total biofilm across sites ranged from 10–85%. CSRB were only detected at 10% of lure samples (n = 3 lures). Observed CSRB relative abundance across sites ranged from 0–26 counts/lure (median = 0.00 counts/lure) and the GLMM's overall posterior forecast distribution ranged from 0.00–8.17 counts/lure (median = 0.01 counts/lure). Estimated RMSE was 4.79 (4.75–4.80), indicating relatively low predictive accuracy. That said, given that 90% of the observed data were zeros, it was not surprising that this global measurement of accuracy was poor, and suggests estimated RMSE was likely strongly influenced by the one sample with high relative abundance (26 counts/lure). Residual diagnostics, which examine model accuracy more locally, instead exemplified that residuals were centered around zero and displayed no strong patterns. This alternatively suggests adequate model fit and that the larger predictive errors represented stochastic variation (Fig. 15).

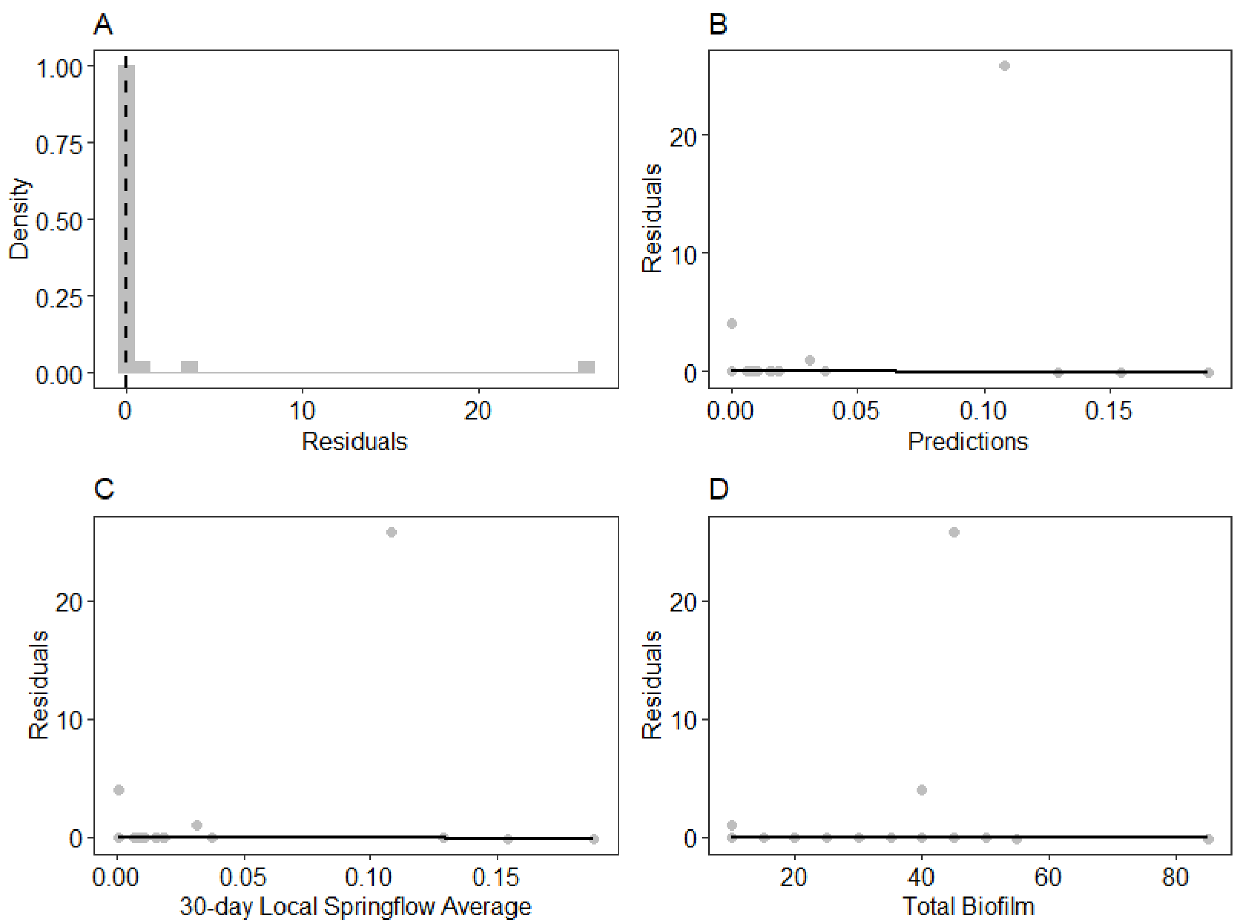


Figure 15. Diagnostic plots for residuals of the generalized linear mixed effects model used to forecast CSRB adult relative abundance during the fall 2024 EAHCP biological monitoring event. Plots include a histogram of residuals (A) and scatterplots of residuals versus predictions (B), 30-day local springflow average (C), and total biofilm (D). The black line fit to scatterplots on panel B–D represent quantile regression line-of-best-fit (quantile = 0.5).

Among sites, observed median relative abundance was 0.00 counts/lure, which closely aligned with expectations predicted by the GLMM. Expected relative abundance was also 0.00 counts/lure at Western Shoreline. At Spring Run 3, the expectation was 0.01 and its 90% BCI (0.00–0.04) included zero. Spring Island observations were slightly lower than expectations, but still approximated the predicted value of 0.07 (0.01–0.35) (Table 8). Boxplots shown in Fig. 16 further demonstrated that posterior forecast distributions only include lower predictions of relative abundance near 0.00 counts/lure for each site.

Table 8. Summary of observed and expected (90% BCI) median relative abundance of CSRB adults during the fall 2024 EAHCP biological monitoring event.

	Median Relative Abundance	
Site	**Observed (Fall 20224)**	**Expected**
Spring Island	0.00	0.07 (0.01-0.35)
Western Shoreline	0.00	0.00 (0.00-0.00)
Spring Run 3	0.00	0.01 (0.01-0.04)

Given that observations approximated expectations predicted by the GLMM, this would lead to the conclusion that patterns of CSRB relative abundance in fall 2024 were likely attributed to covariate effects. This provides evidence to suggest very low relative abundances in fall 2024 were best explained by the extreme low flow conditions experienced in Comal Springs during this time period (55–74 cfs). Underestimates of several lure samples could be due to a variety of stochastic factors that are currently unknown.

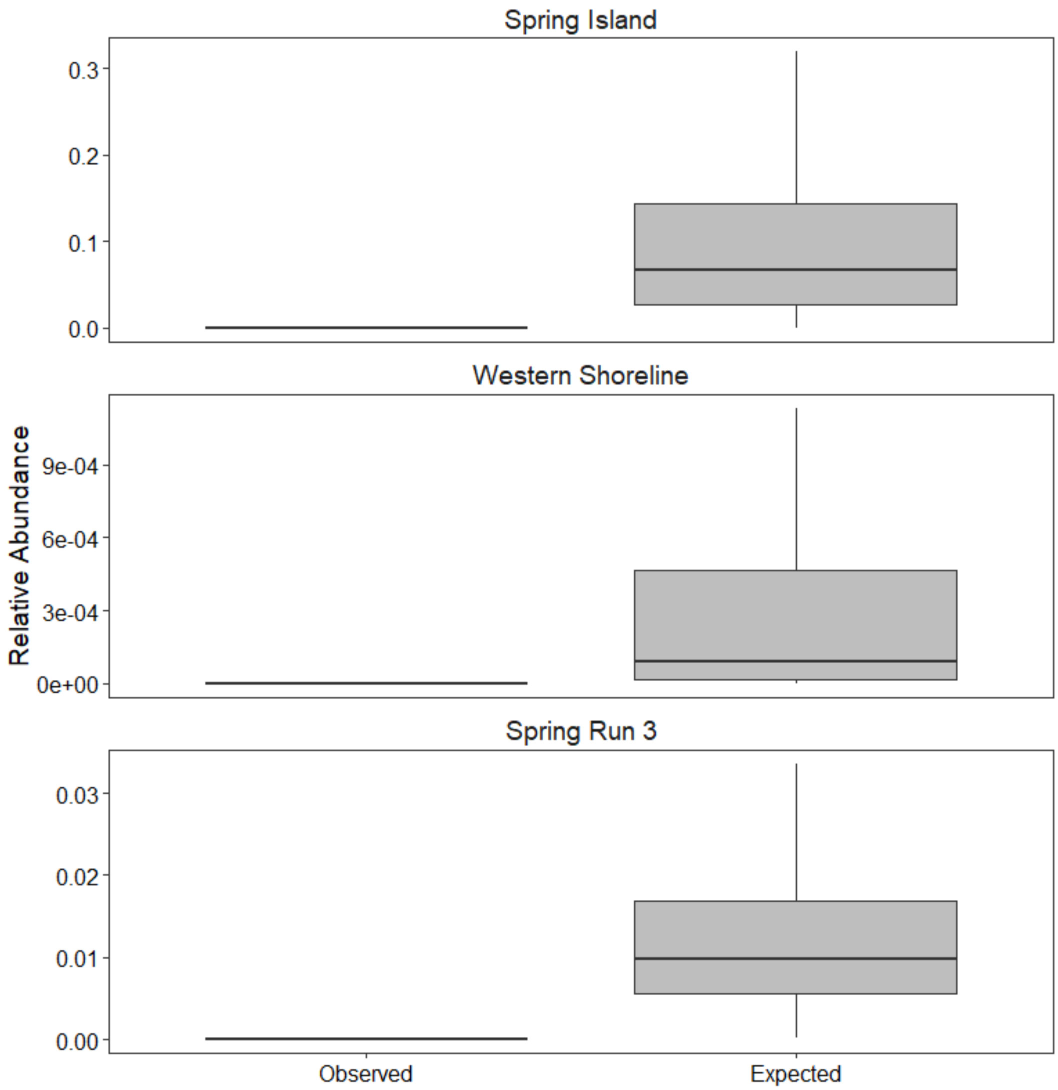


Figure 16. Boxplots comparing CSRB adult relative abundances observed in fall 2024 versus expected values predicted by the generalized linear mixed effects model. The thick horizontal line in each box is the median and the upper and lower bounds of each box represents the interquartile range. Whiskers represent minimum and maximum values up to 1.5 times the interquartile range

5. Discussion

5.1 CSRB spatial and temporal distribution

CSRB were found at least once at nearly all sites in Spring Run 3, Western Shoreline, and Spring Island, but there was only a single occurrence in Spring Run 1 and none in the Upper Spring Run. The highest recorded abundances were around Spring Island, which generally had the most stable habitats that were consistently underwater and maintained springflow throughout the drought. In particular, the upwelling sites northeast of Spring Island reliably supported the highest numbers of CSRB throughout the study (Fig. 6). The lower abundances in Spring Run 3 and Western Shoreline may be a combination of these areas generally supporting fewer CSRB and the effects of drought. Most sites in Spring Run 3 and the Western Shoreline were terrestrial margin habitats that had water levels drop or ceased detectible flow during low-flow periods. Similarly, the lack of CSRB occurrence in Spring Run 1 is possibly a reflection of the ongoing drought that began in 2022 that led to the upper portions of Spring Run 1 completely drying in summer 2023 (and again in late 2024).

There has been only one reported CSRB occurrence from the Upper Spring Run, and our study, combined with prior surveys in the locality, suggest that the area does not support a CSRB subpopulation. Although most of our sites in the Upper Spring Run did not dry at all during the study (five sites were >1 m deep), overall flows were noticeably reduced at all of the sites during summer and fall sampling. Only a single individual of a spring-endemic species was found (*Stygobromus* sp.) in the Upper Spring Run during our study. Conversely, MIPU were found at half of the sites in the Upper Spring Run. Multiple reliable records of *S. comalensis* have been reported from the Upper Spring Run, and this species contrasts with CSRB in that it likely utilizes subterranean habitats. Therefore, *S*. *comalensis* may be able connect to other areas of the Comal Springs system through subterranean passages and recolonize the near-surface sites in the Upper Spring Run when conditions are favorable.

CSRB were found on lures at the entire range of depths that we sampled at, from the deepest site (>2 m) to lures at the water surface. Occurrence of CSRB on lures at or just above the water surface only happened when lures were still wet. This was likely a reflection of a recent drop in water levels in the time since they were set that left beetles that had previously colonized the lures stranded within them; completely dry lures never had CSRB. Our lures were only placed in favorable locations at the time they were set: just below the substrate – water interface where there was noticeable flow. Initial tests of layering lures at different depths largely only found CSRB at the substrate – water surface interface (BIO-WEST unpublished data). The sum of evidence to date suggests that CSRB predominantly occur in these microhabitats, and we hypothesize that there is unlikely a true subsurface population as there probably is with the other endemic spring-associated invertebrates (*S. comalensis*, *Stygobromus* spp.).

While visual examination of the data suggests that there might have been some slight locality-specific changes in mean CSRB adult and larval abundances over time in the study (Appendix Figs. S6–S7), there were no consistent patterns. If CSRB had a clear seasonal phenology, we would have expected to see consistently higher/lower abundances of adults and/or larvae during certain sampling periods. The initial suggestion by Bowles et al. (2003) that CSRB larvae may be more abundant during fall may have actually been differences in abundance related to an environmental factor not accounted for at the time of their study. Additionally, our results suggest that cotton lures are not as reliable at detecting the presence and assessing the abundance of CSRB larvae as they are for adults (see section 5.2).

It has long been suggested that CSRB are negatively impacted by silt or other fine sediments (NAS 2018; USFWS 2024), but there has been a lack of data or direct assessment of this factor. This idea likely originated from observations that lures that experienced noticeable sedimentation as a result of sediment being washed down onto lures and springs from the above terrestrial habitats following significant rainfall events. Only one of our lures experienced significant sedimentation to the extent that it noticeably impacted the quality of the lure, and this was at a site under the rock wall in Spring Run 1 during summer 2023 that partially caved in from above as the spring run dried. Other sites commonly had sediment on top, and lures were placed in sites surrounded by fine sediments (and some entirely in sand and silt). We found no evidence in this study or other recent work (BIO-WEST 2025) that suggests the presence of silt within spring sites has any negative effect on CSRB abundance. It appears that as long as spring sites maintain flow, there is no noticeable effect on CSRB.

5.2 Model results and covariate effects

Our model results indicated that both CSRB adults and larvae responded positively to local springflow and lure biofilm coverage but that other site characteristics did not affect relative abundance. For both CSRB life stages, local springflow had a larger effect than biofilm coverage. The lack of effect of other covariates on CSRB relative abundance support the limited work of previous studies, which also found no effect of various covariates (Bowles et al. 2003). However, while we found that site-level springflow (measured at each lure) had no effect, our calculated measure of local springflow did. This is perhaps suggestive that local springflow is a better indication of local habitat quality and stability, and it reflects conditions that affect entire subpopulations rather than an individual site. Local springflow also characterized average conditions across the entire sampling period lures were set, while site-level springflow was an average of two point-measurements (start, end). Individual sites have more variable site-level counts of beetles than overall localities, potentially owing to imperfect detection or other stochastic processes. While not a perfect indicator of locality-level conditions, when local springflow is modeled within each locality, unique locality-specific relationships are generated that further reflect the stability of the springflow and favorable CSRB habitat in each locality.

The small positive relationship of CSRB relative abundance with biofilm likely reflects the response of CSRB to greater availability of this food resource. This relationship should be expected, but it is perhaps somewhat surprising that this covariate was the only sample-level covariate included in our final model. The causes of variation in biofilm coverage of lures remain unknown, but we expect that it is tied to some other unmeasured characteristic of each site and the site-level processes that inoculated and supported the growth of biofilm on lures. Our estimates of biofilm coverage were obtained by a single person and theoretically were as consistent as possible across the duration of the study. Variation in estimates should be expected if different observers were to estimate coverage. However, because of the relatively small effect of biofilm and potential inaccuracy with variation in observer estimates over time, we explored alternate model formulations that excluded biofilm. These alternate model results performed similarly (Appendix Table S1) and indicated that excluding biofilm from models may be sufficient for assessing the status of CSRB populations over time (see section 5.3) without potential observer-level variation in biofilm estimates.

Marginal and conditional R^2 values for CSRB larvae trended lower than for adults, but all 90% BCIs overlapped (Table 6). This may reflect that while CSRB larval relative abundance was affected by our covariates, the cotton lure methodology is not as effective at assessing relative abundance of CSRB larvae as it is for adults. This also supported by the relative abundance and occupancy estimates for larvae, which were consistently lower with overlapping BCIs for Spring Island, Western Shoreline, and Spring Run 3. This is in contrast to CSRB adults, which had higher relative abundance and occupancy estimates at Spring Island than other localities. We would expect true abundance and occupancy of adults and larvae to be correlated – areas with more adults should also have more larvae. Preliminary results using an alternative sampling method (wood discs), indicated that there was similar abundance of CSRB larvae and adults on wood discs, but much lower abundances of larvae than adults on cotton lures (BIO-WEST 2025), further supporting the supposition that cotton lures are not as effective for assessing CSRB larvae.

The effects of local springflow and biofilm on CSRB contrasts with MIPU, for which all covariate BCIs overlapped with zero (Table 7), rejecting a plausible non-zero effect of both covariates on that species. However, the effect of springflow on MIPU larvae trended towards a negative effect, and further investigation focused on MIPU could elucidate that relationship. These clear differences in the effects of springflow between these two similar, co-occurring species emphasize the importance of springflow for CSRB. This relationship is illustrated across localities in Fig. 13 and indicates that maintaining springflow is essential to sustaining CSRB subpopulations. In Spring Run 1, following the one individual we found in May 2023, the ongoing drought and low-to-zero springflow in that locality has resulted in the absence of CSRB there through December 2024 (BIO-WEST unpublished data). Our modeled relationships between springflow and CSRB apparent occupancy and relative abundance are directly applicable to the range of environmental conditions observed during our study period; extrapolation of the model beyond the observed conditions may not accurately reflect the relationship of CSRB to springflow at higher or lower flows. Future research is needed to investigate flow-ecology relationships at springflow conditions near (or above) historic averages.

The time period in which we conducted this study was incredibly beneficial towards understanding CSRB responses to environmental conditions. We can reasonably assume that at total system springflows above those we experienced (>205 cfs), CSRB populations either continue to increase (at least to a saturation point) or remain stable. Therefore, the relationship between CSRB relative abundance and springflow that we have elucidated at lower springflows has helped to understand how this species is affected as the Comal Springs system dries. We recorded that as flows declined, reaching some of the lowest springflows observed during the past 30 years, CSRB relative abundance at Spring Island declined less dramatically than at Spring Run 3 and the Western Shoreline. The exception in on our model results is Spring Run 1 (Fig. 13), where the point at which a stable population declines towards zero may have been at local springflows above any that we experienced in our study or that have been observed since 2021. Better understanding of the relationship between springflow and CSRB relative abundance in Spring Run 1 (and Spring Run 2, which we did not examine), would require further study. Additionally, given the dominant effect of local springflow and relatively similar performance of models excluding biofilm, further inference regarding the relationship between CSRB and local springflow may be discerned by conducting a broader analysis using the long-term biomonitoring data.

5.3 Applicability to biomonitoring

The framework and its results described in sections 3.3d and 4.3c for applying our model results towards CSRB biomonitoring illustrates its utility for assessing whether observed CSRB relative abundance meets expectations based on our covariates. In our example, we utilized data from fall 2024 biomonitoring, which occurred during the period of lowest springflow during biomonitoring efforts since the program began (similar springflows to those observed during summer 2023 in this study). In one regard, the prevalence of zeros across 90% of sites and calculated relative abundance of 0 across localities should be expected given the low flows. However, it also illustrates the limitations of the model and our existing data of CSRB populations, as we do not have lure data from total system springflows below 55 cfs.

This framework can be used as part of a two-step process for assessing the results of semiannual biomonitoring. The first step, not presented in the methods for the framework, is a modification of the current way in which results are presented in the annual report, which is currently just a visual comparison of current-year averages to long-term averages. Here, the overall status of the population can be assessed by determining whether the relative abundance in each of the three monitored localities (Spring Island, Spring Run 3, Western Shoreline) fits within a given error (e.g., 1 standard deviation) that locality's historic relative abundance when total system springflows were within one standard deviation of their long-term average. This will determine whether current relative abundances match historic averages within each locality or not.

Second, our model and the framework illustrated here can be employed to determine whether the observed values of our covariates explain the observed relative abundances. If the observed relative abundance does not fall within the range of expected values, then some other factor could be having an effect on CSRB populations. Given that the main effect we observed (local springflow) is calculated based on measurements that are not required to be taken at the time of CSRB sampling, along with the similar performance of models without inclusion of the biofilm covariate (discussed in section 5.2), the framework for assessing the biomonitoring program is simpler than may be expected. It could potentially be justified to simplify data collection during biomonitoring to just beetle counts, collection timeframes, and locations, but further analysis of additional data would be needed before such a change is justified. While most covariates may not have had an effect in this study, it does not mean they may not in the future as more data across a wider range of conditions are collected.

The current biomonitoring program sets 30 lures (10 per locality) each spring and fall and has been consistent for 21 years. Under historically normal springflow conditions when relative abundance and occupancy are higher in all localities, it is possible that 30 lures would be more than effective at assessing the status of CSRB populations and could possibly be assessed with fewer lures in each locality. However, this is complicated when flows are lower as was illustrated by the fall 2024 biomonitoring results. Only 3 out of 30 sites had adult CSRB and 26 of the 31 beetles were on a single lure. With a reduced sampling program, you could easily have found no CSRB on all lures. While the model results in both situations would have produced a relative abundance of zero, a recorded abundance of zero would be alarming.

Similarly, maintaining two biomonitoring sampling events per year accounts for potential changes in CSRB populations with seasonal differences in total system springflow.

Further analysis of existing data could be explored to determine what number of lures could be set during biomonitoring while still maintaining the same accuracy as results obtained from ten lures per locality. For instance, if simulations suggest that sampling with five lures per locality twice per year achieves relative abundance values equal to ten lures per locality in 95% of simulations under normal flow conditions, then a change to the biomonitoring program could easily be justified. The five sites could be randomly selected during each sampling event from among the ten existing sites to eliminate biases from potentially selecting the most productive sites (such as the one Spring Island site that has consistently produced the most adult CSRB over the past two years). If flows are low during semiannual biomonitoring, setting lures at all 30 sites may be justified to adequately assess the status of the population. However, the current strategy for sampling during low flow conditions (3 lures in each of the 3 localities) may help maintain adequate detection capability when occurring before and/or after routine biomonitoring.

Maintaining a ~30-day sampling interval using cotton lures is prudent given the response of CSRB to biofilm that we document here. Shorter sampling intervals may be less likely to detect CSRB or adequately assess their abundance, while longer sampling intervals may result in degraded lures. This includes sampling during low-flow conditions, which during 2022 and part of 2023 were conducted every ~15 days. This both allows for biofilm development and limits unnecessary disturbance to each spring site. However, one justification for shorter sampling intervals could be if springflow rapidly dropped from an already low level during the sampling period (such as from 55 to 30 cfs).

The cotton lure methodology and preceding methods have now been used for over 20 years. Recent work (BIO-WEST 2025) suggests alternative "luring" methods using conditioned wood discs may be equally as effective at assessing CSRB abundance (including larvae; see section 5.2) and potentially more effective at assessing CSRB presence. However, further study and analysis of the two methods is needed to assess their comparability, as well as the long-term durability and other potential complicating factors of the wood discs before methods are changed. Maintaining consistent methodology for CSRB data collection should be prioritized until such comparisons are made to ensure methods are consistent and data are reliably comparable.

5.4 Conclusions and further recommendations

With the completion of this study and our review of its findings and the current state of CSRB knowledge, several recommendations can be made for potential future work to fill gaps in our understanding of this species. The key results of this study are 1) both adult and larval CSRB are readily found throughout the year and across nearly all active spring sites in Spring Run 3, Spring Island, and the Western Shoreline, but less is known about the species in Spring Runs 1 and 2; 2) local springflow had a dominant effect on CSRB relative abundance and occupancy across each of these three localities, while biofilm also had a positive effect; and 3) the current collection techniques and models developed here can be used to track and assess CSRB populations over time in the biomonitoring program.

The primary finding of our study was that springflow was the most important factor affecting CSRB relative abundance – CSRB populations in each locality of the Comal Springs system decline as local springflow declines. This relationship, which was not present in the similar co-occurring species, MIPU, emphasizes the importance of maintaining springflow and the associated stable environmental conditions, which showed little to no variation in our study. How this relationship between springflow and relative abundance translates to higher total system springflows and localized springflows in Spring Runs 1 and 2 should be explored further. In the three primary localities, this should be examined by using existing long-term monitoring data and calculating local springflow averages for the entirety of the timeseries. This can be supplemented through a limited study (e.g., one or two sampling events) during time periods when total system springflows remain consistently near or above 300 cfs using all (or most) of the sites included in this study. Data from such a limited repeat study could be combined with data from this study for a more comprehensive assessment CSRB relative abundance over a full range of springflows. A supplemental study like this, or others, could occur at any time of year since we see no indication of phenological variation in abundances of each life stage.

Subpopulations of CSRB in Springs Runs 1 and 2 should be given further consideration, especially in the light of the current drought and potential loss of the population in Spring Run 1. A limited incorporation of each of these localities into the semiannual biomonitoring program (e.g., 3 lures per locality) would go a long way to improving our understanding of the species in those localities. Lure data from these localities have been very limited and sporadic over the past 20 years. More detailed monitoring of Spring Run 1 if/when local springflows consistently return to higher levels could provide valuable data on recolonization following drought. While Spring Run 1 might not support a genetically unique population or be critical to the overall species survival, understanding the response of CSRB there following drought would be valuable to know if a more severe drought were to similarly impact Spring Runs 2 and 3. Similarly, initial data have suggested that CSRB remain near the substrate – water interface (BIO-WEST unpublished data), but further study could confirm this hypothesis.

Although we did not identify other environmental characteristics that have clear effects on CSRB populations, the positive effect of lure biofilm suggests there could be some other characteristic of individual spring sites that indirectly affected our results by affecting the amount of biofilm on lures. This could be something such as local microbial communities that are shaped by plant species with roots near the spring or inputs of certain other types of organic material at each spring location. Detailed microbial assessment of objects occurring in springs and lures would be necessary for making this connection. Other than local springflow, the lack of clear environmental factors affecting CSRB populations is perhaps a greater reflection on the fact that CSRB is a spring-endemic species and adapted to stable environmental conditions that otherwise show little to no variation across its range. This same pattern may be expected of other spring-associated invertebrates, but every species is different and even closely related species can have contrasting responses to environmental conditions as they have evolved to fill their own niche. While the results of this study can be used to inform future studies of other species, the biology of each species should carefully be considered when designing other studies.

The results, models, and framework developed in this study should be used to formalize an annual assessment of CSRB using biomonitoring data. This will enable tracking of the status of CSRB populations and if their relative abundance matches predictions based on springflow. Additional analysis of existing data can be used to assess the efficiency of the sampling program and potentially refine the strategy behind the number of lures and their distribution throughout the system during biomonitoring to maximize resource use and meaningful data collection. This analysis of the biomonitoring program, combined with the additional studies suggested above, are warranted to accomplish the overall goals of the EAHCP – to track and protect these endemic invertebrates over time.

6. Acknowledgements

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8. Appendix

Figure S1. Photograph of the seepage meter in use at an upwelling site in the Spring Island area.

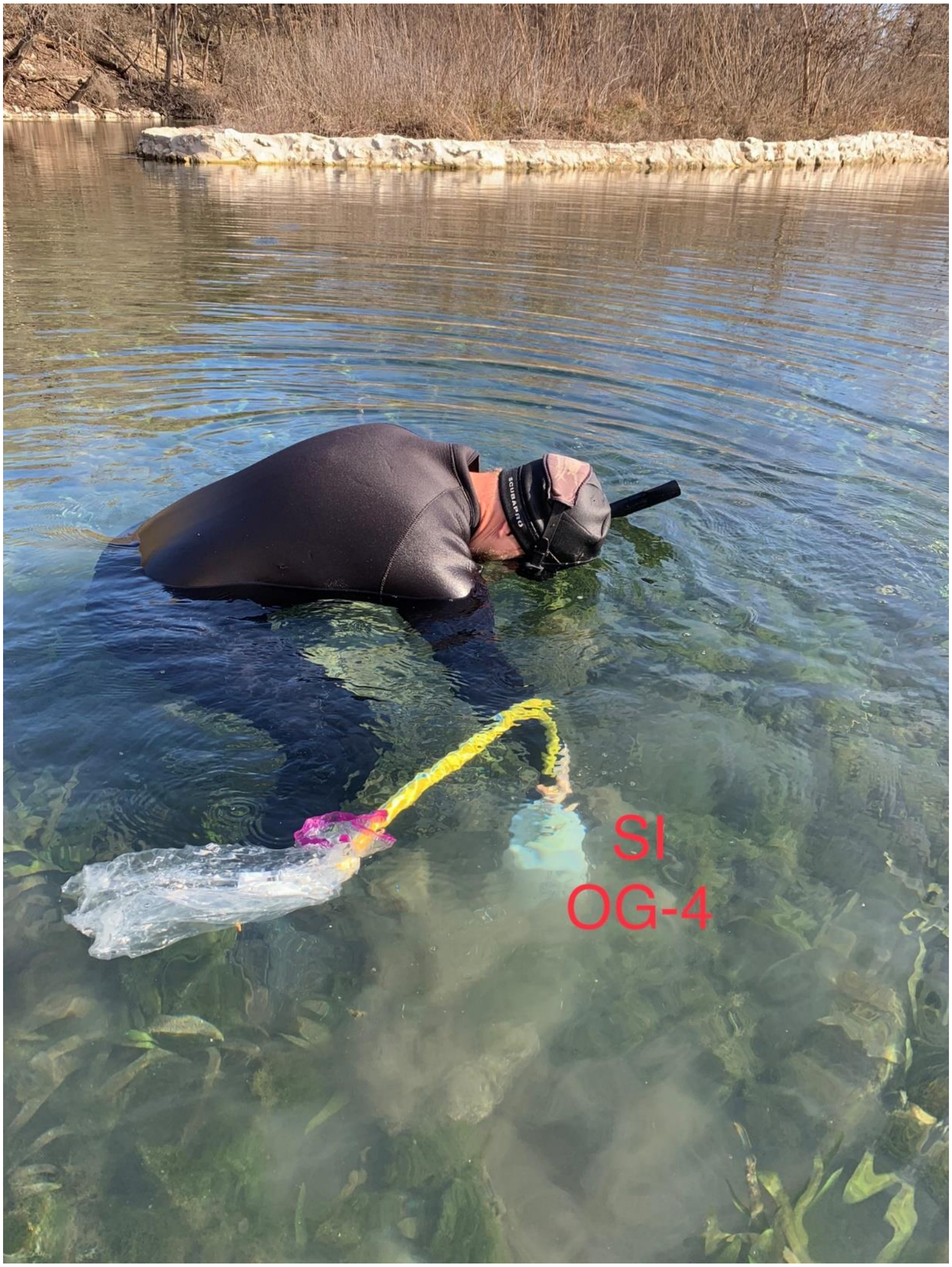


Figure S2. Scatterplot of 51 measurements for which there were measurements of both flow (cm/s) measured with the Hach flow meter and flux (mL/cm²/s) measured with the seepage meter at upwelling sites. This relationship was used to convert flux measurements into approximate flow measurements for direct comparison of the two methods.

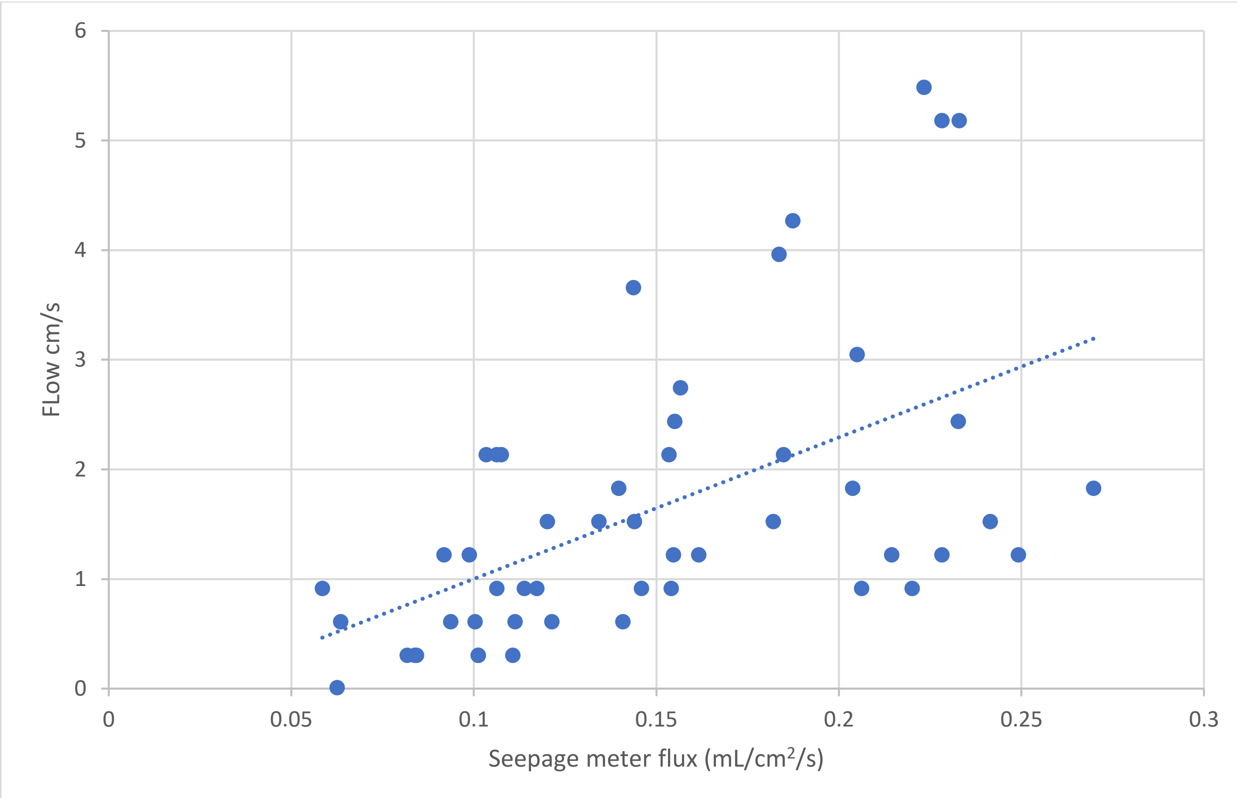


Figure S3. Map of sectors (spatial groupings of sites) at Spring Island.

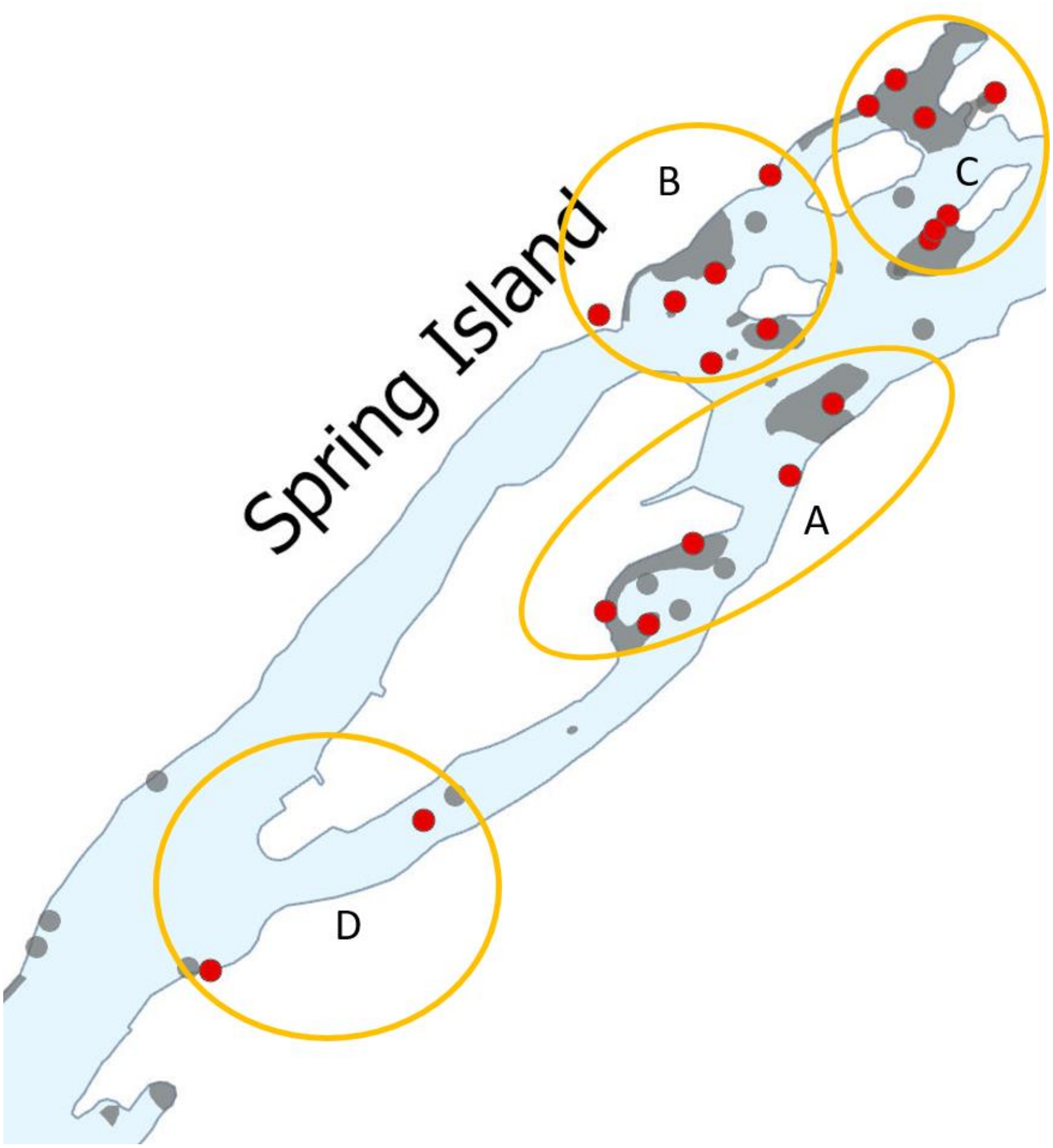


Figure S4. Map of sectors (spatial groupings of sites) at Spring Runs 1 and 3.

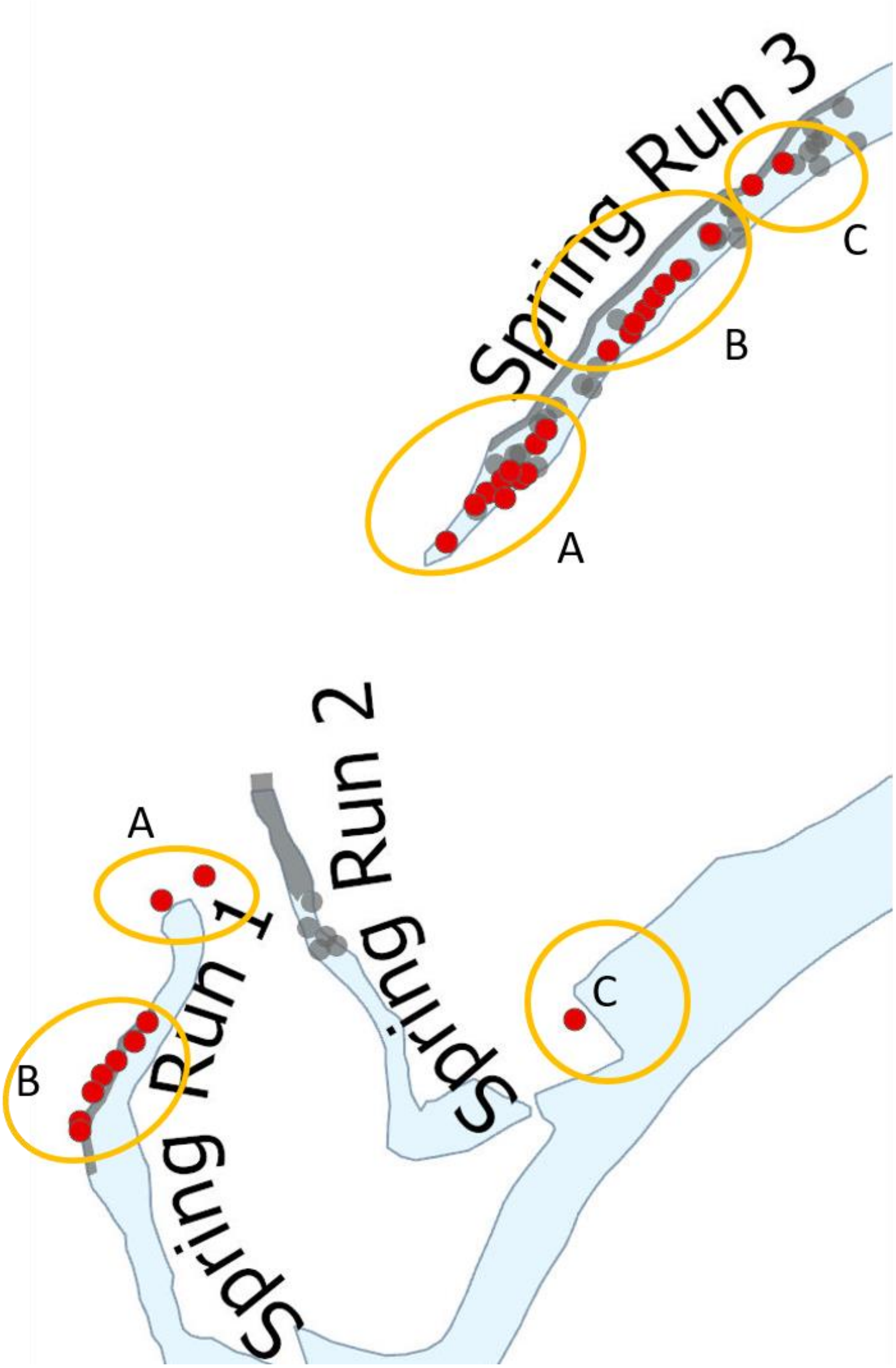


Figure S5. Map of sectors (spatial groupings of sites) at the Western Shoreline.

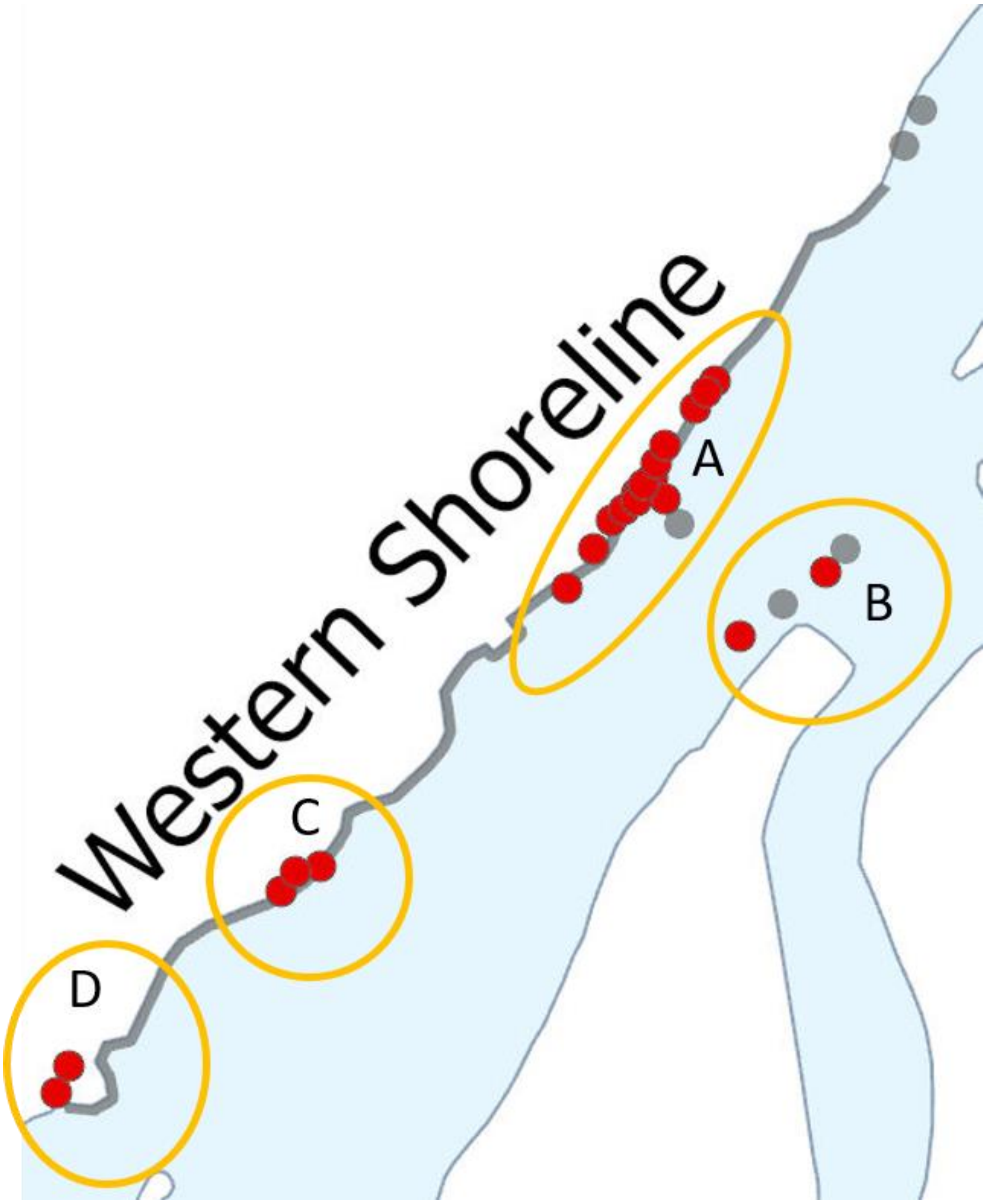


Figure S6. Mean (±SE) of the natural log transformed number of CSRB adults in the three primary sampling localities (excluding Spring Run 1) over the course of the study (by sampling period).

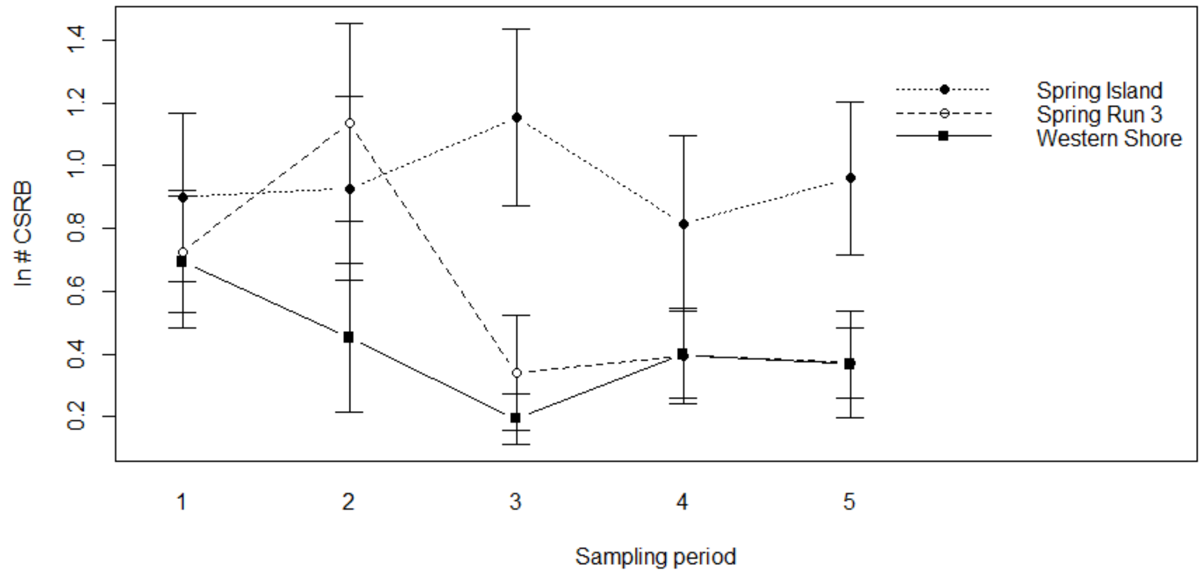


Figure S7. Mean (±SE) of the natural log transformed number of CSRB larvae in the three primary sampling localities over the course of the study (by sampling period).

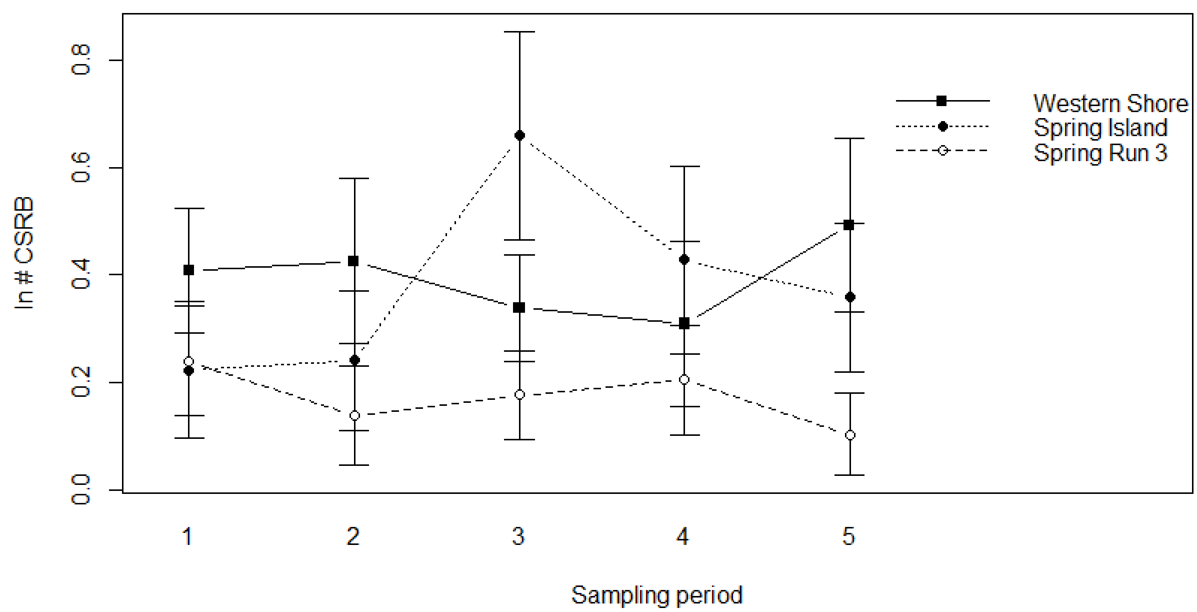


Figure S8. Mean (±SE) of the natural log transformed number of MIPU adults in the three primary sampling localities over the course of the study (by sampling period).

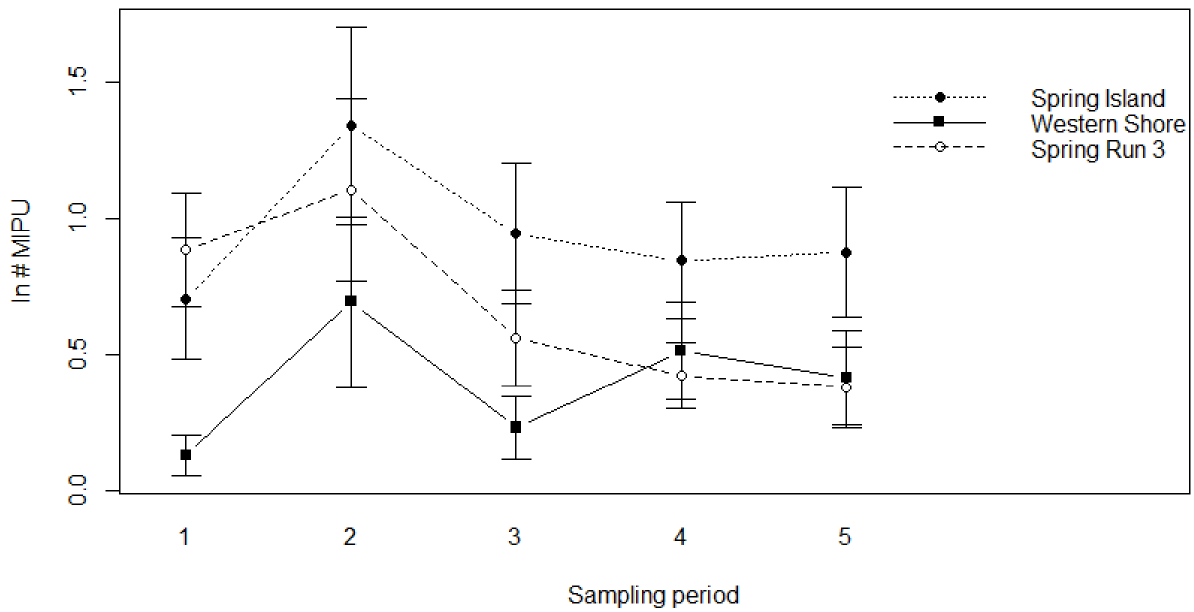


Figure S9. Mean (±SE) of the natural log transformed number of MIPU larvae in the three primary sampling localities over the course of the study (by sampling period).

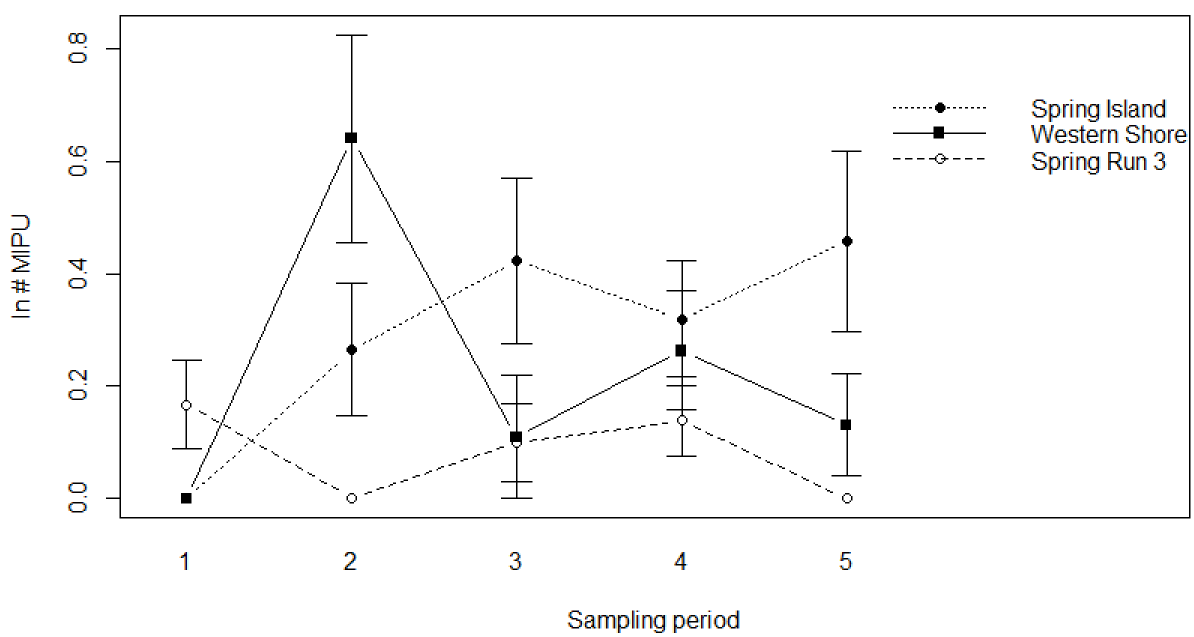


Figure S10. Boxplots of dissolved oxygen by locality and sampling period when lures were set.

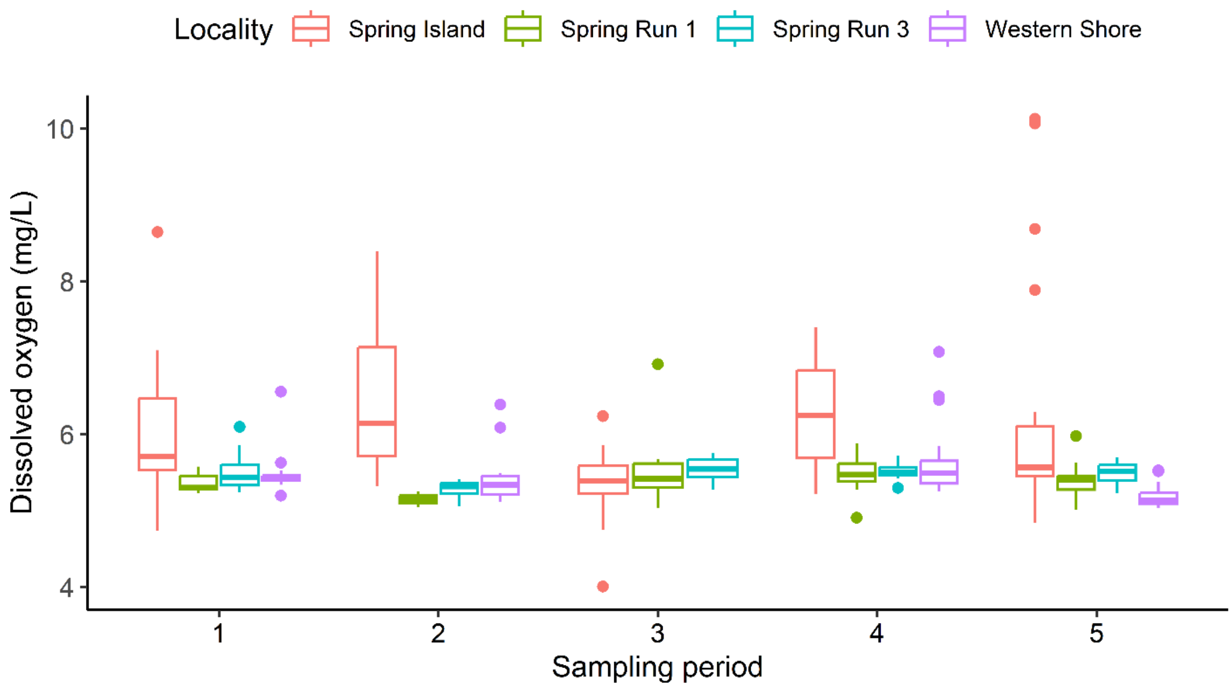


Figure S11. Boxplots of conductivity by locality and sampling period when lures were set.

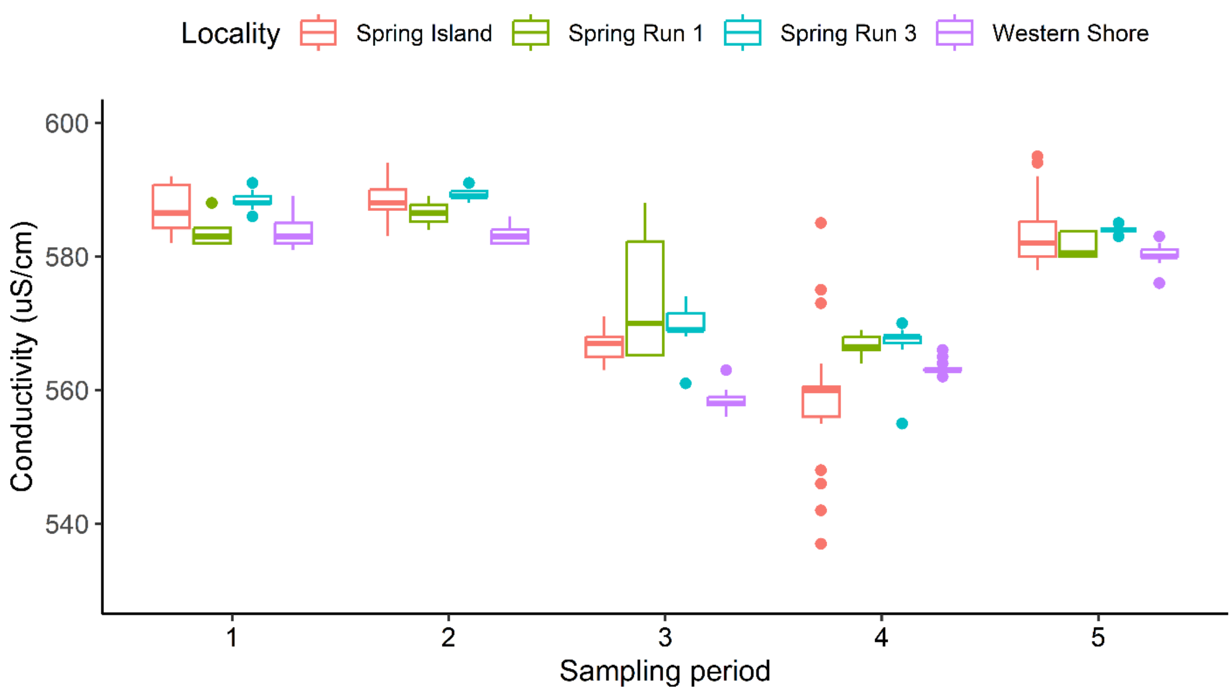


Figure S12. Boxplots of temperature by locality and sampling period when lures were set.

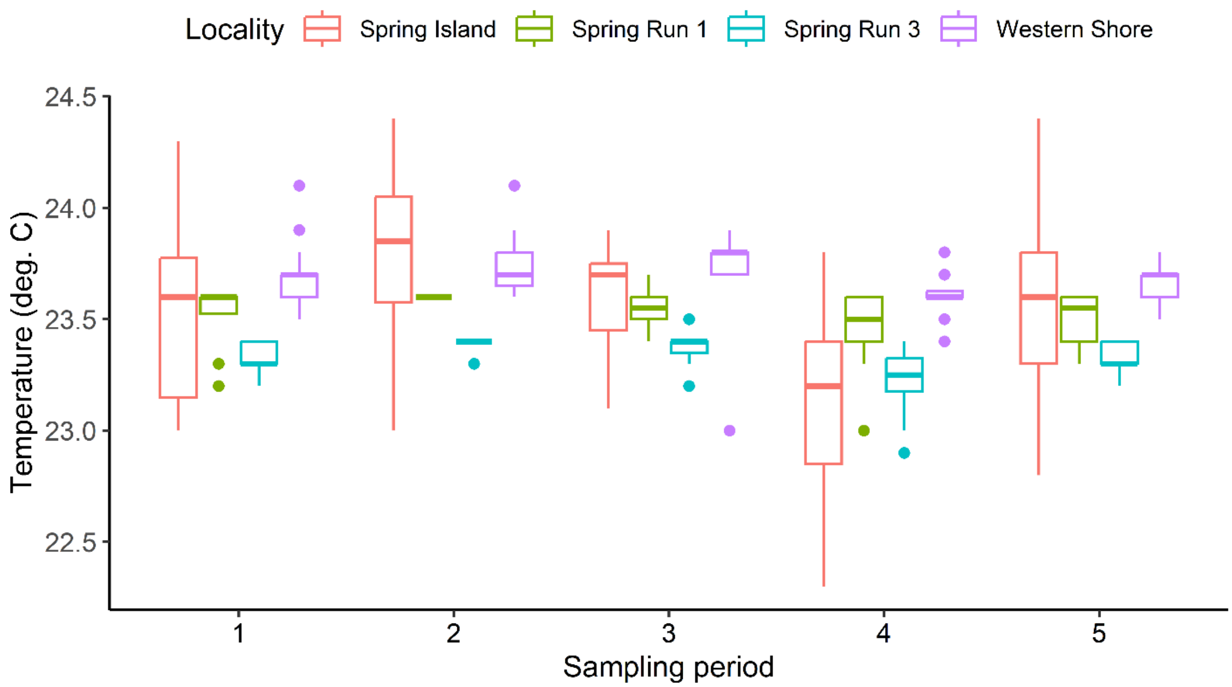


Figure S13. Boxplots of lure depth by locality when lures were set.

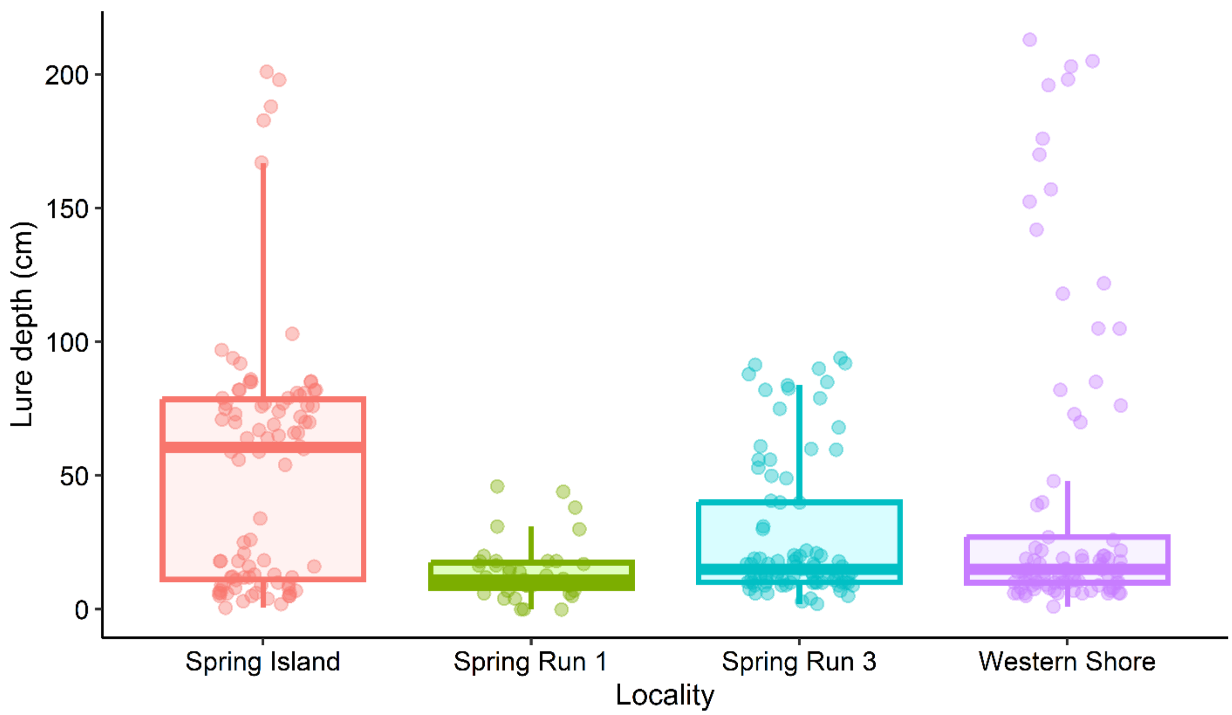


Figure S14. Boxplots of average substrate size by locality when lures were set. Points near the same y value generally are from the same site across different sampling periods.

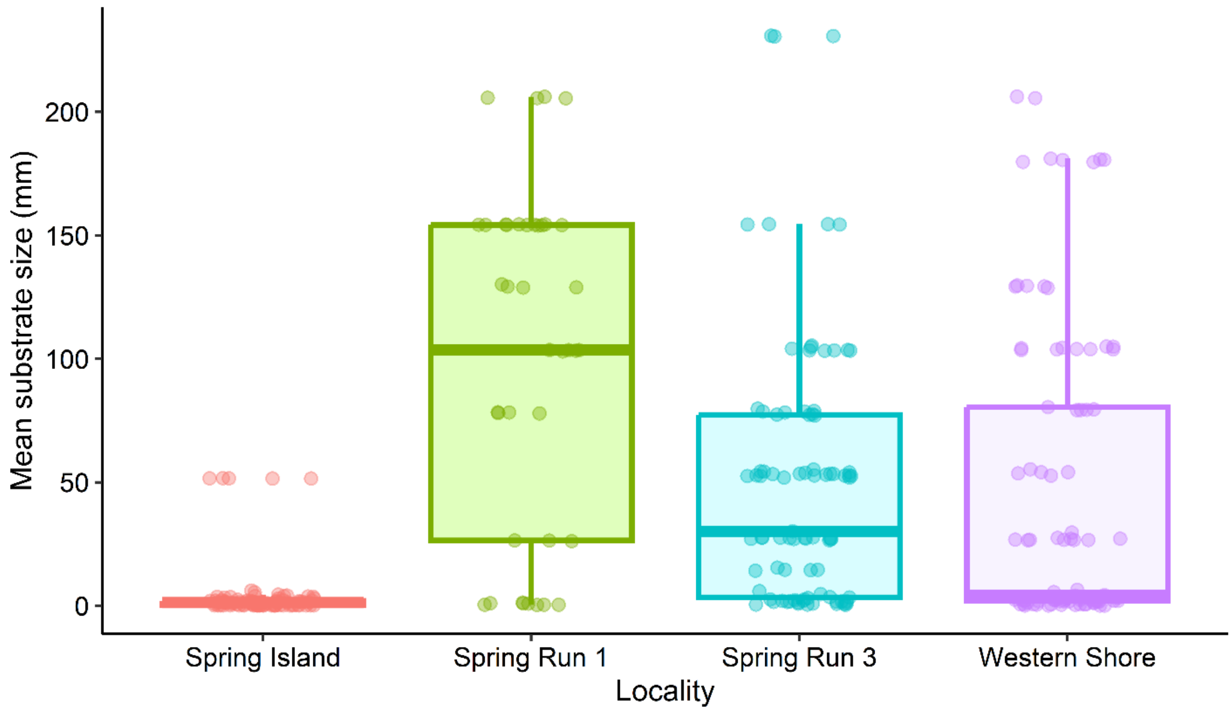
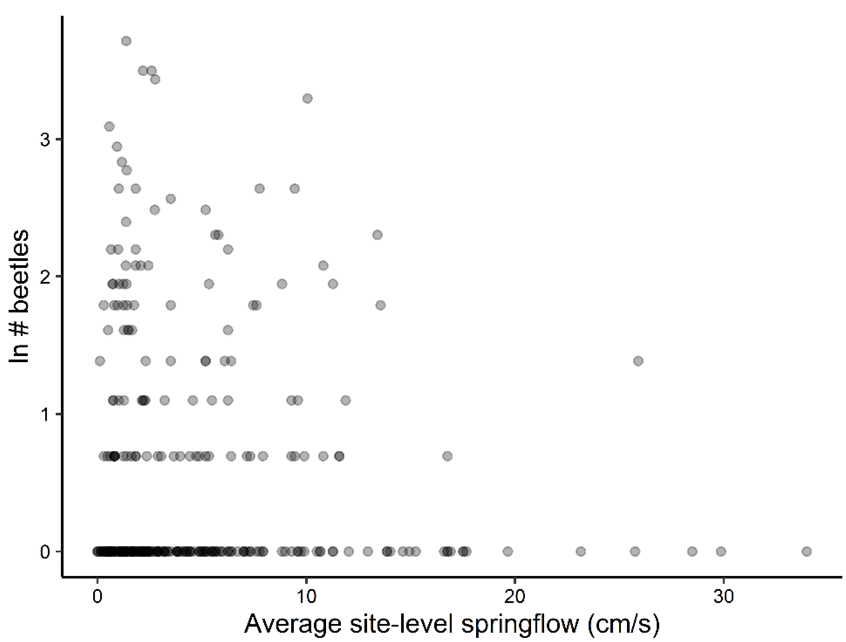


Figure S15. Scatterplot of the natural log-transformed number of CSRB adults versus average site-level springflow.



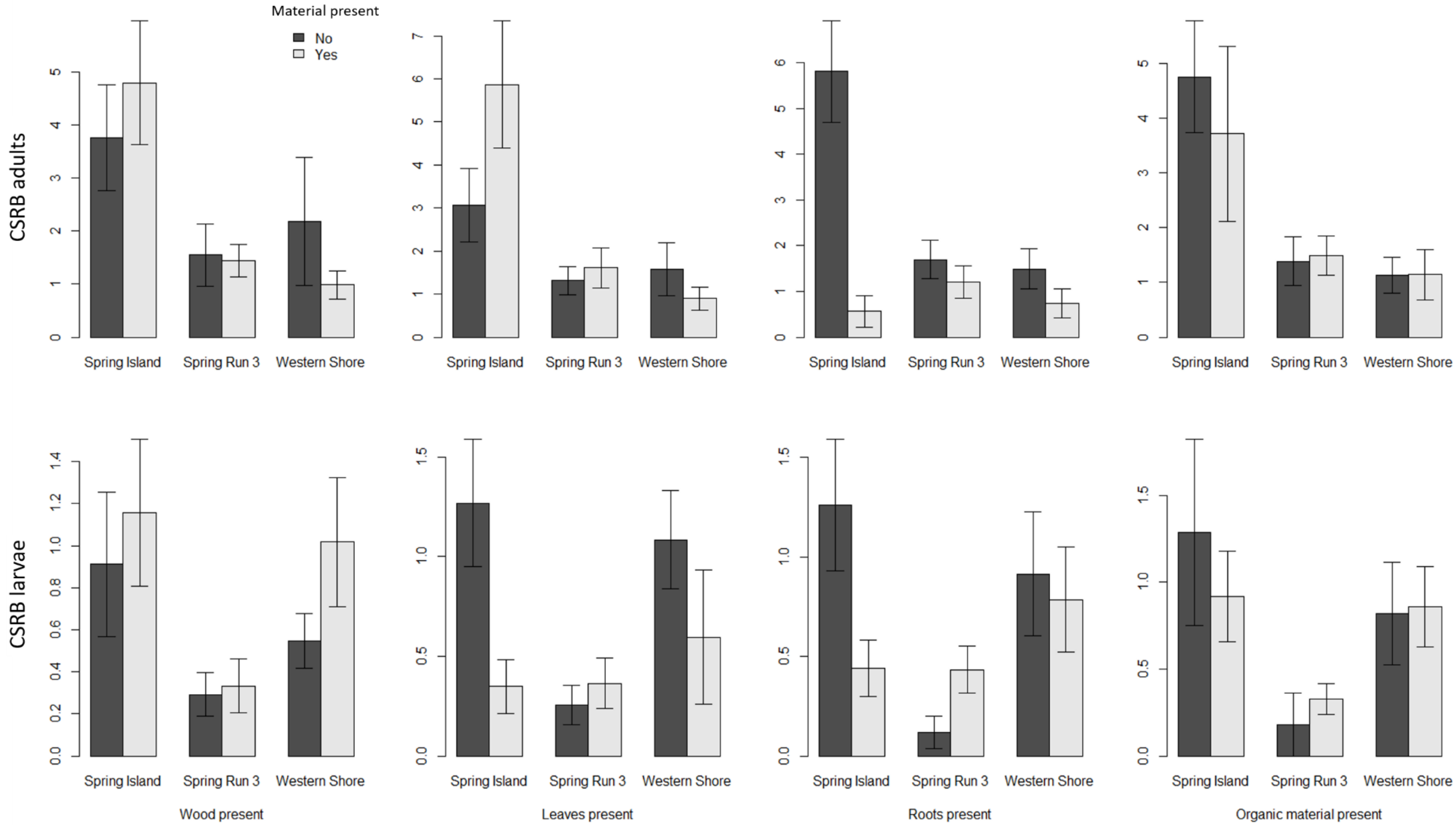


Figure S16. Mean (±SE) CSRB adult and larval abundance by locality (excluding Spring Run 1) based on the presence/absence of wood, leaves, roots, or the three combined (all organic material).

Figure S17. Boxplots of total biofilm coverage on lures by locality and sampling period when lures were retrieved.

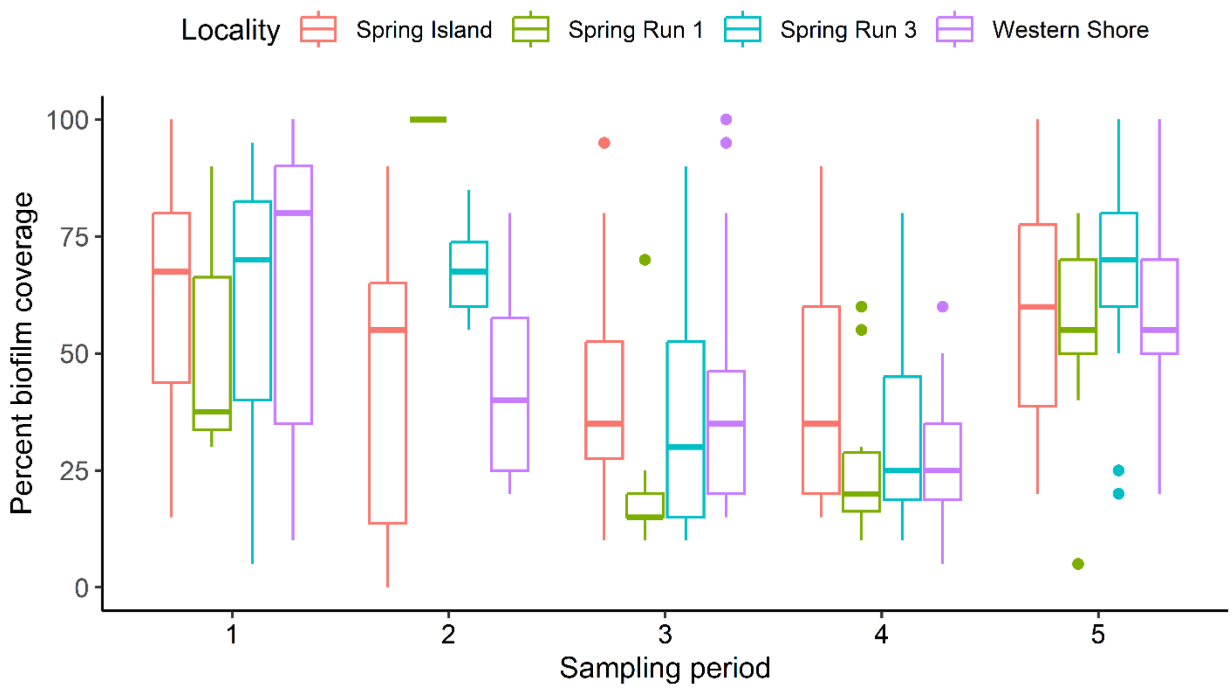


Table S1. Summary of deviance information criteria (DIC) and Bayesian p-values (B_p) for generalized linear mixed effects models with alternate parameterizations. Candidates include models with the intercepts only (Null-model), 30-day local springflow average covariate (SF), total biofilm covariate (TB), and both covariates included (SF + TB). Models with the lowest DIC scores were considered the best supported and highlighted in bold lettering.

	CSRB Adults		CSRB Larvae		MIPU Adults		MIPU Larvae	
	DIC	**B_p**	**DIC**	**B_p**	**DIC**	**B_p**	**DIC**	**B_p**
Null-model	719.99	0.48	521.36	0.50	707.60	0.50	319.75	0.51
SF	**716.57**	**0.49**	521.50	0.52	707.52	0.50	**307.91**	**0.51**
TB	735.92	0.45	**515.89**	**0.50**	702.23	0.50	316.28	0.50
SF + TB	741.42	0.45	519.24	0.52	**699.46**	**0.50**	311.99	0.51

Appendix F2 | **Water Quality Monitoring Report**

EAHCP
EDWARDS AQUIFER
HABITAT CONSERVATION PLAN

2024 EAHCP Annual Expanded Water Quality Report

Table of Contents

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1 | **Introduction**

The Edwards Aquifer Habitat Conservation Plan (EAHCP) Expanded Water Quality Monitoring Program was developed to monitor surface water and groundwater quality of the San Marcos and Comal spring systems and act as an early detection mechanism for water impairments that may negatively affect EAHCP Covered Species. From 2013 – 2016, the Expanded Water Quality Program deployed a broad range of sampling activities including surface water (base flow) sampling, groundwater sampling, sediment sampling, real-time water quality monitoring, and stormwater sampling. A Work Group was assembled in 2016 and charged to review the expanded water quality monitoring program and evaluate the recommendations from the National Academies of Sciences review of the EAHCP. The Work Group prepared a final report that included adjustments to the program including the incorporation of fish tissue analysis, reduced sampling frequency of sediment and stormwater sampling, removal of surface water and groundwater sampling, and the addition of one real-time water quality monitoring station per system. More information can be found in the *Report of the 2016 Expanded Water Quality Monitoring Program Work Group*. During the transition from Phase I to Phase II of the EAHCP, a second review of the program was conducted in 2020 that analyzed the results of contaminant detections among stormwater, sediment, and passive diffusion sampling activities and evaluated the parameters monitored in the real-time water quality network. Overall, the number of contaminant detections was low among sampling events 2013-2020. This is in part due to the focus on industrial and commercial contaminants that may not pose substantial risks to the Edwards Aquifer spring communities. Therefore, suggestions from the EAHCP Science Committee were implemented in 2021 that shifted sampling to focus on nutrients and pharmaceutical and personal care products (PPCPs). Additionally, sampling for sucralose, an artificial sweetener, was initiated in 2021 as measure of human and wastewater influence on the San Marcos and Comal spring systems. The current sampling type and activities can be viewed in Table 1-1. Sampling location and activity are displayed in Figure 1-1 for the San Marcos system and Figure 1-2 for the Comal system.

Table 1-1. EAHCP Expanded Water Quality Monitoring Program Sampling Activities

Sample Type	Activities and Sampling Locations
Real-Time Network	Continuous 15-minute interval, telemetered measurements Analytes include temperature, dissolved oxygen, and conductivity Locations include 3 San Marcos and 3 Comal stations
Surface water	Twice annual sampling in conjunction with Biological Monitoring activities Laboratory analyses are focused on nutrients including total phosphorus, orthophosphate, orthophosphate as P, TOC, DOC, DIC, kjeldahl nitrogen, nitrate at N, and ammonia Locations include upper and lower stations at each spring system
Groundwater	Twice annual sampling in conjunction with EAA springs sampling activities Laboratory analyses are focused on geochemical analytes and industrial, commercial, and emerging contaminants. The analytes include cations, anions, nutrients, metals, VOCs, SVOCs, herbicides, pesticides, bacteria, TOC, PCBs, and PPCPs Locations include Spring 1, Spring 3, and Spring 7 (Comal), Hotel, and Deep (San Marcos)
Sediment	Every other year sampling in even numbered years Laboratory analyses are focused on PAHs Locations include 6 San Marcos and 5 Comal stations
Fish Tissue	Every other year sampling in odd numbered years Laboratory analyses are focused on metals and PPCPs in two fish species Locations include upper and lower stations at each spring system

1.1 Real-Time Network

Real-time water quality (RTWQ) instruments have been deployed within the San Marcos and Comal systems for the entirety of the water quality monitoring program. From 2013-2020, real-time instruments consisted of Eureka Manta+ 30s containing five water quality sensors including, dissolved oxygen (mg/l), specific conductivity (µs/cm), turbidity (NTU), water temperature (°C), and pH (SU). Turbidity sensors were discontinued in 2020, excluding Sessom Creek, due to the high rate of malfunction and cost of replacement. In 2021, pH sensors were also discontinued due to the sensor variability being greater than environmental variability. In 2021, Eureka Manta+30s were replaced with InSitu AT 600 real-time instruments. Measurements are recorded every 15 minutes (excluding the Sessom Creek site that is measured every five minutes) and subjected to quality control measures prior to storage in EAHCP and EAA databases. Table 1-2 describes the stations within each river system including station ID, location from headwaters (i.e., Spring Lake Hotel at San Marcos and Headwaters of Landa Lake at Comal River), and period of data record.

Presently, three RTWQ sites are located in the San Marcos system, including Aquarena Springs Drive (ASD), Texas Parks and Wildlife Department (TPWD) hatchery, and Sessom Creek (Figure 1-1). ASD was deployed and brought online by late May 2013, the TPWD hatchery site was installed in January 2016, and the Sessom Creek station began collecting data in January 2018.

Three RTWQ sites are located in the Comal system, including two locations in Landa Lake (i.e., Spring run 3 (SR 3), and Spring run 7 (SR 7)), and one site in the Old Channel (OC, Figure 1-2). Spring run 3 and SR 7 were installed in 2013 whereas the OC station was installed in April 2018.

Table 1-2. EAA real-time water quality station ID, location, and period of record for the San Marcos and Comal spring systems.

River system	Station ID	Location (river km from headwaters)	Period of record
San Marcos	Sessom Creek	0.5 rkm from SMR confluence	1/1/2018 - present
	Aquarena Springs	0.8	5/30/2013 - present
	Rio Vista	1.9	5/30/2013 – 12/31/2020
	TPWD hatchery	4	1/8/2016 - present
Comal	Upper Spring Run	0.1	4/1/2019 – 12/31/2020
	Spring Run 7	1.0	9/10/2013 - present
	Spring Run 3	1.2	4/11/2013 - present
	Landa Lake	1.2	6/10/2013 – 3/31/2018
	Old Channel	1.5	4/20/2018 - present
	New Channel	2.7	5/30/2013 – 12/31/2020

Real-time water quality stations assist in discerning when and what river conditions result in water quality exceeding critical biological standards. One of EAHCP's long-term management objectives is to maintain water quality conditions that do not deviate > 10% from historical water quality conditions recorded during the EAA Variable Flow Study. Additionally, specific EAHCP water quality thresholds include, maintaining water temperature < 25°C as to not inhibit fountain darter reproduction and recruitment rates (McDonald et al. 2007) and maintaining dissolved oxygen concentrations > 4.0 mg/L throughout fountain darter habitat. EAHCP's RTWQ stations are designed to track water quality conditions within the San Marcos and Comal systems to monitor whether river conditions remain within historic conditions and under specific thresholds.

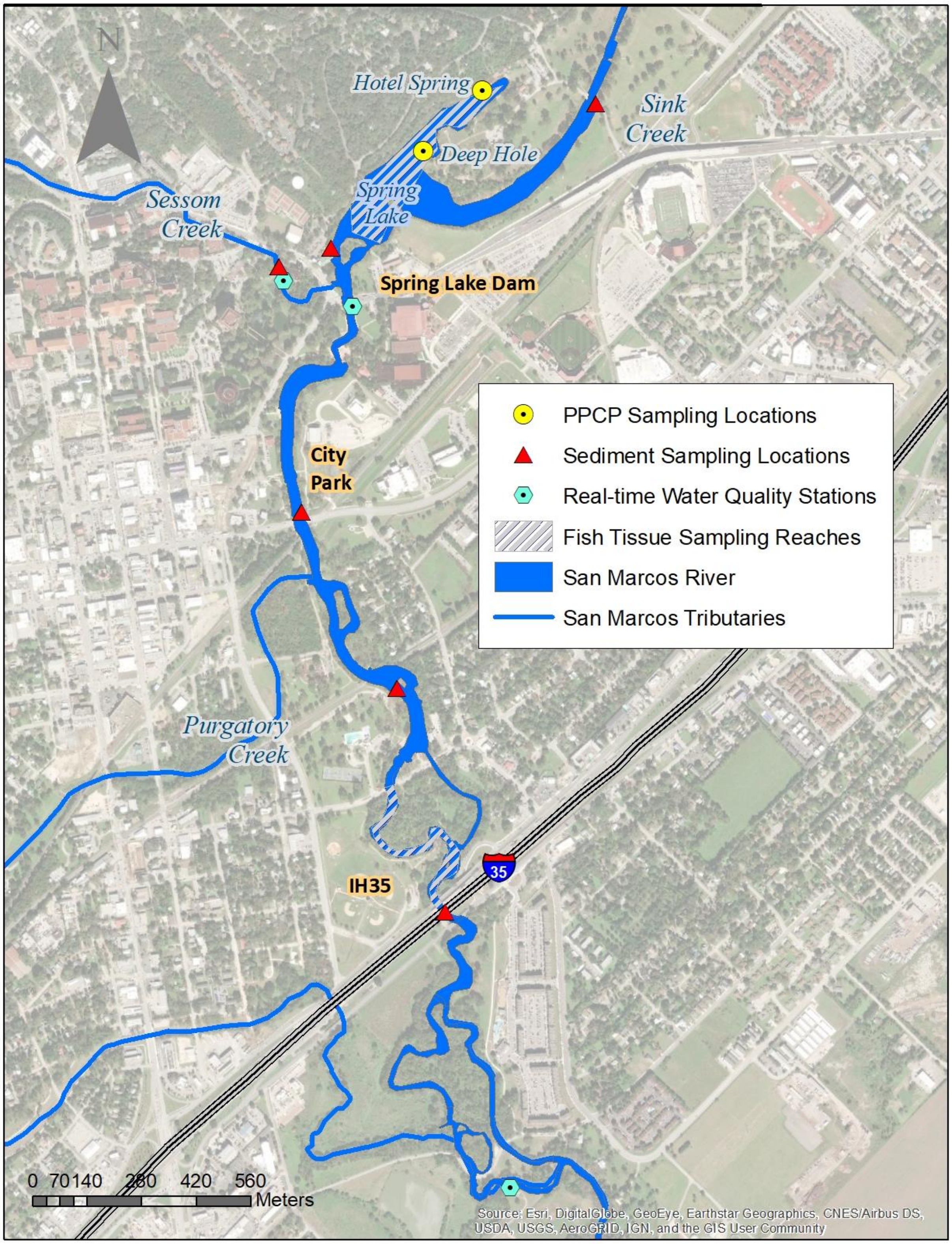

Figure 1-1. Expanded Water Quality Sampling Locations in the San Marcos system.

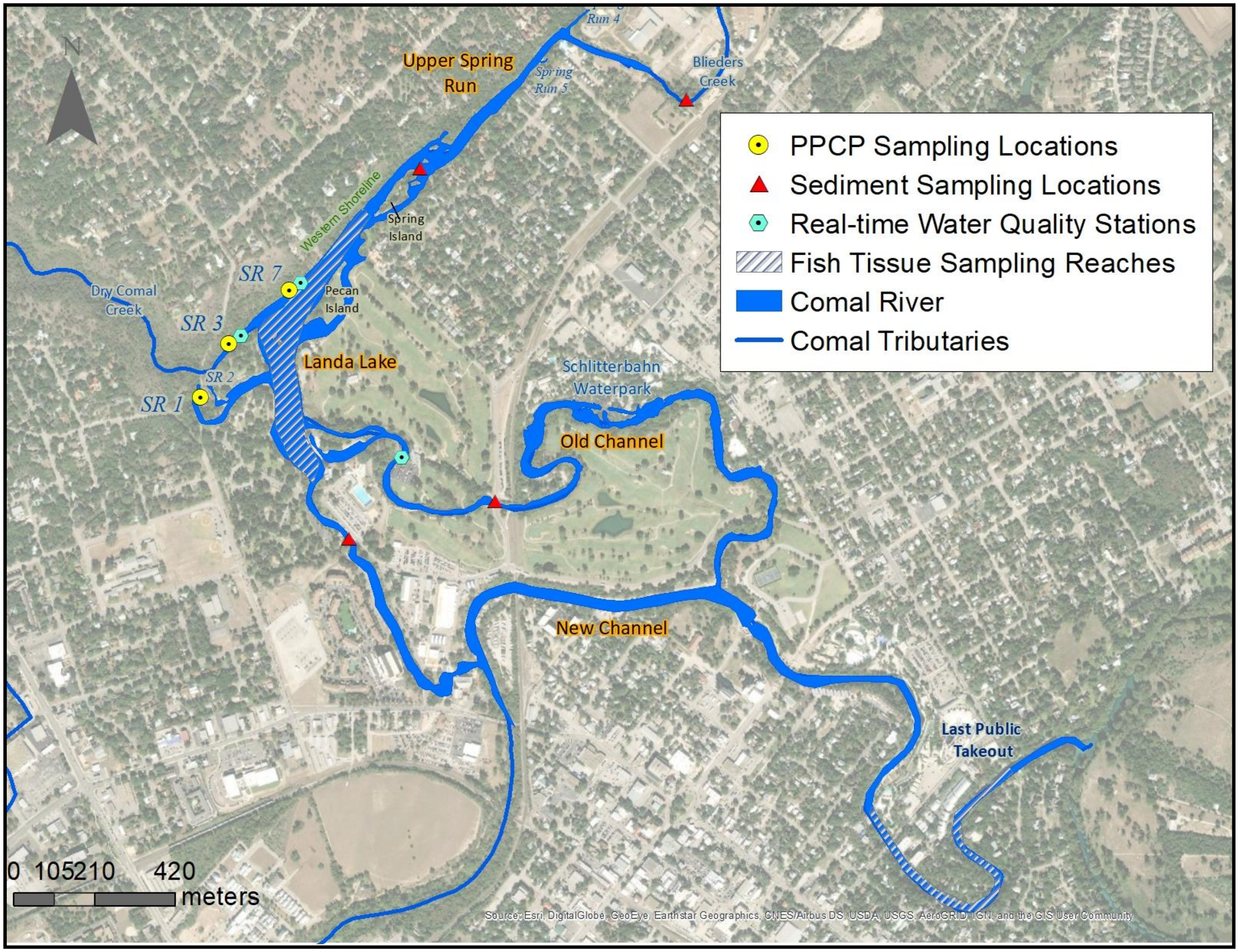

Figure 1-2. Expanded Water Quality Sampling Locations in the Comal system.

1.2 Surface water sampling

Monthly sucralose sampling occurs at one location in each spring system (i.e., Hotel Spring in San Marcos and Spring Run 3 in Comal). Sucralose, an artificial sweetener found in many diet beverages and candies, is not efficiently processed by the body, and subsequently ends up in septic and city wastewater effluent (Whitall et al. 2021). Sucralose has shown minimal degradation when processed through wastewater facilities, is relatively stable in the environment, and has demonstrated reliable detection rates (Oppenheimer et al. 2011). Therefore, monitoring the occurrence and levels of sucralose systems has proven to be a suitable indicator of wastewater input among rivers and groundwater systems.

Additional surface water samples are collected on a biannual basis under normal flow conditions in conjunction with the Biological Monitoring program (Spring and Fall). Sampling locations consist of upper and lower river stations in both systems. For the Comal system, Landa Lake near Spring Island serves as the upper location, and the lower station is located at the last public river take out just upstream of the confluence with the Guadalupe River. In San Marcos, Hotel Spring in Spring Lake serves as the upper location, and the downstream location is located at the most downstream real-time water quality monitoring station (i.e., TPWD hatchery). Samples are submitted to a laboratory for analysis of nutrients (Table 1-3). During the collection event, field parameters are collected that include dissolved oxygen, pH, conductivity, and temperature.

Table 1-3. List of Nutrients Analyzed during Surface Water Sampling

Analyte
Ortho-phosphate as P
Phosphorus (total)
Dissolved Inorganic Carbon (DIC)
Dissolved Organic Carbon (DOC)
Kjeldahl Nitrogen
Nitrate as N
Ammonia

1.3 Groundwater sampling

Groundwater sampling is conducted by the EAA Aquifer Science Division and is part of their routine water quality monitoring of streams, wells, and springs in the Edwards Aquifer Region (Edwards Aquifer Water Quality Summary 2024 Report). Two spring orifices in the San Marcos system (i.e., Hotel Spring and Deep Hole) and three springs within the Comal system (ie., Spring Run 1, Spring Run 3, and Spring Run 7) are sampled on a biannual basis in conjunction with the EAHCP Biological Monitoring program (i.e, Spring and Fall). Beginning in 2022, PPCP samples were also collected every other month at Hotel Spring and Spring Run 3 locations. Groundwater samples are submitted to a laboratory for analysis of cations, anions, nutrients, metals, VOCs, SVOCs, herbicides and pesticides, bacteria, TOC, PCBs, and PPCPs. The analyte list for laboratory analyses along with the methods are shown in Table 1-4. During the collection event, field parameters will be collected that include dissolved oxygen, pH, conductivity, temperature, and alkalinity.

Table 1-4. List of Items Analyzed during Groundwater Sampling

Analyte
Volatile Organic Compounds (VOCs)
Semi-volatile Organic Compounds (SVOCs)
Organochlorine Pesticides
Polychlorinated Biphenyls (PCBs)
Organophosphorous Pesticides
Herbicides
Metals (Al, Sb, As, Ba, Be, B, Cd, Cr (total), Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, Tl, V, and Zn)
General Chemistry (GWQP) Total Alkalinity (as CaCO3), Bicarbonate Alkalinity (as CaCO3), Carbonate Alkalinity (as CaCO3); (Cl, Br, NO_3, SO_4, Fl, pH, TDS, TSS, Ca, Mg, Na, K, Si, Sr, CO_3,)), and Total Suspended Solids (TSS).
Phosphorus (total)
Total Organic Carbon (TOC),
Dissolved Organic Carbon (DOC)
Kjeldahl Nitrogen
Bacteria Testing (*E coli*)
PPCPs

Method	**Method Description**	**Protocol**
8260B	Volatile Organic Compounds	(GC/MS) SW846
8270C	Semivolatile Organic Compounds	(GC/MS) SW846
8081B	Organochlorine Pesticides	(GC) SW846
8082A	Polychlorinated Biphenyls (PCBs)	by Gas Chromatography SW846
8141A	Organophosphorous Pesticides	(GC) SW846
8151A	Herbicides	(GC) SW846
6010B	Metals	(ICP) SW846
6020	Metals	(ICP/MS) SW846
7470A	Mercury	(CVAA) SW846
300.0	Anions,	Ion Chromatography
340.2	Fluoride	MCAWW
365.4	Phosphorus,	Total EPA
9040C	pH	SW846
9060	Organic Carbon,	Total (TOC) SW846
SM 2320B	Alkalinity	SM
SM 2540C	Solids,	Total Dissolved (TDS) SM
SM 2540D	Solids, Total Suspended (TSS)	SM
351.2	Nitrogen, Total Kjeldahl	MCAWW
1694	PPCPs	LC-MS/MS

Protocol References:
EPA = US Environmental Protection Agency
MCAWW = "Methods For Chemical Analysis Of Water And Wastes", EPA-600/4-79-020, March 1983 And Subsequent Revisions.
SM = "Standard Methods For The Examination Of Water And Wastewater",
SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

1.4 Sediment and Fish Tissue sampling

Sediment and fish tissue sampling occurs on an every other year basis with sediment sampling completed in even years and fish tissue sampling in odd years. Sampling collections for sediment and fish tissue occur in the Spring during the EAHCP Biological Monitoring surveys.

Collection of sediment samples within in each spring system was included in the program to help determine potential effects on EAHCP covered species via direct or indirect exposure to sediment contaminants. Sediment samples are collected once from four locations within the Comal system and six locations in San Marcos system (Figures 1-1 and 1-2). Samples were collected at each sample site and composited into one sample for analysis. Sediment samples were analyzed for polycyclic aromatic hydrocarbons (PAHs) and other contaminants listed in Table 1-5.

Table 1-5. List of Contaminants Analyzed during Sediment Sampling.

Analyte
Benzo[a]anthracene
Chrysene
Benzo[a]pyrene
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Fluoranthene
Dibenz(a,h)anthracene
Indeno[1,2,3-cd]pyrene
Pyrene
Phenanthrene
Fluorene
Benzo[g,h,i]perylene
Anthracene
Acenaphthene
Acenaphthylene
Benzo[g,h,i]perylene
Carbazole
2-Methylnaphthalene
Naphthalene
Total Organic Carbon (TOC)

Fish tissue sampling within in each spring system was included to the program in 2017 to serve as a direct link between water quality impairments and their potential effects on EAHCP covered species. Prior to 2017, the linkage between contaminants and metals found in the spring systems and their accumulation in EAHCP covered species was unknown. Surrogate species were selected to represent EAHCP covered species and the two species selected for analysis are *Gambusia* (mosquito fish) and *Micropterus salmoides* (largemouth bass). The mosquito fish serves as a short-lived species, similar to the EAHCP covered fountain darter, whereas the largemouth bass represents the longer-lived species. Mosquito fish and largemouth bass were collected from upper and lower sections in both spring systems. In the San Marcos, fish were collected in Spring Lake (i.e., upper section) and in the San Marcos River near IH35 (i.e., lower section). For the Comal, both species were collected from Landa Lake (i.e., upper section) and in the Comal River near the last public take out (i.e., lower section). For each section, whole body organisms were combined to create a mosquito fish composite sample. Composites for largemouth bass were created from individual fillet aliquots from each fish. Tissue samples were submitted to a laboratory and analyzed for metals and PPCP contaminants listed in Table 1-6.

Table 1-6. List of Metals and Contaminants Analyzed among Fish Tissue Samples.

Analyte
Metals (Al, Sb, As, Ba, Be, B, Cd, Cr (total), Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, Tl, V, and Zn)
PPCPs

Method	**Method Description**	**Protocol**
6010B	Metals	(ICP) SW846
6020	Metals	(ICP/MS) SW846
7470A	Mercury	(CVAA) SW846
1694	PPCPs	LC-MS/MS

Protocol References:
EPA = US Environmental Protection Agency
MCAWW = "Methods For Chemical Analysis Of Water And Wastes", EPA-600/4-79-020, March 1983 And Subsequent Revisions.
SM = "Standard Methods For The Examination Of Water And Wastewater",
SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates

2.1 Real-Time Network

The near continuous (15-minute interval) raw data collected at San Marcos River and Comal system RTWQ sites underwent a quality assurance review process before being utilized for this assessment. Water quality sonde data was overlayed with river streamflow and precipitation data to verify significant increases and decreases in measured values. The data from each site within the basins were also compared to ensure validity. The multiparameter water quality instruments were switched out at 5 to 6-week intervals, with the unit returned to the EAA office for data download, calibration checks, and cleaning. Data obtained from independent field visit measurements and post-deployment sensor calibration checks were used to determine any necessary adjustments to the near continuous raw data sets. Additional quality control was completed to the data in the Power BI Pro License software.

Turbidity data recorded at Sessom Creek were edited for any values in the continuous raw data interpreted as not being representative of actual ambient water quality conditions. Sporadic spikes in turbidity values without any corresponding change in other parameters (i.e. Specific Conductance, Temperature, or Dissolved Oxygen) were deleted from the finalized continuous data sets before their use in this assessment.

Mean daily, maximum daily, and minimum daily values for water quality parameters at each of the San Marcos River and Comal system RTWQ sites were exported from AQUARIUS database. Hydrographs since the start of the EAHCP (2013) for the two systems were constructed using surface water discharge data (recorded in 15-minute intervals) obtained for the San Marcos River at San Marcos (USGS Station 08170500) and the Comal River at New Braunfels (USGS Station 0816900). Mean daily springflow (cfs) for the San Marcos springs (USGS Station 08178710) and the Comal springs (USGS Station 0816900) were used to construct springflow hydrographs for 2013-2021. Differences in maximum daily temperatures and minimum daily dissolved oxygen among sites and seasons were assessed using boxplots. Seasons were defined as: Winter (January, February, December), Spring (March – May), Summer (June – August), and Fall (September – November). For sites exceeding water temperatures > 25°C, 15-minute interval data (5-minute interval data for Sessom Creek) were used to assess the number of days and percent of day a site exceeded 25°C. Similar analysis was completed for sites that dropped below the 4.0 mg/L dissolved oxygen threshold.

2.2 Surface water sampling

Water samples for sucralose were collected from Hotel Spring in the San Marcos system and Spring run 3 in the Comal system monthly January – December 2024. Prior to water sample collection, an Insitu AquaTroll 600 water quality sonde was placed directly in each location to measure water quality parameters (i.e., pH, specific conductivity, dissolved oxygen, and temperature) for a ten-minute period. Sample bottles were submerged directly into the springs to be filled. Field duplicates and field blanks (i.e., bottles filled with DI water) were also filled following sampling protocols. All sample bottles were kept chilled during transport in an ice chest frozen until later shipment to the laboratory that occurred on a quarterly basis.

Surface water samples for nutrient analysis were collected in April and September 2024 at upper and lower sites in the San Marcos and Comal systems. During sampling collections, water quality parameters were measured following same protocols as monthly sucralose sampling. Filtration for methods 6010B (metals), 6020 (metals), and 7470A (mercury) were performed at the sample locations by using a 0.45 micron high capacity cartridge filter inserted into syringe. Preservatives were placed in the bottles (as appropriate) by the contracted laboratory. Field duplicates and field blanks were also filled following sampling protocols. All sample bottles were kept chilled during transport in an ice chest frozen and immediately shipped to the contract laboratory for analysis.

All water quality data were exported to excel and medians values were calculated for field measured water quality parameters collected during sucralose and bi-annual surface water sampling collections.

2.3 Groundwater sampling

Groundwater samples for PPCPs and other analyses were collected from Hotel and Deep Hole springs in the San Marcos system and from Spring Run 1, 3, and 7 within the Comal Spring system in March and September 2024. Additional PPCP samples were also collected every other month (i.e., January, May, July, and November) at Hotel and Spring Run 3 locations. Prior to groundwater collections, an Insitu AquaTroll 600 water quality sonde was placed directly into the spring orifice to measure water quality parameters (i.e., pH, specific conductivity, dissolved oxygen, turbidity, and temperature). Sample bottles were then submerged directly into the spring to obtain samples, except for Deep Hole Spring where EAA staff utilized a peristaltic pump with 30 feet of sample tubing inserted into the spring orifice to collect field parameters and fill sample bottles. Samples were collected in accordance with the criteria set forth in the *EAA Groundwater Monitoring Plan*.

Filtration for methods 6010B (metals), 6020 (metals), 7470A (mercury) and field alkalinity were performed at the sample locations by utilizing a 0.45 micron high capacity cartridge filter inserted into a weighted single sample disposable bailer or sample tubing (if peristaltic pump was used).

Preservatives were placed in the bottles (as appropriate) by the contracted laboratory. Ice was placed into the cooler immediately after sampling and later shipped to the contract laboratory. When not in use or after collection, sampling equipment and/or coolers containing samples were secured inside the EAA vehicles to maintain appropriate sample custody and security.

Analyses for field alkalinity were conducted at EAA's Camden Building using Hach Titralab® AT1000. The method used for field alkalinity is discussed in detail in the *EAA Groundwater Monitoring Plan.*

A full report of groundwater sampling results at Hotel and Deep Hole springs will be available under the Science and Aquifer Protection section on the EAA website and entitled Water Quality Summary Report 2024. Sampling results for PPCPs are reported in Section 3.3.

2.4 Sediment sampling

Sediment samples were collected in August 2024 at six locations in the San Marcos system and four locations in the Comal system (Figures 1-1 and 1-2). At each location, fine sediment was targeted and collected using an aluminum scoop. Once collected, the sediment was sorted to remove as much coarse sediment and other debris as possible before being placed into a 1L glass container. Sample bottles were transported in coolers and frozen before being shipped to contract laboratory.

3 | **Results and Discussion**

3.1 Real-Time Network

3.1.1 San Marcos

Hydrology

Average springflow for the San Marcos Springs calculated from the period of record (i.e., 1956 – present) was 175 cfs. Since 2013, San Marcos springflow ranged from below average in 2013-2014 to above average from mid-2015-2017 (Figure 3-1). During 2013, the San Marcos springflow dropped down to as low as 99 cfs on May 21st. A flow pulse on October 30th, 2013, estimated at 5,400 cfs, resulted in a temporary spike in above average springflow. No substantial rain events occurred in 2014 and consequently, springflow dropped below average. Increased springflow in 2015 occurred following two large precipitation events in late May and October with above average springflow continued into 2016 - 2017. In 2018, springflows dropped below average, reaching 117 cfs in late August. However, several small rain events in the early fall resulted in springflows increasing and becoming above average (~250 cfs). Springflows were largely above average in 2019, but with a lack of large flow pulses (> 500 cfs), springflows lessened throughout the year and dropped just below average beginning in October. With no large flow pulses in 2020, springflows continued to decrease and dropped below 120 cfs by December. Springflow in early 2021 continued to decline and dropped briefly below 100 cfs in April before rain events in late spring resulted in springflow rising to average flows. Springflows dropped slightly during early fall but increased again after significant rain events (i.e., 1,070 cfs pulse on October) to end 2021 at average springflow. No significant rainfall events occurred in 2022 with springflows at critical period monitoring levels during most of the year. Springflows dropped down to ~85 cfs from the end of September-December and is the lowest discharge observed since the start of the EAHCP. Springflows remained below 100 cfs during all of 2023 (median 88 cfs), dropping in August to the lowest observed springflow (66cfs) since 1956. Springflows increased at the beginning of 2024, but steadily decreased and remained below average throughout the year, ending at ~85 cfs in December.

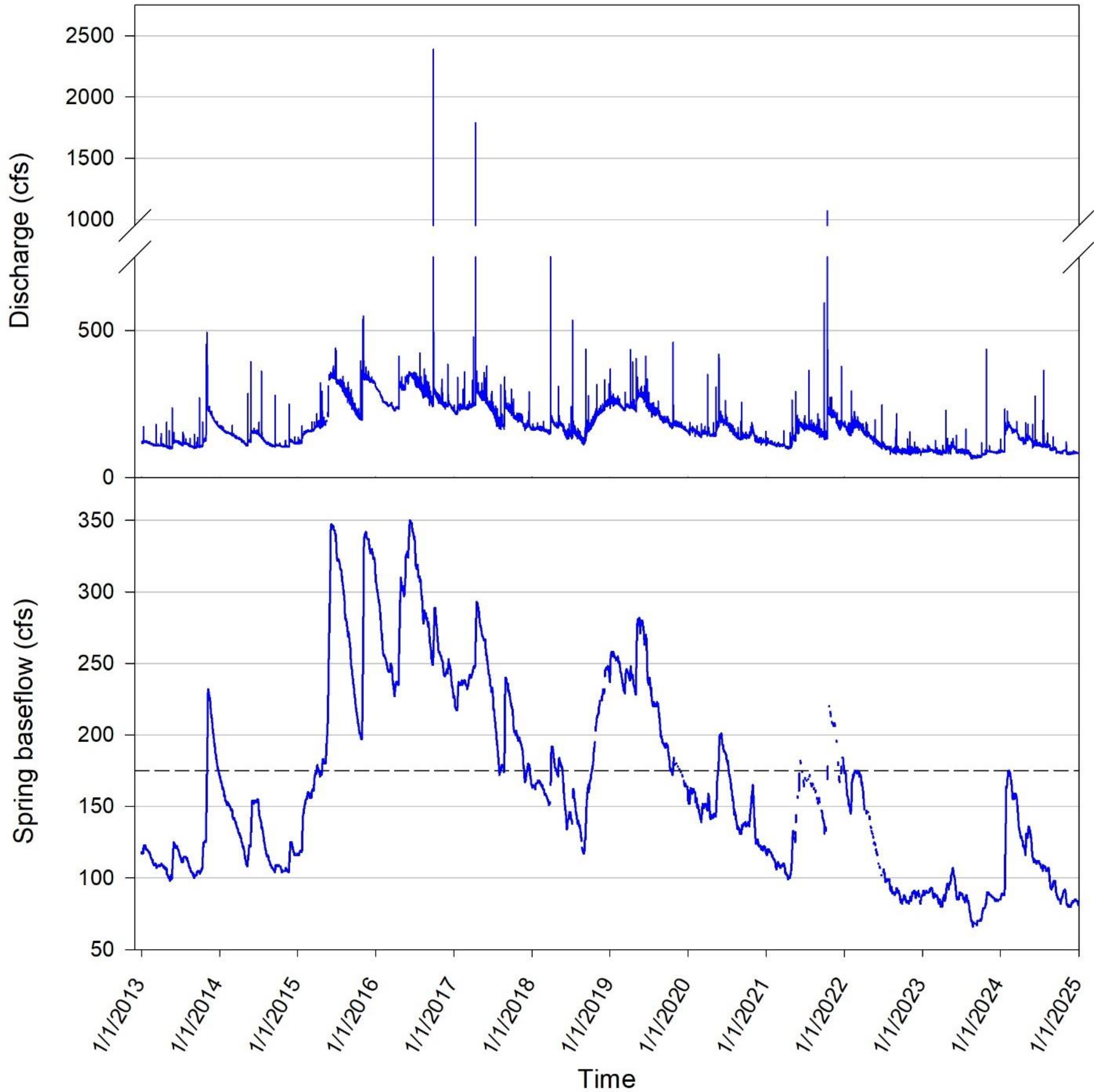

Figure 3.1-1. Hydrographs for the San Marcos River at San Marcos (USGS station 08170500) and mean daily springflow for the San Marcos springs (USGS Station 08170000) 2013 – 2024. Dashed line denotes the long-term average springflow (175 cfs) in the San Marcos River.

Temperature

Table 3.1-1 displays monthly summary statistics (i.e., monthly mean and 15 minute minimum and maximum values reported that month) for water temperatures recorded in 2024 at the San Marcos River RTWQ sites. Slightly more variation in mean water temperatures (~3-4 °C) was observed this year and is likely attributed to lower than average springflows in the system during 2024. The TPWD hatchery site continued to display greater variability in water temperature with minimum daily water temperatures reaching lower temperatures in winter months and warmer maximum daily water temperatures during summer months. Maximum daily water temperatures recorded in 2024 reached the 25°C threshold with the highest temperature (26.98°C) recorded at the TPWD hatchery in August. The lowest temperature (8.89°C) in 2024 was observed at the TPWD hatchery site in January and is associated with a rainfall event when ambient temperatures were cold.

Table 3.1-1. Monthly mean, minimum, and maximum water temperatures among San Marcos River RTWQ (2024).

	Water temperature (°C) at San Marcos Water Quality Sites					
Month (2024)	**Aquarena Springs**			**TPWD hatchery**		
	Mean	Min	Max	Mean	Min	Max
Jan	20.17	12.09	22.21	18.87	8.89	22.35
Feb	21.43	19.87	23.21	21.31	19.16	23.62
Mar	21.88	20.37	23.62	21.81	19.97	24.07
Apr	22.40	20.55	24.74	22.39	20.42	24.43
May	23.20	21.68	24.92	23.28	19.36	25.80
Jun	23.35	22.46	24.89	24.06	22.60	26.75
Jul	23.27	22.39	24.98	23.97	22.49	26.75
Aug	23.48	22.45	25.60	24.22	22.63	26.98
Sept	23.18	21.44	25.05	23.57	21.28	25.73
Oct	22.67	20.88	24.46	22.78	20.21	24.73
Nov	21.70	19.64	23.46	21.40	18.55	23.47
Dec	21.16	19.00	23.02	20.62	16.82	23.06

Box plots for maximum daily temperatures (i.e., highest 15-minute interval recorded daily) observed at San Marcos RTWQ sites from time of equipment deployment (i.e., 2013 for Aquarena Springs Drive (ASD) and 2016 for TPWD hatchery) through 2024 compared to maximum daily temperature observed in 2024 are shown in Figure 3.1-2. The median of maximum daily temperatures for 2024 were slightly higher than the median of maximum daily temperatures from time of equipment deployment at both San Marcos sites but this was not unexpected with sprinflows remaining below average for most of the year.

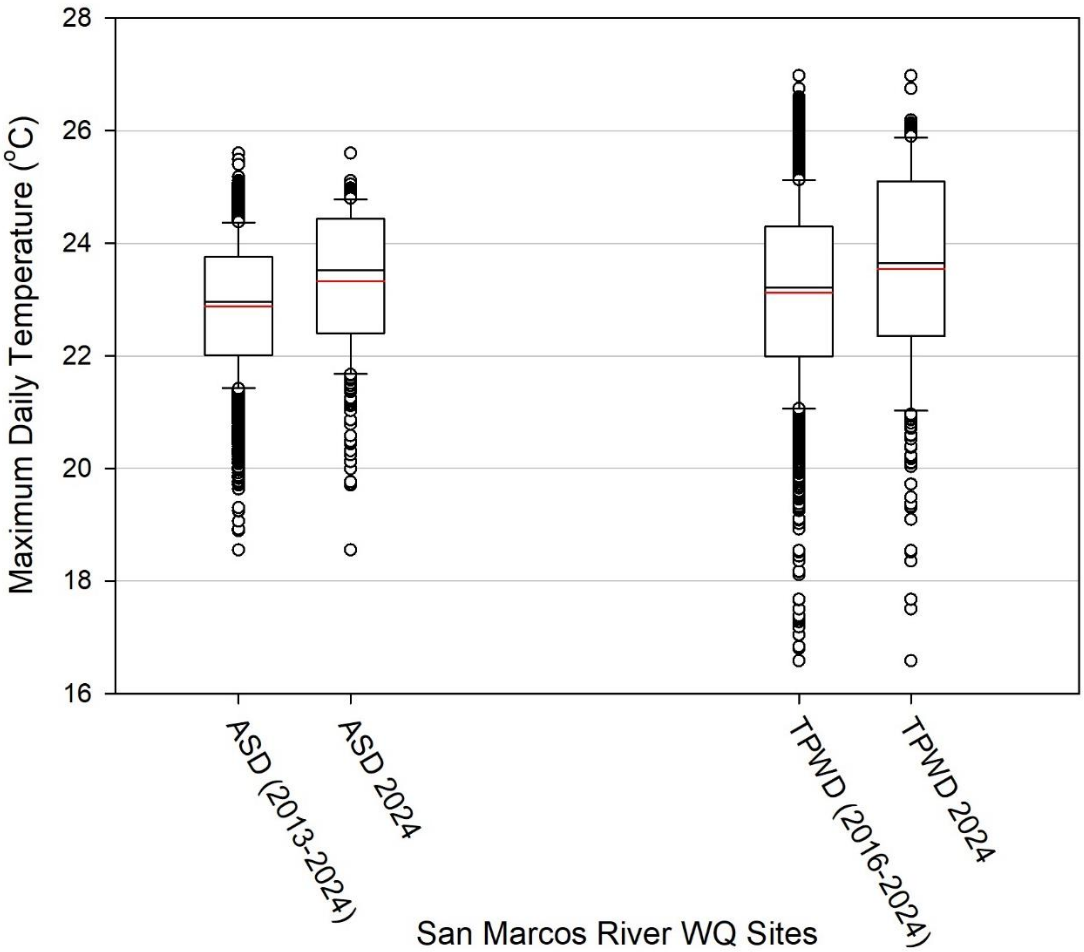

Figure 3.1-2. Box plots of maximum water daily temperatures (°C) among San Marcos River RTWQ sites from time of equipment deployment through 2024 compared to 2024 values. Black lines represent median values and red lines denote mean values. Whiskers represent maximum and minimum temperature values, excluding outliers (open circles).

Maximum daily water temperatures were plotted for San Marcos River RTWQ sites for 2024 (Figure 3.1-3). In 2024, the maximum daily water temperature reached or exceeded 25°C at both EAHCP water quality stations in the San Marcos River. At ASD, the maximum daily water temperature reached 25°C for only three days (August – September) for a period of 0.25-1.25 hours per day. At the TPWD hatchery location, the maximum daily water temperature reached or exceeded 25°C for 98 days during the months of May–September. Within those 98 days, time spent at or above 25°C ranged from 1.25 to 13.25 hours (mean = 6.27 hours; median = 6.75 hours).

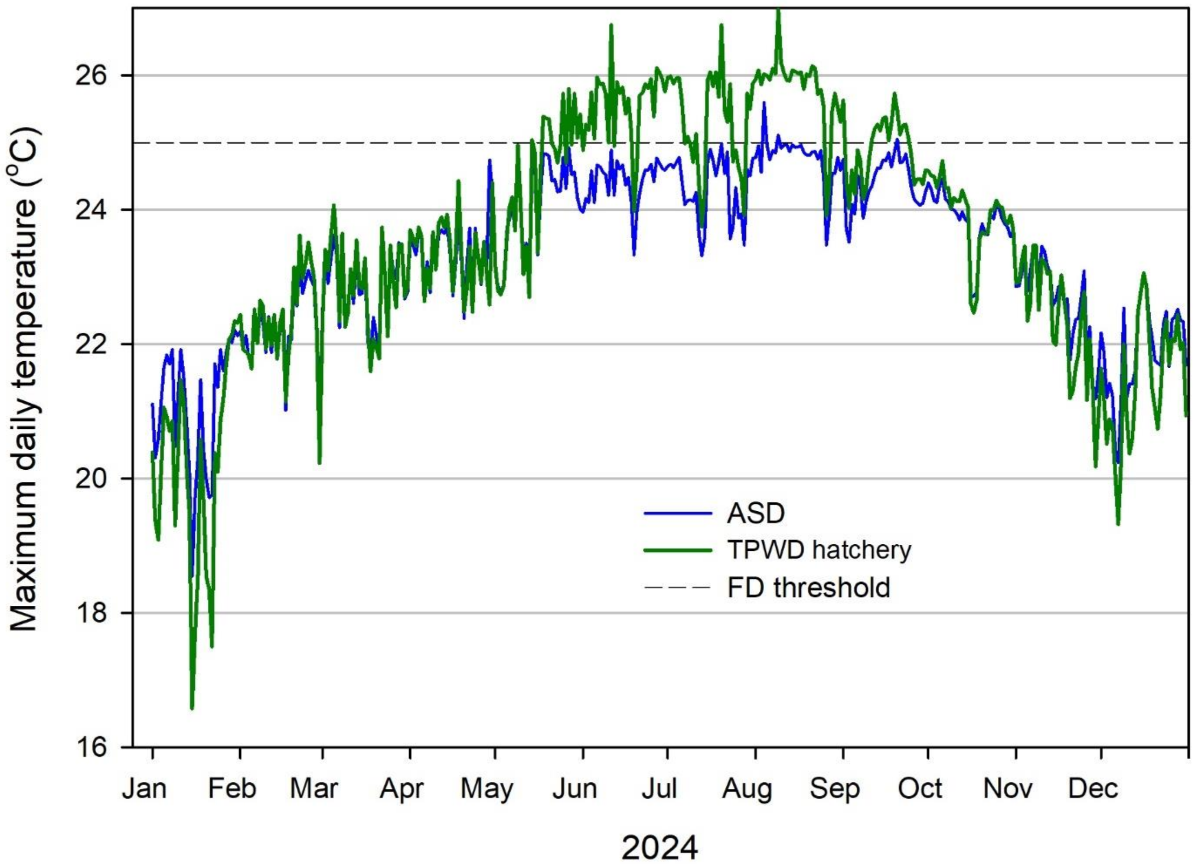

Figure 3.1-3. Maximum daily water temperatures (°C) among San Marcos River RTWQ sites (2024). Dashed line represents temperature threshold for reduced reproduction for the fountain darter (25°C).

Box plots for seasonal maximum daily water temperatures at San Marcos RTWQ sites for 2024 are shown in Figure 3.1-4. Across seasons, median maximum daily temperatures varied by ~3-4°C among San Marcos River WQ sites with some more outlier temperatures observed in winter and fall. Greater variability in temperatures across seasons corresponds with the decrease of springflow that occurred as the year progressed. Winter and Fall showed the greatest range in maximum daily temperatures for San Marcos WQ sites with summer months exhibiting less variability but higher median temperatures.

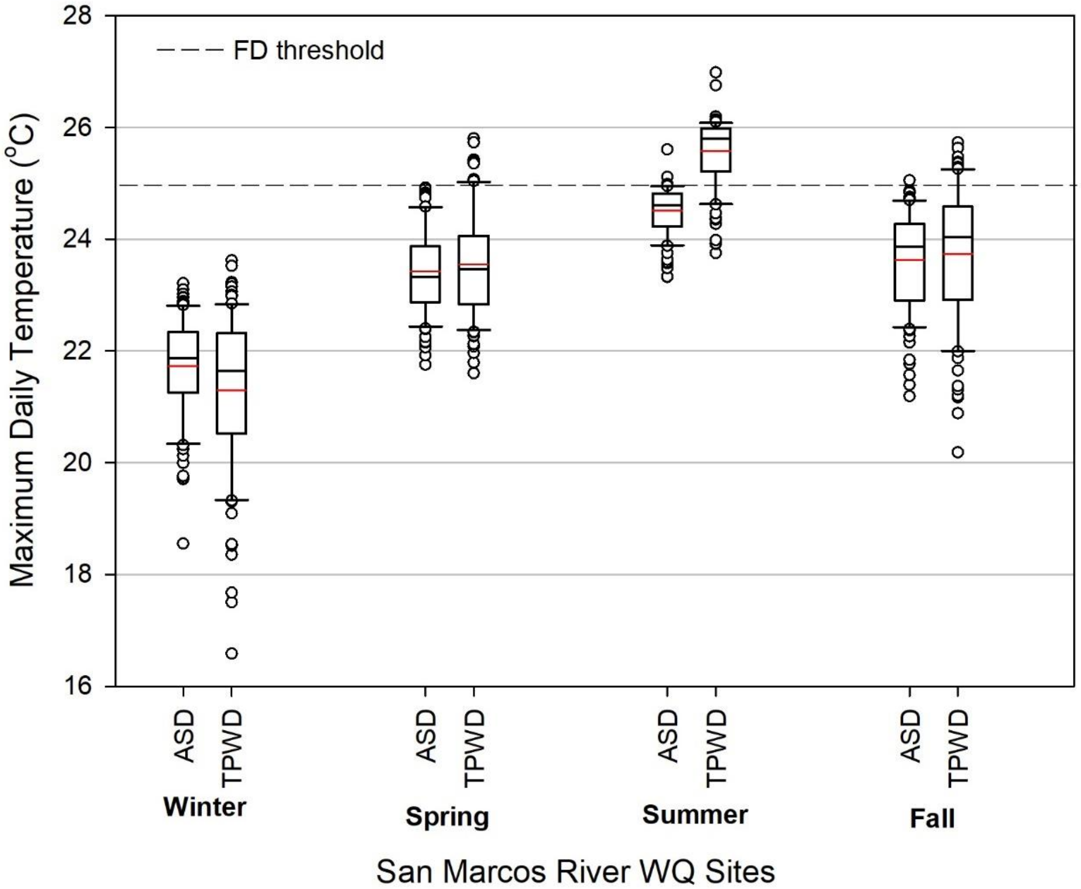

Figure 3.1-4. Box plots of maximum daily water temperatures (°C) among seasons at San Marcos River RTWQ sites in 2024. Black lines represent median values and red lines denote mean values. Whiskers represent maximum and minimum temperature values, excluding outliers (open circles).

Dissolved Oxygen

Table 3.1-2 displays monthly summary statistics for dissolved oxygen (DO) recorded in 2024 at the San Marcos River RTWQ sites. Mean monthly DO remained relatively consistent with variations averaging 1 mg/l within a site and did not vary greatly between the two sites. The TWPD hatchery site demonstrated greater variability in DO in 2024 than the upper ASD site. The highest DO recorded in 2024 was 11.18 mg/l at TPWD hatchery in January, and the lowest DO (5.98mg/l) occurred in May at the ASD site.

Table 3.1-2. Monthly mean, minimum, and maximum DO (mg/l) among San Marcos River RTWQ sites (2024).

	Dissolved oxygen (mg/l) at San Marcos Water Quality Sites					
Month (2024)	**Aquarena Springs**			**TPWD hatchery**		
	Mean	Min	Max	Mean	Min	Max
Jan	8.25	7.34	10.18	8.87	7.66	11.18
Feb	8.07	6.68	9.98	8.56	7.46	10.56
Mar	8.00	6.61	10.06	8.40	7.31	10.42
Apr	7.95	6.67	9.85	8.17	7.14	9.82
May	7.70	5.98	9.46	8.00	6.70	9.67
Jun	7.72	6.67	9.11	7.98	6.75	9.46
Jul	7.88	6.78	9.24	8.11	7.04	9.57
Aug	7.90	6.96	9.30	8.19	6.69	9.75
Sept	7.90	7.04	9.38	8.18	7.22	9.80
Oct	8.00	7.15	9.59	8.33	7.41	9.95
Nov	8.14	7.15	9.67	8.44	6.96	10.10
Dec	8.16	7.20	9.59	8.56	7.62	10.07

Box plots for minimum daily DO (i.e., lowest DO reported for one 15-minute interval in a 24 hour period) observed at San Marcos RTWQ sites from time of equipment deployment (i.e., 2013 for ASD and 2016 for TPWD hatchery) through 2024 compared to minimum daily DO observed in 2024 are shown in Figure 3.1-5. The medians of minimum daily DO for 2024 were lower than the medians of minimum daily DO from time of equipment deployment for San Marcos River RTWQ sites and is likely associated with below average sprinflows experienced for most of 2024.

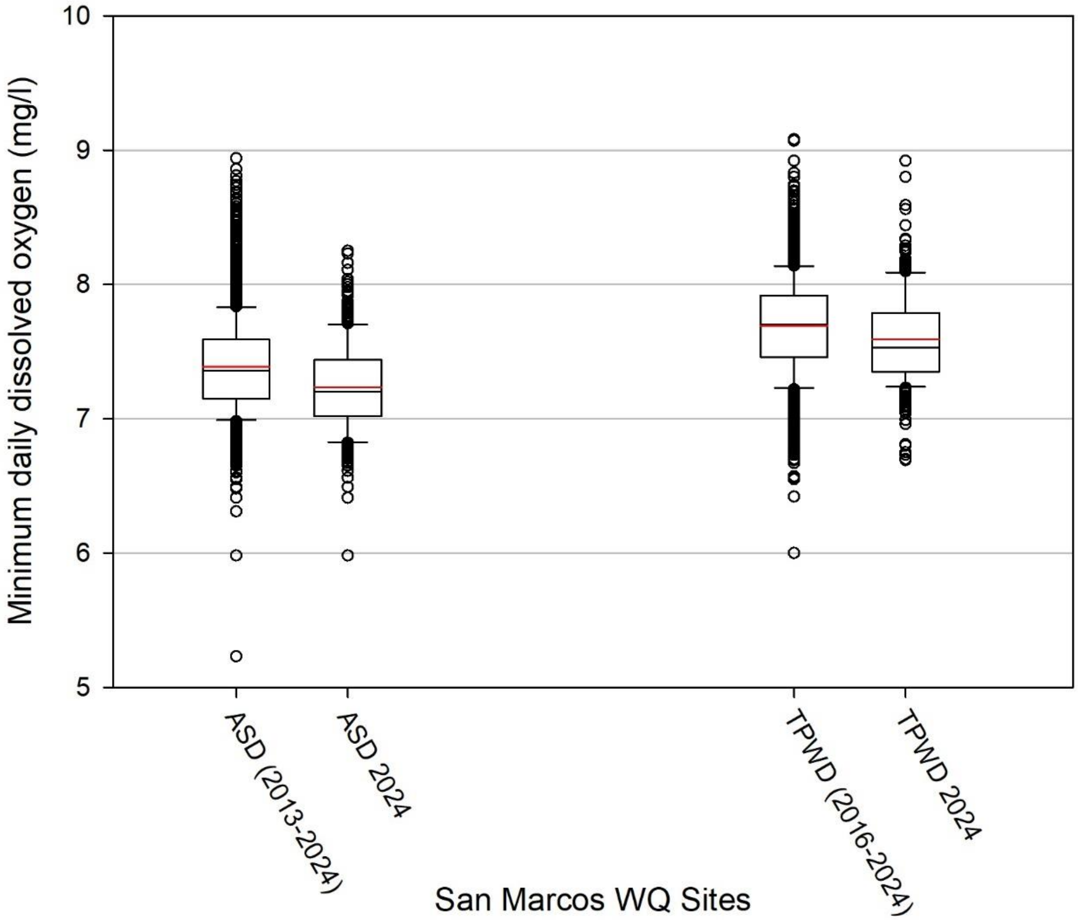

Figure 3.1-5. Box plots of minimum daily DO (mg/l) among RTWQ sites in the San Marcos River from time of equipment deployment through 2024 compared to 2024 only. Black lines represent median values and red lines denote mean values. Whiskers represent maximum and minimum DO values, excluding outliers (open circles).

Minimum daily DO recorded in 2024 were plotted for San Marcos River RTWQ sites (Figure 3.1-6). Similar to previous years, the TPWD hatchery site maintained higher minimum daily DO levels compared to the ASD site. The minimum DO threshold (4 mg/l) was not reached at either San Marcos River RTWQ site in 2024.

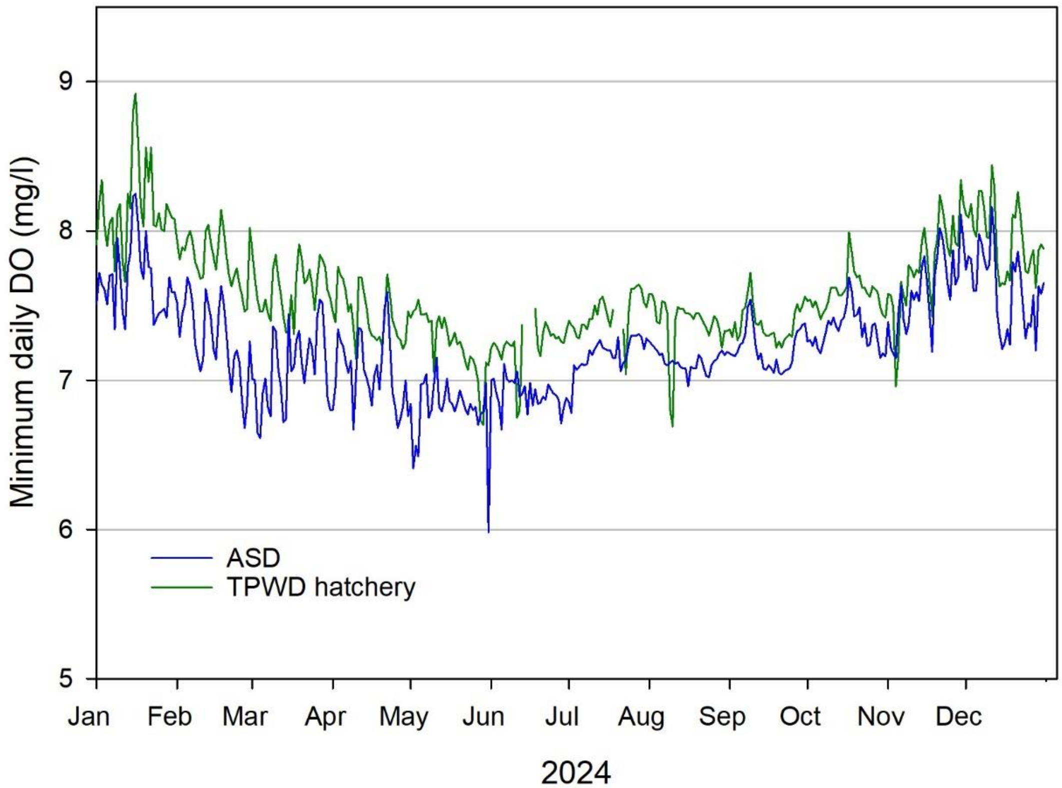

Figure 3.1-6. Minimum daily DO (mg/l) among San Marcos River water quality stations (2024).

Conductivity

Table 3.1-3 displays monthly summary statistics for conductivity (µs/cm) recorded in 2024 at the San Marcos River RTWQ sites. Mean monthly conductivity remained consistent among sites and throughout the year. The highest conductivity in 2024 was recorded at the ASD site in February (655 µs/cm) and the lowest conductivity (171 µs/cm) was also at the TPWD hatchery recorded in January.

San Marcos River discharge and mean daily conductivity were plotted for San Marcos River RTWQ sites for 2024 (Figure 3.1-7). Mean daily conductivity was influenced by rain events in the San Marcos River with decreases in conductivity corresponding with influxes of run-off entering the river. Outside of rain events, mean conductivity generally ranged between 600-640 µs/cm at the two San Marcos RTWQ sites.

Table 3.1-3. Monthly mean, minimum, and maximum conductivity (µs/cm) among San Marcos River RTWQ sites (2024).

	Conductivity (µs/cm) at San Marcos Water Quality Sites					
Month (2024)	**Aquarena Springs**			**TPWD hatchery**		
	Mean	Min	Max	Mean	Min	Max
Jan	621	352	635	601	171	637
Feb	630	571	655	625	432	632
Mar	631	574	636	629	459	641
Apr	635	561	650	628	396	642
May	631	541	642	618	211	642
Jun	634	397	639	628	231	643
Jul	629	402	639	621	177	645
Aug	635	526	647	636	265	647
Sept	633	560	645	638	456	645
Oct	635	621	647	642	635	646
Nov	634	490	648	636	389	646
Dec	640	588	645	636	508	644

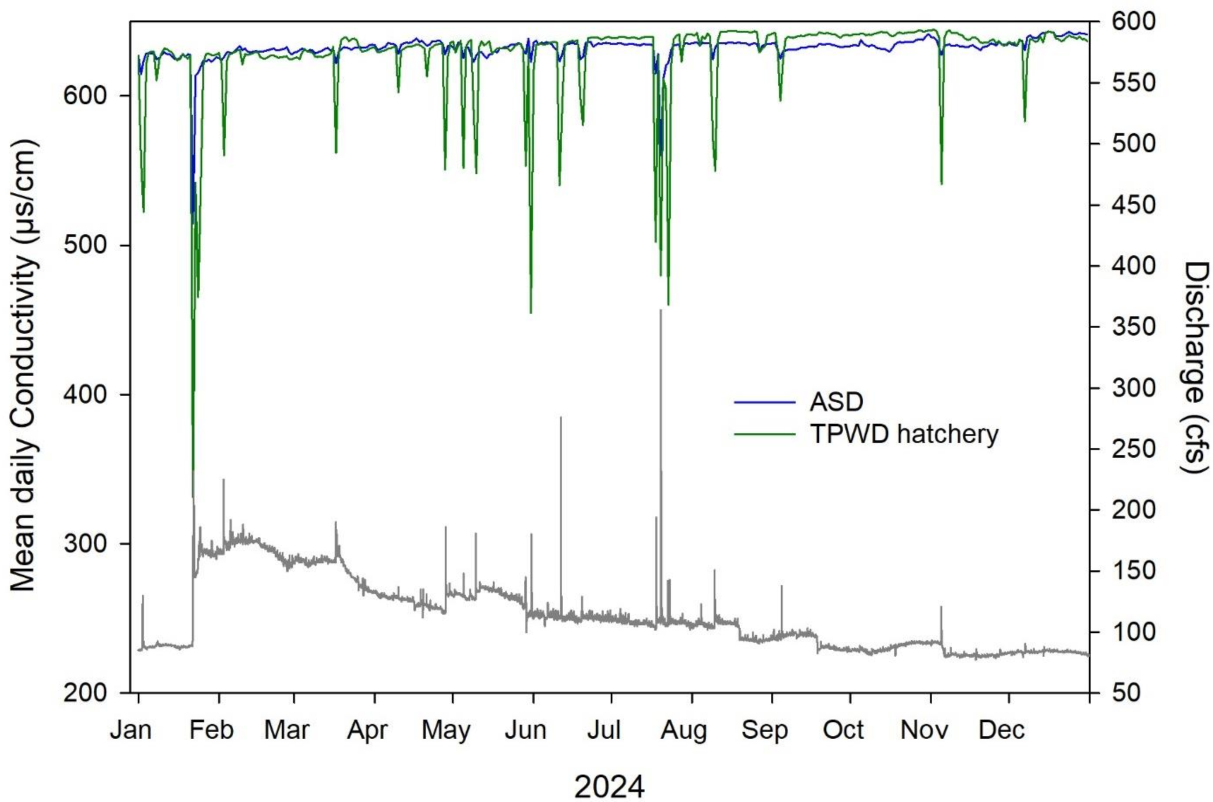

Figure 3.1-7. Mean daily conductivity (µs/cm) among San Marcos River RTWQ sites and San Marcos River discharge (USGS Gage#08170500) in 2024.

Sessom Creek Water Quality Characterization

Table 3.1-4 displays monthly summary statistics for water quality parameters measured in Sessom Creek for 2024. Figures 3.1-8 to 3.1-10 illustrate the daily values for water quality parameters in Sessom Creek (maximum daily temperature, minimum daily DO, mean daily turbidity and conductivity, respectively). Sessom Creek displayed more variability in water quality conditions than the San Marcos River RTWQ sites. The highest maximum daily water temperature reported in Sessom Creek for 2024 was 32.61°C in August. Maximum daily water temperatures exceeded 25°C for 91 days (May – September) in 2024, ranging from 0.1 hours – 20.6 hours (mean = 3.6 hours, median = 2.6 hours) at or above 25°C during those 91 days. DO dropped below 4.0 mg/l in Sessom Creek for 38 days in April – December ranging from 0.1 hours – 24.0 hours (mean = 14.0 hours, median = 13.9 hours). The lower minimum daily DOs observed in Sessom Creek likely corresponded with minimal springflow experienced in the creek towards the end of 2024. Spikes in mean daily turbidity were observed with corresponding drops in conductivity, indicating an influx of run-off from a rain event (Figure 3.1-10).

Table 3.1-4. Monthly mean, minimum, and maximum for water quality parameters in Sessom Creek (2024).

Month (2024)	**Temperature (°C)**			**DO (mg/l)**			**Conductivity (µs/cm)**			**Turbidity (NTU)**		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Jan	15.56	5.05	20.91	7.56	4.12	12.91	661	47	814	12.53	0.00	548
Feb	20.82	15.84	23.16	6.83	5.40	9.79	663	53	788	6.19	0.21	645
Mar	21.35	18.20	23.34	5.98	4.35	9.07	642	70	687	2.75	0.00	324
Apr	21.90	16.73	23.93	5.64	3.88	9.40	611	48	699	4.81	0.27	607
May	23.18	17.79	26.34	5.33	3.23	9.58	617	57	684	11.55	0.13	493
Jun	23.87	22.94	28.69	5.74	4.65	8.66	627	48	926	5.96	0.39	552
Jul	24.12	22.87	27.76	6.01	4.58	8.75	639	42	709	15.58	0.00	493
Aug	23.98	22.99	32.61	5.78	4.05	9.07	640	56	733	4.06	0.14	336
Sept	23.43	21.40	29.09	5.84	4.01	8.95	649	44	681	4.42	0.00	269
Oct	22.63	19.82	24.53	5.68	4.73	8.40	666	601	699	3.14	0.08	20
Nov	21.02	17.51	23.75	5.22	3.16	9.24	656	56	673	3.78	0.00	248
Dec	19.52	9.27	22.82	3.80	0.50	11.40	634	56	699	2.84	0.00	166

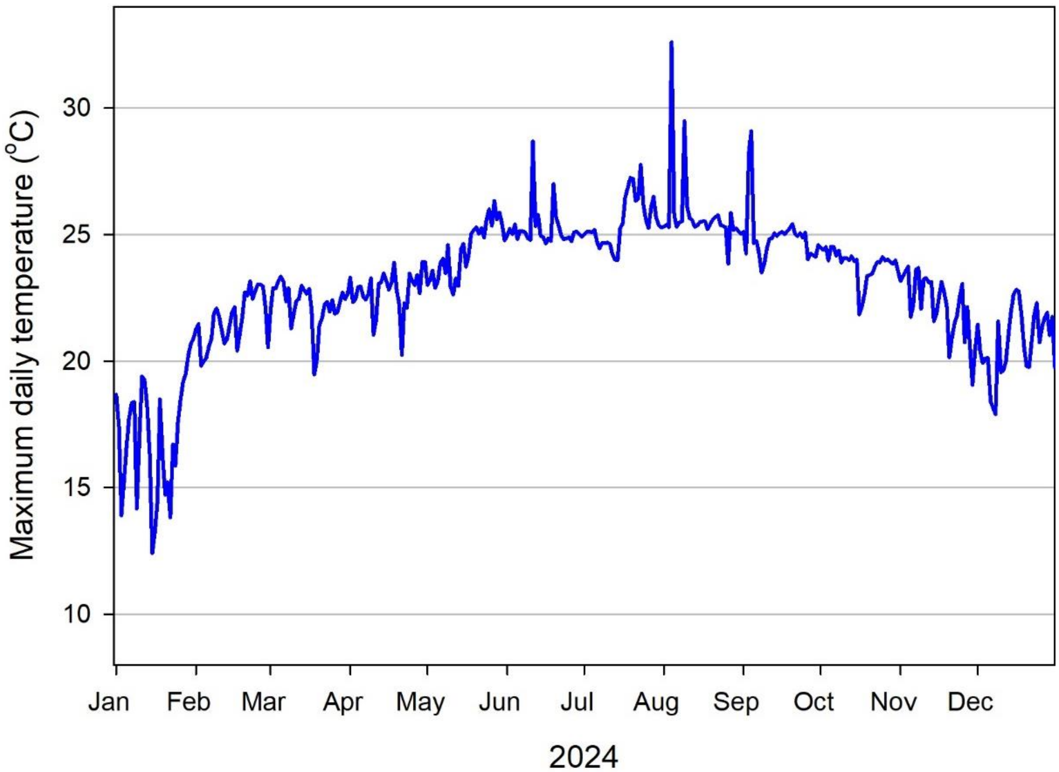

Figure 3.1-8. Maximum daily water temperatures (°C) in Sessom Creek (2024).

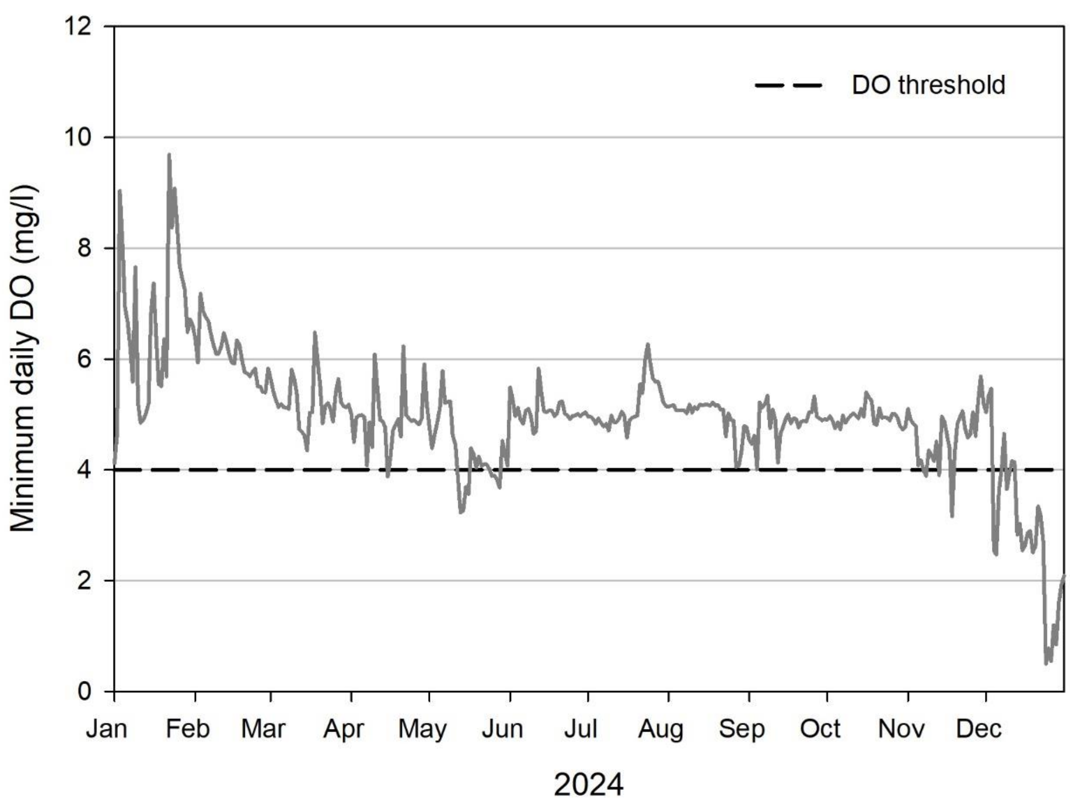

Figure 3.1-9. Minimum daily DO (mg/l) in Sessom Creek (2024).

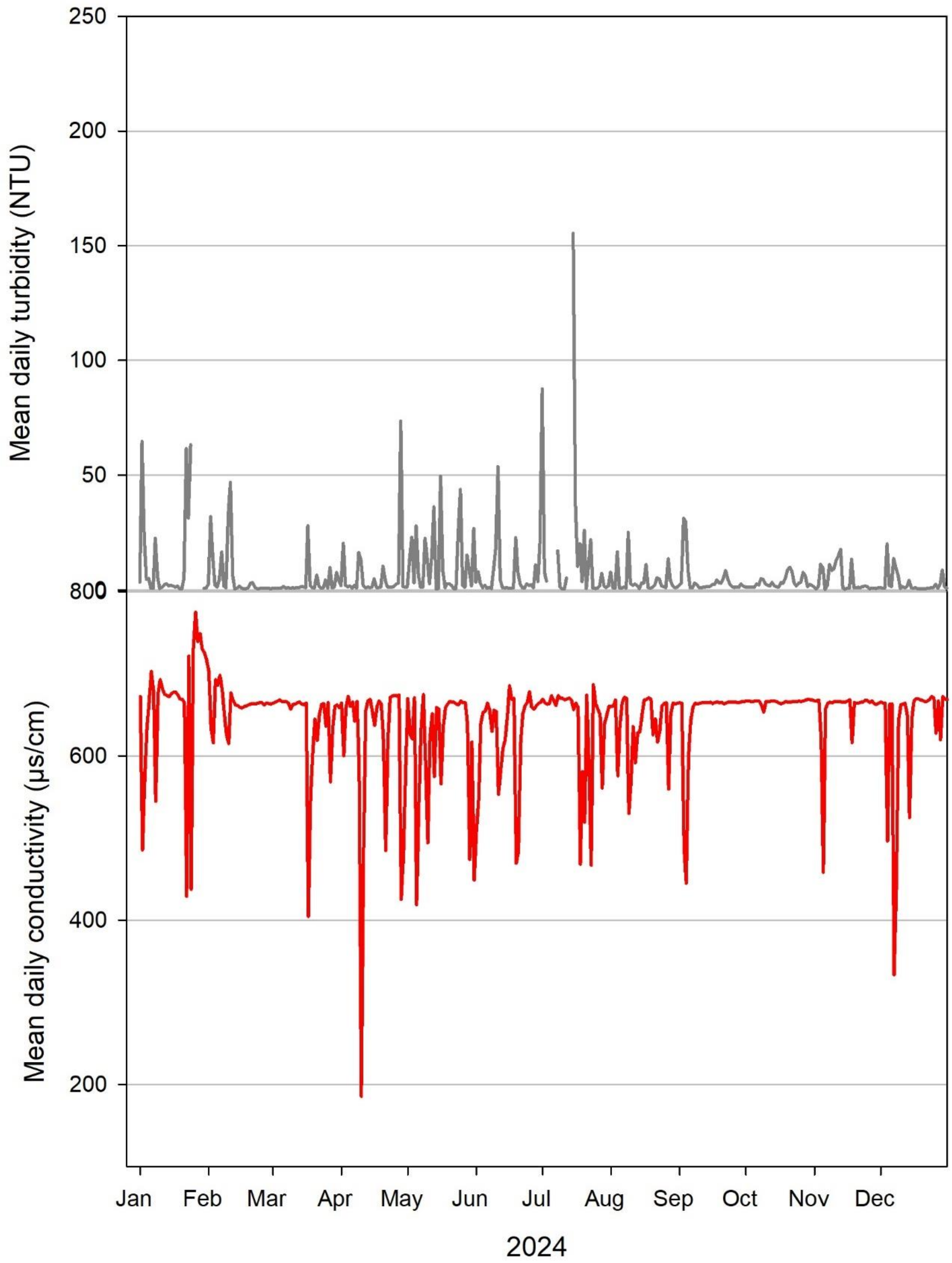

Figure 3.1-10. Mean daily turbidity (NTU) and mean daily conductivity (µs/cm) in Sessom Creek (2024).

3.1.2 Comal

Hydrology

Average springflow at Comal Springs for the period of record (i.e., 1927 – present) was 288 cfs. Since 2013, Comal springflow ranged from below average in 2013-2014 to above average from mid-2015-2017 (Figure 3.1-11). Extended low flow conditions occurred in 2014 and Comal springflow dropped down to as low as 65 cfs on August 29, 2014. In 2015, rainfall throughout the course of the year, particularly two large precipitation events in late May and October, resulted in above average springflow. The large flood pulse on October 30, 2015 had a peak discharge reaching 14,100 cfs. Springflows remained above average in 2016 through 2017 due to several moderate rain events. In 2018, springflow dropped below average, reaching 161 cfs in late August. However, multiple rain events in the early fall resulted in increased springflow and subsequent above average springflow rates. Springflow in 2019 was generally above 350 cfs until July when springflow decreased to average by mid-August but rose above 300 cfs before the end of the year. No substantial flow events occurred in 2019. The absence of large flow event continued into 2020 and springflows continued to decrease, dropping below the long-term average from May to December. Sprinflows continued to decline in early 2021 to just below 200 cfs in April, but rain events in late spring resulted in sprinflows increasing to above average. Additional rain events in fall (i.e., 5,030 cfs pulse in October) helped maintain near average springflows through December 2021. Springflows decreased and remained below average during 2022, dropping below 100 cfs in July and hitting 90 cfs in mid-August. Similar to the San Marcos system, no major run-off events occurred in 2022. In 2023, no large rain events led to springflows declining to levels not observed since 2014 with the lowest flow of 55 cfs recorded in August. Rain events in January 2024 resulted in briefly higher springflows but springflows decreased for the remainder of the year as a result of no major rainfall events occurring.

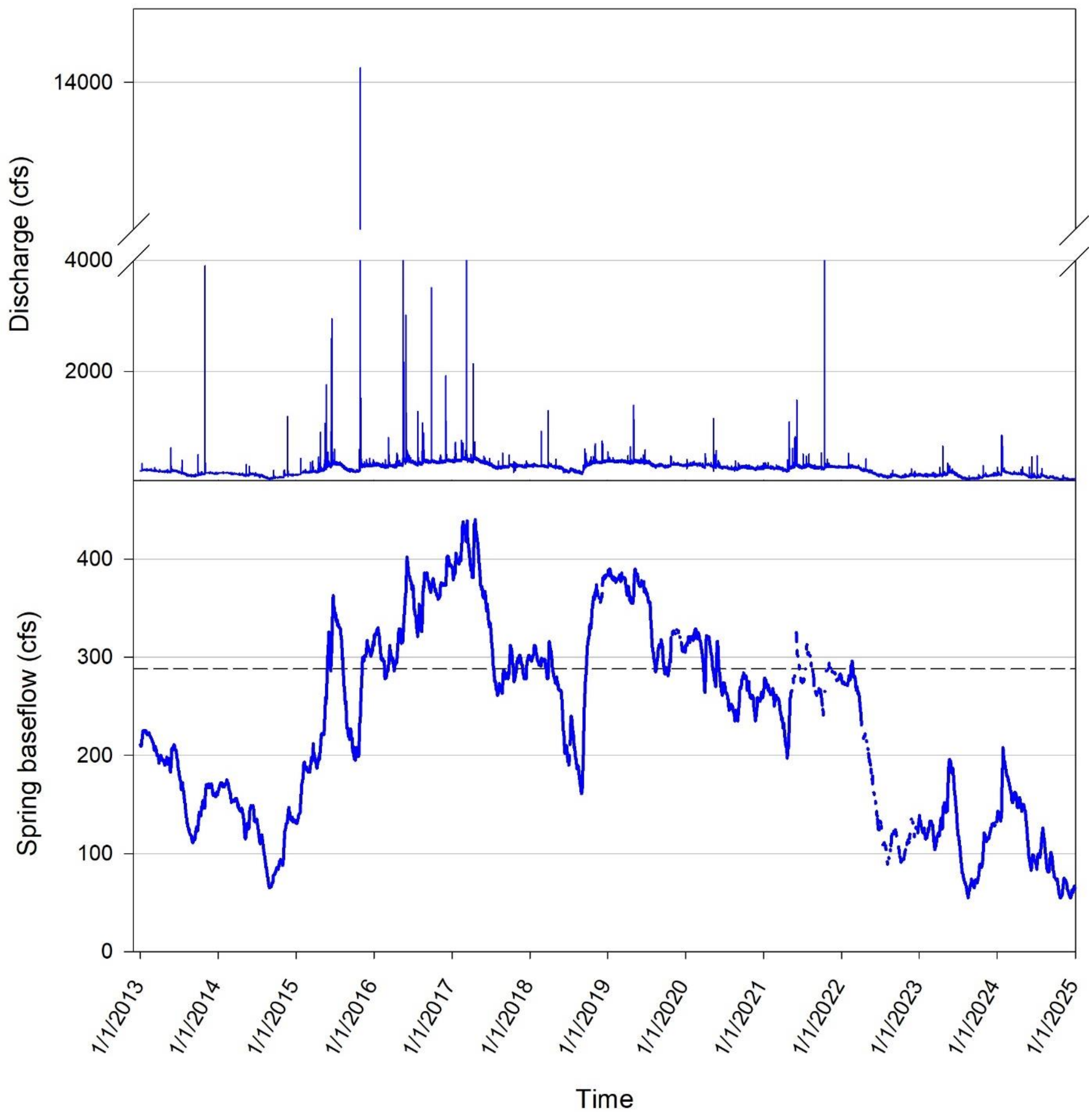

Figure 3.1-11. Hydrographs for the Comal River at New Braunfels (USGS station 08169000) and mean daily springflow for Comal springs (USGS Station 08168710) 2013 – 2024. Dashed line denotes long term average springflow (288 cfs) in the Comal River.

Temperature

Table 3.1-5 displays monthly summary statistics for water temperature at Comal RTWQ sites for 2024. In general, mean monthly water temperatures remained fairly stable within a site with deviations averaging ~1-2 °C and did not vary greatly among sites. Between Spring Run sites, water temperature at SR 7 continued to be slightly warmer than SR 3. Outside the direct influx of spring runs, the Old Channel (OC) exhibited more variability in minimum and maximum monthly water temperatures. The highest water temperature recorded in 2024 was 27.02°C in the OC during July whereas the lowest temperature (19.81°C) occurred in the OC during December.

Table 3.1-5. Monthly mean, minimum, and maximum water temperatures (°C) among Comal RTWQ (2024).

Month (2024)	**Spring Run 3**			**Spring Run 7**			**Old Channel**		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Jan	23.42	21.94	23.54	23.88	23.86	23.90	22.08	19.81	23.92
Feb	23.51	23.46	23.59	23.89	23.84	23.91	22.92	21.22	24.85
Mar	23.52	23.45	23.61	23.84	23.81	23.86	23.27	21.60	25.19
Apr	23.53	23.41	23.61	23.84	23.83	23.87	23.65	22.16	25.87
May	23.55	23.41	23.69	23.83	23.78	23.86	24.21	23.00	26.69
Jun	23.59	23.51	23.80	23.80	23.77	23.83	24.74	23.54	26.96
Jul	23.60	23.54	23.87	23.79	23.76	23.85	24.64	23.50	27.02
Aug	23.60	23.54	23.87	23.79	23.74	23.83	24.77	23.62	26.91
Sept	23.58	23.44	23.83	23.79	23.76	23.83	24.42	22.79	26.70
Oct	23.53	22.96	24.11	23.76	23.73	23.80	24.01	21.91	26.03
Nov	23.37	22.76	23.99	23.78	23.75	23.81	23.13	20.87	25.07
Dec	23.21	22.52	23.67	23.77	23.74	23.80	22.58	20.58	24.40

Box plots for maximum daily water temperatures observed at Comal RTWQ sites from time of sensor deployment (i.e., 2013 for SR 3, SR 7 and 2018 for OC) through 2024 compared to maximum daily water temperatures observed in 2024 are shown in Figure 3.1-12. The medians of maximum daily temperatures for 2024 were slightly higher than the medians of maximum daily temperatures from time of equipment deployment at Comal RTWQ sites. Higher median maximum daily temperatures were most notable at SR 3.

Maximum daily temperatures were plotted for Comal system RTWQ sites for 2024 (Figure 3.1-13). Throughout 2024, maximum daily water temperatures were more variable at the OC river site whereas little variation in maximum daily water temperature was observed at SR 7. More variability and lower maximum daily water temperatures were observed at SR 3 towards the end of 2024 and is likely associated with a combination of cooler ambient temperatures and lower springflow in the run. Maximum daily temperatures reached or exceeded 25°C at the Old Channel station for 172 days during the months of March–November in 2024. Within those 172 days, time spent at or above 25°C ranged from 1.0 to 10.75 hours (mean = 7.17 hours; median = 7.75 hours).

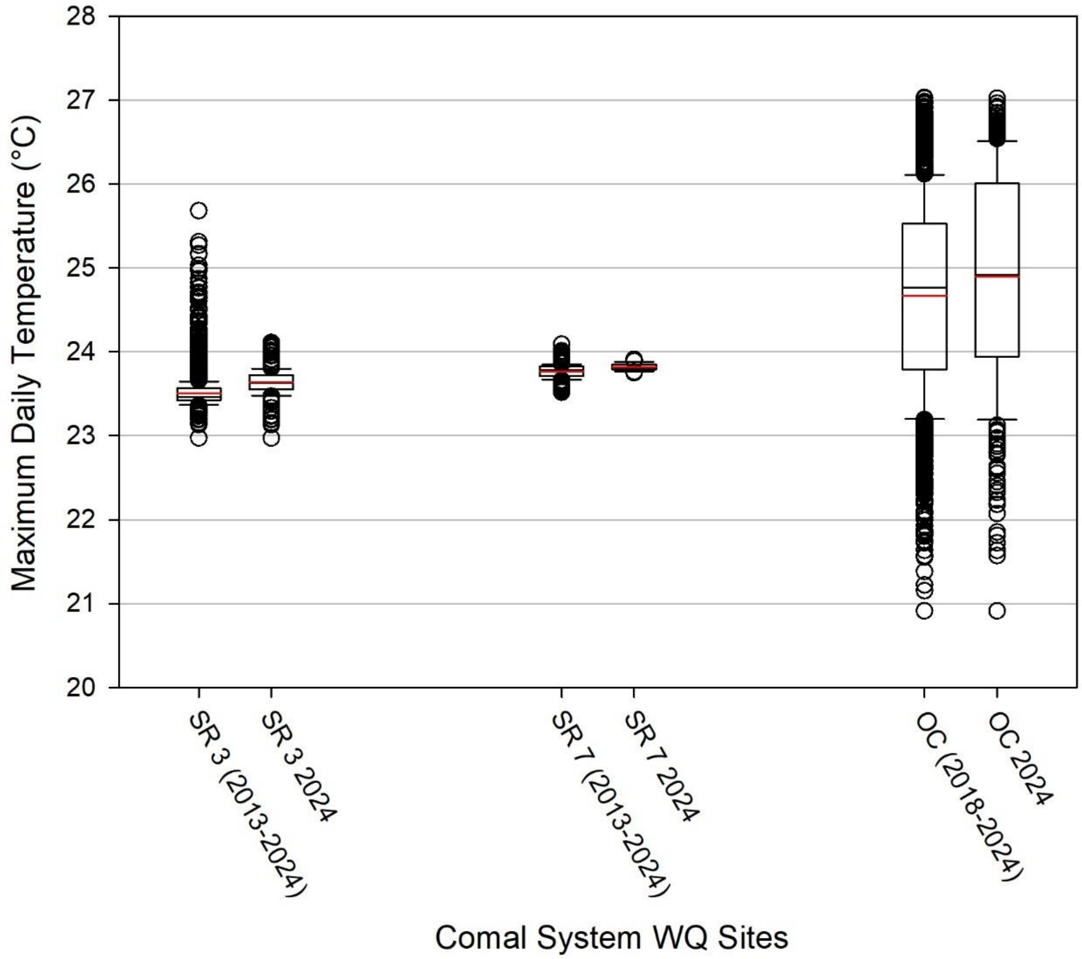

Figure 3.1-12. Box plots of maximum water daily temperatures (°C) among Comal system RTWQ sites from time of deployment through 2024 compared to 2024. Black lines represent median values and red lines denote mean values. Whiskers represent maximum and minimum temperature values, excluding outliers (open circles).

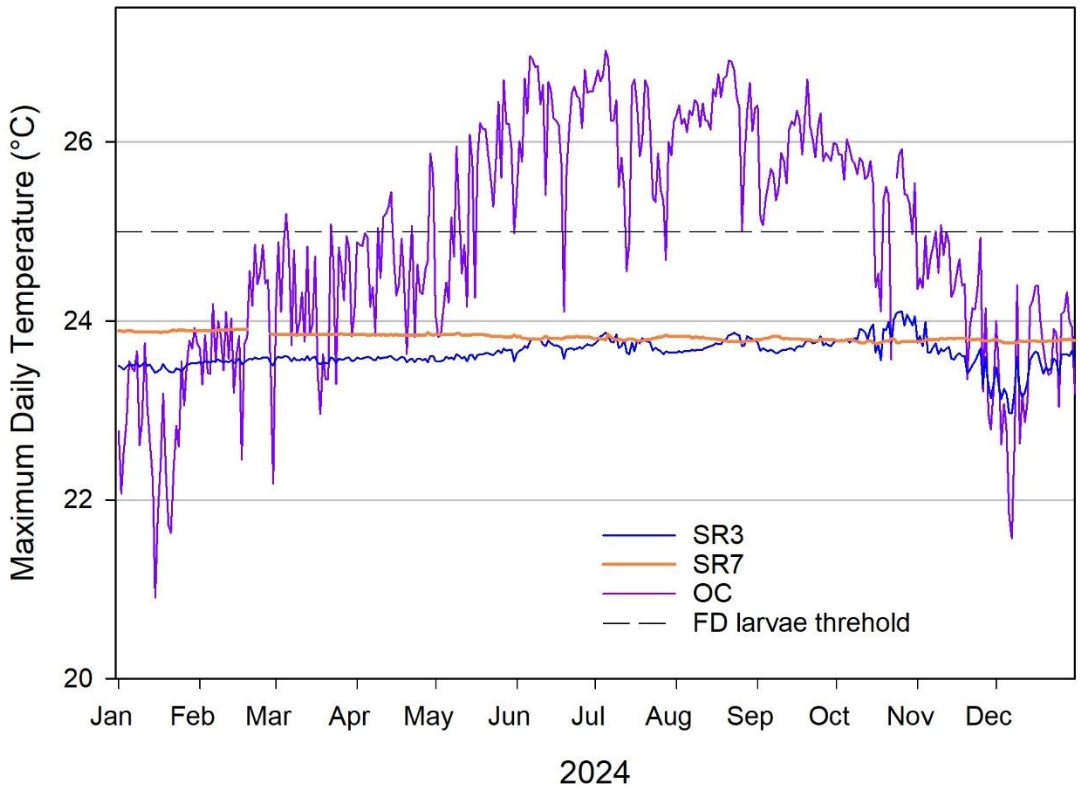

Figure 3.1-13. Maximum daily water temperature (°C) among Comal RTWQ sites (2024).

Box plots for seasonal maximum daily temperatures at the Comal system RTWQ sites for 2024 are shown in Figure 3.1-14. Less seasonal variation in maximum daily temperature (i.e., <1.0°C) was observed at the two spring run sites. However, the OC river site exhibited a wider range in seasonal variation with median values differing ~3 °C. Spring, fall, and winter also showed more variability in maximum daily temperature at the OC site while summer months showed less variability but recorded the highest maximum daily temperatures.

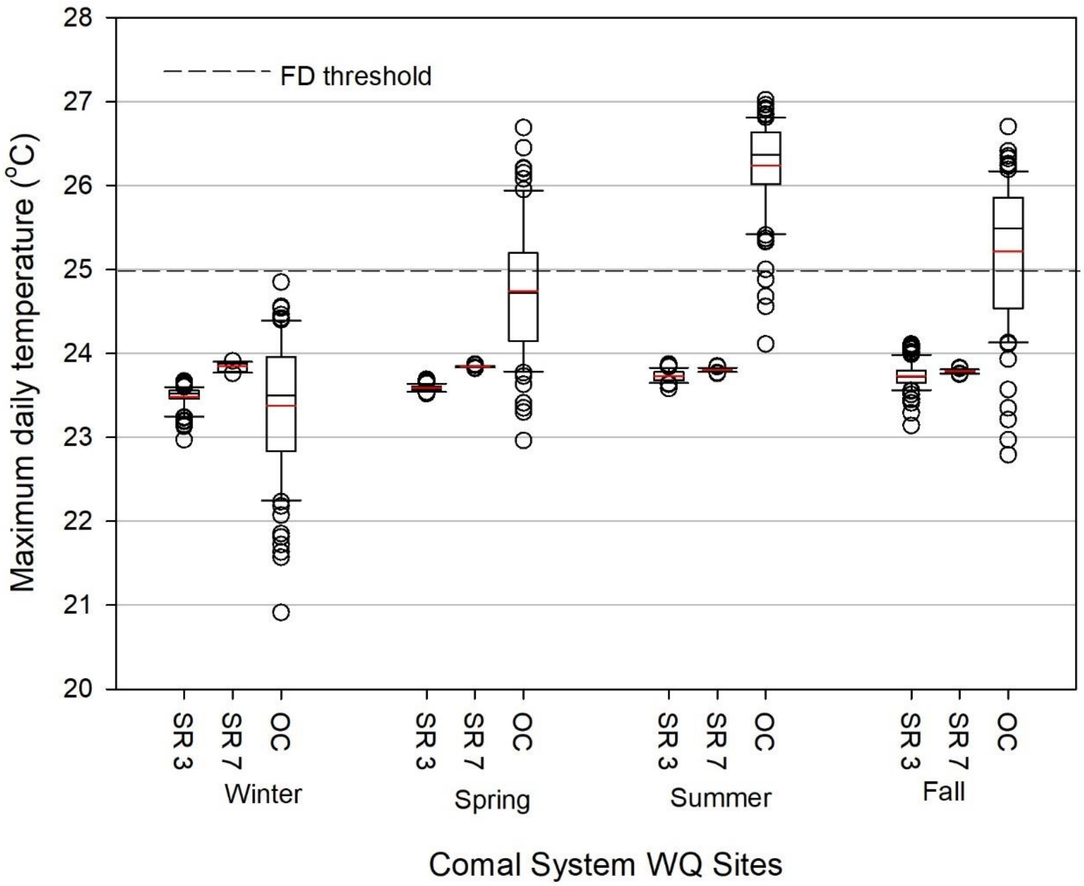

Figure 3.1-14. Box plots of maximum daily water temperatures (°C) among seasons at Comal system RTWQ sites in 2024. Black lines represent median values and red lines denotes mean values. Whiskers represent maximum and minimum temperature values, excluding outliers (open circles).

Dissolved Oxygen

Table 3.1-6 displays monthly summary statistics for dissolved oxygen (DO) recorded for Comal RTWQ sites in 2024. Mean monthly dissolved oxygen remained consistent within a site with variations averaging ~ 1 mg/l. Similar to previous years, mean monthly DO was lower in the spring run sites than the OC river site. The highest DO recorded in 2024 was 10.03 mg/l in the OC during February and the lowest DO (4.85mg/l) occurred at SR 7 in September.

Table 3.1-6. Monthly mean, minimum, and maximum DO (mg/l) among Comal system RTWQ sites (2024).

Month (2024)	Spring Run 3			Spring Run 7			Old Channel		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Jan	5.32	5.16	6.31	5.05	5.03	5.08	7.38	6.03	10.02
Feb	5.23	5.13	5.45	5.04	5.00	5.06	7.37	5.80	10.03
Mar	5.23	5.12	5.47	5.04	5.03	5.05	7.16	5.65	9.73
Apr	5.24	5.14	5.48	4.98	4.92	5.04	7.08	5.64	9.61
May	5.25	5.14	5.77	4.95	4.91	4.97	7.06	5.57	9.41
Jun	5.36	5.21	5.93	4.95	4.93	4.97	7.10	5.41	9.49
Jul	5.37	5.13	5.94	4.94	4.92	4.96	6.86	5.15	9.50
Aug	5.37	5.18	6.06	4.94	4.91	4.96	6.89	5.35	9.05
Sept	5.37	5.11	5.92	4.92	4.85	4.94	7.03	5.40	9.70
Oct	5.60	5.08	6.88	4.93	4.90	4.96	7.16	5.78	9.67
Nov	5.60	4.95	6.65	4.90	4.88	4.93	7.21	5.82	9.49
Dec	5.49	5.03	6.65	4.90	4.88	4.95	7.23	5.95	9.57

Box plots for minimum daily DO observed at Comal system RTWQ sites from time of equipment deployment (i.e., 2013 for SR3, SR7 and 2018 for OC) through 2024 compared to minimum daily DO observed in 2024 are shown in Figure 3.1-15. The medians of minimum daily DO for 2024 were generally consistent with medians of minimum daily DO since time of sensor deployment at Comal system RTWQ sites. However, the median minimum daily DO in the OC for 2024 was slightly lower than minimum daily DO observed since 2018.

Minimum daily DO was plotted for Comal RTWQ sites in 2024. (Figure 3.1-16). Spring run 3, and SR 7 demonstrated relatively constant DO whereas the OC river site was more variable in DO with seasonally drops in minimum daily DO during the summer months. Although greater in variability, the OC maintained higher minimum daily DO compared to the spring run sites and no sites recorded a minimum daily DO below 4.0 mg/l in 2024.

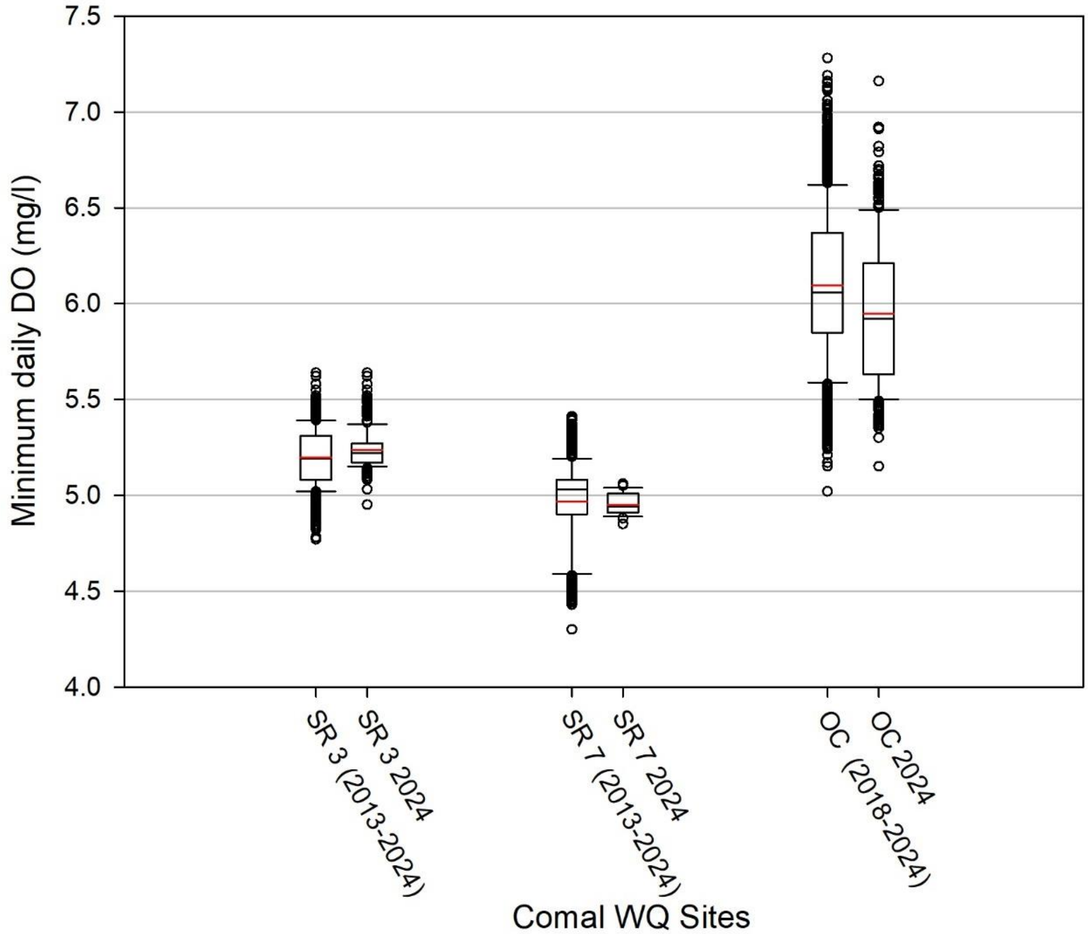

Figure 3.1-15. Box plots of minimum daily DO (mg/l) among Comal system RTWQ sites from time of equipment deployment through 2024 compared to 2024. Black lines represent median values and red lines denotes mean values. Whiskers represent maximum and minimum DO values, excluding outliers (open circles).

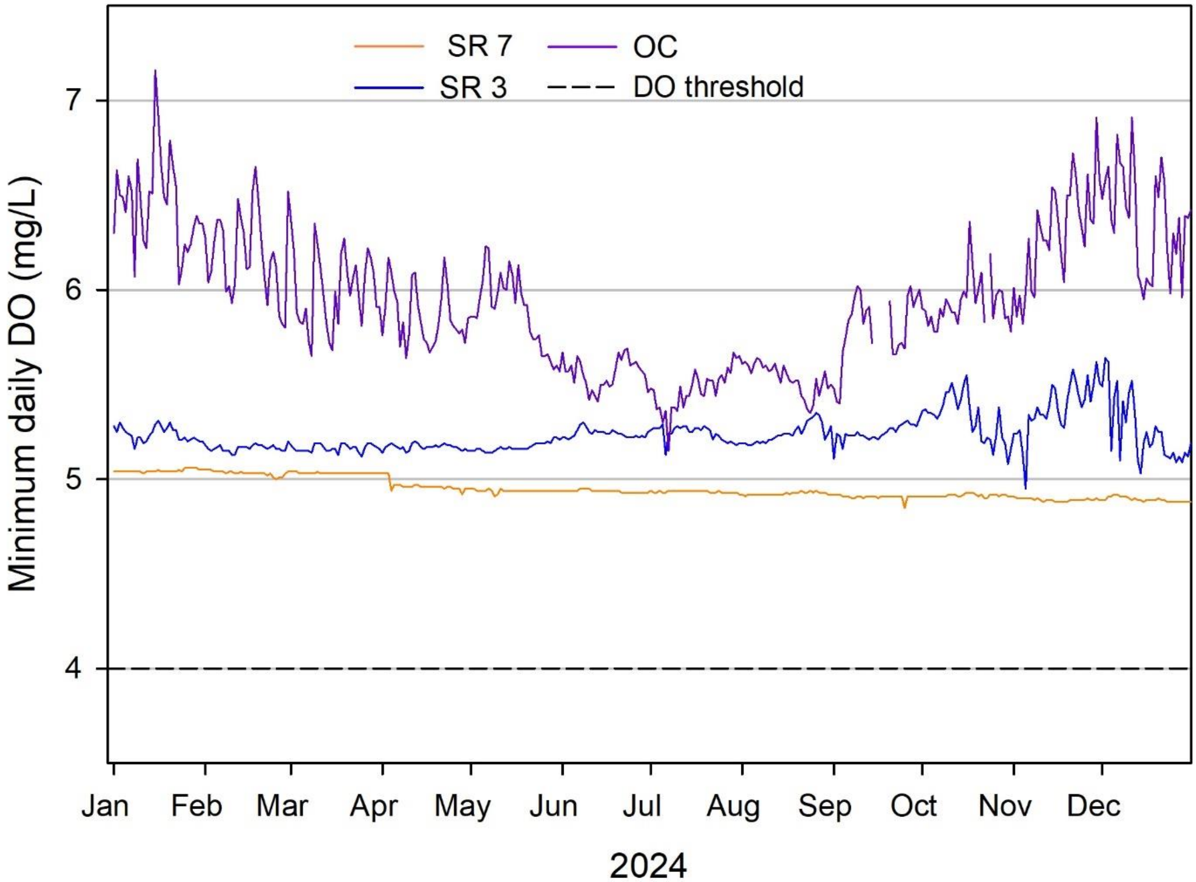

Figure 3.1-16. Minimum daily DO (mg/l) among Comal RTWQ sites (2024).

Conductivity

Table 3.1-7 displays monthly summary statistics for conductivity (µs/cm) recorded at Comal system RTWQ sites during 2024. Mean monthly conductivity remained consistent at the three WQ sites throughout the year with little variability between sites. In general, mean conductivity ranged between 570-575 µs/cm among all Comal system RTWQ sites. The lowest conductivity in 2024 was recorded in the SR 3 in August (461 µs/cm) (Figure 3.1-17).

Comal River discharge (cfs) and mean daily conductivity were plotted for Comal system RTWQ sites for 2024 (Figure 3.1-17). Little variation in mean daily conductivity for all three RTWQ sites occurred in 2024. Since the Comal discharge gage location is located downstream from the confluence of the Old and New Channel of the Comal, some rain events in the system do not result in conductivity drops in the Old Channel. Additionally, the Comal River has slightly lower conductivity than the San Marcos River.

Table 3.1-7. Monthly mean, minimum, and maximum conductivity (µs/cm) among Comal system RTWQ sites (2024).

Month (2024)	Spring Run 3			Spring Run 7			Old Channel		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Jan	573	488	585	573	569	577	572	506	589
Feb	575	571	585	575	568	582	578	565	585
Mar	573	569	578	576	570	579	577	565	585
Apr	574	528	579	573	565	580	576	565	585
May	574	478	577	574	565	580	570	517	585
Jun	573	470	581	574	565	580	569	502	584
Jul	574	461	580	574	560	588	570	504	585
Aug	574	560	581	573	566	582	572	565	580
Sept	575	566	581	572	567	580	570	550	584
Oct	574	565	584	574	565	577	572	558	585
Nov	572	565	584	575	567	578	573	550	581
Dec	572	565	586	576	571	581	573	565	580

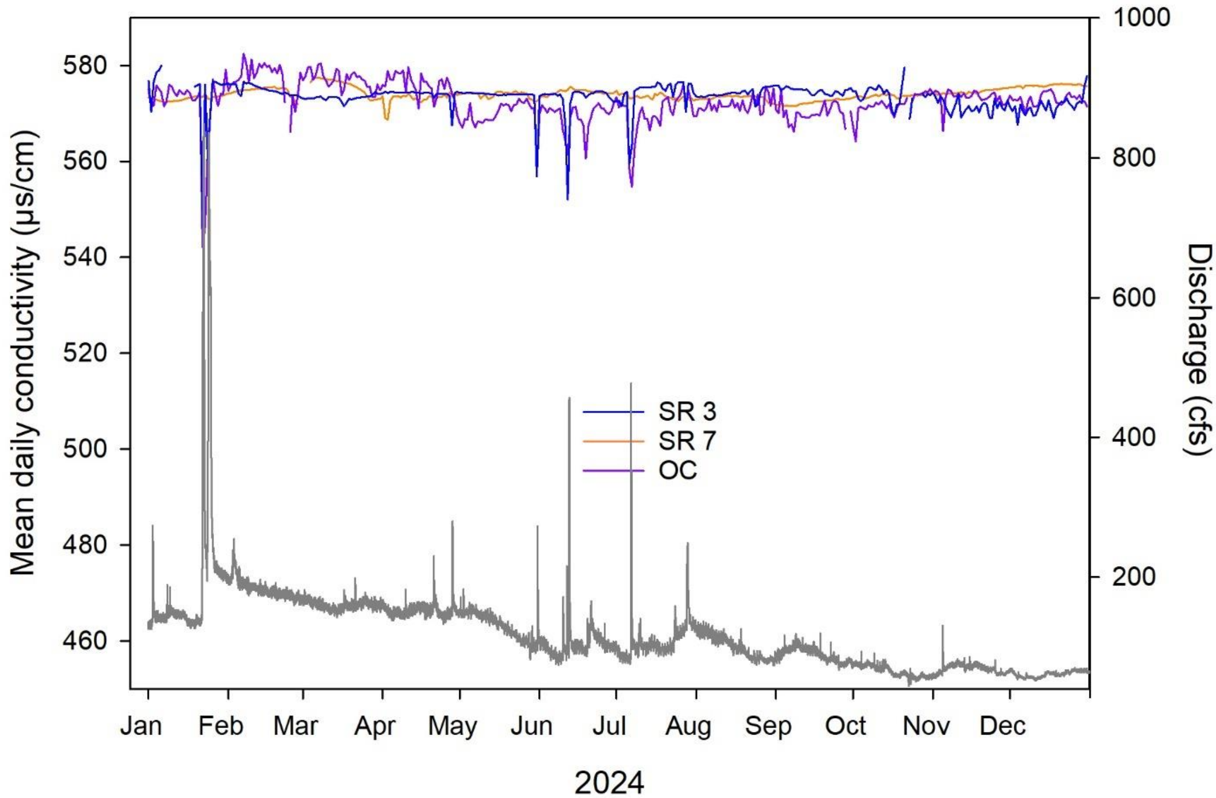

Figure 3.1-17. Mean daily conductivity (µs/cm) among Comal system RTWQ sites and Comal River discharge (Gage#08169000) in 2024.

3.2 Surface water sampling

3.2.1 San Marcos

Table 3.2-1 denotes the water quality parameters collected at Hotel Spring during monthly sucralose collections. Water quality parameters measured during monthly sampling events were consistent with measurements collected by the RTWQ network station at Aquarena Springs.

Table 3.2-1. Monthly (2024) water quality parameters measured at Hotel Spring (Spring Lake, San Marcos).

Month	Conductivity (µs/cm)	DO (mg/l)	pH (SU)	Temperature (°C)
Jan	611	4.45	6.97	22.21
Feb	620	3.74	6.91	21.83
Mar	614	4.02	6.89	21.84
Apr	611	4.32	6.97	21.88
May	617	4.44	6.85	21.94
Jun	611	4.32	6.95	22.29
Jul	NA	NA	NA	NA
Aug	625	4.58	7.05	21.89
Sep	629	4.58	6.99	22.00
Oct	615	4.58	7.03	22.04
Nov	620	4.59	NA	22.09
Dec	625	4.59	NA	22.11

A total of 12 sucralose samples were collected during monthly collections at Hotel Spring in 2024, including one duplicate sample in August and one DI (i.e., deionized water) blank in March. Sucralose was detected in all collected samples at Hotel Spring in 2024 (Table 3.2-2). Quality control spike recoveries for all sampling events were between 68.5 – 124.0 %.

Table 3.2-2. Sucralose concentrations (ng/L) and QC spike recovery (%) measured at Hotel Springs in Spring Lake (2024). Samples with detectable concentrations denoted in bold. Spike recovery amounts shown in parentheses.

Month	Sample (ng/L)
January	**13.3** (83.3)
February	**23.7** (87.9)
March	**23.4**[A] (77.5)
April	**17.9**[R] (124)
May	**15.7** [R] (104)
June	**16.0** [R] (123)
July	**17.0** (85.1)
August	**13.0**[B] (85.3)
September	**28.4** (68.5)
October	NA
November	NA
December	NA

[A] Not detected in DI blank
[B] Detected in duplicate sampling
[R] peak detected but did not meet quantification criteria, result reported represents the estimated maximum possible concentration

During Spring and Fall sampling events, nutrient samples and one duplicate sample per site per season (i.e., upper in Spring and lower in Fall) were taken. Nutrient concentrations measured at the upper and lower sites (i.e., Hotel Springs and near the TPWD hatchery) in the San Marcos system during Spring and Fall are denoted in Table 3.2-3.

Table 3.2-3. Nutrient concentrations measured at the upper and lower sites in the San Marcos system during Spring and Fall (2024). Samples with detectable concentrations denoted in bold.

		Spring		Fall	
Nutrients	**Units**	**Upper**	**Lower**	**Upper**	**Lower**
Total Phosphorus	mg/L	0.01[UA]	0.01[UA]	**0.039**	**0.019**[JA]
Orthophosphate as P	mg/L	0.006[UHAC]	0.006[UHAC]	**0.008**	**0.008**[B]
Total Organic Carbon	mg/L	0.5[UA]	0.5[UA]	**0.57**[J]	**0.644**[JB]
Dissolved Inorganic Carbon	mg/L	**65.5**[BC]	**64.9**[BC]	**62.5**	**63.0**[B]
Dissolved Organic Carbon	mg/L	**1.27**[BC]	**1.42**[BC]	**0.49**[JC]	**0.47**[JBC]
Kjeldahl Nitrogen	mg/L	**0.104**[JB]	**0.111**[JB]	0.089[UF1]	0.089[UB]
Nitrate as N	mg/L	**0.75**[BC]	**0.664**[BC]	**1.18**[C]	**1.35**[BC]
Ammonia	mg/L	0.05[UA]	0.05[UA]	0.05[U]	0.05[UA]

[U] Non-detect
[H] Sample was prepped and analyzed past holding time
[F1] MS and/or MSD recovery exceeds control limits
[J] Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.
[A] Not detected in duplicate sample
[B] Detected in duplicate sample
[C] Detected in laboratory or field blank

3.2.2 Comal

Table 3.2-4 denotes the water quality parameters collected at Spring Run 3 in Landa Lake during monthly sucralose collections in 2024. Water quality parameters measured during monthly sampling events were consistent with measurements collected by the RTWQ network station in Spring Run 3.

Table 3.2-4. Monthly (2024) water quality parameters measured at Spring Run 3 (Landa Lake).

Month	Conductivity (µs/cm)	DO (mg/l)	pH (SU)	Temperature (°C)
Jan	569	5.00	7.03	23.61
Feb	571	5.08	6.93	23.55
Mar	571	5.15	6.89	23.57
Apr	573	5.04	7.00	23.58
May	571	5.02	6.88	23.59
Jun	569	4.84	6.98	24.04
Jul	NA	NA	NA	NA
Aug	579	5.25	7.15	23.51
Sep	585	5.06	NA	23.66
Oct	566	5.03	7.07	23.59
Nov	565	5.07	7.09	23.55
Dec	567	6.37	NA	23.06

A total of 12 sucralose samples were collected during monthly collections at Spring Run 3 in 2024, including one field duplicate sample in June and one DI blank in August. Among monthly collections, sucralose was detected during all sampling events at Spring Run 3 (Table 3.2-5). Quality control spike recoveries for all sampling events were between 77.0 – 115.0 %.

Table 3.2-5. Sucralose concentrations (ng/L) measured at Spring Run 3 in Landa Lake (2024). Samples with detectable concentrations denoted in bold. Spike recovery amounts shown in parentheses.

Month	Sample (ng/L)
January	**5.89**[J] (93.2)
February	**9.61** (104)
March	**9.99** (91.0)
April	**7.83**[J] (133)
May	**7.19**[J] (120)
June	**14.2**[BR] (112)
July	**10.2** (94.2)
August	**6.78**[CJ] (78)
September	**8.8** (79.7)
October	NA
November	NA
December	NA

[A] Non detected in DI blank
[B] Detected in duplicate sample
[C] Detect in DI blank
[J] Concentration < limit of quantification

During Spring and Fall sampling events, nutrient samples were taken including a duplicate sample in the upper site in Spring and a duplicate sample in both upper and lower sites in Fall. Nutrient concentrations measured at the upper and lower sites (i.e., Spring Run 3 and at the last public exit) in the Comal system during Spring and Fall are denoted in Table 3.2-6.

Table 3.2-6. Nutrient concentrations measured at the upper and lower sites in the Comal system during Spring and Fall (2024). Samples with detectable concentrations denoted in bold.

		Spring		Fall	
Nutrients	**Units**	**Upper**	**Lower**	**Upper**	**Lower**
Total Phosphorus	mg/L	0.01[UA]	0.01[U]	0.01[UA]	0.01[UA]
Orthophosphate as P	mg/L	0.006[UHAC]	0.006[UHC]	0.005[UB]	0.005[UB]
Total Organic Carbon	mg/L	0.5[UA]	0.5[U]	0.05[UB]	**0.526**[JB]
Dissolved Inorganic Carbon	mg/L	**59.9**[BC]	**59.1**[C]	**58.7**[B]	**56.2**[B]
Dissolved Organic Carbon	mg/L	**0.707**[BC]	**0.935**[C]	**0.345**[JBC]	**1.05**[BC]
Kjeldahl Nitrogen	mg/L	**0.565**[B]	**0.206**	0.089[UA]	0.089[UB]
Nitrate as N	mg/L	**0.777**[BC]	**0.557**[C]	**1.69**[BC]	**1.61**[BC]
Ammonia	mg/L	0.05[UA]	0.05[U]	0.05[UA]	0.05[UA]

[U] Non-detect
[H] Sample was prepped and analyzed past holding time
[F1] MS and/or MSD recovery exceeds control limits
[J] Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.
[A] Not detected in duplicate sample
[B] Detected in duplicate sample
[C] Detected in laboratory or field blank

3.3 Groundwater sampling

3.3.1 San Marcos

A total of six PPCP samples (i.e., one sample at each sampling site and event) were collected during 2024, including one duplicate sample at Deep Hole in Spring and one DI blank at Hotel in Fall. Samples were taken at Hotel in the months of January, May, July, August, and November (November results not available yet). However, Deep Hole was only sampled in March and August. Results for PPCP sampling during the regular Spring (March) and Fall sampling (August) events are denoted in Table 3.3-1 and 3.3-2. Results for PPCP sampling at Hotel for January, May, and July are denoted in Table 3.3-3 and Table 3.3-4. Flumequine, Oxolinic acid, and Penicillin G were detected during the Spring sampling event at Deep Hole but were flagged as "B", indicating that a concentration was also detected in the lab blank and the sample concentration was 10x less than the blank concentration.

Table 3.3-1. PPCP concentrations (ng/L) measured at Hotel and Deep Hole Spring (Spring Lake, San Marcos) during Spring and Fall sampling events (2024). Samples with detectable concentrations denoted in bold.

	Spring				Fall			
PPCP List	Hotel spring		Deep Hole		Hotel spring		Deep Hole	
Acetaminophen	**3.46**		**0.711**	JC	0.225	U	0.319	U
Azithromycin	**0.345**	B J	**0.164**	B JC	0.116	U	0.0897	U
Caffeine	**3.55**	B J	**1.46**	B JC	**1.06**	B J	**0.924**	B J
Carbadox	0.0684	U	0.0978	U	0.0871	U	0.0642	U
Carbamazepine	0.0017	U	0.0023	U	0.0009	U	0.0011	U
Cefotaxime	2.56	U	1.21	U	5.78	U	6.2	U
Ciprofloxacin	**0.367**	B J	0.424	UC	0.207	U	0.35	U
Clarithromycin	0.0038	U	0.0047	UC	0.0016	U	**0.011**	B J
Clinafloxacin	0.697	U	0.632	U	0.81	U	0.764	U
Cloxacillin	0.276	U H	**8.28**	HC	2.92	U H	11.4	H
Dehydronifedipine	0.0099	U	0.0145	U	0.0067	U	**0.006**	J
Digoxigenin	0.202	U	0.268	U	0.154	U	0.174	U
Digoxin	**0.267**	J	0.223	U	**0.232**	B J	**0.174**	B J
Diltiazem	**0.003**	J	0.0029	U	**0.002**	J	**0.004**	J
Diphenhydramine	**0.111**	J	**0.006**	B JC	**0.007**	B J	**0.007**	B J
Enrofloxacin	0.162	U	0.119	U	0.201	U	0.133	U
Erythromycin-H2O	**0.062**	B H	**0.418**	B HC	1.46	U H	1.57	U H
Flumequine	0.0066	U	0.0086	U	0.0019	U	0.0035	U
Fluoxetine	0.0018	U	0.0011	UC	0.0005	U	**0.001**	B J
Lincomycin	0.0448	U	0.0159	U	0.0018	U	0.0047	U
Lomefloxacin	0.0163	U	**0.053**	B J	0.0171	U	0.0227	U
Miconazole	**0.111**	B J	**0.098**	B JC	**0.018**	B J	**0.034**	B J
Norfloxacin	0.584	U	0.576	U	0.603	U	0.347	U
Norgestimate	**0.31**	J	0.379	U	0.218	U	0.169	U
Ofloxacin	**0.04**	B J	**0.138**	B JC	0.0193	U	**0.107**	J
Ormetoprim	0.0042	U	0.0065	U	**0.004**	B J	0.0029	U
Oxacillin	**0.24**	H	0.4	U H	1.46	U H	1.57	U H
Oxolinic Acid	0.0295	U	0.0243	U	0.024	U	0.0156	U
Penicillin G	**5.08**	B H	**25.2**	B HC	**4.52**	H	**11.6**	H
Penicillin V	**0.29**	B J	**126**	C	**0.169**	B J	3.74	U
Roxithromycin	0.0195	U	0.0482	U	**0.001**	J	0.022	U
Sarafloxacin	0.272	U	0.235	U	**0.168**	J	0.159	U
Sulfachloropyridazine	0.0188	U	0.0253	U	0.0135	U	0.0129	U
Sulfadiazine	0.0078	U	0.015	UC	0.0069	U	0.0062	U
Sulfadimethoxine	0.0071	U	0.0099	U	0.005	U	0.0069	U
Sulfamerazine	0.0059	U	0.0181	U	0.0061	U	0.0059	U
Sulfamethazine	0.0068	U	0.0114	U	0.0058	U	**0.008**	J
Sulfamethizole	0.219	U	0.363	U	0.0364	U	0.095	U
Sulfamethoxazole	**0.081**	J	**0.286**	JC	**0.116**	B J	**0.26**	J
Sulfanilamide	**2.55**	J	**4.54**	JC	**3.07**	B J	**4.45**	J
Sulfathiazole	0.0112	U	0.024	U	0.0152	U	0.0107	U
Thiabendazole	0.0156	U	0.0655	UC	**0.003**	J	**0.018**	J
Trimethoprim	0.0063	U	**0.011**	B JC	0.0036	U	**0.006**	B J
Tylosin	**0.025**	B J	**0.021**	B J	**0.056**	B J	0.0111	U
Virginiamycin M1	0.15	U	1.1	U	**0.356**	J	0.258	U
1,7-Dimethylxanthine	**0.485**	B J	**0.457**	B JC	0.0853	U	**0.261**	B J

[U] Non-detect at reporting limit
[B] Analyte found in associated blank and concentration in sample <10x concentration in lab blank
[C] Detected in duplicate sample
[H] Concentration is estimated
[J] Concentration less than limit of quantification

Table 3.3-2. PPCP concentrations (ng/L) measured at Hotel and Deep Hole Spring (Spring Lake, San Marcos) during Spring and Fall sampling events (2024). Samples with detectable concentrations denoted in bold.

PPCP List	Spring				Fall			
	Hotel spring		Deep Hole		Hotel spring		Deep Hole	
Alprazolam	0.0109	U	0.0098	UC	0.0126	U	0.0142	U
Amitriptyline	0.0099	U	0.0116	U	0.0055	U	0.0046	U
Amlodipine	0.0249	U	0.0186	UC	0.0249	U	0.0151	U
Benzoylecgonine	**0.024**	B J	**0.018**	B JC	**0.025**	B J	**0.047**	B J
Benztropine	**0.418**	B J	**0.403**	B JC	**0.426**	B J	**0.385**	B J
Betamethasone	0.101	U	0.191	U	0.0357	U	0.0376	U
Cocaine	**0.025**	B J	**0.225**	BC	**0.027**	B J	**0.061**	B J
DEET	**1.99**	B	**9.97**	BC	**2.62**	B	**11.6**	B
Desmethyldiltiazem	0.0357	U	**0.016**	B JC	**0.02**	B J	**0.015**	B J
Diazepam	0.0207	U	**0.048**	JC	0.0344	U	0.0198	U
Fluocinonide	0.286	U	0.549	U	0.0731	U	0.45	U
Fluticasone propionate	0.0846	U	0.0957	U	0.068	U	0.101	U
Hydrocortisone	**1.08**	B J	**3.61**	B JC	0.145	U	0.109	U
10-hydroxy-amitriptyline	0.0615	U	0.0878	U	0.0424	U	0.0297	U
Meprobamate	0.0348	U	0.0171	U	0.034	U	0.0214	U
Methylprednisolone	0.435	U	**0.599**	J	0.389	U	0.9	U
Metoprolol	0.0027	U	**0.19**	B JC	**0.005**	B J	**0.009**	B J
Norfluoxetine	0.0044	U	0.0069	U	0.0072	U	0.006	U
Norverapamil	0.0013	U	0.0028	U	0.0014	U	0.0015	U
Paroxetine	0.0205	U	0.0414	U	0.0187	U	0.0602	U
Prednisolone	0.0727	U	**0.151**	B J	0.034	U	0.106	U
Prednisone	**0.204**	J	**0.392**	JC	0.269	U	0.232	U
Promethazine	**0.009**	B J	**0.008**	B JC	0.0025	U	0.0099	U
Propoxyphene	0.0008	U	0.0006	U	0.0007	U	0.0005	U
Propranolol	0.0034	U	0.0108	U	0.0028	U	0.0047	U
Sertraline	0.0251	U	**0.017**	J	0.0052	U	0.0164	U
Simvastatin	0.156	U	0.176	U	0.0323	U	0.103	U
Theophylline	**1.63**	B J	**1.13**	B JC	**0.474**	B J	**0.66**	B J
Trenbolone	0.0081	U	**0.046**	J	0.0162	U	0.0355	U
Trenbolone acetate	0.0327	U	0.0498	U	0.0267	U	0.0325	U
Valsartan	0.0817	U	**0.232**	B JC	**0.047**	J	**0.173**	J
Verapamil	**0.004**	B J	**0.005**	B JC	**0.006**	B J	0.0029	U

[U] Non-detect at reporting limit
[B] Analyte found in associated blank and concentration in sample <10x concentration in lab blank
[C] Detected in duplicate sample
[H] Concentration is estimated
[J] Concentration less than limit of quantification

Table 3.3-3. PPCP concentrations (ng/L) measured at Hotel (Spring Lake, San Marcos) during January, May, and July sampling events (2024). Samples with detectable concentrations denoted in bold.

PPCP List	January	May	July
Acetaminophen	**0.869** J	0.849 U	0.249 U
Azithromycin	**0.287** B J	0.0928 U	0.0806 U
Caffeine	**37.3**	**217**	**3.43** B J
Carbadox	0.0448 U	0.0561 U	0.0442 U
Carbamazepine	0.0019 U	0.001 U	0.0014 U
Cefotaxime	1.49 U	0.589 U	6.24 U
Ciprofloxacin	0.372 U	0.214 U	0.307 U
Clarithromycin	**0.003** B J	0.002 U	**0.002** B J
Clinafloxacin	0.481 U	0.851 U	0.516 U
Cloxacillin	0.167 U H	0.182 U H	3.15 U H
Dehydronifedipine	0.0108 U	0.0058 U	0.0124 U
Digoxigenin	0.134 U	0.197 U	0.164 U
Digoxin	**0.868** J	**0.588** J	**0.302** B J
Diltiazem	**0.002** J	**0.002** B J	**0.004** J
Diphenhydramine	**0.005** B J	**0.119** J	**0.002** B J
Enrofloxacin	**0.123** J	0.119 U	0.293 U
Erythromycin-H2O	**0.158** B H	**0.089** B H	1.58 U H
Flumequine	**0.026** J	**0.005** J	0.0044 U
Fluoxetine	0.0008 U	0.0006 U	**0.001** B J
Lincomycin	0.0102 U	0.013 U	0.0068 U
Lomefloxacin	0.0071 U	0.013 U	0.0202 U
Miconazole	**0.138** B J	**0.068** B J	**0.033** B J
Norfloxacin	0.456 U	0.64 U	0.816 U
Norgestimate	**0.279** J	0.144 U	0.261 U
Ofloxacin	0.0084 U	0.0091 U	**0.0226** U
Ormetoprim	0.003 U	0.0028 U	**0.0032** U
Oxacillin	0.157 U H	0.113 U H	1.58 U H
Oxolinic Acid	0.0396 U	0.114 U	0.0251 U
Penicillin G	**4.5** B H	4.26 R B H	**4.35** H
Penicillin V	**0.284** B J	0.172 U	**0.268** B J
Roxithromycin	0.0049 U	0.0033 U	0.0025 U
Sarafloxacin	0.145 U	0.186 U	0.309 U
Sulfachloropyridazine	0.0151 U	0.0068 U	0.0223 U
Sulfadiazine	0.0084 U	0.004 U	0.0101 U
Sulfadimethoxine	0.0054 U	0.0045 U	0.0116 U
Sulfamerazine	0.0051 U	0.0037 U	0.0103 U
Sulfamethazine	0.0083 U	**0.026** J	0.0141 U
Sulfamethizole	**0.21** J	0.161 U	**0.03** B J
Sulfamethoxazole	**0.122** J	**0.141** J	**0.185** J
Sulfanilamide	**2.31** J	**2.48** J	**3.34** B J
Sulfathiazole	0.0153 U	0.0137 U	0.021 U
Thiabendazole	**0.014** B J	**0.074** B J	**0.013** J
Trimethoprim	**0.004** B J	0.007 U	**0.011** B J
Tylosin	0.0192 U	0.0178 U	**0.043** B J
Virginiamycin M1	**0.253** J	0.0844 U	**0.112** J
1,7-Dimethylxanthine	**2.83** B J	**0.849** B J	**0.667** B J

U Non-detect at reporting limit

B Analyte found in associated blank and concentration in sample <10x concentration in blank

H Concentration is estimated

J Concentration less than limit of quantification

Table 3.3-4. PPCP concentrations (ng/L) measured at Hotel (Spring Lake, San Marcos) during January, May, and July sampling events (2024). Samples with detectable concentrations denoted in bold.

PPCP List Continued	January		May		July	
Alprazolam	0.0114	U	0.0082	U	**0.024**	J
Amitriptyline	0.008	U	0.038	U	0.0335	U
Amlodipine	0.0229	U	0.0086	U	0.0143	U
Benzoylecgonine	**0.009**	B J	**0.136**	B J	**0.036**	B J
Benztropine	**0.482**	B J	**0.384**	B J	**0.458**	B J
Betamethasone	0.154	U	0.0403	U	0.0481	U
Cocaine	**0.035**	B J	**0.571**		**0.028**	B J
DEET	**2.67**	B	**1.28**	B	**1.5**	B
Desmethyldiltiazem	**0.03**	B J	0.0023	U	**0.007**	B J
Diazepam	0.0561	U	0.0354	U	0.0158	U
Fluocinonide	0.472	U	0.412	U	0.202	U
Fluticasone propionate	0.0669	U	**0.124**	J	0.064	U
Hydrocortisone	**1.83**	B J	0.274	U	0.0891	U
10-hydroxy-amitriptyline	0.0597	U	0.0488	U	0.0495	U
Meprobamate	0.0602	U	0.0292	U	0.029	U
Methylprednisolone	0.467	U	0.476	U	0.4	U
Metoprolol	**0.009**	B J	0.0039	U	**0.005**	B J
Norfluoxetine	0.0049	U	0.0062	U	0.0079	U
Norverapamil	0.0022	U	0.0007	U	0.0018	U
Paroxetine	0.0162	U	0.0272	U	0.0064	U
Prednisolone	**0.071**	B J	0.142	U	0.112	U
Prednisone	**0.327**	J	0.211	U	0.116	U
Promethazine	**0.005**	B J	0.0029	U	0.0062	U
Propoxyphene	0.0013	U	0.0005	U	0.0013	U
Propranolol	**0.029**	J	0.0053	U	0.004	U
Sertraline	**0.027**	J	0.0178	U	0.0092	U
Simvastatin	0.154	U	0.189	U	0.127	U
Theophylline	**6.45**	J	**1.42**	B J	**0.751**	B J
Trenbolone	**0.033**	J	0.0447	U	0.0229	U
Trenbolone acetate	0.0312	U	0.0346	U	0.0207	U
Valsartan	**0.389**	B J	**0.331**	B J	**0.221**	J
Verapamil	**0.004**	B J	**0.005**	B J	0.0029	U

U Non-detect at reporting limit

B Analyte found in associated blank and concentration in sample <10x concentration in blank

H Concentration is estimated

J Concentration less than limit of quantification

3.3.2 Comal

A total of eight PPCP samples were collected during Spring and Fall collections in 2024, including one field duplicate sample during the Fall at Spring Run 3 and one DI blank taken at Spring Run 1 in the Spring. Samples were also collected at Spring Run 3 during the months of January, May, July, and November (November results not yet available). Samples were only taken at Spring Run 1 and Spring Run 7 during the standard Spring (March) and Fall (August) sampling events. Results for the Spring and Fall PPCP sampling at Spring Runs 1, 3, and 7 are denoted in Table 3.3-5 and 3.3-6 and PPCP results for Spring Run 3 for January, May, and July are noted in Tables 3.3-7 and 3.3-8.

Table 3.3-5. PPCP concentrations (ng/L) measured at Spring Run 1, Spring Run 3, and Spring Run 7 (Landa Lake) during Spring and Fall sampling events (2024). Samples with detectable concentrations denoted in bold.

PPCP List	Spring			Fall		
	Spring Run 1	Spring Run 3	Spring Run 7	Spring Run 1	Spring Run 3	Spring Run 7
Acetaminophen	0.278 U	0.392 U	**2.2** J	**4.72**	0.284 U	0.296 U
Azithromycin	**0.092** B J	**0.242** B J	**0.183** B J	0.139 U	0.166 U	0.0482 U
Caffeine	**1.07** B J	**0.772** B J	**4.04** B J	**124**	**2.53** B JC	**1.63** B J
Carbadox	0.0438 U	0.0694 U	0.065 U	0.181 U	0.561 U	**0.072** J
Carbamazepine	0.0024 U	0.002 U	0.0016 U	0.0012 U	0.0013 U	0.0014 U
Cefotaxime	2.77 U	0.538 U	0.682 U	5.81 U	6.27 U	6.35 U
Ciprofloxacin	0.195 U	0.289 U	0.312 U	**0.775** J	0.356 U	0.41 U
Clarithromycin	**0.023** B J	0.0037 U	0.0029 U	0.002 U	**0.016** B J	**0.004** B J
Clinafloxacin	0.435 U	0.671 U	1.26 U	0.429 U	0.829 U	0.333 U
Cloxacillin	0.333 U H	0.201 U H	0.246 U H	2.93 U H	3.17 U H	3.21 U H
Dehydronifedipine	0.0153 U	0.0107 U	0.008 U	0.0071 U	0.0083 U	**0.011** J
Digoxigenin	0.205 U	0.496 U	0.303 U	0.102 U	0.133 U	0.116 U
Digoxin	**0.326** J	**0.211** J	**0.203** J	**0.268** B J	**0.299** B JC	**0.288** B J
Diltiazem	0.0024 U	0.0012 U	**0.003** J	**0.003** J	**0.004** JC	**0.005** J
Diphenhydramine	**0.104** J	**0.003** B J	0.0023 U	**0.071** J	**0.009** B J	**0.004** B J
Enrofloxacin	0.117 U	0.136 U	0.148 U	0.128 U	0.107 U	0.126 U
Erythromycin-H2O	**0.064** B H	**0.081** B H	**0.098** B H	1.47 U H	1.58 U H	1.6 U H
Flumequine	0.0062 U	0.0047 U	0.0056 U	0.0041 U	**0.003** B JC	0.0039 U
Fluoxetine	0.0019 U	**0.002** B J	**0.002** B J	0.0007 U	0.0005 U	0.0007 U
Lincomycin	0.0069 U	**0.008** J	0.0051 U	0.0038 U	**0.004** J	0.0034 U
Lomefloxacin	0.0256 U	**0.054** B J	0.0111 U	0.014 U	0.0094 UC	0.0115 U
Miconazole	**0.092** B J	**0.114** B J	**0.118** B J	0.0087 U	0.0089 UC	**0.02** B J
Norfloxacin	0.34 U	0.461 U	**0.393** J	0.706 U	0.553 U	0.777 U
Norgestimate	0.446 U	0.553 U	0.481 U	0.35 U	0.298 U	0.18 U
Ofloxacin	0.0155 U	**0.057** B J	0.0327 U	0.0753 U	**0.044** J	0.0055 U
Ormetoprim	0.0036 U	0.0038 U	0.002 U	0.0043 U	**0.003** B J	0.0056 U
Oxacillin	0.508 U H	**0.24** H	0.147 U H	1.47 U H	1.58 U H	1.6 U H
Oxolinic Acid	0.0247 U	0.0404 U	0.0317 U	0.0249 U	0.0253 U	0.0112 U
Penicillin G	**1.69** B H	**5.04** B H	1.71 U H	2.93 U H	3.17 U H	3.21 U H
Penicillin V	0.2 U	0.206 U	**0.276** B J	**0.44** B J	0.208 UC	**0.235** B J
Roxithromycin	0.0065 U	**0.027** J	0.0038 U	0.0018 U	0.0022 U	0.0026 U
Sarafloxacin	0.149 U	0.107 U	0.162 U	0.174 U	0.18 U	0.094 U
Sulfachloropyridazine	0.0156 U	0.0208 U	0.0086 U	0.0138 U	0.0124 U	0.0251 U
Sulfadiazine	0.0155 U	0.0132 U	**0.017** B J	0.0086 U	0.0065 U	0.0067 U
Sulfadimethoxine	0.0114 U	0.0146 U	0.0071 U	0.0208 U	0.0068 U	0.0105 U
Sulfamerazine	0.0201 U	0.0134 U	0.0053 U	0.0066 U	**0.013** J	0.0102 U
Sulfamethazine	0.0158 U	0.0123 U	0.112 U	0.0079 U	0.0052 U	0.0084 U
Sulfamethizole	0.414 U	**0.379** J	0.324 U	0.0368 U	0.0151 U	0.0341 U
Sulfamethoxazole	**0.262** J	**0.538** J	**0.534** J	**0.421** J	**0.541** JC	**0.253** J
Sulfanilamide	**2.35** J	**2.24** J	**3.38** J	**2.64** B J	**3.89** JC	**2.56** B J
Sulfathiazole	0.0326 U	0.0367 U	0.0158 U	0.0427 U	0.0146 U	0.0239 U
Thiabendazole	**0.006** B J	**0.032** B J	**0.037** B J	**0.026** J	**0.017** JC	0.0091 U
Trimethoprim	**0.011** B J	0.0645 U	0.0046 U	0.0193 U	**0.006** B JC	**0.007** B J
Tylosin	0.0204 U	0.0169 U	0.0154 U	**0.025** B J	**0.193** J	0.011 U
Virginiamycin M1	0.0688 U	0.0703 U	0.183 U	**0.147** J	0.0345 U	**0.342** J
1,7-Dimethylxanthine	**0.405** B J	**0.664** B J	**1.01** B J	**2.13** B J	**0.303** B JC	**0.194** B J

U Non-detect at reporting limit
B Analyte found in associated blank and concentration in sample <10x concentration in lab blank
C Detected in duplicate sample
H Concentration is estimated
J Concentration less than limit of quantification

Table 3.3-6. PPCP concentrations (ng/L) measured at Spring Run 1, Spring Run 3, and Spring Run 7 (Landa Lake) during Spring and Fall sampling events (2024). Samples with detectable concentrations denoted in bold.

PPCP List Continued	Spring			Fall		
	Spring Run 1	Spring Run 3	Spring Run 7	Spring Run 1	Spring Run 3	Spring Run 7
Alprazolam	**0.017** B J	**0.014** B J	**0.022** B J	0.0106 U	0.0242 U	0.0135 U
Amitriptyline	**0.011** J	0.0128 U	0.0132 U	0.012 U	0.0281 U	0.012 U
Amlodipine	0.0178 U	0.0107 U	0.0281 U	0.009 U	0.0144 U	0.0488 U
Benzoylecgonine	**0.018** B J	**0.037** B J	**0.013** B J	**0.041** B J	**0.023** B JC	**0.088** B J
Benztropine	**0.4** B J	**0.451** B J	**0.386** B J	**0.444** B J	**0.482** B JC	**0.463** B J
Betamethasone	0.166 U	0.196 U	0.161 U	0.0332 U	0.0379 U	0.0561 U
Cocaine	**0.033** B J	**0.027** B J	**0.016** B J	**0.078** B J	**0.051** B JC	**0.048** B J
DEET	**1.72** B	**2.58** B	**1.87** B	**2.8** B	**3.18** BC	**3.19** B
Desmethyldiltiazem	**0.013** B J	**0.024** B J	**0.036** B J	**0.006** B J	**0.009** B JC	**0.003** B J
Diazepam	0.0403 U	**0.058** J	0.0489 U	0.0135 U	0.0171 U	0.0183 U
Fluocinonide	0.291 U	0.477 U	0.291 U	0.143 U	0.139 U	0.0768 U
Fluticasone propionate	0.108 U	0.0991 U	0.108 U	0.0496 U	0.0772 U	0.0425 U
Hydrocortisone	**2.3** B J	**2.61** B J	**2.06** B J	**0.215** J	0.0558 U	0.114 U
10-hydroxy-amitriptyline	0.0681 U	0.053 U	0.112 U	0.0433 U	0.0408 U	0.0564 U
Meprobamate	0.0148 U	**0.0321** B J	0.0247 U	0.0257 U	0.0385 U	0.0431 U
Methylprednisolone	0.457 U	0.699 U	0.264 U	0.546 U	0.528 U	0.429 U
Metoprolol	0.0067 U	**0.008** B J	0.0051 U	**0.004** B J	**0.009** B JC	**0.005** B J
Norfluoxetine	0.0052 U	0.0081 U	0.0115 U	0.0039 U	0.0071 U	0.0108 U
Norverapamil	0.0017 U	0.0087 U	0.0013 U	0.0013 U	0.0012 U	0.0011 U
Paroxetine	0.0174 U	0.029 U	0.0348 U	0.0268 U	0.0419 U	0.0119 U
Prednisolone	**0.105** B J	**0.044** B J	**0.066** B J	0.0561 U	0.0439 U	0.067 U
Prednisone	**0.186** J	**0.513** J	**0.161** J	0.167 U	0.141 U	0.191 U
Promethazine	0.0075 U	0.0196 U	0.018 U	0.0037 U	0.0012 U	0.0024 U
Propoxyphene	0.0009 U	**0.002** B J	**0.002** B J	0.0013 U	**0.003** J H	0.0005 U
Propranolol	**0.009** J	**0.007** J	0.0044 U	0.0042 U	0.0041 U	0.0038 U
Sertraline	0.0162 U	0.0285 U	**0.019** J	0.0076 U	**0.01** J	0.0102 U
Simvastatin	0.115 U	0.231 U	0.154 U	0.0831 U	0.059 U	0.0627 U
Theophylline	**0.876** B J	**0.574** B J	**2.05** B J	**4.19** J	**0.484** B JC	**0.364** B J
Trenbolone	**0.029** J	0.0129 U	**0.096** J	**0.086** J	0.0221 U	0.0459 U
Trenbolone acetate	**0.047** J	0.0448 U	0.0338 U	0.031 U	0.0274 U	0.0285 U
Valsartan	**0.079** B J	**0.365** B J	0.0797 U	**0.06** J	**0.17** JC	0.04 U
Verapamil	**0.005** B J	**0.018** B J	0.0071 U	0.0018 U	0.002 U	0.0015 U

U Non-detect at reporting limit
B Analyte found in associated blank and concentration in sample <10x concentration in lab blank
C Detected in duplicate sample
H Concentration is estimated
J Concentration less than limit of quantification

Table 3.3-7. PPCP concentrations (ng/L) measured at Spring Run 3 (Landa Lake, New Braunfels) during January, May, and July sampling events (2024). Samples with detectable concentrations denoted in bold.

PPCP List	January		May		July	
Acetaminophen	**0.869**	J	0.849	U	0.249	U
Azithromycin	**0.287**	B J	0.0928	U	0.0806	U
Caffeine	**37.3**		**217**		**3.43**	B J
Carbadox	0.0448	U	0.0561	U	0.0442	U
Carbamazepine	0.0019	U	0.001	U	0.0014	U
Cefotaxime	1.49	U	0.589	U	6.24	U
Ciprofloxacin	0.372	U	0.214	U	0.307	U
Clarithromycin	**0.003**	B J	0.002	U	**0.002**	B J
Clinafloxacin	0.481	U	0.851	U	0.516	U
Cloxacillin	0.167	U H	0.182	U H	3.15	U H
Dehydronifedipine	0.0108	U	0.0058	U	0.0124	U
Digoxigenin	0.134	U	0.197	U	0.164	U
Digoxin	**0.868**	J	**0.588**	J	**0.302**	B J
Diltiazem	**0.002**	J	**0.002**	B J	**0.004**	J
Diphenhydramine	**0.005**	B J	**0.119**	J	**0.002**	B J
Enrofloxacin	**0.123**	J	0.119	U	0.293	U
Erythromycin-H2O	**0.158**	B H	**0.089**	B H	1.58	U H
Flumequine	**0.026**	J	**0.005**	J	0.0044	U
Fluoxetine	0.0008	U	0.0006	U	**0.001**	B J
Lincomycin	0.0102	U	0.013	U	0.0068	U
Lomefloxacin	0.0071	U	0.013	U	0.0202	U
Miconazole	**0.138**	B J	**0.068**	B J	**0.033**	B J
Norfloxacin	0.456	U	0.64	U	0.816	U
Norgestimate	**0.279**	J	0.144	U	0.261	U
Ofloxacin	0.0084	U	0.0091	U	**0.0226**	U
Ormetoprim	0.003	U	0.0028	U	**0.0032**	U
Oxacillin	0.157	U H	0.113	U H	1.58	U H
Oxolinic Acid	0.0396	U	0.114	U	0.0251	U
Penicillin G	**4.5**	B H	4.26	R B H	**4.35**	H
Penicillin V	**0.284**	B J	0.172	U	**0.268**	B J
Roxithromycin	0.0049	U	0.0033	U	0.0025	U
Sarafloxacin	0.145	U	0.186	U	0.309	U
Sulfachloropyridazine	0.0151	U	0.0068	U	0.0223	U
Sulfadiazine	0.0084	U	0.004	U	0.0101	U
Sulfadimethoxine	0.0054	U	0.0045	U	0.0116	U
Sulfamerazine	0.0051	U	0.0037	U	0.0103	U
Sulfamethazine	0.0083	U	**0.026**	J	0.0141	U
Sulfamethizole	**0.21**	J	0.161	U	**0.03**	B J
Sulfamethoxazole	**0.122**	J	**0.141**	J	**0.185**	J
Sulfanilamide	**2.31**	J	**2.48**	J	**3.34**	B J
Sulfathiazole	0.0153	U	0.0137	U	0.021	U
Thiabendazole	**0.014**	B J	**0.074**	B J	**0.013**	J
Trimethoprim	**0.004**	B J	0.007	U	**0.011**	B J
Tylosin	0.0192	U	0.0178	U	**0.043**	B J
Virginiamycin M1	**0.253**	J	0.0844	U	**0.112**	J
1,7-Dimethylxanthine	**2.83**	B J	**0.849**	B J	**0.667**	B J

[U] Non-detect at reporting limit
[B] Analyte found in associated blank and concentration in sample <10x concentration in blank
[H] Concentration is estimated
[J] Concentration less than limit of quantification

Table 3.3-8. PPCP concentrations (ng/L) measured at Spring Run 3 (Landa Lake, New Braunfels) during January, May, and July sampling events (2024). Samples with detectable concentrations denoted in bold.

PPCP List Continued	January		May		July	
Alprazolam	0.012	U	0.0154	U	0.0157	U
Amitriptyline	**0.021**	J	**0.01**	J	**0.012**	J
Amlodipine	0.035	U	0.0726	U	0.0174	U
Benzoylecgonine	**0.022**	B J	**0.027**	B J	**0.089**	B J
Benztropine	**0.424**	B J	**0.441**	B J	**0.459**	B J
Betamethasone	0.131	U	0.0848	U	0.0516	U
Cocaine	**0.006**	B J	**0.091**	B J	**0.1**	B J
DEET	**2.61**	B	**1.23**	B	**1.81**	B
Desmethyldiltiazem	**0.01**	B J	**0.027**	B J	**0.003**	B J
Diazepam	0.0386	U	0.0381	U	0.0208	U
Fluocinonide	0.388	U	0.54	U	0.148	U
Fluticasone propionate	0.0721	U	0.12	U	0.0679	U
Hydrocortisone	**1.16**	B J	0.325	U	0.284	U
10-hydroxy-amitriptyline	0.0912	U	0.0557	U	0.0429	U
Meprobamate	**0.024**	B J	0.0447	U	0.0382	U
Methylprednisolone	0.565	U	0.412	U	0.709	U
Metoprolol	0.0024	U	0.0035	U	**0.007**	B J
Norfluoxetine	0.0115	U	0.0065	U	0.0099	U
Norverapamil	0.0021	U	0.0018	U	0.0018	U
Paroxetine	0.0023	U	0.0115	U	0.0164	U
Prednisolone	**0.119**	B J	0.165	U	0.0845	U
Prednisone	**0.23**	J	0.213	U	0.16	U
Promethazine	0.0049	U	0.0101	U	0.0048	U
Propoxyphene	0.0009	U	**0.003**	J	0.0007	U
Propranolol	0.0046	U	**0.011**	J	0.0044	U
Sertraline	**0.024**	J	0.0117	U	0.0131	U
Simvastatin	0.0979	U	0.246	U	0.083	U
Theophylline	**0.914**	B J	**0.565**	B J	**6.83**	J
Trenbolone	**0.039**	J	0.0498	U	0.0278	U
Trenbolone acetate	0.0486	U	0.0477	U	0.0335	U
Valsartan	**0.454**	B J	**0.751**	B J	**0.275**	J
Verapamil	**0.005**	B J	**0.012**	B J	**0.008**	B J

[U] Non-detect at reporting limit

[B] Analyte found in associated blank and concentration in sample <10x concentration in blank

[J] Concentration less than limit of quantification

3.4 Sediment sampling

3.4.1 San Marcos

Table 3.4-1 denotes the contaminant results for sediment samples collected in 2024 at the San Marcos system sites. Overall, several of the same contaminants were detected at each site and many of the contaminants are associated with being a byproduct from combustion engines or is a product in dyes, insecticides, or preservatives.

Table 3.4-1. Contaminant concentrations (µg/Kg) measured in sediment samples collected from the San Marcos system in August 2024. Samples with detectable concentrations are denoted in bold.

Analyte	Sink Creek	Spring Lake	Sessom Creek	City Park	Rio Vista	IH35	IH35[2]	Lab Blank
1-Methylnaphthalene	<59.8 U	<132 U	<157 U	<123 U	<74.1 U	<45.7 U	<48.1 U	<2.31 U
2-Methylnaphthalene	<58.2 U	<128 U	<153 U	<119 U	<72.1 U	<44.5 U	<46.8 U	<2.24 U
Acenaphthene	<53.7 U	<118 U	<141 U	<110 U	<66.5 U	<41.0 U	<43.2 U	<2.07 U
Acenaphthylene	<37.2 U	<81.9 U	<97.6 U	<76.3 U	<46.1 U	<28.5 U	<29.9 U	<1.43 U
Anthracene	<51.7 U	<114 U	**475** J	<106 U	<64.1 U	<39.6 U	<41.6 U	<1.99 U
Benzo[a]anthracene	**114** J	**1300**	**3270**	**561**	**214**	**211**	**126**	<1.51 U
Benzo[a]pyrene	**113** J	**1600**	**3170**	**745**	**278**	**262**	**175**	<1.95 U
Benzo[b]fluoranthene	**152** J	**2450**	**4250**	**1140**	**455**	**374**	**255**	<2.14 U
Benzo[g,h,i]perylene	**99.8** J	**1510**	**2500**	**674**	**252** J	**232**	**161** J	<1.91 U
Benzo[k]fluoranthene	**64.1** J	**990**	**1820**	**486** J	**181** J	**161** J	**107** J	<1.95 U
Chrysene	**127** J	**1640**	**3450**	**894**	**300** J	**271**	**194** J	<1.82 U
Dibenz(a,h)anthracene	<52.3 U	**339**	**587**	**157** J	<64.8 U	**53.0** J	<42.1 U	<2.02 U
Fluoranthene	**185** J	**2150**	**7360**	**1290**	**435**	**346**	**233**	<2.48 U
Fluorene	<49.6 U	<109 U	<130 U	<102 U	<61.4 U	<37.9 U	<39.9 U	<1.91 U
Indeno[1,2,3-cd]pyrene	**107** J	**1610**	**2680**	**738**	**268** J	**258**	**181** J	<2.76 U
Naphthalene	<74.3 U	<164 U	<195 U	<152 U	<92.0 U	<56.8 U	<59.8 U	<2.86 U
Phenanthrene	<80.1 U	**358** J	**2720**	**348** J	<99.2 U	**70.9** J	<64.5 U	<3.09 U
Pyrene	**182** J	**1890**	**5800**	**1140**	**394**	**313**	**242**	<2.23 U

[U] non-detect at MDL (Method Detection Limit)

[J] Result is less than the RL (reporting limit) but greater than the MDL.

3.4.2 Comal

Table 3.4-2 denotes the contaminant results for sediment samples collected in 2024 at the Comal system sites. Many of the contaminants were detected at each of the Comal system sites but, in general, the Comal system reported fewer detections and lower values than the San Marcos system. Among sites, the Old Channel had the greatest number of detectable contaminants whereas Bleiders Creek and Spring Island in Landa Lake reported no contaminant detections.

Table 3.4-2 Contaminant concentrations (µg/Kg) measured in sediment samples collected from the Comal system in August 2024. Samples with detectable concentrations are denoted in bold.

Analyte	Bleiders Creek	Spring Island	Old Channel	Old Channel[2]	New Channel	Lab Blank
1-Methylnaphthalene	<92.2 U	<82.0 U	<58.1 U	<40.4 U	<66.1 U	<2.31 U
2-Methylnaphthalene	<89.7 U	<79.8 U	<56.6 U	<39.3 U	<64.3 U	<2.24 U
Acenaphthene	<82.7 U	<73.6 U	<52.2 U	<36.3 U	<59.3 U	<2.07 U
Acenaphthylene	<57.4 U	<51.0 U	**51.5** J	<25.1 U	<41.1 U	<1.43 U
Anthracene	<79.8 U	<70.9 U	<50.3 U	<35.0 U	<57.1 U	<1.99 U
Benzo[a]anthracene	<60.5 U	<53.8 U	**417**	**119**	**53.6** J	<1.51 U
Benzo[a]pyrene	<78.0 U	<69.4 U	**319**	**79.9** J	<55.9 U	<1.95 U
Benzo[b]fluoranthene	<85.7 U	<76.2 U	**580**	**151** J	**75.2** J	<2.14 U
Benzo[g,h,i]perylene	<76.3 U	<67.9 U	**172** J	**46.9** J	<54.7 U	<1.91 U
Benzo[k]fluoranthene	<77.9 U	<69.3 U	**238** J	**66.5** J	<55.8 U	<1.95 U
Chrysene	<72.6 U	<64.6 U	**501**	**143** J	**64.2** J	<1.82 U
Dibenz(a,h)anthracene	<80.7 U	<71.7 U	**53.6** J	<35.3 U	<57.8 U	<2.02 U
Fluoranthene	<99.4 U	<88.4 U	**1200**	**283**	**79.8** J	<2.48 U
Fluorene	<76.4 U	<68.0 U	<48.2 U	<33.5 U	<54.8 U	<1.91 U
Indeno[1,2,3-cd]pyrene	<110 U	<98.3 U	**210** J	**57.1** J	<79.2 U	<2.76 U
Naphthalene	<115 U	<102 U	<72.2 U	<50.2 U	<82.1 U	<2.86 U
Phenanthrene	<124 U	<110 U	**156** J	**62.1** J	<88.5 U	<3.09 U
Pyrene	<89.0 U	<79.2 U	**910**	**209**	**77.1** J	<2.23 U

U non-detect at MDL (Method Detection Limit)

J Result is less than the RL (reporting limit) but greater than the MDL.

4 | References

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Appendix F3 | **Comal Biological Monitoring Report**

HABITAT CONSERVATION PLAN

BIOLOGICAL MONITORING PROGRAM

Comal Springs/River Aquatic Ecosystem

ANNUAL REPORT

December 2024

Prepared for:

Edwards Aquifer Authority
900 East Quincy
San Antonio, Texas 78215

Prepared by:

BIO-WEST, Inc.
1812 Central Commerce Court
Round Rock, Texas 78664

BIO-WEST

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EXECUTIVE SUMMARY

The Edwards Aquifer Habitat Conservation Plan (EAHCP) Biological Monitoring Program continued to track biota and habitat conditions of the Comal Springs/River ecosystem in 2024 through a series of routine and Critical Period monitoring activities outlined in this report. Monitoring in the Comal system consisted of routine surveys specific to EAHCP Covered Species: Fountain Darter (*Etheostoma fonticola*), Comal Springs Salamander (*Eurycea* sp.), and multiple Comal Springs invertebrates. Community-level monitoring data were also collected on aquatic vegetation, fish, and benthic macroinvertebrates. In addition to routine monitoring, multiple Critical Period and species-specific low-flow sampling events were triggered as springflows remained at the lowest levels observed since the start of biological monitoring in 2000. Results from 2024 biological monitoring provided valuable data to further assess spatiotemporal trends of aquatic biota in the Comal Springs/River ecosystem, as well as a unique opportunity to better understand ecological responses under sustained low-flow scenarios.

In 2024, central Texas experienced continued drought conditions with low precipitation and higher ambient temperatures. Low-flow conditions in the Comal Springs/River System persisted from the previous year but were briefly interrupted by one temporary high flow event at the end of January. With minimal rain following this event, discharge stayed well below long-term median flows for the entire year and continued the decreasing trend observed since 2022. This resulted in a second year under the lowest flow conditions documented over the course of the 23-year biological monitoring program. When compared to previous drought years, median and minimum daily mean discharge were similar in 2024 (125 cubic feet per second [cfs] and 55 cfs, respectively) and 2023 (121 and 55 cfs, respectively), but both were lower than the previous monitoring program low observed in 2014 (135 and 65 cfs, respectively) and considerably lower than other drought years in 2009, 2011, and 2013. Monthly median discharges were below the long-term 10th percentiles throughout the year, except for the month of August when they approximated 10th percentile levels. Flows dropped below 100 cfs in June, resulting in one Critical Period sampling event. Small rain events in June and July slightly increased the aquifer level and helped total discharge remain around 100 cfs until flows began decreasing in mid-August. Although 2023 and 2024 shared similar annual median and minimum daily mean discharge values, the timing of the minimum flows varied. In 2023, the minimum mean daily flow was reached in August, aligning with the hottest air temperatures and fewest rain events. In 2024, flows remained low the entire year, but the same minimum mean daily flow (55 cfs) was not observed until October. This triggered habitat evaluations, discharge and flow partitioning measurements, and multiple species-specific events which were all coupled with routine fall monitoring.

Notable habitat degradations were observed at upper spring reaches and spring runs. As flows declined, atypically larger increases in temperature were observed near Upper Spring Run and Spring Island. While Upper Spring Run total vegetation coverage was higher than historical averages throughout the year, the dominant vegetation was the macroalgae *Chara* which proliferates in slackwater environments and has low Fountain Darter densities. Wetted surface habitat in spring areas was greatly reduced beginning in summer, leaving Spring Run 1 and the spring run at Spring Island completely dry through October. Furthermore, by fall sampling, the majority of salamander sampling area at Spring Island Outfall and Spring Run 3 were dewatered. The extent and duration of desiccation observed throughout spring areas resulted in obvious impacts to surface habitat for salamanders and spring-associated invertebrates. Salamanders were documented in all monitored spring runs in spring 2024, which followed several months of poor conditions (i.e., algae, desiccation) during summer 2023 and subsequent improved habitat conditions in fall 2023. However, improved conditions at the end of 2023 and beginning of 2024 did not remain long enough for salamander counts to rebound to long-term averages. *Eurycea* salamanders are known to use subsurface habitats and genomics data suggests that migration events are occurring between various spring locations within the Edwards Aquifer region (Devitt et al. 2019). Given their ability to occupy subsurface habitats and previous monitoring data showing recolonization after spring run desiccation events (e.g., 2014), it is assumed that salamanders will recolonize these areas as surface flow returns. However, additional monitoring is needed to confirm this as well as to evaluate recolonization rates and population responses.

Similar to salamanders, abundance estimates for *Stygobromus* sp. from spring drift-net sampling and Comal Springs Riffle Beetle from cotton-lure surveys were both down compared to historical data. Although drift-net counts of *Stygobromus* sp. are standardized per cubic meter of water, lower spring discharge may decrease the number of these organisms dislodged from near-spring environments. Across sites and seasons, a temporal decline in the number of Comal Springs Riffle Beetles observed per lure was noted when comparing 2024 data to 5-year and long-term datasets. In particular, abundance estimates have been low since fall 2021 suggesting population abundance was potentially impacted by low springflows observed the past three years. However, like the *Eurycea* salamanders described above, Comal Springs Riffle Beetles are capable of using sub-surface habitats. Therefore, reduced abundance on cotton lures set near spring surface habitats may not reflect a true population-level decline. A low-flow habitat utilization investigation conducted by BIO-WEST researchers as part of the species-specific triggered monitoring in fall 2023 suggested that Comal Springs Riffle Beetles follow water levels sub-surface when spring surface habitats dry up. Additional EAHCP research is currently being conducted to better understand Comal Springs Riffle Beetle population dynamics and its relationship to surface and subsurface habitat utilization.

The influence of extremely low springflows was also evident on abiotic habitat and aquatic vegetation conditions across all study reaches and resulted in an overall declining trend among Fountain Darter population metrics. Spring was the only season which approximated 5-year and long-term trends among all metrics. Fountain Darter densities met or exceeded long-term medians in April, but densities declined well below long-term values for all reaches by fall. Likewise, median CPUE and occurrence were greater in the spring than fall. In contrast, recruitment rates were lower than expected during the routine spring sampling event, which occurred during the Fountain Darter peak reproductive period. Lower recruitment during the June Critical Period at end of spring was not surprising given it occurred well after the typical period of peak reproduction. Declines in Fountain Darter population condition are likely the combined result of elevated summer water temperatures and changes in vegetation assemblages driven by low flows. Water temperature exceeded laboratory-estimated thresholds for maximum optimal Fountain Darter egg and larval production more commonly and for longer durations than during typical flow conditions at some upper spring stations.

After several years of continued low flows, a pattern of declining bryophyte coverage and increasing filamentous algae coverage has emerged in several study reaches. This was initially observed in Upper Spring Run, but the pattern appears to be extending to riverine reaches in 2024. The post-restoration vegetation community within the Old Channel has typically maintained high amounts of bryophytes over the past five years and Fountain Darter drop-net densities have remained near or above the long-term median for most events. However, fall 2024 deviated from this and demonstrated larger reductions in bryophytes and the lowest darter density observed over the past five years. Median densities in spring and fall have steadily declined since 2020 largely due to changes in suitable vegetation coverages (e.g., reductions in *Cabomba* and bryophytes). Although Landa Lake has maintained more vegetation and thermal stability than other reaches, it has also had the largest annual fluctuations in Fountain Darter densities over the past five years which could suggest that this reach is characterized by over-compensatory dynamics.

Asynchronous trends among Overall Habitat Suitability Index (OHSI) and Fountain Darter population metrics have become more apparent during low-flow years. For example, Upper Spring Run exhibited higher OHSI in 2024, largely due to increased coverage of filamentous algae, but Fountain Darter densities remained low. Additionally, Upper New Channel reach exhibited higher vegetation coverage and OHSI in 2024 which can be attributed to lack of scouring from high flow events within the Dry Comal Creek watershed. Despite the increased OHSI at Upper New Channel, low densities of Fountain Darters in spring and lack of Fountain Darters in fall were observed. This suggests that OHSI factors other than vegetation coverage and composition may be influencing Fountain Darter population dynamics under low flow conditions. Existing OHSI could benefit from incorporating other relevant habitat factors such as occurrence of bryophytes within other vegetation types and a water temperature component.

At a community scale, fish and macroinvertebrate community-level responses to low flows were not as evident as those within Covered Species populations. In 2024, reductions in spring fish relative density were noted in the New Channel. However, in general, no long-term temporal trends in overall or spring-associated fish diversity, richness, and relative density are evident from fish community monitoring data. Macroinvertebrate Index of Biotic Integrity (IBI) scores did show slight declines at some upper reaches (Upper Spring Run and Landa Lake) suggesting that low flows may have led to habitat homogenization and reduction in abundance of fluvial specialists in these areas. Though besides these minor deviations, fish and macroinvertebrate community data were generally comparable to historical data.

Overall, 2024 biological monitoring provided insights into the current condition of the EAHCP Covered Species in the Comal Springs/River System, as well as flow-ecology relationships related to the broader aquatic community. Similar to 2023, spring discharge in 2024 was among the lowest observed since initiation of biological monitoring in 2000. As a result, acute impacts to Covered Species habitats and resulting responses of population metrics were noted. Despite the extreme conditions observed, all Covered Species are still present at multiple habitats within the system and show potential to persist and rebound once more typical flow conditions return. Subsequent monitoring will be critical to assess the ultimate response of species populations to these unique, and at present, continuing stressors.

INTRODUCTION

The Edwards Aquifer Habitat Conservation Plan (EAHCP) is intended to provide assurance of suitable habitat for threatened and endangered species (i.e., Covered Species) (Table 1) in both the San Marcos and Comal Springs. Established in 2012, the EAHCP supports the issuance of an Incidental Take Permit that allows the "incidental take" of Covered Species from otherwise lawful activities in the Comal Springs system. Section 6.3.1 of the HCP established a continuation of biological monitoring in the Comal Springs/River. This biological monitoring program was first established in 2000 (formerly known as the Edwards Aquifer Authority [EAA] Variable Flow Study), and its original purpose was to evaluate the effects of variable flow on the biological resources of the Comal Springs/River, with an emphasis on threatened and endangered species. However, the utility of the HCP biological monitoring program has surpassed its initial purpose (EAHCP 2012). The biological data collected since the implementation of this monitoring program (BIO-WEST 2001–2024) now serves as the cornerstone for several underlying sections in the HCP, which include the following: (1) long-term biological goals (LTBGs) and management objectives (Section 4.1); (2) determination of potential impacts to Covered Species, "incidental take" assessment, and Environmental Impact Statement alternatives (Section 4.2); and (3) establishment of core adaptive-management activities for triggered monitoring and adaptive-management response actions (Section 6.4.3). Additionally, biological monitoring program data, in conjunction with other available information, are essential to adaptive management as the EAHCP proceeds. Current and future data collection will help assess the effectiveness and efficiency of certain EAHCP mitigation and restoration activities conducted in the Comal Springs/River and calculate the EAHCP habitat baseline and net disturbance determination and annual "incidental take" estimate (EAHCP 2012).

Table 1. Covered Species sampled for under the Edwards Aquifer Habitat Conservation Plan in the Comal spring and river ecosystems.

SCIENTIFIC NAME	COMMON NAME	ESA STATUS
Insects		
Haideoporus texanus	Edwards Aquifer Diving Beetle	Petitioned
Heterelmis comalensis	Comal Springs Riffle Beetle	Endangered
Stygoparnus comalensis	Comal Springs Dryopid Beetle	Endangered
Crustaceans		
Lirceolus smithii	Texas Troglobitic Water Slater	N/A
Stygobromus pecki	Peck's Cave Amphipod	Endangered
Amphibians		
Eurycea sp.	Comal Springs Salamander	N/A
Fish		
Etheostoma fonticola	Fountain Darter	Endangered

This report provides the methodology and results for biological monitoring activities conducted in 2024 within the Comal Spring/River ecosystem. In addition to routine monitoring, Critical Period and species-specific low-flow sampling were triggered. The results include summaries of current physiochemical conditions, as well as current conditions of floral and faunal communities, encompassing routine and low-flow sampling. For all aquatic organisms, historic observations (BIO-WEST 2001–2023a) are also used to provide context to current conditions.

METHODS

Study Location

The Comal Springs System is the largest spring complex in Texas. It encompasses an extensive headsprings system and the Comal River (New Braunfels, Comal County, Texas), and is fed by the Edwards Aquifer (Brune 2002). Dam construction and channelization during the late-1800s modified headspring habitats (Odgen et al. 1986; Crowe and Sharpe 1997) and drainage patterns of the river (Ottmers 1987). Impoundment of Comal Springs resulted in the formation of Landa Lake (Linam et al. 1993), which is fed by four spring runs of variable size (Ogden et al. 1986; Crowe and Sharpe 1997). From the headwaters, the river flows about 5 kilometers (km) before its confluence with the Guadalupe River. Under typical springflow conditions (>150 cfs), the majority of water that exits Landa Lake flows through the "New Channel", an engineered diversion that was originally created to act as a cooling system for a power generation plant. Under typical conditions, approximately 55-60 cfs are diverted to the original river channel, known as the "Old Channel," that rejoins the New Channel about 2.5 km downstream (Ottmers 1987). As springflow declines (<100 cfs), the flow split shifts, and proportionally more water is diverted to the Old Channel to maximize protection of habitat and maintain suitable water temperatures. For example, when total Comal springflow was approximately 60 cfs, ~35 cfs was sent down the Old Channel and 25 cfs was sent down the New Channel.

The watershed is dominated by urban landcover and is subjected to recreational use. Spring inputs from the Edwards Aquifer provide stable physiochemical conditions, and springflow conditions are dictated by aquifer recharge and human water use (Sung and Li 2010). In the 1950s, Comal Springs temporarily ceased flowing (Schneck and Whiteside 1976; Brune 2002). Despite this, the Comal Springs System maintains diverse assemblages of floral and faunal communities (Bowles and Arsuffi 1993; Crowe and Sharpe 1997) and includes multiple endemic aquatic organisms, such as Comal Springs Riffle Beetle, Peck's Cave Amphipod, Comal Springs Salamander, and Fountain Darter.

Sampling Strategy

Based on the long-term biological goals (LTBGs) and management objectives outlined in the HCP, study areas were established to conduct long-term monitoring and quantify population trends of the Covered Species (EAHCP 2012). The sampling locations selected are designed to cover the entire extent of Covered Species habitats, but they also allow for holistic ecological interpretation while maximizing resources (Figures 1–3).

Comprehensive sampling within the established study area varies temporally and spatially among Covered Species. The current sampling strategy includes five spatial resolutions:

1. System-wide sampling
   a. Aquatic vegetation mapping: 5-year intervals (winter)
2. Select longitudinal locations
   a. Water temperature monitoring: year-round at permanent monitoring stations
   b. Discharge measurements: 2 events/year (spring, fall)
3. Reach sampling
   a. Aquatic vegetation mapping: 2 events/year (spring, fall)
   b. Fountain Darter drop-net sampling: 2 events/year (spring, fall)
   c. Fountain Darter random-station dip-net surveys: 3 events/year (spring, summer, fall)
4. Springs Sampling
   a. Endangered Comal invertebrate sampling: 2 events/year (spring, fall)
   b. Comal Salamander surveys: 2 events/year (spring, fall)
   c. Fountain Darter visual surveys: 2 events/year (spring, fall)
5. River section/segment
   a. Fountain Darter timed dip-net surveys: 3 events/year (spring, summer, fall)
   b. Fish community sampling: 2 events/year (spring, fall)
   c. Macroinvertebrate community sampling: 2 events/year (spring, fall)

In addition to annual comprehensive sampling outlined above, low-flow sampling may also be conducted, but is dependent on HCP flow triggers, which include Critical Period Low-Flow Sampling and species-specific sampling (EAHCP 2012). Discharge decreased below 100 cfs in June, which resulted in a Critical Period low-flow full sampling event. Critical Period water grab sampling results are presented in Appendix B. Species-specific monitoring was conducted from June to November for the Fountain Darter and Comal Springs Riffle Beetle (Appendix A). Habitats were assessed at approximately every 10 cfs decline and thermistors were downloaded at regular intervals to ensure suitable Covered Species habitat availability and system stability.

The remaining methods sections provide brief descriptions of the procedures utilized for comprehensive sampling efforts, which includes details on all Critical Period and species-specific sampling efforts. A more-detailed description of the gear types used, methodologies employed, and specific GPS coordinates can be found in the Standard Operating Procedures Manual for the HCP biological monitoring program for the Comal Springs/River ecosystem (EAA 2017).

Comal River Discharge and Springflow

River hydrology in 2024 was assessed using US Geological Survey (USGS) stream gage data from January 1 to October 31. Mean daily discharge expressed in cubic feet per second (cfs) was acquired from USGS gage #08169000, which represents cumulative river discharge that encompasses springflow and local runoff contributions. It should be noted that some of these data are provisional and are subject to revision at a later date (USGS 2024). The annual distribution of mean daily discharge was compared for the past 5-years using boxplots. The distribution of 2024 mean daily discharge was summarized by month using boxplots. Monthly discharge levels were compared with long-term (1928–present) 10th, 50th (i.e., median), and 90th percentiles.

Discharge was also measured in spring and fall at five cross-section stations (Upper Spring Run, Spring Run 1, Spring Run 2, Spring Run 3, Old Channel) using a flowmeter and adjustable wading rod, with the exceptions of measurements at Spring Run 1 and Spring Run 2 in the fall due to dry conditions. Additional discharge measurements were conducted at all cross-section stations during the Critical Period event triggered in June (n = 1). Additionally, discharge was measured at four M9 stations (Spring Island Upper Far, Spring Island Lower Near, Spring Island Lower Far, Landa Lake Cable) by EAA personnel using a SonTek RiverSurveyor Acoustic Doppler Profiler (Figure 3). M9 station measurements were conducted during the same periods as cross-section stations, as well as during an additional event in August. EAA personnel also measured discharge at Spring Run 1–3 cross-section stations in June and August.

To quantify the contribution of each station to total system discharge, percent total discharge ([discharge(station *x*)/cumulative river discharge]*100) was calculated. Cumulative river discharge was based on the mean daily discharge value on the day of each measurement. Discharge and percent total discharge were summarized for spring, summer, and fall measurements, which were compared to 5-year and long-term (cross-section stations: 2003–present; M9 stations: 2014–present) averages ±95% confidence intervals using bar graphs. Results for cross-section stations are presented in the main body of the report and includes M9 measurements conducted in June (spring) and August (summer). Results for M9 stations can be found in Appendix E.

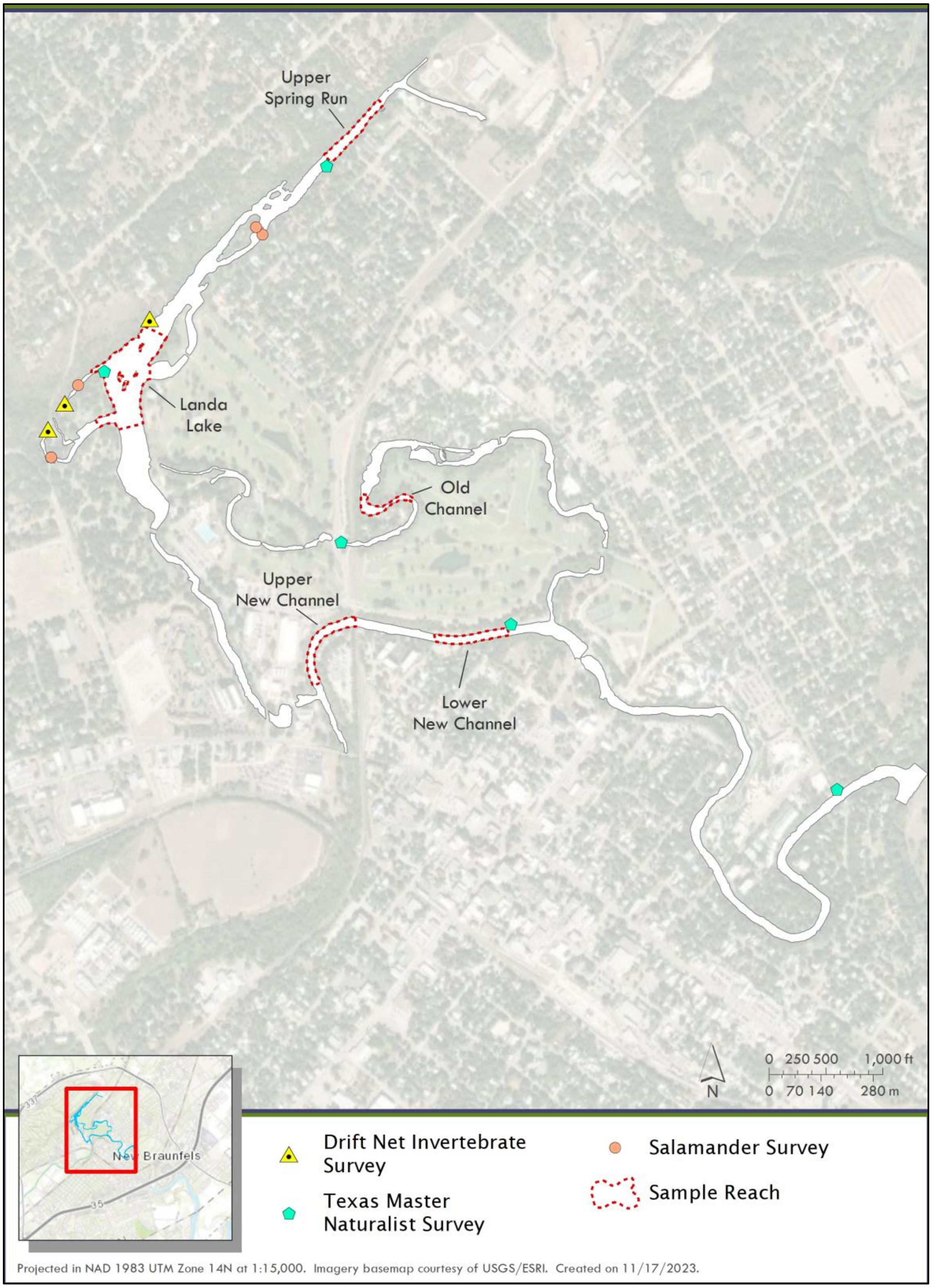

Figure 1. Locations of drift-net invertebrate, Comal Springs Salamander, Texas Master Naturalist, and biomonitoring (includes aquatic vegetation mapping, drop-net sampling, presence/absence dip-net sampling, and macroinvertebrate community sampling) sample areas within the Comal Spring/River study area.

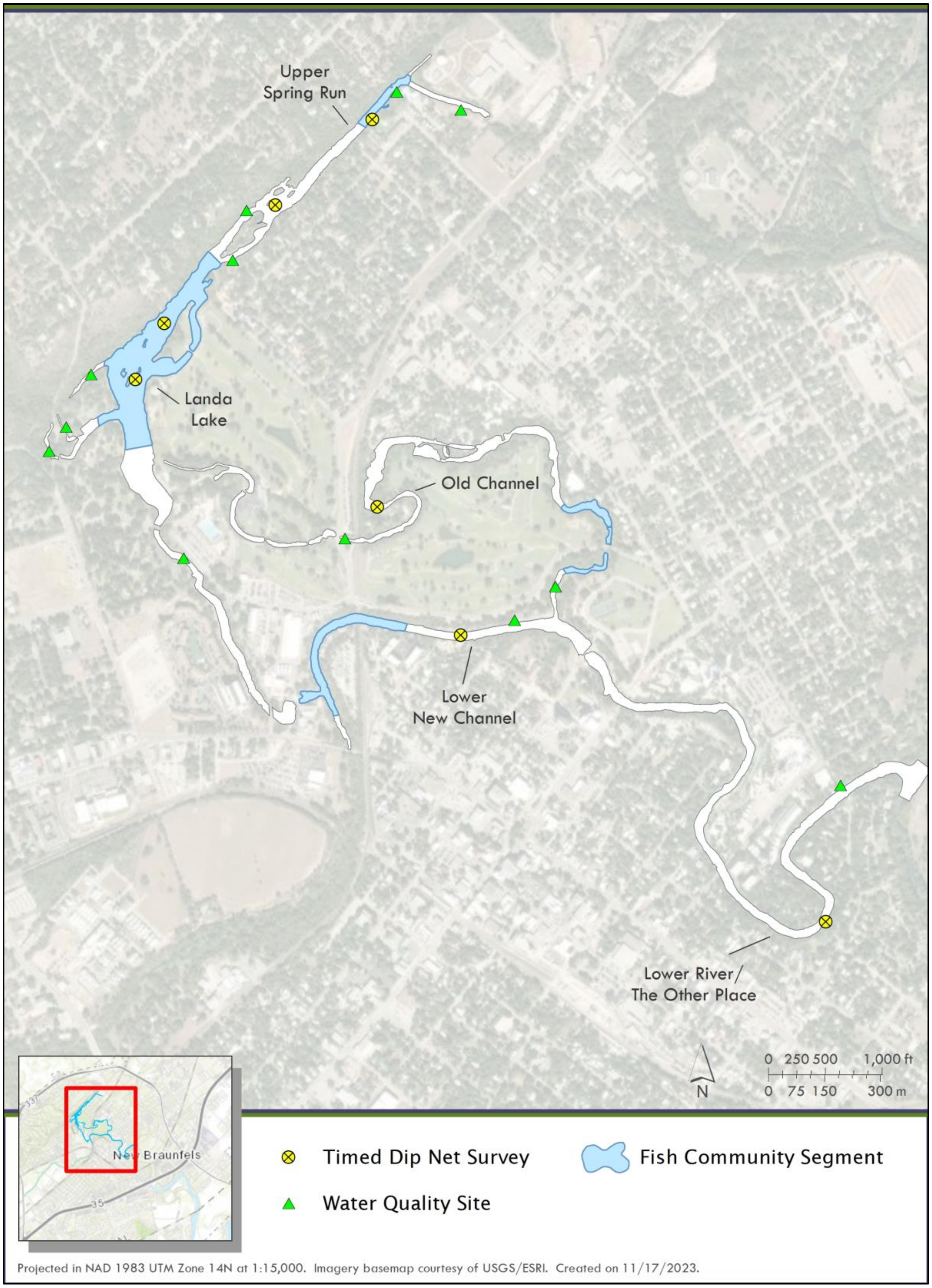

Figure 2. Locations of fish community, water quality, and Fountain Darter timed dip-net surveys within the Comal Springs/River study area.

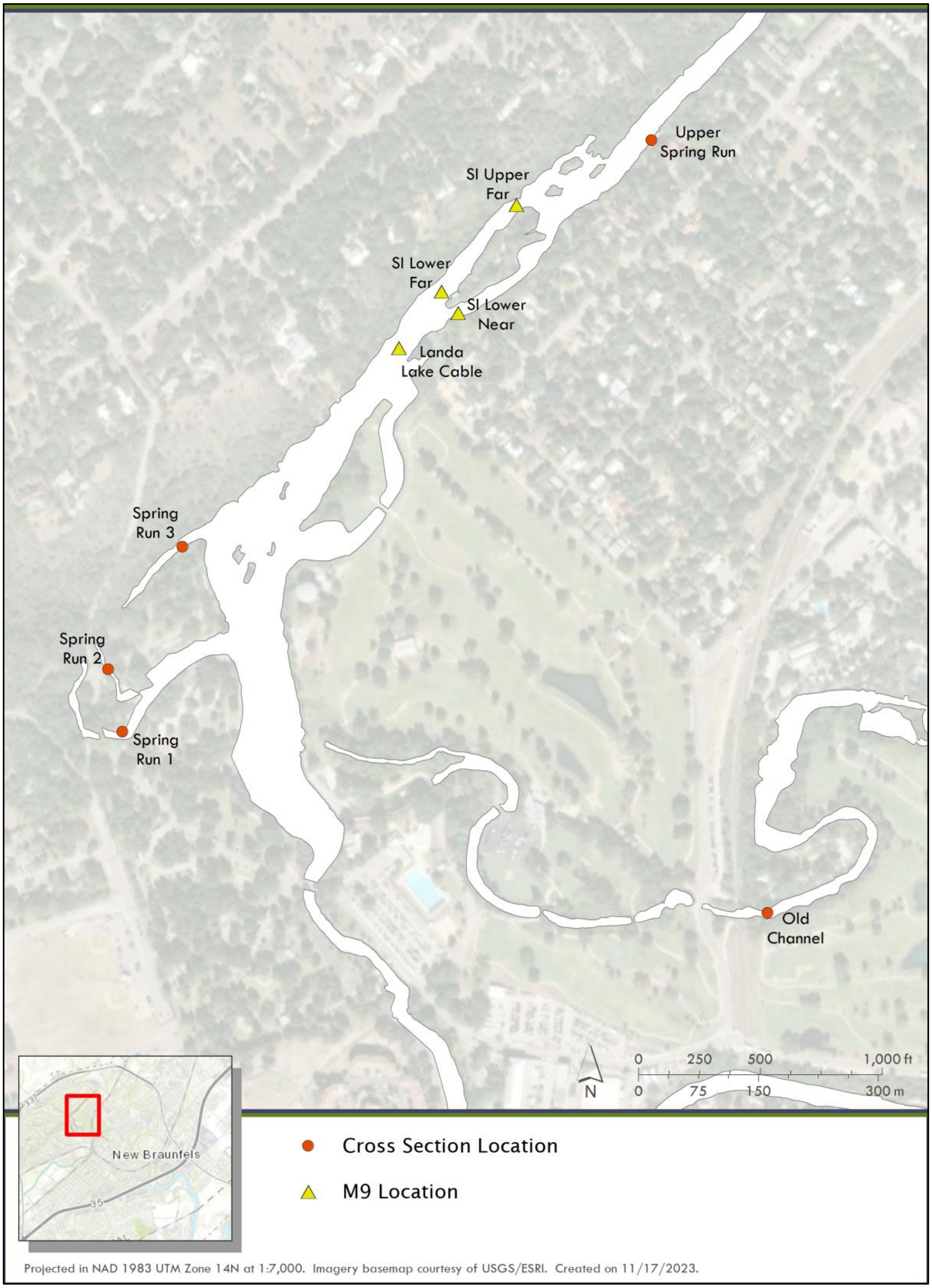

Figure 3. **Cross-section and M9 discharge collection locations in the Comal Springs/River study area.**

Water Temperature

Spatiotemporal trends in water temperature were assessed using temperature data loggers (HOBO Tidbit v2 Temp Loggers) at the 13 permanent monitoring stations established in 2000. Data loggers recorded water temperature every 10 minutes and were downloaded at regular intervals. Prior to analysis, data processing was conducted to locate potential data logger errors per station by comparing time-series for the current year with previous years. Timeframes displaying temperatures that deviated substantially from historical data and did not exhibit ecologically rational trends (e.g., discontinuities, ascending drift) were considered unreliable and omitted from the dataset. For analysis, the distribution of water temperatures for the current year was assessed among stations based on 4-hour intervals and summarized using boxplots. Data from the current year were also compared to their 5-year and long-term trends. Water temperatures were also compared with maximum optimal temperature requirements for Fountain Darter larval (≥25 °C) and egg (≥26 °C) production (McDonald et al. 2007). Further, 25 °C is also the designated threshold within the HCP Fountain Darter LTBGs study reaches (Upper Spring Run [Heidelberg], Landa Lake, New Channel, Old Channel) (EAHCP 2012). In the case of stations that surpassed either water temperature threshold during the year, the general timeframes in which those exceedances occurred are discussed in the text.

Texas Master Naturalist Monitoring

Volunteers with the Texas Master Naturalist program continued their monitoring efforts in 2024 at select locations along the Comal system. Volunteers collected water quality and recreation data at the following five sites: (1) Houston Street site within the Upper Spring Run reach, (2) Gazebo site within the Landa Lake reach, (3) Elizabeth Avenue site upstream of the Old Channel reach, (4) New Channel site within the New Channel reach, and (5) the downstream-most Union Avenue site (Figure 1). Volunteer monitoring was performed on a weekly basis, with surveys conducted primarily on Friday afternoons between 1200 and 1500 hours. At each site, an Oakton Waterproof EcoTester pH 2 was used to measure pH, and a LaMotte Carbon Dioxide Test Kit was used to measure carbon dioxide (CO_2) concentrations in the water column. In addition to water-quality measurements, recreational-use data were collected at each site by counting the number of tubers, kayakers, anglers, etc., within the survey site at the time of sampling. Volunteers also took photographs at each site during each sampling event, and occasionally made additional notes on recreational use or the condition of the river. Results from this monitoring effort can be found in Appendix D.

Aquatic Vegetation

Mapping

The team used a sit-in kayak to complete aquatic vegetation mapping in each sample reach during the spring, June Critical Period, and fall monitoring events (Figure 1). A Trimble GPS unit and external Tempest antenna set on the bow of the kayak was used to collect high-accuracy (10–60 centimeter [cm]) geospatial data. A data dictionary with pre-determined attributes was loaded into the GPS unit for data collection in the field. Discrete patch dimensions and the type and density of vegetation were recorded from the kayak. In some instances, an accompanying free diver was used to provide additional detail and to verify surface observations. The discreteness of an individual vegetation patch was determined by the dominant species located within the patch compared to surrounding vegetation. Once a patch of vegetation was visually delineated, the kayak was maneuvered around the perimeter of the vegetation patch to collect geospatial data with the GPS unit, thus creating a vegetation polygon. Attributes assigned to each polygon included species type and percent cover of each of the four most-dominant species. The type of substrate (silt, sand, gravel, cobble, organic) was identified if substrate was a dominant feature within the patch. Rooted aquatic vegetation, floating aquatic vegetation, bryophytes, and algae were mapped as separate features. Only aquatic vegetation patches 1 meter (m) in diameter or larger were mapped as polygons.

Data Processing and Analysis

During data processing, Microsoft pathfinder was used to correct spatial data and create shapefiles. Spatial data were projected using the Projected Coordinate System NAD 1983 Zone 14N. Post processing was conducted to clean polygon intersections, check for and correct errors, and calculate cover for individual discrete polygons as well as totals for all encountered aquatic plant species.

Vegetation types are described in the Results and Discussion section by genus. Vegetation community composition among taxa and grouped by native vs. invasive taxa are compared for the last five years using stacked bar graphs. Total surface area of aquatic vegetation, measured in square meters (m^2), is presented for each season using bar graphs and is compared with long-term averages (2001–present) from spring, fall, high-flow events, and low-flow events. High-flow and low-flow averages were calculated from Critical Period events. These events are based on predetermined river discharge triggers (Appendix A), which result in additional mapping events to assess flow-related impacts to the vegetation community.

Fountain Darter

Drop-Net Sampling

Drop-net sampling was utilized to quantify Fountain Darter densities and evaluate habitat utilization during the spring, June Critical Period, and fall monitoring events (Figure 1). Sample stations were selected using a random-stratified design. In each study reach, two sample stations per vegetation strata were randomly selected based on dominant aquatic vegetation (including open areas) mapped prior to sampling (see Aquatic Vegetation Mapping for details). At each sample station, all organisms were first trapped using a 2 m^2 drop-net. Organisms were then collected by sweeping a 1 m^2 dip net along the river bottom within the drop-net. If no fish were collected after the first 10 dip-net sweeps, the station was considered complete, and if fish were collected, an additional 5 sweeps were conducted. If Fountain Darters were collected on sweep 15, additional sweeps were conducted until no Fountain Darters were collected.

Most fishes collected were identified to species and enumerated. Two morphologically similar species, Western Mosquitofish (*Gambusia affinis*) and Largespring Gambusia (*Gambusia geiseri*), which are known to hybridize, were classified by genus (*Gambusia* sp.). Larval and juvenile fishes too small to confidently identify to species in the field were also classified by genus. All Fountain Darters and the first 25 individuals of other fish taxa were measured (total length in millimeters [mm]).

Physiochemical habitat data were collected at each drop-net location. Water depth in feet (ft) and velocity in feet per second (ft/s) were collected at the upstream end of drop-net samples using a flowmeter and adjustable wading rod. Water-velocity measurements were collected at 15 cm above the river bottom to characterize flows that directly influence Fountain Darters. Mean-column velocity was measured at 60% of water depth at depths of less than three feet. At depths of three feet or greater, water velocities were measured at 20% and 80% of depth and averaged to estimate mean column velocity. Water quality was measured within each drop-net using a multiprobe, which included water temperature (degrees Celsius [°C]), pH, dissolved oxygen (milligrams per liter [mg/L], percent saturation), and specific conductance (microsiemens per centimeter [µs/cm]). Mid-column water quality was measured at water depths of less than three feet, whereas bottom and surface values were measured and averaged at depths of three feet or greater. Lastly, vegetation composition (%) was visually estimated and dominant substrate type was recorded within and around each drop-net sample.

Dip-Net Sampling

Dip-net sampling was used to provide additional metrics for assessing Fountain Darter population trends and included qualitative timed surveys and random-station presence/absence surveys. All sampling was conducted using a 40x40-cm (1.6-mm-mesh) dip-net, and surveys for both methods were conducted in spring, summer, and fall. Spring sampling included one Critical Period event in addition to the routine spring monitoring.

Timed dip-net sampling was conducted to examine patterns in Fountain Darter abundance and size structure along a more extensive longitudinal gradient compared to drop-net sampling. Surveys were conducted within established monitoring sites for a fixed amount of search effort (Upper Spring Run: 0.5 hour, Spring Island: 0.5 hour, Landa Lake: 1 hour, Old Channel: 1.0 hour, New Channel: 1.0 hour, Lower River: 1.0 hour) (Figure 2). In each study reach, a single surveyor used a dip-net to collect Fountain Darters in a downstream to upstream fashion. Collection efforts mainly focused on suitable Fountain Darter habitat, specifically in areas with dense aquatic vegetation. Non-wadable habitats (>1.4 m) were not sampled. All Fountain Darters collected were enumerated, measured (mm), and returned to the river at point of collection.

Random-station presence/absence surveys were implemented to assess Fountain Darter occurrence. During each monitoring event, sampling stations were randomly selected within the vegetated area of each sample reach (Upper Spring Run: 5, Landa Lake: 20, Old Channel: 20, New Channel: 5) (Figure 1). At each random station, presence/absence was recorded during four independent dips. To avoid recapture, collected Fountain Darters were returned to the river in areas adjacent to the random station being sampled. Habitat variables recorded at each station included dominant aquatic vegetation, and presence/absence of bryophytes and algae.

Visual Surveys

Visual surveys with the aid of SCUBA gear were conducted at Landa Lake in areas too deep for implementing the Fountain Darter sampling methods described above (Figure 1). Sampling occurred during the spring and fall monitoring events. To standardize data relative to any potential diel patterns in behavior, observations were conducted in early afternoon during each sampling event. A specially designed grid (7.8 m^2) was used to quantify the number of Fountain

Darters using these deeper habitats. During each survey, all Fountain Darters within the grid were counted and the percentage of bryophyte coverage within the grid was recorded. Results of visual surveys are presented in Appendix E.

Data Analysis

Key demographic parameters used to evaluate Fountain Darter observations included population performance, size structure, and recruitment. Population performance was assessed using drop-net, timed dip-net, and random dip-net data. Counts of darters per drop-net sample were standardized as density (darters/m^2). Timed dip-net total darter counts per study reach were standardized as catch-per-unit-effort (CPUE; darters/person-hour [p-h]) for each sampling event. Random dip-net occurrence per station was based on whether or not a Fountain Darter was observed during any of the four dips and percent occurrence was calculated per sampling event at each reach as: (sum[darter presence]/sum[random stations])*100. Fountain Darter density, CPUE, and percent occurrence were compared among seasons using boxplots. In addition, most seasonal observations were compared to observations from the past five years and long-term observations (2001–present). Lastly, temporal trends in Fountain Darter density were assessed per sampling event for each study reach over the past five years using boxplots and compared to their respective long-term (2001–present) medians and quartiles (25th and 75th percentile).

Size structure and recruitment were assessed among seasons. Fall and spring were assessed by combining drop-net and timed dip-net data, and summer was assessed only using timed dip-net data. Boxplots coupled with violin plots were used to display the distribution of darter lengths per sampling event during each season for the past five years. Boxplots show basic length-distribution statistics (i.e., median, quartiles, range) and violin plots visually display the full distribution of lengths relative to each sampling event using kernel probability density estimation (Hintze and Nelson 1998). Recruitment was quantified as the percent of darters ≤20 mm during each sampling event. Based on a linear model built by Brandt et al. (1993) that looked at age-length relationships of laboratory-reared Fountain Darters, individuals of this size are likely less than 3 months old and not sexually mature (Brandt et al. 1993; Schenck and Whiteside 1976). Percent recruitment ±95% confidence intervals (i.e., beta distribution quantiles; McDonald 2014) were shown for the past five years by season and compared to their respective long-term averages. Size structure and recruitment in spring 2024 were analyzed separately for the routine (April 25–May 1st) and critical period (June 11–17) events to distinguish between the peak reproductive period from late-winter to early-spring and periods of lower output from late-spring to mid-summer (Schenck and Whiteside 1977).

Habitat use was assessed based on population performance and size structure among vegetation strata using drop-net and random-station dip-net observations. Fountain Darter density by vegetation taxa was compared based on current, five-year, and long-term (2001–present) observations using boxplots. Proportion of occurrence was also calculated among vegetation types sampled during random-station dip-netting for the current year. Lastly, boxplots coupled with violin plots were used to display the distribution of darter lengths by vegetation taxa using drop-net data to examine habitat use among size classes for the current year.

Habitat suitability was quantified to examine reach-level changes in habitat quality for Fountain Darters through time. First, Habitat Suitability Criteria (HSC) ranging from 0 (unsuitable habitat) to 1 (most suitable habitat) were built based on occurrence data for all vegetation types (including open habitat) that have been sampled using logistic regression (Manly et al. 1993). Resulting HSC were then multiplied by the areal coverage of each vegetation strata mapped during a biomonitoring event, and results were summed across vegetation strata to calculate a weighted usable area for each reach. To make data comparable between reaches of different sizes, the total weighted usable area of each reach was then divided by the total area of the reach, resulting in an Overall Habitat Suitability Index (OHSI) for each reach during each sampling event. Following this method, temporal trends of Fountain Darter OHSI ±95% CI were calculated per sampling event for each study reach (Upper Spring Run, Landa Lake, Old Channel, Upper New Channel, Lower New Channel) for the past five years. Long-term (2003–present) OHSI and 95% CI averages were also calculated to provide historical context to recent OHSI observations. Data analyses were modified from previous calculations of OHSI for Upper Spring Run and included the addition of green algae (i.e., *Chara*, *Nitella*) due to *Chara* representing as much as ~50% of the vegetation community. Specific details on the analytical framework used for developing OHSI and evaluating its efficacy as a Fountain Darter habitat index, including methods to build HSC, can be found in Appendix H.

Fish Community

Mesohabitat, Microhabitat, and Seine Sampling

Fish community sampling was conducted in the spring, June Critical Period event, and fall to quantify fish assemblage composition/structure and to assess Fountain Darter population performance in river segments and habitats (e.g., deeper areas) not sampled during drop-net and timed dip-net surveys. The following four monitoring segments were sampled: Upper Spring Run, Landa Lake, Old Channel, and New Channel (Figure 2). Deeper habitats were sampled using visual transect surveys, and shallow habitats were sampled via seining.

A total of three mesohabitat transects were sampled at each segment during visual surveys. At each transect, four divers swam from bank-to-bank at approximately mid-column depth, enumerating all fishes observed and identifying them to the lowest possible taxonomic level. After each mesohabitat transect was completed, microhabitat sampling was also conducted along four, 5-meter-long PVC pipe segments (micro-transect pipes) placed on the stream bottom, spaced evenly along the original transect. Divers started at the downstream end and swam up the pipe searching through the vegetation, if present, and substrate within approximately 1 m of the pipe. All fishes observed were identified to species and enumerated. For both surveys, any individuals that could not be identified to species were classified by genus. At each micro-transect pipe, total area surveyed (m^2), aquatic vegetation composition (%), and substrate composition (%) were recorded. Water depth (ft) and velocity (ft/s) data were collected in the middle of each micro-transect pipe using a portable flowmeter and adjustable wading rod. Water-velocity measurements were taken 15 cm from the bottom, mid-column, and at the surface. Standard water-quality parameters were also recorded once at each mesohabitat transect using a handheld water-quality sonde.

In shallow habitats, at least three seining transects were sampled within each monitoring segment (except for Landa Lake). At each of these, multiple seine hauls were pulled until the entire wadable area had been covered. After each seine haul, fish were identified, measured (mm), and enumerated. Total area surveyed (m^2) was visually estimated for each seining transect. Habitat data from each seine haul location included substrate and vegetation composition (%); water depth (ft); and velocity (ft/s) measured at 15 cm above the river bottom, at mid-column, and at the surface. Fish taxonomy herein follows the most recent guide published by the American Fisheries Society (AFS 2023).

Data Analysis

To evaluate fish community results, all analyses were conducted using fishes identified to species; fishes identified to genus or family were excluded. Total counts of species from independent samples were first quantified as density (fish/m^2) to standardize abundance among the three gear types used.

Based on microhabitat sampling, temporal trends in Fountain Darter density were assessed per sampling event for each study reach for the past five years using boxplots and compared to their respective long-term (2014–present) medians and quartiles. Overall species richness and diversity using the Shannon's diversity index (Spellerberg and Fedor 2003) for each study segment was assessed for the past five years and plotted with bar graphs. Richness and relative density (%; [sum(species *x* density)/sum(all species density)]*100) of spring-associated fishes (Table 2) were also quantified and presented in the same manner as species richness and diversity.

Table 2. Spring-associated fishes within the Comal Springs System based on Craig et al. (2016).

SCIENTIFIC NAME	COMMON NAME
Dionda nigrotaeniata	Guadalupe Roundnose Minnow
Notropis amabilis	Texas Shiner
Astyanax argentatus	Texas Tetra
Gambusia geiseri	Largespring Gambusia
Etheostoma fonticola	Fountain Darter
Etheostoma lepidum	Greenthroat Darter
Percina apristis	Guadalupe Darter
Percina carbonaria	Texas Logperch

Comal Springs Salamander Surveys

In spring and fall, biologists performed timed visual surveys for Comal Springs Salamanders within the four following established sampling areas: Spring Run 1, Spring Run 3, Spring Island Spring Run, and Spring Island East Outfall (Figure 1). One additional Critical Period sampling event occurred in June. Timed surveys involved sampling from downstream to upstream within the extent of the sampling area. Biologists inspected under rocks within the top 5 cm of the substrate surface and within aquatic vegetation to quantify salamanders while moving upstream toward the main spring orifice. A dive mask and snorkel were utilized to view organisms, as depth permitted. Locations of all Comal Springs Salamander observations were recorded using pin flags. Following survey completion, and water depth (ft) and presence/absence of vegetation were noted to potentially serve as a baseline assessment of habitat parameters should the salamander population change significantly in subsequent sampling years. To account for any potential diel patterns in behavior, all surveys were initiated in the morning and completed by early afternoon.

Survey effort was previously fixed during routine sampling. Within Spring Run 1, a one-hour survey was conducted from the Landa Park Drive Bridge upstream to just below the head spring orifice. Spring Run 3 was surveyed for one hour from the pedestrian bridge closest to Landa Lake upstream to the second pedestrian bridge. Surveys in the Spring Island area were divided into the following two sections: (1) one 30-minute survey of Spring Island Run and (2) one 30-minute survey of the east outfall upwelling area on the east side of Spring Island near Edgewater Drive. Based on this, effort across all sites represents a total of 6 person-hours (p-h) under the established monitoring methodology. However, reduced habitat availability associated with low-flow conditions experienced from 2022-2024 required modification in search times. Specifically, total survey effort at each site was adjusted relative to the percent of wetted habitats available for salamanders at a given sampling event. For example, if wetted habitats were reduced by 50% at Spring Run 1, a 50% reduction in survey time was implemented (i.e., 30 minutes).

Data Analysis

Comal Springs Salamander counts and CPUE (salamanders/p-h) were used to assess seasonal and five-year trends, respectively. Data from all sampling events in 2024 were used for analysis despite varied search effort at each site. Since adjustments in search time were scalable, varied effort offset differences in total survey area, providing statistically valid comparisons in catch rates. Salamander counts were presented for each season using bar graphs and are compared with long-term (2001–present) spring, fall, high-flow event, and low-flow event averages. High-flow and low-flow event averages were calculated from Critical Period Events. These events are based on predetermined river discharge triggers (Appendix A), which result in additional survey events to assess flow-related impacts to the Comal Springs Salamander population. Temporal trends in salamander density were also assessed per sampling event for each sampling area for the past five years using bar graphs.

Macroinvertebrates

Drift-net Sampling and Data Analysis

Macroinvertebrate samples were collected via drift-net at three sites in the Comal system. During each comprehensive sampling event, drift-nets were placed over the major spring openings of Comal Spring Runs 1 and 3 and a moderate-sized spring upwelling (Spring 7) along the western shoreline of Landa Lake; alternate locations were used in Spring Run 1 when no water was observed at the major opening (Figure 1). Drift-nets were anchored into the substrate directly over each spring opening, with the net facing perpendicular to the direction of flow. Net openings were circular with a 0.45-m diameter, and the mesh size was 100 micrometers (µm). The tail of the drift-net was connected to a detachable, 0.28-m-long cylindrical bucket (200 µm mesh), which was removed at 6-hour intervals during sampling, after which cup contents were sorted and invertebrates removed in the field. The remaining bulk samples were preserved in ethanol and sorted later in the laboratory, where minute organisms that had been overlooked in the field were removed. All Comal Springs Riffle Beetles, Peck's Cave Amphipods, and Comal Springs Dryopid Beetles captured via drift-net were returned to their spring of origin, with the exception of voucher organisms (fewer than 20 living specimens of each species identifiable in the field). All non-endangered invertebrates were preserved in 70% ethanol. Additionally, water-quality measurements (temperature, pH, conductivity, dissolved oxygen, and current velocity) were taken at each drift-net site using a water-quality meter and handheld flow meter.

The total numbers of endangered species at each site are presented in the results and a summary of total numbers for all taxa can be found in Appendix E. Temporal trends in *Stygobromus pecki* per cubic meter were assessed per sampling event for each sampling area over the past five years using boxplots and compared to their respective long-term (2003–present) medians and quartiles (25th and 75th percentile).

Comal Springs Riffle Beetle Sampling and Data Analysis

Comal Springs Riffle Beetles were collected from three areas in the Comal River system during two routine sampling events in spring and fall. Two additional species-specific sampling events occurred from July through October. Sampling followed the methods of the Cotton Lure standard operating procedure developed for the HCP (EAA 2017). This methodology consists of placing lures of 15x15 cm pieces of 60% cotton/40% polyester cloth into spring openings/upwellings in the Comal system, where they remain in situ for approximately 30 days. During this time, they become inoculated with local organic and inorganic matter, biofilms, and invertebrates, including Comal Springs Riffle Beetles. These lures were placed in sets of 10 in the following three areas: (1) Spring Run 3, (2) along the western shoreline of Landa Lake ("Western Shoreline"), and (3) near Spring Island. Due to declines in wetted habitats in the summer, alternate sampling methods were implemented during low-flow sampling events to limit disturbance from over sampling. For the two additional low-flow events (July 2nd to August 12th and September 9th to October 8th), lures were set in collaboration with an ongoing study of Comal Springs Dryopid Beetle. Lures were placed in the most suitable habitat available at each site and remained in situ for about 30 days. Lures lost, disturbed, or buried by sedimentation were not included in subsequent analyses. Numbered tags placed on the banks of Spring Run 3 and Western Shoreline were utilized, when possible, to identify lure locations.

Comal Springs Riffle Beetles collected with cotton lures were identified, counted, and larvae were returned to their spring of origin during each sampling effort. A dissecting scope with a maximum magnification of 90x was used to correctly identify riffle beetles in the field. The sampling crew also recorded counts of *Microcylloepus pusillus*, Comal Springs Dryopid Beetle, Peck's Cave Amphipod, and *Lirceolus* pp. collected on lures. Some adult Comal Springs Riffle Beetles, Comal Springs Dryopid Beetles, and Peck's Cave Amphipods were retained by SMARC personnel for incorporation into the refugia program. Any other spring invertebrates collected on the lures were also placed back into their spring of origin. Crews utilized a mask and snorkel to place and remove lures in areas with deeper water depths.

Adult Comal Springs Riffle Beetle relative abundance (beetles/lure) were compared among seasons for each area using boxplots. In addition, seasonal observations were compared to five-year and long-term observations (2004–present). Temporal trends in relative abundance were also assessed per sampling event for each area for the past five years using boxplots and compared to their respective long-term (2004–present) medians and quartiles (25th and 75th percentile). Data collected during the two low-flow sampling with alternate methods were omitted from all analyses. Due to variation in sampling sites and methodology, these data were not directly comparable to routine biomonitoring events, and were instead summarized for each event separately, based on total adult Comal Springs Riffle Beetle counts per site.

Rapid Bioassessment Sampling and Data Analysis

Rapid bioassessment protocols (RBPs) are tools for evaluating biotic integrity and overall habitat health based on the community of organisms present (Barbour et al. 1999). Macroinvertebrates are the most frequently used biological units for RBPs because they are ubiquitous, diverse, and there is an acceptable working knowledge of their taxonomy and life histories (Poff et al. 2006, Merritt et al. 2008).

BIO-WEST performed sampling and processing of freshwater benthic macroinvertebrates, following Texas RBP standards (TCEQ 2014). Macroinvertebrates were sampled with a D-frame kick net (500 µm mesh) by disturbing riffle or run habitat (consisting primarily of cobble-gravel substrate) for five minutes while moving in a zig-zag fashion upstream. Invertebrates were then haphazardly distributed in a tray and subsamples were taken by scooping out haphazard portions of material and placing them into a separate sorting tray.

All macroinvertebrates were picked from the tray before another subsample was taken. This process was continued until a minimum of 140 individuals were picked to represent a sample. If the entire sample did not contain 140 individuals, the process was repeated again until this minimum count was reached. Macroinvertebrates were collected in this fashion from Upper Spring Run, Landa Lake, Old Channel, New Channel, and the Lower River (Other Place) reaches (Figure 1).

Picked samples were preserved in 80% denatured ethanol, returned to the laboratory, and identified to established taxonomic levels (TCEQ 2014), usually genus. Members of the family Chironomidae (non-biting midges) and class Oligochaeta (worms) were retained at those taxonomic levels. The 12 ecological metrics of the Texas RBP benthic index of biotic integrity (B-IBI) were calculated for each sample. Each metric represents a functional aspect of the macroinvertebrate community related to ecosystem health, and sample values are scored from 1 to 4 based on benchmarks set by reference streams for the state of Texas. The aggregate of all 12 metric scores for a sample represent the B-IBI score for the reach that sample was taken from. The B-IBI point-scores for each sample are compared to benchmark ranges and are described as having aquatic-life-uses of “Exceptional”, “High”, “Intermediate”, or “Limited”. In this way, point-scores were calculated and the aquatic-life-use for each sample reach was evaluated. Temporal trends in B-IBI scores were assessed per sampling event for each reach during the past five years using bar graphs.

RESULTS and DISCUSSION

In 2024, central Texas experienced a continuation of low precipitation and higher than normal ambient temperatures that began in 2022. By fall, drought conditions worsened to extreme (as designated by the National Weather Service [NWS]), covering large portions of the Hill Country, including the Edwards Aquifer Recharge Zone. As described in the next section, total river discharge in the Comal System was below the long-term 10th percentile for most of the year, continuing the declining trend observed since 2022. In 2023, flows declined to levels which had not been observed since 2014. Variability in flow magnitude has remained low since 2023 (~50 cfs) with only one temporary high-flow event (>90th percentile magnitude) occurring in January 2024. Similar median annual mean daily discharge and minimum mean daily discharge were observed in 2023 (121 cfs and 55 cfs, respectively) and 2024 (125 cfs and 55 cfs, respectively). Median and minimum mean daily discharge were lower in both years than in 2014 (135 and 65 cfs, respectively) and lower than other low-flow years in 2009, 2011, and 2013 (195–255 and 111–159 cfs, respectively). Despite the sustained low-flow conditions experienced in 2024, water quality parameters measured during Critical Period sampling were within the range of historical observations (Appendix B, Table B1 and B2; Crowe and Sharp 1997). Nitrate concentrations were similar to historical data (0.97–1.74 mg/L; Crowe and Sharp 1997) at all stations in both spring (i.e., Spring Runs, Landa Lake) and riverine (i.e., lower Old Channel and New Channel) habitats. See Appendix B for a complete summary of water quality data collected during Critical Period low-flow sampling.

Habitat quality for the Covered Species varied spatially as flows declined. Aquatic vegetation coverage in Upper Spring Run and Upper New Channel exceeded long-term expectations, while vegetation coverage in Landa Lake and Old Channel were well below long-term averages. Declines in bryophyte abundance were observed throughout the system, including in the Old Channel. Fountain Darter egg and larval production thresholds were exceeded more frequently in 2024 at Blieders Creek, Heidelberg, and Booneville Far than at other stations which corresponded with degraded Fountain Darter population condition at Upper Spring Run and Spring Island. Water temperatures were also elevated at Old Channel and New Channel, which coupled with declines in suitable aquatic vegetation (e.g., *Cabomba* and bryophytes) and reduced flow, possibly resulted in a synergistic negative effect on Fountain Darters in these areas. Habitat for Comal Springs Salamander (i.e., Spring Runs) and invertebrates (i.e., Spring Runs and Landa Lake's western shoreline) were noticeably reduced as water levels decreased. Most notably, the entire Comal Springs Salamander survey areas at Spring Run 1 and the spring run on Spring Island were dry and a majority of the area was dry at Spring Island Outfall and Spring Run 3 during the lowest flows.

In summary, total river discharge in the Comal System in 2024 repeated patterns observed the previous year with the lowest sustained flows observed since the inception of biological monitoring in 2000. Based on past habitat and species responses to low-flow conditions observed in 2014, it remains important to keep tracking the system-wide Fountain Darter and surface-dwelling invertebrate habitat conditions as these lower-than average discharge levels continue to persist. The remaining sections of the Results and Discussion describe current trends in river discharge, water temperature, Covered Species populations, and select floral and faunal communities through the Comal Spring/River System during this low-flow year.

River Discharge and Springflow

Low flow conditions continued to persist in 2024. Over the last five years, median annual mean daily discharge decreased from 2020 (275 cfs) to 2024 (125 cfs), representing a decline from ~38th to ~6th percentile of long-term median daily discharge (1928-2024), respectively. Minimum discharge also decreased from 2020 (235 cfs) to 2024 (55 cfs). Further, annual minimum daily discharges observed in 2023 and 2024 represent the first years that mean daily magnitudes were below 60 cfs (i.e., 2nd percentile) since 1990 (USGS 2024). Maximum annual daily discharge was highest in 2021 (1,850 cfs), representing a >99th percentile event, and was lowest in 2023 (259 cfs). The maximum discharge in 2021 was the only time when a >1,000 cfs high pulse event occurred. In addition, median discharge was at similarly low magnitudes from 2022 to 2024 (122–134 cfs), though variation in discharge (i.e., interquartile range) decreased from 132 cfs to ~50 cfs, with flows in 2023 and 2024 displaying similar levels of stability to 2020 (55 cfs) and 2021 (27 cfs). General distributional patterns of river discharge were similar between 2023 and 2024. That said, high flow events >90th percentile magnitude (394 cfs) occurred in 2024 (n = 3 days) and were absent in 2023 (Figure 4A).

Monthly median discharges were below their respective long-term medians for the entirety of 2024. Monthly medians decreased from January (149 cfs) to October (63 cfs). Median discharge per month was 1.7 (February) to 4.5 (October) times lower than long-term median discharge. Further, median discharge only aligned with the long-term 10th percentile in August, and was 1.1 to 1.3 times lower in all other months except October, which was 2.4 times below its long-term 10th percentile. Minimum monthly discharge was >100 cfs from January to April (133–168 cfs) and decreased from 98 cfs in May to 55 cfs in October. Mean daily river discharge only exceeded 90th percentile magnitudes in January (>407 cfs). Maximum discharge for the remaining months rarely exceeded 10th percentile flows. As such, flow variability was higher in January (63 cfs) compared to other months (12–30 cfs) (Figure 4B).

Cross-section discharges in spring habitats were below historical means for the majority of measurements in 2024 and decreased from spring to fall across all stations. Upper Spring Run was still flowing in spring. All spring runs showed slight increases in discharge from spring to summer, which was likely explained by increased aquifer level in the recharge zone at the end of July (J-17 Index Well: + ~8 ft; EAA 2024). Upper Spring Run was not measured in summer 2024, though likely also experienced a similarly small increase during this time period. By fall, discharge at Upper Spring Run, Spring Run 1, and Spring Run 2 decreased to 0 cfs. Spring Run 3 discharge also decreased in fall but remained flowing (0.67 cfs). Since the inception of the monitoring program, discharge at Spring Run 3 has never dropped to 0 cfs. That said, the only periods when Spring Run 3 fell to magnitudes <1 cfs were in summer 2023 and fall 2024. Discharge at the Old Channel decreased in 2024 and fall discharge was below historical averages. Similar to 2023, the percent total discharge at Old Channel in 2024 was higher than what is typical and directly related to lower contributions from spring runs (Figure 5) and EAHCP flow split management.

One noteworthy flow event not captured by river discharge and springflow analyses was a sub daily period of limited to zero flow (21.5 hours) that occurred at Old Channel as a result of construction maintenance contractor miscommunication. Based on USGS gage #08168913, discharge on October 22nd decreased from 36 cfs at 10:00 am to 0 cfs at 3:30 pm, and remained at 0 cfs until it increased to 25 cfs on October 23rd at 1:00 pm (USGS 2024). See subsequent sections for further discussion.

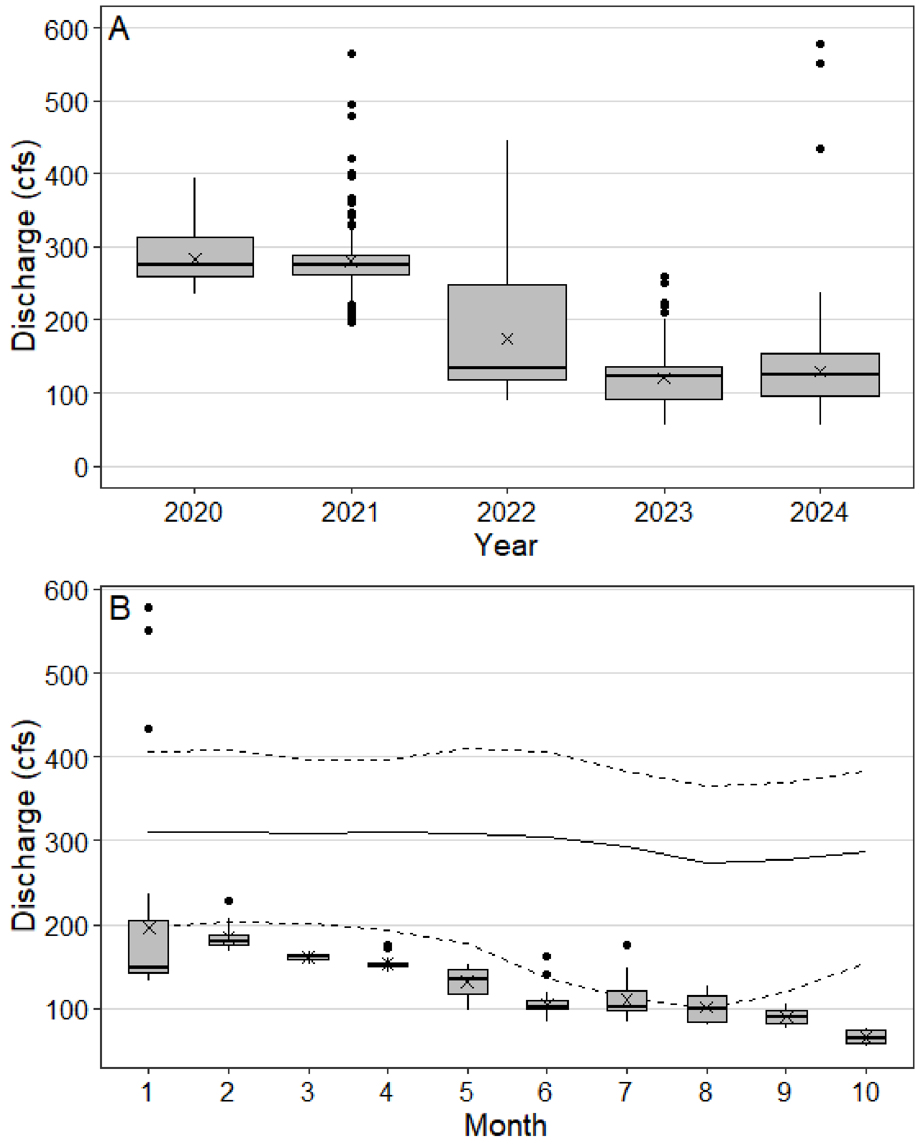

Figure 4. **Boxplots displaying Comal River mean daily discharge annually from 2020–2024 (A) and among months (January–October) in 2024 (B). Each month is compared to the 10th percentile (lower dashed line), median (solid line), and 90th percentile (upper dashed line) of their long-term (1956–2024) daily means. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range, and outliers beyond this are designated with solid black circles. One outlier for year 2021 in panel A is not shown (1,850 cfs).**

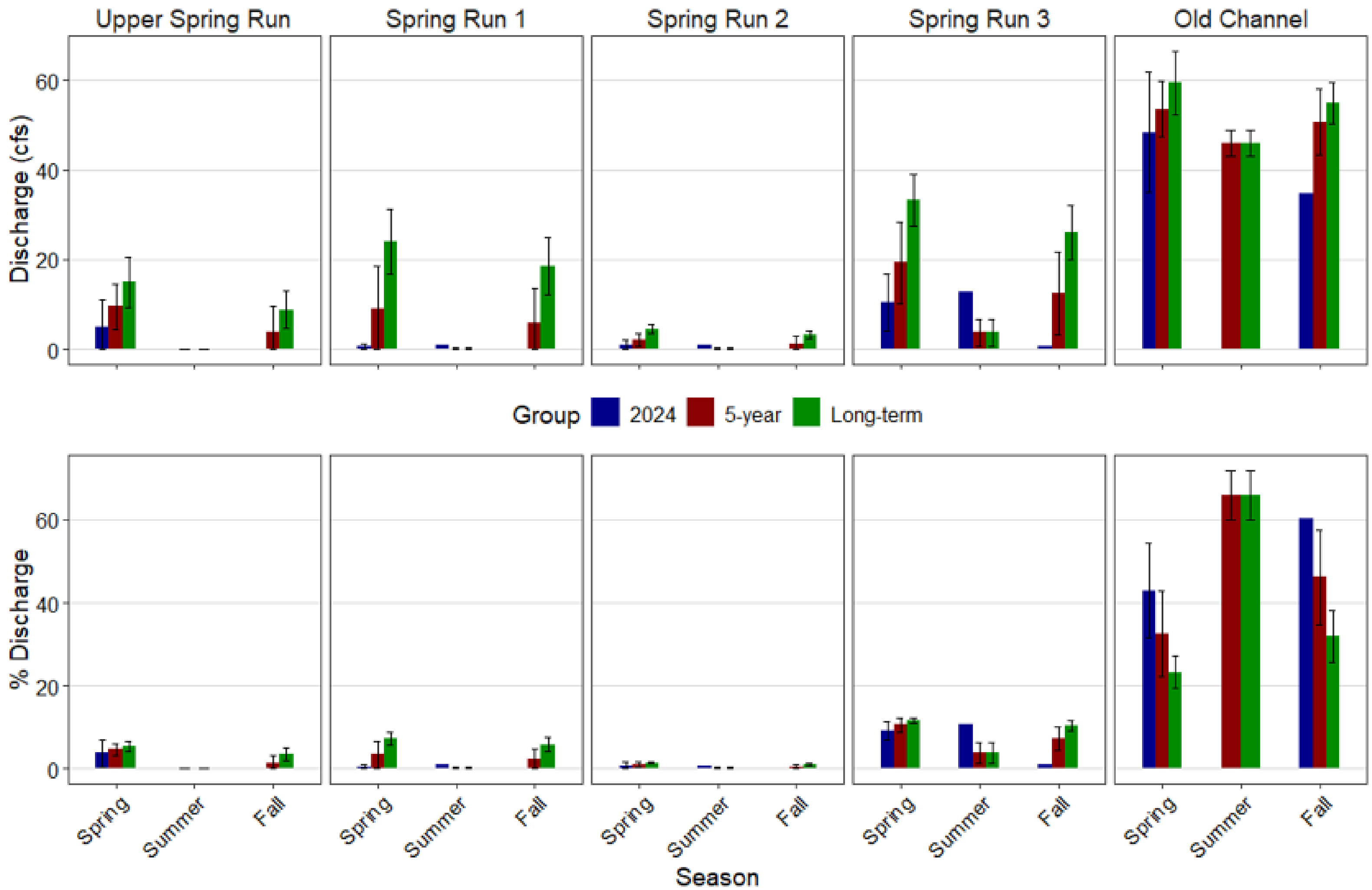

Figure 5. **Current (blue bars), five-year (2020–2024; red bars), and long-term (2003–2024; green bars) discharge and percent total discharge based on spring and fall cross-section measurements in the Comal Springs/River. Five-year and long-term values are represented as means and error bars denote 95% confidence interval**

Water Temperature

Water temperature gradients were spatially variable in Comal Springs (stations include Blieders, Heidelberg, Booneville Near, Booneville Far, Landa Lake Upper, Spring Run 1, Spring Run 2, Spring Run 3, and Landa Lake Lower). Median water temperature decreased from Blieders Creek (26.1 °C) to Booneville Near (23.9 °C), but increased at Booneville Far (27.4 °C). Moving downstream, median temperature decreased to stable levels at Landa Lake Stations (~23.8 °C) and its associated spring runs (~23.4 °C). Higher median water temperatures in Comal Springs were associated with more frequent temperatures >26 °C at Blieders Creek and Booneville Far, both showing greater temperatures in 2024 compared to 5-year and long-term values (Figure 6). Other stations in Comal Springs were more similar to historical expectations. Temperatures also surpassed 26 °C at Heidelberg and Spring Run 2, though were infrequent and considered outliers. The remaining stations in Comal Springs never exceeded 25 °C. In riverine environments (stations include Old Channel, New Channel Upstream, New Channel Downstream, and Other Place), median water temperature was similar between stations (23.8–24.1 °C) but illustrated a trend of increasing variability (i.e., interquartile range) from Old Channel (1.8 °C) and New Channel Upstream (1.5 °C) to Other Place (3.0 °C). Temperatures greater than 25 °C were generally rare across riverine stations but relatively more common at Other Place. Water temperatures exceeding 26 °C occurred more frequently at upper spring stations. All riverine stations generally aligned with historical data, though the upper quartile water temperature at Other Place was higher than the 5-year and long-term values (Figure 6).

Longitudinal trends displayed by riverine stations in 2024 aligned with expectations for spring-associated systems, increasing in magnitude and variation farther downstream from spring inputs (Groeger et al. 1997, Kollaus and Bonner 2012). In contrast, spatially variable temperature gradients observed in Comal Springs this year were atypical compared to historical data. Larger increases in water temperatures at Heidelberg and Booneville Far were associated with decreases in local springflow discharge that began in June at Upper Spring Run and Spring Island, respectively. That said, the remaining stations did not show similar increases in temperature. This suggests effects of reduced springflow in 2024 on patterns in local water temperatures varied spatially and was dependent on the contributions of proximal springs.

The Fountain Darter larval production threshold (25 °C) was exceeded from February to October. In Comal Springs, this threshold was exceeded >10 days per month at Heidelberg in June, September, and October, at Booneville Far in May, and Spring Run 2 in August. Larval threshold exceedance within riverine stations increased from early spring (~1–5 days per month) to July (25–30 days). Exceedance frequencies decreased through October, but were still higher than observations in early spring and occurred for ~50% of each month (10–17 days). In addition, monthly patterns in exceedance of the optimal egg production threshold (26 °C) were more frequent than larval production at Heidelberg and Booneville Far, occurring almost every day in July and August. Egg production exceedance occurred roughly 15–20 days per month through October 2024 at these two stations. At riverine stations, temperatures above the egg production threshold increased from early spring (~2 days per month) to June (~ 25 days) and decreased to zero in October at all stations except Old Channel (3 days).

At stations with higher water temperatures, Fountain Darter larval and/or egg production thresholds were mostly exceeded from spring to summer in 2024. Exceedance of these early life stage thresholds does not typically occur during the period of peak Fountain Darter reproduction in spring, which may explain why recruitment in April 2024 was lower than expected and the majority of recent recruits were observed at Landa Lake, where water temperatures remained at optimal levels. In contrast, historical data shows it is common for some 4-hour water temperature measurements to exceed these thresholds for ≥ 10 days per month in summer. This would indicate that lower population condition for Fountain Darters at Upper Spring Run, Spring Island, Old Channel, and New Channel in fall 2024 were not due to elevated summer water temperatures. However, it is possible that increased temperatures starting in spring resulted in a cumulative effect on Fountain Darters that eventually manifested by fall (Shreck 2000). Alternatively, elevated temperatures, reduced flows, and decreased coverages of suitable vegetation might have had a negative synergistic effect on the population (Matthaei and Lange 2016) (see Fountain Darter sections for further discussion).

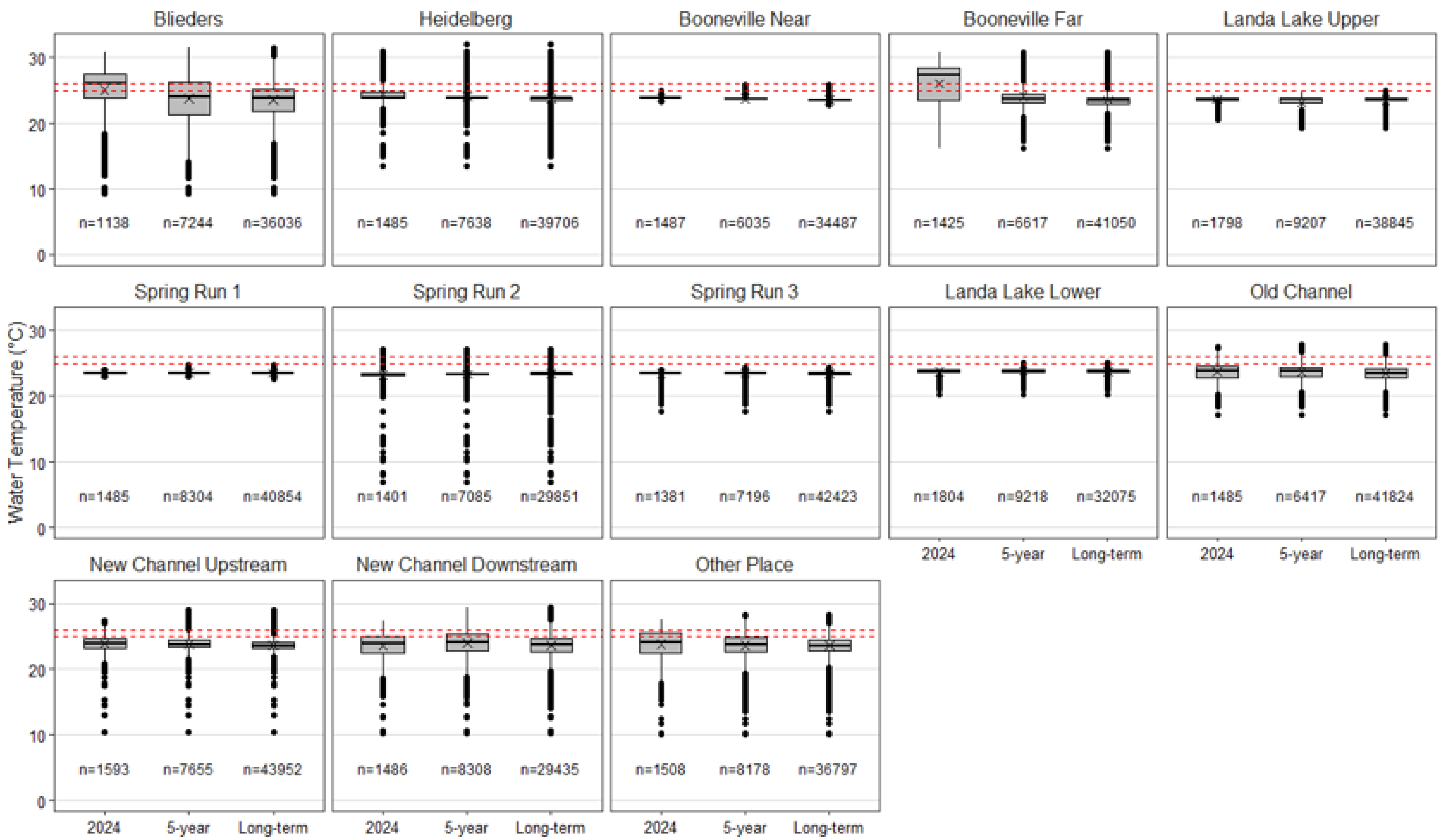

Figure 6. **Boxplots displaying 2024, 5-year (2020–2024), and long-term (2020–2024) water temperature trends in the Comal Springs/River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range, and outliers beyond this are designated with solid black circles. The "n" values along the x-axis represent the number of individual temperature measurements in each category. The lower and upper red dashed lines indicate maximum optimal temperatures for Fountain Darter larval (≥25 °C) and egg (≥26 °C) production (McDonald et al. 2007), respectively.**

Aquatic Vegetation

Long-term Biological Goal Reach Mapping

Long-term biological goal reach mapping occurred in spring and fall, as well as low-flow events in June and August.

Upper Spring Run Reach

Low springflows due to the ongoing drought continued to impact the Upper Spring Run reach throughout 2024. Despite this, both spring and fall vegetation cover were above their respective long-term averages (Figure 7). Aquatic vegetation coverage was highest in the spring (2,679 m^2) and lowest in the fall (2,044 m^2), with total coverage during both low-flow events remaining in between (Figure 7). Consistent low flows contributed to higher sediment deposition and less scouring which allowed for the expansion of vegetation such as *Chara* and *Cabomba*. The macroalgae *Chara* was the most dominant vegetation in the spring, June low-flow, and fall events, while *Sagittaria* dominated in the August low-flow event. *Cabomba* increased in cover from 50 m^2 in the spring to a maximum of 182 m^2 in the June low-flow event. Total *Cabomba* coverage then decreased in subsequent events, although it remained above 100 m^2. Benthic and epiphytic algae, dominated by *Spirogyra*, were absent or less prominent in the spring and June low-flow events but increased considerably by the fall (823 m^2) (Figure 7). Bryophytes were largely absent across all mapping events with the exception of 150 m^2 in the spring. Reduced bryophyte coverage represents a continuation of the declining trend in this reach which has likely been influenced by low flows from 2022 through 2024 (Figure 8).

Landa Lake Reach

Total aquatic vegetation coverage was similar in spring (13,230 m^2) and fall (13,900 m^2), yet coverages for both seasons were below their respective long-term seasonal averages (Figure 7). Vegetation coverage was highest in the June (14,897 m^2) and August (14,391 m^2) low-flow events. Compared to other study reaches, aquatic vegetation coverage in Landa Lake typically exhibits less impact from flow disturbance events and less inter- and intra-annual variability. As in previous years, dominant vegetation taxa at Landa Lake were *Vallisneria* and *Sagittaria*. Both taxa are strongly rooted and exhibit consistent coverage across seasons (BIO-WEST 2001-2024). *Vallisneria* accounted for greater than 50% of the total coverage throughout 2024; however, it did retreat in some areas of the lake which was likely due to reduced water velocities and vegetation mats that limited sunlight. Reduced coverage can also partially be attributed to 2024 EAHCP restoration activities which included placing tarps over areas of *Vallisneria*. Denuded areas due to natural reductions and restoration activities appeared below the Landa Lake islands and along the eastern edge. Similar to 2023, *Cabomba* coverage in 2024 (668 m^2 – 880 m^2) was greater than previous years with higher flow (e.g., 2019-2021) when coverage ranged from 239 m^2 to 432 m^2. Expansion of *Cabomba* beginning in 2022 likely occurred as a result of reductions in *Vallisneria* and active planting related to HCP restoration activities. Bryophytes were not abundant in Landa Lake during any mapping event and continued to follow the decreasing trend of recent years (Figure 8). Epiphytic and benthic algae were present in varying abundance throughout Landa Lake. The annual Comal River Restoration Report provides more information regarding the restoration of native vegetation in the Landa Lake reach (BIO-WEST 2024b).

Old Channel Reach

In the Old Channel reach, total rooted vegetation in 2024 was well below the long-term averages for all events. The lowest rooted vegetation coverage occurred in the June low-flow event (252 m^2) and the highest coverage occurred in the fall (320 m^2) (Figure 7). However, non-rooted bryophyte coverage was highest in the June low-flow event (521 m^2) and lowest in the fall (196 m^2). This coverage was not represented in total areal coverage calculations presented in Figure 7, which exclusively quantify rooted vegetation. *Ludwigia* coverage has fluctuated since 2020, but it has remained an important component of the vegetation assemblage over this time period. Beginning in 2023, *Cabomba* coverage declined and was completely absent by spring 2024. *Cabomba* remained absent until the fall of 2024 when a small patch (8 m^2) was documented (Figure 8). Rooted vegetation coverages in the past several years being well below long-term averages were due to *Hygrophila* historically dominating the reach prior to restoration activities in 2013. Since restoration activities removed *Hygrophila* in this reach, the dominant taxa from year to year are now bryophytes and epiphytic filamentous algae. As such, lower overall coverages relative to the pre-HCP timeframe should not be interpreted as an indicator of degraded conditions but instead represent an improvement in Fountain Darter habitat conditions within this reach. However, in fall 2024, filamentous algae was more prevalent than bryophytes (Figure 8) which warrants concern and future monitoring.

Upper New Channel Reach

In the spring and fall of 2024, vegetation coverage was higher than average in the Upper New Channel (Figure 7). Spring vegetation coverage decreased from 1,809 m^2 to 1,218 m^2 in the June low-flow event. After this, vegetation coverage began increasing to its peak at 2,172 m^2 in the August event with coverage remaining similar in the fall (2,167 m^2). *Hygrophila* expanded throughout 2024 with the highest coverage occurring in fall (2,037 m^2). Aquatic vegetation coverage was impacted by heavy recreation in the early summer months, but it quickly rebounded in the fall. In addition to reduced recreation, increased vegetation in this reach can likely be attributed to the prolonged absence of flood pulses in Dry Comal Creek which prevents scouring. Unlike previous years, bryophytes were completely absent in this reach during all of 2024. In fall 2023, large reductions in bryophyte abundance were observed along with increases in filamentous algae (BIO-WEST 2024). Filamentous algae remained abundant in 2024, ranging from 283 m^2 to 1,024 m^2 (Figure 8).

Lower New Channel Reach

The spring and fall coverages for 2024 in the Lower New Channel were greater than their respective long-term averages, with an increasing trend from spring to fall (Figure 7). Vegetation coverage began at 2,292 m^2 in the spring and decreased to the lowest coverage during the June low-flow event (959 m^2). The large reduction in vegetation was a direct result of high recreation and reduced water depth. This reach is typically too deep for wading, but depths were approximately 2 ft in most areas during 2024 low flows which allowed recreators to wade in the channel and disturb the substrate. Coverage increased throughout the remainder of the year to 2,533 m^2 in the fall. A large decrease in *Cabomba* was the driving factor in reduction of overall vegetation coverage. The two dominant taxa in this reach, *Cabomba* and *Hygrophila*, lose biomass during higher flows or recreation, but can quickly recover once river conditions stabilize. This seasonal pattern in recreation influence was also observed in 2023 as the spring, July, and August mapping demonstrated consecutively lower coverages, with a subsequent gain in fall.

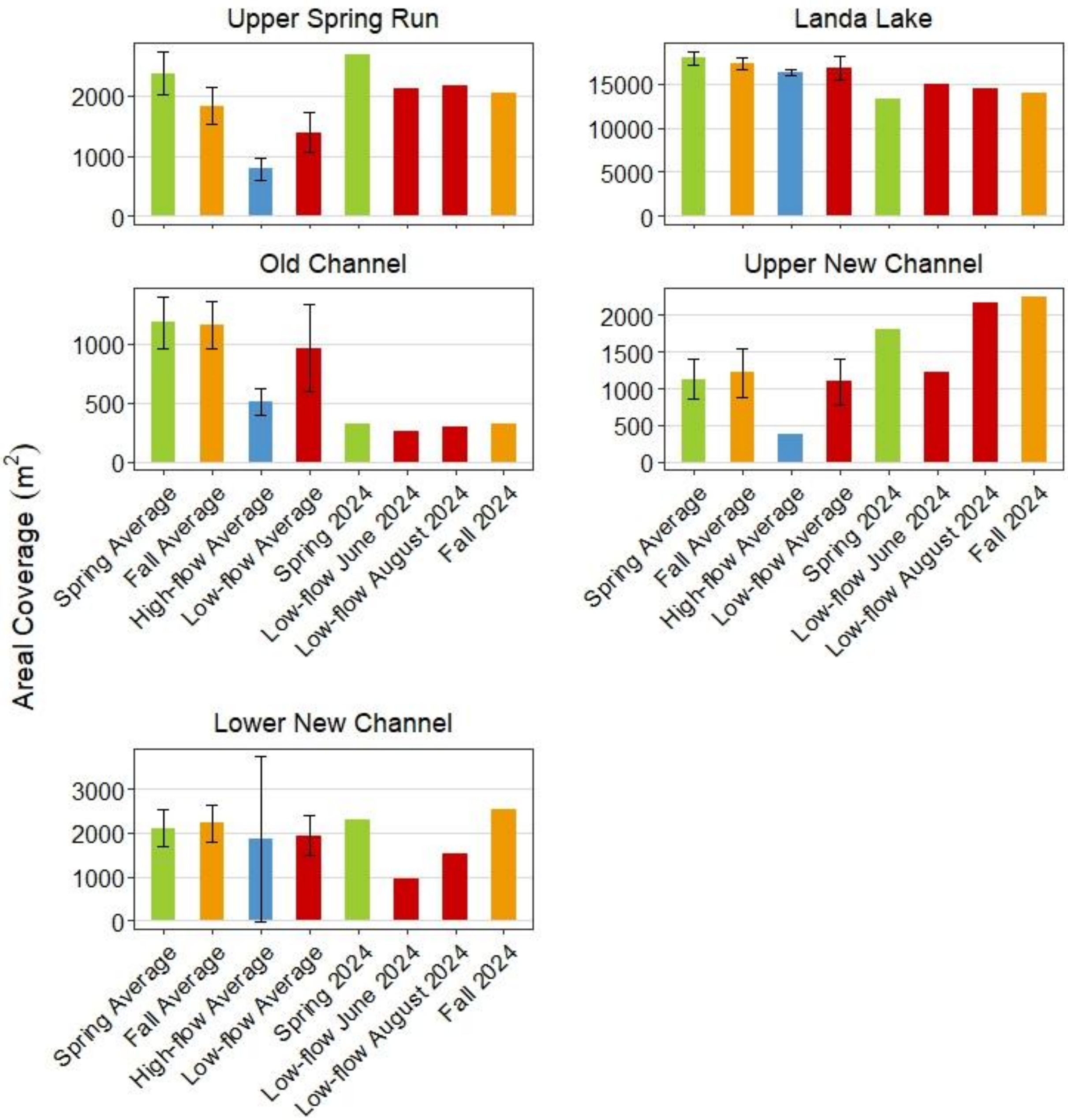

Figure 7. **Areal coverage (m²) of rooted aquatic vegetation among study reaches in the Comal Springs/River. Long-term (2001–2024) study averages are provided with error bars representing 95% confidence intervals.**

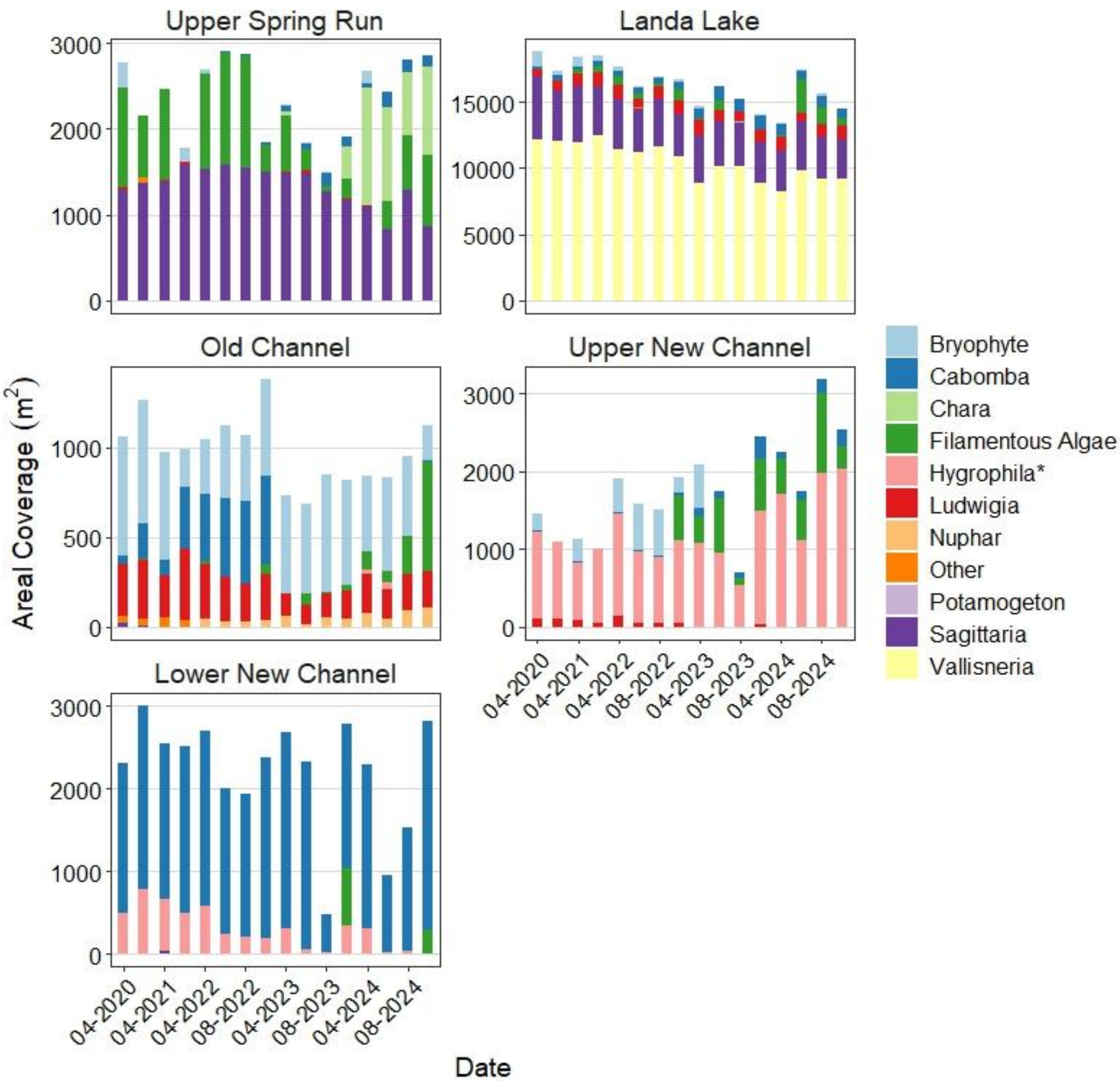

Figure 8. **Aquatic vegetation coverage (m²) among taxa from 2020–2024 in the Comal Springs/River. (*) in the legend denotes non-native taxa.**

Fountain Darter

A total of 1,835 Fountain Darters were observed at 98 drop-net samples in 2024. Drop-net densities ranged from 0.00–93.00 darters/m^2. Community summaries and raw drop-net data are included in appendices E and G, respectively. Summaries of habitat conditions observed during drop-netting can be found in Table 3. Timed dip-netting resulted in a total of 933 Fountain Darters during 20 person-hours (p-h) of effort. Site CPUE ranged from 0–180 darters/p-h. Lastly, Fountain Darters were detected at 96 out of 200 (48%) random-stations and reach-level percent occurrence among monitoring events ranged from 0–100%. A summary of occurrences per reach and vegetation taxa can be found in Table 4. Visual surveys in Landa Lake resulted in 39 darters observed and densities ranged from 1.54–3.46 darters/m^2 (bryophyte coverage = 15–35%) (Appendix E, Figure E11).

Table 3. Habitat conditions observed during 2024 drop-net sampling in the Comal Springs/River. Physical habitat parameters include counts of dominant vegetation (median % composition) and dominant substrate type sampled. Depth/velocity and water quality parameters include medians (min-max) of each variable among all drop-net samples.

HABITAT PARAMETERS	USR	LL	OC	NC
Vegetation				
Bryophyte[1]	6 (70%)	6 (50%)	6 (100%)	0
Cabomba[1]	2 (85%)	6 (100%)	0	6 (100%)
Chara[1]	6 (100%)	0	0	0
Hygrophila[1]	0	0	0	6 (100%)
Ludwigia[1]	0	6 (100%)	6 (100%)	0
Open	6 (98%)	6 (95%)	6 (95%)	6 (100%)
Sagittaria[2]	6 (100%)	6 (100%)	0	0
Vallisneria[2]	0	6 (100%)	0	0
Substrate				
Cobble	10	4	7	0
Gravel	10	4	2	5
Sand	0	7	3	3
Silt	6	21	6	10
Depth-velocity				
Water depth (ft)	2.1 (0.5–3.0)	1.9 (1.1–2.8)	2.3 (1.1–3.0)	2.4 (0.8–3.5)
Mean column velocity (ft/s)	0.0 (0.0–0.1)	0.0 (0.0–0.3)	0.3 (0.0–1.2)	0.1 (0.0–0.7)
15-cm column velocity (ft/s)	0.0 (0.0–0.1)	0.0 (0.0–0.2)	0.2 (0.0–1.0)	0.0 (0.0–0.5)
Water quality				
Water temperature (°C)	24.1 (23.4–24.7)	24.3 (23.3–25.3)	24.4 (23.5–25.5)	23.9 (23.7–24.7)
DO (mg/L)	6.2 (3.4–9.0)	7.1 (3.5–10.7)	8.1 (6.4–8.9)	8.1 (7.6–8.6)
DO % saturation	73.9 (41.1–107.9)	84.7 (41.2–130.9)	97.0 (75.4–106.8)	96.7 (90.4–101.7)
pH	8.3 (7.7–8.8)	8.2 (7.8–8.5)	8.4 (8.2–8.4)	8.5 (8.3–8.5)
Specific conductance (µs/cm)	580 (570–588)	582 (544–588)	580 (579–584)	581 (580–584)

[1]Denotes ornate vegetation taxa with complex leaf structure
[2]Denotes long broad or ribbon-like, austere-leaved vegetation taxa

Table 4. Summary of vegetation types sampled among reaches during 2024 random-station surveys in the Comal Springs/River and the percent occurrence of Fountain Darters in each vegetation type and reach. Raw numbers represent the sum of detections per reach-vegetation type combination and '-' denotes that the vegetation type was not sampled.

Vegetation Type	USR	LL	OC	NC	Total	Total Samples	Occurrence (%)
Bryophyte[1]	-	-	13	-	**13**	**21**	**61.9**
Cabomba[1]	0	7	-	6	**13**	**27**	**48.1**
Chara[1]	1	-	-	-	**1**	**5**	**20.0**
Filamentous algae[1]	1	2	4	0	**7**	**12**	**58.3**
Hygrophila[1]	-	-	0	-	**0**	**2**	**0.0**
Ludwigia[1]	-	3	26	-	**29**	**49**	**59.2**
Nuphar[2]	-	-	1	-	**1**	**7**	**14.3**
Sagittaria[2]	1	10	-	-	**11**	**38**	**28.9**
Vallisneria[2]	-	21	-	-	**21**	**39**	**53.8**
Total	**3**	**43**	**44**	**6**	**96**	**200**	**48**
Total samples	**20**	**80**	**80**	**20**	**-**	**-**	**-**
Occurrence (%)	**15.0**	**53.8**	**55.0**	**30.0**	**-**	**-**	**-**

[1]Denotes ornate vegetation taxa with complex filamentous or leaf structure
[2]Denotes long broad or ribbon-like, austere-leaved vegetation taxa

Population Demography

Seasonal population trends

Median Fountain Darter density in 2024 was higher in the spring (2.50 darters/m^2; includes routine and June Critical Period sampling) compared to fall (0.00 darters/m^2). Upper quartile density, and thus, variation in density (i.e., interquartile range), were also higher in spring (14.00 darters/m^2) compared to fall (2.00 darters/m^2) (Figure 9A). Timed and random dip-netting illustrated similar seasonal trends in 2024. Median CPUE and occurrence were greater in spring (64 darters/p-h and 63%, respectively), decreased in summer (11 darters/p-h and 20%, respectively), and increased in fall (28 darters/p-h and 33%) to index levels that were still below results from spring (Figure 9B, 9C). Across indices, patterns observed in spring represented the only season that approximated 5-year and long-term trends, though median index values were still lower than historical medians. Lower median index values for spring are likely due to the inclusion of the June Critical Period sampling event which occurred from June 11th - 17th, prior to the summer solstice on June 20th (see sections below for further discussion). Median index values in summer and fall were approximately equal to or less than 5-year and long-term lower quartiles (Figure 9).

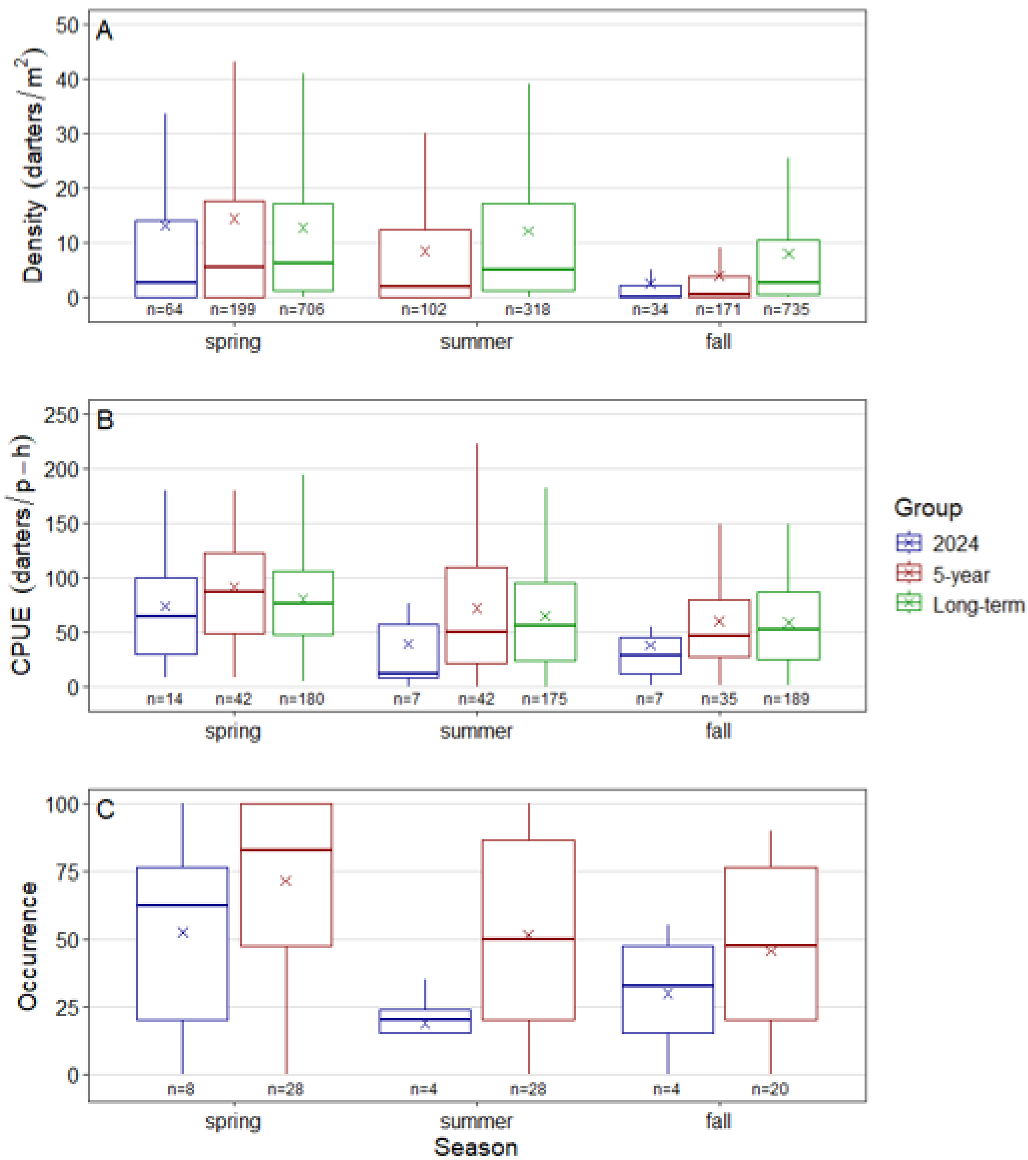

Figure 9. **Boxplots comparing Fountain Darter density from drop-net sampling (A), catch-per-unit-effort (CPUE) from timed dip-netting (B), and percent occurrence from random-station dip-netting (C) among seasons in the Comal Springs/River. Temporal groups include 2024, 5-year (2020–2024), and long-term (2001–2024) observations. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent the number of samples per category.**

Ubiquitous declines across indices in summer and fall suggest that the prolonged period of extremely reduced flows have resulted in a decline in population condition. That said, these patterns are not uniform across the system and other results in this report illustrate that population condition varied spatially both within and among sampling events.

Drop-net sampling density trends

Temporal trends in Fountain Darter density from 2020–2024 varied across reaches. Median densities over time were not strongly correlated ($r < 0.7$) between reaches, suggesting spatially variable dynamics the past five years. At Upper Spring Run, median density from 2020–2023 was most frequently 0.00 darters/m^2. Samples above the long-term median (1.00 darters/m^2) were rare and median density only exceeded this threshold in spring 2022 (3.75 darters/m^2). In 2024, median density at Upper Spring Run increased above its long-term median in April (2.50 darters/m^2) but then declined back to 0.00 darters/m^2 by fall. Density trends at Landa Lake over the past five years showed no strong directionality and instead illustrated regular seasonal cycles. Median density typically increased above Landa Lake's long-term median (2.50 darters/m^2) in spring and decreased below this threshold by fall. Interestingly, median densities that were above the long-term expectation in spring were followed by decreases 8–24 times lower in the subsequent fall, as demonstrated in 2024 (20.00 to 2.50 darters/m^2). Median density in spring 2022 (7.25 darters/m^2) was the only seasonal event below its long-term median and was followed by a minimal decrease the next fall (6.25 darters/m^2) (Figure 10).

Density trends at Old Channel also displayed regular seasonal cycles with higher densities in spring and lower densities in summer and fall. In contrast to Landa Lake, median density displayed a declining trend from 2020–2024. During this time, median density generally decreased from 16.75 to 5.50 darters/m^2 during sampling events in spring and decreased from 4.75 to 1.25 darters/m^2 in the fall. Despite this notable downward trend, median density from 2023–2024 still approximated Old Channel's long-term median (3.50 darters/m^2), except in fall 2024 (1.25 darters/m^2). Density trends at New Channel displayed the greatest deviations from historical expectations compared to other reaches. Median density showed minimal directionality from 2020–2022 (0.00–3.75 darters/m^2). Changes in upper quartiles showed seasonality and were higher in spring (3.50–11.13 darters/m^2) compared to fall (0.13–2.13 darters/m^2). Median density substantially increased in spring 2023 (23.50 darters/m^2), which was 12 times higher than the long-term median (2.00 darters/m^2). Median density then decreased, but remained higher than the long-term upper quartile by fall 2023 (8.00 darters/m^2). In 2024, density continued to decrease throughout the year and zero Fountain Darters were collected in this reach in the fall (Figure 10).

Across all reaches, median densities in April 2024 were above the long-term median, while median densities in June were below or approximated long-term medians (Figure 10). This suggests that inclusion of the June Critical Period event in the spring season likely contributed to lower overall spring median density compared to 5-year and long-term values (Figure 9).General reach-level differences in temporal patterns can likely be best explained by dissimilarities in habitat stability. Discontinuous trends observed at Upper Spring Run was probably a result of greater variability in environmental conditions relative to other reaches. In 2023, for example, decreases in bryophyte coverage at Upper Spring Run were associated with springflow declining to 0 cfs, and median Foutain Darter density consequently was zero. Median density increased in spring 2024 when both springflow and bryophyte coverage increased, but declined to zero again as both environmental parameters also fell to zero. In contrast to Upper Spring Run, temporal patterns at Landa Lake and Old Channel illustrated more regular seasonal oscillations. Population cycles are a more common phenomenon in stable environments, with changes in abundance typically driven by timing of reproduction (Berryman 2002). Moreover, changes in density from spring to fall occurred at much greater magnitudes at Landa Lake compared to Old Channel, particularly after spring densities greatly exceeded long-term values. While substantial declines in fall 2023 and 2024 can be partially explained by decreases of bryophytes due to low flows, the consistency of these large seasonal changes suggests this reach is characterized by over-compensatory dynamics (Rose et al. 2001). Under this dynamics scenario, recruitment rates at low densities greatly exceeds carrying capacity, subsequently resulting in intense competitive population regulation over a short time frame (Berryman 2002, Shoemaker et al. 2020).

Fountain Darter median density in the Old Channel was well above long-term values from spring 2020 to summer 2022 due to habitat restoration in this reach which has replaced *Hygrophila* with bryophytes. However, patterns in Fountain Darter density at Old Channel have shown a downward trend recently and are likely due to changes in coverages *Cabomba*, which has largely been absent in the reach since 2023. Additionally, as mentioned previously, flows at Old Channel study reach dropped to zero for ~22 hours on October 22nd this year, approximately one-week before drop-net sampling. Fall 2024 densities were the lowest since 2020 and potentially influenced by this zero-flow anomaly.

Lastly, abrupt increases in density at New Channel in 2023 were surprising, but can again be explained by the influence of flow on habitat conditions. Recruit densities were high in 2023, resulting from expansion of more suitable vegetation (e.g., bryophytes, *Hygrophila*) due to flow stability (Katz and Freeman 2015). However, any potential positive effect was brief and densities declined to zero by fall 2024 as flows continued to decline, bryophytes disappeared, and filamentous algae increased. As with the Old Channel, zero-flow anomalies also occurred at the New Channel this fall. Based on USGS gage # 08168932, the continuous duration of zero-flow was less than Old Channel, though the number of days where it occurred was greater (n = 7 days; USGS 2024).

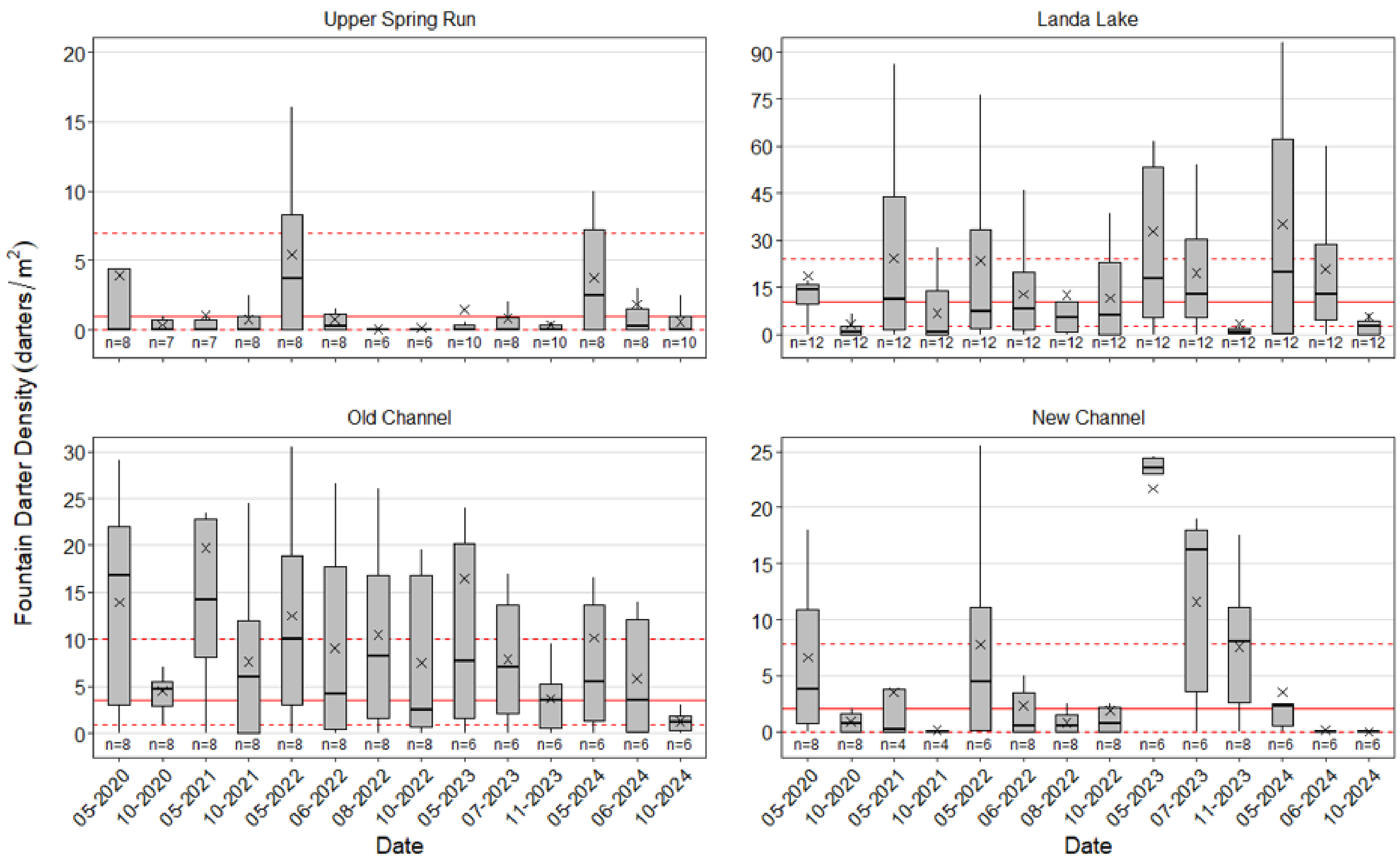

Figure 10. **Boxplots displaying temporal trends in Fountain Darter density (darters/m²) among study reaches from 2020–2024 during drop-net sampling in the Comal Springs/River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent the number of drop-net samples in each category. Solid and dashed red lines denote long-term (2001–2024) medians and interquartile ranges, respectively.**

Size structure and recruitment trends

Seasonal differences in size structure and recruitment remained mostly consistent from 2020–2024, as demonstrated by lower median lengths and higher recruitment rates in spring (19–25 mm and 19.0–60.4%, respectively) compared to summer (24–26 mm and 17.8–35.5%, respectively) and fall (23–27 mm and 18.1–45.2%, respectively). Violin plots also illustrated a greater proportion of smaller darters in spring relative to other seasons. That said, five-year trends in Fountain Darter recruitment deviated from long-term expectations during 1–3 sampling events per season. Recruitment in spring approximated or exceeded the long-term mean (48.3%) from 2020–2023 (48.5–60.4%), but was lower than expected in April (40.2%) and June (19.0%) of 2024. Summer recruitment approximated long-term expectations (22.4%) all years except 2021, when it was higher (35.5%). Recruitment in fall greatly exceeded the long-term mean (19.5%) in 2022 (45.2%) and 2024 (38.4%) (Figure 11).

Lower than expected spring recruitment in June was not surprising given that this was a low-flow Critical Period event and is not within the window of peak reproduction (Schenk and Whiteside 1977). However, results from April indicated that spring recruitment rates were reduced in 2024. Drop-net and timed dip-net data from April sampling illustrated that ~70% of recent recruits were observed at Landa Lake and the remaining study areas contributed ≤ ~10% to overall recruitment. This suggests impacts to reproductive output were greatest at Upper Spring Run, where springflows went to zero, and at the Old and New Channels which are farther from spring outputs. The large increase in recruitment that occurred in fall 2024 was also mostly due to output at Landa Lake (~74%), followed by Upper Spring Run (~13%) and Old Channel (~10%). It was previously suggested that stable and/or low flows increases young-of-year survival (BIO-WEST 2023a; BIO-WEST 2024a), which other fisheries studies observed and suggested as a potential resistance mechanism against reduced flows (McCargo and Peterson 2010, Katz and Freeman 2015). Results from April 2024 demonstrated suppressed recruitment of Fountain Darters throughout the system during the peak reproductive period, with the exception of Landa Lake. This indicates that environmental conditions have degraded in riverine and upper spring habitats (e.g., increased coverage of filamentous algae) as extreme low-flow conditions persisted, which also likely relates to the lower population condition observed by fall 2024.

Water temperature is also considered a limiting factor on Fountain Darter egg and larval production. Exceedance of optimal temperature thresholds from previous laboratory studies likely explains some of the recruitment patterns observed in 2024, particularly in April. Egg and larval production thresholds were exceeded within riverine habitats and upper spring habitats from spring to fall, but was never exceeded at Landa Lake. Based on this, impacts observed in fall may have been the result of cumulative effects of increased water temperatures since the spring (Shreck 2000). Impacts at reaches in upper spring and riverine habitats may instead have resulted in a negative synergistic effect by the combination of increased temperatures, reduced flow, and decreased coverage of suitable vegetation (Matthaei and Lange 2016). That said, recruits were observed during fall sampling at Upper Spring Run, which occurred when water temperatures began to exceed these production thresholds less frequently. This illustrates that recruitment can still occur in more heavily impacted habitats when suitable environmental conditions return, suggesting population resiliency.

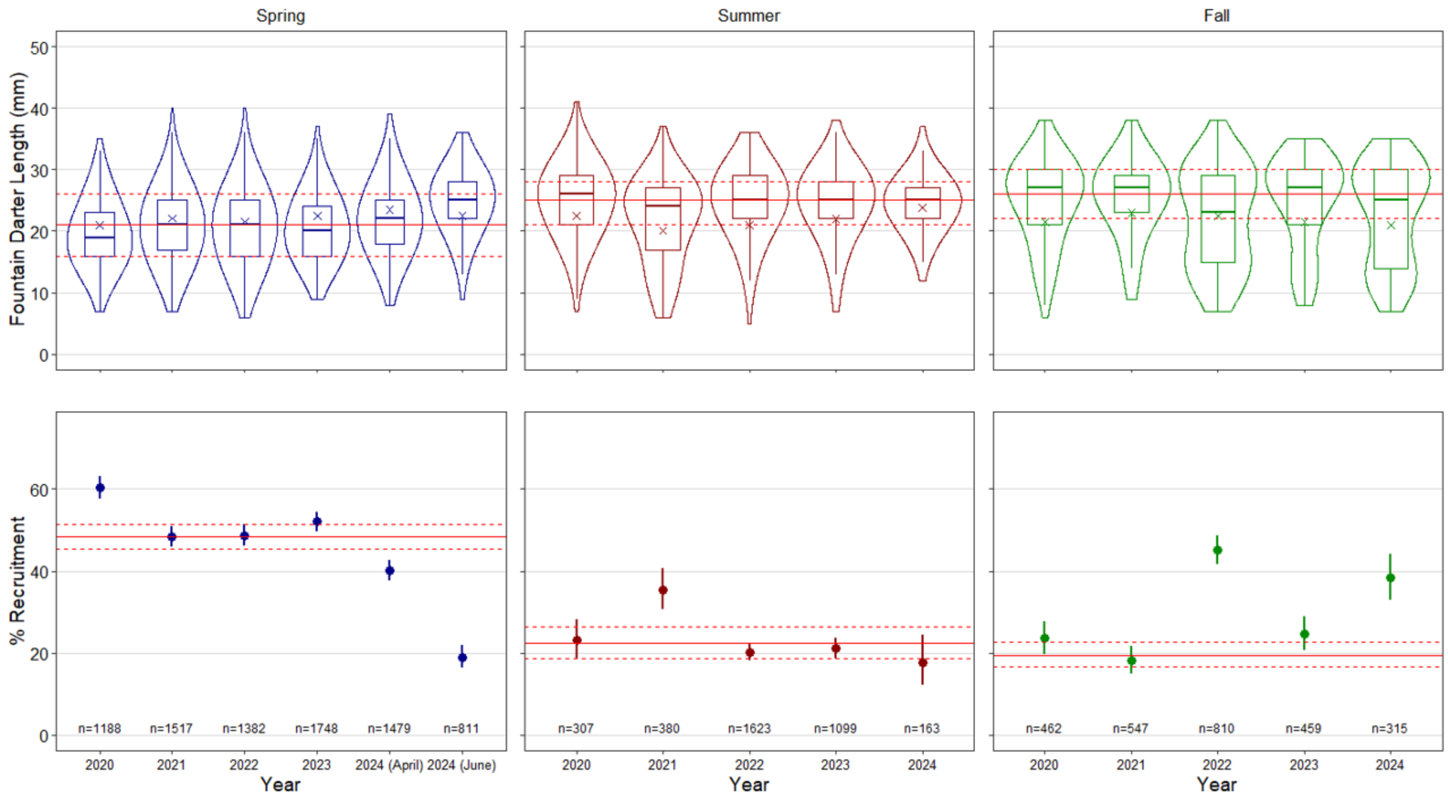

Figure 11. **Seasonal trends of Fountain Darter size structure (mm; top row) and percent recruitment (bottom row) in the Comal River from 2020–2024. Spring and fall trends are based on drop-net and timed dip-net data in aggregate, whereas summer trends are based on timed dip-net data only. Size structure is displayed with boxplots (median, quartiles, range) and violin plots (probability density; polygons outlining boxplots). The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axis of the top row represent the number of Fountain Darter length measurements in each distribution. Recruitment is the percent relative abundance (± 95% CI) of darters ≤20 mm. Long-term (2001–2024) trends in size structure are represented by median (solid red line) and interquartile range (dashed red lines). Recruitment is compared to the long-term mean percentage (solid red line) and 95% CI (dashed red lines).**

Habitat Use and Suitability

Density trends among vegetation taxa

Median densities in 2024 were highest in bryophytes (9.25 darters/m^2), *Vallisneria* (7.75 darters/m^2), and *Ludwigia* (5.50 darters/m^2). Median estimates were lower in *Cabomba* (2.25 darters/m^2), *Chara* (2.00 darters/m^2), and *Hygrophila* (0.50 darters/m^2), and were 0.00 darters/m^2 in *Sagittaria* or open habitats. Fountain Darter densities in *Vallisneria* were greater than historical medians in 2024. In contrast, *Cabomba* and *Hygrophila* densities were lower than historical expectations. Densities in bryophytes closely approximated 5-year trends in 2024, but both median estimates were below the long-term median. The remaining taxa and open habitats aligned with historical expectations, although densities in *Ludwigia* were extremely variable and exceeded 50 darters/m^2 at multiple samples in Landa Lake (Figure 12).

Greater densities within ornate taxa aligned with expectations based on historical data and past research on Fountain Darter habitat associations (Schenck and Whiteside 1976, Linam et al. 1993, Alexander and Phillips 2012, Edwards and Bonner 2022). Similar to 2023, higher than typical densities in *Ludwigia* and *Vallisneria* were directly related to greater prevalence of bryophytes within, creating greater complexity in physical structure that is more suitable for darters (Alexander and Phillips 2012, Edwards and Bonner 2022). Lower densities in *Cabomba* and *Hygrophila* this year was mainly attributed to reach-level differences in current environmental conditions. For example, median density in *Cabomba* was ~20 darters/m^2 at Landa Lake and 0 darters/m^2 at Upper Spring Run and New Channel. As mentioned previously, both Upper Spring Run and New Channel experienced zero-flow conditions in 2024 and elevated water temperatures, which likely best explains these observed spatial differences. Similarly, bryophyte densities the past five years have been lower than expected, which can be explained by the general decreasing trend in coverage of this taxon and the increasing amount of filamentous algae which is often intermixed with bryophytes.

Size structure among vegetation taxa

Boxplot summary statistics and violin plots showed that Fountain Darter size structure varied among vegetation taxa sampled in 2024. The lowest median lengths occurred in open (19 mm), *Cabomba* (22 mm), and *Ludwigia* (22 mm), were intermediate in *Vallisneria* (23 mm) and bryophytes (25 mm), and highest in *Chara* (28 mm), *Sagittaria* (29 mm), and *Hygrophila* (29 mm). Size structure distributions for *Cabomba* suggest it was important habitat for recent recruits. Bryophyte size patterns were left-skewed, though the importance of this habitat for juvenile darters is clear, based on darters <15 mm being relatively frequent. Approximately symmetric length distributions for *Ludwigia* and *Vallisneria* illustrated these taxa were important habitat across life stages in 2024. Distributional patterns for the remaining taxa were left-skewed, suggesting they mainly provided habitat for adults. A greater proportion of younger darters were observed in *Ludwigia* and *Vallisneria* compared to 2023, further demonstrating that increased bryophyte coverage within macrophytes provides complex habitat suitable for juveniles (Figure 13) (Edwards and Bonner 2022; BIO-WEST 2024).

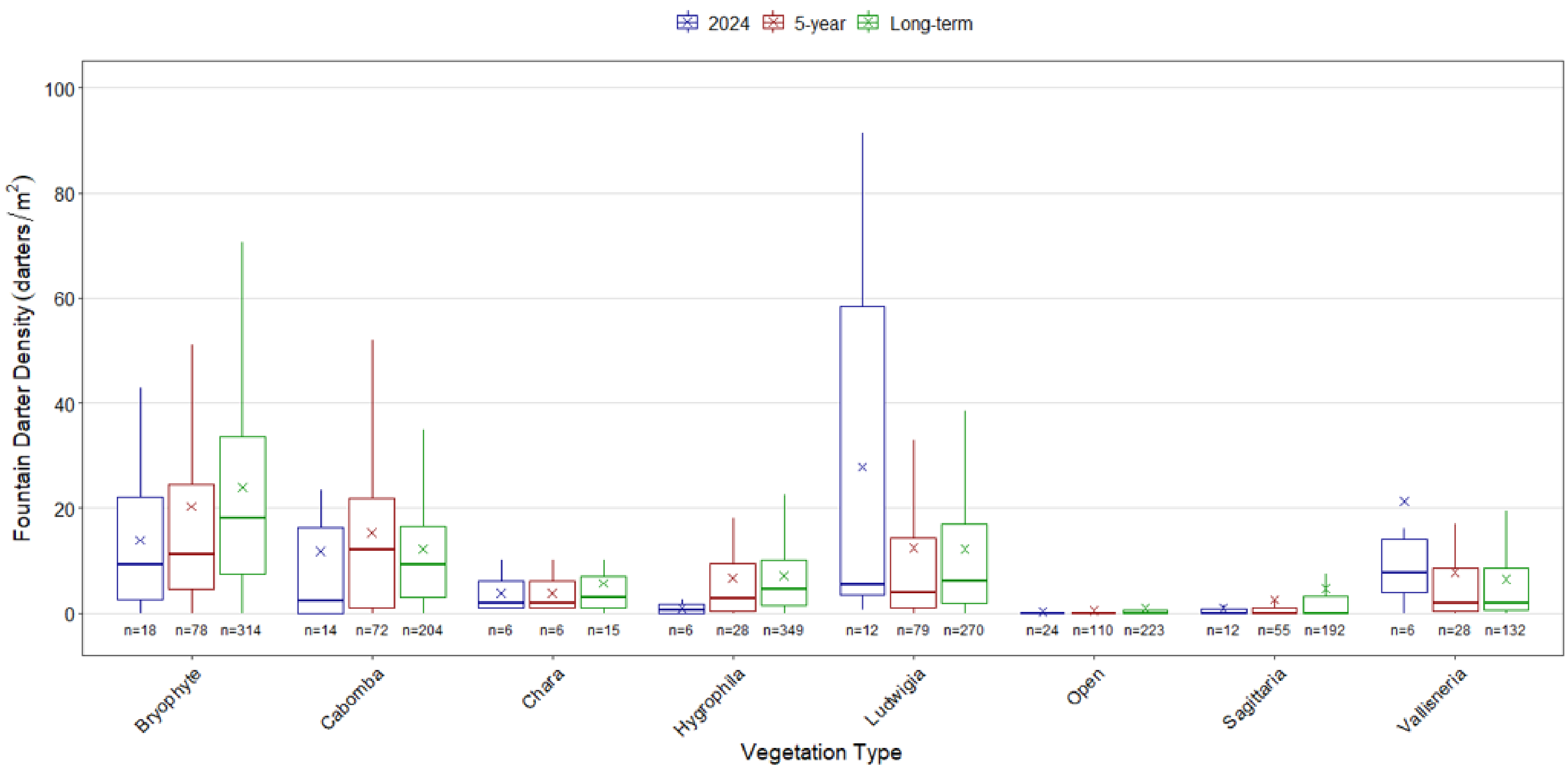

Figure 12. **Boxplots displaying 2024, 5-year (2020–2024), and long-term (2001–2024) drop-net Fountain Darter density (darters/m^2) among vegetation types in the Comal Springs/River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent drop-net sample sizes per group.**

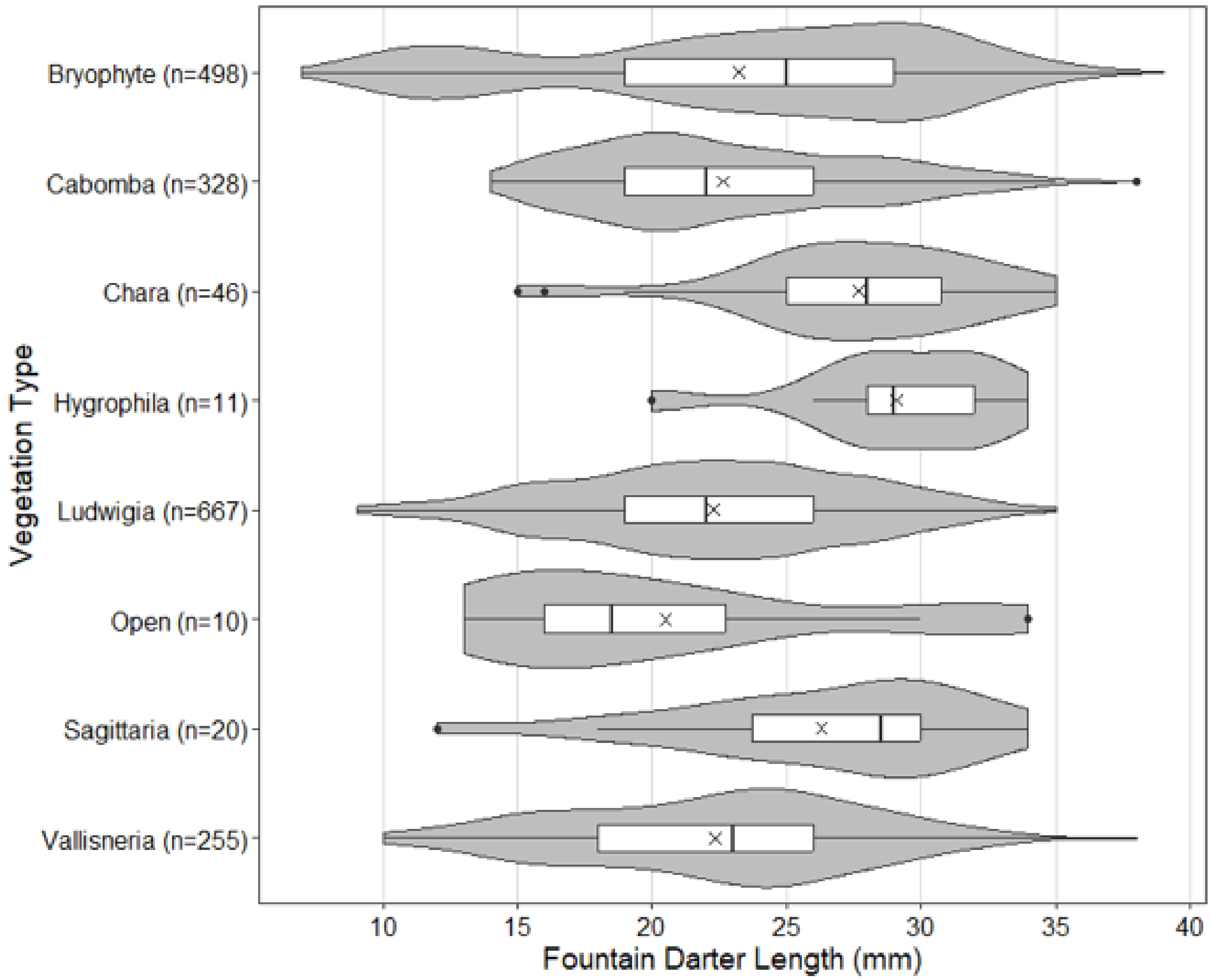

Figure 13. Boxplots and violin plots (grey polygons) displaying Fountain Darter lengths among dominant vegetation types during 2024 drop-net sampling in the Comal Springs/River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range, and outliers beyond this are designated with solid black circles. The "n" values represent the number of Fountain Darter length measurements per vegetation type.

Habitat suitability

Temporal trends in the Fountain Darter Overall Habitat Suitability Index (OHSI) from 2020–2024 varied among reaches. Patterns in OHSI estimates were not strongly correlated ($r < 0.7$) between reaches, except for Landa Lake and Upper New Channel, which demonstrated a moderate negative correlation ($r = -0.6$). This indicates spatial variability in habitat conditions the past five years. OHSI patterns at Upper Spring Run and both New Channel reaches displayed more variation compared to other reaches, demonstrating more regular seasonal cycles. Upper Spring Run and Lower New Channel showed no strong directionality in OHSI trends, while Upper New Channel increased moderately the past five years. OHSI at Landa Lake and Old Channel have decreased over time, with distinct shifts to lower, but relatively stable OHSI trends starting in 2022 and 2023. For most of the time-series, OHSI estimates were generally within the bounds of long-term 95% confidence intervals in all reaches except Landa Lake, which have mostly fallen below this threshold since 2023. That said, OHSI confidence intervals at Landa Lake during this time did overlap with the long-term, emphasizing that there is some uncertainty regarding whether these values differ from long-term expectations (Figure 14).

Variable trends in OHSI observed the past five years can be explained by differences in the strength of associations between vegetation coverage and OHSI between reaches. Changes in OHSI at Upper Spring Run were most related to coverage of filamentous algae. OHSI at Landa Lake was most influenced by the two most dominant taxa (*Vallisneria* and *Sagittaria*) and by bryophytes. Habitat suitability at Old Channel and both New Channel reaches were strongly associated with changes in coverage of *Cabomba*. In addition, Old Channel and Upper New Channel OHSIs were also influenced by changes in *Ludwigia* and *Hygrophila* coverages, respectively. Although increases in intermixed bryophytes resulted in increased Fountain Darter densities in 2023 and 2024, this is not captured by the OHSI which assigns long-term taxa-specific suitability criteria based on dominant vegetation. For example, a patch of *Vallisneria* with intermixed bryophytes (and thus high Fountain Darter density as seen at Landa Lake) would be assigned the long-term *Vallisneria* suitability criteria (0.46 ± 0.07) for OHSI calculations. As a result, the current OHSI framework does not accurately reflect the increased habitat structure at these microhabitat spatial resolutions. Therefore, habitat suitability may be higher than shown by OHSI estimates at Landa Lake this year. Similarly, increased OHSI at Upper Spring Run was due to increased filamentous algae coverage. However, based on Fountain Darter population condition being low in this reach in 2024, long-term suitability values for filamentous algae may not accurately reflect current habitat suitability in this reach, and OHSI may overestimate habitat condition at Upper Spring Run. Conversely, there may be other factors such as water temperature influencing Fountain Darter population in this reach more than habitat.

In summary, observed trends in habitat suitability help partially explain the positive and negative population responses of Fountain Darters in the Comal system. Future assessments may benefit from incorporating other relevant habitat factors to provide more complete realizations of habitat suitability. Increasing model complexity for OHSI estimates by incorporating other environmental factors as Habitat Suitability Criteria could provide better realizations of spatial variation in habitat suitability, both within and among reaches.

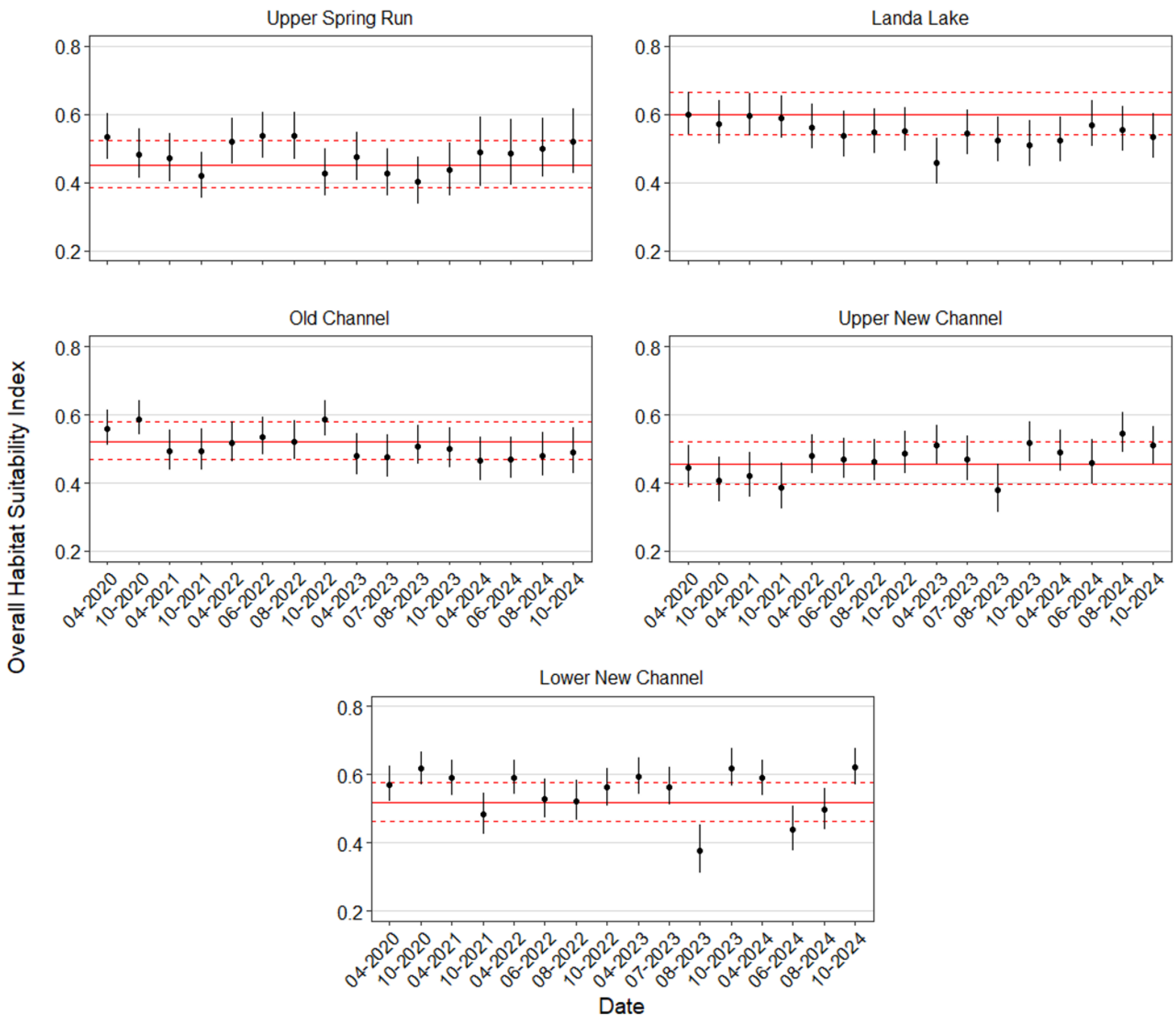

Figure 14. **Overall Habitat Suitability Index (OHSI) (±95% CI) from 2020–2024 among study reaches in the Comal Springs/River. Solid and dashed red lines denote means of long-term (2003–2024) OHSI and 95% CI, respectively.**

Fish Community

In 2024, a total of 14,252 fishes represented by seven families and 25 unique species were observed in the Comal Springs/River System. Complete summaries of segment-level community composition can be found in Appendix E. Fish assemblage structure (percent relative abundance) varied from spring-influenced to riverine areas. Guadalupe Roundnose Minnow (*Dionda nigrotaeniata*) was the dominant species in upstream spring-associated reaches including Upper Spring Run (57.2%) and Landa Lake (57.1%) (Appendix E, Table E2). Other spring-associated species dominated the assemblages at these two reaches, including the Fountain Darter which was the third most abundant species at Landa Lake (5.1%) and fourth most abundant species in Upper Spring Run (6.0%). Texas Tetra (*Astyanax argentatus*) was a dominant species in both spring and riverine areas as it was the most abundant species at Old Channel (24.0%) and second most abundant species at Landa Lake (23.1%) and New Channel (16.1%) (Appendix E, Table E2).

Temporal trends in fish communities varied between and within study segments. In general, species richness and diversity were higher in riverine areas (i.e., Old Channel and New Channel) and lowest at Landa Lake, though both metrics varied from event to event and displayed no detectable temporal patterns (Figure 15). Species richness and diversity were intermediate at Upper Spring Run, yet both metrics were more similar to riverine segments than to spring segments. Diversity has generally increased at Landa Lake and Old Channel over the past five years when compared to entire monitoring period (2014-present), though it did vary for some events (Appendix E, Figure E16). Increases in diversity over the past five years could suggest that community composition in both reaches has become more heterogenous.

Temporal trends in richness of spring fishes aligned with community-level observations and were generally stable throughout the study area. Spring fishes' richness ranged from 4–6 species across all segments, generally not changing by more than one species from one event to the next. Relative density of spring fishes at Landa Lake was higher and more consistent than at Upper Spring Run, Old Channel, or New Channel. However, relative density at Old Channel has been more stable since 2023 and generally higher than the previous three years (Figure 16). In contrast, relative density of spring fishes has varied more at New Channel over the course of 2024. Relative density declined sharply between fall 2023 (83.3%) and April 2024 (43.0%) and between June 2024 (70.6%) and fall 2024 (23.0%), which was the lowest observed over the monitoring period (Figure 16 and Appendix E, Figure E17).

Temporal trends in Fountain Darter density from 2020–2024 were based on microhabitat sampling data. Median density increased from spring to fall at Upper Spring Run and Old Channel (Figure 17). At Landa Lake, median density fluctuated slightly below the long-term median in April and October and above in June. At New Channel, median densities were higher in April 2024 then decreased in June. By fall sampling, densities increased near the long-term median (Figure 17). Historically, trends in microhabitat sampling were similar to Fountain Darter densities from drop-net sampling in which higher densities generally occurred in the spring and lower densities generally occurred in the fall. However, microhabitat densities in 2024 approximated long-term medians in the fall, with some reaches increasing from spring to fall. In contrast, drop-net densities in all reaches declined well below long-term medians. These patterns together could suggest that Fountain Darters sought refuge in deeper water and highlight the importance of multiple sampling methodologies.

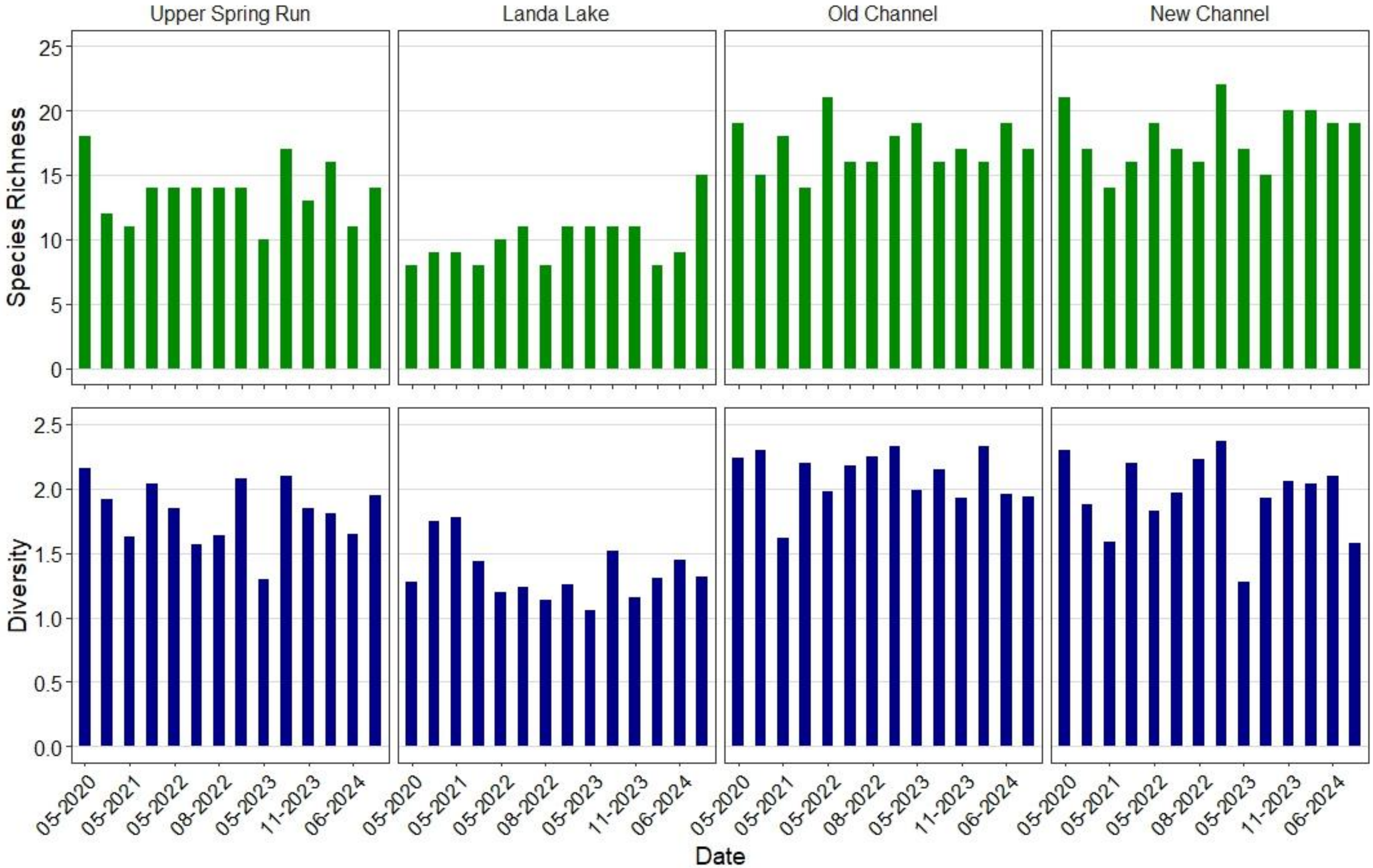

Figure 15. Bar graphs displaying species richness (top row) and diversity (bottom row) from 2020–2024 based on all three fish community sampling methods in the Comal Springs/River.

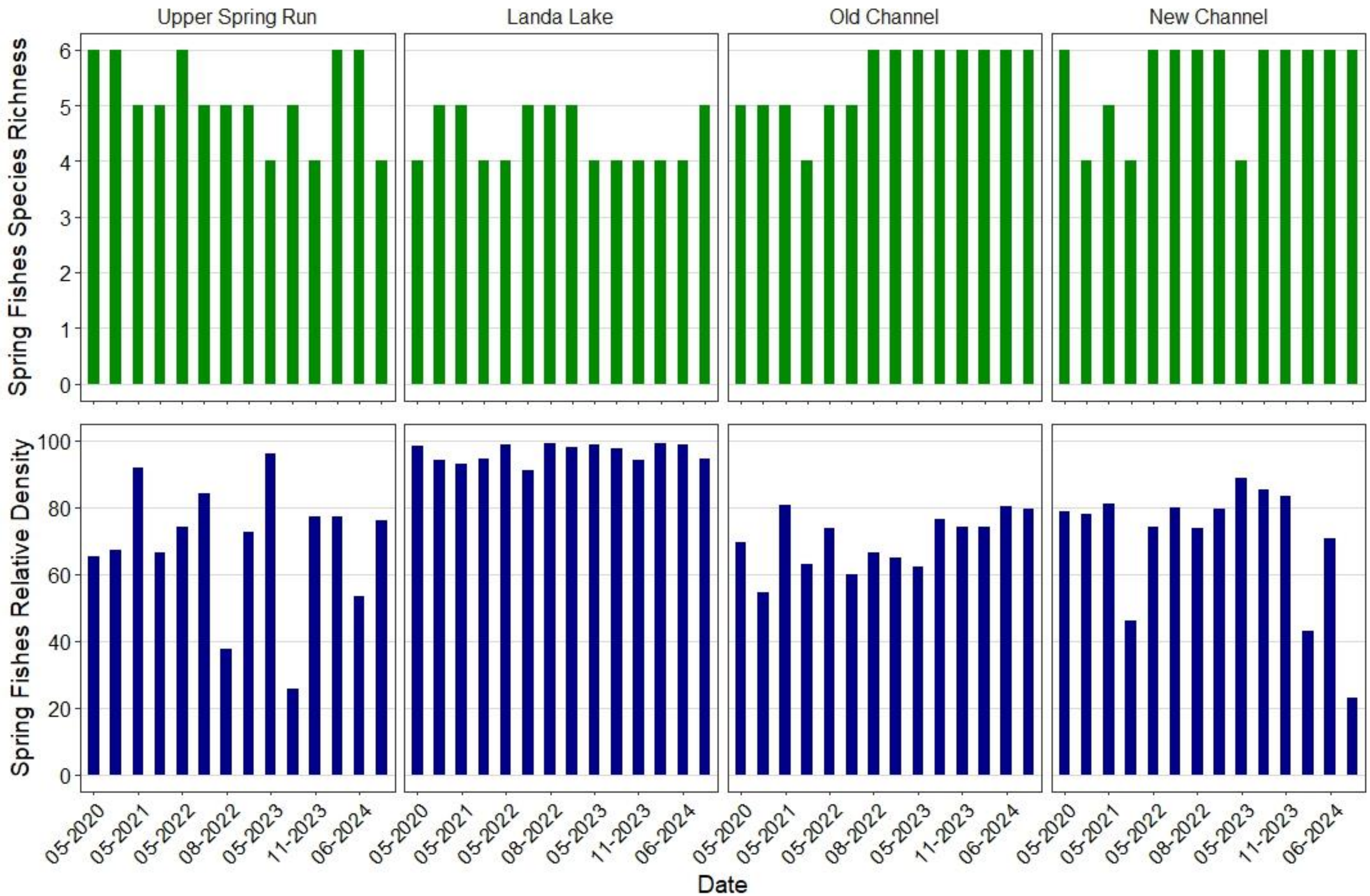

Figure 16. Bar graphs displaying spring fish richness (top row) and relative density (RD; %) (bottom row) from 2020–2024 based on all three fish community sampling methods in the upper Comal Springs/River.

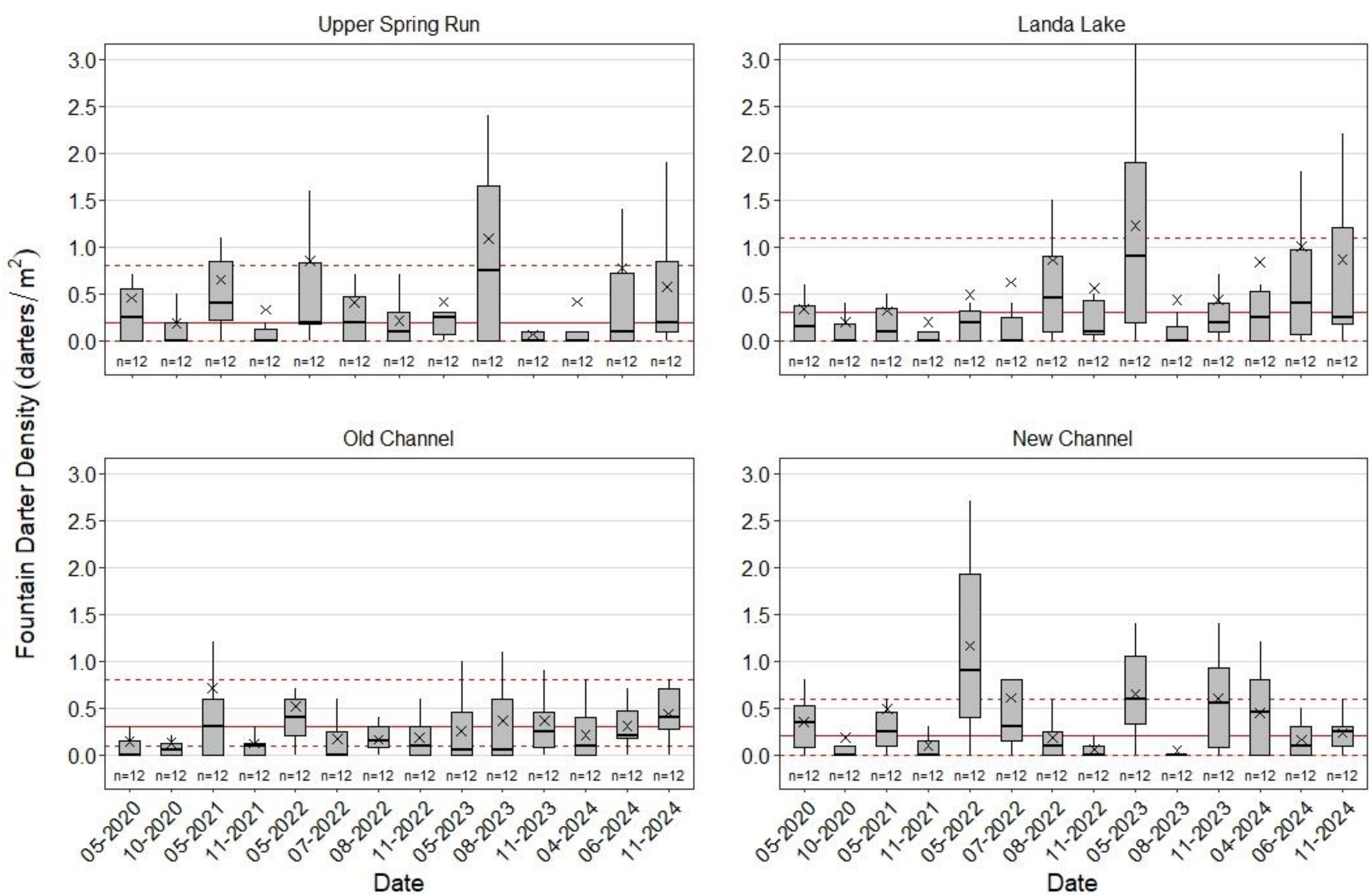

Figure 17. **Boxplots displaying temporal trends in Fountain Darter density (darters/m²) among study reaches from 2020–2024 during fish community microhabitat sampling in the Comal Springs/River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent the number of microhabitat samples per category. Solid and dashed red lines denote long-term (2014–2023) medians and interquartile ranges, respectively.**

Comal Springs Salamander

Low springflows in 2024 resulted in substantial reductions to surface salamander habitat similar to 2023. A total of 56 Comal Springs Salamanders were observed during three survey efforts. Sampling was not conducted at Spring Island Run and Spring Run 1 during the June Critical Period and fall events because these sites were completely desiccated. A third consecutive year of ongoing drought with reduced springflow and desiccated conditions resulted in lower than average counts in 2024 across all sites except at Spring Island Outfall during April and June when counts overlapped with long-term averages (Figure 18). Flows were lowest during fall sampling and resulted in larger reduction in wetted habitat (e.g., 50% at Spring Island Outfall) than in previous years, contributing to lower salamander numbers at Spring Island Outfall and Spring Run 3.

Five-year trends at Spring Island Run did not display any distinct patterns in CPUE and generally varied about 1 to 3 salamanders/p-h until this run dried up in summer 2023 (Figure 19). Although salamanders were observed in spring 2024 after several months of desiccated conditions, catch rates were lower than previous years. Spring Island Outfall has varied from 8 salamanders/p-h to over 40 salamanders/p-h between 2020 and 2024. Catch rates were consistently high from spring 2020 to spring 2022 but have been variable since that time. Despite sustained low flows throughout most of 2023 and 2024, catch rates in 2024 increased from spring to fall. At Spring Run 1, the lowest observed catch rates over the past five years occurred in spring 2024. Flows did not remain at Spring Run 1 long enough to see if typical catch rates would return. At Spring Run 3, salamander CPUE trends were generally above 20 salamanders/p-h until August 2023 when CPUE began decreasing. However, the catch rate of 48.57 salamanders/p-h in October 2023 was the second highest recorded over the past five years. This increase was temporary as catch rates decreased from spring through fall in 2024. Continued monitoring will provide further insight to how catch rates are affected following dry conditions during this low-flow year.

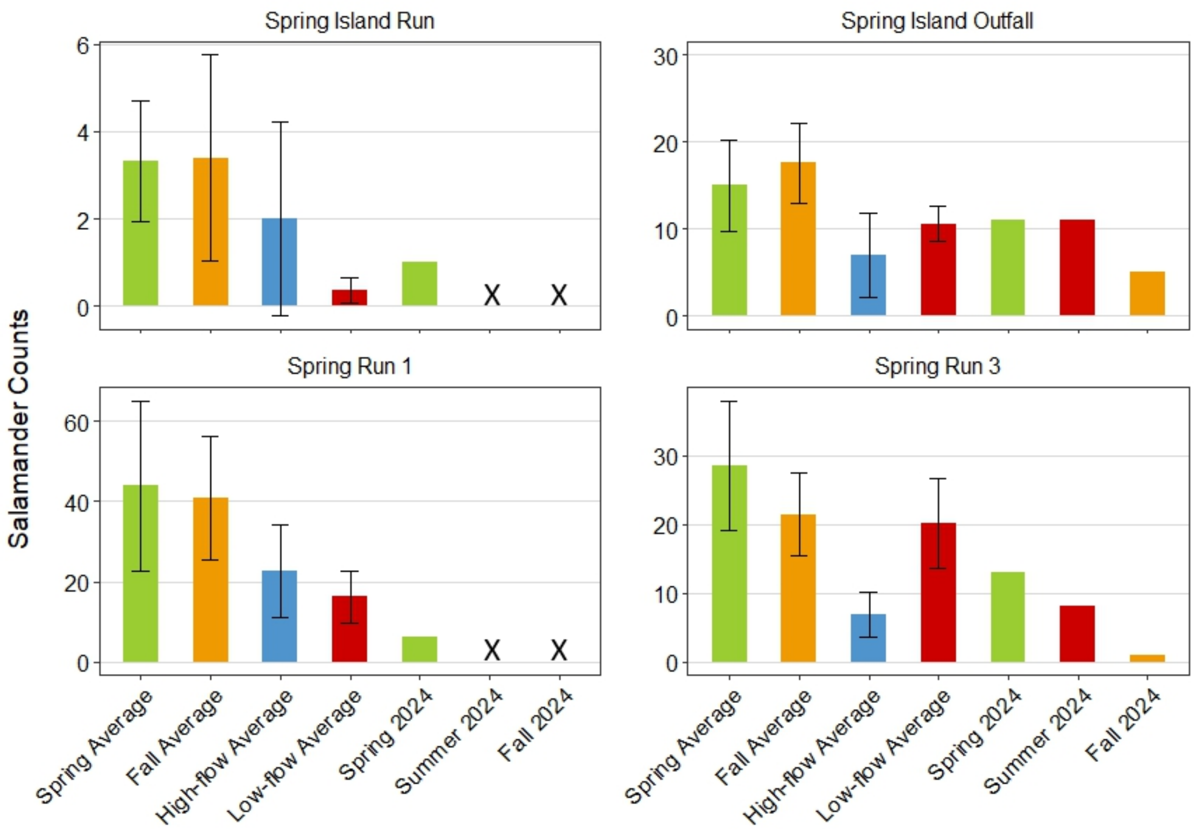

Figure 18. **Comal Springs Salamander counts among Comal Springs survey sites in 2024, with the long-term (2001–2024) average for each sampling event. Error bars for long-term averages represent 95% confidence intervals. X within dates at Spring Island Run and Spring Run 1 denotes lack of sampling due to dry conditions.**

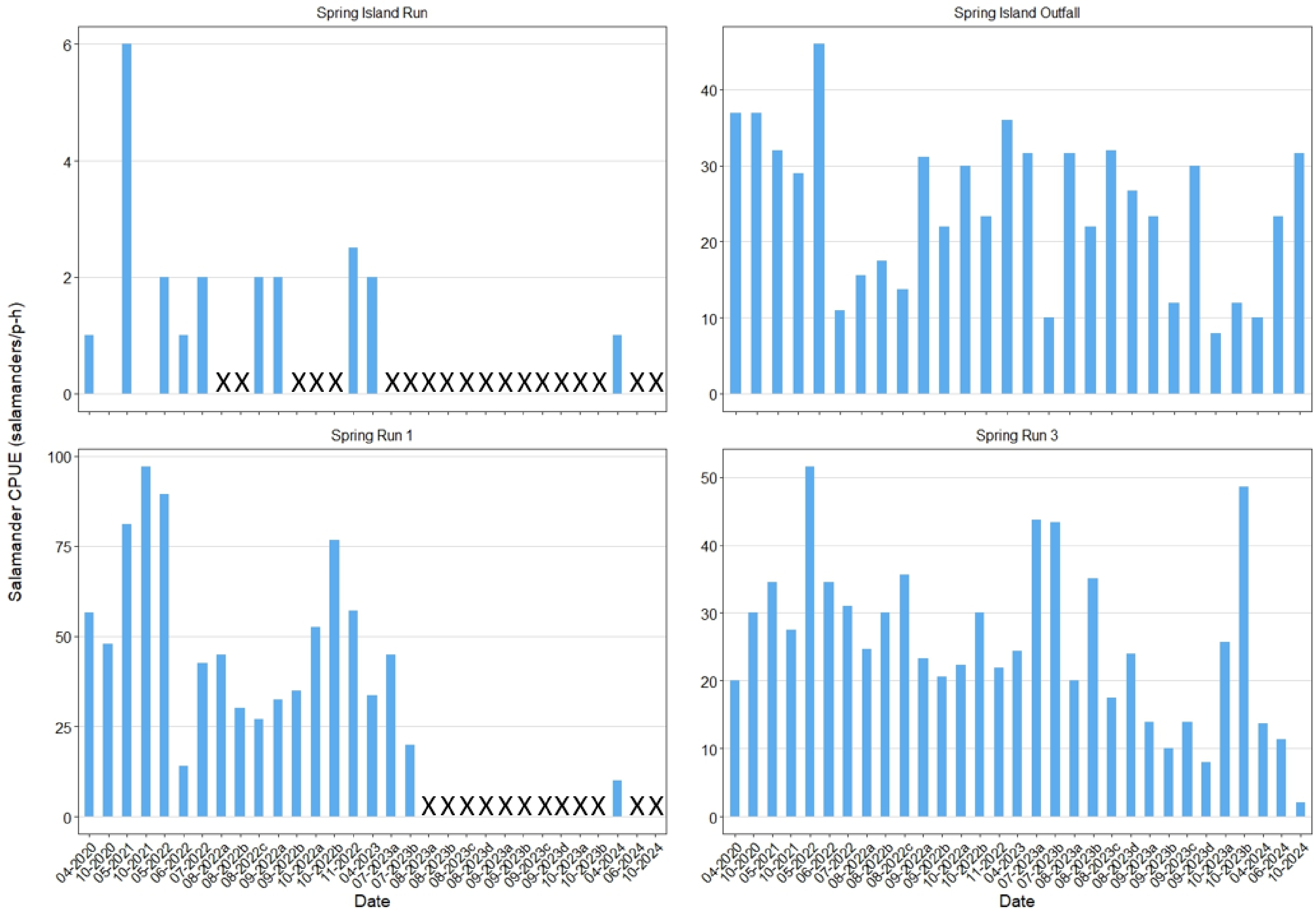

Figure 19. **Comal Springs Salamander catch-per-unit-effort (CPUE; salamanders/person-hr) among sites from 2020–2024 in the Comal Springs. No bar within dates at Spring Island Run denotes zero salamanders observed. X within dates at Spring Island Run and Spring Run 1 denotes lack of sampling due to dry conditions.**

Macroinvertebrates

Drift-Net Sampling

A total of 389 macroinvertebrates represented by 12 families and 22 taxa were collected during 144 drift-net hours. The total number of individuals collected was lower at Spring Run 1 (n = 29) than Spring Run 3 (n = 125) and Western Upwelling (n = 235). All three locations had fewer invertebrates than they have historically which can likely be attributed to reduced springflows in 2024. For example, while the drift-net at Spring Run 1 was set at an alternate downstream location from fall 2022 through fall 2023, flows were so low in fall 2024 that this location was moved farther downstream in Spring Run 1 to a site never previously sampled with a drift-net (Figure 20). Across all sampling efforts, dominant taxa included amphipods (*Stygobromus* spp., 50.9%), snails (*Vitropyrgus lillianae* 9.3%), and ostracods (*Comalcandona tressleri*, 5.9%). The remaining taxa each represented less than 3% of the total catch. Of the Covered Species, a total of 15 Peck's Cave Amphipods (*Stygobromus pecki*) were positively identified out of 213 total *Stygobromus* spp. and 1 larval Comal Springs Riffle Beetle was observed in 2024 (Table 5). Full drift-net results are presented in Appendix E. Over the past 5 years, the median counts of *Stygobromus* spp. per cubic meter of water filtered aligned with the long-term median from 2020 to spring 2022 (0.02 *Stygobromus*/m^3). Since fall 2022 median counts have been lower than the long-term, but means and upper quartiles have been relatively high (Figure 21). Lower counts at Spring Run 1 and Spring Run 3 in 2023 and 2024 were likely attributed to the desiccated conditions at Spring Run 1 and reduced springflow at Spring Run 3 throughout the summer and fall; whereas counts at Western Upwelling, where springflow was less variable, were higher and consistent with previous years.

Figure 20. **Photos displaying the habitat conditions during fall sampling in Spring Run 1 (A), Spring Run 3 (B), and Western Shoreline (C) and the alternate drift-net location at Spring Run 1 (A). The Spring Run 1 drift-net was moved from its usual location and past alternate locations due to all upstream sections of the run being dry.**

Table 5. **Total numbers of endangered species collected at each site during drift-net sampling in May and November 2024. Full drift-net results are presented in Appendix E.**

	SITE (TOTAL DRIFT-NET HOURS)		
TAXA	**RUN 1 (48)**	**RUN 3 (48)**	**UPWELLING (48)**
Crustaceans			
Amphipoda			
Crangonyctidae			
Stygobromus pecki	0	0	15
Insects			
Coleoptera			
Elmidae			
Heterelmis comalensis	1 (larva)	0	0

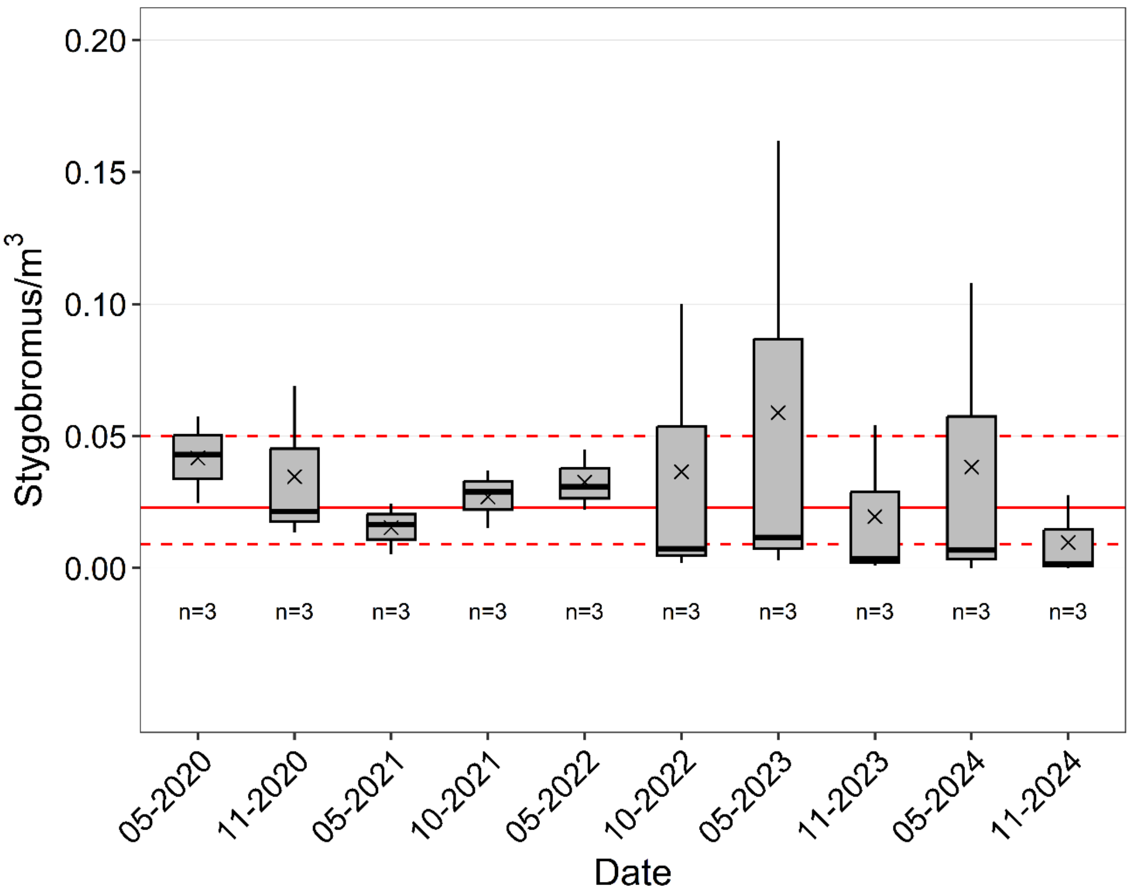

Figure 21. Boxplots displaying *Stygobromus* spp. counts per cubic meter of water (*Stygobromus*/m³) at Western Upwelling, Spring Run 1, and Spring Run 3 from 2019–2024. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. Solid and dashed red lines denote long-term (2003–2024) medians and interquartile ranges, respectively.

Comal Springs Riffle Beetle

Ninety-nine adult Comal Springs Riffle Beetles (CSRB) were collected at 60 lures during spring and fall sampling efforts in 2024 and counts ranged from 0–30 beetles/lure. Adult beetles occupied 25% of lures across spring and fall. The two CSRB low-flow sampling events from July through October yielded 92 adult CSRB on 19 lures at Spring Island, 3 CSRB on 8 lures at Western Shoreline, and 0 CSRB on 6 lures at Spring Run 3. However, this was not included in seasonal and temporal analyses due to use of alternative sites to those typically used in biomonitoring and variation in placement methods (e.g., adjacent to conditioned wood).

For spring and fall routine sampling, only 15 of 60 lures had adult CSRB, and median counts across both seasons for all three areas were zero beetles/lure. Mean beetles per lure across all areas were higher during spring than fall at Spring Island (spring = 5.3 beetles/lure; fall = 2.7), Western Shoreline (spring = 1 beetle/lure; fall = 0.4), and Spring Run 3 (spring = 0.5

beetles/lure; fall = 0) (Figure 22). During the initial low-flow summer effort (July–August) not included for analysis, adult CSRB were detected at Spring Island (52 adult CSRB) and the Western Shoreline (3 adult CSRB) but not Spring Run 3. During the second low-flow summer effort (September–October), adult CSRB were only found at Spring Island (40 adult CSRB). In summary, counts in 2024 decreased from spring to fall across all sites. Overall, seasonal metrics were lower than historical data (Figures 22 and 23). Among all the lures set during the spring, low-flow, and fall events, only four lures had more than eight CSRB. All four lures with these values (26, 30, 33, and 47 beetles/lure) were at the same site at Spring Island; these outliers are not shown in Figures 22 and 23.

When analyzed in conjunction with the long-term dataset, a general temporal decline in the number of beetles per lure is evident across sites and seasons (Figure 23). Over the past five years, beetles per lure have rarely approached long-term medians at the Western Shoreline or Spring Run 3 (e.g., only during late 2020 through 2022), while counts at Spring Island have only been consistent with long-term averages during spring. Medians and means across all areas have been low for the past five years relative to the entire 21-year dataset. The short-term (5-yr) CSRB average across Comal Springs is now the lowest observed during 21 years of monitoring. This suggests that extended low-flow conditions during 2022–2024 may be contributing to sustained and continued declines of surface CSRB populations. That being said, it is unclear whether the declines observed during low-flow periods are true population-level trends or if catch rates are potentially confounded by imperfect detection in near-surface habitats which are the focus of sampling. Low-flow habitat utilization studies conducted by BIO-WEST in 2023 suggested that CSRB follow water levels down into the substrate when spring surface habitats are desiccated. However, all beetles in that study were still observed at optimal locations that are consistent with sites chosen for biomonitoring. Although monitoring suggests declines in surface populations with recent reductions in springflow, continued targeted research related to this species is critical in understanding the relationship between population dynamics and springflow.

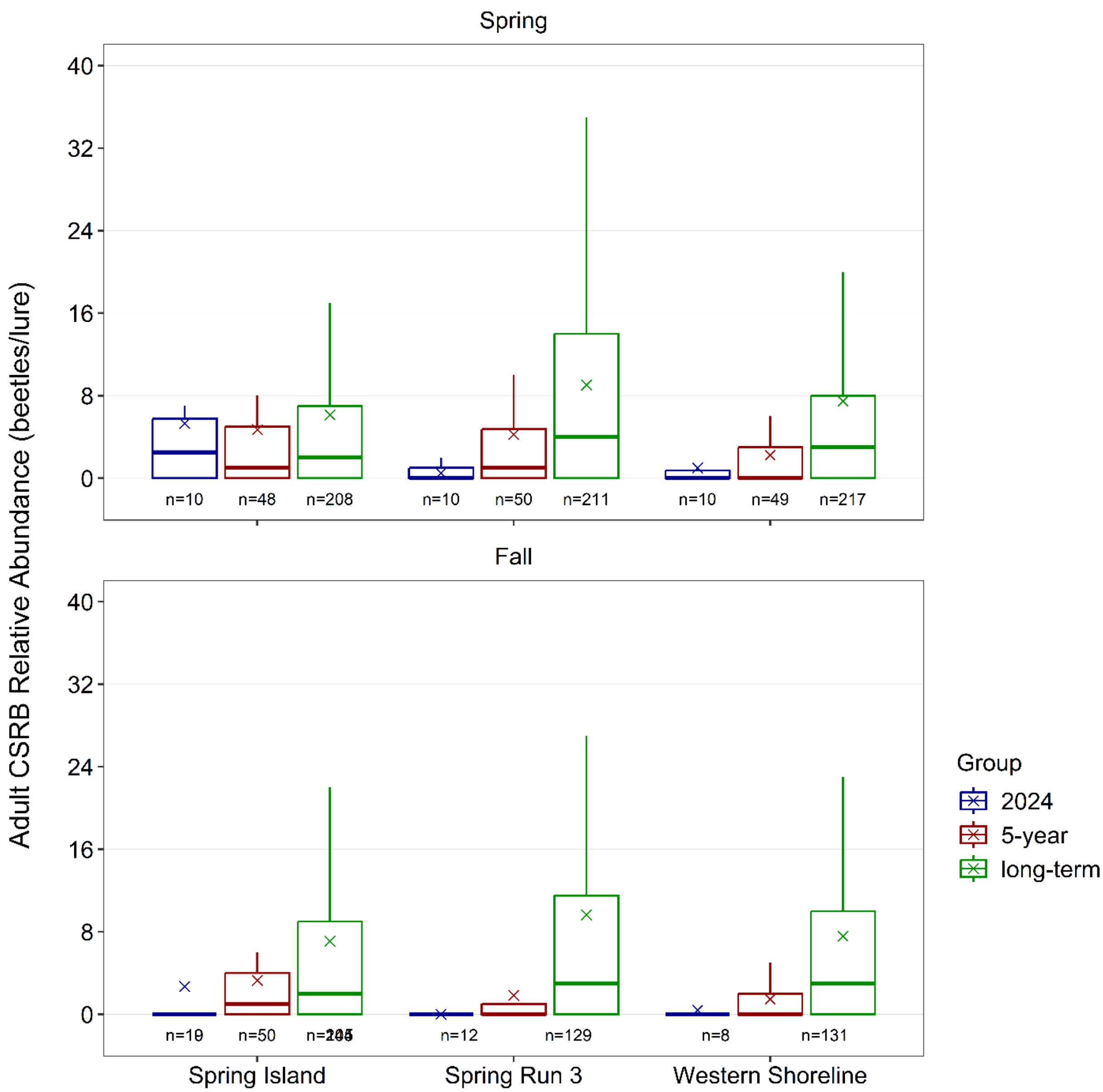

Figure 22. **Boxplots displaying 2024, 5-year (2020–2024), and long-term (2004–2024) trends in adult Comal Springs Riffle Beetle abundance per retrieved lure by season across sites in the Comal Springs. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent the number of lures included in each category.**

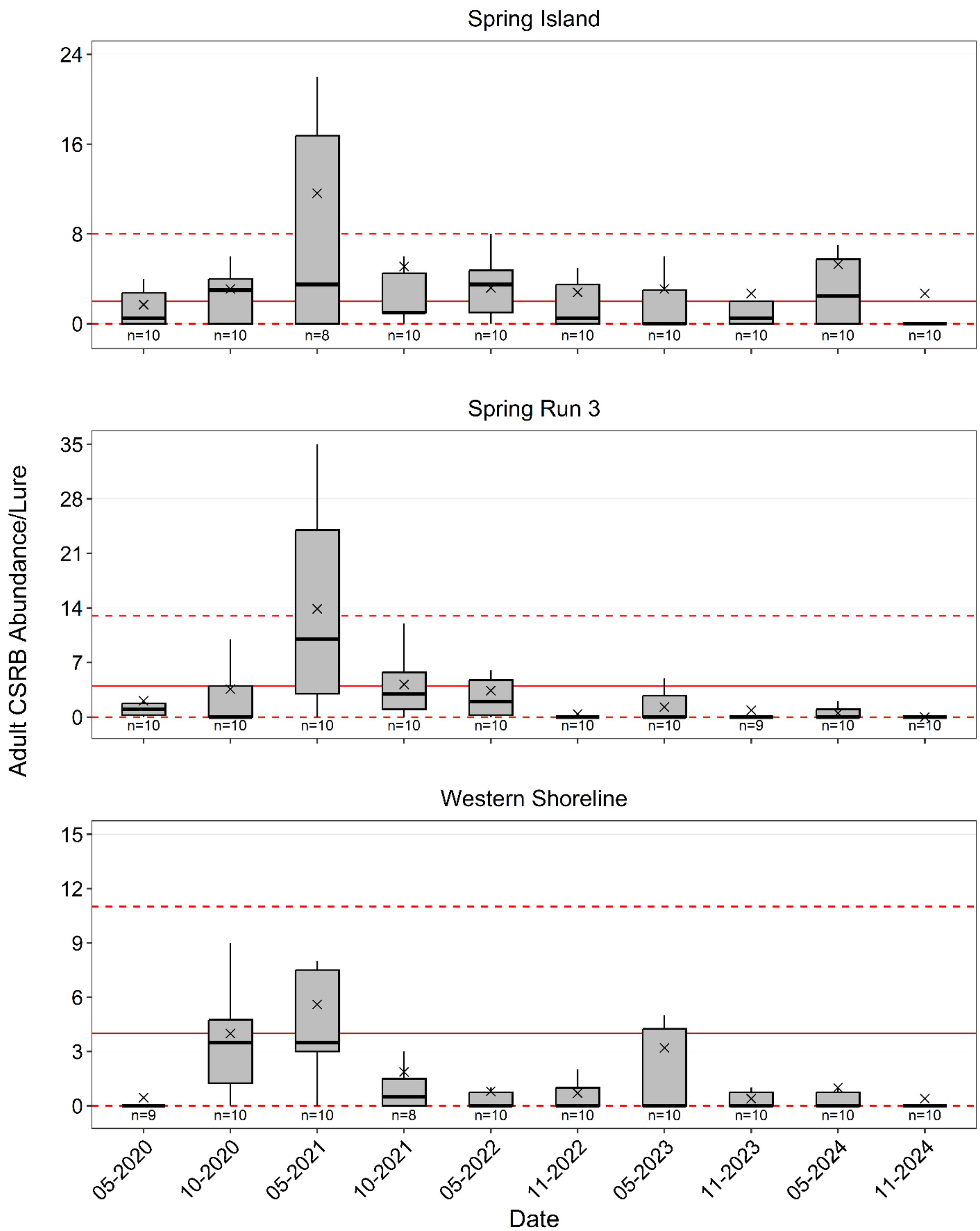

Figure 23. **Boxplots displaying temporal trends in adult CSRB abundance per retrieved lure among study reaches from 2020–2024 during lure sampling in Comal Springs. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent the number of lures in each category. Solid and dashed red lines denote long-term (2004–2024) medians and interquartile ranges, respectively.**

Benthic Macroinvertebrate Rapid Bioassessment

Benthic macroinvertebrate rapid bioassessment data was collected during both the spring and fall sampling events in 2024 (raw data presented in Appendix F). All samples in 2024 consisted of kick samples with suitable cobble-gravel habitat. In addition, organic material was also sampled at each site, either in the form of debris jams or root wads. Cumulative scores and corresponding aquatic-life-use designations are displayed in Figure 24, while metric scores for calculating the B-IBI can be found in Table 6. A total of 828 and 765 individual macroinvertebrates, representing 35 and 44 unique taxa were sampled in spring and fall, respectively. Altogether, 52 unique taxa were represented among all samples from 2024.

Table 6. Metric value scoring ranges for calculating the Texas RBP B-IBI (TCEQ 2014).

METRIC	SCORING CRITERIA			
	4	3	2	1
Taxa richness	>21	15–21	8–14	<8
EPT taxa abundance	>9	7–9	4–6	<4
Biotic index (HBI)	<3.77	3.77–4.52	4.56–5.27	>5.27
% Chironomidae	0.79–4.10	4.11–9.48	9.49–16.19	<0.79 or >16.19
% Dominant taxon	<22.15	22.15–31.01	31.02–39.88	>39.88
% Dominant FFG	<36.50	36.50–45.30	45.31–54.12	>54.12
% Predators	4.73–15.20	15.21–25.67	25.68–36.14	<4.73 or >36.14
Ratio of intolerant: tolerant taxa	>4.79	3.21–4.79	1.63–3.20	<1.63
% of total Trichoptera as Hydropsychidae	<25.50	25.51–50.50	50.51–75.50	>75.50 or no Trichoptera
# of non–insect taxa	>5	4–5	2–3	<2
% Collector–gatherers	8.00–19.23	19.24–30.46	30.47–41.68	<8.00 or >41.68
% of total number as Elmidae	0.88–10.04	10.05–20.08	20.09–30.12	<0.88 or >30.12

Benthic IBI scores ranged from 15 during fall at Landa Lake resulting in "Limited" designation, to 34 during both seasons at New Channel resulting in a "High" designation. Lower scores observed at Upper Spring Run and Landa Lake compared to riverine sites were likely due to differences in mesohabitats available for sampling. Specifically, these communities are naturally different compared to the "least-disturbed reference streams", which contain swifter riffle habitats. As such, higher scores would be expected at riverine sites due to a higher likelihood of supporting more fluvial specialists, resulting in greater taxa diversity overall. It should also be noted that most reference streams do not exhibit the stenothermal conditions present within the Comal Springs/River System and this may result in differing community composition. Based on this, the value of the score is less important in this spring-associated system than the consistency or trends in results per reach over time.

Aquatic-life-use designations in 2024 generally aligned with years prior and indicate stable trends at most reaches (Figure 24). Scores in the New Channel have been very consistent over the past five years, scoring "High" in all but one sampling event. In fall 2024, the Upper Spring Run scored the lowest ("Limited") of any sampling period during the past five years, potentially corresponding to lower water levels and lack of flow in this area exacerbated by the ongoing drought. The Old Channel was described as "Intermediate" for both seasons, with scores similar to 2023 and was generally comparable, although slightly lower, to previous years. Aquatic-life-use at Landa Lake was ranked as "Limited" during both sampling events, maintaining the lower scores typically observed in this reach. Reduced water levels observed in Landa Lake during fall 2022 and fall 2023 might have increased velocity near the substrate in some areas, which in turn supported greater habitat diversity and resulted in higher scores than were observed historically when lake levels were higher, but flows during fall 2024 were perhaps too low to maintain this habitat diversity. The Other Place ranked as "Intermediate" for both seasons with scores notably lower since the drought started in fall 2022. Reduced flows at this riverine reach may have resulted in homogenization of habitats, and thus a reduction in fluvial specialists. Additional monitoring will be needed to see if observed trends continue at Landa Lake and Other Place, as well as to generate a robust reference dataset for the development of scoring criteria specific to this unique ecosystem, providing a more accurate realization of ecological health.

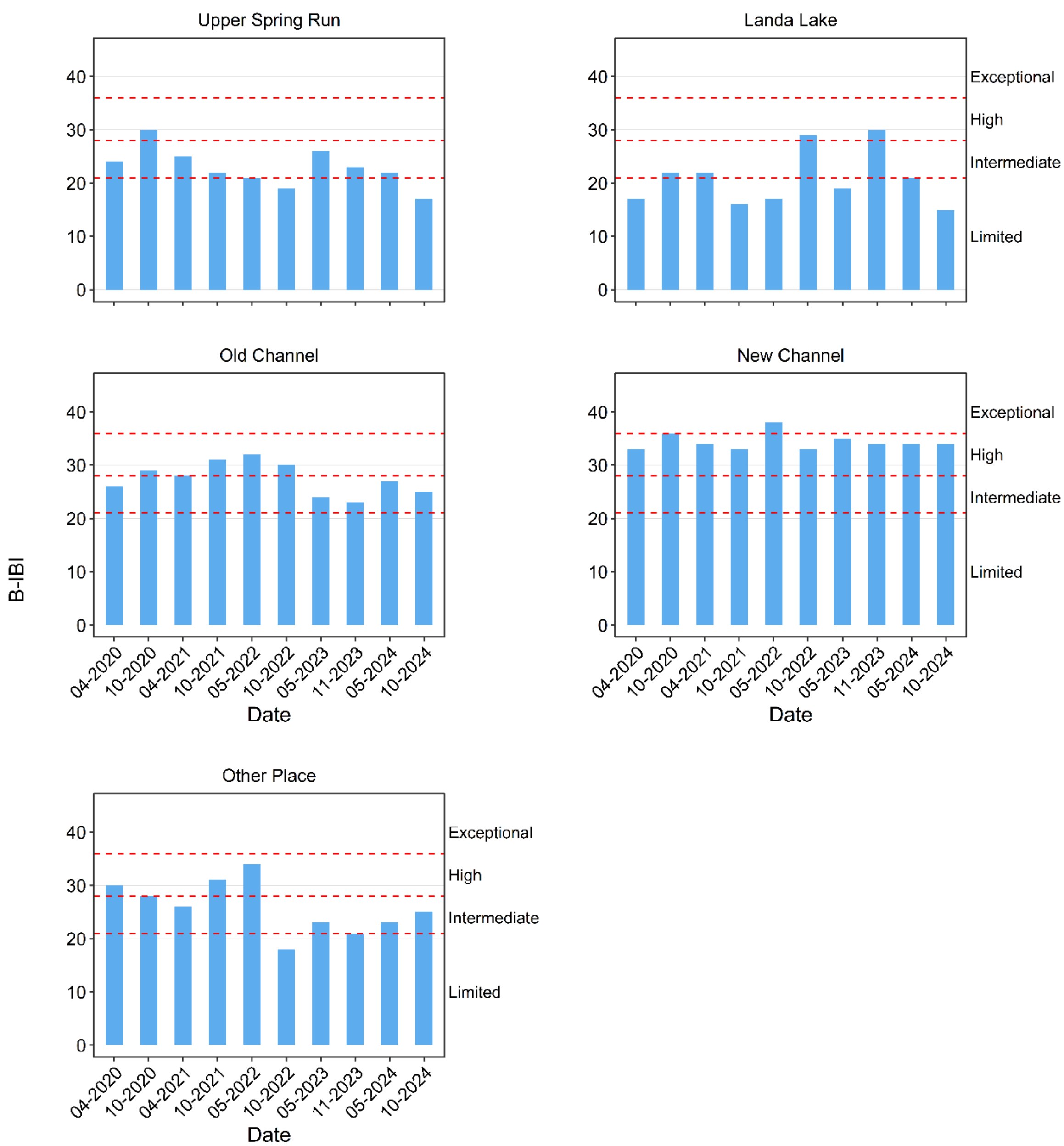

Figure 24. **Benthic macroinvertebrate Index of Biotic Integrity (B-IBI) scores and aquatic-life-use designations from 2020–2024 in the Comal Springs/River.**

CONCLUSION

Results from 2024 biological monitoring in the Comal Springs/River system indicated continued declining trends in discharge from ongoing drought conditions and subsequent declines in some Covered Species population metrics. Median annual mean daily discharge in 2024 (125 cfs) was below 10^{th} percentile flows for all months. Spatial patterns in water temperature fluctuation were typical, with low variation in reaches closer to springs (i.e., Landa Lake) and higher variation at reaches farther from springs (i.e., Other Place). Temperature exceedance of Fountain Darter larval and egg production thresholds increased in frequency and duration throughout the summer. Additionally, atypically larger increases in temperature were observed near Upper Spring Run and Spring Island in association with decreases in discharge.

Degraded habitat conditions were noted at upper spring reaches and spring runs (e.g., Spring Run 1 was dry throughout the summer and fall). Where wetted surface habitat was available for Comal Springs Salamanders, counts and catch rates decreased significantly by fall, except at Spring Island Outfall. Salamander monitoring following previous drought years suggests that Comal Springs Salamanders populations will return to Spring Run 1 and Spring Island Spring Run when surface flows return; however, continued monitoring is necessary to confirm this and document how quickly recolonization occurs. Degraded habitat conditions at upper spring reaches and spring runs also influenced spring macroinvertebrates (i.e., *Stygobromus* sp., Comal Springs Riffle Beetle). Lower riffle beetle counts this year, when compared to historical observations, suggests the current extended drought may have resulted in reduced abundance. However, subsurface migration of both salamanders and riffle beetles may yield reductions in counts that are not accurate representations of true population abundance. For Comal Springs Riffle Beetle, a separate population assessment is being completed to gain a greater understanding of population dynamics.

Vegetation mapping demonstrated that seasonal patterns in total aquatic vegetation coverage varied spatially. Coverages at Upper Spring Run and both New Channel reaches were higher than long-term averages in spring and fall; whereas, coverages at Landa Lake and Old Channel were lower than expected. Habitat suitability indices at Landa Lake and Old Channel remained below long-term averages which was likely due to reductions in bryophytes and *Cabomba* coverage. Despite lower OHSI for Fountain Darters in these reaches, Fountain Darter densities were higher than expected until fall. Declines in Fountain Darter densities by fall in the Old Channel were attributed reductions in quality habitat, as bryophytes were greatly reduced and only one small patch of *Cabomba* remained. Despite higher vegetation coverages at Upper Spring Run and the New Channel, degraded Fountain Darter populations were apparent by fall. Much of the increased vegetation was due to expansion of *Chara* (Upper Spring Run) or *Hygrophila* (Upper New Channel), which alone do not provide optimal Fountain Darter habitat. Population impacts in these reaches were likely influenced by greater variability in environmental conditions, including decreased bryophyte coverage, and potentially larger and more frequent exceedances of reproductive temperature thresholds due to reduced springflow. Overall lower densities and occurrence rates observed in fall 2024 indicate potential negative effects of extended periods of low flow in Comal Springs.

Evidence of detectable temporal trends in fish communities varied among the selected metrics, as well as between and within study segments. Species richness and diversity were typically higher in riverine areas and lowest at Landa Lake. Five-year trends in species richness usually varied among events and displayed no detectable patterns. Relative density of spring fishes remained consistently high and varied substantially less at Landa Lake than other segments. Abrupt declines in relative density of spring fishes in the fall at New Channel may be influenced by prolonged periods of low flow with no flow pulses. Temporal trends in richness of spring-associated fishes were congruent with community-level observations and generally stable throughout the study area.

In summary, 2024 biological monitoring provided insights into the current condition of the EAHCP Covered Species in the Comal Springs/River System, and documented important flow-ecology relationships driving population dynamics. Results indicated variability in aquatic habitat conditions among reaches and resulting reductions in population metrics of multiple Covered Species. Overall, declines in system stability have become more apparent after two consecutive years of extremely low flows. Historical data indicates that ecological conditions will likely improve when typical flows return. Subsequent monitoring efforts will provide opportunities to better understand the dynamics of this complex ecological system and how it responds to future hydrologic conditions.

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APPENDIX A: CRITICAL PERIOD MONITORING SCHEDULES

COMAL RIVER/SPRINGS
Critical Period Low-Flow Sampling – Schedule and Parameters

FLOW TRIGGER (+ or - 10 cfs)	**PARAMETERS**
200 cfs	Full Sampling Event
150 cfs	Full Sampling Event
120 - 80 cfs	Riffle Beetles and spring discharge – Every 10 cfs decline (maximum weekly)
100 cfs	Full Sampling Event
100 - 50 cfs	Habitat Evaluations - Every 10 cfs decline (maximum weekly)
50 cfs	Full Sampling Event
50 - 0 cfs	Habitat Evaluations - Every 10 cfs decline (maximum weekly)
10 - 0 cfs	Full Sampling Event
RECOVERY	
25 - 100 cfs	Full Sampling Event (dependent on flow stabilization)
100 - 200 cfs	Full Sampling Event (dependent on flow stabilization)

PARAMETER DESCRIPTION

Full Sampling Event	Aquatic Vegetation Mapping Fountain Darter Sampling Drop Net, Dip net (Presence/Absence), and Visual Parasite evaluations Fish Community Sampling Salamander Sampling - Visual Riffle Beetle – Cotton lure sampling Fish Sampling - Exotics/Predation (100 cfs and below) Water Quality - Suite I and Suite II
Riffle Beetle Monitoring	Spring discharge and wetted perimeter measurements
Habitat Evaluations	Photographs

COMAL RIVER/SPRINGS
Species-Specific Triggered Sampling

FLOW RATE (+ or - 5 cfs)	SPECIES	FREQUENCY	PARAMETERS
≤150 or ≥80 cfs	Fountain Darter	Every other month	Aquatic vegetation mapping to include Upper Spring Run reach, Landa Lake, Old Channel reach, and New Channel reach
≤150 or ≥80 cfs	Fountain Darter	Every other month	Conduct Dip net sampling/visual parasite evaluations at five (5) sites in the Upper Spring Reach; twenty (20) sites in Landa Lake; twenty (20) sites in the Old Channel reach and; at five (5) sites in the New Channel reach.
≤60 cfs	Fountain Darter	Weekly	Conduct Dip net sampling/visual parasite evaluations at five (5) sites in the Upper Spring Reach; twenty (20) sites in Landa Lake; twenty (20) sites in the Old Channel reach and; at five (5) sites in the New Channel reach.
≤60 cfs	Fountain Darter	Monthly	Aquatic vegetation mapping at Upper Spring Run reach, Landa Lake, Old Channel reach, and New Channel reach
≤120 cfs	Comal Springs Riffle Beetle	Every 2 weeks	Monitoring via cotton lures at Spring Run 3, western shore of Landa Lake, and Spring Island upwelling
≤120 cfs or ≥80 cfs	Comal Springs Salamander	Every other week	Salamander snorkel surveys will be conducted at three sites (Spring Runs 1 and 3 and the Spring Island area)
≤80 cfs	Comal Springs Salamander	Weekly	Salamander snorkel surveys will be conducted at three sites (Spring Runs 1 and 3 and the Spring Island area)

APPENDIX B: LOW-FLOW CRITICAL PERIOD WATER QUALITY SAMPING

Water Quality Sampling Results

Table B1. **Water quality sampling at select stations during Low-flow Critical Period Monitoring in July 2024. Measurements were taken at the middle of the water-column.**

Site	Date	Time	Temp (°C)	SpCond (µs/cm)	pH	D.O. (mg/L)	Depth (ft)	Velocity (ft/s)	Weather Conditions
Blieder's Creek	2024-07-02	8:16	28.5	594	7.54	6.81	1.7	0.00	Sunny, 79(F), clear water
Heidelberg Main Channel	2024-07-02	8:29	24.9	606	7.17	4.00	2.3	0.01	Sunny, 80(F), clear water
Island Park Far	2024-07-02	8:47	24.4	607	7.23	5.72	1.5	0.09	Sunny, 81(F), clear water
Island Park Near	2024-07-02	8:54	23.9	604	7.18	4.64	3.7	0.12	Sunny, 81(F), clear water
Landa Lake	2024-07-02	9:49	24.2	604	7.22	5.97	1.9	0.58	Sunny, 84(F), clear water
Spring Run 3	2024-07-02	9:56	23.8	606	7.26	5.53	0.3	0.80	Sunny, 85(F), clear water
Spring Run 2	2024-07-02	9:27	23.7	606	7.20	4.87	1.1	0.03	Sunny, 83(F), clear water
Spring Run 1	2024-07-02	9:17	24.2	601	7.49	6.49	1.0	0.03	Sunny, 83(F), clear water
SR1-SR2 Confluence	2024-07-02	9:39	24.3	606	7.46	6.26	1.1	0.05	Sunny, 84(F), clear water
Old Channel Upstream	2024-07-02	10:13	24.2	604	7.30	5.29	3.9	0.63	Sunny, 86(F), clear water
Old Channel Downstream	2024-07-02	10:31	24.7	603	7.50	7.72	2.5	0.85	Sunny, 87(F), clear water
New Channel Upstream	2024-07-02	10:47	24.6	606	7.64	7.22	1.3	1.57	Sunny, 88(F), clear water
New Channel Downstream	2024-07-02	10:55	25.3	604	7.64	7.63	4.9	0.01	Sunny, 88(F), clear water

Table B2. **Lab results from water quality grab samples collected at select stations during Low-flow Critical Period Monitoring on July 2, 2024. The unit for each parameter is milligrams per liter (mg/L). ND for each parameters denotes that it was not detectable.**

Site	Nitrate as N	Total N	Ammonia	Total P	Alkalinity	Total Suspended Solids
Blieder's Creek	0.967	ND	0.066	0.0107	237	10.9
Heidelberg Main Channel	1.52	1.52	0.044	ND	237	1.16
Island Park Far	1.65	1.65	ND	ND	245	ND
Island Park Near	1.74	1.74	ND	ND	244	ND
Landa Lake	1.73	1.73	ND	ND	246	ND
Spring Run 3	1.66	1.66	0.042	ND	242	ND
Spring Run 2	1.64	1.64	ND	ND	238	8
Spring Run 1	1.53	1.53	0.043	ND	240	1.16
New Channel Upstream	1.47	1.47	ND	ND	242	ND
Old Channel Upstream	1.41	1.41	ND	ND	236	1.89
Old Channel Downstream	1.4	1.4	ND	ND	244	3.05
New Channel Downstream	1.57	1.57	0.047	ND	239	7.68

APPENDIX C: AQUATIC VEGETATION MAPS

Long-term Biological Goals Study Reaches

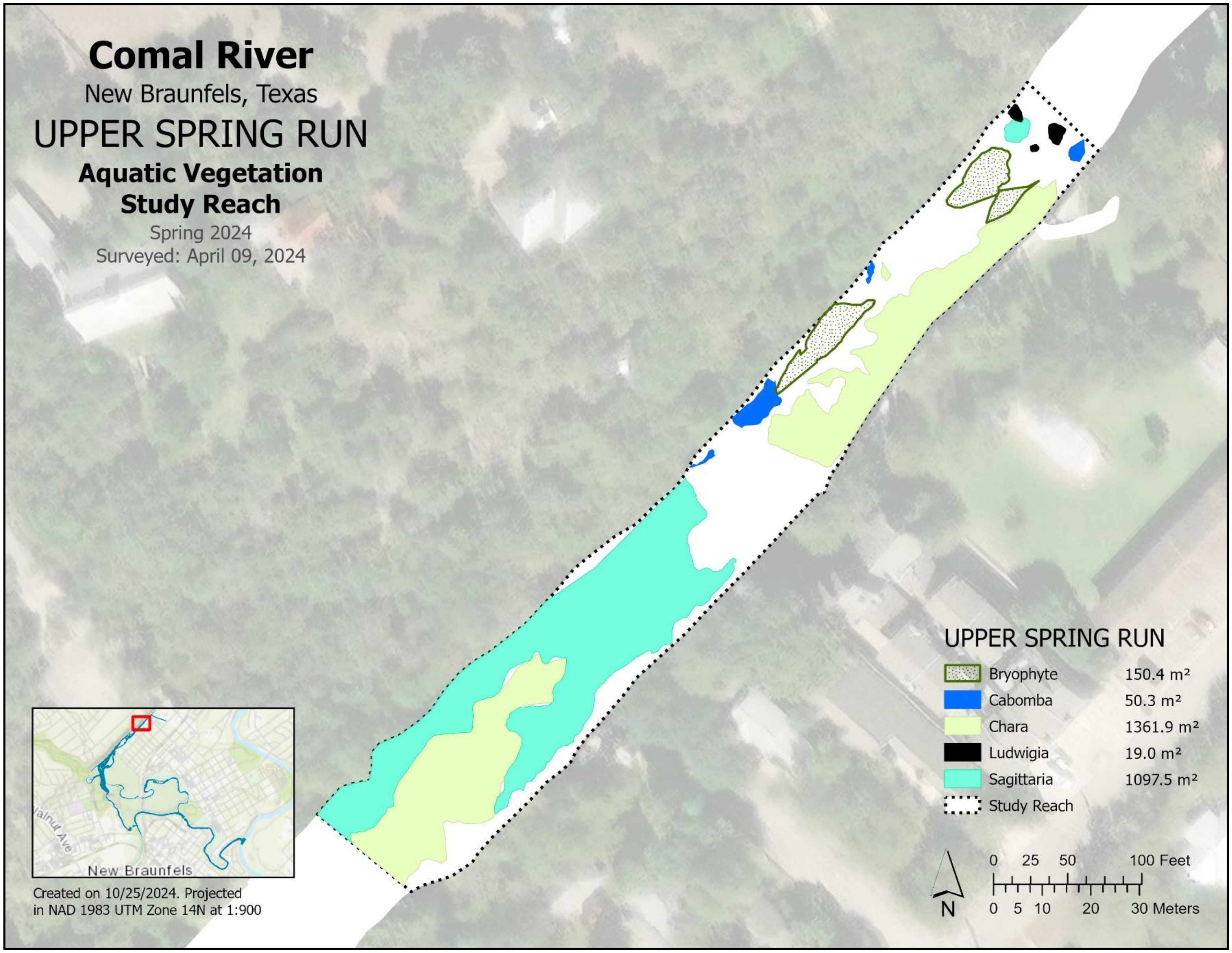

Figure C1. Map of aquatic vegetation coverage at Upper Spring Run Study Reach in spring 2024.

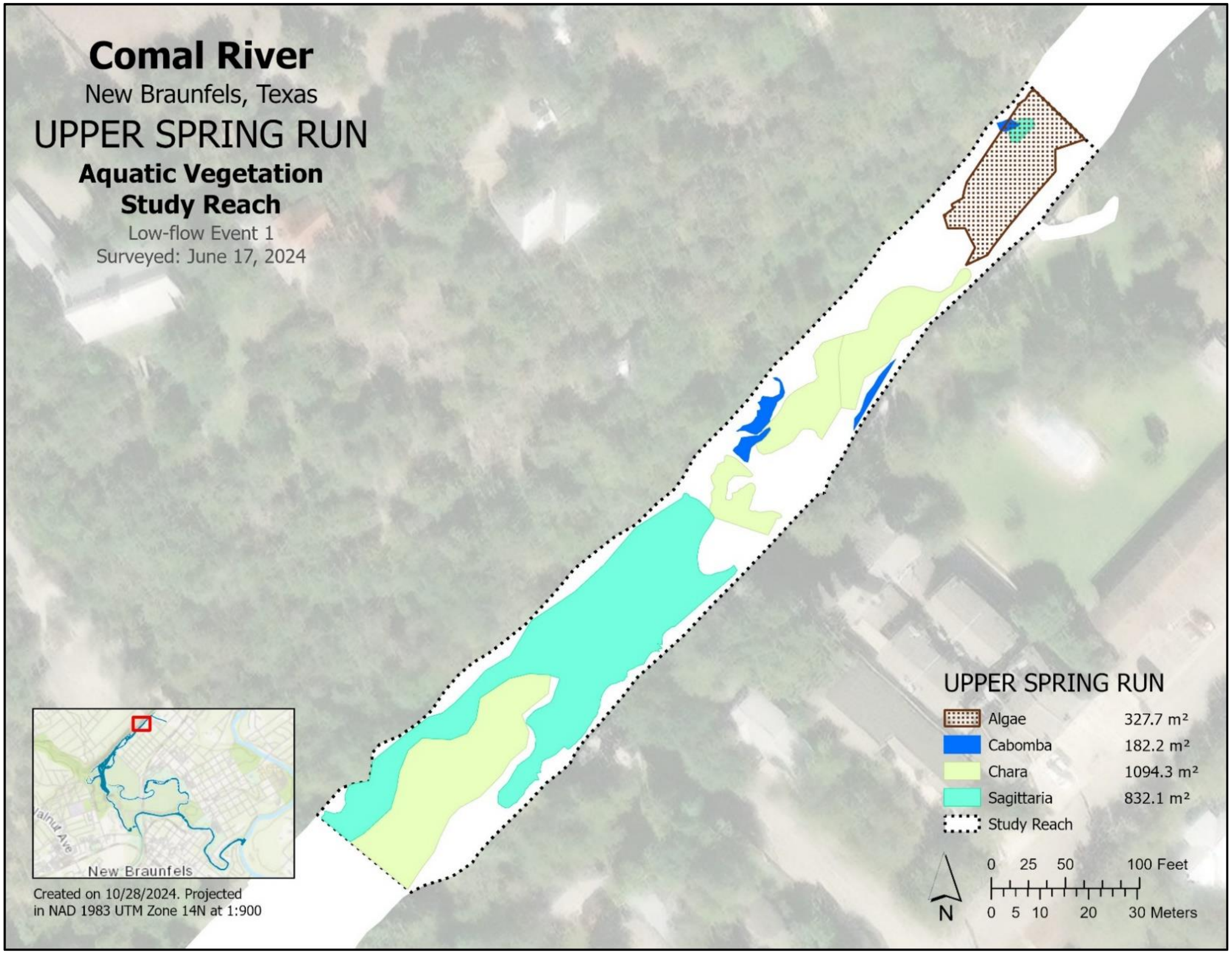

Figure C2. **Map of aquatic vegetation coverage at Upper Spring Run Study Reach in summer 2024 during the first Critical Period low-flow sampling event (June).**

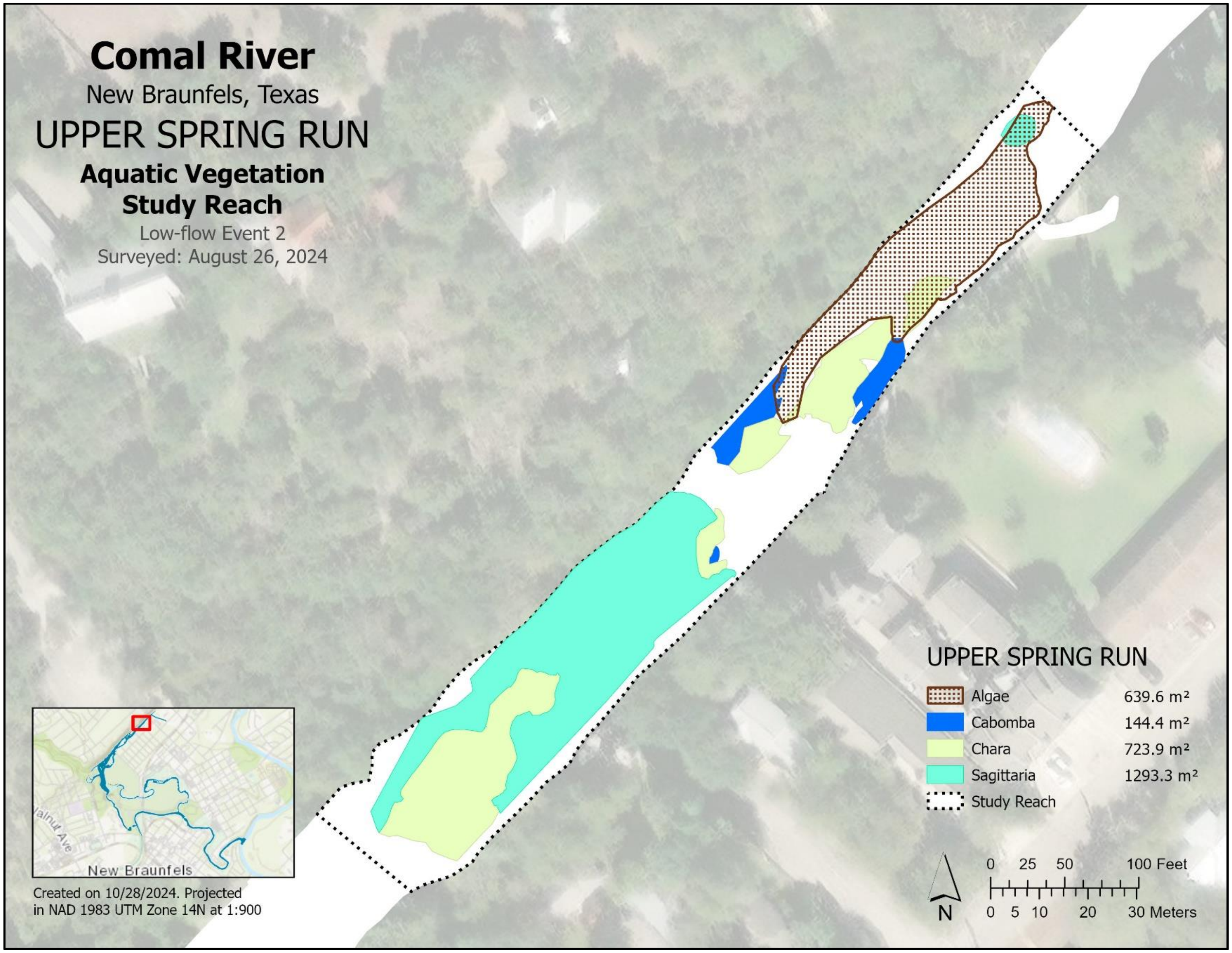

Figure C3. **Map of aquatic vegetation coverage at Upper Spring Run Study Reach in summer 2024 during the second low-flow sampling event (August).**

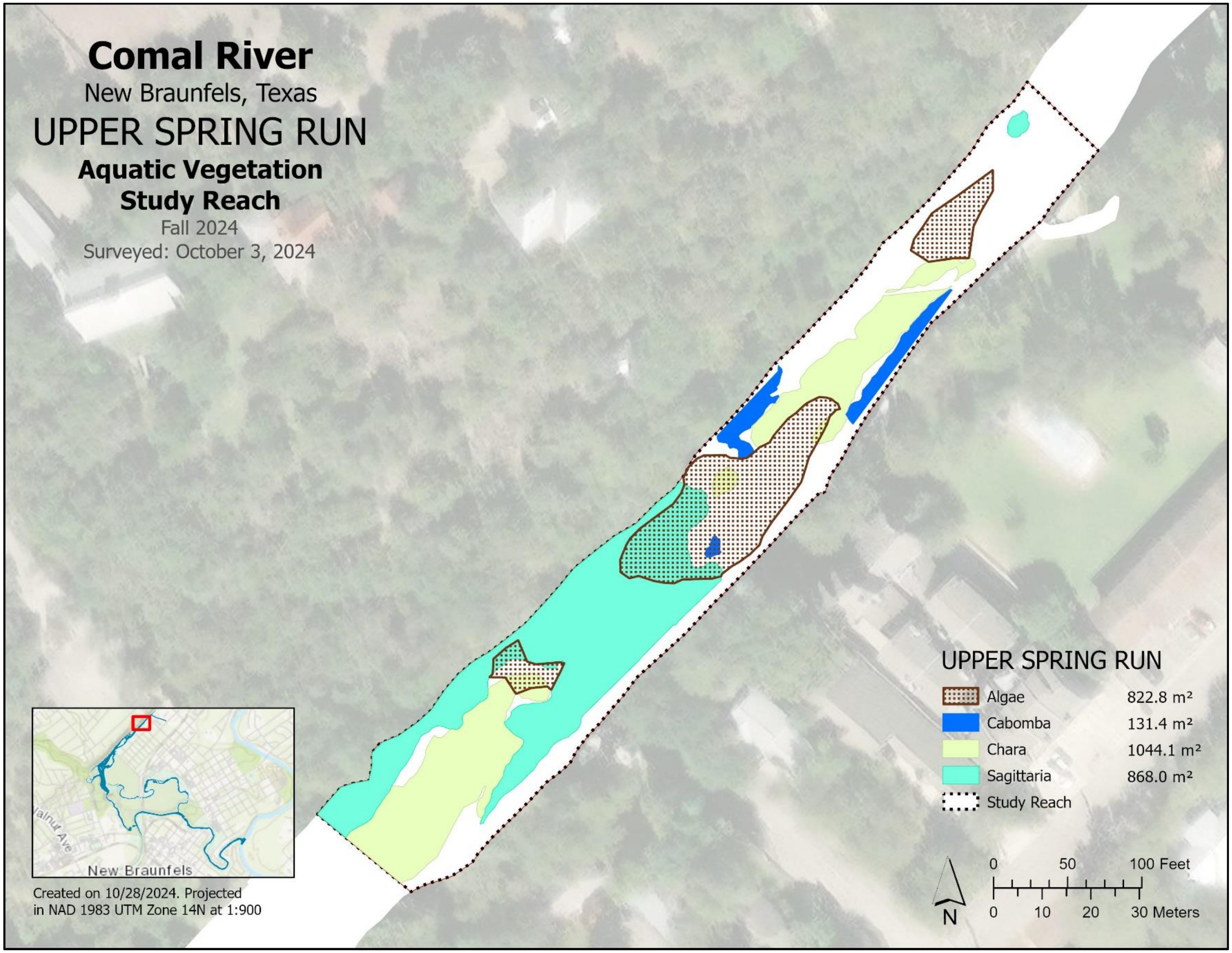

Figure C4. Map of aquatic vegetation coverage at Upper Spring Run Study Reach in fall 2024.

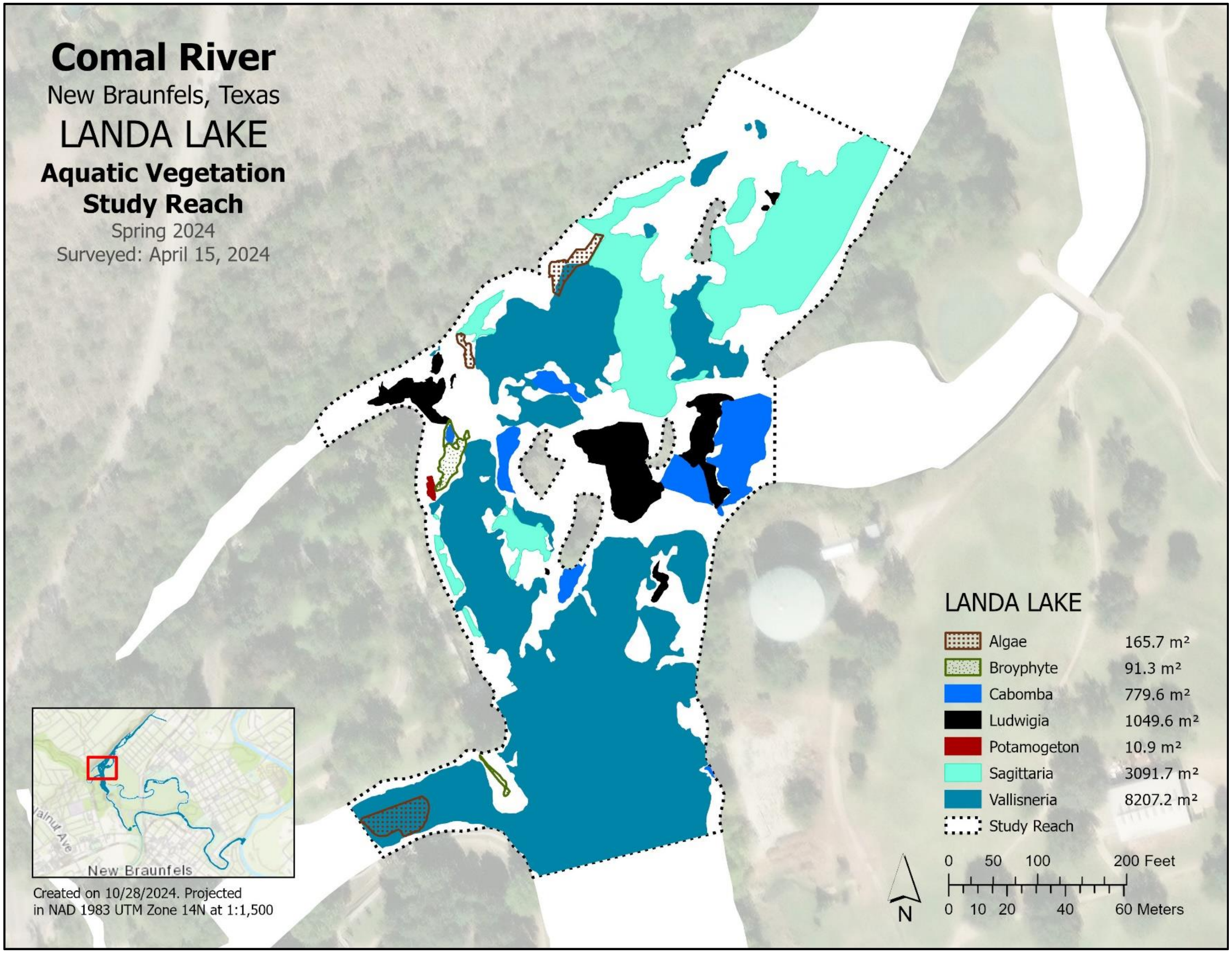

Figure C5. Map of aquatic vegetation coverage at Landa Lake Study Reach in spring 2024.

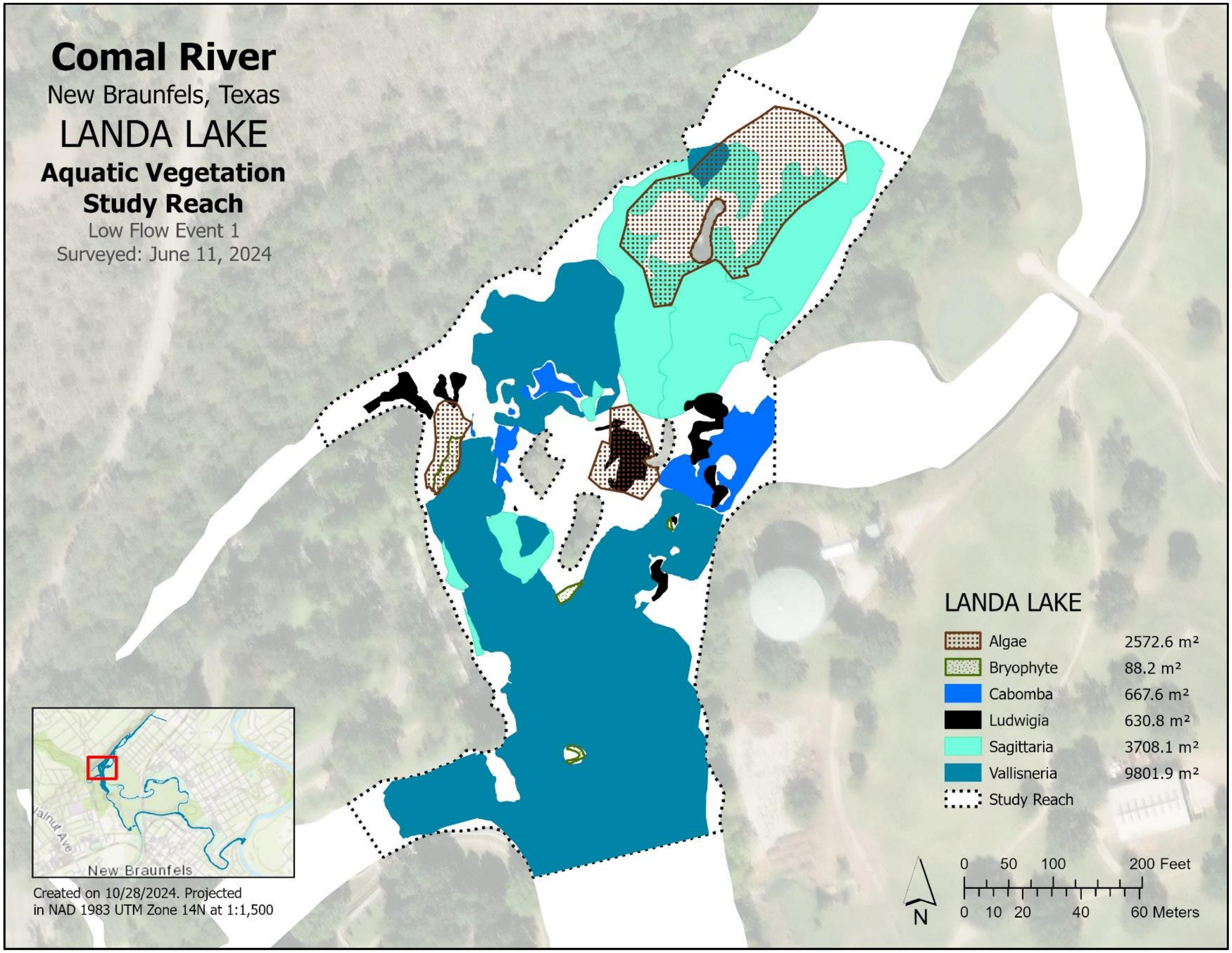

Figure C6. Map of aquatic vegetation coverage at Landa Lake Study Reach in summer 2024 during the first Critical Period low-flow sampling event (June).

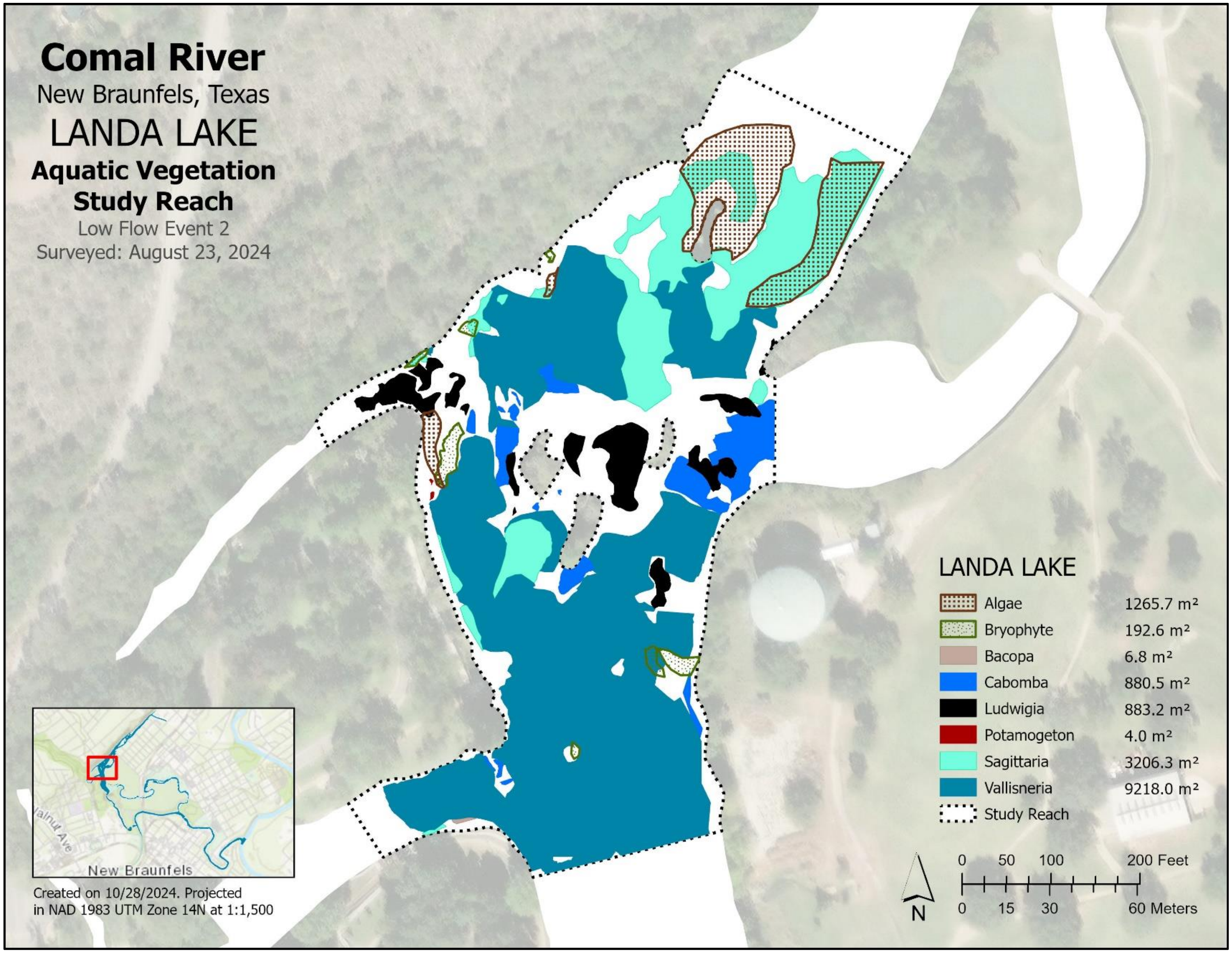

Figure C7. **Map of aquatic vegetation coverage at Landa Lake Study Reach in summer 2024 during the second low-flow sampling event (August).**

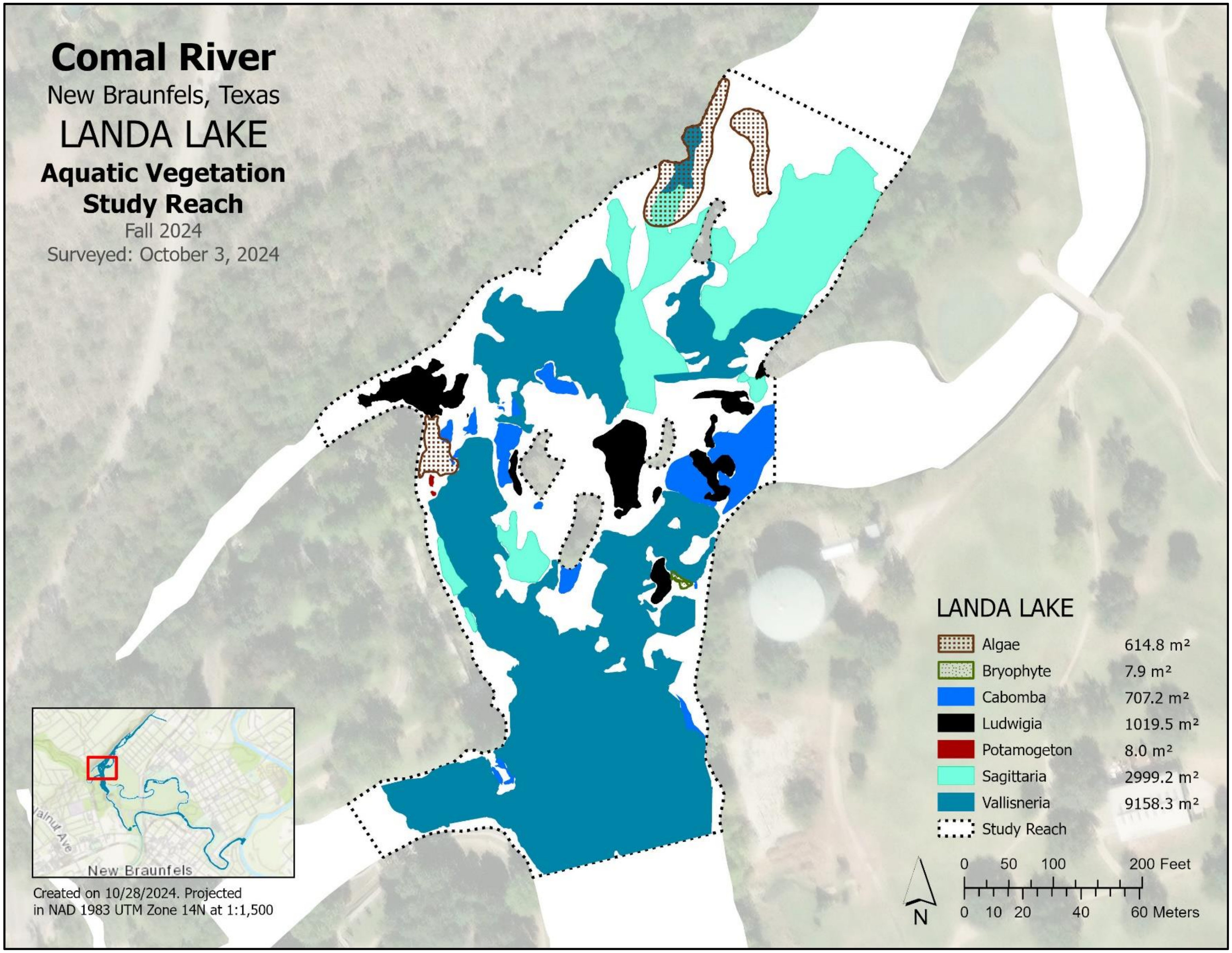

Figure C8. Map of aquatic vegetation coverage at Landa Lake Study Reach in fall 2024.

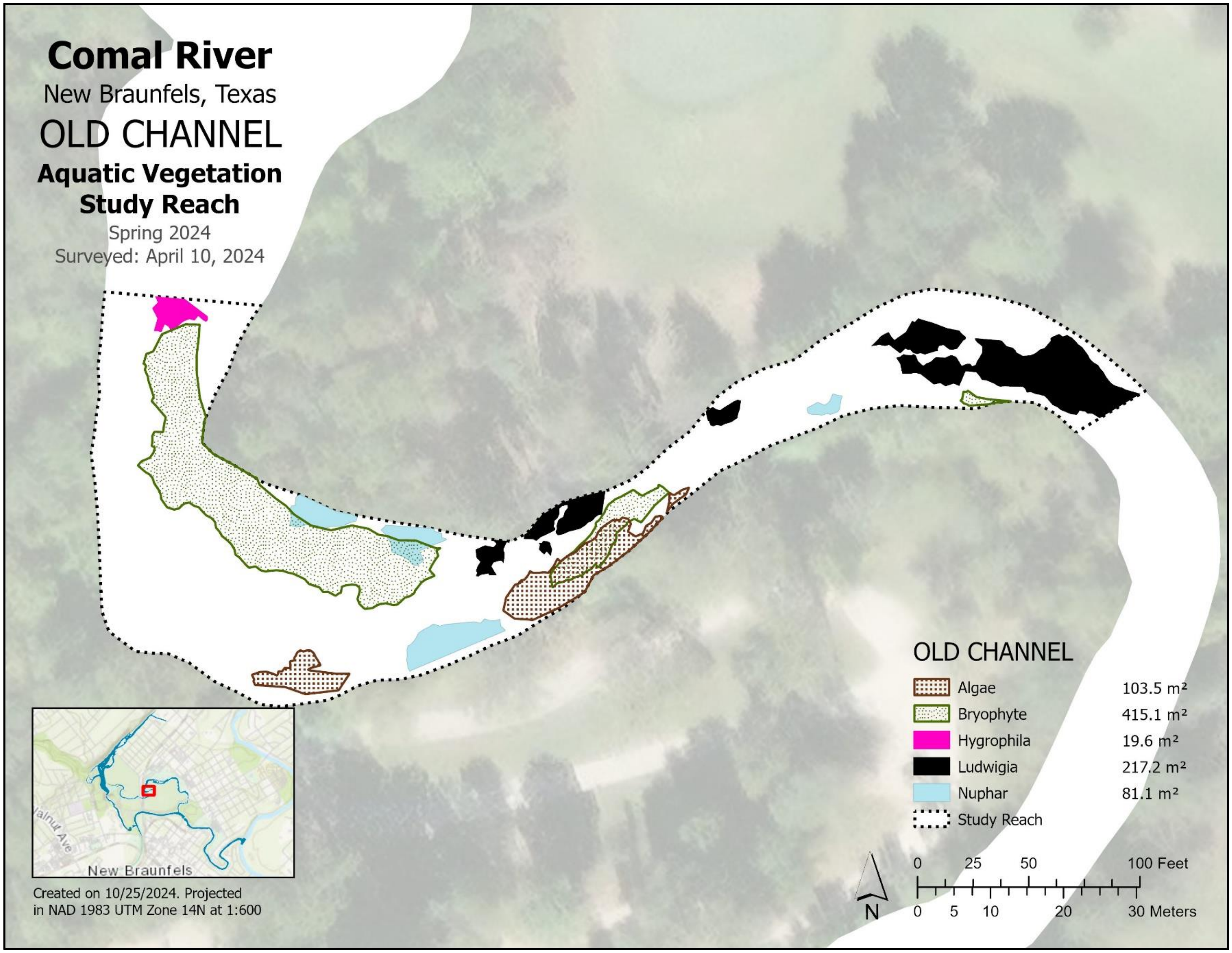

Figure C9. Map of aquatic vegetation coverage at Old Channel Study Reach in spring 2024.

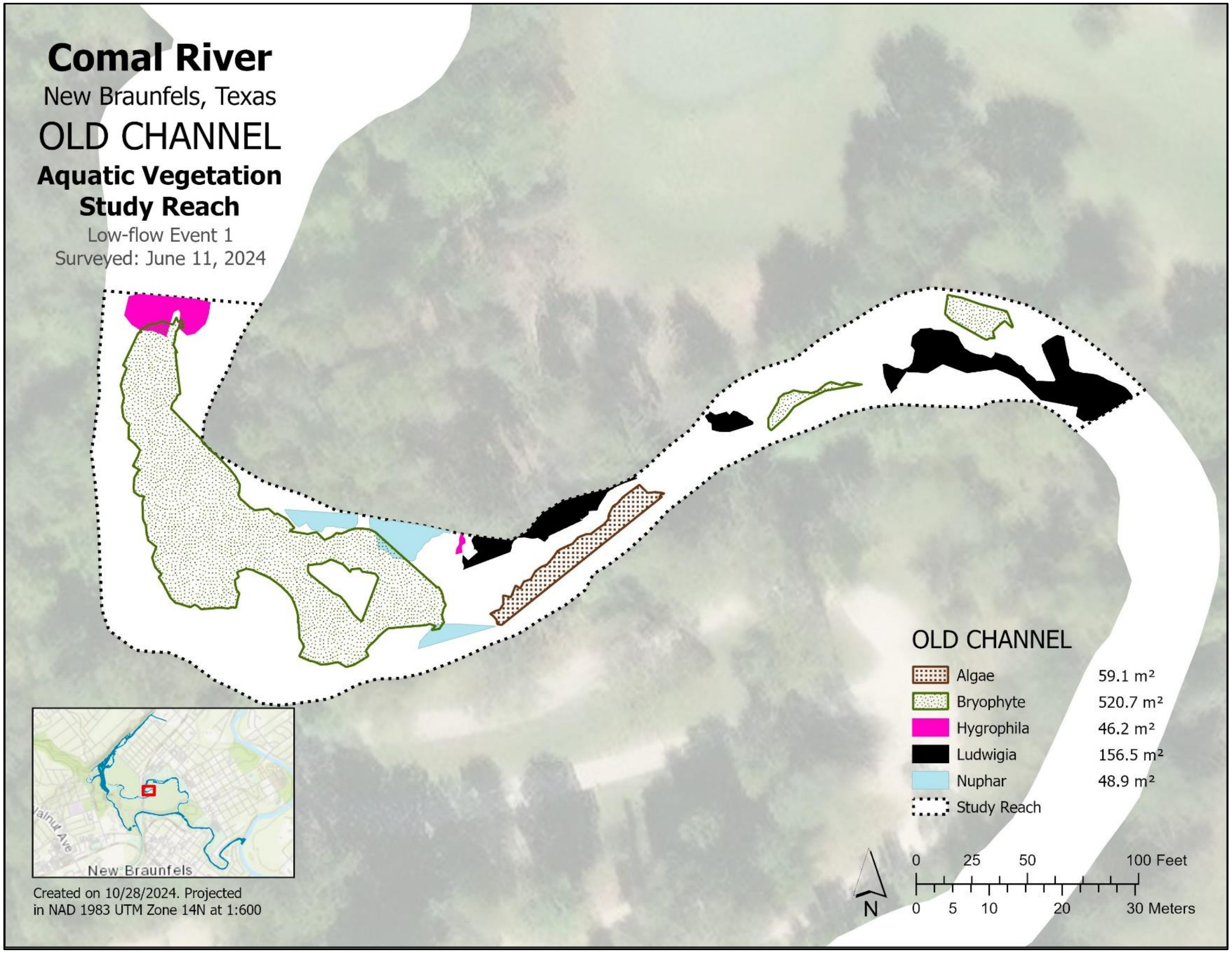

Figure C10. Map of aquatic vegetation coverage at Older Channel Reach in summer 2024 during the first Critical Period low-flow sampling event (June).

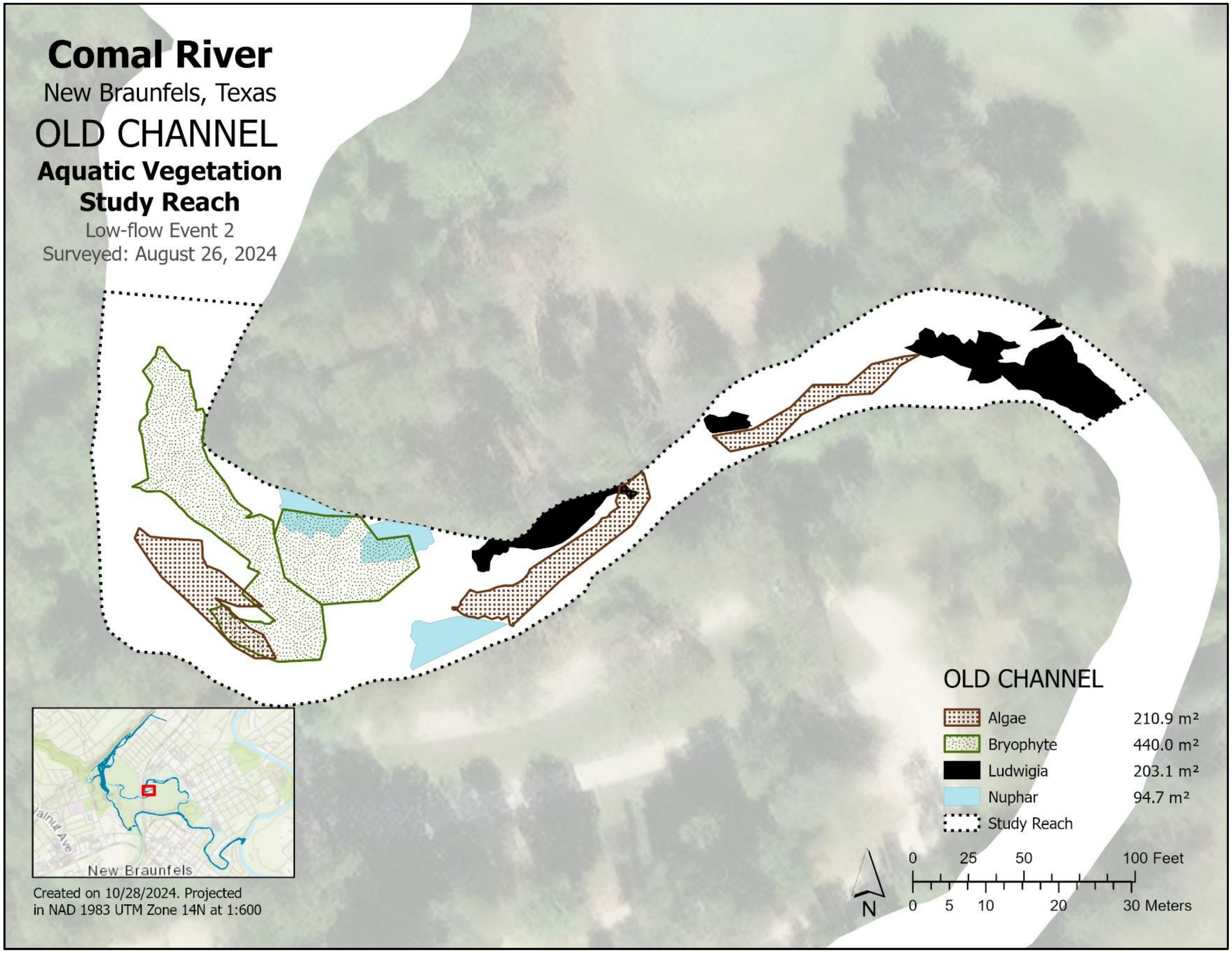

Figure C11. Map of aquatic vegetation coverage at Old Channel Study Reach in summer 2024 during the second low-flow sampling event (August).

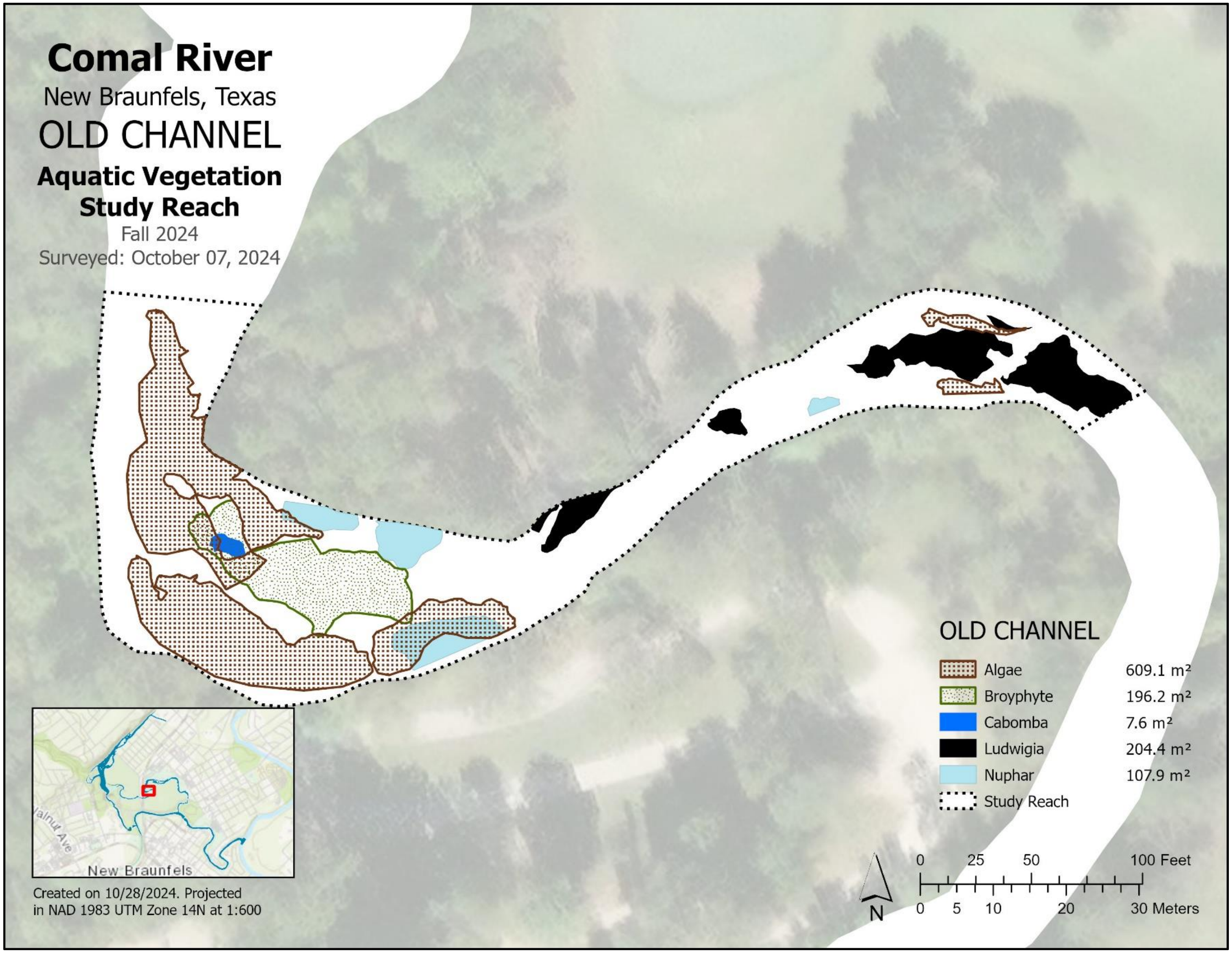

Figure C12. Map of aquatic vegetation coverage at Old Channel Study Reach in fall 2024.

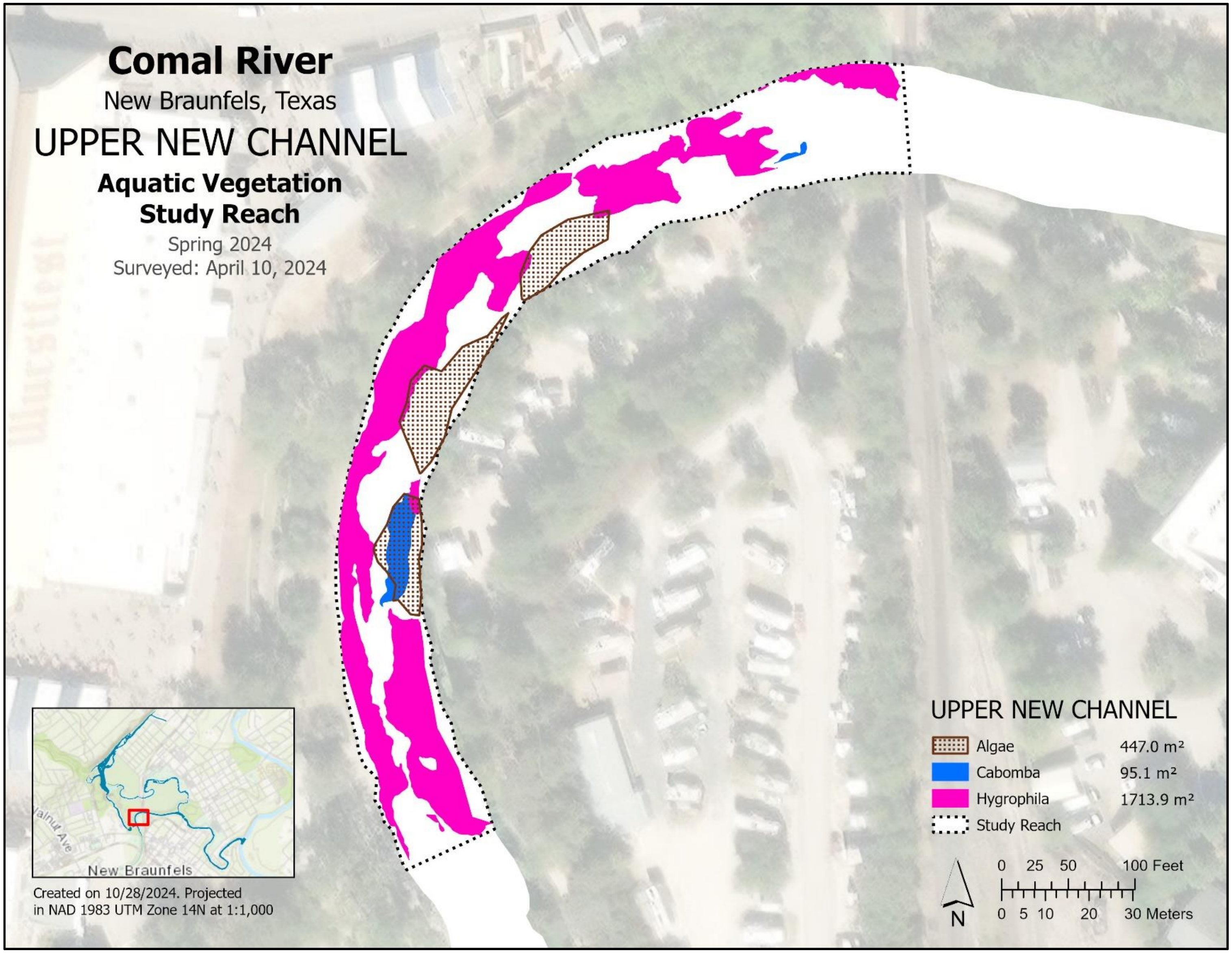

Figure C13. Map of aquatic vegetation coverage at Upper New Channel Study Reach in spring 2024.

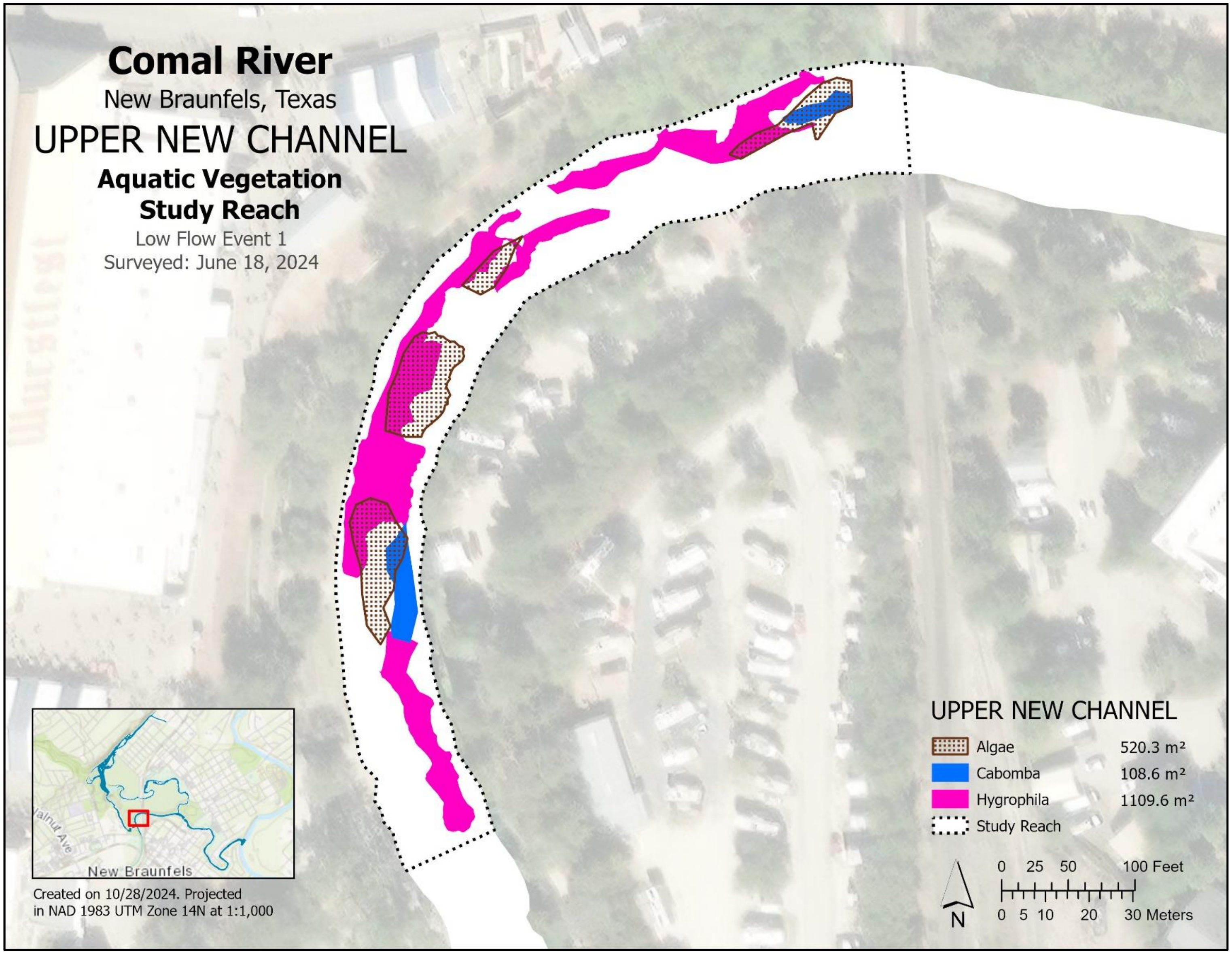

Figure C14. Map of aquatic vegetation coverage at Upper New Channel in summer 2024 during the first Critical Period low-flow sampling event (June).

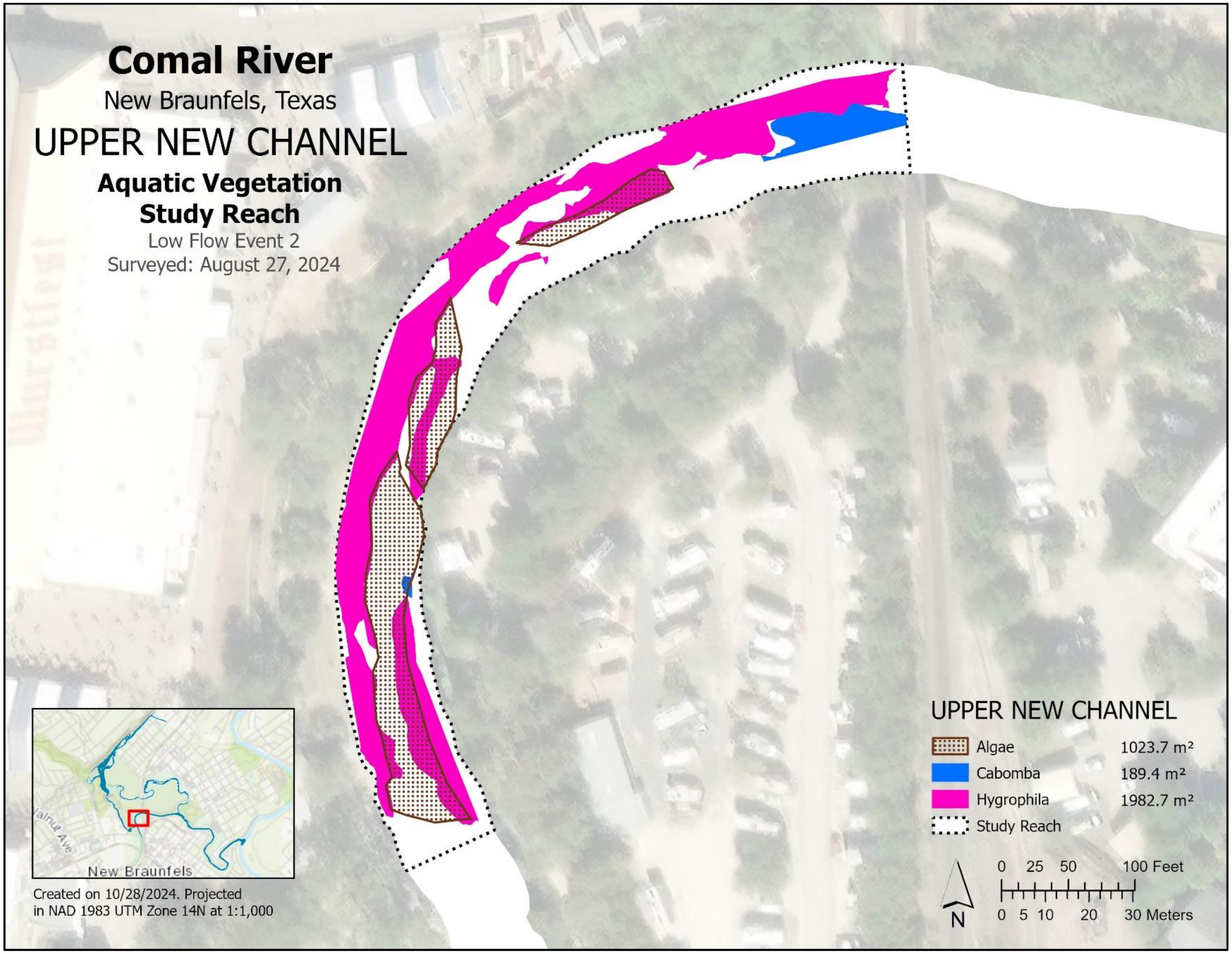

Figure C15. Map of aquatic vegetation coverage at Upper New Channel Study Reach in summer 2024 during the second low-flow sampling event (August).

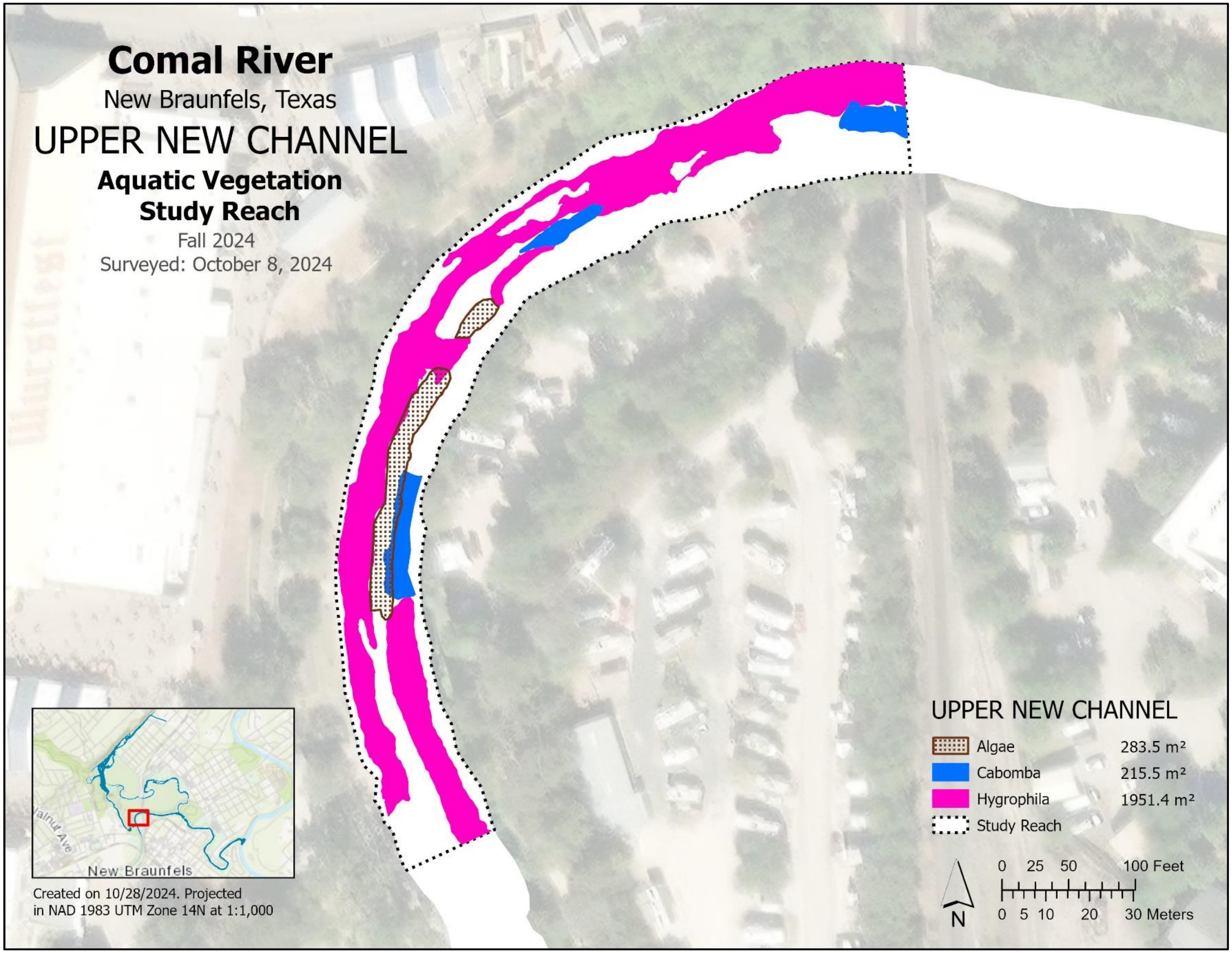

Figure C16. Map of aquatic vegetation coverage at Upper New Channel Study Reach in fall 2024.

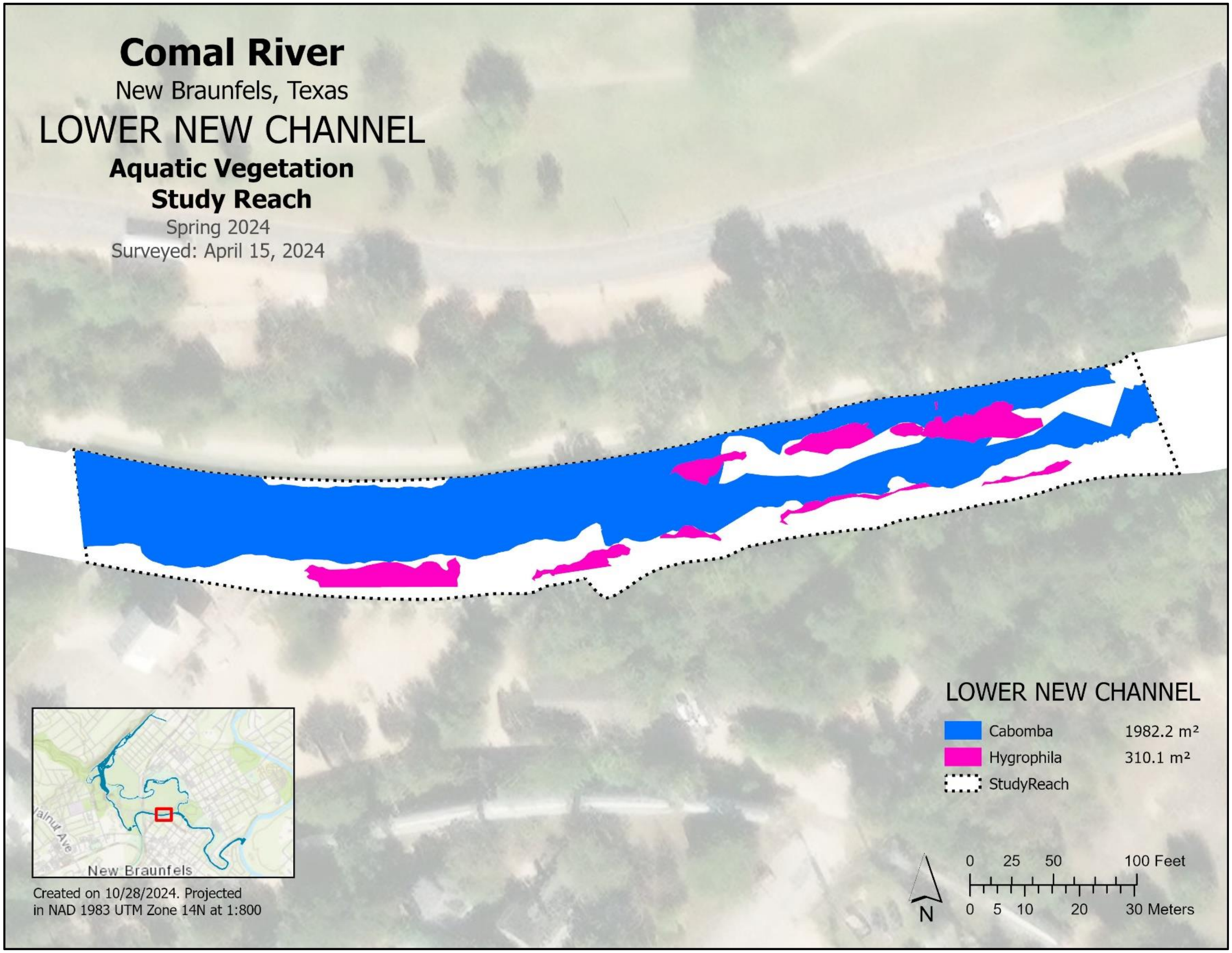

Figure C17. Map of aquatic vegetation coverage at Lower New Channel Study Reach in spring 2024.

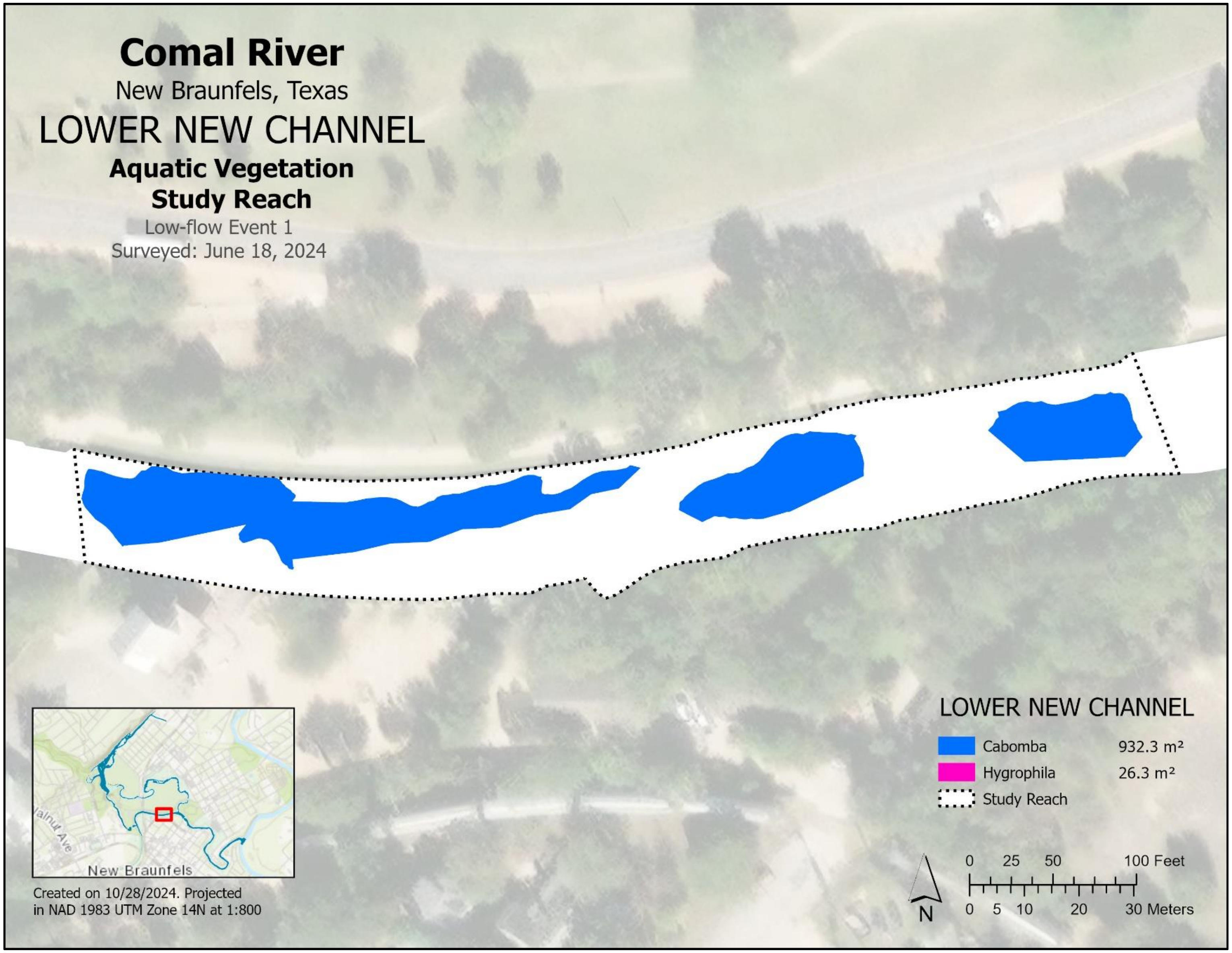

Figure C18. Map of aquatic vegetation coverage at Lower New Channel in summer 2024 during the first Critical Period low-flow sampling event (June).

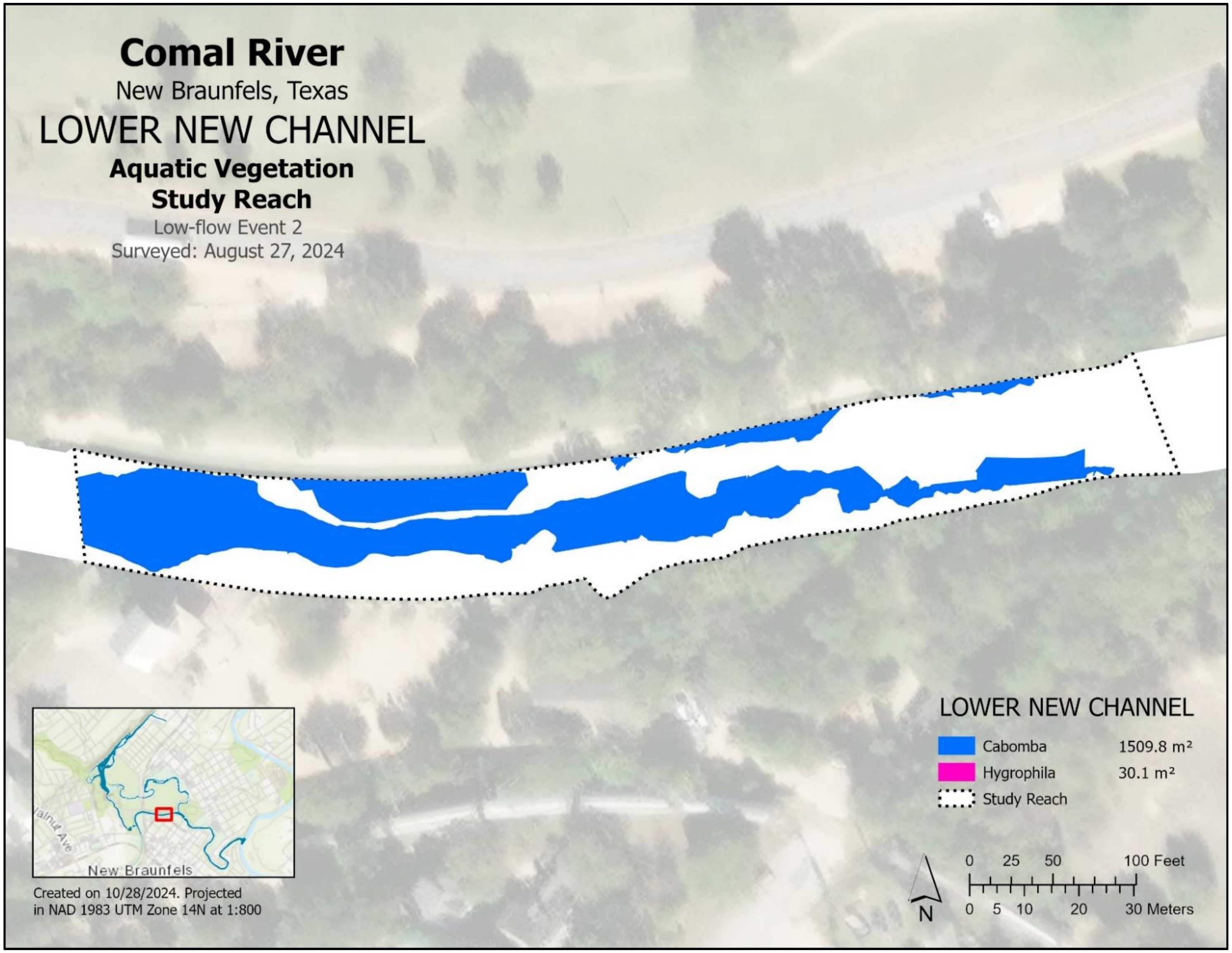

Figure C19. Map of aquatic vegetation coverage at Lower New Channel Study Reach in summer 2024 during the second low-flow sampling event (August).

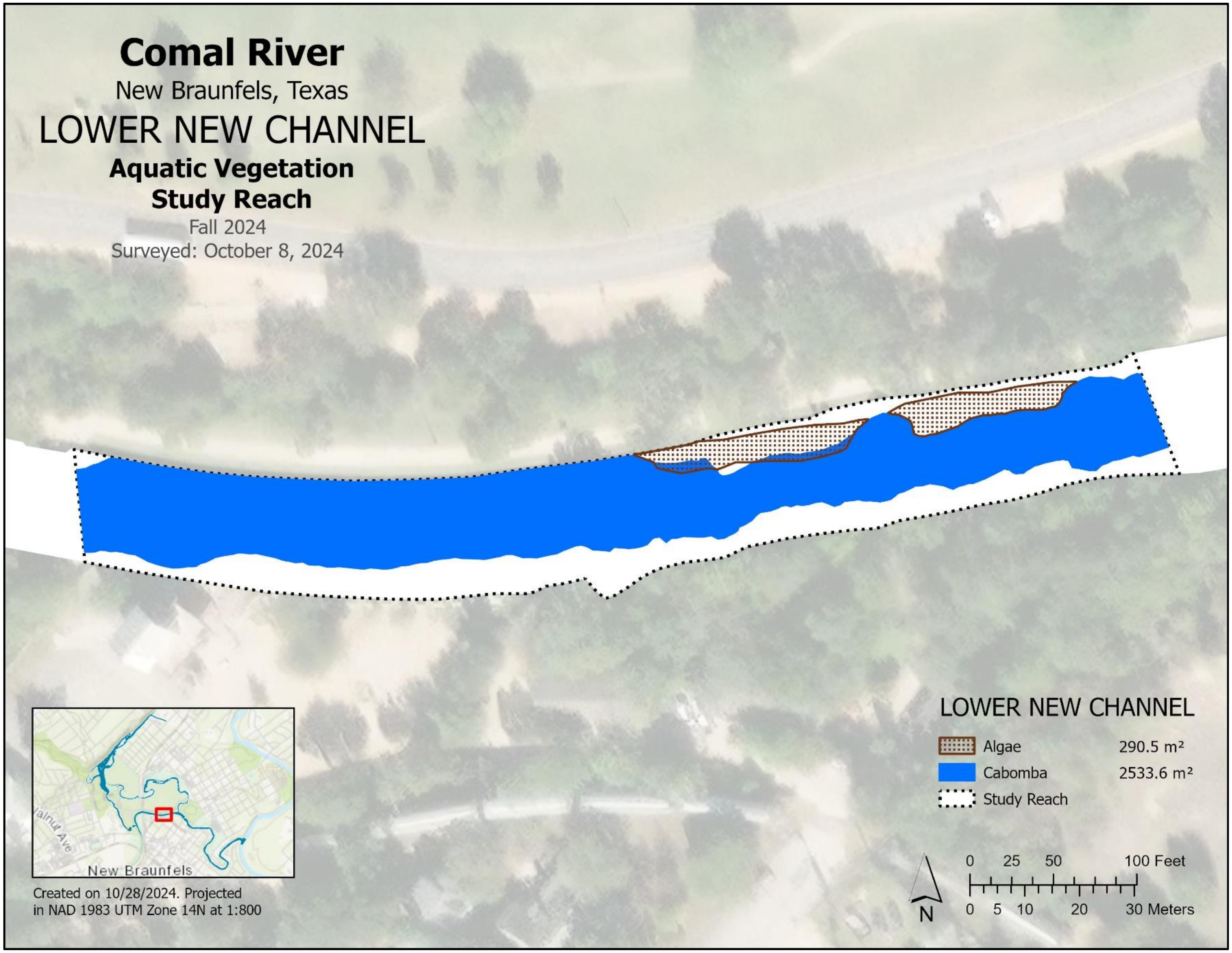

Figure C20. Map of aquatic vegetation coverage at Lower New Channel Study Reach in fall 2024.

APPENDIX D: TEXAS MASTER NATURALIST MONITORING RESULTS

Site locations are shown in Figure 2 of the report and are listed from upstream (Houston Street) to downstream (Union Avenue). Water quality data collected by Master Naturalist volunteers in 2024 were similar to previous years, observing CO2 concentrations highest at sites near springs, such as the Houston Street (Upper Spring Run Reach) and Gazebo (Landa Lake/Spring Run 3) sample sites (Figure D1). Also continuing with past observations, pH measurements increased with increased distance from the springs (Figure D2). The inverse relationship between CO2 and pH is directly related to greater concentrations of carbonic acid in spring waters. As CO2 concentrations decline going downstream, pH rises in the system. Within sites, year-to-year variation was relatively limited in both pH and CO2 concentrations.

To compare recreational use at the various sites, weekly counts of recreation users collected by the Texas Master Naturalist volunteers were converted to monthly averages and plotted over a long-term survey period (Figures D3–D7). In 2024, the New Channel continued as the most recreated area in the system. Recreation was second highest at Union Avenue, though levels were much lower than during previous years and those observed at the New Channel site. As in previous years, recreational use at Elizabeth Street (Old Channel) was low because this site is not located within a city park or advertised for recreational use (Figures D3–D7).

The New Channel site has received the most recreation pressure throughout the Texas Master Naturalist monitoring (2006–2024). The peak of recreational use is usually during the summer months of June through September (Figure D6). During the warmer months, the New Channel site becomes a popular destination for tubers and others seeking relief from the heat in the cooler spring-fed water. There was a brief decrease in activity during the lockdowns associated with the COVID-19 pandemic in 2020; however, activity at the New Channel site has returned to levels similar to historical trends in 2024. Much like the New Channel site, recreation pressure at the Union Avenue site can also be substantial during summer because this is a take-out site for many tubers floating the river (Figure D7), however, a marked decrease in recreation compared to 2023 was observed in 2024. A possible explanation for this could be due to reduced flows.

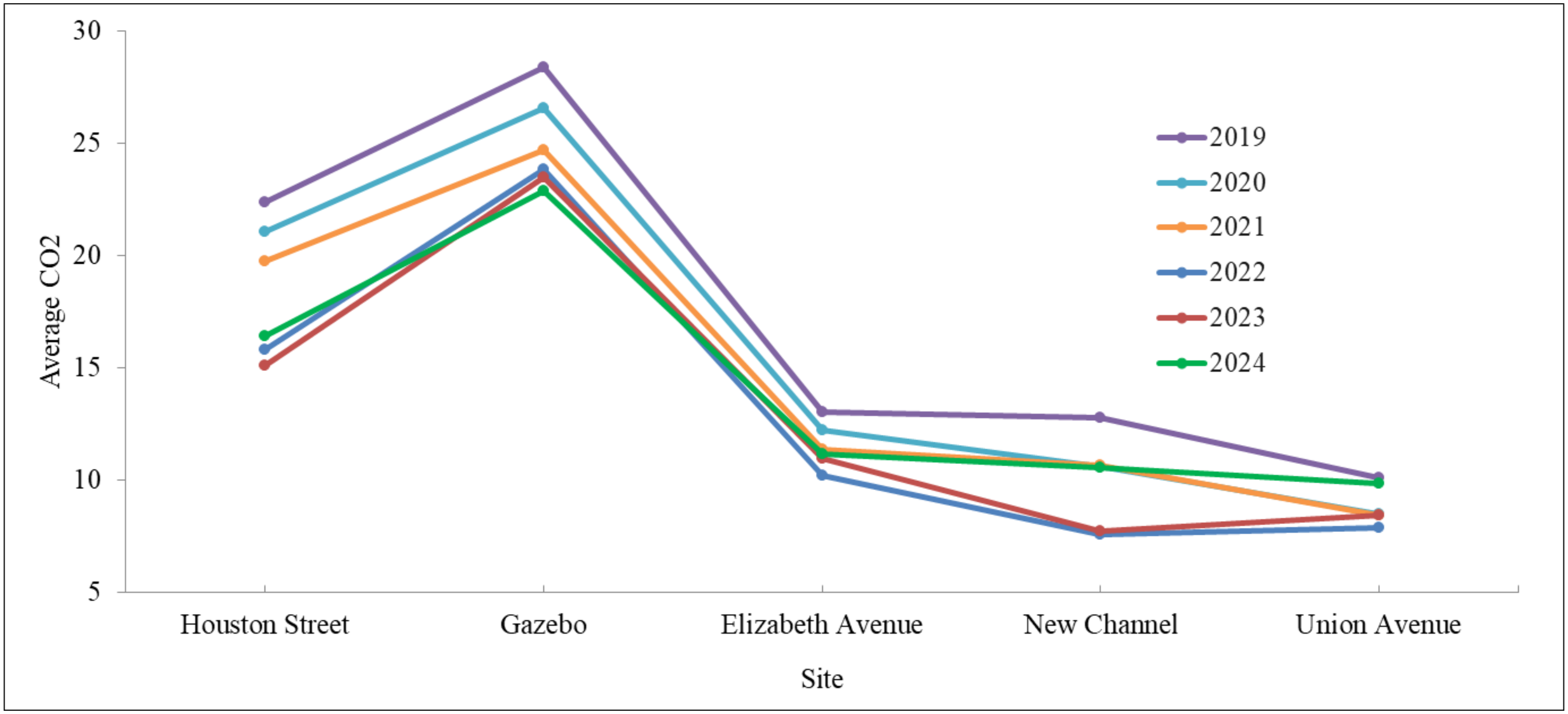

Figure D1. **Annual average dissolved carbon dioxide (CO_2) concentrations at five sites on the Comal River system (2019–2024).**

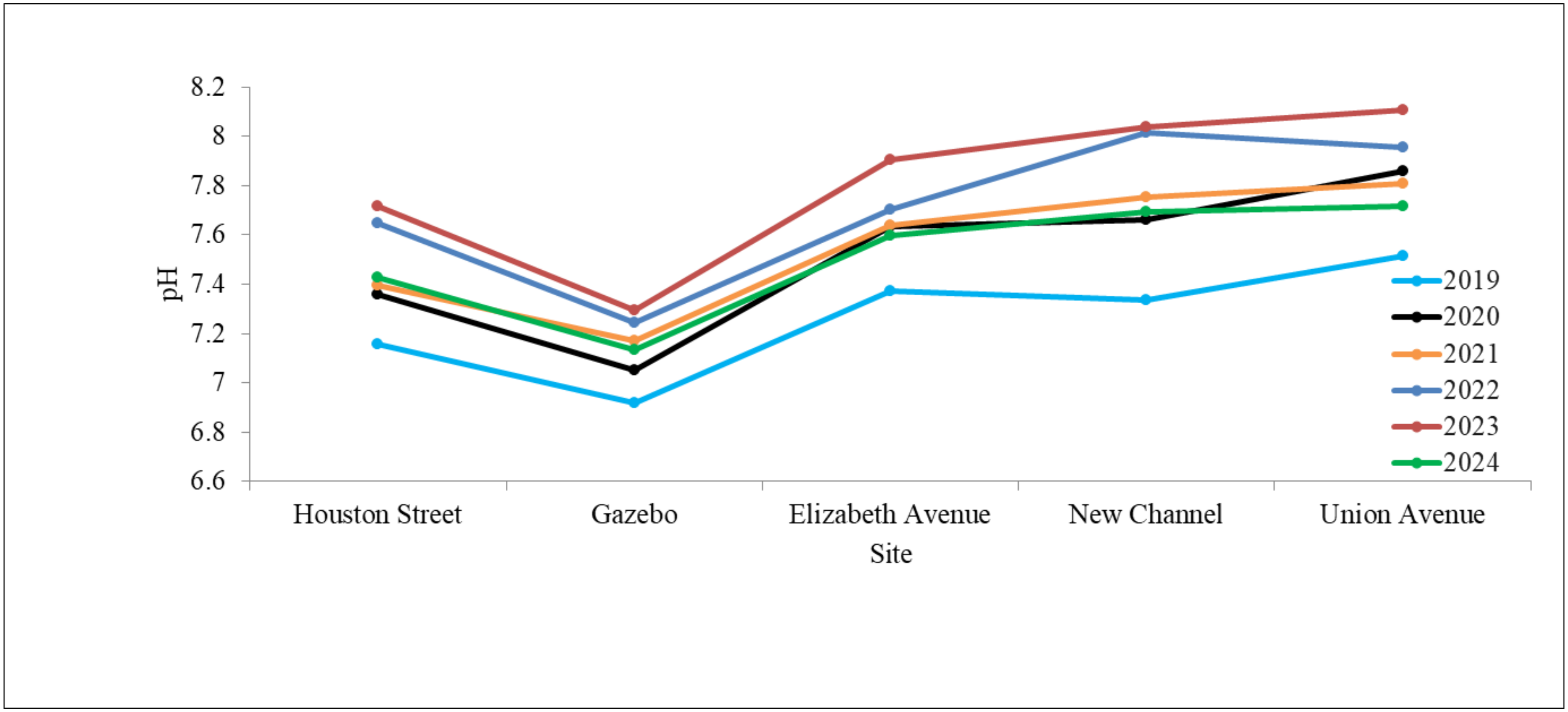

Figure D2. **Annual average pH values at five sites on the Comal River system (2019–2024).**

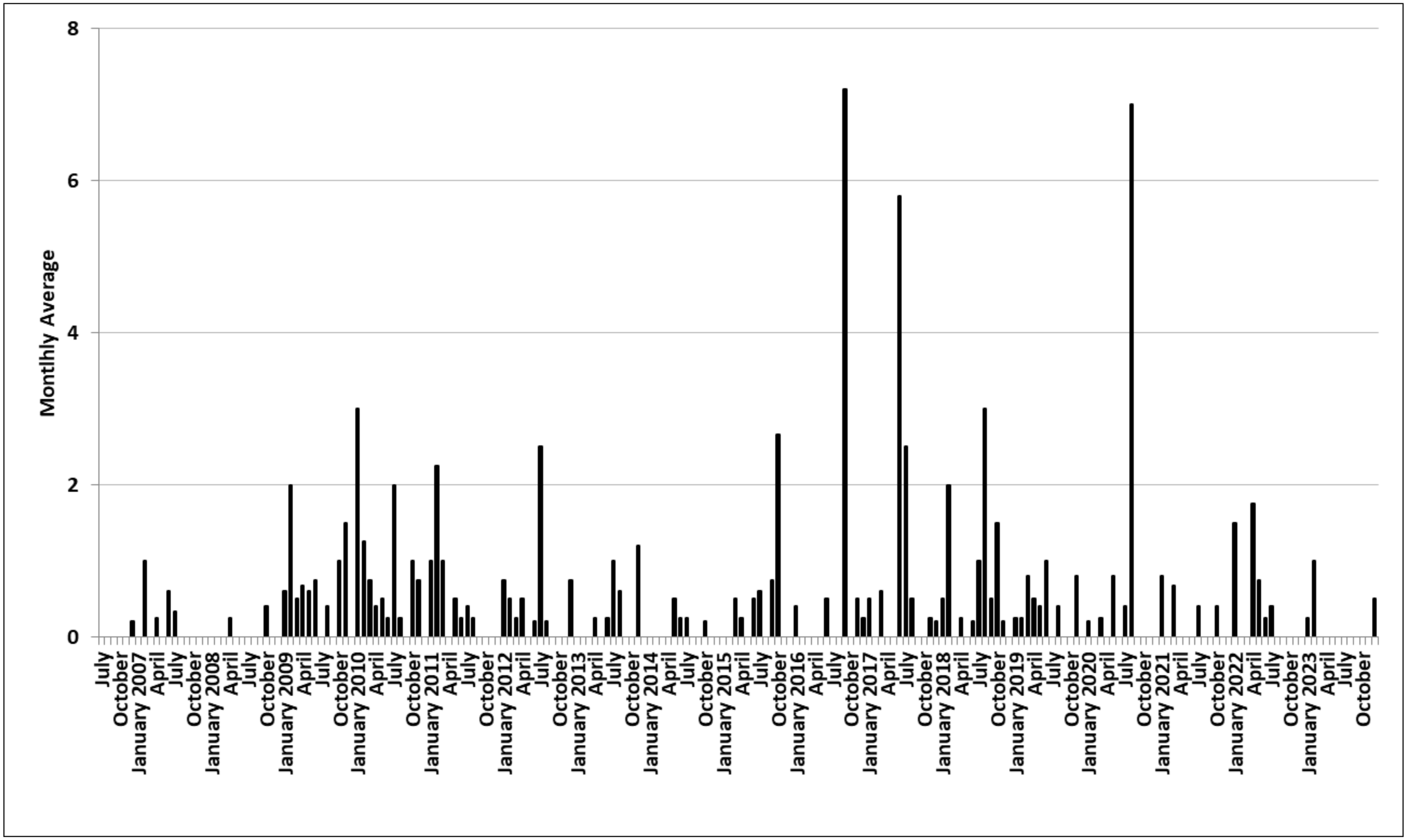

Figure D3. Average daily recreational user counts at the Elizabeth Avenue site (2006–2024).

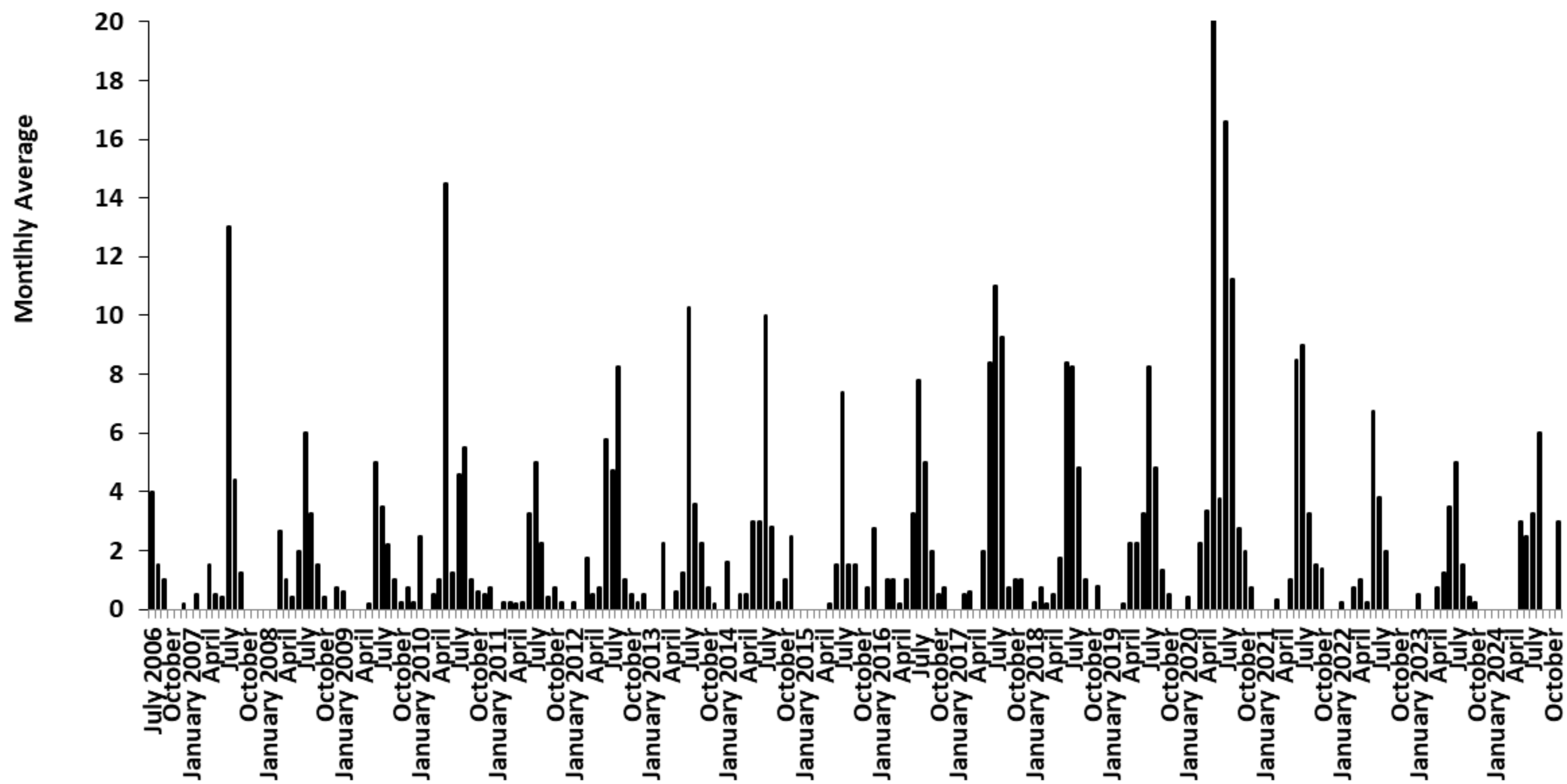

Figure D4. **Average daily recreational user counts at the Upper Spring Run site (2006–2024).**

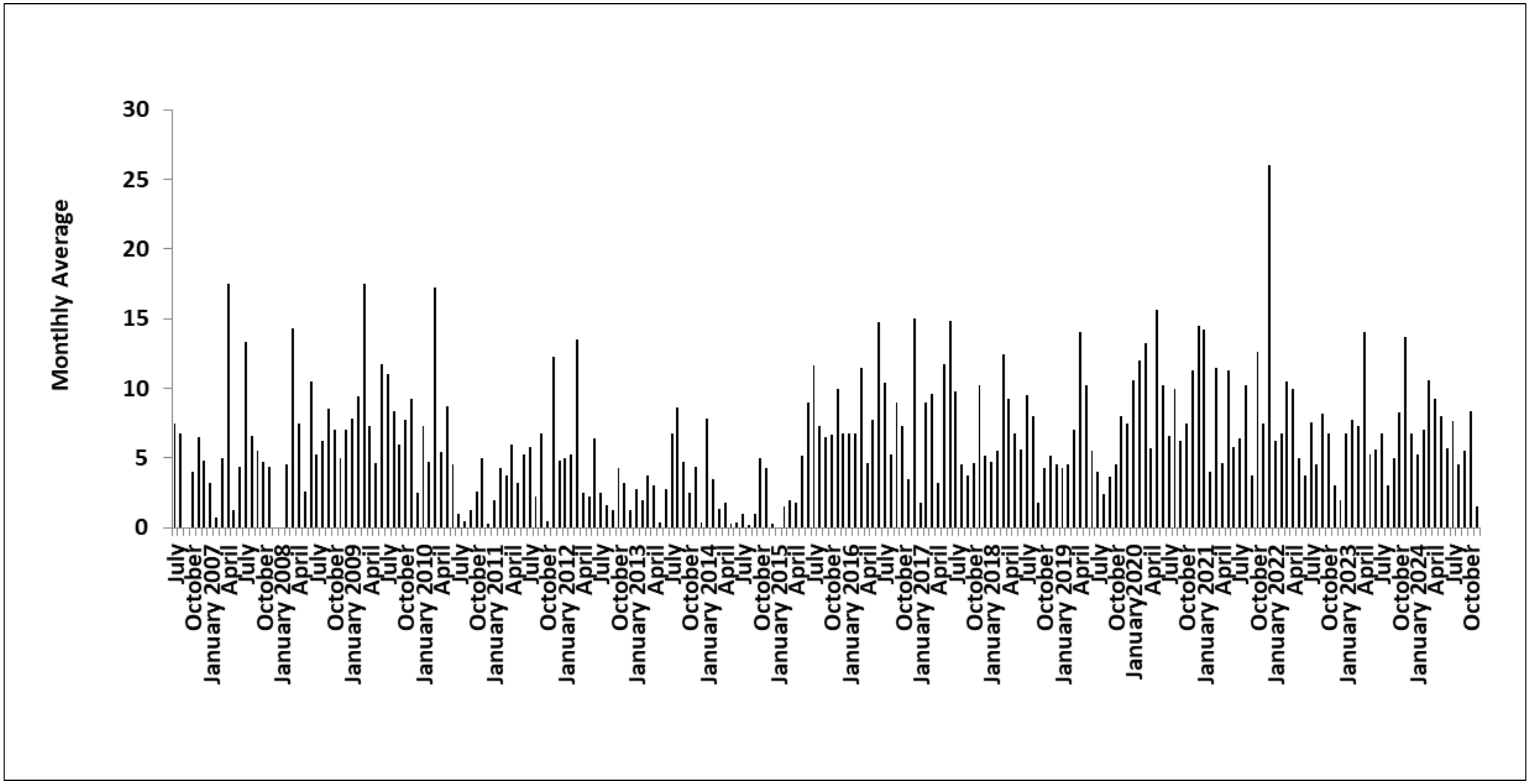

Figure D5. **Average daily user counts at the Landa Lake Park Gazebo site (2006–2024).**

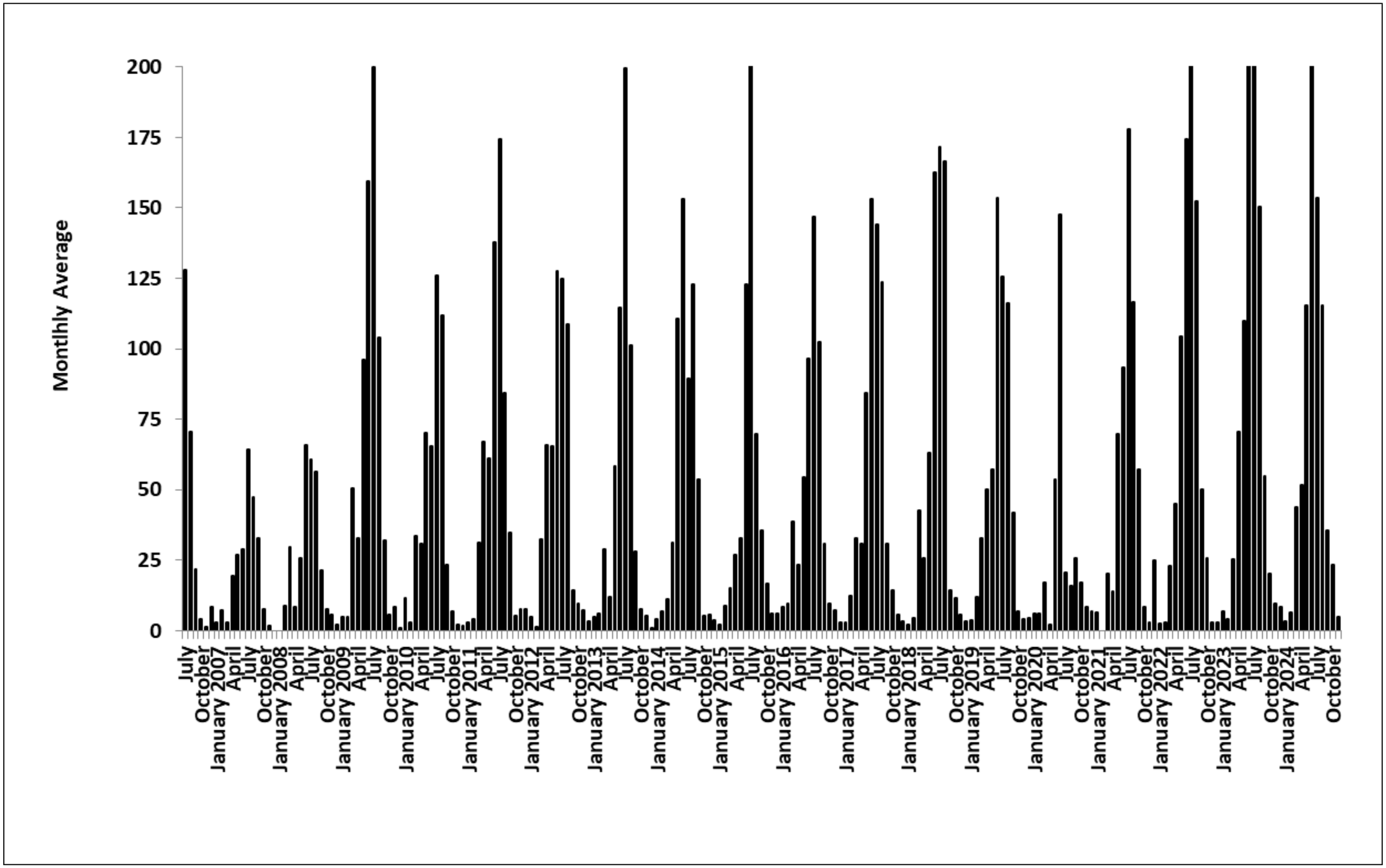

Figure D6. **Average daily user counts at the New Channel site (2006-2024).**

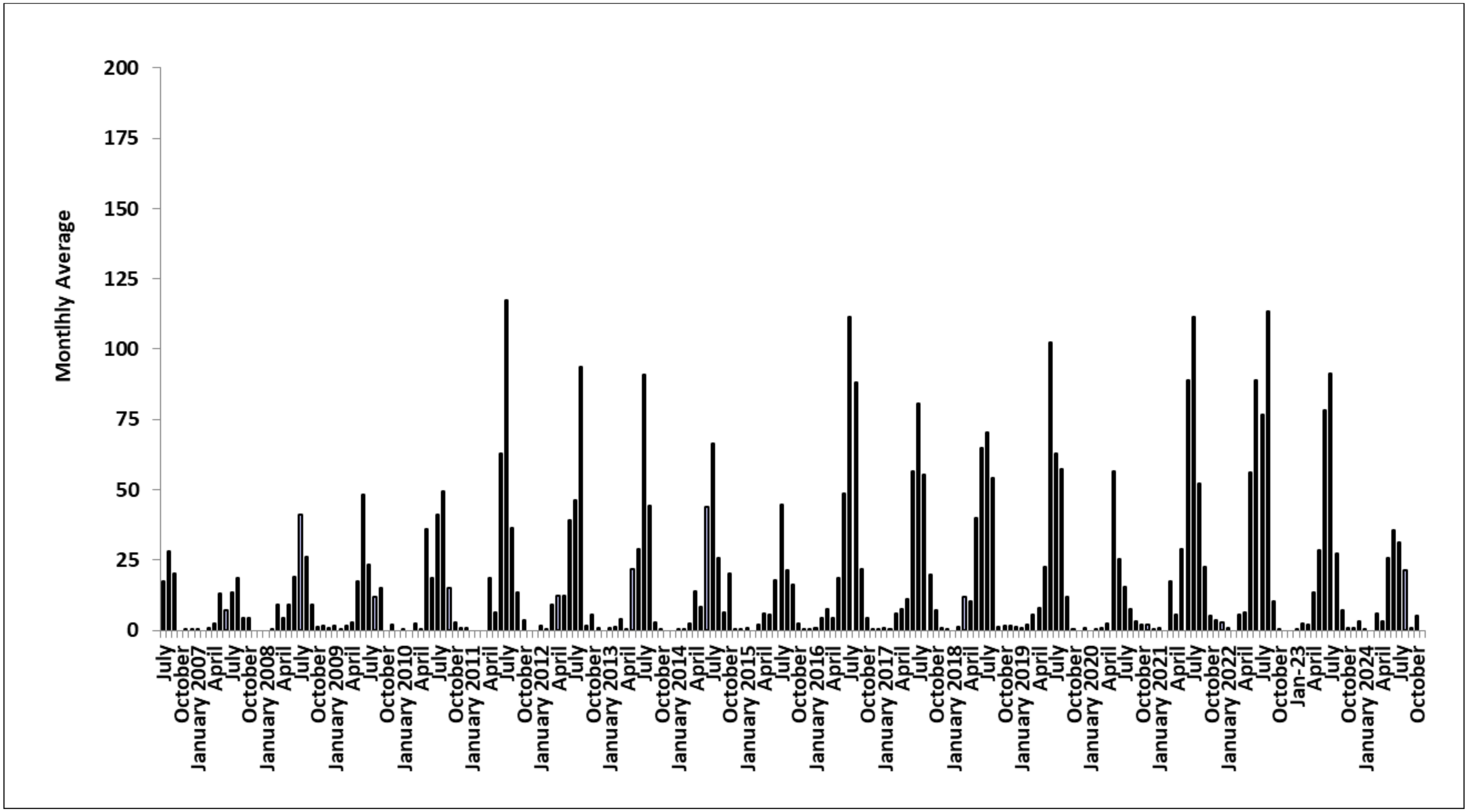

Figure D7. **Average daily recreational user counts at the Union Avenue site (2006–2024).**

APPENDIX E: TABLES AND FIGURES

TABLES

Fish Assemblage Results:
Drop-Net and Fish Community Sampling

Table E1. Overall number (#) and percent relative abundance (%) of fishes collected from the three long-term biological goals study reaches during drop-net sampling in 2024.

TAXA	UPPER SPRING RUN		LANDA LAKE		OLD CHANNEL		NEW CHANNEL	
	#	%	#	%	#	%	#	%
Leuciscidae								
Dionda nigrotaeniata	72	17.73	68	3.71	2	0.37	3	0.45
Notropis amabilis	0	0.00	0	0.00	64	11.74	0	0.00
Paranotropis volucellus	0	0.00	0	0.00	1	0.18	0	0.00
Characidae								
*Astyanax argentatus**	41	10.10	71	3.87	1	0.18	4	0.61
Ictaluridae								
Ameiurus natalis	0	0.00	10	0.55	2	0.37	2	0.30
Poeciliidae								
Gambusia sp.	24	5.91	52	2.84	3	0.55	4	0.61
Poecilia latipinna	0	0.00	0	0.00	0	0.00	1	0.15
Centrarchidae								
*Ambloplites rupestris**	0	0.00	0	0.00	0	0.00	5	0.76
Lepomis cyanellus	0	0.00	0	0.00	1	0.18	90	13.64
Lepomis gulosus	0	0.00	0	0.00	0	0.00	21	3.18
Lepomis miniatus	76	18.72	116	6.32	10	1.83	28	4.24
Lepomis sp.	32	7.88	23	1.25	245	44.95	4	0.61
Micropterus salmoides	33	8.13	10	0.55	0	0.00	5	0.76
Percidae								
Etheostoma fonticola	102	25.12	1482	80.81	207	37.98	44	6.67
Etheostoma lepidum	10	2.46	0	0.00	0	0.00	0	0.00
Cichlidae								
*Herichthys cyanoguttatus**	16	3.94	2	0.11	9	1.65	449	68.03
TOTAL	**406**		**1834**		**545**		**660**	

Asterisks (*) denotes introduced species

Table E2. Overall number (#) and percent relative abundance (%) of fishes collected during fish community sampling in 2024.

	Upper Spring Run		Landa Lake		Old Channel		New Channel	
TAXA	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**
Leuciscidae								
Cyprinella lutrensis	0	0.0	0	0.0	1	0.1	0	0.0
Cyprinella venusta	0	0.0	0	0.0	0	0.0	1	0.0
Dionda nigrotaeniata	2490	57.2	3630	57.1	53	4.1	175	7.8
Notropis amabilis	101	2.3	10	0.2	35	2.7	8	0.4
Paranotropis volucellus	0	0.0	0	0.0	19	1.5	1	0.0
Characidae								
*Astyanax argentatus**	204	4.7	1471	23.1	313	24.0	359	16.1
Ictaluridae								
Ameiurus natalis	1	0.0	0	0.0	0	0.0	3	0.1
Ictaluris punctatus	0	0.0	0	0.0	1	0.1	0	0.0
Loricariidae								
Loricariidae sp.	0	0.0	0	0.0	6	0.5	0	0.0
Poeciliidae								
Gambusia affinis	22	0.5	0	0.0	29	2.2	394	17.6
Gambusia geiseri	22	0.5	0	0.0	76	5.8	220	9.8
Gambusia sp.	115	2.6	235	3.7	269	20.6	133	6.0
*Poecilia latipinna**	1	0.0	110	1.7	0	0.0	144	6.4
Centrarchidae								
*Ambloplites rupestris**	0	0.0	0	0.0	1	0.1	0	0.0
*Lepomis auritus**	24	0.6	7	0.1	44	3.4	84	3.8
Lepomis cyanellus	0	0.0	0	0.0	0	0.0	3	0.1
Lepomis gulosus	0	0.0	0	0.0	0	0.0	12	0.5
Lepomis macrochirus	13	0.3	0	0.0	3	0.2	0	0.0
Lepomis megalotis	5	0.1	0	0.0	1	0.1	16	0.7
Lepomis microlophus	0	0.0	3	0.0	0	0.0	0	0.0
Lepomis miniatus	160	3.7	2	0.0	42	3.2	90	4.0
Lepomis sp.	14	0.3	63	1.0	115	8.8	67	3.0
Micropterus salmoides	389	8.9	249	3.9	43	3.3	71	3.2
Micropterus sp.	21	0.5	0	0.0	0	0.0	2	0.1
Percidae								
Etheostoma fonticola	261	6.0	326	5.1	132	10.1	165	7.4
Etheostoma lepidum	140	3.2	79	1.2	38	2.9	45	2.0
Etheostoma sp.	221	5.1	159	2.5	11	0.8	66	3.0
Cichlidae								
*Herichthys cyanoguttatus**	132	3.0	6	0.1	72	5.5	176	7.9

Oreochromis aureus	15	0.3	10	0.2	2	0.2	0	0.0
Total	**4,351**		**6,360**		**1,306**		**2,235**	

Asterisks (*) denotes introduced species

Table E3. **Total numbers of stygobitic and endangered species collected at each site (24 hours per event) during spring and fall 2024. Federally endangered species are designated with (E). A = adults; L = larvae.**

TAXA	RUN 1	RUN 3	UPWELLING	TOTAL
Crustaceans				
Amphipoda				
Crangonyctidae				
Stygobromus pecki (E)			15	15
Stygobromus russelli				0
Stygobromus bifurcatus				0
Stygobromus flagellatus				0
Stygobromus spp.	3	15	180	198
All *Stygobromus*	3	15	195	213
Hadziidae				
Mexiweckelia hardeni	2	4	1	7
Sebidae				
Seborgia relicta		2	3	5
Bogidiellidae				
Artesia subterranea				0
Parabogidiella americana				0
Ingolfiellidae				
Ingolfiella n. sp				0
Isopoda				
Asellidae				
Lirceolus spp.	2	51	8	61
Cirolanidae				
Cirolanides texensis			1	1
Cirolanides wassenichae				0
Microceberidae				
Texicerberus sp.				0
Ostracoda				

Candonidae				
Cavernocypris sp.			5	5
Comalcandona tressleri	5	7	11	23
Comalcandona gibsoni	7	2		9
Rugosuscandona scharfi	4			4
Lacromacanadona sp.?	1			1
Ufocandona hannaleeae				0
Thermosbaenacea				
Monodellidae				
Tethysbaena texana				0
Bathynellacea				
Parabathynellidae				
Texanobathynella bowmani				0
Bathynellidae				
Hobbsinella edwardensis				0
Turbellaria				
Kenkiidae				
Sphalloplana mohri	1		0	1
Mollusca				
Gastropda				
Cochliopidae				
Phreatodrobia micra			2	2
Phreatodrobia nugax				0
Phreatodrobia plana		1	4	5
Phreatodrobia rotunda		1		1
Phreatodrobia spica		2	2	4
Vitropyrgus lillianae	1	34	1	36
Annelids				
Lumbriculata				
Lumbriculidae				
Eremidrilus sp.		4	0	4

Haplotaxis sp.				0
<u>Arachnids</u>				
Hydrachnoidea				
Hydryphantidae				
Almuerzothyas comalensis	2	2	2	6
<u>Insects</u>				
Coleoptera				
Dytiscidae				
Comaldessus stygius	1(adult)			1
Haideoporus texanus				0
Dryopidae				
Stygoparnus comalensis (E)				0
Elmidae				
Heterelmis comalensis (E)	1 (larva)			1

FIGURES

Springflow: M9 Measurements

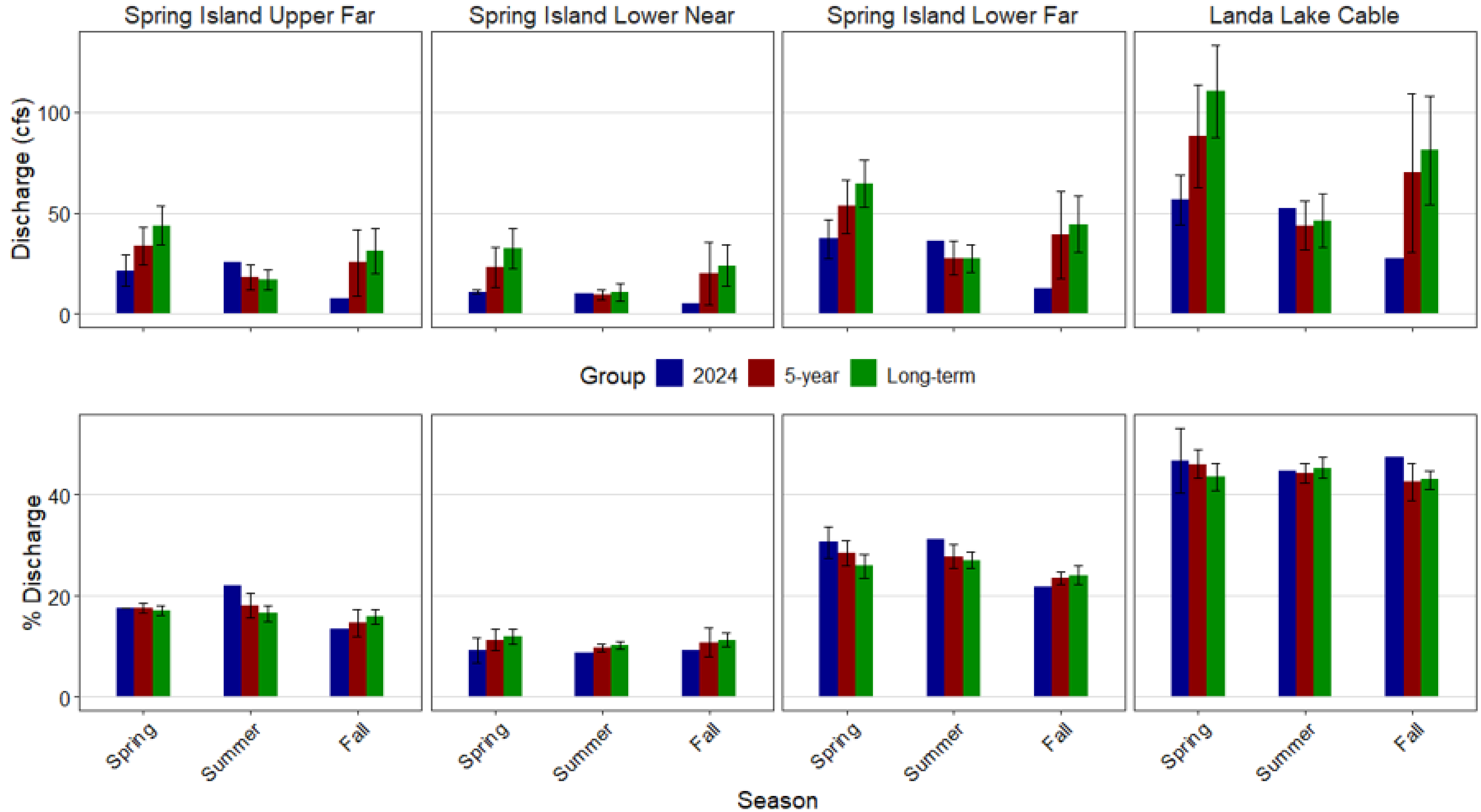

Figure E1. **Current (blue bars), five-year (2020–2024; red bars), and long-term (2014–2024; green bars) discharge and percent total discharge based on spring and fall M9 measurements in the Comal Springs/River. Five-year and long-term values are represented as means and error bars denote 95% confidence intervals.**

Aquatic Vegetation

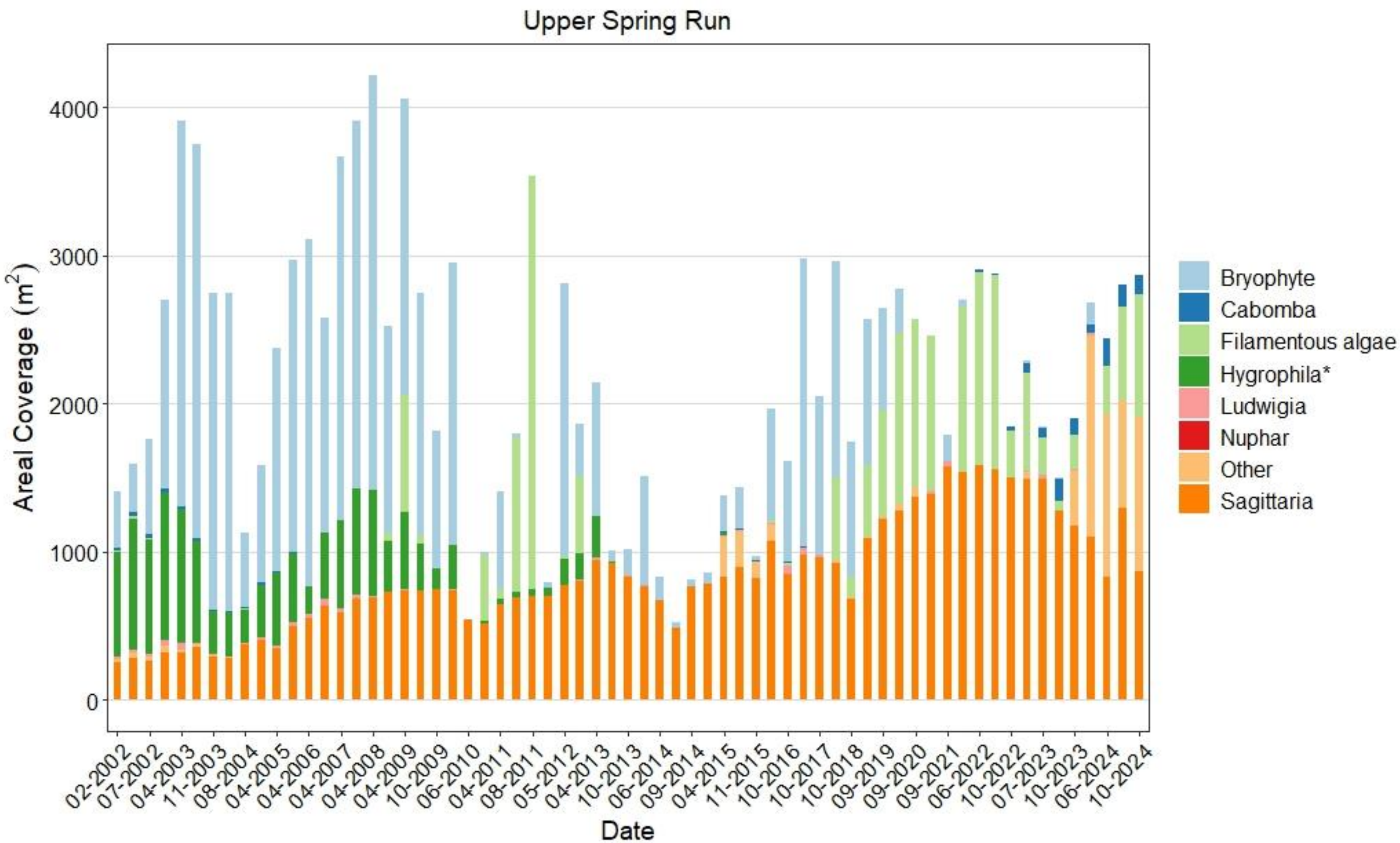

Figure E2. **Aquatic vegetation composition (m^2) among select taxa from 2002–2024 at the Upper Spring Run.**

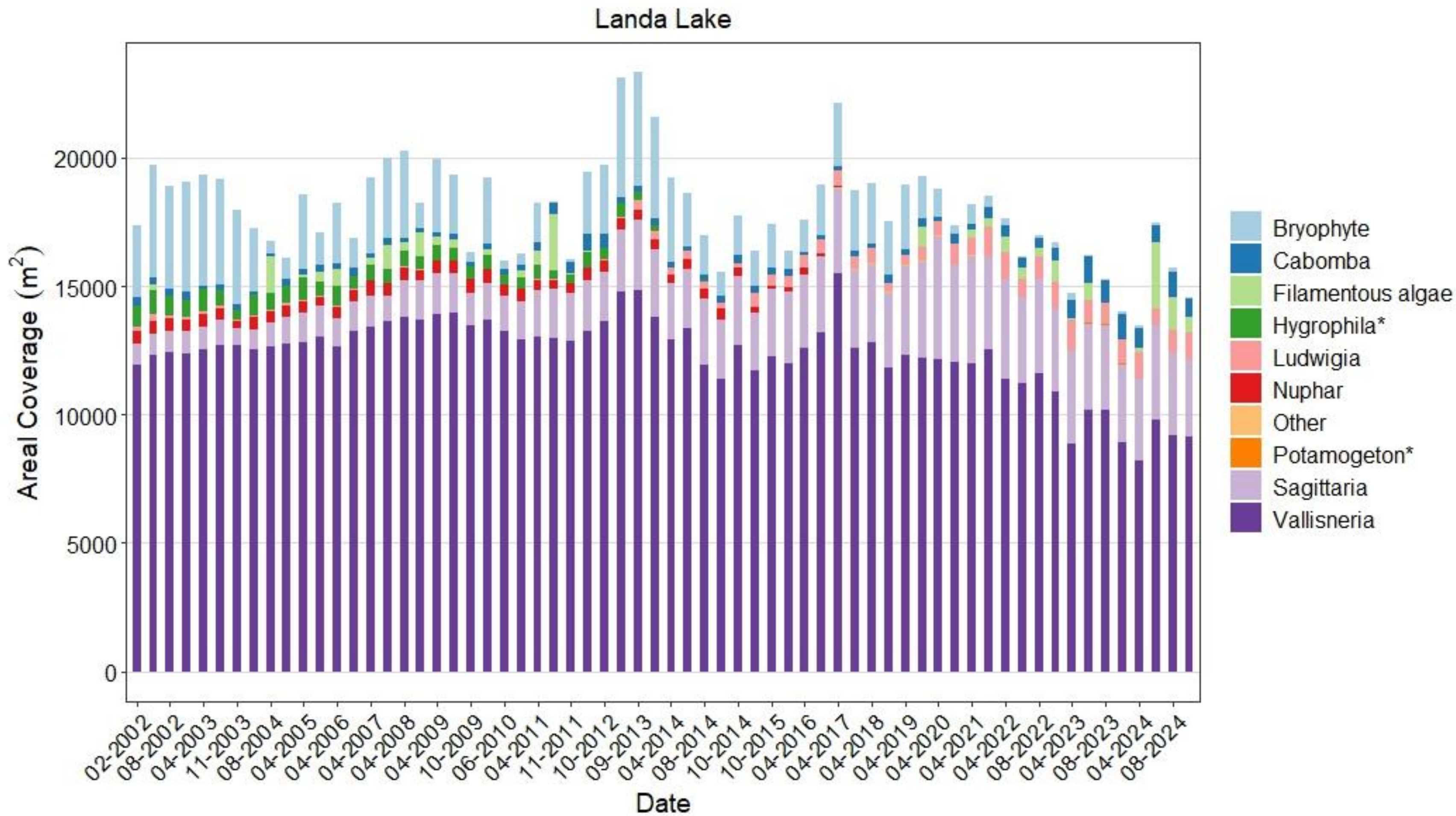

Figure E3. Aquatic vegetation composition (m^2) among select taxa from 2002–2024 at Landa Lake.

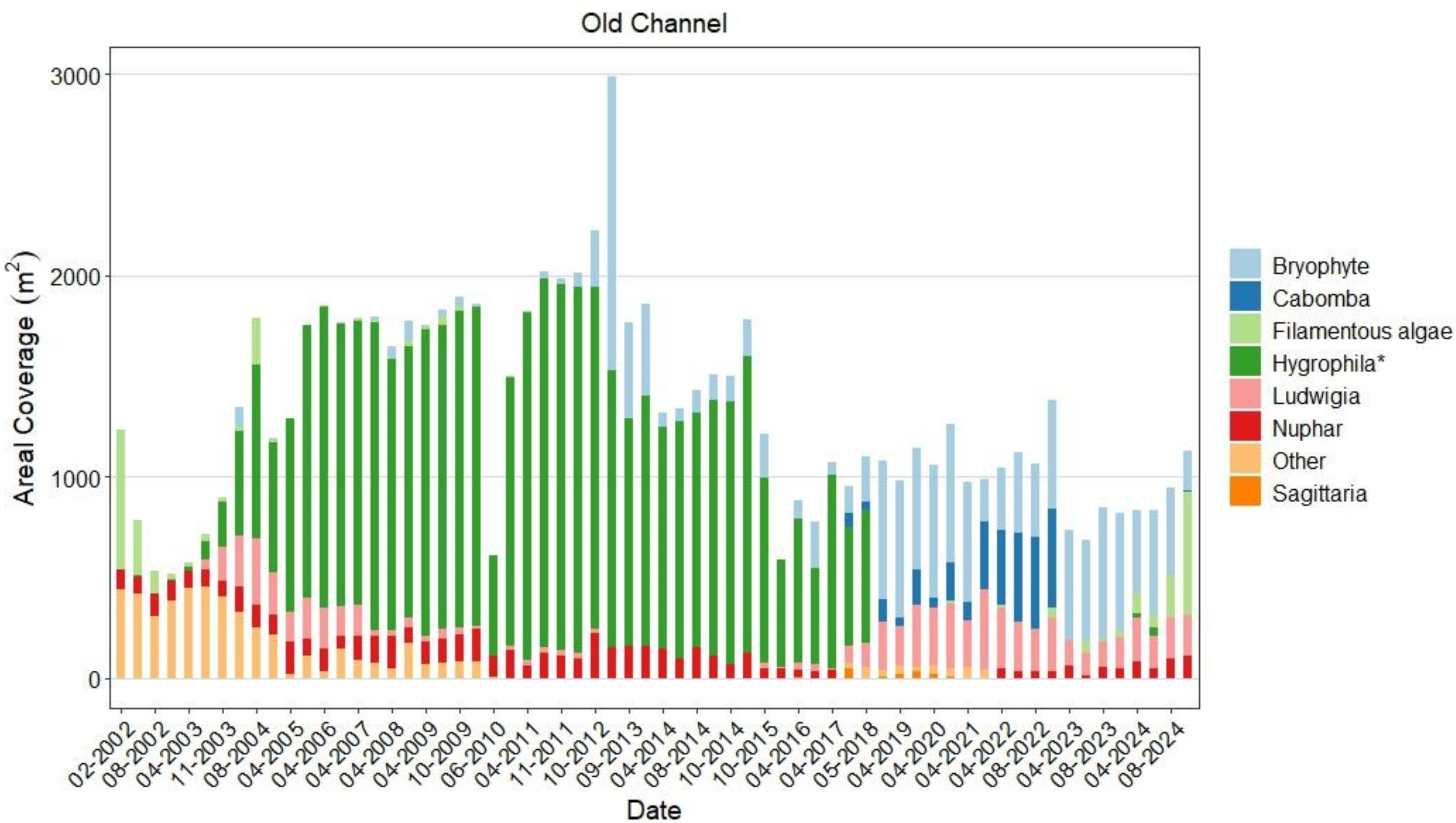

Figure E4. **Aquatic vegetation composition (m^2) among select taxa from 2002–2024 at the Old Channel.**

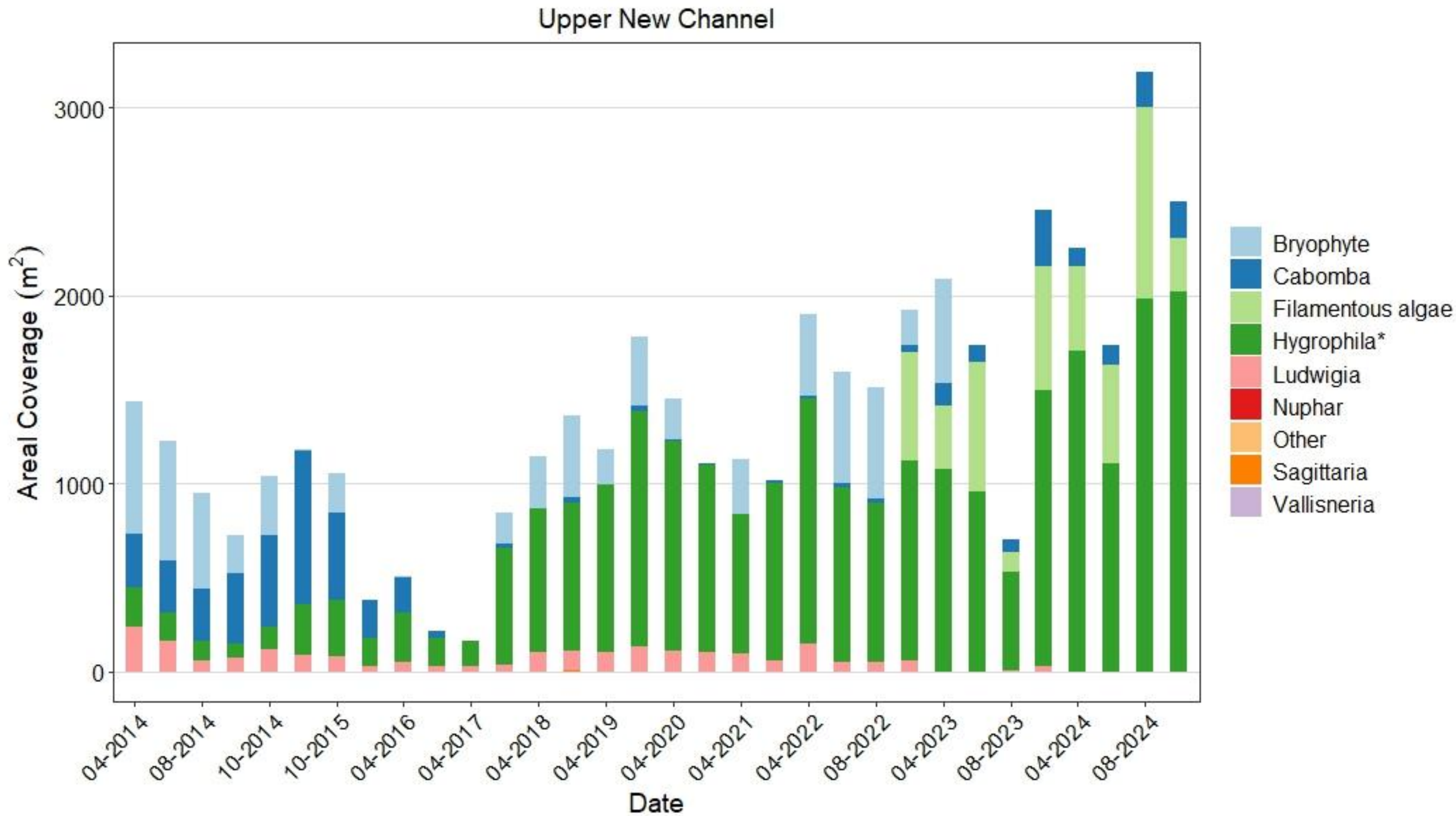

Figure E5. **Aquatic vegetation composition (m^2) among select taxa from 2014–2024 at the Upper New Channel.**

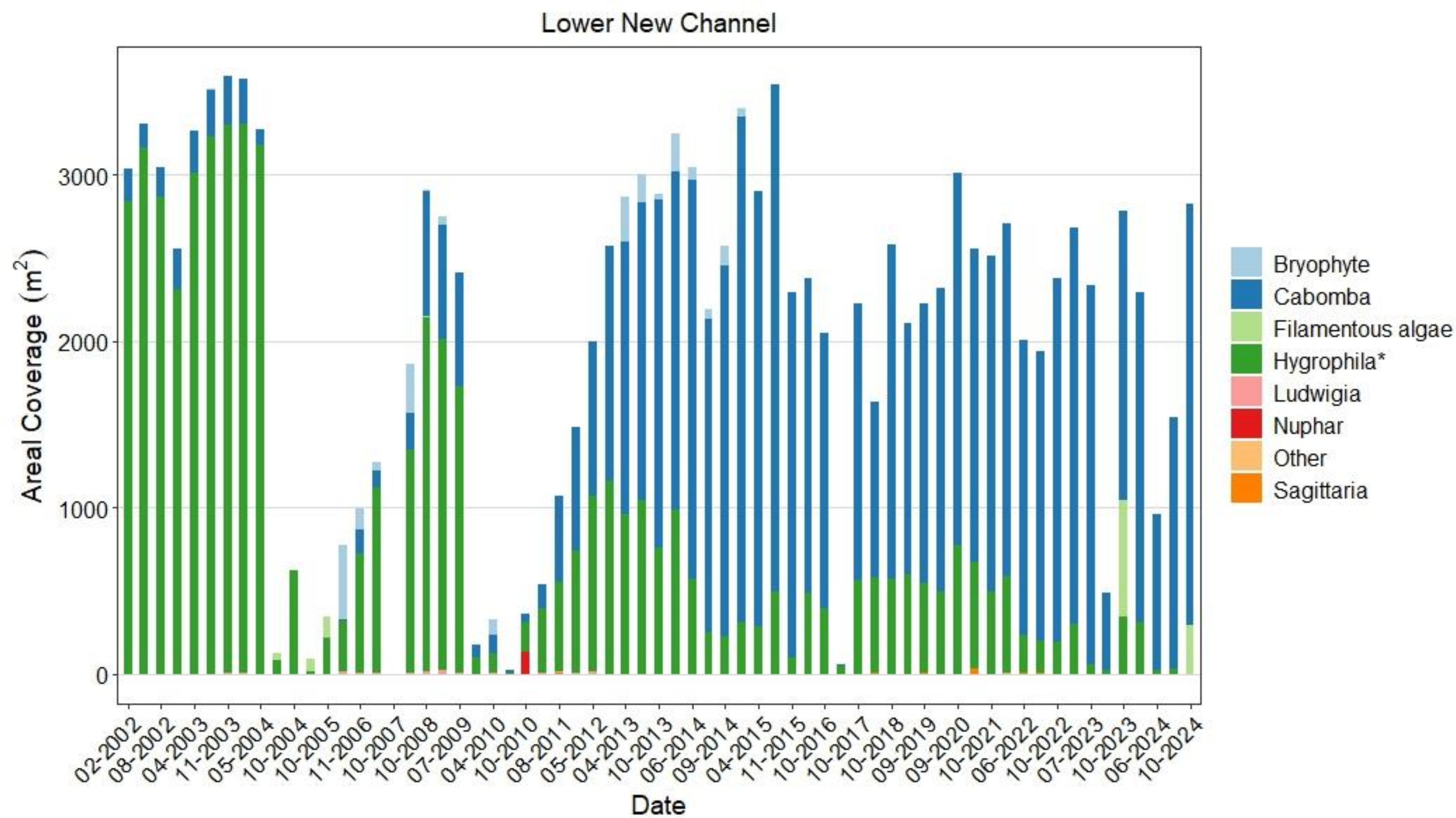

Figure E6. **Aquatic vegetation composition (m^2) among select taxa from 2002–2024 at the Lower New Channel. (*) in the legend denotes non-native taxa.**

Fountain Darter

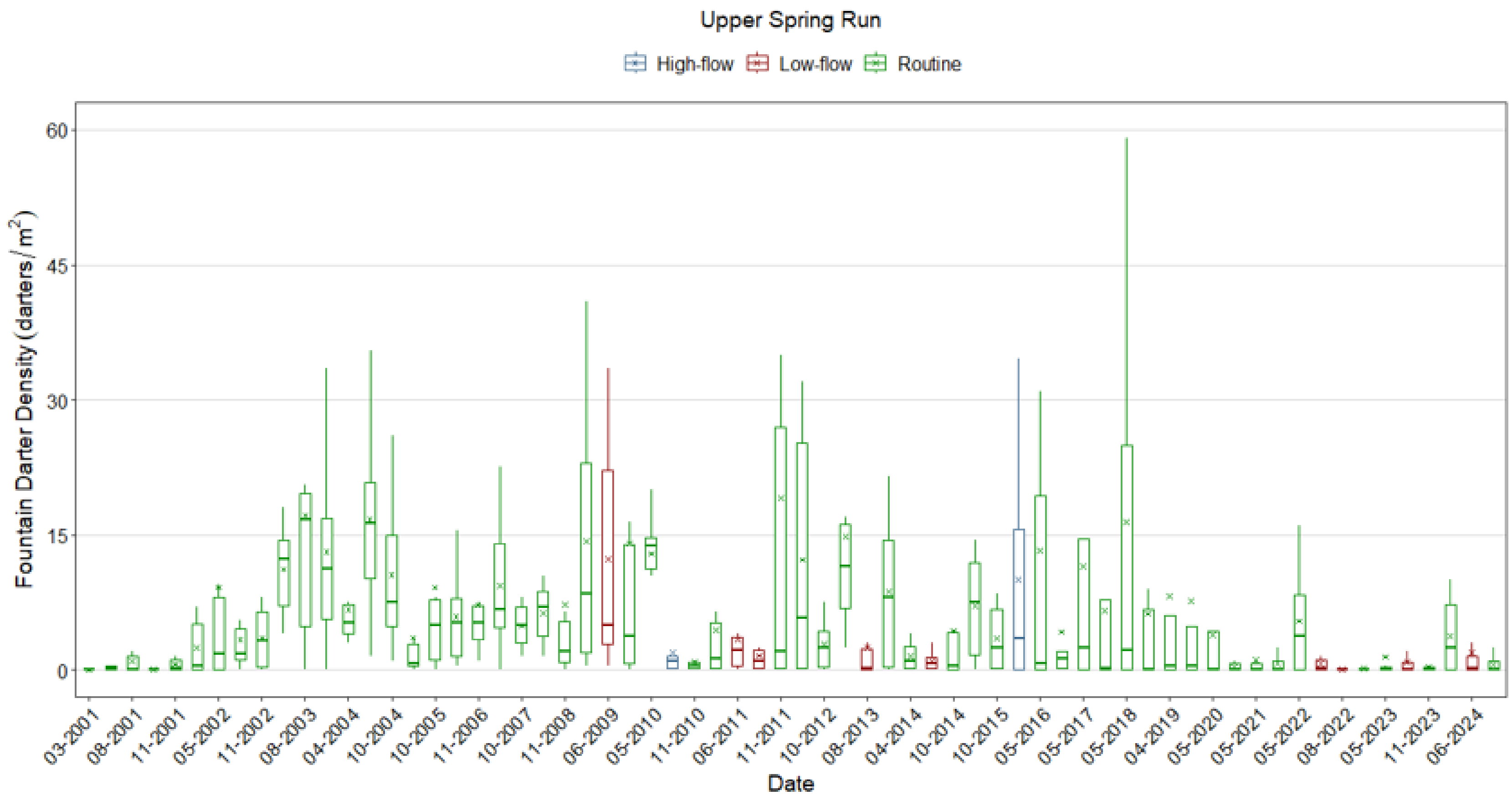

Figure E7. **Boxplots displaying temporal trends in Fountain Darter density (darters/m^2) from 2001–2024 during drop-net sampling at Upper Spring Run. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.**

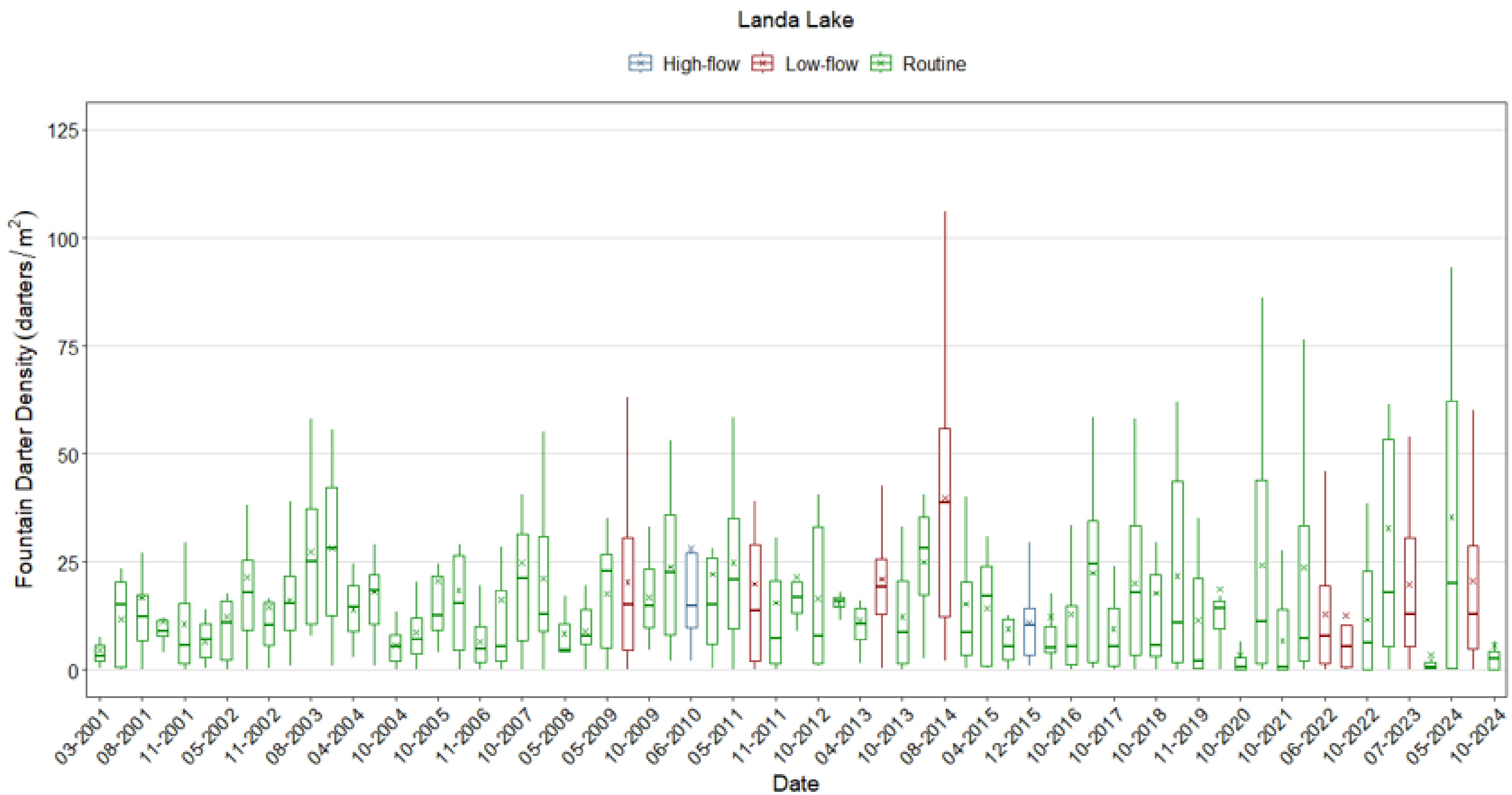

Figure E8. Boxplots displaying temporal trends in Fountain Darter density (darters/m²) from 2001–2024 during drop-net sampling at Landa Lake. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.

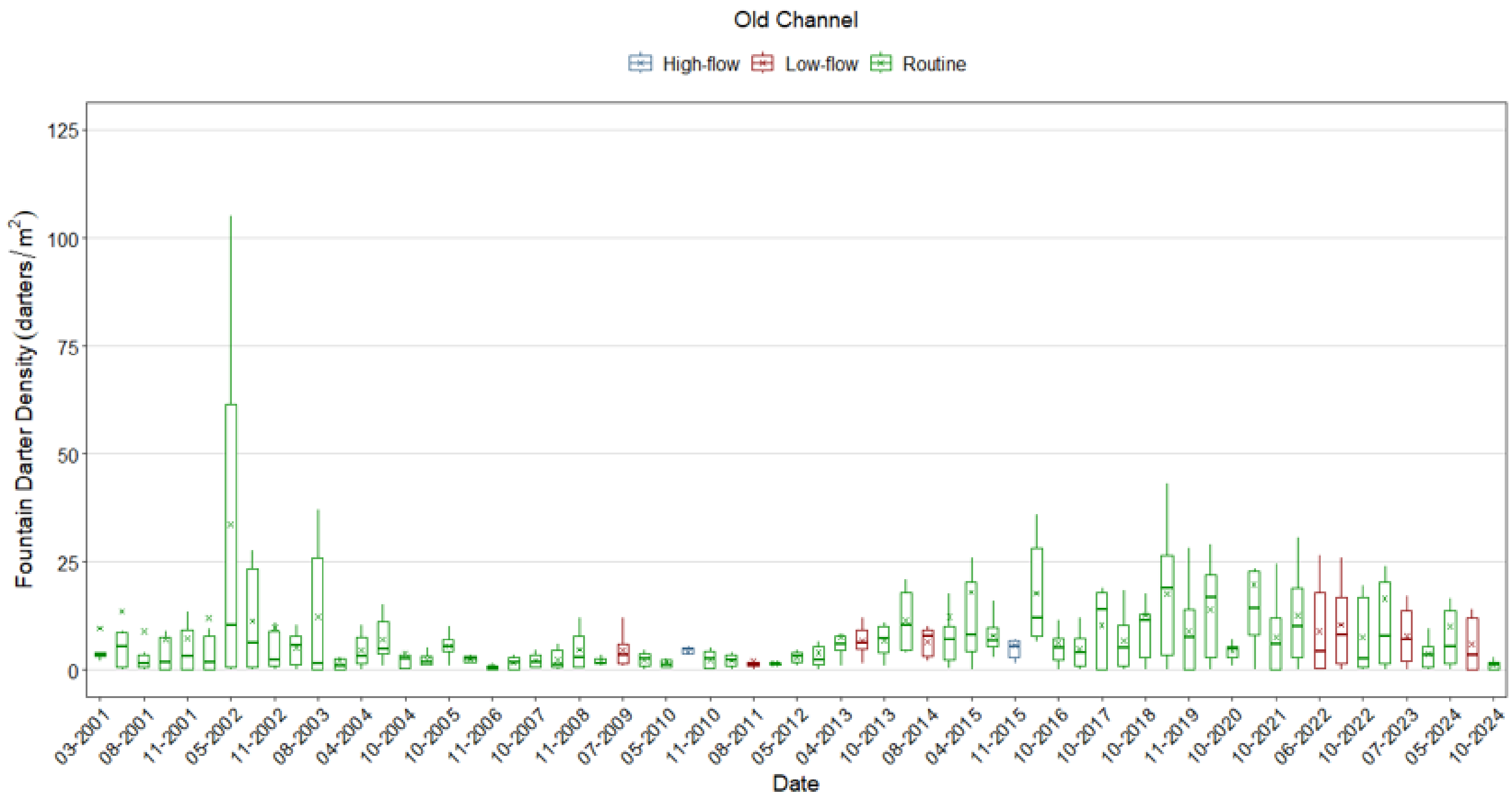

Figure E9. **Boxplots displaying temporal trends in Fountain Darter density (darters/m²) from 2001–2024 during drop-net sampling at Old Channel. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.**

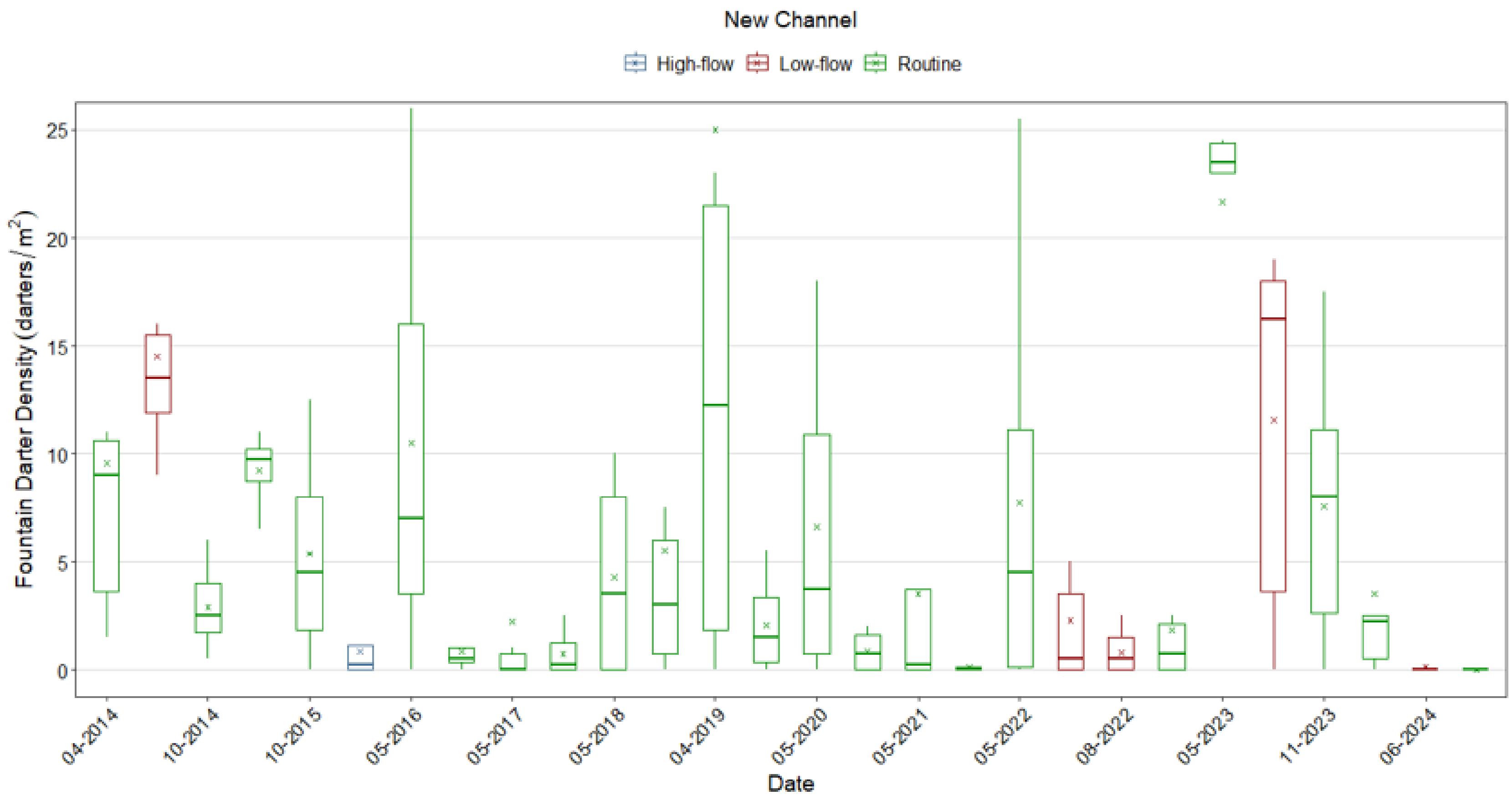

Figure E10. **Boxplots displaying temporal trends in Fountain Darter density (darters/m^2) from 2014–2024 during drop-net sampling at New Channel. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.**

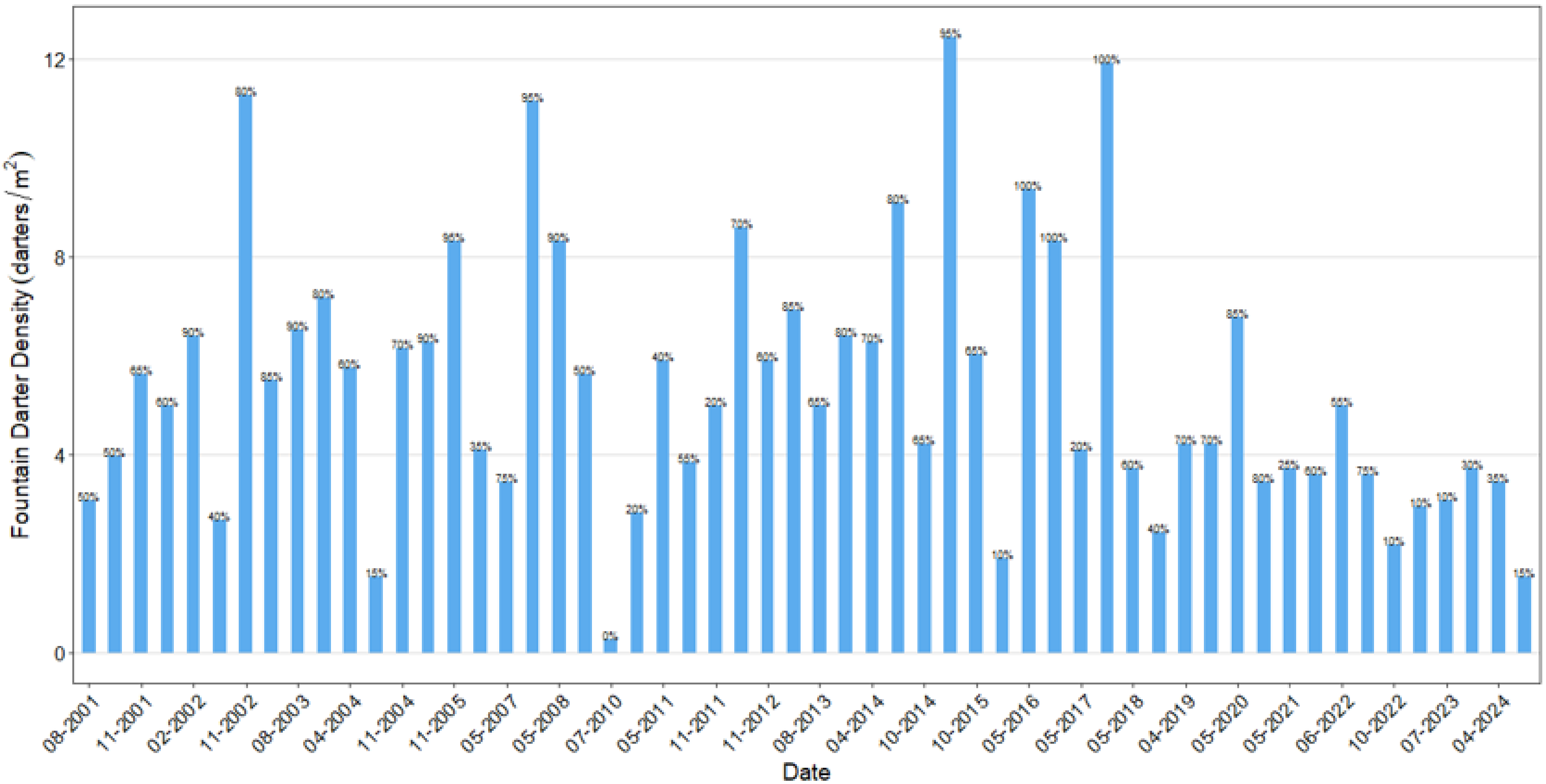

Figure E11. **Boxplots displaying temporal trends in Fountain Darter density (darters/m^2) from 2001–2024 during visual surveys at Landa Lake. Percentages above the bars represent bryophyte coverage observed during each survey event.**

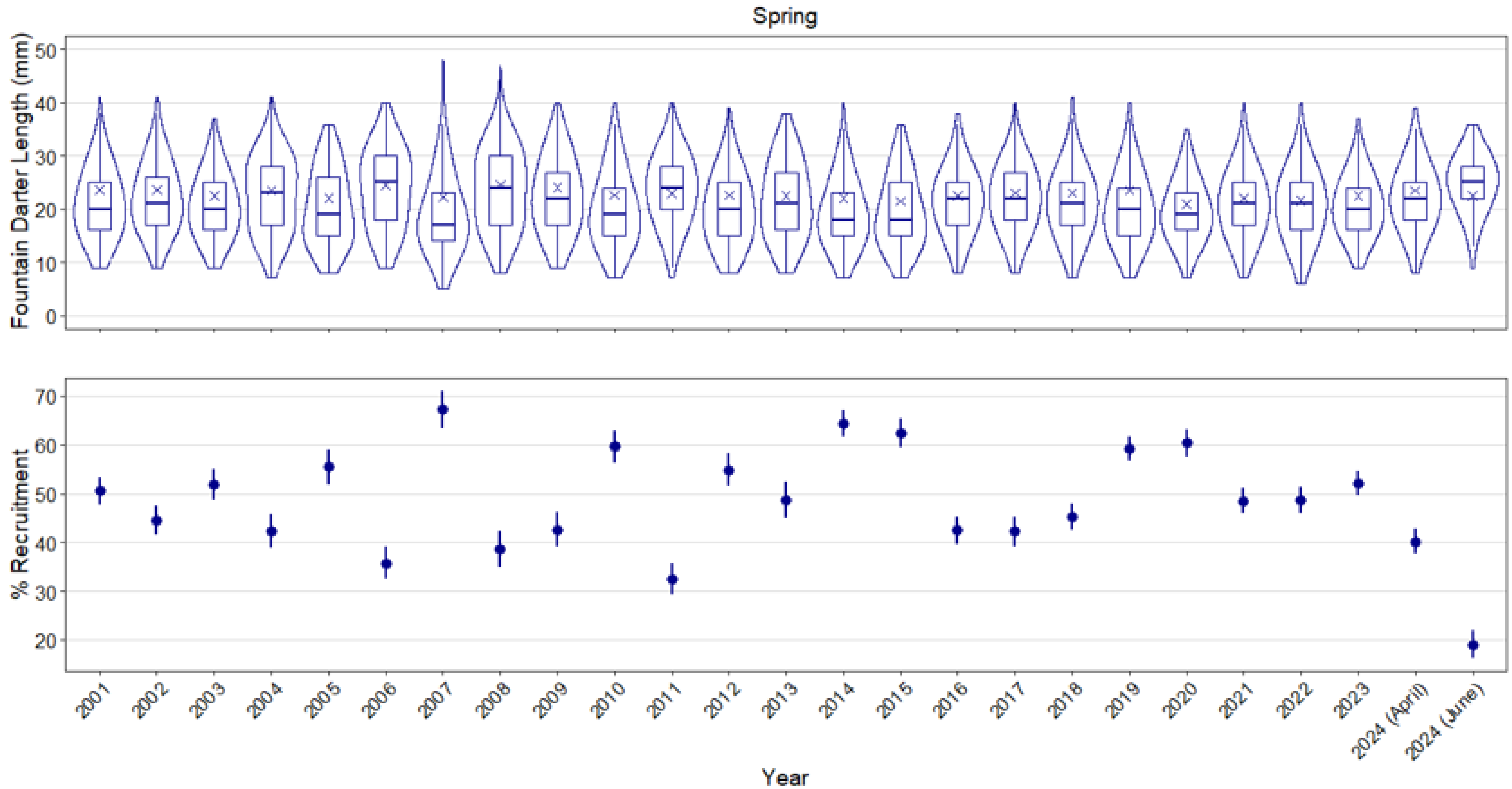

Figure E12. **Fountain Darter size structure (mm; top row) and percent recruitment (bottom row) in the Comal Springs and River during spring sampling (i.e., drop-net and timed dip-net data) events from 2001–2024. Size structure is displayed with boxplots (median, quartiles, range) and violin plots (probability density; polygons outlining boxplots). The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. Recruitment is the percent relative abundance (± 95% CI) of darters ≤20 mm.**

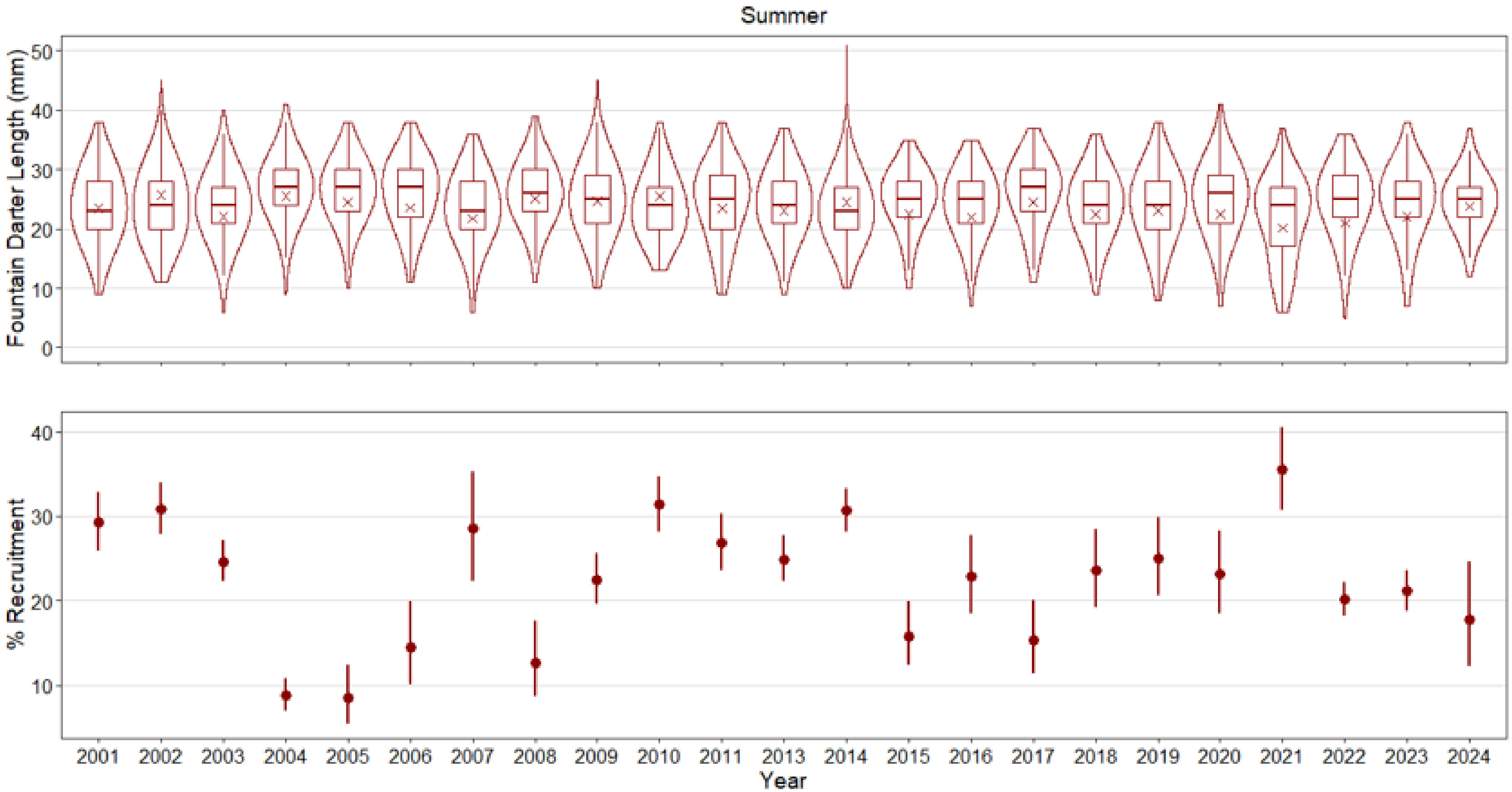

Figure E13. **Fountain Darter size structure (mm; top row) and percent recruitment (bottom row) in the Comal Springs and River during summer sampling (i.e., drop-net and timed dip-net data) events from 2001–2024. Size structure is displayed with boxplots (median, quartiles, range) and violin plots (probability density; polygons outlining boxplots). The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. Recruitment is the percent relative abundance (± 95% CI) of darters ≤20 mm.**

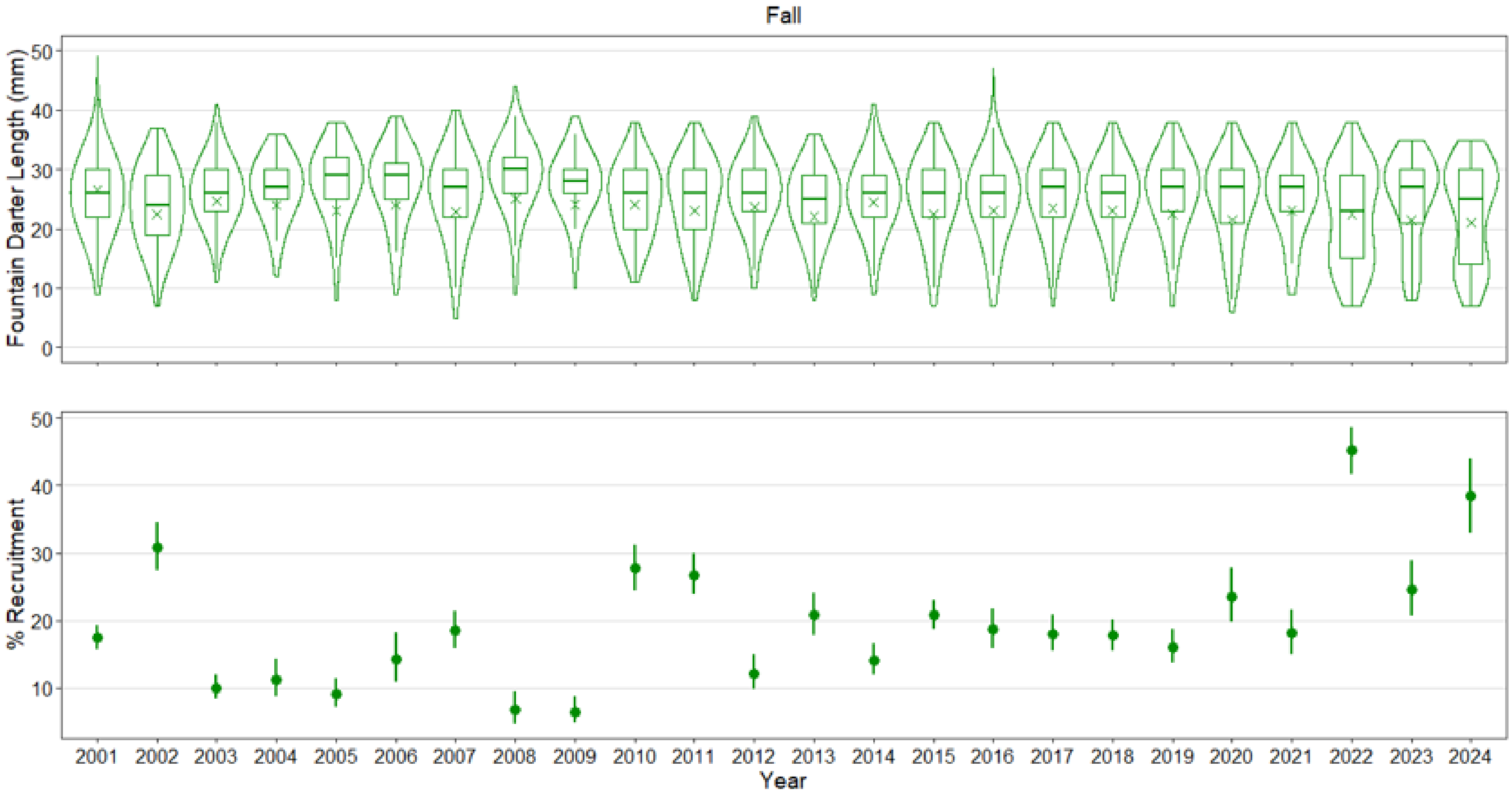

Figure E14. **Fountain Darter size structure (mm; top row) and percent recruitment (bottom row) in the Comal Springs and River during fall sampling (i.e., drop-net and timed dip-net data) events from 2001–2024. Size structure is displayed with boxplots (median, quartiles, range) and violin plots (probability density; polygons outlining boxplots). The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. Recruitment is the percent relative abundance (± 95% CI) of darters ≤20 mm.**

Figure E15. **Overall Habitat Suitability Index (OHSI) (±95% CI) from 2003–2024 among study reaches in the Comal Springs/River.**

Fish Community

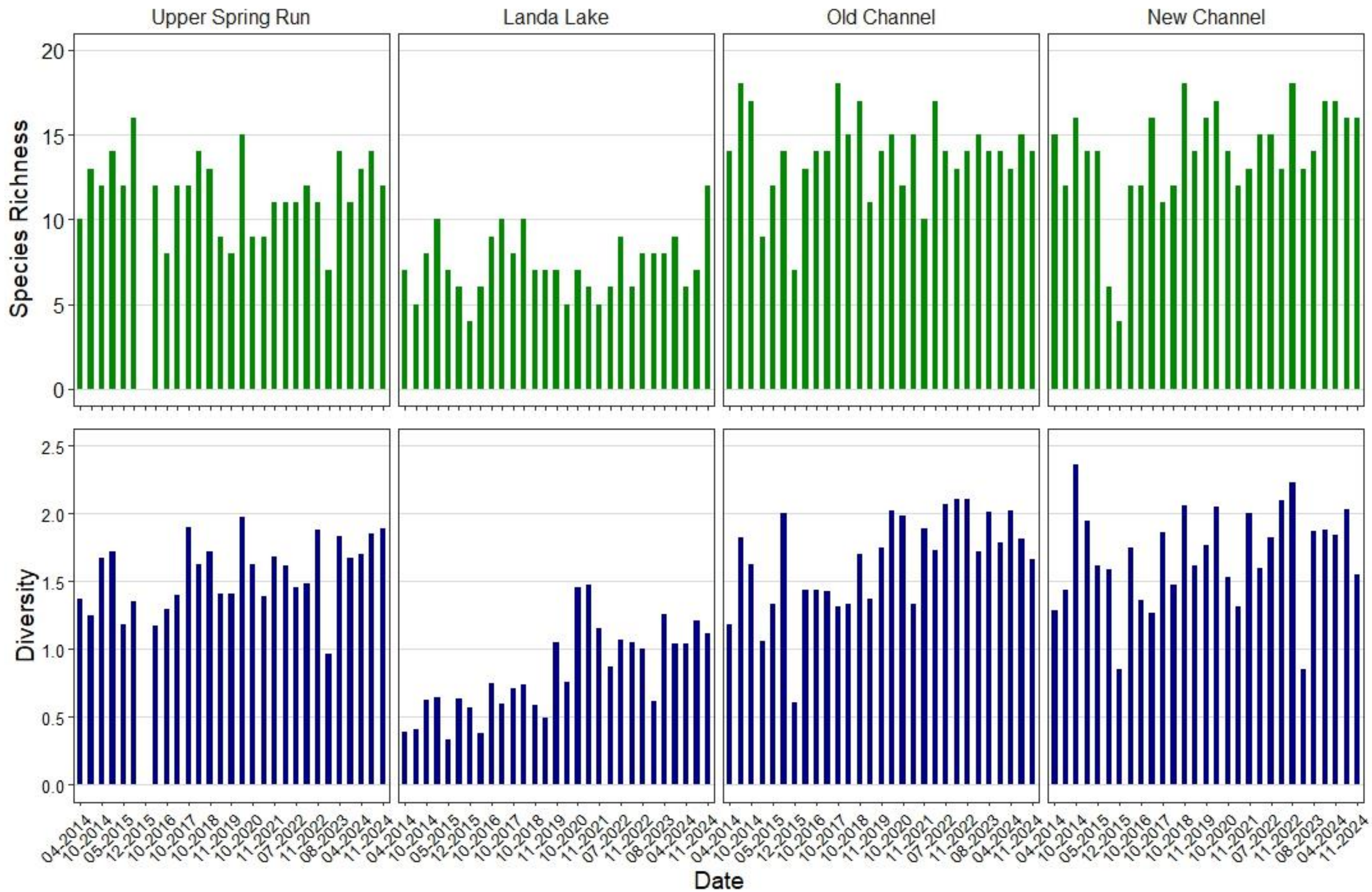

Figure E16. **Bar graphs displaying temporal trends in species richness and diversity among study reaches from 2014–2024 during fish community sampling in the Comal Springs/River.**

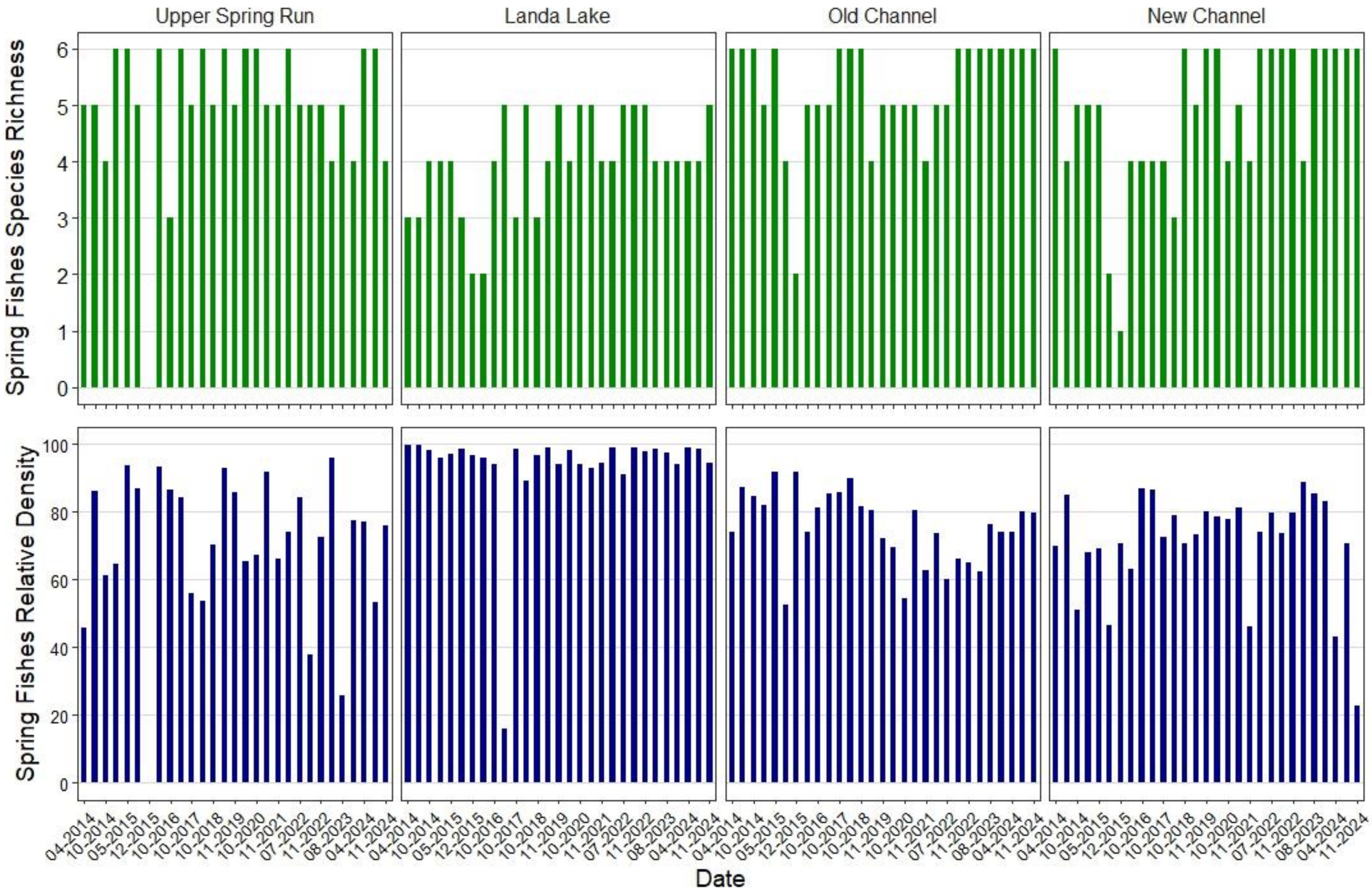

Figure E17. **Bar graphs displaying temporal trends in spring fishes species richness and percent relative density among study reaches from 2014–2024 during fish community sampling in the Comal Springs/River.**

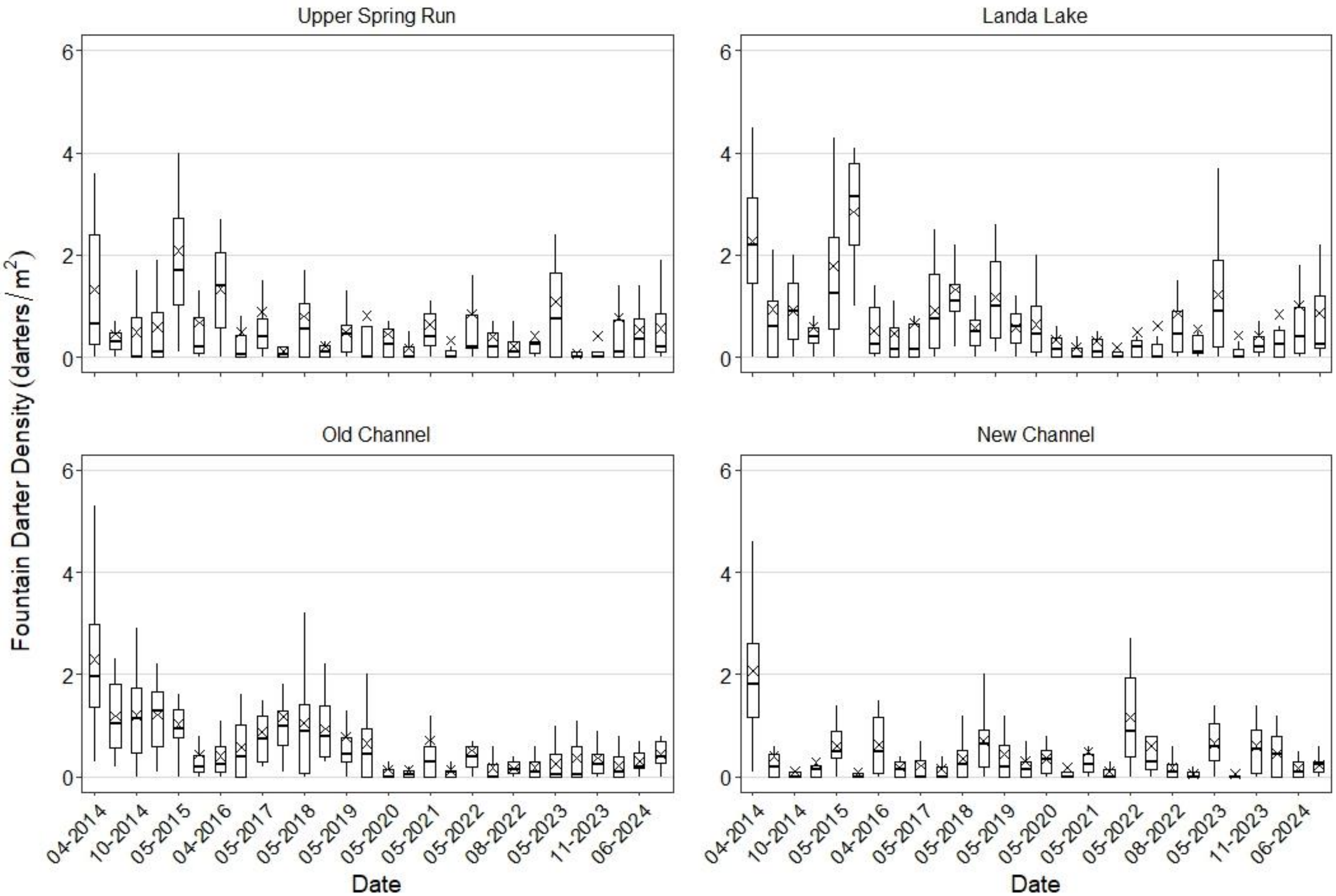

Figure E18. Boxplots displaying temporal trends in Fountain Darter density (darters/m^2) among study reaches from 2014–2024 during fish community microhabitat sampling in the Comal Springs/River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.

Comal Springs Salamander

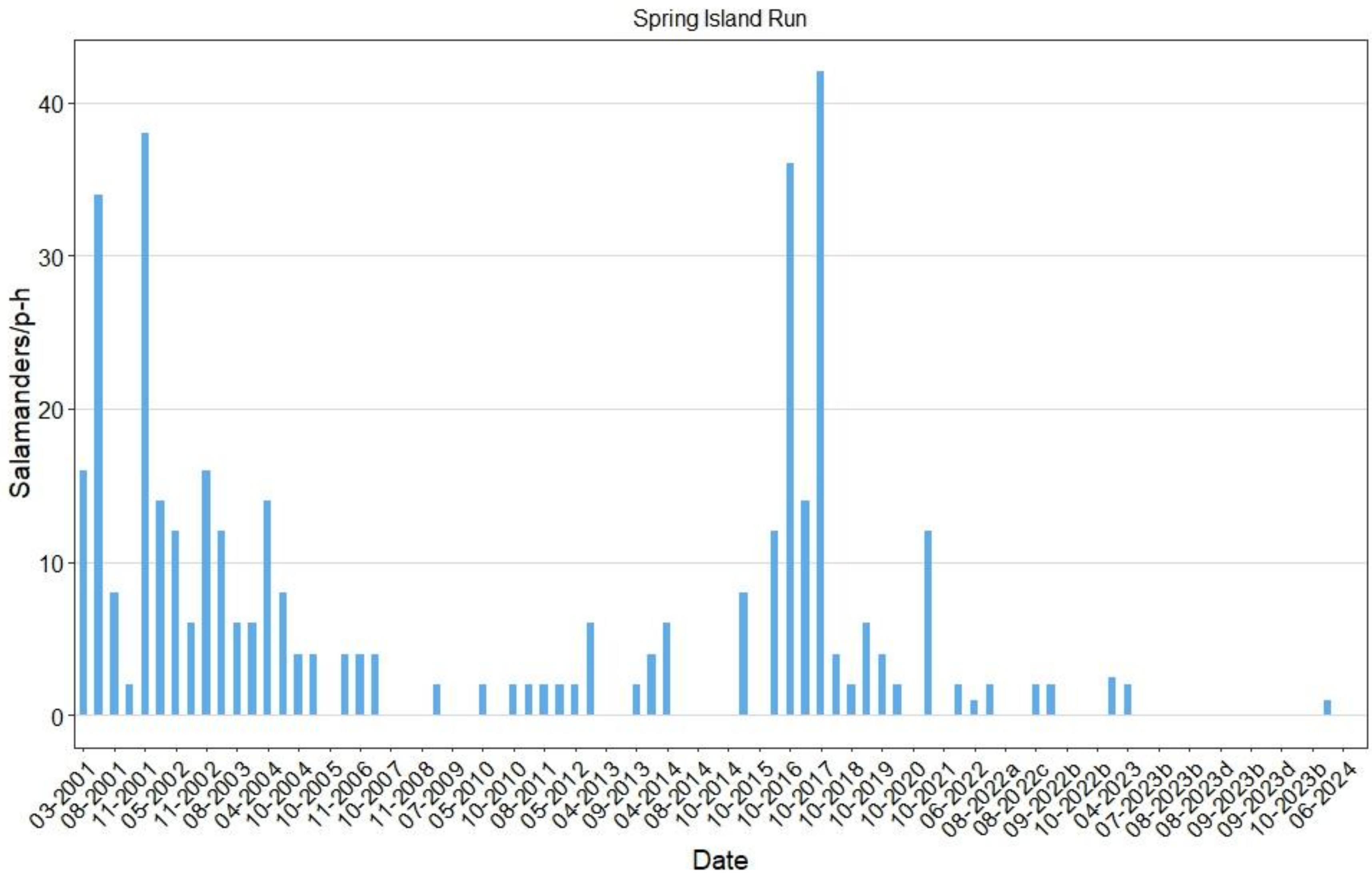

Figure E19. **Comal Springs Salamander catch-per-unit-effort (CPUE; salamanders/person-hr) from 2001–2024 at Spring Island Run.**

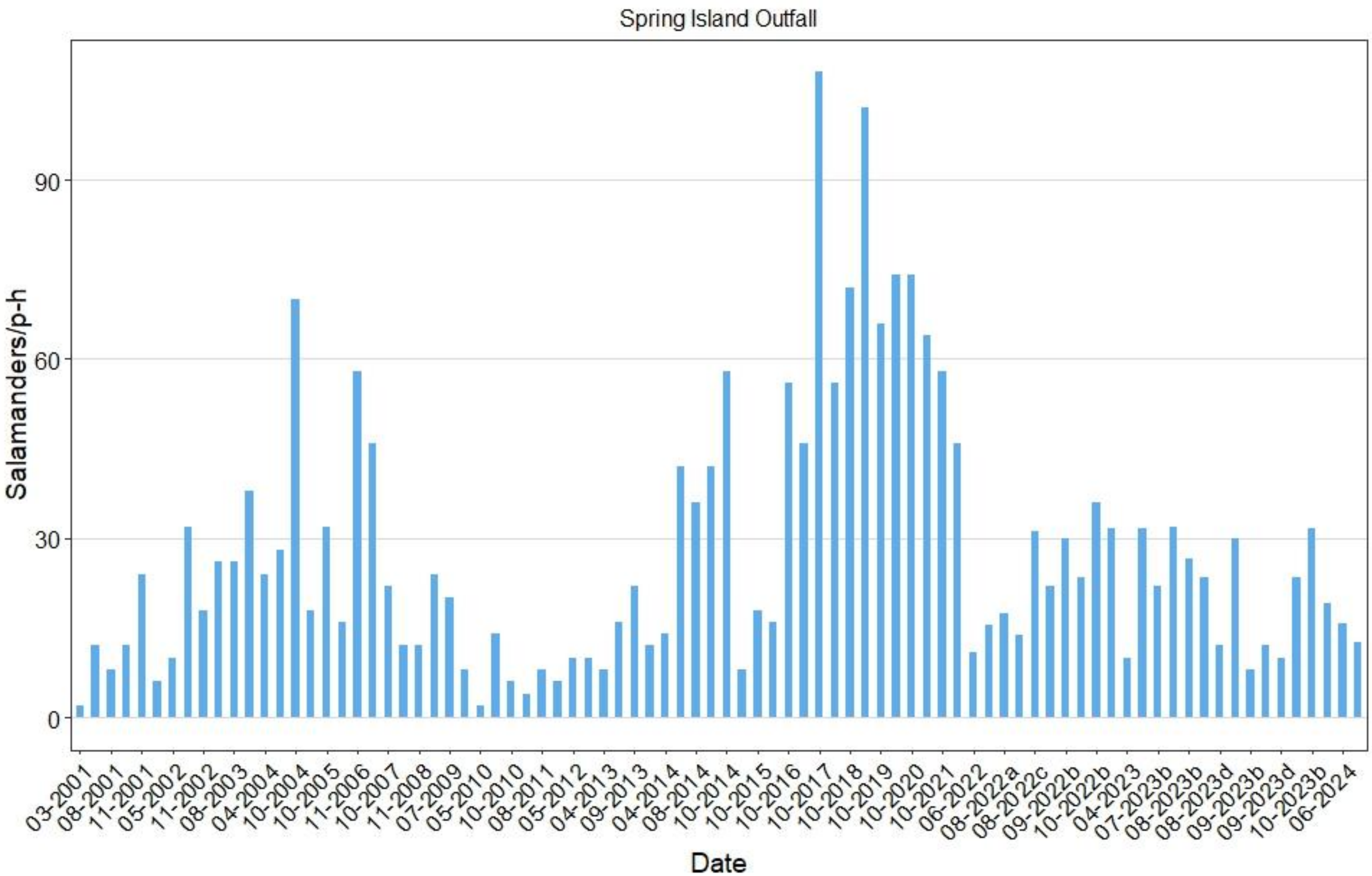

Figure E20. **Comal Springs Salamander catch-per-unit-effort (CPUE; salamanders/person-hr) from 2001–2024 at Spring Island Outfall.**

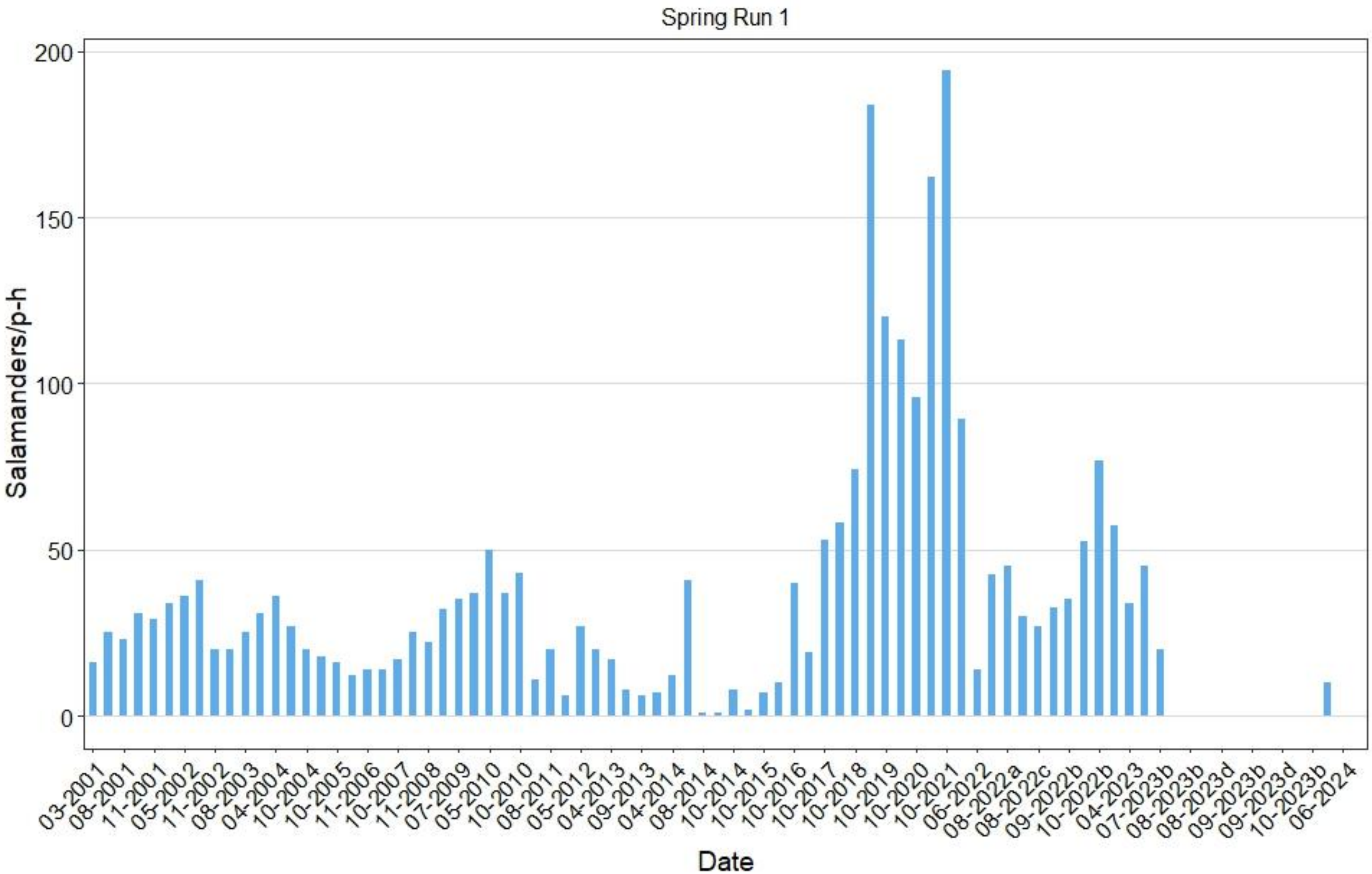

Figure E21. **Comal Springs Salamander catch-per-unit-effort (CPUE; salamanders/person-hr) from 2001–2024 at Spring Run 1.**

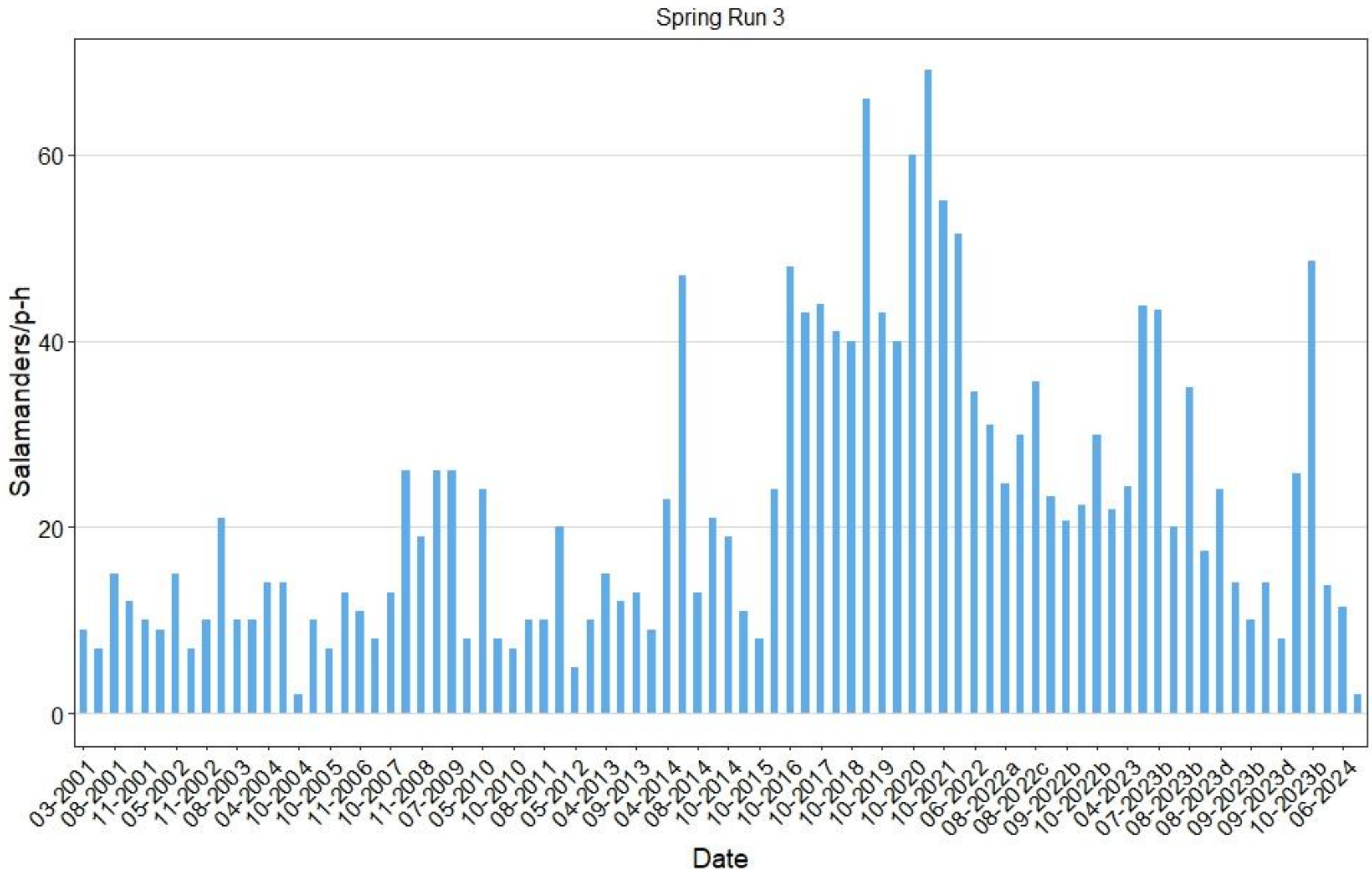

Figure E22. **Comal Springs Salamander catch-per-unit-effort (CPUE; salamanders/person-hr) from 2001–2024 at Spring Run 3.**

Macroinvertebrates

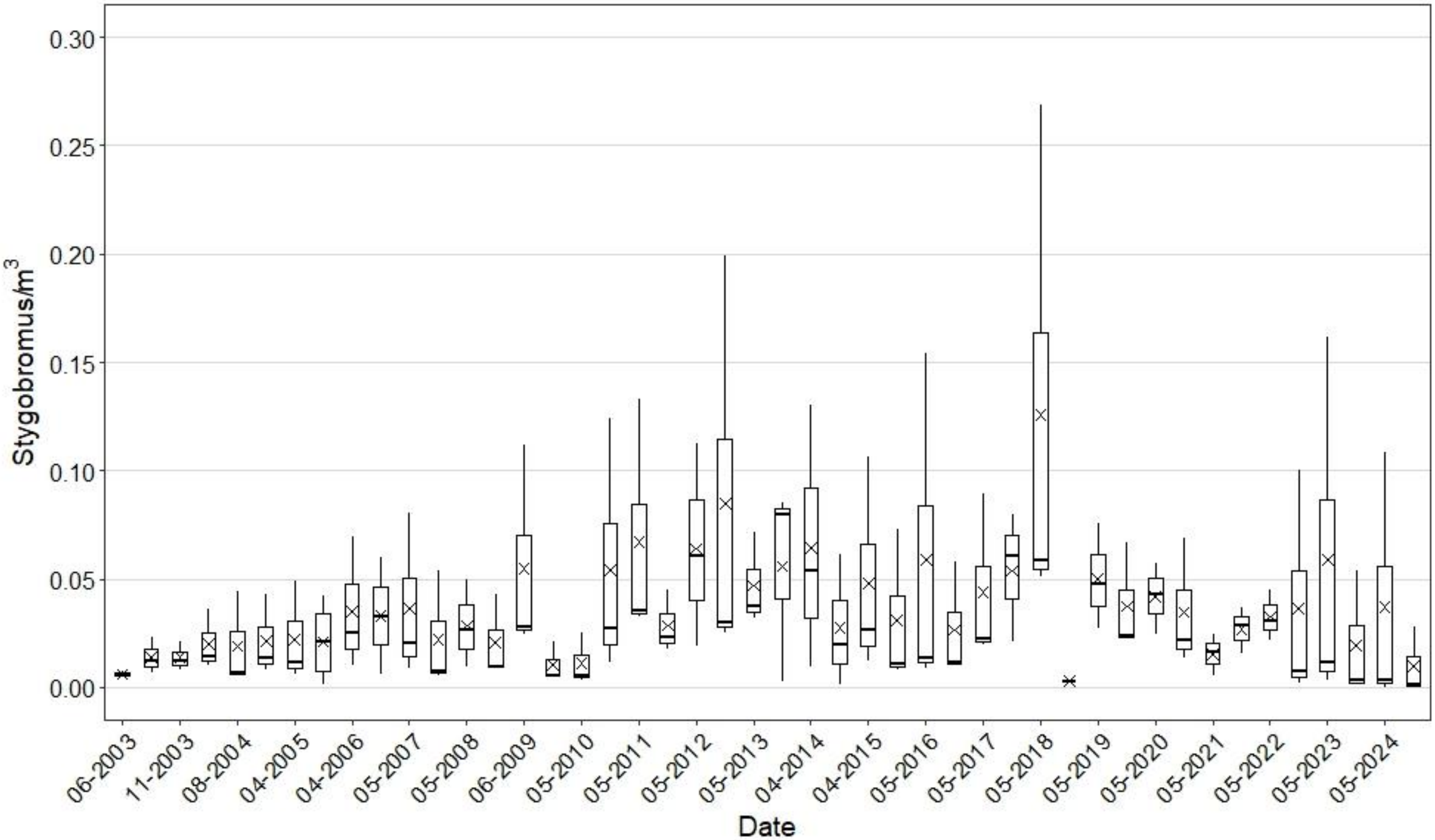

Figure E23. **Boxplots displaying *Stygobromus* sp. per cubic meters of water at Western Upwelling, Spring Run 1, and Spring Run 3 from 2003–2024. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.**

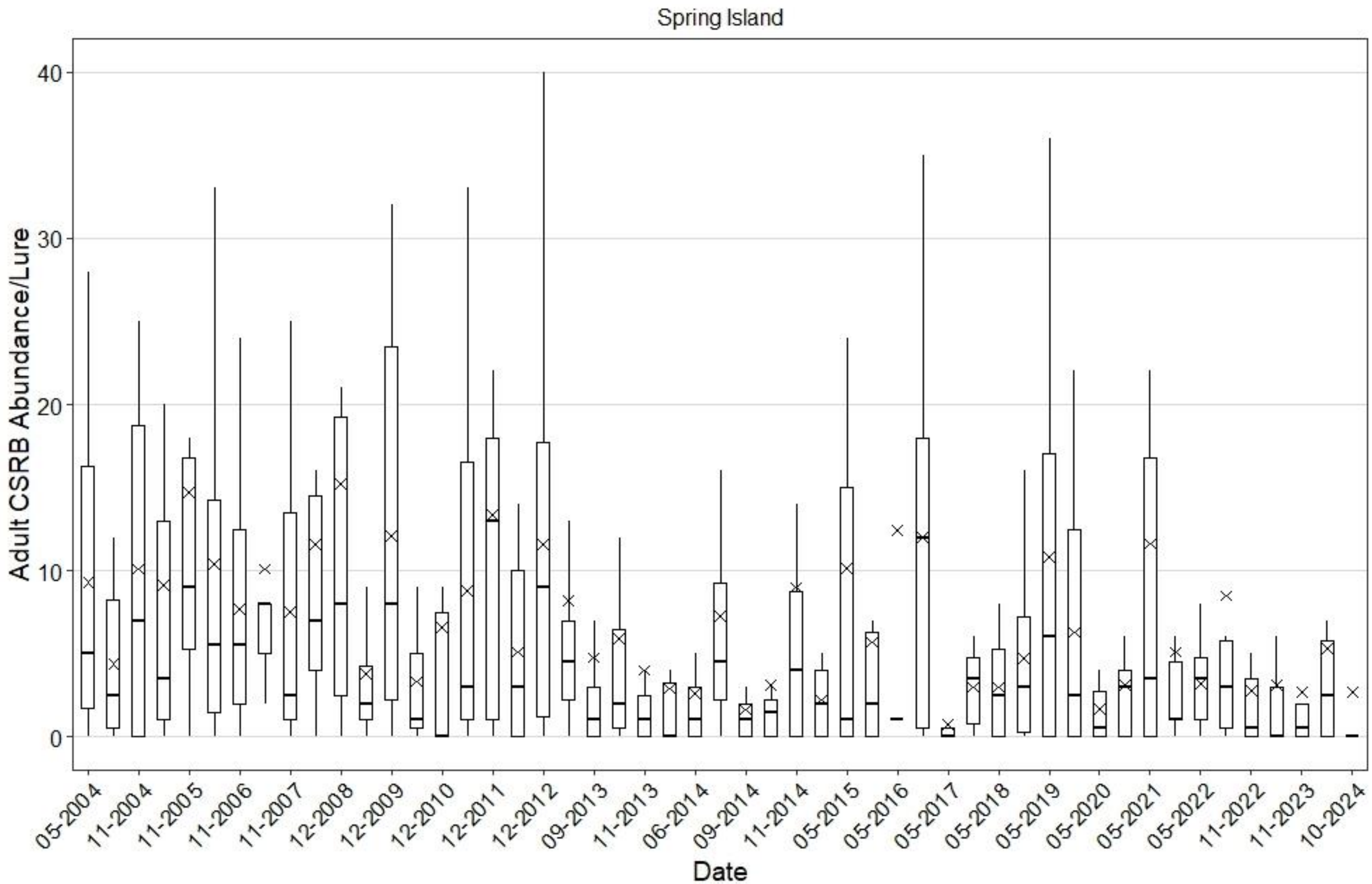

Figure E24. **Boxplots displaying temporal trends in adult CSRB abundance per retrieved at Spring Island from 2004–2024 during lure sampling in Comal Springs. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.**

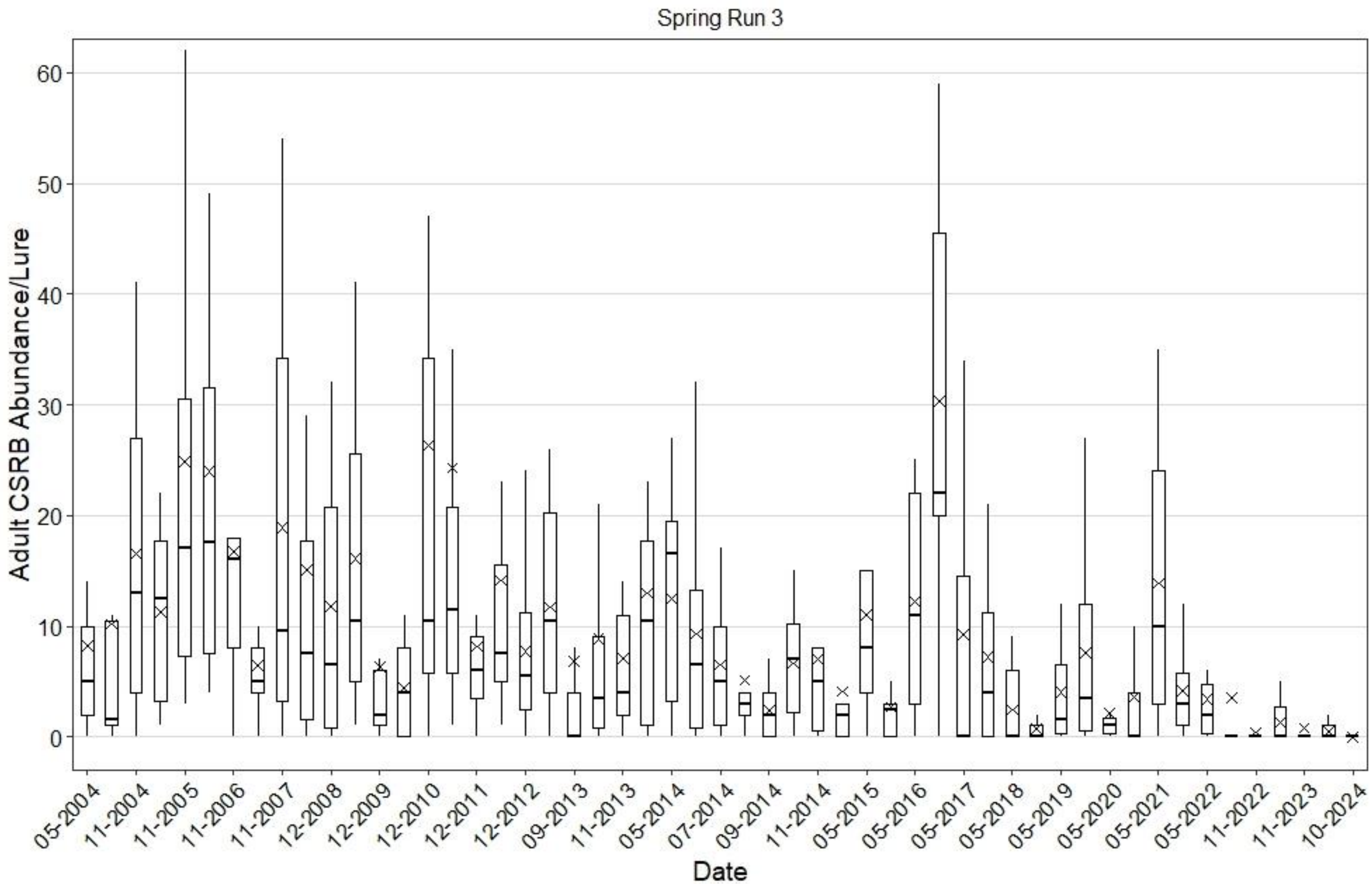

Figure E25. Boxplots displaying temporal trends in adult CSRB abundance per retrieved at Spring Run 3 from 2004–2024 during lure sampling in Comal Springs. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.

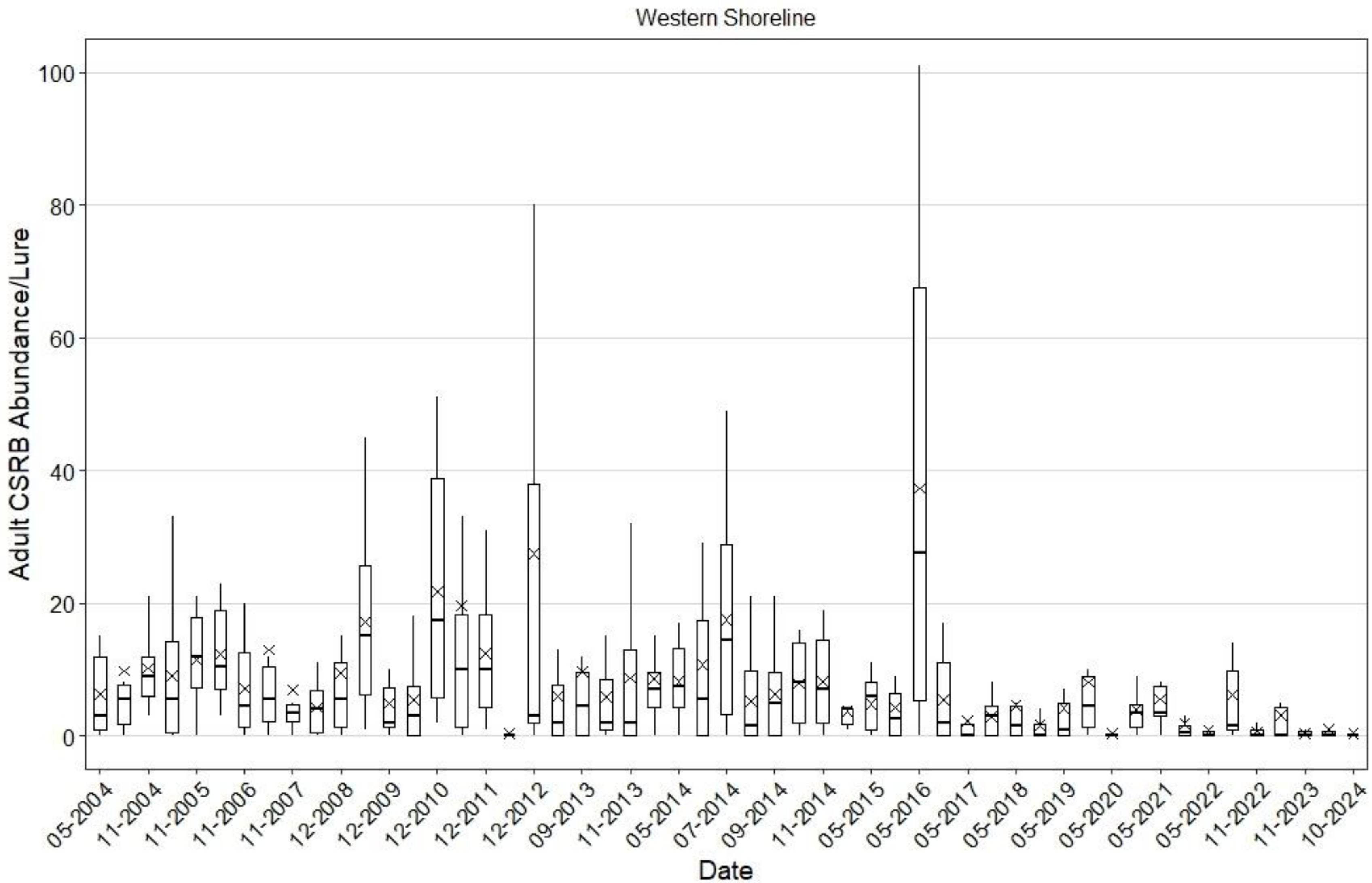

Figure E26. Boxplots displaying temporal trends in adult CSRB abundance per retrieved at the Western Shoreline from 2004–2024 during lure sampling in Comal Springs. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.

APPENDIX F: MACROINVERTEBRATE RAW DATA

Site	Date	Season	Class	Order	Family	FinalID	Counts
Upper Spring Run	5/1/2024	Spring	Malacostraca	Amphipoda	Hyalellidae	Hyalella	76
Upper Spring Run	5/1/2024	Spring	Insecta	Coleoptera	Dytiscidae	Neoclypeodytes discretus	2
Upper Spring Run	5/1/2024	Spring	Insecta	Coleoptera	Elmidae	Stenelmis	1
Upper Spring Run	5/1/2024	Spring	Insecta	Coleoptera	Psephenidae	Psephenus texanus	16
Upper Spring Run	5/1/2024	Spring	Malacostraca	Decapoda	Cambaridae	Cambaridae	3
Upper Spring Run	5/1/2024	Spring	Insecta	Diptera	Chironomidae	Chironomidae	4
Upper Spring Run	5/1/2024	Spring	Insecta	Ephemeroptera	Baetidae	Callibaetis	39
Upper Spring Run	5/1/2024	Spring	Insecta	Ephemeroptera	Caenidae	Caenis	2
Upper Spring Run	5/1/2024	Spring	Insecta	Ephemeroptera	Heptageniidae	Stenonema	5
Upper Spring Run	5/1/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	32
Upper Spring Run	5/1/2024	Spring	Gastropoda	Littorinimorpha	Hydrobiidae	Hydrobiidae	4
Upper Spring Run	5/1/2024	Spring	Insecta	Odonata	Coenagrionidae	Enallagma	5
Upper Spring Run	5/1/2024	Spring	Gastropoda		Physidae	Physella	1
Upper Spring Run	5/1/2024	Spring	Gastropoda		Planorbidae	Planorbella	3
Upper Spring Run	5/1/2024	Spring	Gastropoda		Pleuroceridae	Elimia	1
Upper Spring Run	5/1/2024	Spring	Gastropoda		Thiaridae	Melanoides tuberculata	10
Upper Spring Run	5/1/2024	Spring	Clitellata			Hirudinea	1
Upper Spring Run	5/1/2024	Spring	Clitellata			Oligochaeta	2
Upper Spring Run	10/23/2024	Fall	Malacostraca	Amphipoda	Hyalellidae	Hyalella	117
Upper Spring Run	10/23/2024	Fall	Insecta	Coleoptera	Dytiscidae	Neoclypeodytes discretus	1
Upper Spring Run	10/23/2024	Fall	Insecta	Coleoptera	Helophoridae	Helophorus	1
Upper Spring Run	10/23/2024	Fall	Insecta	Coleoptera	Hydrophilidae	Helochares	1
Upper Spring Run	10/23/2024	Fall	Insecta	Coleoptera	Psephenidae	Psephenus texanus	4
Upper Spring Run	10/23/2024	Fall	Malacostraca	Decapoda	Cambaridae	Cambaridae	2
Upper Spring Run	10/23/2024	Fall	Insecta	Diptera	Ceratopogonidae	Bezzia complex	3
Upper Spring Run	10/23/2024	Fall	Insecta	Diptera	Chironomidae	Chironomidae	14
Upper Spring Run	10/23/2024	Fall	Insecta	Diptera	Culicidae	Culicidae	1
Upper Spring Run	10/23/2024	Fall	Insecta	Ephemeroptera	Baetidae	Callibaetis	7
Upper Spring Run	10/23/2024	Fall	Insecta	Ephemeroptera	Caenidae	Caenis	1

Upper Spring Run	10/23/2024	Fall	Gastropoda		Thiaridae	Melanoides tuberculata	1
Upper Spring Run	10/23/2024	Fall	Clitellata			Oligochaeta	2
Landa Lake	5/1/2024	Spring	Malacostraca	Amphipoda	Hyalellidae	Hyalella	93
Landa Lake	5/1/2024	Spring	Insecta	Coleoptera	Scirtidae	Scirtidae	1
Landa Lake	5/1/2024	Spring	Malacostraca	Decapoda	Cambaridae	Cambaridae	3
Landa Lake	5/1/2024	Spring	Malacostraca	Decapoda	Palaemonidae	Palaemon	5
Landa Lake	5/1/2024	Spring	Insecta	Diptera	Ceratopogonidae	Bezzia complex	1
Landa Lake	5/1/2024	Spring	Insecta	Diptera	Chironomidae	Chironomidae	2
Landa Lake	5/1/2024	Spring	Insecta	Ephemeroptera	Baetidae	Callibaetis	8
Landa Lake	5/1/2024	Spring	Insecta	Ephemeroptera	Caenidae	Caenis	3
Landa Lake	5/1/2024	Spring	Insecta	Ephemeroptera	Heptageniidae	Stenonema	1
Landa Lake	5/1/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	5
Landa Lake	5/1/2024	Spring	Insecta	Hemiptera	Corixidae	Trichocorixa	5
Landa Lake	5/1/2024	Spring	Insecta	Odonata	Coenagrionidae	Enallagma	1
Landa Lake	5/1/2024	Spring	Gastropoda		Physidae	Physella	3
Landa Lake	5/1/2024	Spring	Gastropoda		Planorbidae	Planorbella	1
Landa Lake	5/1/2024	Spring	Gastropoda		Pleuroceridae	Elimia	2
Landa Lake	5/1/2024	Spring	Gastropoda		Thiaridae	Melanoides tuberculata	21
Landa Lake	5/1/2024	Spring	Clitellata			Hirudinea	3
Landa Lake	5/1/2024	Spring	Clitellata			Oligochaeta	3
Landa Lake	10/23/2024	Fall	Malacostraca	Amphipoda	Hyalellidae	Hyalella	111
Landa Lake	10/23/2024	Fall	Insecta	Coleoptera	Haliplidae	Peltodytes sexmaculatus	1
Landa Lake	10/23/2024	Fall	Insecta	Coleoptera	Hydrophilidae	Helochares	3
Landa Lake	10/23/2024	Fall	Malacostraca	Decapoda	Cambaridae	Cambaridae	2
Landa Lake	10/23/2024	Fall	Insecta	Ephemeroptera	Baetidae	Callibaetis	3
Landa Lake	10/23/2024	Fall	Insecta	Ephemeroptera	Caenidae	Caenis	1
Landa Lake	10/23/2024	Fall	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	2
Landa Lake	10/23/2024	Fall	Insecta	Odonata	Aeshnidae	Aeshnidae	1
Landa Lake	10/23/2024	Fall	Insecta	Odonata	Libellulidae	Libellulidae	1
Landa Lake	10/23/2024	Fall	Gastropoda		Thiaridae	Melanoides tuberculata	18

Landa Lake	10/23/2024	Fall	Clitellata			Oligochaeta	1
Old Channel	5/1/2024	Spring	Malacostraca	Amphipoda	Hyalellidae	Hyalella	56
Old Channel	5/1/2024	Spring	Insecta	Coleoptera	Psephenidae	Psephenus texanus	2
Old Channel	5/1/2024	Spring	Malacostraca	Decapoda	Cambaridae	Cambaridae	3
Old Channel	5/1/2024	Spring	Insecta	Diptera	Chironomidae	Chironomidae	2
Old Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Caenidae	Caenis	3
Old Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Ephemeridae	Hexagenia	2
Old Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Heptageniidae	Stenonema	8
Old Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	24
Old Channel	5/1/2024	Spring	Insecta	Hemiptera	Naucoridae	Limnocoris lutzi	3
Old Channel	5/1/2024	Spring	Insecta	Odonata	Calopterygidae	Hetaerina	1
Old Channel	5/1/2024	Spring	Insecta	Odonata	Coenagrionidae	Argia	2
Old Channel	5/1/2024	Spring	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	2
Old Channel	5/1/2024	Spring	Insecta	Trichoptera	Leptoceridae	Nectopsyche	3
Old Channel	5/1/2024	Spring	Gastropoda		Pleuroceridae	Elimia	1
Old Channel	5/1/2024	Spring	Gastropoda		Thiaridae	Melanoides tuberculata	8
Old Channel	5/1/2024	Spring	Clitellata			Hirudinea	3
Old Channel	5/1/2024	Spring	Clitellata			Oligochaeta	11
Old Channel	10/23/2024	Fall	Malacostraca	Amphipoda	Hyalellidae	Hyalella	50
Old Channel	10/23/2024	Fall	Insecta	Coleoptera	Elmidae	Microcylloepus	1
Old Channel	10/23/2024	Fall	Malacostraca	Decapoda	Cambaridae	Cambaridae	2
Old Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Baetidae	Baetis	18
Old Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Caenidae	Caenis	1
Old Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Ephemeridae	Hexagenia	1
Old Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Heptageniidae	Stenonema	2
Old Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	22
Old Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Leptophlebiidae	Thraulodes	1
Old Channel	10/23/2024	Fall	Insecta	Hemiptera	Naucoridae	Limnocoris lutzi	1
Old Channel	10/23/2024	Fall	Annelida	Hirudinea	Erpobdellidae	Erpobdella	1
Old Channel	10/23/2024	Fall	Annelida	Hirudinea	Glossosiphonidae	Glossosiphonidae	1

Old Channel	10/23/2024	Fall	Insecta	Odonata	Calopterygidae	Hetaerina	1
Old Channel	10/23/2024	Fall	Insecta	Odonata	Coenagrionidae	Argia	14
Old Channel	10/23/2024	Fall	Insecta	Odonata	Gomphidae	Phyllogomphoides	3
Old Channel	10/23/2024	Fall	Insecta	Odonata	Macromiidae	Didymops	1
Old Channel	10/23/2024	Fall	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	4
Old Channel	10/23/2024	Fall		Tricladida	Dugesiidae	Dugesia	2
Old Channel	10/23/2024	Fall	Gastropoda		Pleuroceridae	Elimia	2
Old Channel	10/23/2024	Fall	Gastropoda		Thiaridae	Melanoides tuberculata	5
Old Channel	10/23/2024	Fall	Clitellata			Oligochaeta	9
Upper New Channel	5/1/2024	Spring	Malacostraca	Amphipoda	Hyalellidae	Hyalella	52
Upper New Channel	5/1/2024	Spring	Insecta	Coleoptera	Dytiscidae	Neoclypeodytes discretus	1
Upper New Channel	5/1/2024	Spring	Insecta	Coleoptera	Elmidae	Macrelmis	23
Upper New Channel	5/1/2024	Spring	Insecta	Coleoptera	Psephenidae	Psephenus texanus	10
Upper New Channel	5/1/2024	Spring	Malacostraca	Decapoda	Cambaridae	Cambaridae	1
Upper New Channel	5/1/2024	Spring	Malacostraca	Decapoda	Palaemonidae	Palaemon	2
Upper New Channel	5/1/2024	Spring	Insecta	Diptera	Chironomidae	Chironomidae	2
Upper New Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Baetidae	Callibaetis	4
Upper New Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Heptageniidae	Stenonema	2
Upper New Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	4
Upper New Channel	5/1/2024	Spring	Insecta	Lepidoptera	Crambidae	Crambidae	1

Upper New Channel	5/1/2024	Spring	Insecta	Odonata	Coenagrionidae	Argia	3
Upper New Channel	5/1/2024	Spring	Insecta	Odonata	Coenagrionidae	Enallagma	2
Upper New Channel	5/1/2024	Spring	Insecta	Trichoptera	Glossosomatidae	Protoptila	2
Upper New Channel	5/1/2024	Spring	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	22
Upper New Channel	5/1/2024	Spring	Insecta	Trichoptera	Leptoceridae	Nectopsyche	2
Upper New Channel	5/1/2024	Spring	Insecta	Trichoptera	Philopotamidae	Chimarra	2
Upper New Channel	5/1/2024	Spring	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	2
Upper New Channel	5/1/2024	Spring		Tricladida	Dugesiidae	Dugesia	4
Upper New Channel	5/1/2024	Spring	Gastropoda		Physidae	Physella	2
Upper New Channel	5/1/2024	Spring	Gastropoda		Planorbidae	Planorbella	1
Upper New Channel	5/1/2024	Spring	Gastropoda		Pleuroceridae	Elimia	17
Upper New Channel	5/1/2024	Spring	Gastropoda		Thiaridae	Melanoides tuberculata	5
Upper New Channel	5/1/2024	Spring	Clitellata			Hirudinea	3
Upper New Channel	5/1/2024	Spring	Clitellata			Oligochaeta	1
Upper New Channel	10/23/2024	Fall	Malacostraca	Amphipoda	Hyalellidae	Hyalella	40
Upper New Channel	10/23/2024	Fall	Insecta	Coleoptera	Elmidae	Macrelmis	2
Upper New Channel	10/23/2024	Fall	Insecta	Coleoptera	Psephenidae	Psephenus texanus	3

Upper New Channel	10/23/2024	Fall	Malacostraca	Decapoda	Palaemonidae	Palaemon	1
Upper New Channel	10/23/2024	Fall	Insecta	Diptera	Chironomidae	Chironomidae	15
Upper New Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Baetidae	Baetis	15
Upper New Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Baetidae	Baetodes	1
Upper New Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	4
Upper New Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Leptophlebiidae	Thraulodes	2
Upper New Channel	10/23/2024	Fall	Insecta	Hemiptera	Naucoridae	Ambrysus	3
Upper New Channel	10/23/2024	Fall	Annelida	Hirudinea	Glossosiphonidae	Glossosiphonidae	1
Upper New Channel	10/23/2024	Fall	Insecta	Odonata	Coenagrionidae	Argia	12
Upper New Channel	10/23/2024	Fall	Insecta	Odonata	Coenagrionidae	Enallagma	2
Upper New Channel	10/23/2024	Fall	Insecta	Odonata	Libellulidae	Libellulidae	1
Upper New Channel	10/23/2024	Fall	Insecta	Trichoptera	Glossosomatidae	Protoptila	1
Upper New Channel	10/23/2024	Fall	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	21
Upper New Channel	10/23/2024	Fall	Insecta	Trichoptera	Leptoceridae	Nectopsyche	2
Upper New Channel	10/23/2024	Fall	Insecta	Trichoptera	Philopotamidae	Chimarra	13
Upper New Channel	10/23/2024	Fall	Gastropoda		Physidae	Physella	1
Upper New Channel	10/23/2024	Fall	Gastropoda		Pleuroceridae	Elimia	2

Upper New Channel	10/23/2024	Fall	Gastropoda		Thiaridae	Melanoides tuberculata	19
Lower New Channel	5/1/2024	Spring	Malacostraca	Amphipoda	Hyalellidae	Hyalella	5
Lower New Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Baetidae	Callibaetis	3
Lower New Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Leptohyphes	2
Lower New Channel	5/1/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	25
Lower New Channel	5/1/2024	Spring	Gastropoda	Littorinimorpha	Hydrobiidae	Hydrobiidae	6
Lower New Channel	5/1/2024	Spring	Insecta	Odonata	Coenagrionidae	Argia	1
Lower New Channel	5/1/2024	Spring	Insecta	Odonata	Coenagrionidae	Enallagma	1
Lower New Channel	5/1/2024	Spring	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	4
Lower New Channel	5/1/2024	Spring	Insecta	Trichoptera	Leptoceridae	Nectopsyche	26
Lower New Channel	5/1/2024	Spring	Gastropoda		Thiaridae	Melanoides tuberculata	80
Lower New Channel	5/1/2024	Spring	Clitellata			Oligochaeta	3
Lower New Channel	10/23/2024	Fall	Malacostraca	Amphipoda	Hyalellidae	Hyalella	40
Lower New Channel	10/23/2024	Fall	Insecta	Coleoptera	Haliplidae	Peltodytes	2
Lower New Channel	10/23/2024	Fall	Malacostraca	Decapoda	Cambaridae	Cambaridae	1
Lower New Channel	10/23/2024	Fall	Insecta	Diptera	Chironomidae	Chironomidae	1
Lower New Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Baetidae	Callibaetis	9

Lower New Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Caenidae	Caenis	1
Lower New Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Leptohyphidae	Leptohyphes	8
Lower New Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	29
Lower New Channel	10/23/2024	Fall	Insecta	Ephemeroptera	Leptophlebiidae	Thraulodes	3
Lower New Channel	10/23/2024	Fall	Insecta	Odonata	Aeshnidae	Basiaeschna	1
Lower New Channel	10/23/2024	Fall	Insecta	Odonata	Calopterygidae	Hetaerina	1
Lower New Channel	10/23/2024	Fall	Insecta	Odonata	Coenagrionidae	Argia	8
Lower New Channel	10/23/2024	Fall	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	2
Lower New Channel	10/23/2024	Fall	Insecta	Trichoptera	Leptoceridae	Nectopsyche	2
Lower New Channel	10/23/2024	Fall	Gastropoda		Thiaridae	Melanoides tuberculata	54
Lower New Channel	10/23/2024	Fall	Clitellata			Oligochaeta	1

APPENDIX G: DROP-NET RAW DATA

SiteCode	Reach	Site_No	Date	Dip_Net	Species	Length	Count
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	26	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	29	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	24	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	35	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	25	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	24	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	18	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	21	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	36	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	25	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	25	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	20	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	24	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	25	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	21	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	24	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Dionda nigrotaeniata	25	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Herichthys cyanoguttatus	71	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Herichthys cyanoguttatus	24	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Micropterus salmoides	49	1
3133	Upper Spring Run	Algae-1	2024-04-30	1	Palaemonetes sp.		3
3133	Upper Spring Run	Algae-1	2024-04-30	2	Dionda nigrotaeniata	22	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Dionda nigrotaeniata	24	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Dionda nigrotaeniata	23	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Dionda nigrotaeniata	24	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Dionda nigrotaeniata	34	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Dionda nigrotaeniata		1

3133	Upper Spring Run	Algae-1	2024-04-30	2	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Etheostoma fonticola	30	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Etheostoma fonticola	28	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Etheostoma fonticola	30	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Astyanax mexicanus	34	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Lepomis miniatus	29	1
3133	Upper Spring Run	Algae-1	2024-04-30	2	Lepomis miniatus	28	1
3133	Upper Spring Run	Algae-1	2024-04-30	3	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	3	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	3	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	3	Palaemonetes sp.		2
3133	Upper Spring Run	Algae-1	2024-04-30	3	Procambarus sp.		1
3133	Upper Spring Run	Algae-1	2024-04-30	3	Lepomis miniatus	36	1
3133	Upper Spring Run	Algae-1	2024-04-30	3	Micropterus salmoides	43	1
3133	Upper Spring Run	Algae-1	2024-04-30	3	Astyanax mexicanus	15	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Lepomis miniatus	87	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Etheostoma fonticola	25	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Etheostoma fonticola	25	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Etheostoma fonticola	29	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Etheostoma fonticola	25	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Etheostoma fonticola	32	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Etheostoma fonticola	24	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Palaemonetes sp.		4
3133	Upper Spring Run	Algae-1	2024-04-30	4	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Micropterus salmoides	44	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Micropterus salmoides	43	1
3133	Upper Spring Run	Algae-1	2024-04-30	4	Astyanax mexicanus	34	1

3133	Upper Spring Run	Algae-1	2024-04-30	5	Micropterus salmoides	45	1
3133	Upper Spring Run	Algae-1	2024-04-30	5	Micropterus salmoides	42	1
3133	Upper Spring Run	Algae-1	2024-04-30	5	Etheostoma lepidum	60	1
3133	Upper Spring Run	Algae-1	2024-04-30	5	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	5	Astyanax mexicanus	28	1
3133	Upper Spring Run	Algae-1	2024-04-30	5	Lepomis miniatus	32	1
3133	Upper Spring Run	Algae-1	2024-04-30	6	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	6	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	6	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	6	Micropterus salmoides	55	1
3133	Upper Spring Run	Algae-1	2024-04-30	6	Astyanax mexicanus	22	1
3133	Upper Spring Run	Algae-1	2024-04-30	6	Palaemonetes sp.		2
3133	Upper Spring Run	Algae-1	2024-04-30	7	Etheostoma fonticola	32	1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Etheostoma fonticola	31	1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Etheostoma fonticola	30	1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Etheostoma fonticola	27	1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Etheostoma fonticola	28	1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Herichthys cyanoguttatus	20	1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Lepomis miniatus	30	1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Lepomis miniatus	36	1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Micropterus salmoides	48	1
3133	Upper Spring Run	Algae-1	2024-04-30	7	Palaemonetes sp.		1
3133	Upper Spring Run	Algae-1	2024-04-30	8	Procambarus sp.		1
3133	Upper Spring Run	Algae-1	2024-04-30	8	Micropterus salmoides	45	1
3133	Upper Spring Run	Algae-1	2024-04-30	8	Etheostoma fonticola	26	1
3133	Upper Spring Run	Algae-1	2024-04-30	8	Etheostoma fonticola	27	1
3133	Upper Spring Run	Algae-1	2024-04-30	9	Etheostoma fonticola	26	1
3133	Upper Spring Run	Algae-1	2024-04-30	9	Etheostoma fonticola	34	1

3133	Upper Spring Run	Algae-1	2024-04-30	9	Etheostoma fonticola	30	1
3133	Upper Spring Run	Algae-1	2024-04-30	9	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	9	Palaemonetes sp.		2
3133	Upper Spring Run	Algae-1	2024-04-30	9	Micropterus salmoides	52	1
3133	Upper Spring Run	Algae-1	2024-04-30	9	Micropterus salmoides	41	1
3133	Upper Spring Run	Algae-1	2024-04-30	10	Procambarus sp.		1
3133	Upper Spring Run	Algae-1	2024-04-30	10	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	10	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	10	Etheostoma fonticola	28	1
3133	Upper Spring Run	Algae-1	2024-04-30	11	Dionda nigrotaeniata		1
3133	Upper Spring Run	Algae-1	2024-04-30	11	Micropterus salmoides	50	1
3133	Upper Spring Run	Algae-1	2024-04-30	12	Lepomis miniatus	26	1
3133	Upper Spring Run	Algae-1	2024-04-30	12	Lepomis miniatus	33	1
3133	Upper Spring Run	Algae-1	2024-04-30	13	Micropterus salmoides	57	1
3133	Upper Spring Run	Algae-1	2024-04-30	13	Herichthys cyanoguttatus	45	1
3133	Upper Spring Run	Algae-1	2024-04-30	14	No fish collected		
3133	Upper Spring Run	Algae-1	2024-04-30	15	No fish collected		
3134	Upper Spring Run	Sag-1	2024-04-30	1	Lepomis miniatus	140	1
3134	Upper Spring Run	Sag-1	2024-04-30	2	Procambarus sp.		1
3134	Upper Spring Run	Sag-1	2024-04-30	2	Herichthys cyanoguttatus	60	1
3134	Upper Spring Run	Sag-1	2024-04-30	3	Micropterus salmoides	60	1
3134	Upper Spring Run	Sag-1	2024-04-30	3	Herichthys cyanoguttatus	64	1
3134	Upper Spring Run	Sag-1	2024-04-30	4	Lepomis miniatus	80	1
3134	Upper Spring Run	Sag-1	2024-04-30	5	Lepomis miniatus	85	1
3134	Upper Spring Run	Sag-1	2024-04-30	6	No fish collected		
3134	Upper Spring Run	Sag-1	2024-04-30	7	Dionda nigrotaeniata	33	1
3134	Upper Spring Run	Sag-1	2024-04-30	8	No fish collected		
3134	Upper Spring Run	Sag-1	2024-04-30	9	No fish collected		
3134	Upper Spring Run	Sag-1	2024-04-30	10	Procambarus sp.		1
3134	Upper Spring Run	Sag-1	2024-04-30	11	Procambarus sp.		1

3134	Upper Spring Run	Sag-1	2024-04-30	12	No fish collected		
3134	Upper Spring Run	Sag-1	2024-04-30	13	Procambarus sp.		2
3134	Upper Spring Run	Sag-1	2024-04-30	14	Procambarus sp.		1
3134	Upper Spring Run	Sag-1	2024-04-30	15	No fish collected		
3135	Upper Spring Run	Sag-2	2024-04-30	1	Procambarus sp.		4
3135	Upper Spring Run	Sag-2	2024-04-30	1	Lepomis miniatus	76	1
3135	Upper Spring Run	Sag-2	2024-04-30	1	Lepomis miniatus	34	1
3135	Upper Spring Run	Sag-2	2024-04-30	1	Lepomis miniatus	22	1
3135	Upper Spring Run	Sag-2	2024-04-30	1	Lepomis sp.	14	1
3135	Upper Spring Run	Sag-2	2024-04-30	1	Lepomis sp.	17	1
3135	Upper Spring Run	Sag-2	2024-04-30	1	Lepomis sp.	15	1
3135	Upper Spring Run	Sag-2	2024-04-30	2	Procambarus sp.		1
3135	Upper Spring Run	Sag-2	2024-04-30	3	Procambarus sp.		3
3135	Upper Spring Run	Sag-2	2024-04-30	4	Procambarus sp.		3
3135	Upper Spring Run	Sag-2	2024-04-30	5	Procambarus sp.		1
3135	Upper Spring Run	Sag-2	2024-04-30	6	Procambarus sp.		1
3135	Upper Spring Run	Sag-2	2024-04-30	7	Procambarus sp.		4
3135	Upper Spring Run	Sag-2	2024-04-30	8	Lepomis miniatus	73	1
3135	Upper Spring Run	Sag-2	2024-04-30	9	No fish collected		
3135	Upper Spring Run	Sag-2	2024-04-30	10	Gambusia sp.	19	1
3135	Upper Spring Run	Sag-2	2024-04-30	11	No fish collected		
3135	Upper Spring Run	Sag-2	2024-04-30	12	Procambarus sp.		1
3135	Upper Spring Run	Sag-2	2024-04-30	13	No fish collected		
3135	Upper Spring Run	Sag-2	2024-04-30	14	No fish collected		
3135	Upper Spring Run	Sag-2	2024-04-30	15	Lepomis miniatus	95	1
3136	Upper Spring Run	Bryo-1	2024-04-30	1	Procambarus sp.		2
3136	Upper Spring Run	Bryo-1	2024-04-30	1	Etheostoma fonticola	24	1
3136	Upper Spring Run	Bryo-1	2024-04-30	1	Etheostoma fonticola	14	1
3136	Upper Spring Run	Bryo-1	2024-04-30	1	Etheostoma fonticola	21	1
3136	Upper Spring Run	Bryo-1	2024-04-30	2	Etheostoma fonticola	16	1

3136	Upper Spring Run	Bryo-1	2024-04-30	3	Procambarus sp.		1
3136	Upper Spring Run	Bryo-1	2024-04-30	3	Etheostoma fonticola	35	1
3136	Upper Spring Run	Bryo-1	2024-04-30	3	Etheostoma fonticola	21	1
3136	Upper Spring Run	Bryo-1	2024-04-30	4	Etheostoma fonticola	11	1
3136	Upper Spring Run	Bryo-1	2024-04-30	5	Etheostoma fonticola	22	1
3136	Upper Spring Run	Bryo-1	2024-04-30	5	Etheostoma fonticola	34	1
3136	Upper Spring Run	Bryo-1	2024-04-30	5	Etheostoma fonticola	10	1
3136	Upper Spring Run	Bryo-1	2024-04-30	6	Etheostoma fonticola	25	1
3136	Upper Spring Run	Bryo-1	2024-04-30	7	Etheostoma fonticola	25	1
3136	Upper Spring Run	Bryo-1	2024-04-30	7	Lepomis sp.	12	1
3136	Upper Spring Run	Bryo-1	2024-04-30	7	Lepomis sp.	12	1
3136	Upper Spring Run	Bryo-1	2024-04-30	8	No fish collected		
3136	Upper Spring Run	Bryo-1	2024-04-30	9	Procambarus sp.		1
3136	Upper Spring Run	Bryo-1	2024-04-30	10	Etheostoma fonticola	25	1
3136	Upper Spring Run	Bryo-1	2024-04-30	10	Etheostoma fonticola	22	1
3136	Upper Spring Run	Bryo-1	2024-04-30	11	Etheostoma fonticola	26	1
3136	Upper Spring Run	Bryo-1	2024-04-30	12	Etheostoma fonticola	31	1
3136	Upper Spring Run	Bryo-1	2024-04-30	13	No fish collected		
3136	Upper Spring Run	Bryo-1	2024-04-30	14	No fish collected		
3136	Upper Spring Run	Bryo-1	2024-04-30	15	No fish collected		
3137	Upper Spring Run	Algae-2	2024-04-30	1	Micropterus salmoides	59	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Micropterus salmoides	48	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Micropterus salmoides	47	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Dionda nigrotaeniata	25	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Dionda nigrotaeniata	32	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Dionda nigrotaeniata	27	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Dionda nigrotaeniata	32	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Dionda nigrotaeniata	30	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Dionda nigrotaeniata	12	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Palaemonetes sp.		6

3137	Upper Spring Run	Algae-2	2024-04-30	1	Lepomis miniatus	40	1
3137	Upper Spring Run	Algae-2	2024-04-30	1	Lepomis miniatus	23	1
3137	Upper Spring Run	Algae-2	2024-04-30	2	Dionda nigrotaeniata	35	1
3137	Upper Spring Run	Algae-2	2024-04-30	2	Dionda nigrotaeniata	29	1
3137	Upper Spring Run	Algae-2	2024-04-30	2	Astyanax mexicanus	44	1
3137	Upper Spring Run	Algae-2	2024-04-30	2	Lepomis miniatus	70	1
3137	Upper Spring Run	Algae-2	2024-04-30	2	Micropterus salmoides	52	1
3137	Upper Spring Run	Algae-2	2024-04-30	2	Micropterus salmoides	45	1
3137	Upper Spring Run	Algae-2	2024-04-30	2	Etheostoma fonticola	28	1
3137	Upper Spring Run	Algae-2	2024-04-30	2	Palaemonetes sp.		2
3137	Upper Spring Run	Algae-2	2024-04-30	2	Gambusia sp.	11	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Lepomis miniatus	116	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Lepomis miniatus	28	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Astyanax mexicanus	53	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Dionda nigrotaeniata	22	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Dionda nigrotaeniata	18	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Dionda nigrotaeniata	28	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Micropterus salmoides	35	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Micropterus salmoides	38	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Micropterus salmoides	45	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Etheostoma fonticola	24	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Etheostoma fonticola	16	1
3137	Upper Spring Run	Algae-2	2024-04-30	3	Palaemonetes sp.		3
3137	Upper Spring Run	Algae-2	2024-04-30	3	Gambusia sp.	10	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Lepomis miniatus	85	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Lepomis miniatus	105	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Astyanax mexicanus	46	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Astyanax mexicanus	40	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Astyanax mexicanus	40	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Etheostoma fonticola	22	1

3137	Upper Spring Run	Algae-2	2024-04-30	4	Dionda nigrotaeniata	20	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Dionda nigrotaeniata	30	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Dionda nigrotaeniata	30	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Dionda nigrotaeniata	29	1
3137	Upper Spring Run	Algae-2	2024-04-30	4	Palaemonetes sp.		2
3137	Upper Spring Run	Algae-2	2024-04-30	5	Astyanax mexicanus	50	1
3137	Upper Spring Run	Algae-2	2024-04-30	5	Astyanax mexicanus	59	1
3137	Upper Spring Run	Algae-2	2024-04-30	5	Herichthys cyanoguttatus	66	1
3137	Upper Spring Run	Algae-2	2024-04-30	5	Palaemonetes sp.		3
3137	Upper Spring Run	Algae-2	2024-04-30	5	Micropterus salmoides	38	1
3137	Upper Spring Run	Algae-2	2024-04-30	5	Lepomis miniatus	27	1
3137	Upper Spring Run	Algae-2	2024-04-30	5	Dionda nigrotaeniata	22	1
3137	Upper Spring Run	Algae-2	2024-04-30	5	Etheostoma fonticola	27	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Dionda nigrotaeniata	30	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Dionda nigrotaeniata	31	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Dionda nigrotaeniata	25	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Dionda nigrotaeniata	30	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Dionda nigrotaeniata	26	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Dionda nigrotaeniata	22	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Dionda nigrotaeniata	23	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Dionda nigrotaeniata		1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Palaemonetes sp.		2
3137	Upper Spring Run	Algae-2	2024-04-30	6	Lepomis miniatus	35	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Lepomis miniatus	87	1
3137	Upper Spring Run	Algae-2	2024-04-30	6	Lepomis miniatus	32	1
3137	Upper Spring Run	Algae-2	2024-04-30	7	Etheostoma lepidum	58	1
3137	Upper Spring Run	Algae-2	2024-04-30	7	Etheostoma fonticola	15	1
3137	Upper Spring Run	Algae-2	2024-04-30	7	Palaemonetes sp.		1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Lepomis miniatus	142	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Lepomis miniatus	73	1

3137	Upper Spring Run	Algae-2	2024-04-30	8	Lepomis miniatus	31	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Lepomis miniatus	27	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Lepomis miniatus	31	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Lepomis miniatus	24	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Lepomis miniatus	26	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Herichthys cyanoguttatus	53	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Etheostoma fonticola	23	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Etheostoma fonticola	19	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Etheostoma fonticola	26	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Dionda nigrotaeniata		1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Lepomis sp.	18	1
3137	Upper Spring Run	Algae-2	2024-04-30	8	Palaemonetes sp.		1
3137	Upper Spring Run	Algae-2	2024-04-30	9	Palaemonetes sp.		1
3137	Upper Spring Run	Algae-2	2024-04-30	9	Etheostoma fonticola	25	1
3137	Upper Spring Run	Algae-2	2024-04-30	10	Lepomis sp.	16	1
3137	Upper Spring Run	Algae-2	2024-04-30	10	Gambusia sp.	10	1
3137	Upper Spring Run	Algae-2	2024-04-30	11	Etheostoma fonticola	29	1
3137	Upper Spring Run	Algae-2	2024-04-30	11	Gambusia sp.	18	1
3137	Upper Spring Run	Algae-2	2024-04-30	11	Gambusia sp.	14	1
3137	Upper Spring Run	Algae-2	2024-04-30	12	Etheostoma fonticola	25	1
3137	Upper Spring Run	Algae-2	2024-04-30	12	Etheostoma fonticola	26	1
3137	Upper Spring Run	Algae-2	2024-04-30	12	Dionda nigrotaeniata		1
3137	Upper Spring Run	Algae-2	2024-04-30	12	Lepomis miniatus	30	1
3137	Upper Spring Run	Algae-2	2024-04-30	12	Lepomis miniatus	29	1
3137	Upper Spring Run	Algae-2	2024-04-30	12	Palaemonetes sp.		1
3137	Upper Spring Run	Algae-2	2024-04-30	13	Lepomis miniatus	71	1
3137	Upper Spring Run	Algae-2	2024-04-30	13	Astyanax mexicanus	55	1
3137	Upper Spring Run	Algae-2	2024-04-30	13	Herichthys cyanoguttatus	33	1
3137	Upper Spring Run	Algae-2	2024-04-30	13	Micropterus salmoides	46	1
3137	Upper Spring Run	Algae-2	2024-04-30	13	Dionda nigrotaeniata		1

3137	Upper Spring Run	Algae-2	2024-04-30	13	Etheostoma fonticola	27	1
3137	Upper Spring Run	Algae-2	2024-04-30	14	Lepomis miniatus	41	1
3137	Upper Spring Run	Algae-2	2024-04-30	15	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	1	Etheostoma fonticola	18	1
3138	Upper Spring Run	Bryo-2	2024-04-30	2	Lepomis miniatus	30	1
3138	Upper Spring Run	Bryo-2	2024-04-30	3	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	4	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	5	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	6	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	7	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	8	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	9	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	10	Lepomis miniatus	20	1
3138	Upper Spring Run	Bryo-2	2024-04-30	11	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	12	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	13	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	14	No fish collected		
3138	Upper Spring Run	Bryo-2	2024-04-30	15	Etheostoma fonticola	25	1
3138	Upper Spring Run	Bryo-2	2024-04-30	16	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	1	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	2	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	3	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	4	Etheostoma fonticola	34	1
3139	Upper Spring Run	Open-1	2024-04-30	5	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	6	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	7	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	8	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	9	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	10	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	11	Etheostoma fonticola	22	1

3139	Upper Spring Run	Open-1	2024-04-30	11	Etheostoma fonticola	16	1
3139	Upper Spring Run	Open-1	2024-04-30	11	Etheostoma fonticola	13	1
3139	Upper Spring Run	Open-1	2024-04-30	11	Etheostoma fonticola	16	1
3139	Upper Spring Run	Open-1	2024-04-30	11	Etheostoma fonticola	14	1
3139	Upper Spring Run	Open-1	2024-04-30	12	Etheostoma fonticola	18	1
3139	Upper Spring Run	Open-1	2024-04-30	13	Etheostoma fonticola	23	1
3139	Upper Spring Run	Open-1	2024-04-30	13	Etheostoma lepidum	25	1
3139	Upper Spring Run	Open-1	2024-04-30	14	No fish collected		
3139	Upper Spring Run	Open-1	2024-04-30	15	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	1	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	2	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	3	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	4	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	5	Etheostoma lepidum	39	1
3140	Upper Spring Run	Open-2	2024-04-30	6	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	7	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	8	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	9	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	10	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	11	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	12	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	13	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	14	No fish collected		
3140	Upper Spring Run	Open-2	2024-04-30	15	No fish collected		
3141	Landa Lake	Sag-1	2024-04-25	1	Procambarus sp.		1
3141	Landa Lake	Sag-1	2024-04-25	1	Astyanax mexicanus	24	1
3141	Landa Lake	Sag-1	2024-04-25	1	Astyanax mexicanus	37	1
3141	Landa Lake	Sag-1	2024-04-25	1	Astyanax mexicanus	21	1
3141	Landa Lake	Sag-1	2024-04-25	1	Astyanax mexicanus	20	1
3141	Landa Lake	Sag-1	2024-04-25	1	Astyanax mexicanus	18	1

3141	Landa Lake	Sag-1	2024-04-25	1	Astyanax mexicanus	17	1
3141	Landa Lake	Sag-1	2024-04-25	1	Lepomis miniatus	25	1
3141	Landa Lake	Sag-1	2024-04-25	1	Lepomis miniatus	26	1
3141	Landa Lake	Sag-1	2024-04-25	1	Lepomis sp.	18	1
3141	Landa Lake	Sag-1	2024-04-25	1	Lepomis sp.	17	1
3141	Landa Lake	Sag-1	2024-04-25	1	Lepomis sp.	18	1
3141	Landa Lake	Sag-1	2024-04-25	1	Lepomis sp.	10	1
3141	Landa Lake	Sag-1	2024-04-25	2	Lepomis sp.	19	1
3141	Landa Lake	Sag-1	2024-04-25	2	Procambarus sp.		1
3141	Landa Lake	Sag-1	2024-04-25	2	Astyanax mexicanus	29	1
3141	Landa Lake	Sag-1	2024-04-25	2	Astyanax mexicanus	32	1
3141	Landa Lake	Sag-1	2024-04-25	2	Astyanax mexicanus	26	1
3141	Landa Lake	Sag-1	2024-04-25	3	Micropterus salmoides	39	1
3141	Landa Lake	Sag-1	2024-04-25	3	Lepomis sp.	19	1
3141	Landa Lake	Sag-1	2024-04-25	3	Lepomis sp.	15	1
3141	Landa Lake	Sag-1	2024-04-25	4	Procambarus sp.		1
3141	Landa Lake	Sag-1	2024-04-25	4	Astyanax mexicanus	24	1
3141	Landa Lake	Sag-1	2024-04-25	5	Lepomis miniatus	24	1
3141	Landa Lake	Sag-1	2024-04-25	6	Lepomis miniatus	28	1
3141	Landa Lake	Sag-1	2024-04-25	6	Astyanax mexicanus	30	1
3141	Landa Lake	Sag-1	2024-04-25	6	Gambusia sp.	11	1
3141	Landa Lake	Sag-1	2024-04-25	7	Procambarus sp.		1
3141	Landa Lake	Sag-1	2024-04-25	8	No fish collected		
3141	Landa Lake	Sag-1	2024-04-25	9	No fish collected		
3141	Landa Lake	Sag-1	2024-04-25	10	No fish collected		
3141	Landa Lake	Sag-1	2024-04-25	11	No fish collected		
3141	Landa Lake	Sag-1	2024-04-25	12	No fish collected		
3141	Landa Lake	Sag-1	2024-04-25	13	No fish collected		
3141	Landa Lake	Sag-1	2024-04-25	14	No fish collected		
3141	Landa Lake	Sag-1	2024-04-25	15	No fish collected		

3142	Landa Lake	Sag-2	2024-04-25	1	Procambarus sp.		1
3142	Landa Lake	Sag-2	2024-04-25	1	Micropterus salmoides	56	1
3142	Landa Lake	Sag-2	2024-04-25	1	Micropterus salmoides	36	1
3142	Landa Lake	Sag-2	2024-04-25	1	Lepomis miniatus	60	1
3142	Landa Lake	Sag-2	2024-04-25	1	Lepomis miniatus	41	1
3142	Landa Lake	Sag-2	2024-04-25	1	Lepomis miniatus	24	1
3142	Landa Lake	Sag-2	2024-04-25	1	Lepomis miniatus	25	1
3142	Landa Lake	Sag-2	2024-04-25	1	Lepomis miniatus	28	1
3142	Landa Lake	Sag-2	2024-04-25	1	Lepomis miniatus	23	1
3142	Landa Lake	Sag-2	2024-04-25	1	Astyanax mexicanus	35	1
3142	Landa Lake	Sag-2	2024-04-25	1	Astyanax mexicanus	37	1
3142	Landa Lake	Sag-2	2024-04-25	1	Astyanax mexicanus	30	1
3142	Landa Lake	Sag-2	2024-04-25	1	Astyanax mexicanus	29	1
3142	Landa Lake	Sag-2	2024-04-25	1	Astyanax mexicanus	24	1
3142	Landa Lake	Sag-2	2024-04-25	1	Astyanax mexicanus	31	1
3142	Landa Lake	Sag-2	2024-04-25	1	Astyanax mexicanus	24	1
3142	Landa Lake	Sag-2	2024-04-25	1	Astyanax mexicanus	26	1
3142	Landa Lake	Sag-2	2024-04-25	1	Lepomis sp.	20	1
3142	Landa Lake	Sag-2	2024-04-25	1	Lepomis sp.	20	1
3142	Landa Lake	Sag-2	2024-04-25	1	Palaemonetes sp.		1
3142	Landa Lake	Sag-2	2024-04-25	2	Procambarus sp.		1
3142	Landa Lake	Sag-2	2024-04-25	2	Astyanax mexicanus	26	1
3142	Landa Lake	Sag-2	2024-04-25	2	Astyanax mexicanus	26	1
3142	Landa Lake	Sag-2	2024-04-25	2	Lepomis miniatus	41	1
3142	Landa Lake	Sag-2	2024-04-25	2	Lepomis miniatus	25	1
3142	Landa Lake	Sag-2	2024-04-25	2	Lepomis miniatus	38	1
3142	Landa Lake	Sag-2	2024-04-25	2	Lepomis sp.	17	1
3142	Landa Lake	Sag-2	2024-04-25	3	Astyanax mexicanus	23	1
3142	Landa Lake	Sag-2	2024-04-25	4	No fish collected		
3142	Landa Lake	Sag-2	2024-04-25	5	Astyanax mexicanus	18	1

3142	Landa Lake	Sag-2	2024-04-25	5	Astyanax mexicanus	24	1
3142	Landa Lake	Sag-2	2024-04-25	5	Astyanax mexicanus	25	1
3142	Landa Lake	Sag-2	2024-04-25	5	Lepomis miniatus	26	1
3142	Landa Lake	Sag-2	2024-04-25	6	No fish collected		
3142	Landa Lake	Sag-2	2024-04-25	7	No fish collected		
3142	Landa Lake	Sag-2	2024-04-25	8	No fish collected		
3142	Landa Lake	Sag-2	2024-04-25	9	Lepomis miniatus	32	1
3142	Landa Lake	Sag-2	2024-04-25	10	No fish collected		
3142	Landa Lake	Sag-2	2024-04-25	11	No fish collected		
3142	Landa Lake	Sag-2	2024-04-25	12	Lepomis miniatus	24	1
3142	Landa Lake	Sag-2	2024-04-25	12	Astyanax mexicanus	17	1
3142	Landa Lake	Sag-2	2024-04-25	13	No fish collected		
3142	Landa Lake	Sag-2	2024-04-25	14	No fish collected		
3142	Landa Lake	Sag-2	2024-04-25	15	No fish collected		
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	28	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	34	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	14	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	18	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	23	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	18	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	16	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	23	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	27	1

3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	21	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	19	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	18	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	17	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	16	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	23	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	15	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	21	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	16	1
3143	Landa Lake	Cab-1	2024-04-25	1	Etheostoma fonticola	15	1
3143	Landa Lake	Cab-1	2024-04-25	1	Procambarus sp.		2
3143	Landa Lake	Cab-1	2024-04-25	1	Palaemonetes sp.		8
3143	Landa Lake	Cab-1	2024-04-25	1	Gambusia sp.	11	1
3143	Landa Lake	Cab-1	2024-04-25	2	Procambarus sp.		3
3143	Landa Lake	Cab-1	2024-04-25	2	Etheostoma fonticola	38	1
3143	Landa Lake	Cab-1	2024-04-25	2	Etheostoma fonticola	18	1
3143	Landa Lake	Cab-1	2024-04-25	2	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	2	Etheostoma fonticola	18	1
3143	Landa Lake	Cab-1	2024-04-25	2	Etheostoma fonticola	23	1
3143	Landa Lake	Cab-1	2024-04-25	2	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	2	Etheostoma fonticola	21	1
3143	Landa Lake	Cab-1	2024-04-25	2	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	2	Etheostoma fonticola	28	1
3143	Landa Lake	Cab-1	2024-04-25	2	Palaemonetes sp.		4
3143	Landa Lake	Cab-1	2024-04-25	3	Palaemonetes sp.		6
3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	21	1
3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	28	1

3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	32	1
3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	22	1
3143	Landa Lake	Cab-1	2024-04-25	3	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	3	Procambarus sp.		3
3143	Landa Lake	Cab-1	2024-04-25	3	Gambusia sp.	15	1
3143	Landa Lake	Cab-1	2024-04-25	4	Procambarus sp.		2
3143	Landa Lake	Cab-1	2024-04-25	4	Etheostoma fonticola	22	1
3143	Landa Lake	Cab-1	2024-04-25	4	Etheostoma fonticola	31	1
3143	Landa Lake	Cab-1	2024-04-25	4	Etheostoma fonticola	23	1
3143	Landa Lake	Cab-1	2024-04-25	4	Etheostoma fonticola	29	1
3143	Landa Lake	Cab-1	2024-04-25	4	Palaemonetes sp.		2
3143	Landa Lake	Cab-1	2024-04-25	5	Procambarus sp.		1
3143	Landa Lake	Cab-1	2024-04-25	5	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	5	Etheostoma fonticola	31	1
3143	Landa Lake	Cab-1	2024-04-25	5	Etheostoma fonticola	28	1
3143	Landa Lake	Cab-1	2024-04-25	5	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	5	Etheostoma fonticola	19	1
3143	Landa Lake	Cab-1	2024-04-25	6	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	6	Etheostoma fonticola	28	1
3143	Landa Lake	Cab-1	2024-04-25	6	Etheostoma fonticola	29	1
3143	Landa Lake	Cab-1	2024-04-25	6	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	6	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	6	Etheostoma fonticola	17	1
3143	Landa Lake	Cab-1	2024-04-25	6	Etheostoma fonticola	22	1
3143	Landa Lake	Cab-1	2024-04-25	6	Etheostoma fonticola	29	1
3143	Landa Lake	Cab-1	2024-04-25	6	Procambarus sp.		1

3143	Landa Lake	Cab-1	2024-04-25	6	Palaemonetes sp.		1
3143	Landa Lake	Cab-1	2024-04-25	7	Procambarus sp.		2
3143	Landa Lake	Cab-1	2024-04-25	8	Procambarus sp.		2
3143	Landa Lake	Cab-1	2024-04-25	8	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	8	Etheostoma fonticola	22	1
3143	Landa Lake	Cab-1	2024-04-25	8	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	8	Etheostoma fonticola	16	1
3143	Landa Lake	Cab-1	2024-04-25	8	Etheostoma fonticola	22	1
3143	Landa Lake	Cab-1	2024-04-25	8	Etheostoma fonticola	32	1
3143	Landa Lake	Cab-1	2024-04-25	8	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	8	Etheostoma fonticola	22	1
3143	Landa Lake	Cab-1	2024-04-25	8	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	8	Palaemonetes sp.		2
3143	Landa Lake	Cab-1	2024-04-25	9	Palaemonetes sp.		1
3143	Landa Lake	Cab-1	2024-04-25	9	Etheostoma fonticola	29	1
3143	Landa Lake	Cab-1	2024-04-25	9	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	9	Etheostoma fonticola	21	1
3143	Landa Lake	Cab-1	2024-04-25	9	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	9	Etheostoma fonticola	16	1
3143	Landa Lake	Cab-1	2024-04-25	9	Etheostoma fonticola	21	1
3143	Landa Lake	Cab-1	2024-04-25	9	Etheostoma fonticola	21	1
3143	Landa Lake	Cab-1	2024-04-25	10	Procambarus sp.		1
3143	Landa Lake	Cab-1	2024-04-25	10	Palaemonetes sp.		2
3143	Landa Lake	Cab-1	2024-04-25	10	Etheostoma fonticola	29	1
3143	Landa Lake	Cab-1	2024-04-25	10	Etheostoma fonticola	19	1
3143	Landa Lake	Cab-1	2024-04-25	10	Etheostoma fonticola	25	1
3143	Landa Lake	Cab-1	2024-04-25	11	Procambarus sp.		2
3143	Landa Lake	Cab-1	2024-04-25	11	Etheostoma fonticola	26	1
3143	Landa Lake	Cab-1	2024-04-25	11	Etheostoma fonticola	20	1
3143	Landa Lake	Cab-1	2024-04-25	11	Etheostoma fonticola	18	1

3143	Landa Lake	Cab-1	2024-04-25	11	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	12	Etheostoma fonticola	22	1
3143	Landa Lake	Cab-1	2024-04-25	12	Etheostoma fonticola	30	1
3143	Landa Lake	Cab-1	2024-04-25	12	Etheostoma fonticola	24	1
3143	Landa Lake	Cab-1	2024-04-25	12	Etheostoma fonticola	22	1
3143	Landa Lake	Cab-1	2024-04-25	12	Etheostoma fonticola	19	1
3143	Landa Lake	Cab-1	2024-04-25	13	No fish collected		
3143	Landa Lake	Cab-1	2024-04-25	14	Etheostoma fonticola	21	1
3143	Landa Lake	Cab-1	2024-04-25	14	Etheostoma fonticola	23	1
3143	Landa Lake	Cab-1	2024-04-25	15	Palaemonetes sp.		1
3144	Landa Lake	Cab-2	2024-04-25	1	Palaemonetes sp.		36
3144	Landa Lake	Cab-2	2024-04-25	1	Etheostoma fonticola	20	1
3144	Landa Lake	Cab-2	2024-04-25	1	Etheostoma fonticola	24	1
3144	Landa Lake	Cab-2	2024-04-25	1	Etheostoma fonticola	19	1
3144	Landa Lake	Cab-2	2024-04-25	1	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	1	Lepomis sp.	17	1
3144	Landa Lake	Cab-2	2024-04-25	1	Lepomis sp.	16	1
3144	Landa Lake	Cab-2	2024-04-25	1	Lepomis miniatus	49	1
3144	Landa Lake	Cab-2	2024-04-25	1	Micropterus salmoides	44	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	25	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	35	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	27	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	27	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	15	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	2	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	2	Palaemonetes sp.		25

3144	Landa Lake	Cab-2	2024-04-25	2	Astyanax mexicanus	37	1
3144	Landa Lake	Cab-2	2024-04-25	2	Astyanax mexicanus	35	1
3144	Landa Lake	Cab-2	2024-04-25	2	Gambusia sp.	16	1
3144	Landa Lake	Cab-2	2024-04-25	2	Lepomis miniatus	28	1
3144	Landa Lake	Cab-2	2024-04-25	2	Lepomis miniatus	32	1
3144	Landa Lake	Cab-2	2024-04-25	3	Etheostoma fonticola	19	1
3144	Landa Lake	Cab-2	2024-04-25	3	Etheostoma fonticola	29	1
3144	Landa Lake	Cab-2	2024-04-25	3	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	3	Etheostoma fonticola	20	1
3144	Landa Lake	Cab-2	2024-04-25	3	Etheostoma fonticola	24	1
3144	Landa Lake	Cab-2	2024-04-25	3	Palaemonetes sp.		12
3144	Landa Lake	Cab-2	2024-04-25	3	Lepomis sp.	20	1
3144	Landa Lake	Cab-2	2024-04-25	4	Procambarus sp.		1
3144	Landa Lake	Cab-2	2024-04-25	4	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	4	Etheostoma fonticola	24	1
3144	Landa Lake	Cab-2	2024-04-25	4	Etheostoma fonticola	29	1
3144	Landa Lake	Cab-2	2024-04-25	4	Etheostoma fonticola	29	1
3144	Landa Lake	Cab-2	2024-04-25	4	Etheostoma fonticola	17	1
3144	Landa Lake	Cab-2	2024-04-25	4	Etheostoma fonticola	20	1
3144	Landa Lake	Cab-2	2024-04-25	4	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	4	Palaemonetes sp.		4
3144	Landa Lake	Cab-2	2024-04-25	5	Procambarus sp.		1
3144	Landa Lake	Cab-2	2024-04-25	5	Lepomis miniatus	32	1
3144	Landa Lake	Cab-2	2024-04-25	5	Palaemonetes sp.		7
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	22	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	17	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	18	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	25	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	21	1

3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	18	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	18	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	22	1
3144	Landa Lake	Cab-2	2024-04-25	5	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	6	Etheostoma fonticola	28	1
3144	Landa Lake	Cab-2	2024-04-25	6	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	6	Etheostoma fonticola	18	1
3144	Landa Lake	Cab-2	2024-04-25	6	Etheostoma fonticola	33	1
3144	Landa Lake	Cab-2	2024-04-25	6	Etheostoma fonticola	24	1
3144	Landa Lake	Cab-2	2024-04-25	6	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	6	Etheostoma fonticola	22	1
3144	Landa Lake	Cab-2	2024-04-25	6	Etheostoma fonticola	26	1
3144	Landa Lake	Cab-2	2024-04-25	6	Palaemonetes sp.		5
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	26	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	29	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	23	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	15	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	27	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	31	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	19	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	30	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	25	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	18	1

3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	18	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	17	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	20	1
3144	Landa Lake	Cab-2	2024-04-25	7	Etheostoma fonticola	19	1
3144	Landa Lake	Cab-2	2024-04-25	7	Palaemonetes sp.		6
3144	Landa Lake	Cab-2	2024-04-25	7	Lepomis miniatus	20	1
3144	Landa Lake	Cab-2	2024-04-25	8	Procambarus sp.		2
3144	Landa Lake	Cab-2	2024-04-25	8	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	8	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	8	Etheostoma fonticola	19	1
3144	Landa Lake	Cab-2	2024-04-25	8	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	8	Etheostoma fonticola	19	1
3144	Landa Lake	Cab-2	2024-04-25	9	Palaemonetes sp.		1
3144	Landa Lake	Cab-2	2024-04-25	9	Etheostoma fonticola	24	1
3144	Landa Lake	Cab-2	2024-04-25	9	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	9	Lepomis sp.	19	1
3144	Landa Lake	Cab-2	2024-04-25	10	Procambarus sp.		1
3144	Landa Lake	Cab-2	2024-04-25	10	Lepomis miniatus	40	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	18	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	20	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	26	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	26	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	22	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	22	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	29	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	20	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	26	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	16	1

3144	Landa Lake	Cab-2	2024-04-25	10	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	10	Palaemonetes sp.		1
3144	Landa Lake	Cab-2	2024-04-25	11	Procambarus sp.		1
3144	Landa Lake	Cab-2	2024-04-25	11	Etheostoma fonticola	25	1
3144	Landa Lake	Cab-2	2024-04-25	11	Etheostoma fonticola	20	1
3144	Landa Lake	Cab-2	2024-04-25	11	Etheostoma fonticola	20	1
3144	Landa Lake	Cab-2	2024-04-25	11	Etheostoma fonticola	20	1
3144	Landa Lake	Cab-2	2024-04-25	11	Palaemonetes sp.		1
3144	Landa Lake	Cab-2	2024-04-25	12	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	12	Etheostoma fonticola	16	1
3144	Landa Lake	Cab-2	2024-04-25	12	Etheostoma fonticola	25	1
3144	Landa Lake	Cab-2	2024-04-25	12	Etheostoma fonticola	22	1
3144	Landa Lake	Cab-2	2024-04-25	12	Etheostoma fonticola	26	1
3144	Landa Lake	Cab-2	2024-04-25	12	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	12	Etheostoma fonticola	22	1
3144	Landa Lake	Cab-2	2024-04-25	12	Procambarus sp.		2
3144	Landa Lake	Cab-2	2024-04-25	13	Lepomis miniatus	25	1
3144	Landa Lake	Cab-2	2024-04-25	13	Lepomis miniatus	48	1
3144	Landa Lake	Cab-2	2024-04-25	13	Procambarus sp.		1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	28	1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	19	1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	25	1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	28	1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	24	1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	22	1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	15	1
3144	Landa Lake	Cab-2	2024-04-25	13	Etheostoma fonticola	23	1
3144	Landa Lake	Cab-2	2024-04-25	14	Etheostoma fonticola	25	1

3144	Landa Lake	Cab-2	2024-04-25	14	Etheostoma fonticola	21	1
3144	Landa Lake	Cab-2	2024-04-25	15	Lepomis sp.	14	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	29	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	27	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	23	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	27	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	12	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	13	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	23	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	11	1
3145	Landa Lake	Lud-1	2024-04-25	1	Etheostoma fonticola	10	1
3145	Landa Lake	Lud-1	2024-04-25	1	Lepomis miniatus	98	1
3145	Landa Lake	Lud-1	2024-04-25	1	Lepomis miniatus	23	1
3145	Landa Lake	Lud-1	2024-04-25	1	Lepomis miniatus	27	1
3145	Landa Lake	Lud-1	2024-04-25	1	Lepomis miniatus	28	1
3145	Landa Lake	Lud-1	2024-04-25	1	Procambarus sp.		1
3145	Landa Lake	Lud-1	2024-04-25	1	Palaemonetes sp.		8
3145	Landa Lake	Lud-1	2024-04-25	1	Gambusia sp.	11	1
3145	Landa Lake	Lud-1	2024-04-25	1	Gambusia sp.	12	1

3145	Landa Lake	Lud-1	2024-04-25	2	Procambarus sp.		6
3145	Landa Lake	Lud-1	2024-04-25	2	Dionda nigrotaeniata	35	1
3145	Landa Lake	Lud-1	2024-04-25	2	Micropterus salmoides	45	1
3145	Landa Lake	Lud-1	2024-04-25	2	Micropterus salmoides	35	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	2	Etheostoma fonticola	10	1
3145	Landa Lake	Lud-1	2024-04-25	2	Palaemonetes sp.		1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	27	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	11	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	13	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	24	1

3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	24	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	3	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	3	Procambarus sp.		3
3145	Landa Lake	Lud-1	2024-04-25	3	Lepomis miniatus	86	1
3145	Landa Lake	Lud-1	2024-04-25	3	Palaemonetes sp.		2
3145	Landa Lake	Lud-1	2024-04-25	4	Dionda nigrotaeniata	31	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	35	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	32	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	28	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	23	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	24	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	23	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	30	1

3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	24	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	23	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	28	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	11	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	25	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	23	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	25	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	20	1

3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	4	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	4	Procambarus sp.		4
3145	Landa Lake	Lud-1	2024-04-25	4	Lepomis miniatus	67	1
3145	Landa Lake	Lud-1	2024-04-25	4	Palaemonetes sp.		4
3145	Landa Lake	Lud-1	2024-04-25	5	Procambarus sp.		2
3145	Landa Lake	Lud-1	2024-04-25	5	Palaemonetes sp.		5
3145	Landa Lake	Lud-1	2024-04-25	5	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	5	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	5	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	5	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	5	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	5	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	5	Etheostoma fonticola	25	1
3145	Landa Lake	Lud-1	2024-04-25	5	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	5	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	6	Procambarus sp.		3
3145	Landa Lake	Lud-1	2024-04-25	6	Etheostoma fonticola	24	1
3145	Landa Lake	Lud-1	2024-04-25	6	Etheostoma fonticola	24	1
3145	Landa Lake	Lud-1	2024-04-25	6	Etheostoma fonticola	33	1
3145	Landa Lake	Lud-1	2024-04-25	6	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	6	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	6	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	6	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	6	Etheostoma fonticola	10	1
3145	Landa Lake	Lud-1	2024-04-25	7	Procambarus sp.		2
3145	Landa Lake	Lud-1	2024-04-25	7	Etheostoma fonticola	30	1

3145	Landa Lake	Lud-1	2024-04-25	7	Etheostoma fonticola	24	1
3145	Landa Lake	Lud-1	2024-04-25	7	Etheostoma fonticola	10	1
3145	Landa Lake	Lud-1	2024-04-25	7	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	8	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	8	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	8	Etheostoma fonticola	10	1
3145	Landa Lake	Lud-1	2024-04-25	8	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	9	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	10	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	10	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	25	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	15	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	30	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	28	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	17	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	23	1
3145	Landa Lake	Lud-1	2024-04-25	11	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	12	Etheostoma fonticola	25	1
3145	Landa Lake	Lud-1	2024-04-25	12	Etheostoma fonticola	24	1

3145	Landa Lake	Lud-1	2024-04-25	12	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	12	Etheostoma fonticola	19	1
3145	Landa Lake	Lud-1	2024-04-25	12	Etheostoma fonticola	20	1
3145	Landa Lake	Lud-1	2024-04-25	12	Palaemonetes sp.		1
3145	Landa Lake	Lud-1	2024-04-25	13	Etheostoma fonticola	18	1
3145	Landa Lake	Lud-1	2024-04-25	13	Etheostoma fonticola	25	1
3145	Landa Lake	Lud-1	2024-04-25	13	Etheostoma fonticola	14	1
3145	Landa Lake	Lud-1	2024-04-25	13	Etheostoma fonticola	11	1
3145	Landa Lake	Lud-1	2024-04-25	13	Etheostoma fonticola	9	1
3145	Landa Lake	Lud-1	2024-04-25	13	Procambarus sp.		1
3145	Landa Lake	Lud-1	2024-04-25	14	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	14	Etheostoma fonticola	24	1
3145	Landa Lake	Lud-1	2024-04-25	14	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	14	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	14	Etheostoma fonticola	22	1
3145	Landa Lake	Lud-1	2024-04-25	14	Etheostoma fonticola	29	1
3145	Landa Lake	Lud-1	2024-04-25	14	Palaemonetes sp.		2
3145	Landa Lake	Lud-1	2024-04-25	15	Etheostoma fonticola	11	1
3145	Landa Lake	Lud-1	2024-04-25	15	Palaemonetes sp.		1
3145	Landa Lake	Lud-1	2024-04-25	16	Etheostoma fonticola	28	1
3145	Landa Lake	Lud-1	2024-04-25	17	Palaemonetes sp.		1
3145	Landa Lake	Lud-1	2024-04-25	17	Etheostoma fonticola	13	1
3145	Landa Lake	Lud-1	2024-04-25	18	Etheostoma fonticola	21	1
3145	Landa Lake	Lud-1	2024-04-25	18	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	19	Etheostoma fonticola	16	1
3145	Landa Lake	Lud-1	2024-04-25	20	No fish collected		
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	31	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	13	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	17	1

3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	13	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	13	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	17	1
3146	Landa Lake	Lud-2	2024-04-25	1	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	1	Procambarus sp.		3
3146	Landa Lake	Lud-2	2024-04-25	1	Palaemonetes sp.		12
3146	Landa Lake	Lud-2	2024-04-25	1	Lepomis miniatus	32	1
3146	Landa Lake	Lud-2	2024-04-25	2	Procambarus sp.		2
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	2	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	2	Lepomis miniatus	37	1
3146	Landa Lake	Lud-2	2024-04-25	2	Lepomis miniatus	35	1
3146	Landa Lake	Lud-2	2024-04-25	2	Lepomis miniatus	21	1
3146	Landa Lake	Lud-2	2024-04-25	2	Palaemonetes sp.		10

3146	Landa Lake	Lud-2	2024-04-25	2	Lepomis sp.	17	1
3146	Landa Lake	Lud-2	2024-04-25	2	Gambusia sp.	22	1
3146	Landa Lake	Lud-2	2024-04-25	3	Procambarus sp.		5
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	28	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	13	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	28	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	29	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	10	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	14	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	3	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	3	Lepomis miniatus	26	1
3146	Landa Lake	Lud-2	2024-04-25	3	Palaemonetes sp.		8

3146	Landa Lake	Lud-2	2024-04-25	4	Palaemonetes sp.		10
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	12	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	28	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	26	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	30	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	12	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	4	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	4	Lepomis miniatus	30	1
3146	Landa Lake	Lud-2	2024-04-25	4	Lepomis miniatus	35	1
3146	Landa Lake	Lud-2	2024-04-25	4	Gambusia sp.	18	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	26	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	26	1

3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	17	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	5	Etheostoma fonticola	11	1
3146	Landa Lake	Lud-2	2024-04-25	5	Procambarus sp.		1
3146	Landa Lake	Lud-2	2024-04-25	5	Lepomis miniatus	30	1
3146	Landa Lake	Lud-2	2024-04-25	5	Lepomis miniatus	22	1
3146	Landa Lake	Lud-2	2024-04-25	5	Lepomis miniatus	22	1
3146	Landa Lake	Lud-2	2024-04-25	5	Palaemonetes sp.		4
3146	Landa Lake	Lud-2	2024-04-25	6	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	6	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	6	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	6	Etheostoma fonticola	17	1
3146	Landa Lake	Lud-2	2024-04-25	6	Palaemonetes sp.		3
3146	Landa Lake	Lud-2	2024-04-25	7	Lepomis miniatus	26	1
3146	Landa Lake	Lud-2	2024-04-25	7	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	7	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	7	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	7	Etheostoma fonticola	29	1
3146	Landa Lake	Lud-2	2024-04-25	7	Etheostoma fonticola	20	1

3146	Landa Lake	Lud-2	2024-04-25	7	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	7	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	7	Palaemonetes sp.		2
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	30	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	28	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	28	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	29	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	29	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	23	1
3146	Landa Lake	Lud-2	2024-04-25	8	Etheostoma fonticola	10	1
3146	Landa Lake	Lud-2	2024-04-25	8	Palaemonetes sp.		3
3146	Landa Lake	Lud-2	2024-04-25	8	Procambarus sp.		1
3146	Landa Lake	Lud-2	2024-04-25	9	Palaemonetes sp.		1

3146	Landa Lake	Lud-2	2024-04-25	9	Etheostoma fonticola	28	1
3146	Landa Lake	Lud-2	2024-04-25	9	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	9	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	9	Etheostoma fonticola	14	1
3146	Landa Lake	Lud-2	2024-04-25	9	Etheostoma fonticola	17	1
3146	Landa Lake	Lud-2	2024-04-25	9	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	9	Gambusia sp.	13	1
3146	Landa Lake	Lud-2	2024-04-25	10	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	10	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	10	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	10	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	10	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	10	Etheostoma fonticola	12	1
3146	Landa Lake	Lud-2	2024-04-25	10	Procambarus sp.		1
3146	Landa Lake	Lud-2	2024-04-25	10	Lepomis miniatus	25	1
3146	Landa Lake	Lud-2	2024-04-25	11	Procambarus sp.		1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	14	1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	11	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	11	Palaemonetes sp.		5
3146	Landa Lake	Lud-2	2024-04-25	11	Lepomis miniatus	25	1
3146	Landa Lake	Lud-2	2024-04-25	12	Procambarus sp.		1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	20	1

3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	26	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	15	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	12	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	13	Procambarus sp.		2
3146	Landa Lake	Lud-2	2024-04-25	13	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	13	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	13	Etheostoma fonticola	17	1
3146	Landa Lake	Lud-2	2024-04-25	13	Etheostoma fonticola	11	1
3146	Landa Lake	Lud-2	2024-04-25	13	Lepomis miniatus	25	1
3146	Landa Lake	Lud-2	2024-04-25	13	Lepomis miniatus	70	1
3146	Landa Lake	Lud-2	2024-04-25	13	Lepomis miniatus	37	1
3146	Landa Lake	Lud-2	2024-04-25	13	Palaemonetes sp.		1
3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	29	1
3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	28	1
3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	24	1
3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	22	1
3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	19	1
3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	27	1
3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	19	1

3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	12	1
3146	Landa Lake	Lud-2	2024-04-25	14	Etheostoma fonticola	16	1
3146	Landa Lake	Lud-2	2024-04-25	14	Procambarus sp.		1
3146	Landa Lake	Lud-2	2024-04-25	15	Etheostoma fonticola	31	1
3146	Landa Lake	Lud-2	2024-04-25	15	Etheostoma fonticola	18	1
3146	Landa Lake	Lud-2	2024-04-25	15	Etheostoma fonticola	25	1
3146	Landa Lake	Lud-2	2024-04-25	15	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	15	Etheostoma fonticola	28	1
3146	Landa Lake	Lud-2	2024-04-25	15	Etheostoma fonticola	21	1
3146	Landa Lake	Lud-2	2024-04-25	15	Etheostoma fonticola	20	1
3146	Landa Lake	Lud-2	2024-04-25	15	Palaemonetes sp.		1
3146	Landa Lake	Lud-2	2024-04-25	16	Procambarus sp.		4
3147	Landa Lake	Bryo-1	2024-04-30	1	Palaemonetes sp.		3
3147	Landa Lake	Bryo-1	2024-04-30	1	Etheostoma fonticola	22	1
3147	Landa Lake	Bryo-1	2024-04-30	1	Dionda nigrotaeniata	17	1
3147	Landa Lake	Bryo-1	2024-04-30	1	Dionda nigrotaeniata	12	1
3147	Landa Lake	Bryo-1	2024-04-30	2	Palaemonetes sp.		5
3147	Landa Lake	Bryo-1	2024-04-30	2	Etheostoma fonticola	31	1
3147	Landa Lake	Bryo-1	2024-04-30	2	Etheostoma fonticola	33	1
3147	Landa Lake	Bryo-1	2024-04-30	2	Etheostoma fonticola	31	1
3147	Landa Lake	Bryo-1	2024-04-30	2	Etheostoma fonticola	32	1
3147	Landa Lake	Bryo-1	2024-04-30	2	Etheostoma fonticola	27	1
3147	Landa Lake	Bryo-1	2024-04-30	2	Etheostoma fonticola	24	1
3147	Landa Lake	Bryo-1	2024-04-30	2	Etheostoma fonticola	21	1
3147	Landa Lake	Bryo-1	2024-04-30	3	Etheostoma fonticola	31	1
3147	Landa Lake	Bryo-1	2024-04-30	3	Palaemonetes sp.		1
3147	Landa Lake	Bryo-1	2024-04-30	4	Etheostoma fonticola	23	1
3147	Landa Lake	Bryo-1	2024-04-30	4	Etheostoma fonticola	30	1
3147	Landa Lake	Bryo-1	2024-04-30	4	Etheostoma fonticola	31	1
3147	Landa Lake	Bryo-1	2024-04-30	4	Etheostoma fonticola	30	1

3147	Landa Lake	Bryo-1	2024-04-30	4	Palaemonetes sp.		2
3147	Landa Lake	Bryo-1	2024-04-30	5	Etheostoma fonticola	28	1
3147	Landa Lake	Bryo-1	2024-04-30	5	Etheostoma fonticola	30	1
3147	Landa Lake	Bryo-1	2024-04-30	5	Etheostoma fonticola	32	1
3147	Landa Lake	Bryo-1	2024-04-30	6	Etheostoma fonticola	32	1
3147	Landa Lake	Bryo-1	2024-04-30	7	No fish collected		
3147	Landa Lake	Bryo-1	2024-04-30	8	Etheostoma fonticola	25	1
3147	Landa Lake	Bryo-1	2024-04-30	8	Etheostoma fonticola	39	1
3147	Landa Lake	Bryo-1	2024-04-30	9	No fish collected		
3147	Landa Lake	Bryo-1	2024-04-30	10	Etheostoma fonticola	31	1
3147	Landa Lake	Bryo-1	2024-04-30	11	No fish collected		
3147	Landa Lake	Bryo-1	2024-04-30	12	Etheostoma fonticola	35	1
3147	Landa Lake	Bryo-1	2024-04-30	13	Procambarus sp.		1
3147	Landa Lake	Bryo-1	2024-04-30	14	No fish collected		
3147	Landa Lake	Bryo-1	2024-04-30	15	Palaemonetes sp.		1
3148	Landa Lake	Bryo-2	2024-04-30	1	Gambusia sp.	10	1
3148	Landa Lake	Bryo-2	2024-04-30	1	Gambusia sp.	12	1
3148	Landa Lake	Bryo-2	2024-04-30	1	Procambarus sp.		2
3148	Landa Lake	Bryo-2	2024-04-30	1	Etheostoma fonticola	16	1
3148	Landa Lake	Bryo-2	2024-04-30	1	Dionda nigrotaeniata	15	1
3148	Landa Lake	Bryo-2	2024-04-30	1	Palaemonetes sp.		1
3148	Landa Lake	Bryo-2	2024-04-30	2	Etheostoma fonticola	30	1
3148	Landa Lake	Bryo-2	2024-04-30	2	Etheostoma fonticola	15	1
3148	Landa Lake	Bryo-2	2024-04-30	2	Etheostoma fonticola	30	1
3148	Landa Lake	Bryo-2	2024-04-30	2	Etheostoma fonticola	16	1
3148	Landa Lake	Bryo-2	2024-04-30	2	Palaemonetes sp.		1
3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	26	1
3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	31	1
3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	20	1
3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	22	1

3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	22	1
3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	32	1
3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	21	1
3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	33	1
3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	19	1
3148	Landa Lake	Bryo-2	2024-04-30	3	Etheostoma fonticola	16	1
3148	Landa Lake	Bryo-2	2024-04-30	3	Palaemonetes sp.		1
3148	Landa Lake	Bryo-2	2024-04-30	3	Procambarus sp.		1
3148	Landa Lake	Bryo-2	2024-04-30	4	Etheostoma fonticola	31	1
3148	Landa Lake	Bryo-2	2024-04-30	4	Etheostoma fonticola	28	1
3148	Landa Lake	Bryo-2	2024-04-30	4	Etheostoma fonticola	28	1
3148	Landa Lake	Bryo-2	2024-04-30	4	Etheostoma fonticola	32	1
3148	Landa Lake	Bryo-2	2024-04-30	4	Etheostoma fonticola	23	1
3148	Landa Lake	Bryo-2	2024-04-30	4	Etheostoma fonticola	19	1
3148	Landa Lake	Bryo-2	2024-04-30	4	Etheostoma fonticola	20	1
3148	Landa Lake	Bryo-2	2024-04-30	5	Etheostoma fonticola	20	1
3148	Landa Lake	Bryo-2	2024-04-30	5	Etheostoma fonticola	26	1
3148	Landa Lake	Bryo-2	2024-04-30	5	Etheostoma fonticola	12	1
3148	Landa Lake	Bryo-2	2024-04-30	5	Etheostoma fonticola	11	1
3148	Landa Lake	Bryo-2	2024-04-30	5	Etheostoma fonticola	11	1
3148	Landa Lake	Bryo-2	2024-04-30	6	Etheostoma fonticola	31	1
3148	Landa Lake	Bryo-2	2024-04-30	6	Etheostoma fonticola	23	1
3148	Landa Lake	Bryo-2	2024-04-30	6	Etheostoma fonticola	14	1
3148	Landa Lake	Bryo-2	2024-04-30	6	Palaemonetes sp.		1
3148	Landa Lake	Bryo-2	2024-04-30	7	Etheostoma fonticola	30	1
3148	Landa Lake	Bryo-2	2024-04-30	7	Etheostoma fonticola	21	1
3148	Landa Lake	Bryo-2	2024-04-30	7	Etheostoma fonticola	9	1
3148	Landa Lake	Bryo-2	2024-04-30	8	Palaemonetes sp.		1
3148	Landa Lake	Bryo-2	2024-04-30	9	Etheostoma fonticola	31	1
3148	Landa Lake	Bryo-2	2024-04-30	9	Etheostoma fonticola	15	1

3148	Landa Lake	Bryo-2	2024-04-30	10	Etheostoma fonticola	20	1
3148	Landa Lake	Bryo-2	2024-04-30	10	Procambarus sp.		1
3148	Landa Lake	Bryo-2	2024-04-30	11	Etheostoma fonticola	14	1
3148	Landa Lake	Bryo-2	2024-04-30	11	Etheostoma fonticola	17	1
3148	Landa Lake	Bryo-2	2024-04-30	11	Etheostoma fonticola	32	1
3148	Landa Lake	Bryo-2	2024-04-30	11	Etheostoma fonticola	34	1
3148	Landa Lake	Bryo-2	2024-04-30	11	Etheostoma fonticola	20	1
3148	Landa Lake	Bryo-2	2024-04-30	12	Procambarus sp.		1
3148	Landa Lake	Bryo-2	2024-04-30	12	Etheostoma fonticola	21	1
3148	Landa Lake	Bryo-2	2024-04-30	13	Etheostoma fonticola	11	1
3148	Landa Lake	Bryo-2	2024-04-30	14	Etheostoma fonticola	28	1
3148	Landa Lake	Bryo-2	2024-04-30	14	Etheostoma fonticola	34	1
3148	Landa Lake	Bryo-2	2024-04-30	14	Etheostoma fonticola	31	1
3148	Landa Lake	Bryo-2	2024-04-30	14	Etheostoma fonticola	25	1
3148	Landa Lake	Bryo-2	2024-04-30	14	Etheostoma fonticola	12	1
3148	Landa Lake	Bryo-2	2024-04-30	15	No fish collected		
3149	Landa Lake	Val-1	2024-04-30	1	Astyanax mexicanus	32	1
3149	Landa Lake	Val-1	2024-04-30	1	Astyanax mexicanus	28	1
3149	Landa Lake	Val-1	2024-04-30	1	Astyanax mexicanus	27	1
3149	Landa Lake	Val-1	2024-04-30	1	Astyanax mexicanus	25	1
3149	Landa Lake	Val-1	2024-04-30	1	Procambarus sp.		2
3149	Landa Lake	Val-1	2024-04-30	1	Lepomis miniatus	25	1
3149	Landa Lake	Val-1	2024-04-30	1	Lepomis miniatus	20	1
3149	Landa Lake	Val-1	2024-04-30	1	Palaemonetes sp.		13
3149	Landa Lake	Val-1	2024-04-30	1	Dionda nigrotaeniata	19	1
3149	Landa Lake	Val-1	2024-04-30	1	Etheostoma fonticola	12	1
3149	Landa Lake	Val-1	2024-04-30	2	Astyanax mexicanus	27	1
3149	Landa Lake	Val-1	2024-04-30	2	Astyanax mexicanus	30	1
3149	Landa Lake	Val-1	2024-04-30	2	Astyanax mexicanus	31	1
3149	Landa Lake	Val-1	2024-04-30	2	Astyanax mexicanus	32	1

3149	Landa Lake	Val-1	2024-04-30	2	Astyanax mexicanus	35	1
3149	Landa Lake	Val-1	2024-04-30	2	Astyanax mexicanus	31	1
3149	Landa Lake	Val-1	2024-04-30	2	Astyanax mexicanus	25	1
3149	Landa Lake	Val-1	2024-04-30	2	Lepomis miniatus	25	1
3149	Landa Lake	Val-1	2024-04-30	2	Palaemonetes sp.		18
3149	Landa Lake	Val-1	2024-04-30	3	Palaemonetes sp.		8
3149	Landa Lake	Val-1	2024-04-30	3	Etheostoma fonticola	21	1
3149	Landa Lake	Val-1	2024-04-30	3	Etheostoma fonticola	17	1
3149	Landa Lake	Val-1	2024-04-30	3	Etheostoma fonticola	12	1
3149	Landa Lake	Val-1	2024-04-30	3	Etheostoma fonticola	14	1
3149	Landa Lake	Val-1	2024-04-30	4	Astyanax mexicanus	30	1
3149	Landa Lake	Val-1	2024-04-30	4	Etheostoma fonticola	18	1
3149	Landa Lake	Val-1	2024-04-30	4	Etheostoma fonticola	23	1
3149	Landa Lake	Val-1	2024-04-30	4	Lepomis miniatus	25	1
3149	Landa Lake	Val-1	2024-04-30	4	Palaemonetes sp.		2
3149	Landa Lake	Val-1	2024-04-30	5	Palaemonetes sp.		14
3149	Landa Lake	Val-1	2024-04-30	5	Procambarus sp.		1
3149	Landa Lake	Val-1	2024-04-30	5	Lepomis miniatus	25	1
3149	Landa Lake	Val-1	2024-04-30	5	Etheostoma fonticola	16	1
3149	Landa Lake	Val-1	2024-04-30	6	Astyanax mexicanus	29	1
3149	Landa Lake	Val-1	2024-04-30	6	Astyanax mexicanus	38	1
3149	Landa Lake	Val-1	2024-04-30	6	Astyanax mexicanus	32	1
3149	Landa Lake	Val-1	2024-04-30	6	Astyanax mexicanus	25	1
3149	Landa Lake	Val-1	2024-04-30	6	Astyanax mexicanus	26	1
3149	Landa Lake	Val-1	2024-04-30	6	Etheostoma fonticola	29	1
3149	Landa Lake	Val-1	2024-04-30	6	Etheostoma fonticola	22	1
3149	Landa Lake	Val-1	2024-04-30	6	Etheostoma fonticola	25	1
3149	Landa Lake	Val-1	2024-04-30	6	Lepomis miniatus	30	1
3149	Landa Lake	Val-1	2024-04-30	6	Palaemonetes sp.		7
3149	Landa Lake	Val-1	2024-04-30	7	Lepomis miniatus	32	1

3149	Landa Lake	Val-1	2024-04-30	7	Etheostoma fonticola	23	1
3149	Landa Lake	Val-1	2024-04-30	7	Etheostoma fonticola	29	1
3149	Landa Lake	Val-1	2024-04-30	7	Etheostoma fonticola	26	1
3149	Landa Lake	Val-1	2024-04-30	7	Procambarus sp.		1
3149	Landa Lake	Val-1	2024-04-30	7	Astyanax mexicanus	22	1
3149	Landa Lake	Val-1	2024-04-30	7	Astyanax mexicanus	22	1
3149	Landa Lake	Val-1	2024-04-30	7	Palaemonetes sp.		3
3149	Landa Lake	Val-1	2024-04-30	8	Lepomis miniatus	30	1
3149	Landa Lake	Val-1	2024-04-30	8	Palaemonetes sp.		6
3149	Landa Lake	Val-1	2024-04-30	8	Procambarus sp.		1
3149	Landa Lake	Val-1	2024-04-30	8	Astyanax mexicanus	35	1
3149	Landa Lake	Val-1	2024-04-30	8	Etheostoma fonticola	21	1
3149	Landa Lake	Val-1	2024-04-30	8	Etheostoma fonticola	17	1
3149	Landa Lake	Val-1	2024-04-30	8	Etheostoma fonticola	19	1
3149	Landa Lake	Val-1	2024-04-30	8	Etheostoma fonticola	24	1
3149	Landa Lake	Val-1	2024-04-30	8	Lepomis sp.	17	1
3149	Landa Lake	Val-1	2024-04-30	9	Palaemonetes sp.		3
3149	Landa Lake	Val-1	2024-04-30	9	Etheostoma fonticola	20	1
3149	Landa Lake	Val-1	2024-04-30	9	Etheostoma fonticola	25	1
3149	Landa Lake	Val-1	2024-04-30	9	Etheostoma fonticola	14	1
3149	Landa Lake	Val-1	2024-04-30	9	Etheostoma fonticola	26	1
3149	Landa Lake	Val-1	2024-04-30	10	Procambarus sp.		3
3149	Landa Lake	Val-1	2024-04-30	10	Etheostoma fonticola	22	1
3149	Landa Lake	Val-1	2024-04-30	10	Etheostoma fonticola	15	1
3149	Landa Lake	Val-1	2024-04-30	10	Palaemonetes sp.		1
3149	Landa Lake	Val-1	2024-04-30	11	Procambarus sp.		1
3149	Landa Lake	Val-1	2024-04-30	11	Etheostoma fonticola	24	1
3149	Landa Lake	Val-1	2024-04-30	11	Etheostoma fonticola	20	1
3149	Landa Lake	Val-1	2024-04-30	11	Palaemonetes sp.		6
3149	Landa Lake	Val-1	2024-04-30	12	Etheostoma fonticola	18	1

3149	Landa Lake	Val-1	2024-04-30	12	Palaemonetes sp.		9
3149	Landa Lake	Val-1	2024-04-30	13	Procambarus sp.		1
3149	Landa Lake	Val-1	2024-04-30	13	Etheostoma fonticola	20	1
3149	Landa Lake	Val-1	2024-04-30	13	Etheostoma fonticola	23	1
3149	Landa Lake	Val-1	2024-04-30	13	Palaemonetes sp.		1
3149	Landa Lake	Val-1	2024-04-30	14	Procambarus sp.		1
3149	Landa Lake	Val-1	2024-04-30	14	Palaemonetes sp.		1
3149	Landa Lake	Val-1	2024-04-30	14	Etheostoma fonticola	24	1
3149	Landa Lake	Val-1	2024-04-30	15	Etheostoma fonticola	26	1
3149	Landa Lake	Val-1	2024-04-30	16	Lepomis sp.	15	1
3149	Landa Lake	Val-1	2024-04-30	16	Etheostoma fonticola	20	1
3149	Landa Lake	Val-1	2024-04-30	17	Palaemonetes sp.		2
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	15	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	19	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	30	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	11	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	20	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	14	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	18	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	22	1

3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	11	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	19	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	21	1
3150	Landa Lake	Val-2	2024-04-30	1	Etheostoma fonticola	14	1
3150	Landa Lake	Val-2	2024-04-30	1	Procambarus sp.		1
3150	Landa Lake	Val-2	2024-04-30	1	Dionda nigrotaeniata	34	1
3150	Landa Lake	Val-2	2024-04-30	1	Dionda nigrotaeniata	34	1
3150	Landa Lake	Val-2	2024-04-30	1	Lepomis miniatus	28	1
3150	Landa Lake	Val-2	2024-04-30	1	Lepomis miniatus	24	1
3150	Landa Lake	Val-2	2024-04-30	1	Lepomis miniatus	37	1
3150	Landa Lake	Val-2	2024-04-30	1	Palaemonetes sp.		1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	27	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	15	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	19	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	30	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	30	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	27	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	21	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	29	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	15	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	17	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	10	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	19	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	10	1

3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	29	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	27	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	15	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	17	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	19	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	2	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	2	Procambarus sp.		3
3150	Landa Lake	Val-2	2024-04-30	2	Dionda nigrotaeniata	35	1
3150	Landa Lake	Val-2	2024-04-30	2	Dionda nigrotaeniata	19	1
3150	Landa Lake	Val-2	2024-04-30	2	Palaemonetes sp.		3
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	29	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	32	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	17	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	27	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	17	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	3	Etheostoma fonticola	14	1

3150	Landa Lake	Val-2	2024-04-30	3	Dionda nigrotaeniata	32	1
3150	Landa Lake	Val-2	2024-04-30	3	Procambarus sp.		2
3150	Landa Lake	Val-2	2024-04-30	3	Micropterus salmoides	50	1
3150	Landa Lake	Val-2	2024-04-30	3	Palaemonetes sp.		2
3150	Landa Lake	Val-2	2024-04-30	4	Dionda nigrotaeniata	36	1
3150	Landa Lake	Val-2	2024-04-30	4	Dionda nigrotaeniata	34	1
3150	Landa Lake	Val-2	2024-04-30	4	Dionda nigrotaeniata	40	1
3150	Landa Lake	Val-2	2024-04-30	4	Dionda nigrotaeniata	27	1
3150	Landa Lake	Val-2	2024-04-30	4	Dionda nigrotaeniata	34	1
3150	Landa Lake	Val-2	2024-04-30	4	Lepomis miniatus	26	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	20	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	19	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	13	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	19	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	21	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	17	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	4	Etheostoma fonticola	21	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	32	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	20	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	22	1

3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	21	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	20	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	15	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	5	Etheostoma fonticola	15	1
3150	Landa Lake	Val-2	2024-04-30	5	Palaemonetes sp.		1
3150	Landa Lake	Val-2	2024-04-30	5	Astyanax mexicanus	30	1
3150	Landa Lake	Val-2	2024-04-30	6	Palaemonetes sp.		1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	27	1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	21	1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	29	1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	27	1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	6	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	6	Palaemonetes sp.		2
3150	Landa Lake	Val-2	2024-04-30	6	Lepomis miniatus	15	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	29	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	19	1

3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	10	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	11	1
3150	Landa Lake	Val-2	2024-04-30	7	Etheostoma fonticola	13	1
3150	Landa Lake	Val-2	2024-04-30	7	Dionda nigrotaeniata	36	1
3150	Landa Lake	Val-2	2024-04-30	8	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	8	Etheostoma fonticola	31	1
3150	Landa Lake	Val-2	2024-04-30	8	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	8	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	8	Etheostoma fonticola	14	1
3150	Landa Lake	Val-2	2024-04-30	8	Etheostoma fonticola	21	1
3150	Landa Lake	Val-2	2024-04-30	8	Lepomis miniatus	23	1
3150	Landa Lake	Val-2	2024-04-30	8	Lepomis miniatus	27	1
3150	Landa Lake	Val-2	2024-04-30	9	Etheostoma fonticola	17	1
3150	Landa Lake	Val-2	2024-04-30	9	Etheostoma fonticola	20	1
3150	Landa Lake	Val-2	2024-04-30	9	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	9	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	9	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	9	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	9	Etheostoma fonticola	18	1
3150	Landa Lake	Val-2	2024-04-30	9	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	9	Lepomis miniatus	28	1
3150	Landa Lake	Val-2	2024-04-30	9	Palaemonetes sp.		1
3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	14	1
3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	14	1
3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	21	1
3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	14	1
3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	22	1

3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	18	1
3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	10	Etheostoma fonticola	12	1
3150	Landa Lake	Val-2	2024-04-30	10	Palaemonetes sp.		1
3150	Landa Lake	Val-2	2024-04-30	11	Etheostoma fonticola	38	1
3150	Landa Lake	Val-2	2024-04-30	11	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	11	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	11	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	11	Etheostoma fonticola	18	1
3150	Landa Lake	Val-2	2024-04-30	11	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	12	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	12	Etheostoma fonticola	18	1
3150	Landa Lake	Val-2	2024-04-30	12	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	12	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	12	Etheostoma fonticola	21	1
3150	Landa Lake	Val-2	2024-04-30	12	Astyanax mexicanus	47	1
3150	Landa Lake	Val-2	2024-04-30	12	Dionda nigrotaeniata	49	1
3150	Landa Lake	Val-2	2024-04-30	12	Procambarus sp.		2
3150	Landa Lake	Val-2	2024-04-30	12	Lepomis miniatus	28	1
3150	Landa Lake	Val-2	2024-04-30	13	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	13	Etheostoma fonticola	30	1
3150	Landa Lake	Val-2	2024-04-30	13	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	13	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	13	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	13	Dionda nigrotaeniata	35	1
3150	Landa Lake	Val-2	2024-04-30	14	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	14	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	14	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	14	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	14	Etheostoma fonticola	19	1

3150	Landa Lake	Val-2	2024-04-30	14	Procambarus sp.		2
3150	Landa Lake	Val-2	2024-04-30	15	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	15	Etheostoma fonticola	24	1
3150	Landa Lake	Val-2	2024-04-30	15	Etheostoma fonticola	13	1
3150	Landa Lake	Val-2	2024-04-30	15	Dionda nigrotaeniata	36	1
3150	Landa Lake	Val-2	2024-04-30	16	Lepomis miniatus	28	1
3150	Landa Lake	Val-2	2024-04-30	16	Etheostoma fonticola	15	1
3150	Landa Lake	Val-2	2024-04-30	16	Etheostoma fonticola	15	1
3150	Landa Lake	Val-2	2024-04-30	16	Etheostoma fonticola	26	1
3150	Landa Lake	Val-2	2024-04-30	16	Etheostoma fonticola	27	1
3150	Landa Lake	Val-2	2024-04-30	16	Etheostoma fonticola	30	1
3150	Landa Lake	Val-2	2024-04-30	16	Etheostoma fonticola	15	1
3150	Landa Lake	Val-2	2024-04-30	17	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	17	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	17	Etheostoma fonticola	27	1
3150	Landa Lake	Val-2	2024-04-30	17	Palaemonetes sp.		1
3150	Landa Lake	Val-2	2024-04-30	18	Etheostoma fonticola	18	1
3150	Landa Lake	Val-2	2024-04-30	18	Etheostoma fonticola	18	1
3150	Landa Lake	Val-2	2024-04-30	19	Etheostoma fonticola	33	1
3150	Landa Lake	Val-2	2024-04-30	19	Dionda nigrotaeniata	35	1
3150	Landa Lake	Val-2	2024-04-30	20	Etheostoma fonticola	32	1
3150	Landa Lake	Val-2	2024-04-30	20	Etheostoma fonticola	17	1
3150	Landa Lake	Val-2	2024-04-30	20	Etheostoma fonticola	20	1
3150	Landa Lake	Val-2	2024-04-30	20	Etheostoma fonticola	20	1
3150	Landa Lake	Val-2	2024-04-30	21	Etheostoma fonticola	23	1
3150	Landa Lake	Val-2	2024-04-30	21	Etheostoma fonticola	22	1
3150	Landa Lake	Val-2	2024-04-30	22	Etheostoma fonticola	25	1
3150	Landa Lake	Val-2	2024-04-30	22	Etheostoma fonticola	16	1
3150	Landa Lake	Val-2	2024-04-30	23	Etheostoma fonticola	28	1
3150	Landa Lake	Val-2	2024-04-30	23	Etheostoma fonticola	23	1

3150	Landa Lake	Val-2	2024-04-30	24	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	1	Etheostoma fonticola	30	1
3151	Landa Lake	Open-1	2024-04-30	2	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	3	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	4	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	5	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	6	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	7	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	8	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	9	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	10	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	11	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	12	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	13	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	14	No fish collected		
3151	Landa Lake	Open-1	2024-04-30	15	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	1	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	2	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	3	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	4	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	5	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	6	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	7	Etheostoma fonticola	19	1
3152	Landa Lake	Open-2	2024-04-30	8	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	9	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	10	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	11	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	12	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	13	No fish collected		
3152	Landa Lake	Open-2	2024-04-30	14	No fish collected		

3152	Landa Lake	Open-2	2024-04-30	15	No fish collected		
3153	Old Channel Reach	Bryo-1	2024-05-01	1	Etheostoma fonticola	20	1
3153	Old Channel Reach	Bryo-1	2024-05-01	1	Etheostoma fonticola	24	1
3153	Old Channel Reach	Bryo-1	2024-05-01	1	Palaemonetes sp.		1
3153	Old Channel Reach	Bryo-1	2024-05-01	2	Etheostoma fonticola	24	1
3153	Old Channel Reach	Bryo-1	2024-05-01	2	Etheostoma fonticola	20	1
3153	Old Channel Reach	Bryo-1	2024-05-01	2	Etheostoma fonticola	23	1
3153	Old Channel Reach	Bryo-1	2024-05-01	2	Etheostoma fonticola	23	1
3153	Old Channel Reach	Bryo-1	2024-05-01	2	Procambarus sp.		2
3153	Old Channel Reach	Bryo-1	2024-05-01	3	Etheostoma fonticola	21	1
3153	Old Channel Reach	Bryo-1	2024-05-01	3	Etheostoma fonticola	22	1
3153	Old Channel Reach	Bryo-1	2024-05-01	3	Etheostoma fonticola	22	1
3153	Old Channel Reach	Bryo-1	2024-05-01	3	Etheostoma fonticola	15	1
3153	Old Channel Reach	Bryo-1	2024-05-01	3	Etheostoma fonticola	12	1
3153	Old Channel Reach	Bryo-1	2024-05-01	3	Procambarus sp.		2
3153	Old Channel Reach	Bryo-1	2024-05-01	4	Etheostoma fonticola	26	1
3153	Old Channel Reach	Bryo-1	2024-05-01	4	Etheostoma fonticola	19	1
3153	Old Channel Reach	Bryo-1	2024-05-01	4	Etheostoma fonticola	19	1
3153	Old Channel Reach	Bryo-1	2024-05-01	5	Etheostoma fonticola	30	1
3153	Old Channel Reach	Bryo-1	2024-05-01	5	Etheostoma fonticola	23	1
3153	Old Channel Reach	Bryo-1	2024-05-01	6	Procambarus sp.		2
3153	Old Channel Reach	Bryo-1	2024-05-01	6	Etheostoma fonticola	23	1
3153	Old Channel Reach	Bryo-1	2024-05-01	6	Etheostoma fonticola	20	1
3153	Old Channel Reach	Bryo-1	2024-05-01	6	Etheostoma fonticola	26	1
3153	Old Channel Reach	Bryo-1	2024-05-01	7	Procambarus sp.		5
3153	Old Channel Reach	Bryo-1	2024-05-01	7	Palaemonetes sp.		1
3153	Old Channel Reach	Bryo-1	2024-05-01	7	Etheostoma fonticola	22	1
3153	Old Channel Reach	Bryo-1	2024-05-01	7	Etheostoma fonticola	22	1
3153	Old Channel Reach	Bryo-1	2024-05-01	8	Etheostoma fonticola	20	1
3153	Old Channel Reach	Bryo-1	2024-05-01	8	Etheostoma fonticola	28	1

3153	Old Channel Reach	Bryo-1	2024-05-01	8	Etheostoma fonticola	27	1
3153	Old Channel Reach	Bryo-1	2024-05-01	9	Etheostoma fonticola	25	1
3153	Old Channel Reach	Bryo-1	2024-05-01	9	Etheostoma fonticola	23	1
3153	Old Channel Reach	Bryo-1	2024-05-01	9	Etheostoma fonticola	21	1
3153	Old Channel Reach	Bryo-1	2024-05-01	9	Etheostoma fonticola	20	1
3153	Old Channel Reach	Bryo-1	2024-05-01	10	Procambarus sp.		2
3153	Old Channel Reach	Bryo-1	2024-05-01	10	Etheostoma fonticola	23	1
3153	Old Channel Reach	Bryo-1	2024-05-01	11	Etheostoma fonticola	20	1
3153	Old Channel Reach	Bryo-1	2024-05-01	11	Etheostoma fonticola	35	1
3153	Old Channel Reach	Bryo-1	2024-05-01	11	Etheostoma fonticola	23	1
3153	Old Channel Reach	Bryo-1	2024-05-01	11	Etheostoma fonticola	13	1
3153	Old Channel Reach	Bryo-1	2024-05-01	12	Procambarus sp.		1
3153	Old Channel Reach	Bryo-1	2024-05-01	13	Procambarus sp.		1
3153	Old Channel Reach	Bryo-1	2024-05-01	14	No fish collected		
3153	Old Channel Reach	Bryo-1	2024-05-01	15	No fish collected		
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	12	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	18	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	30	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	23	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	24	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	27	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	25	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	27	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	28	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	17	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	26	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	19	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	30	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	23	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	22	1

3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	20	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	14	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	19	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	28	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Etheostoma fonticola	20	1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Palaemonetes sp.		1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Procambarus sp.		1
3154	Old Channel Reach	Bryo-2	2024-05-01	1	Astyanax mexicanus	10	1
3154	Old Channel Reach	Bryo-2	2024-05-01	2	Procambarus sp.		4
3154	Old Channel Reach	Bryo-2	2024-05-01	2	Etheostoma fonticola	28	1
3154	Old Channel Reach	Bryo-2	2024-05-01	2	Etheostoma fonticola	24	1
3154	Old Channel Reach	Bryo-2	2024-05-01	2	Etheostoma fonticola	28	1
3154	Old Channel Reach	Bryo-2	2024-05-01	2	Etheostoma fonticola	30	1
3154	Old Channel Reach	Bryo-2	2024-05-01	3	Etheostoma fonticola	26	1
3154	Old Channel Reach	Bryo-2	2024-05-01	3	Etheostoma fonticola	34	1
3154	Old Channel Reach	Bryo-2	2024-05-01	3	Etheostoma fonticola	30	1
3154	Old Channel Reach	Bryo-2	2024-05-01	4	Procambarus sp.		3
3154	Old Channel Reach	Bryo-2	2024-05-01	4	Etheostoma fonticola	20	1
3154	Old Channel Reach	Bryo-2	2024-05-01	4	Etheostoma fonticola	21	1
3154	Old Channel Reach	Bryo-2	2024-05-01	4	Etheostoma fonticola	27	1
3154	Old Channel Reach	Bryo-2	2024-05-01	4	Etheostoma fonticola	23	1
3154	Old Channel Reach	Bryo-2	2024-05-01	4	Etheostoma fonticola	20	1
3154	Old Channel Reach	Bryo-2	2024-05-01	4	Etheostoma fonticola	26	1
3154	Old Channel Reach	Bryo-2	2024-05-01	4	Etheostoma fonticola	29	1
3154	Old Channel Reach	Bryo-2	2024-05-01	4	Etheostoma fonticola	12	1
3154	Old Channel Reach	Bryo-2	2024-05-01	5	Etheostoma fonticola	23	1
3154	Old Channel Reach	Bryo-2	2024-05-01	5	Etheostoma fonticola	30	1
3154	Old Channel Reach	Bryo-2	2024-05-01	5	Etheostoma fonticola	17	1
3154	Old Channel Reach	Bryo-2	2024-05-01	5	Etheostoma fonticola	26	1
3154	Old Channel Reach	Bryo-2	2024-05-01	5	Etheostoma fonticola	33	1

3154	Old Channel Reach	Bryo-2	2024-05-01	5	Etheostoma fonticola	20	1
3154	Old Channel Reach	Bryo-2	2024-05-01	5	Etheostoma fonticola	30	1
3154	Old Channel Reach	Bryo-2	2024-05-01	5	Etheostoma fonticola	22	1
3154	Old Channel Reach	Bryo-2	2024-05-01	6	Procambarus sp.		14
3154	Old Channel Reach	Bryo-2	2024-05-01	6	Etheostoma fonticola	29	1
3154	Old Channel Reach	Bryo-2	2024-05-01	6	Etheostoma fonticola	25	1
3154	Old Channel Reach	Bryo-2	2024-05-01	6	Etheostoma fonticola	27	1
3154	Old Channel Reach	Bryo-2	2024-05-01	7	Etheostoma fonticola	34	1
3154	Old Channel Reach	Bryo-2	2024-05-01	7	Procambarus sp.		4
3154	Old Channel Reach	Bryo-2	2024-05-01	8	Procambarus sp.		3
3154	Old Channel Reach	Bryo-2	2024-05-01	8	Etheostoma fonticola	24	1
3154	Old Channel Reach	Bryo-2	2024-05-01	9	Etheostoma fonticola	28	1
3154	Old Channel Reach	Bryo-2	2024-05-01	9	Etheostoma fonticola	28	1
3154	Old Channel Reach	Bryo-2	2024-05-01	9	Etheostoma fonticola	20	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Etheostoma fonticola	19	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Etheostoma fonticola	21	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Etheostoma fonticola	25	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Etheostoma fonticola	25	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Etheostoma fonticola	27	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Etheostoma fonticola	29	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Etheostoma fonticola	28	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Etheostoma fonticola	27	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Etheostoma fonticola	18	1
3154	Old Channel Reach	Bryo-2	2024-05-01	10	Procambarus sp.		2
3154	Old Channel Reach	Bryo-2	2024-05-01	11	Etheostoma fonticola	30	1
3154	Old Channel Reach	Bryo-2	2024-05-01	11	Etheostoma fonticola	28	1
3154	Old Channel Reach	Bryo-2	2024-05-01	11	Etheostoma fonticola	31	1
3154	Old Channel Reach	Bryo-2	2024-05-01	11	Procambarus sp.		1
3154	Old Channel Reach	Bryo-2	2024-05-01	12	Procambarus sp.		1
3154	Old Channel Reach	Bryo-2	2024-05-01	13	Procambarus sp.		1

3154	Old Channel Reach	Bryo-2	2024-05-01	14	Etheostoma fonticola	29	1
3154	Old Channel Reach	Bryo-2	2024-05-01	14	Etheostoma fonticola	22	1
3154	Old Channel Reach	Bryo-2	2024-05-01	14	Etheostoma fonticola	24	1
3154	Old Channel Reach	Bryo-2	2024-05-01	14	Procambarus sp.		1
3154	Old Channel Reach	Bryo-2	2024-05-01	15	Etheostoma fonticola	31	1
3154	Old Channel Reach	Bryo-2	2024-05-01	16	No fish collected		
3155	Old Channel Reach	Lud-1	2024-05-01	1	Lepomis miniatus	48	1
3155	Old Channel Reach	Lud-1	2024-05-01	1	Palaemonetes sp.		8
3155	Old Channel Reach	Lud-1	2024-05-01	1	Etheostoma fonticola	22	1
3155	Old Channel Reach	Lud-1	2024-05-01	2	Etheostoma fonticola	23	1
3155	Old Channel Reach	Lud-1	2024-05-01	2	Palaemonetes sp.		5
3155	Old Channel Reach	Lud-1	2024-05-01	3	Etheostoma fonticola	21	1
3155	Old Channel Reach	Lud-1	2024-05-01	3	Etheostoma fonticola	29	1
3155	Old Channel Reach	Lud-1	2024-05-01	3	Palaemonetes sp.		2
3155	Old Channel Reach	Lud-1	2024-05-01	4	Etheostoma fonticola	22	1
3155	Old Channel Reach	Lud-1	2024-05-01	4	Palaemonetes sp.		9
3155	Old Channel Reach	Lud-1	2024-05-01	5	No fish collected		
3155	Old Channel Reach	Lud-1	2024-05-01	6	Palaemonetes sp.		4
3155	Old Channel Reach	Lud-1	2024-05-01	7	Etheostoma fonticola	23	1
3155	Old Channel Reach	Lud-1	2024-05-01	7	Etheostoma fonticola	24	1
3155	Old Channel Reach	Lud-1	2024-05-01	7	Palaemonetes sp.		4
3155	Old Channel Reach	Lud-1	2024-05-01	8	Palaemonetes sp.		1
3155	Old Channel Reach	Lud-1	2024-05-01	9	Gambusia sp.	24	1
3155	Old Channel Reach	Lud-1	2024-05-01	9	Etheostoma fonticola	30	1
3155	Old Channel Reach	Lud-1	2024-05-01	9	Palaemonetes sp.		1
3155	Old Channel Reach	Lud-1	2024-05-01	10	Palaemonetes sp.		2
3155	Old Channel Reach	Lud-1	2024-05-01	10	Etheostoma fonticola	20	1
3155	Old Channel Reach	Lud-1	2024-05-01	11	Etheostoma fonticola	23	1
3155	Old Channel Reach	Lud-1	2024-05-01	12	Etheostoma fonticola	20	1
3155	Old Channel Reach	Lud-1	2024-05-01	13	No fish collected		

3155	Old Channel Reach	Lud-1	2024-05-01	14	Palaemonetes sp.		1
3155	Old Channel Reach	Lud-1	2024-05-01	15	No fish collected		
3156	Old Channel Reach	Lud-2	2024-05-01	1	Herichthys cyanoguttatus	46	1
3156	Old Channel Reach	Lud-2	2024-05-01	1	Herichthys cyanoguttatus	65	1
3156	Old Channel Reach	Lud-2	2024-05-01	1	Dionda nigrotaeniata	35	1
3156	Old Channel Reach	Lud-2	2024-05-01	1	Procambarus sp.		2
3156	Old Channel Reach	Lud-2	2024-05-01	1	Etheostoma fonticola	17	1
3156	Old Channel Reach	Lud-2	2024-05-01	1	Etheostoma fonticola	17	1
3156	Old Channel Reach	Lud-2	2024-05-01	1	Palaemonetes sp.		4
3156	Old Channel Reach	Lud-2	2024-05-01	2	Dionda nigrotaeniata	34	1
3156	Old Channel Reach	Lud-2	2024-05-01	2	Palaemonetes sp.		1
3156	Old Channel Reach	Lud-2	2024-05-01	2	Etheostoma fonticola	13	1
3156	Old Channel Reach	Lud-2	2024-05-01	3	Etheostoma fonticola	22	1
3156	Old Channel Reach	Lud-2	2024-05-01	3	Etheostoma fonticola	18	1
3156	Old Channel Reach	Lud-2	2024-05-01	4	No fish collected		
3156	Old Channel Reach	Lud-2	2024-05-01	5	Procambarus sp.		1
3156	Old Channel Reach	Lud-2	2024-05-01	5	Herichthys cyanoguttatus	80	1
3156	Old Channel Reach	Lud-2	2024-05-01	5	Etheostoma fonticola	25	1
3156	Old Channel Reach	Lud-2	2024-05-01	5	Etheostoma fonticola	28	1
3156	Old Channel Reach	Lud-2	2024-05-01	5	Palaemonetes sp.		5
3156	Old Channel Reach	Lud-2	2024-05-01	6	Procambarus sp.		1
3156	Old Channel Reach	Lud-2	2024-05-01	7	Etheostoma fonticola	24	1
3156	Old Channel Reach	Lud-2	2024-05-01	7	Palaemonetes sp.		2
3156	Old Channel Reach	Lud-2	2024-05-01	8	Etheostoma fonticola	23	1
3156	Old Channel Reach	Lud-2	2024-05-01	8	Procambarus sp.		2
3156	Old Channel Reach	Lud-2	2024-05-01	9	No fish collected		
3156	Old Channel Reach	Lud-2	2024-05-01	10	Etheostoma fonticola	18	1
3156	Old Channel Reach	Lud-2	2024-05-01	11	Procambarus sp.		1
3156	Old Channel Reach	Lud-2	2024-05-01	12	Etheostoma fonticola	24	1
3156	Old Channel Reach	Lud-2	2024-05-01	12	Herichthys cyanoguttatus	49	1

3156	Old Channel Reach	Lud-2	2024-05-01	13	Procambarus sp.		1
3156	Old Channel Reach	Lud-2	2024-05-01	14	No fish collected		
3156	Old Channel Reach	Lud-2	2024-05-01	15	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	1	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	2	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	3	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	4	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	5	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	6	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	7	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	8	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	9	No fish collected		
3157	Old Channel Reach	Open-1	2024-05-01	10	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	1	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	2	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	3	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	4	Notropis amabilis	21	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	35	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	26	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	38	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	25	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	35	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	33	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	25	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	34	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	34	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	28	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	23	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	34	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	26	1

3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	30	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	27	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	29	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	30	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	23	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	32	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	21	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	30	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	24	1
3158	Old Channel Reach	Open-2	2024-05-01	5	Notropis amabilis	28	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	34	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	32	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	31	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	30	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	30	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	31	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	31	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	28	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	26	1
3158	Old Channel Reach	Open-2	2024-05-01	6	Notropis amabilis	35	1
3158	Old Channel Reach	Open-2	2024-05-01	7	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	8	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	9	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	10	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	11	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	12	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	13	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	14	No fish collected		
3158	Old Channel Reach	Open-2	2024-05-01	15	No fish collected		
3159	Upper New Channel Reach	Cab-1	2024-05-01	1	Etheostoma fonticola	32	1

3159	Upper New Channel Reach	Cab-1	2024-05-01	1	Etheostoma fonticola	32	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	1	Etheostoma fonticola	15	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	1	Etheostoma fonticola	20	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	2	Etheostoma fonticola	23	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	2	Etheostoma fonticola	30	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	2	Etheostoma fonticola	16	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	2	Etheostoma fonticola	17	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	3	Etheostoma fonticola	33	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	3	Etheostoma fonticola	20	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	3	Etheostoma fonticola	32	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	3	Etheostoma fonticola	28	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	3	Etheostoma fonticola	25	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	3	Etheostoma fonticola	29	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	3	Etheostoma fonticola	21	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	4	Procambarus sp.		1
3159	Upper New Channel Reach	Cab-1	2024-05-01	4	Etheostoma fonticola	33	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	5	Procambarus sp.		1
3159	Upper New Channel Reach	Cab-1	2024-05-01	5	Lepomis cyanellus	58	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	6	Procambarus sp.		1
3159	Upper New Channel Reach	Cab-1	2024-05-01	6	Etheostoma fonticola	30	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	6	Etheostoma fonticola	30	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	6	Etheostoma fonticola	32	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	7	Etheostoma fonticola	26	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	7	Etheostoma fonticola	30	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	7	Etheostoma fonticola	15	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	7	Lepomis gulosus	59	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	7	Procambarus sp.		3
3159	Upper New Channel Reach	Cab-1	2024-05-01	7	Lepomis cyanellus	51	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	8	Etheostoma fonticola	26	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	8	Procambarus sp.		1

3159	Upper New Channel Reach	Cab-1	2024-05-01	9	Etheostoma fonticola	30	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	10	Etheostoma fonticola	19	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	11	Procambarus sp.		1
3159	Upper New Channel Reach	Cab-1	2024-05-01	11	Etheostoma fonticola	29	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	12	Etheostoma fonticola	22	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	12	Etheostoma fonticola	15	1
3159	Upper New Channel Reach	Cab-1	2024-05-01	13	No fish collected		
3159	Upper New Channel Reach	Cab-1	2024-05-01	14	Procambarus sp.		1
3159	Upper New Channel Reach	Cab-1	2024-05-01	15	Procambarus sp.		1
3160	Upper New Channel Reach	Cab-2	2024-05-01	1	Lepomis gulosus	55	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	1	Lepomis cyanellus	66	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	1	Lepomis cyanellus	50	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	2	Procambarus sp.		3
3160	Upper New Channel Reach	Cab-2	2024-05-01	3	Etheostoma fonticola	26	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	3	Etheostoma fonticola	20	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	4	No fish collected		
3160	Upper New Channel Reach	Cab-2	2024-05-01	5	Procambarus sp.		2
3160	Upper New Channel Reach	Cab-2	2024-05-01	5	Lepomis gulosus	64	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	6	Procambarus sp.		1
3160	Upper New Channel Reach	Cab-2	2024-05-01	6	Etheostoma fonticola	30	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	7	No fish collected		
3160	Upper New Channel Reach	Cab-2	2024-05-01	8	Procambarus sp.		1
3160	Upper New Channel Reach	Cab-2	2024-05-01	8	Lepomis miniatus	72	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	9	Procambarus sp.		3
3160	Upper New Channel Reach	Cab-2	2024-05-01	9	Etheostoma fonticola	24	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	10	Etheostoma fonticola	29	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	11	No fish collected		
3160	Upper New Channel Reach	Cab-2	2024-05-01	12	Procambarus sp.		2
3160	Upper New Channel Reach	Cab-2	2024-05-01	12	Palaemonetes sp.		1
3160	Upper New Channel Reach	Cab-2	2024-05-01	13	Procambarus sp.		1

3160	Upper New Channel Reach	Cab-2	2024-05-01	14	Procambarus sp.		1
3160	Upper New Channel Reach	Cab-2	2024-05-01	14	Lepomis miniatus	45	1
3160	Upper New Channel Reach	Cab-2	2024-05-01	15	No fish collected		
3161	Upper New Channel Reach	Hyg-1	2024-05-01	1	Procambarus sp.		6
3161	Upper New Channel Reach	Hyg-1	2024-05-01	1	Etheostoma fonticola	34	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	1	Palaemonetes sp.		2
3161	Upper New Channel Reach	Hyg-1	2024-05-01	1	Lepomis miniatus	50	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	1	Micropterus salmoides	32	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	1	Ambloplites rupestris	24	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	1	Ambloplites rupestris	17	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	2	Procambarus sp.		3
3161	Upper New Channel Reach	Hyg-1	2024-05-01	2	Lepomis sp.	15	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	2	Etheostoma fonticola	32	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	2	Etheostoma fonticola	32	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	2	Palaemonetes sp.		2
3161	Upper New Channel Reach	Hyg-1	2024-05-01	3	Procambarus sp.		5
3161	Upper New Channel Reach	Hyg-1	2024-05-01	3	Lepomis gulosus	60	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	3	Palaemonetes sp.		1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	4	Procambarus sp.		1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	4	Palaemonetes sp.		1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	5	Procambarus sp.		1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	6	Palaemonetes sp.		1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	7	Procambarus sp.		2
3161	Upper New Channel Reach	Hyg-1	2024-05-01	7	Ambloplites rupestris	20	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	8	Procambarus sp.		1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	9	Palaemonetes sp.		2
3161	Upper New Channel Reach	Hyg-1	2024-05-01	10	No fish collected		
3161	Upper New Channel Reach	Hyg-1	2024-05-01	11	Etheostoma fonticola	28	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	11	Lepomis miniatus	31	1
3161	Upper New Channel Reach	Hyg-1	2024-05-01	12	Palaemonetes sp.		1

3161	Upper New Channel Reach	Hyg-1	2024-05-01	13	No fish collected		
3161	Upper New Channel Reach	Hyg-1	2024-05-01	14	No fish collected		
3161	Upper New Channel Reach	Hyg-1	2024-05-01	15	No fish collected		
3161	Upper New Channel Reach	Hyg-1	2024-05-01	6	Procambarus sp.		1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Lepomis gulosus	51	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Lepomis gulosus	62	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Lepomis gulosus	63	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Lepomis miniatus	46	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Astyanax mexicanus	35	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Astyanax mexicanus	25	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Etheostoma fonticola	28	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Etheostoma fonticola	28	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Procambarus sp.		2
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Palaemonetes sp.		18
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Ambloplites rupestris	20	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Lepomis cyanellus	51	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Lepomis cyanellus	55	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Micropterus salmoides	52	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	1	Micropterus salmoides	46	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	2	Procambarus sp.		4
3162	Upper New Channel Reach	Hyg-2	2024-05-01	2	Etheostoma fonticola	31	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	2	Etheostoma fonticola	20	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	2	Etheostoma fonticola	32	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	2	Palaemonetes sp.		3
3162	Upper New Channel Reach	Hyg-2	2024-05-01	2	Micropterus salmoides	34	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	3	Procambarus sp.		3
3162	Upper New Channel Reach	Hyg-2	2024-05-01	3	Lepomis miniatus	36	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	4	Procambarus sp.		7
3162	Upper New Channel Reach	Hyg-2	2024-05-01	4	Ameiurus natalis	93	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	5	Procambarus sp.		4

3162	Upper New Channel Reach	Hyg-2	2024-05-01	5	Palaemonetes sp.		2
3162	Upper New Channel Reach	Hyg-2	2024-05-01	5	Lepomis cyanellus	54	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	6	Procambarus sp.		4
3162	Upper New Channel Reach	Hyg-2	2024-05-01	6	Palaemonetes sp.		2
3162	Upper New Channel Reach	Hyg-2	2024-05-01	7	Procambarus sp.		2
3162	Upper New Channel Reach	Hyg-2	2024-05-01	7	Palaemonetes sp.		1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	8	Procambarus sp.		4
3162	Upper New Channel Reach	Hyg-2	2024-05-01	8	Micropterus salmoides	40	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	8	Palaemonetes sp.		1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	9	Procambarus sp.		1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	9	Lepomis gulosus	59	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	10	Procambarus sp.		1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	11	Procambarus sp.		2
3162	Upper New Channel Reach	Hyg-2	2024-05-01	11	Lepomis miniatus	57	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	12	Lepomis miniatus	56	1
3162	Upper New Channel Reach	Hyg-2	2024-05-01	13	No fish collected		
3162	Upper New Channel Reach	Hyg-2	2024-05-01	14	No fish collected		
3162	Upper New Channel Reach	Hyg-2	2024-05-01	15	Procambarus sp.		2
3162	Upper New Channel Reach	Hyg-2	2024-05-01	15	Palaemonetes sp.		1
3163	Upper New Channel Reach	Open-1	2024-05-01	1	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	2	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	3	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	4	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	5	Lepomis cyanellus	75	1
3163	Upper New Channel Reach	Open-1	2024-05-01	6	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	7	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	8	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	9	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	10	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	11	No fish collected		

3163	Upper New Channel Reach	Open-1	2024-05-01	12	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	13	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	14	No fish collected		
3163	Upper New Channel Reach	Open-1	2024-05-01	15	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	1	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	2	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	3	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	4	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	5	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	6	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	7	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	8	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	9	No fish collected		
3164	Upper New Channel Reach	Open-2	2024-05-01	10	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	1	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	2	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	3	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	4	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	5	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	6	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	7	Gambusia sp.	27	1
3165	Upper Spring Run	Open-1	2024-06-11	8	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	9	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	10	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	11	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	12	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	13	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	14	No fish collected		
3165	Upper Spring Run	Open-1	2024-06-11	15	No fish collected		
3166	Upper Spring Run	Sag-1	2024-06-11	1	Gambusia sp.	35	1

3166	Upper Spring Run	Sag-1	2024-06-11	1	Gambusia sp.	27	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Gambusia sp.	21	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Gambusia sp.	19	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Gambusia sp.	20	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Gambusia sp.	14	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Gambusia sp.	15	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Herichthys cyanoguttatus	68	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Astyanax mexicanus	36	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Lepomis miniatus	46	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Lepomis miniatus	45	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Lepomis miniatus	37	1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Procambarus sp.		1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Palaemonetes sp.		1
3166	Upper Spring Run	Sag-1	2024-06-11	1	Micropterus salmoides	45	1
3166	Upper Spring Run	Sag-1	2024-06-11	2	Procambarus sp.		1
3166	Upper Spring Run	Sag-1	2024-06-11	2	Gambusia sp.	13	1
3166	Upper Spring Run	Sag-1	2024-06-11	2	Gambusia sp.	22	1
3166	Upper Spring Run	Sag-1	2024-06-11	2	Gambusia sp.	24	1
3166	Upper Spring Run	Sag-1	2024-06-11	2	Gambusia sp.	18	1
3166	Upper Spring Run	Sag-1	2024-06-11	2	Gambusia sp.	19	1
3166	Upper Spring Run	Sag-1	2024-06-11	2	Gambusia sp.	27	1
3166	Upper Spring Run	Sag-1	2024-06-11	2	Micropterus salmoides	55	1
3166	Upper Spring Run	Sag-1	2024-06-11	3	Procambarus sp.		4
3166	Upper Spring Run	Sag-1	2024-06-11	3	Lepomis miniatus	42	1
3166	Upper Spring Run	Sag-1	2024-06-11	3	Lepomis sp.	11	1
3166	Upper Spring Run	Sag-1	2024-06-11	3	Gambusia sp.	22	1
3166	Upper Spring Run	Sag-1	2024-06-11	4	Lepomis miniatus	65	1
3166	Upper Spring Run	Sag-1	2024-06-11	4	Procambarus sp.		1
3166	Upper Spring Run	Sag-1	2024-06-11	5	Procambarus sp.		1
3166	Upper Spring Run	Sag-1	2024-06-11	5	Gambusia sp.	27	1

3166	Upper Spring Run	Sag-1	2024-06-11	6	Herichthys cyanoguttatus	106	1
3166	Upper Spring Run	Sag-1	2024-06-11	7	Procambarus sp.		1
3166	Upper Spring Run	Sag-1	2024-06-11	8	Lepomis miniatus	44	1
3166	Upper Spring Run	Sag-1	2024-06-11	9	No fish collected		
3166	Upper Spring Run	Sag-1	2024-06-11	10	Procambarus sp.		1
3166	Upper Spring Run	Sag-1	2024-06-11	11	Lepomis miniatus	125	1
3166	Upper Spring Run	Sag-1	2024-06-11	12	Procambarus sp.		1
3166	Upper Spring Run	Sag-1	2024-06-11	13	No fish collected		
3166	Upper Spring Run	Sag-1	2024-06-11	14	Procambarus sp.		1
3166	Upper Spring Run	Sag-1	2024-06-11	15	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	1	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	2	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	3	Procambarus sp.		1
3167	Upper Spring Run	Sag-2	2024-06-11	3	Lepomis miniatus	50	1
3167	Upper Spring Run	Sag-2	2024-06-11	3	Etheostoma fonticola	29	1
3167	Upper Spring Run	Sag-2	2024-06-11	4	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	5	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	6	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	7	Gambusia sp.	18	1
3167	Upper Spring Run	Sag-2	2024-06-11	8	Procambarus sp.		2
3167	Upper Spring Run	Sag-2	2024-06-11	8	Lepomis miniatus	42	1
3167	Upper Spring Run	Sag-2	2024-06-11	9	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	10	Lepomis miniatus	86	1
3167	Upper Spring Run	Sag-2	2024-06-11	11	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	12	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	13	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	14	No fish collected		
3167	Upper Spring Run	Sag-2	2024-06-11	15	Procambarus sp.		1
3168	Upper Spring Run	Open-2	2024-06-11	1	No fish collected		
3168	Upper Spring Run	Open-2	2024-06-11	2	No fish collected		

3168	Upper Spring Run	Open-2	2024-06-11	3	No fish collected		
3168	Upper Spring Run	Open-2	2024-06-11	4	No fish collected		
3168	Upper Spring Run	Open-2	2024-06-11	5	No fish collected		
3168	Upper Spring Run	Open-2	2024-06-11	6	No fish collected		
3168	Upper Spring Run	Open-2	2024-06-11	7	No fish collected		
3168	Upper Spring Run	Open-2	2024-06-11	8	No fish collected		
3168	Upper Spring Run	Open-2	2024-06-11	9	No fish collected		
3168	Upper Spring Run	Open-2	2024-06-11	10	No fish collected		
3169	Upper Spring Run	Algae-1	2024-06-11	1	Lepomis miniatus	40	1
3169	Upper Spring Run	Algae-1	2024-06-11	1	Palaemonetes sp.		1
3169	Upper Spring Run	Algae-1	2024-06-11	1	Etheostoma lepidum	37	1
3169	Upper Spring Run	Algae-1	2024-06-11	1	Micropterus salmoides	44	1
3169	Upper Spring Run	Algae-1	2024-06-11	1	Herichthys cyanoguttatus	32	1
3169	Upper Spring Run	Algae-1	2024-06-11	2	Procambarus sp.		2
3169	Upper Spring Run	Algae-1	2024-06-11	3	No fish collected		
3169	Upper Spring Run	Algae-1	2024-06-11	4	Palaemonetes sp.		1
3169	Upper Spring Run	Algae-1	2024-06-11	4	Etheostoma fonticola	30	1
3169	Upper Spring Run	Algae-1	2024-06-11	4	Etheostoma fonticola	31	1
3169	Upper Spring Run	Algae-1	2024-06-11	5	No fish collected		
3169	Upper Spring Run	Algae-1	2024-06-11	6	Procambarus sp.		1
3169	Upper Spring Run	Algae-1	2024-06-11	7	No fish collected		
3169	Upper Spring Run	Algae-1	2024-06-11	8	Procambarus sp.		1
3169	Upper Spring Run	Algae-1	2024-06-11	9	No fish collected		
3169	Upper Spring Run	Algae-1	2024-06-11	10	Etheostoma fonticola	29	1
3169	Upper Spring Run	Algae-1	2024-06-11	10	Etheostoma fonticola	33	1
3169	Upper Spring Run	Algae-1	2024-06-11	10	Etheostoma lepidum	50	1
3169	Upper Spring Run	Algae-1	2024-06-11	11	Etheostoma fonticola	34	1
3169	Upper Spring Run	Algae-1	2024-06-11	12	Etheostoma fonticola	35	1
3169	Upper Spring Run	Algae-1	2024-06-11	12	Procambarus sp.		1
3169	Upper Spring Run	Algae-1	2024-06-11	13	No fish collected		

3169	Upper Spring Run	Algae-1	2024-06-11	14	No fish collected		
3169	Upper Spring Run	Algae-1	2024-06-11	15	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	1	Lepomis miniatus	78	1
3170	Upper Spring Run	Algae-2	2024-06-11	1	Lepomis miniatus	25	1
3170	Upper Spring Run	Algae-2	2024-06-11	1	Etheostoma lepidum	48	1
3170	Upper Spring Run	Algae-2	2024-06-11	1	Palaemonetes sp.		1
3170	Upper Spring Run	Algae-2	2024-06-11	2	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	3	Gambusia sp.	16	1
3170	Upper Spring Run	Algae-2	2024-06-11	4	Etheostoma fonticola	32	1
3170	Upper Spring Run	Algae-2	2024-06-11	5	Palaemonetes sp.		1
3170	Upper Spring Run	Algae-2	2024-06-11	6	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	7	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	8	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	9	Etheostoma fonticola	31	1
3170	Upper Spring Run	Algae-2	2024-06-11	10	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	11	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	12	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	13	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	14	No fish collected		
3170	Upper Spring Run	Algae-2	2024-06-11	15	No fish collected		
3171	Upper Spring Run	Bryo-1	2024-06-11	1	Micropterus salmoides	88	1
3171	Upper Spring Run	Bryo-1	2024-06-11	1	Micropterus salmoides	74	1
3171	Upper Spring Run	Bryo-1	2024-06-11	2	Lepomis miniatus	62	1
3171	Upper Spring Run	Bryo-1	2024-06-11	3	Palaemonetes sp.		1
3171	Upper Spring Run	Bryo-1	2024-06-11	3	Lepomis sp.	18	1
3171	Upper Spring Run	Bryo-1	2024-06-11	4	No fish collected		
3171	Upper Spring Run	Bryo-1	2024-06-11	5	Micropterus salmoides	38	1
3171	Upper Spring Run	Bryo-1	2024-06-11	6	No fish collected		
3171	Upper Spring Run	Bryo-1	2024-06-11	7	No fish collected		
3171	Upper Spring Run	Bryo-1	2024-06-11	8	No fish collected		

3171	Upper Spring Run	Bryo-1	2024-06-11	9	No fish collected		
3171	Upper Spring Run	Bryo-1	2024-06-11	10	No fish collected		
3171	Upper Spring Run	Bryo-1	2024-06-11	11	No fish collected		
3171	Upper Spring Run	Bryo-1	2024-06-11	12	Palaemonetes sp.		1
3171	Upper Spring Run	Bryo-1	2024-06-11	13	No fish collected		
3171	Upper Spring Run	Bryo-1	2024-06-11	14	No fish collected		
3171	Upper Spring Run	Bryo-1	2024-06-11	15	No fish collected		
3172	Upper Spring Run	Bryo-2	2024-06-11	1	Procambarus sp.		3
3172	Upper Spring Run	Bryo-2	2024-06-11	1	Etheostoma fonticola	26	1
3172	Upper Spring Run	Bryo-2	2024-06-11	1	Etheostoma fonticola	25	1
3172	Upper Spring Run	Bryo-2	2024-06-11	1	Etheostoma fonticola	14	1
3172	Upper Spring Run	Bryo-2	2024-06-11	1	Etheostoma fonticola	26	1
3172	Upper Spring Run	Bryo-2	2024-06-11	2	Procambarus sp.		1
3172	Upper Spring Run	Bryo-2	2024-06-11	3	Etheostoma fonticola	30	1
3172	Upper Spring Run	Bryo-2	2024-06-11	3	Palaemonetes sp.		1
3172	Upper Spring Run	Bryo-2	2024-06-11	3	Herichthys cyanoguttatus	15	1
3172	Upper Spring Run	Bryo-2	2024-06-11	4	Etheostoma fonticola	30	1
3172	Upper Spring Run	Bryo-2	2024-06-11	4	Etheostoma fonticola	20	1
3172	Upper Spring Run	Bryo-2	2024-06-11	5	Etheostoma fonticola	26	1
3172	Upper Spring Run	Bryo-2	2024-06-11	5	Etheostoma fonticola	22	1
3172	Upper Spring Run	Bryo-2	2024-06-11	5	Etheostoma fonticola	30	1
3172	Upper Spring Run	Bryo-2	2024-06-11	6	Etheostoma fonticola	26	1
3172	Upper Spring Run	Bryo-2	2024-06-11	6	Etheostoma fonticola	27	1
3172	Upper Spring Run	Bryo-2	2024-06-11	6	Etheostoma fonticola	30	1
3172	Upper Spring Run	Bryo-2	2024-06-11	6	Etheostoma fonticola	13	1
3172	Upper Spring Run	Bryo-2	2024-06-11	6	Procambarus sp.		1
3172	Upper Spring Run	Bryo-2	2024-06-11	7	Procambarus sp.		1
3172	Upper Spring Run	Bryo-2	2024-06-11	8	Etheostoma lepidum	35	1
3172	Upper Spring Run	Bryo-2	2024-06-11	9	No fish collected		
3172	Upper Spring Run	Bryo-2	2024-06-11	10	Etheostoma fonticola	31	1

3172	Upper Spring Run	Bryo-2	2024-06-11	10	Etheostoma fonticola	32	1
3172	Upper Spring Run	Bryo-2	2024-06-11	11	Etheostoma fonticola	10	1
3172	Upper Spring Run	Bryo-2	2024-06-11	12	Etheostoma fonticola	32	1
3172	Upper Spring Run	Bryo-2	2024-06-11	12	Etheostoma fonticola	29	1
3172	Upper Spring Run	Bryo-2	2024-06-11	12	Procambarus sp.		1
3172	Upper Spring Run	Bryo-2	2024-06-11	13	No fish collected		
3172	Upper Spring Run	Bryo-2	2024-06-11	14	Etheostoma fonticola	21	1
3172	Upper Spring Run	Bryo-2	2024-06-11	14	Etheostoma fonticola	22	1
3172	Upper Spring Run	Bryo-2	2024-06-11	15	No fish collected		
3173	Landa Lake	Sag-1	2024-06-12	1	Etheostoma fonticola	30	1
3173	Landa Lake	Sag-1	2024-06-12	1	Etheostoma fonticola	23	1
3173	Landa Lake	Sag-1	2024-06-12	1	Lepomis miniatus	40	1
3173	Landa Lake	Sag-1	2024-06-12	1	Lepomis miniatus	31	1
3173	Landa Lake	Sag-1	2024-06-12	1	Dionda nigrotaeniata	32	1
3173	Landa Lake	Sag-1	2024-06-12	1	Dionda nigrotaeniata	48	1
3173	Landa Lake	Sag-1	2024-06-12	1	Dionda nigrotaeniata	37	1
3173	Landa Lake	Sag-1	2024-06-12	1	Procambarus sp.		1
3173	Landa Lake	Sag-1	2024-06-12	1	Palaemonetes sp.		7
3173	Landa Lake	Sag-1	2024-06-12	2	Procambarus sp.		3
3173	Landa Lake	Sag-1	2024-06-12	2	Palaemonetes sp.		2
3173	Landa Lake	Sag-1	2024-06-12	2	Lepomis miniatus	66	1
3173	Landa Lake	Sag-1	2024-06-12	2	Lepomis miniatus	48	1
3173	Landa Lake	Sag-1	2024-06-12	2	Lepomis miniatus	25	1
3173	Landa Lake	Sag-1	2024-06-12	2	Dionda nigrotaeniata	38	1
3173	Landa Lake	Sag-1	2024-06-12	2	Dionda nigrotaeniata	35	1
3173	Landa Lake	Sag-1	2024-06-12	2	Ameiurus natalis	62	1
3173	Landa Lake	Sag-1	2024-06-12	2	Etheostoma fonticola	22	1
3173	Landa Lake	Sag-1	2024-06-12	2	Etheostoma fonticola	24	1
3173	Landa Lake	Sag-1	2024-06-12	3	Procambarus sp.		1
3173	Landa Lake	Sag-1	2024-06-12	3	Dionda nigrotaeniata	28	1

3173	Landa Lake	Sag-1	2024-06-12	3	Dionda nigrotaeniata	31	1
3173	Landa Lake	Sag-1	2024-06-12	3	Dionda nigrotaeniata	32	1
3173	Landa Lake	Sag-1	2024-06-12	3	Dionda nigrotaeniata	30	1
3173	Landa Lake	Sag-1	2024-06-12	3	Etheostoma fonticola	30	1
3173	Landa Lake	Sag-1	2024-06-12	3	Lepomis miniatus	72	1
3173	Landa Lake	Sag-1	2024-06-12	3	Lepomis miniatus	34	1
3173	Landa Lake	Sag-1	2024-06-12	4	Lepomis miniatus	45	1
3173	Landa Lake	Sag-1	2024-06-12	4	Etheostoma fonticola	29	1
3173	Landa Lake	Sag-1	2024-06-12	4	Procambarus sp.		1
3173	Landa Lake	Sag-1	2024-06-12	4	Palaemonetes sp.		1
3173	Landa Lake	Sag-1	2024-06-12	5	Palaemonetes sp.		3
3173	Landa Lake	Sag-1	2024-06-12	5	Etheostoma fonticola	30	1
3173	Landa Lake	Sag-1	2024-06-12	5	Etheostoma fonticola	24	1
3173	Landa Lake	Sag-1	2024-06-12	6	Procambarus sp.		2
3173	Landa Lake	Sag-1	2024-06-12	7	Dionda nigrotaeniata	31	1
3173	Landa Lake	Sag-1	2024-06-12	7	Dionda nigrotaeniata	35	1
3173	Landa Lake	Sag-1	2024-06-12	7	Dionda nigrotaeniata	35	1
3173	Landa Lake	Sag-1	2024-06-12	7	Dionda nigrotaeniata	22	1
3173	Landa Lake	Sag-1	2024-06-12	7	Etheostoma fonticola	26	1
3173	Landa Lake	Sag-1	2024-06-12	8	Etheostoma fonticola	33	1
3173	Landa Lake	Sag-1	2024-06-12	9	Procambarus sp.		1
3173	Landa Lake	Sag-1	2024-06-12	9	Lepomis miniatus	44	1
3173	Landa Lake	Sag-1	2024-06-12	9	Dionda nigrotaeniata	32	1
3173	Landa Lake	Sag-1	2024-06-12	10	Etheostoma fonticola	19	1
3173	Landa Lake	Sag-1	2024-06-12	11	Procambarus sp.		3
3173	Landa Lake	Sag-1	2024-06-12	11	Dionda nigrotaeniata	26	1
3173	Landa Lake	Sag-1	2024-06-12	11	Dionda nigrotaeniata	41	1
3173	Landa Lake	Sag-1	2024-06-12	12	Lepomis miniatus	47	1
3173	Landa Lake	Sag-1	2024-06-12	12	Dionda nigrotaeniata	29	1
3173	Landa Lake	Sag-1	2024-06-12	13	No fish collected		

3173	Landa Lake	Sag-1	2024-06-12	14	No fish collected		
3173	Landa Lake	Sag-1	2024-06-12	15	No fish collected		
3174	Landa Lake	Sag-2	2024-06-12	1	Lepomis miniatus	39	1
3174	Landa Lake	Sag-2	2024-06-12	1	Lepomis miniatus	55	1
3174	Landa Lake	Sag-2	2024-06-12	1	Procambarus sp.		2
3174	Landa Lake	Sag-2	2024-06-12	1	Palaemonetes sp.		10
3174	Landa Lake	Sag-2	2024-06-12	2	Procambarus sp.		6
3174	Landa Lake	Sag-2	2024-06-12	2	Ameiurus natalis	36	1
3174	Landa Lake	Sag-2	2024-06-12	2	Etheostoma fonticola	25	1
3174	Landa Lake	Sag-2	2024-06-12	2	Palaemonetes sp.		2
3174	Landa Lake	Sag-2	2024-06-12	3	Ameiurus natalis	50	1
3174	Landa Lake	Sag-2	2024-06-12	3	Procambarus sp.		2
3174	Landa Lake	Sag-2	2024-06-12	4	Procambarus sp.		1
3174	Landa Lake	Sag-2	2024-06-12	4	Ameiurus natalis	28	1
3174	Landa Lake	Sag-2	2024-06-12	4	Palaemonetes sp.		1
3174	Landa Lake	Sag-2	2024-06-12	5	Procambarus sp.		1
3174	Landa Lake	Sag-2	2024-06-12	6	Etheostoma fonticola	29	1
3174	Landa Lake	Sag-2	2024-06-12	7	Procambarus sp.		7
3174	Landa Lake	Sag-2	2024-06-12	7	Lepomis miniatus	45	1
3174	Landa Lake	Sag-2	2024-06-12	7	Etheostoma fonticola	32	1
3174	Landa Lake	Sag-2	2024-06-12	7	Etheostoma fonticola	12	1
3174	Landa Lake	Sag-2	2024-06-12	7	Palaemonetes sp.		1
3174	Landa Lake	Sag-2	2024-06-12	8	Procambarus sp.		2
3174	Landa Lake	Sag-2	2024-06-12	9	Procambarus sp.		1
3174	Landa Lake	Sag-2	2024-06-12	9	Ameiurus natalis	56	1
3174	Landa Lake	Sag-2	2024-06-12	10	Procambarus sp.		1
3174	Landa Lake	Sag-2	2024-06-12	10	Etheostoma fonticola	29	1
3174	Landa Lake	Sag-2	2024-06-12	11	Procambarus sp.		2
3174	Landa Lake	Sag-2	2024-06-12	11	Palaemonetes sp.		1
3174	Landa Lake	Sag-2	2024-06-12	12	Procambarus sp.		1

3174	Landa Lake	Sag-2	2024-06-12	13	Procambarus sp.		1
3174	Landa Lake	Sag-2	2024-06-12	14	Procambarus sp.		1
3174	Landa Lake	Sag-2	2024-06-12	15	No fish collected		
3175	Landa Lake	Lud-1	2024-06-12	1	Palaemonetes sp.		30
3175	Landa Lake	Lud-1	2024-06-12	1	Procambarus sp.		2
3175	Landa Lake	Lud-1	2024-06-12	1	Dionda nigrotaeniata	40	1
3175	Landa Lake	Lud-1	2024-06-12	1	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	1	Etheostoma fonticola	27	1
3175	Landa Lake	Lud-1	2024-06-12	1	Etheostoma fonticola	20	1
3175	Landa Lake	Lud-1	2024-06-12	1	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	1	Etheostoma fonticola	15	1
3175	Landa Lake	Lud-1	2024-06-12	1	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	1	Etheostoma fonticola	12	1
3175	Landa Lake	Lud-1	2024-06-12	1	Etheostoma fonticola	20	1
3175	Landa Lake	Lud-1	2024-06-12	1	Gambusia sp.	10	1
3175	Landa Lake	Lud-1	2024-06-12	1	Gambusia sp.	12	1
3175	Landa Lake	Lud-1	2024-06-12	2	Palaemonetes sp.		19
3175	Landa Lake	Lud-1	2024-06-12	2	Procambarus sp.		1
3175	Landa Lake	Lud-1	2024-06-12	2	Etheostoma fonticola	17	1
3175	Landa Lake	Lud-1	2024-06-12	2	Etheostoma fonticola	15	1
3175	Landa Lake	Lud-1	2024-06-12	2	Etheostoma fonticola	20	1
3175	Landa Lake	Lud-1	2024-06-12	2	Etheostoma fonticola	27	1
3175	Landa Lake	Lud-1	2024-06-12	2	Etheostoma fonticola	14	1
3175	Landa Lake	Lud-1	2024-06-12	2	Dionda nigrotaeniata	30	1
3175	Landa Lake	Lud-1	2024-06-12	3	Procambarus sp.		3
3175	Landa Lake	Lud-1	2024-06-12	3	Palaemonetes sp.		9
3175	Landa Lake	Lud-1	2024-06-12	3	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	3	Etheostoma fonticola	27	1
3175	Landa Lake	Lud-1	2024-06-12	3	Etheostoma fonticola	22	1
3175	Landa Lake	Lud-1	2024-06-12	3	Etheostoma fonticola	21	1

3175	Landa Lake	Lud-1	2024-06-12	3	Gambusia sp.	14	1
3175	Landa Lake	Lud-1	2024-06-12	3	Gambusia sp.	10	1
3175	Landa Lake	Lud-1	2024-06-12	3	Lepomis miniatus	31	1
3175	Landa Lake	Lud-1	2024-06-12	4	Procambarus sp.		2
3175	Landa Lake	Lud-1	2024-06-12	4	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	4	Etheostoma fonticola	19	1
3175	Landa Lake	Lud-1	2024-06-12	4	Etheostoma fonticola	20	1
3175	Landa Lake	Lud-1	2024-06-12	4	Palaemonetes sp.		2
3175	Landa Lake	Lud-1	2024-06-12	5	Procambarus sp.		8
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	19	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	21	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	29	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	31	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	23	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	27	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	23	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	23	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	24	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	24	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	27	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	19	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	16	1
3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	15	1

3175	Landa Lake	Lud-1	2024-06-12	5	Etheostoma fonticola	16	1
3175	Landa Lake	Lud-1	2024-06-12	5	Palaemonetes sp.		4
3175	Landa Lake	Lud-1	2024-06-12	6	Procambarus sp.		10
3175	Landa Lake	Lud-1	2024-06-12	6	Palaemonetes sp.		4
3175	Landa Lake	Lud-1	2024-06-12	6	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	6	Etheostoma fonticola	22	1
3175	Landa Lake	Lud-1	2024-06-12	6	Etheostoma fonticola	23	1
3175	Landa Lake	Lud-1	2024-06-12	6	Etheostoma fonticola	23	1
3175	Landa Lake	Lud-1	2024-06-12	6	Etheostoma fonticola	22	1
3175	Landa Lake	Lud-1	2024-06-12	6	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	6	Etheostoma fonticola	9	1
3175	Landa Lake	Lud-1	2024-06-12	6	Etheostoma fonticola	20	1
3175	Landa Lake	Lud-1	2024-06-12	6	Ameiurus natalis	14	1
3175	Landa Lake	Lud-1	2024-06-12	6	Ameiurus natalis	12	1
3175	Landa Lake	Lud-1	2024-06-12	7	Procambarus sp.		4
3175	Landa Lake	Lud-1	2024-06-12	7	Etheostoma fonticola	20	1
3175	Landa Lake	Lud-1	2024-06-12	7	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	7	Etheostoma fonticola	23	1
3175	Landa Lake	Lud-1	2024-06-12	7	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	7	Etheostoma fonticola	27	1
3175	Landa Lake	Lud-1	2024-06-12	7	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	7	Gambusia sp.	12	1
3175	Landa Lake	Lud-1	2024-06-12	8	Procambarus sp.		3
3175	Landa Lake	Lud-1	2024-06-12	8	Etheostoma fonticola	27	1
3175	Landa Lake	Lud-1	2024-06-12	8	Etheostoma fonticola	22	1
3175	Landa Lake	Lud-1	2024-06-12	8	Palaemonetes sp.		1
3175	Landa Lake	Lud-1	2024-06-12	9	Procambarus sp.		13
3175	Landa Lake	Lud-1	2024-06-12	9	Palaemonetes sp.		1
3175	Landa Lake	Lud-1	2024-06-12	9	Etheostoma fonticola	32	1
3175	Landa Lake	Lud-1	2024-06-12	9	Etheostoma fonticola	25	1

3175	Landa Lake	Lud-1	2024-06-12	9	Etheostoma fonticola	32	1
3175	Landa Lake	Lud-1	2024-06-12	9	Etheostoma fonticola	29	1
3175	Landa Lake	Lud-1	2024-06-12	9	Etheostoma fonticola	24	1
3175	Landa Lake	Lud-1	2024-06-12	9	Etheostoma fonticola	22	1
3175	Landa Lake	Lud-1	2024-06-12	10	Procambarus sp.		3
3175	Landa Lake	Lud-1	2024-06-12	10	Palaemonetes sp.		2
3175	Landa Lake	Lud-1	2024-06-12	10	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	10	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	10	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	10	Etheostoma fonticola	23	1
3175	Landa Lake	Lud-1	2024-06-12	10	Etheostoma fonticola	22	1
3175	Landa Lake	Lud-1	2024-06-12	11	Procambarus sp.		7
3175	Landa Lake	Lud-1	2024-06-12	11	Palaemonetes sp.		1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	23	1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	22	1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	32	1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	32	1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	27	1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	24	1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	11	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	19	1
3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	24	1
3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	24	1
3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	18	1
3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	28	1

3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	22	1
3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	12	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	12	Procambarus sp.		1
3175	Landa Lake	Lud-1	2024-06-12	13	Procambarus sp.		3
3175	Landa Lake	Lud-1	2024-06-12	13	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	13	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	13	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	13	Etheostoma fonticola	27	1
3175	Landa Lake	Lud-1	2024-06-12	13	Etheostoma fonticola	32	1
3175	Landa Lake	Lud-1	2024-06-12	13	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	14	Procambarus sp.		1
3175	Landa Lake	Lud-1	2024-06-12	14	Etheostoma fonticola	32	1
3175	Landa Lake	Lud-1	2024-06-12	14	Etheostoma fonticola	30	1
3175	Landa Lake	Lud-1	2024-06-12	14	Etheostoma fonticola	17	1
3175	Landa Lake	Lud-1	2024-06-12	14	Lepomis miniatus	45	1
3175	Landa Lake	Lud-1	2024-06-12	15	Palaemonetes sp.		2
3175	Landa Lake	Lud-1	2024-06-12	15	Procambarus sp.		2
3175	Landa Lake	Lud-1	2024-06-12	15	Etheostoma fonticola	21	1
3175	Landa Lake	Lud-1	2024-06-12	16	Etheostoma fonticola	17	1
3175	Landa Lake	Lud-1	2024-06-12	16	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	16	Etheostoma fonticola	20	1
3175	Landa Lake	Lud-1	2024-06-12	16	Procambarus sp.		3
3175	Landa Lake	Lud-1	2024-06-12	16	Palaemonetes sp.		1
3175	Landa Lake	Lud-1	2024-06-12	16	Gambusia sp.	10	1
3175	Landa Lake	Lud-1	2024-06-12	17	Palaemonetes sp.		1
3175	Landa Lake	Lud-1	2024-06-12	17	Etheostoma fonticola	24	1
3175	Landa Lake	Lud-1	2024-06-12	17	Etheostoma fonticola	19	1
3175	Landa Lake	Lud-1	2024-06-12	17	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	17	Etheostoma fonticola	28	1

3175	Landa Lake	Lud-1	2024-06-12	17	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	17	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	18	Procambarus sp.		1
3175	Landa Lake	Lud-1	2024-06-12	18	Etheostoma fonticola	25	1
3175	Landa Lake	Lud-1	2024-06-12	18	Etheostoma fonticola	26	1
3175	Landa Lake	Lud-1	2024-06-12	19	Procambarus sp.		2
3175	Landa Lake	Lud-1	2024-06-12	19	Etheostoma fonticola	20	1
3175	Landa Lake	Lud-1	2024-06-12	19	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	19	Etheostoma fonticola	12	1
3175	Landa Lake	Lud-1	2024-06-12	19	Etheostoma fonticola	15	1
3175	Landa Lake	Lud-1	2024-06-12	20	Procambarus sp.		1
3175	Landa Lake	Lud-1	2024-06-12	20	Etheostoma fonticola	15	1
3175	Landa Lake	Lud-1	2024-06-12	20	Etheostoma fonticola	28	1
3175	Landa Lake	Lud-1	2024-06-12	21	Procambarus sp.		1
3175	Landa Lake	Lud-1	2024-06-12	21	Etheostoma fonticola	19	1
3175	Landa Lake	Lud-1	2024-06-12	22	Etheostoma fonticola	20	1
3175	Landa Lake	Lud-1	2024-06-12	22	Etheostoma fonticola	32	1
3175	Landa Lake	Lud-1	2024-06-12	23	Procambarus sp.		1
3175	Landa Lake	Lud-1	2024-06-12	23	Etheostoma fonticola	22	1
3175	Landa Lake	Lud-1	2024-06-12	24	Procambarus sp.		1
3175	Landa Lake	Lud-1	2024-06-12	24	Palaemonetes sp.		1
3176	Landa Lake	Cab-1	2024-06-12	1	Etheostoma fonticola	23	1
3176	Landa Lake	Cab-1	2024-06-12	1	Etheostoma fonticola	19	1
3176	Landa Lake	Cab-1	2024-06-12	1	Etheostoma fonticola	18	1
3176	Landa Lake	Cab-1	2024-06-12	1	Etheostoma fonticola	18	1
3176	Landa Lake	Cab-1	2024-06-12	1	Etheostoma fonticola	16	1
3176	Landa Lake	Cab-1	2024-06-12	1	Etheostoma fonticola	25	1
3176	Landa Lake	Cab-1	2024-06-12	1	Etheostoma fonticola	20	1
3176	Landa Lake	Cab-1	2024-06-12	1	Etheostoma fonticola	19	1
3176	Landa Lake	Cab-1	2024-06-12	2	Etheostoma fonticola	24	1

3176	Landa Lake	Cab-1	2024-06-12	2	Etheostoma fonticola	19	1
3176	Landa Lake	Cab-1	2024-06-12	3	Etheostoma fonticola	27	1
3176	Landa Lake	Cab-1	2024-06-12	3	Etheostoma fonticola	18	1
3176	Landa Lake	Cab-1	2024-06-12	3	Etheostoma fonticola	14	1
3176	Landa Lake	Cab-1	2024-06-12	3	Etheostoma fonticola	22	1
3176	Landa Lake	Cab-1	2024-06-12	3	Etheostoma fonticola	18	1
3176	Landa Lake	Cab-1	2024-06-12	3	Etheostoma fonticola	18	1
3176	Landa Lake	Cab-1	2024-06-12	4	Etheostoma fonticola	16	1
3176	Landa Lake	Cab-1	2024-06-12	4	Etheostoma fonticola	18	1
3176	Landa Lake	Cab-1	2024-06-12	5	Etheostoma fonticola	29	1
3176	Landa Lake	Cab-1	2024-06-12	5	Etheostoma fonticola	21	1
3176	Landa Lake	Cab-1	2024-06-12	5	Etheostoma fonticola	28	1
3176	Landa Lake	Cab-1	2024-06-12	5	Etheostoma fonticola	22	1
3176	Landa Lake	Cab-1	2024-06-12	5	Etheostoma fonticola	27	1
3176	Landa Lake	Cab-1	2024-06-12	6	Etheostoma fonticola	22	1
3176	Landa Lake	Cab-1	2024-06-12	7	No fish collected		
3176	Landa Lake	Cab-1	2024-06-12	8	Procambarus sp.		1
3176	Landa Lake	Cab-1	2024-06-12	8	Etheostoma fonticola	28	1
3176	Landa Lake	Cab-1	2024-06-12	8	Etheostoma fonticola	24	1
3176	Landa Lake	Cab-1	2024-06-12	8	Etheostoma fonticola	20	1
3176	Landa Lake	Cab-1	2024-06-12	8	Etheostoma fonticola	17	1
3176	Landa Lake	Cab-1	2024-06-12	8	Etheostoma fonticola	19	1
3176	Landa Lake	Cab-1	2024-06-12	8	Etheostoma fonticola	28	1
3176	Landa Lake	Cab-1	2024-06-12	9	No fish collected		
3176	Landa Lake	Cab-1	2024-06-12	10	Etheostoma fonticola	15	1
3176	Landa Lake	Cab-1	2024-06-12	11	Procambarus sp.		1
3176	Landa Lake	Cab-1	2024-06-12	12	Etheostoma fonticola	26	1
3176	Landa Lake	Cab-1	2024-06-12	12	Etheostoma fonticola	26	1
3176	Landa Lake	Cab-1	2024-06-12	13	Etheostoma fonticola	19	1
3176	Landa Lake	Cab-1	2024-06-12	14	Procambarus sp.		1

3176	Landa Lake	Cab-1	2024-06-12	15	No fish collected		
3177	Landa Lake	Cab-2	2024-06-12	1	Etheostoma fonticola	18	1
3177	Landa Lake	Cab-2	2024-06-12	1	Etheostoma fonticola	20	1
3177	Landa Lake	Cab-2	2024-06-12	1	Etheostoma fonticola	18	1
3177	Landa Lake	Cab-2	2024-06-12	1	Etheostoma fonticola	19	1
3177	Landa Lake	Cab-2	2024-06-12	1	Etheostoma fonticola	21	1
3177	Landa Lake	Cab-2	2024-06-12	1	Etheostoma fonticola	17	1
3177	Landa Lake	Cab-2	2024-06-12	2	Etheostoma fonticola	31	1
3177	Landa Lake	Cab-2	2024-06-12	2	Etheostoma fonticola	22	1
3177	Landa Lake	Cab-2	2024-06-12	2	Etheostoma fonticola	22	1
3177	Landa Lake	Cab-2	2024-06-12	2	Etheostoma fonticola	19	1
3177	Landa Lake	Cab-2	2024-06-12	2	Etheostoma fonticola	21	1
3177	Landa Lake	Cab-2	2024-06-12	2	Etheostoma fonticola	17	1
3177	Landa Lake	Cab-2	2024-06-12	2	Etheostoma fonticola	26	1
3177	Landa Lake	Cab-2	2024-06-12	2	Etheostoma fonticola	18	1
3177	Landa Lake	Cab-2	2024-06-12	2	Procambarus sp.		1
3177	Landa Lake	Cab-2	2024-06-12	3	Etheostoma fonticola	28	1
3177	Landa Lake	Cab-2	2024-06-12	3	Etheostoma fonticola	20	1
3177	Landa Lake	Cab-2	2024-06-12	3	Etheostoma fonticola	30	1
3177	Landa Lake	Cab-2	2024-06-12	3	Etheostoma fonticola	18	1
3177	Landa Lake	Cab-2	2024-06-12	3	Etheostoma fonticola	19	1
3177	Landa Lake	Cab-2	2024-06-12	3	Etheostoma fonticola	20	1
3177	Landa Lake	Cab-2	2024-06-12	3	Etheostoma fonticola	17	1
3177	Landa Lake	Cab-2	2024-06-12	3	Gambusia sp.	8	1
3177	Landa Lake	Cab-2	2024-06-12	3	Procambarus sp.		3
3177	Landa Lake	Cab-2	2024-06-12	4	Etheostoma fonticola	23	1
3177	Landa Lake	Cab-2	2024-06-12	4	Etheostoma fonticola	19	1
3177	Landa Lake	Cab-2	2024-06-12	4	Procambarus sp.		2
3177	Landa Lake	Cab-2	2024-06-12	5	Etheostoma fonticola	24	1
3177	Landa Lake	Cab-2	2024-06-12	5	Etheostoma fonticola	29	1

3177	Landa Lake	Cab-2	2024-06-12	5	Etheostoma fonticola	22	1
3177	Landa Lake	Cab-2	2024-06-12	5	Lepomis miniatus	45	1
3177	Landa Lake	Cab-2	2024-06-12	5	Lepomis sp.	8	1
3177	Landa Lake	Cab-2	2024-06-12	5	Procambarus sp.		1
3177	Landa Lake	Cab-2	2024-06-12	6	Procambarus sp.		5
3177	Landa Lake	Cab-2	2024-06-12	6	Etheostoma fonticola	24	1
3177	Landa Lake	Cab-2	2024-06-12	6	Etheostoma fonticola	29	1
3177	Landa Lake	Cab-2	2024-06-12	6	Etheostoma fonticola	28	1
3177	Landa Lake	Cab-2	2024-06-12	7	Etheostoma fonticola	22	1
3177	Landa Lake	Cab-2	2024-06-12	7	Etheostoma fonticola	33	1
3177	Landa Lake	Cab-2	2024-06-12	8	Etheostoma fonticola	18	1
3177	Landa Lake	Cab-2	2024-06-12	8	Procambarus sp.		1
3177	Landa Lake	Cab-2	2024-06-12	9	Etheostoma fonticola	19	1
3177	Landa Lake	Cab-2	2024-06-12	9	Etheostoma fonticola	20	1
3177	Landa Lake	Cab-2	2024-06-12	9	Etheostoma fonticola	19	1
3177	Landa Lake	Cab-2	2024-06-12	9	Etheostoma fonticola	28	1
3177	Landa Lake	Cab-2	2024-06-12	9	Etheostoma fonticola	16	1
3177	Landa Lake	Cab-2	2024-06-12	9	Etheostoma fonticola	28	1
3177	Landa Lake	Cab-2	2024-06-12	9	Lepomis miniatus	45	1
3177	Landa Lake	Cab-2	2024-06-12	10	Etheostoma fonticola	18	1
3177	Landa Lake	Cab-2	2024-06-12	10	Etheostoma fonticola	27	1
3177	Landa Lake	Cab-2	2024-06-12	10	Etheostoma fonticola	15	1
3177	Landa Lake	Cab-2	2024-06-12	10	Procambarus sp.		1
3177	Landa Lake	Cab-2	2024-06-12	11	No fish collected		
3177	Landa Lake	Cab-2	2024-06-12	12	Procambarus sp.		2
3177	Landa Lake	Cab-2	2024-06-12	12	Etheostoma fonticola	19	1
3177	Landa Lake	Cab-2	2024-06-12	13	Etheostoma fonticola	33	1
3177	Landa Lake	Cab-2	2024-06-12	13	Etheostoma fonticola	16	1
3177	Landa Lake	Cab-2	2024-06-12	13	Etheostoma fonticola	19	1
3177	Landa Lake	Cab-2	2024-06-12	14	Etheostoma fonticola	22	1

3177	Landa Lake	Cab-2	2024-06-12	14	Etheostoma fonticola	22	1
3177	Landa Lake	Cab-2	2024-06-12	15	Procambarus sp.		1
3178	Landa Lake	Lud-2	2024-06-12	1	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	1	Etheostoma fonticola	27	1
3178	Landa Lake	Lud-2	2024-06-12	1	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	1	Etheostoma fonticola	22	1
3178	Landa Lake	Lud-2	2024-06-12	1	Etheostoma fonticola	30	1
3178	Landa Lake	Lud-2	2024-06-12	1	Procambarus sp.		7
3178	Landa Lake	Lud-2	2024-06-12	1	Palaemonetes sp.		7
3178	Landa Lake	Lud-2	2024-06-12	1	Gambusia sp.	8	1
3178	Landa Lake	Lud-2	2024-06-12	1	Gambusia sp.	10	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	23	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	24	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	23	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	27	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	21	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	31	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	24	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	32	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	18	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	23	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	27	1

3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	29	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	34	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	22	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	24	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	18	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	21	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	22	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	29	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	20	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	15	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	20	1
3178	Landa Lake	Lud-2	2024-06-12	2	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	2	Procambarus sp.		38
3178	Landa Lake	Lud-2	2024-06-12	2	Palaemonetes sp.		6
3178	Landa Lake	Lud-2	2024-06-12	2	Gambusia sp.	15	1
3178	Landa Lake	Lud-2	2024-06-12	2	Gambusia sp.	13	1
3178	Landa Lake	Lud-2	2024-06-12	3	Procambarus sp.		16
3178	Landa Lake	Lud-2	2024-06-12	3	Palaemonetes sp.		5
3178	Landa Lake	Lud-2	2024-06-12	3	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	3	Etheostoma fonticola	31	1
3178	Landa Lake	Lud-2	2024-06-12	3	Etheostoma fonticola	19	1
3178	Landa Lake	Lud-2	2024-06-12	3	Etheostoma fonticola	22	1
3178	Landa Lake	Lud-2	2024-06-12	3	Etheostoma fonticola	24	1
3178	Landa Lake	Lud-2	2024-06-12	3	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	3	Etheostoma fonticola	19	1

3178	Landa Lake	Lud-2	2024-06-12	4	Procambarus sp.		3
3178	Landa Lake	Lud-2	2024-06-12	4	Lepomis miniatus	39	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	20	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	30	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	30	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	30	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	24	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	24	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	21	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	31	1
3178	Landa Lake	Lud-2	2024-06-12	4	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	5	Lepomis miniatus	35	1
3178	Landa Lake	Lud-2	2024-06-12	5	Lepomis miniatus	45	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	29	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	22	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	29	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	24	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	29	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	22	1
3178	Landa Lake	Lud-2	2024-06-12	5	Etheostoma fonticola	16	1
3178	Landa Lake	Lud-2	2024-06-12	5	Procambarus sp.		4
3178	Landa Lake	Lud-2	2024-06-12	6	Etheostoma fonticola	33	1
3178	Landa Lake	Lud-2	2024-06-12	6	Etheostoma fonticola	32	1

3178	Landa Lake	Lud-2	2024-06-12	6	Etheostoma fonticola	27	1
3178	Landa Lake	Lud-2	2024-06-12	6	Etheostoma fonticola	30	1
3178	Landa Lake	Lud-2	2024-06-12	6	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	6	Etheostoma fonticola	31	1
3178	Landa Lake	Lud-2	2024-06-12	6	Procambarus sp.		8
3178	Landa Lake	Lud-2	2024-06-12	7	Lepomis miniatus	30	1
3178	Landa Lake	Lud-2	2024-06-12	7	Procambarus sp.		5
3178	Landa Lake	Lud-2	2024-06-12	7	Etheostoma fonticola	29	1
3178	Landa Lake	Lud-2	2024-06-12	7	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	7	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	8	Gambusia sp.	12	1
3178	Landa Lake	Lud-2	2024-06-12	8	Etheostoma fonticola	27	1
3178	Landa Lake	Lud-2	2024-06-12	8	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	8	Etheostoma fonticola	31	1
3178	Landa Lake	Lud-2	2024-06-12	8	Palaemonetes sp.		1
3178	Landa Lake	Lud-2	2024-06-12	8	Procambarus sp.		1
3178	Landa Lake	Lud-2	2024-06-12	9	Procambarus sp.		19
3178	Landa Lake	Lud-2	2024-06-12	9	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	9	Etheostoma fonticola	32	1
3178	Landa Lake	Lud-2	2024-06-12	9	Etheostoma fonticola	15	1
3178	Landa Lake	Lud-2	2024-06-12	9	Etheostoma fonticola	27	1
3178	Landa Lake	Lud-2	2024-06-12	9	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	9	Etheostoma fonticola	17	1
3178	Landa Lake	Lud-2	2024-06-12	9	Etheostoma fonticola	20	1
3178	Landa Lake	Lud-2	2024-06-12	9	Etheostoma fonticola	27	1
3178	Landa Lake	Lud-2	2024-06-12	9	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	10	Etheostoma fonticola	31	1
3178	Landa Lake	Lud-2	2024-06-12	10	Etheostoma fonticola	29	1
3178	Landa Lake	Lud-2	2024-06-12	10	Etheostoma fonticola	29	1
3178	Landa Lake	Lud-2	2024-06-12	10	Etheostoma fonticola	30	1

3178	Landa Lake	Lud-2	2024-06-12	10	Etheostoma fonticola	30	1
3178	Landa Lake	Lud-2	2024-06-12	10	Etheostoma fonticola	27	1
3178	Landa Lake	Lud-2	2024-06-12	10	Palaemonetes sp.		1
3178	Landa Lake	Lud-2	2024-06-12	10	Procambarus sp.		12
3178	Landa Lake	Lud-2	2024-06-12	11	Etheostoma fonticola	30	1
3178	Landa Lake	Lud-2	2024-06-12	11	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	11	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	11	Etheostoma fonticola	17	1
3178	Landa Lake	Lud-2	2024-06-12	11	Lepomis miniatus	35	1
3178	Landa Lake	Lud-2	2024-06-12	11	Procambarus sp.		2
3178	Landa Lake	Lud-2	2024-06-12	12	Etheostoma fonticola	27	1
3178	Landa Lake	Lud-2	2024-06-12	12	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	12	Etheostoma fonticola	23	1
3178	Landa Lake	Lud-2	2024-06-12	12	Procambarus sp.		5
3178	Landa Lake	Lud-2	2024-06-12	13	Procambarus sp.		3
3178	Landa Lake	Lud-2	2024-06-12	13	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	13	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	14	Procambarus sp.		2
3178	Landa Lake	Lud-2	2024-06-12	14	Etheostoma fonticola	32	1
3178	Landa Lake	Lud-2	2024-06-12	14	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	14	Etheostoma fonticola	28	1
3178	Landa Lake	Lud-2	2024-06-12	14	Etheostoma fonticola	27	1
3178	Landa Lake	Lud-2	2024-06-12	15	Etheostoma fonticola	35	1
3178	Landa Lake	Lud-2	2024-06-12	15	Etheostoma fonticola	31	1
3178	Landa Lake	Lud-2	2024-06-12	16	Etheostoma fonticola	26	1
3178	Landa Lake	Lud-2	2024-06-12	16	Etheostoma fonticola	25	1
3178	Landa Lake	Lud-2	2024-06-12	16	Etheostoma fonticola	30	1
3178	Landa Lake	Lud-2	2024-06-12	16	Procambarus sp.		1
3178	Landa Lake	Lud-2	2024-06-12	17	Procambarus sp.		1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	33	1

3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	25	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	36	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	9	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	34	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	33	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	23	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	20	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	32	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	26	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Etheostoma fonticola	20	1
3179	Landa Lake	Bryo-1	2024-06-12	1	Palaemonetes sp.		14
3179	Landa Lake	Bryo-1	2024-06-12	1	Procambarus sp.		1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	29	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	25	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	24	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	30	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	30	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	20	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	22	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	30	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	34	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	26	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Etheostoma fonticola	27	1
3179	Landa Lake	Bryo-1	2024-06-12	2	Palaemonetes sp.		14
3179	Landa Lake	Bryo-1	2024-06-12	3	Palaemonetes sp.		4
3179	Landa Lake	Bryo-1	2024-06-12	3	Etheostoma fonticola	29	1

3179	Landa Lake	Bryo-1	2024-06-12	3	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	3	Etheostoma fonticola	25	1
3179	Landa Lake	Bryo-1	2024-06-12	3	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	3	Etheostoma fonticola	30	1
3179	Landa Lake	Bryo-1	2024-06-12	3	Etheostoma fonticola	20	1
3179	Landa Lake	Bryo-1	2024-06-12	3	Etheostoma fonticola	31	1
3179	Landa Lake	Bryo-1	2024-06-12	3	Etheostoma fonticola	10	1
3179	Landa Lake	Bryo-1	2024-06-12	3	Etheostoma fonticola	23	1
3179	Landa Lake	Bryo-1	2024-06-12	4	Palaemonetes sp.		1
3179	Landa Lake	Bryo-1	2024-06-12	4	Etheostoma fonticola	32	1
3179	Landa Lake	Bryo-1	2024-06-12	4	Etheostoma fonticola	24	1
3179	Landa Lake	Bryo-1	2024-06-12	4	Etheostoma fonticola	25	1
3179	Landa Lake	Bryo-1	2024-06-12	4	Etheostoma fonticola	26	1
3179	Landa Lake	Bryo-1	2024-06-12	4	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	4	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	4	Etheostoma fonticola	18	1
3179	Landa Lake	Bryo-1	2024-06-12	5	Palaemonetes sp.		2
3179	Landa Lake	Bryo-1	2024-06-12	5	Etheostoma fonticola	30	1
3179	Landa Lake	Bryo-1	2024-06-12	5	Etheostoma fonticola	24	1
3179	Landa Lake	Bryo-1	2024-06-12	5	Etheostoma fonticola	31	1
3179	Landa Lake	Bryo-1	2024-06-12	5	Etheostoma fonticola	35	1
3179	Landa Lake	Bryo-1	2024-06-12	5	Etheostoma fonticola	16	1
3179	Landa Lake	Bryo-1	2024-06-12	6	Etheostoma fonticola	32	1
3179	Landa Lake	Bryo-1	2024-06-12	6	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	6	Etheostoma fonticola	25	1
3179	Landa Lake	Bryo-1	2024-06-12	6	Procambarus sp.		1
3179	Landa Lake	Bryo-1	2024-06-12	6	Palaemonetes sp.		1
3179	Landa Lake	Bryo-1	2024-06-12	7	Etheostoma fonticola	27	1
3179	Landa Lake	Bryo-1	2024-06-12	7	Etheostoma fonticola	29	1
3179	Landa Lake	Bryo-1	2024-06-12	7	Etheostoma fonticola	32	1

3179	Landa Lake	Bryo-1	2024-06-12	7	Etheostoma fonticola	30	1
3179	Landa Lake	Bryo-1	2024-06-12	7	Palaemonetes sp.		2
3179	Landa Lake	Bryo-1	2024-06-12	7	Procambarus sp.		1
3179	Landa Lake	Bryo-1	2024-06-12	8	Etheostoma fonticola	14	1
3179	Landa Lake	Bryo-1	2024-06-12	9	Etheostoma fonticola	25	1
3179	Landa Lake	Bryo-1	2024-06-12	9	Etheostoma fonticola	23	1
3179	Landa Lake	Bryo-1	2024-06-12	9	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	9	Etheostoma fonticola	14	1
3179	Landa Lake	Bryo-1	2024-06-12	10	Etheostoma fonticola	31	1
3179	Landa Lake	Bryo-1	2024-06-12	10	Etheostoma fonticola	29	1
3179	Landa Lake	Bryo-1	2024-06-12	11	Etheostoma fonticola	17	1
3179	Landa Lake	Bryo-1	2024-06-12	11	Etheostoma fonticola	26	1
3179	Landa Lake	Bryo-1	2024-06-12	11	Etheostoma fonticola	21	1
3179	Landa Lake	Bryo-1	2024-06-12	11	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	11	Palaemonetes sp.		1
3179	Landa Lake	Bryo-1	2024-06-12	12	Etheostoma fonticola	21	1
3179	Landa Lake	Bryo-1	2024-06-12	12	Etheostoma fonticola	30	1
3179	Landa Lake	Bryo-1	2024-06-12	12	Etheostoma fonticola	29	1
3179	Landa Lake	Bryo-1	2024-06-12	12	Etheostoma fonticola	30	1
3179	Landa Lake	Bryo-1	2024-06-12	12	Etheostoma fonticola	23	1
3179	Landa Lake	Bryo-1	2024-06-12	13	Etheostoma fonticola	31	1
3179	Landa Lake	Bryo-1	2024-06-12	13	Etheostoma fonticola	35	1
3179	Landa Lake	Bryo-1	2024-06-12	14	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	14	Etheostoma fonticola	28	1
3179	Landa Lake	Bryo-1	2024-06-12	15	Palaemonetes sp.		1
3179	Landa Lake	Bryo-1	2024-06-12	15	Etheostoma fonticola	35	1
3179	Landa Lake	Bryo-1	2024-06-12	16	Etheostoma fonticola	29	1
3179	Landa Lake	Bryo-1	2024-06-12	17	Etheostoma fonticola	26	1
3179	Landa Lake	Bryo-1	2024-06-12	18	Etheostoma fonticola	27	1
3179	Landa Lake	Bryo-1	2024-06-12	18	Etheostoma fonticola	27	1

3179	Landa Lake	Bryo-1	2024-06-12	18	Procambarus sp.		1
3179	Landa Lake	Bryo-1	2024-06-12	19	Etheostoma fonticola	30	1
3179	Landa Lake	Bryo-1	2024-06-12	20	Etheostoma fonticola	24	1
3179	Landa Lake	Bryo-1	2024-06-12	20	Etheostoma fonticola	25	1
3179	Landa Lake	Bryo-1	2024-06-12	21	Etheostoma fonticola	22	1
3179	Landa Lake	Bryo-1	2024-06-12	22	Procambarus sp.		1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	19	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	20	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	25	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	23	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	23	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	32	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	23	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	15	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	30	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	30	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Etheostoma fonticola	22	1
3180	Landa Lake	Bryo-2	2024-06-12	1	Palaemonetes sp.		12
3180	Landa Lake	Bryo-2	2024-06-12	2	Etheostoma fonticola	27	1
3180	Landa Lake	Bryo-2	2024-06-12	2	Etheostoma fonticola	31	1
3180	Landa Lake	Bryo-2	2024-06-12	2	Etheostoma fonticola	29	1
3180	Landa Lake	Bryo-2	2024-06-12	2	Procambarus sp.		1
3180	Landa Lake	Bryo-2	2024-06-12	2	Palaemonetes sp.		5
3180	Landa Lake	Bryo-2	2024-06-12	3	Palaemonetes sp.		1
3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	26	1
3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	26	1
3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	26	1
3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	24	1
3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	26	1
3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	31	1

3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	24	1
3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	32	1
3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	32	1
3180	Landa Lake	Bryo-2	2024-06-12	3	Etheostoma fonticola	23	1
3180	Landa Lake	Bryo-2	2024-06-12	4	Etheostoma fonticola	26	1
3180	Landa Lake	Bryo-2	2024-06-12	4	Etheostoma fonticola	29	1
3180	Landa Lake	Bryo-2	2024-06-12	4	Etheostoma fonticola	34	1
3180	Landa Lake	Bryo-2	2024-06-12	4	Etheostoma fonticola	20	1
3180	Landa Lake	Bryo-2	2024-06-12	4	Etheostoma fonticola	22	1
3180	Landa Lake	Bryo-2	2024-06-12	4	Etheostoma fonticola	26	1
3180	Landa Lake	Bryo-2	2024-06-12	4	Etheostoma fonticola	35	1
3180	Landa Lake	Bryo-2	2024-06-12	5	Etheostoma fonticola	20	1
3180	Landa Lake	Bryo-2	2024-06-12	5	Etheostoma fonticola	24	1
3180	Landa Lake	Bryo-2	2024-06-12	6	Etheostoma fonticola	22	1
3180	Landa Lake	Bryo-2	2024-06-12	7	Etheostoma fonticola	21	1
3180	Landa Lake	Bryo-2	2024-06-12	7	Palaemonetes sp.		2
3180	Landa Lake	Bryo-2	2024-06-12	8	Palaemonetes sp.		1
3180	Landa Lake	Bryo-2	2024-06-12	9	No fish collected		
3180	Landa Lake	Bryo-2	2024-06-12	10	Etheostoma fonticola	33	1
3180	Landa Lake	Bryo-2	2024-06-12	10	Etheostoma fonticola	24	1
3180	Landa Lake	Bryo-2	2024-06-12	11	Etheostoma fonticola	22	1
3180	Landa Lake	Bryo-2	2024-06-12	11	Etheostoma fonticola	26	1
3180	Landa Lake	Bryo-2	2024-06-12	11	Etheostoma fonticola	24	1
3180	Landa Lake	Bryo-2	2024-06-12	12	Etheostoma fonticola	13	1
3180	Landa Lake	Bryo-2	2024-06-12	12	Etheostoma fonticola	23	1
3180	Landa Lake	Bryo-2	2024-06-12	13	Etheostoma fonticola	28	1
3180	Landa Lake	Bryo-2	2024-06-12	13	Etheostoma fonticola	30	1
3180	Landa Lake	Bryo-2	2024-06-12	14	Etheostoma fonticola	25	1
3180	Landa Lake	Bryo-2	2024-06-12	14	Etheostoma fonticola	30	1
3180	Landa Lake	Bryo-2	2024-06-12	15	Etheostoma fonticola	30	1

3180	Landa Lake	Bryo-2	2024-06-12	15	Etheostoma fonticola	23	1
3180	Landa Lake	Bryo-2	2024-06-12	15	Procambarus sp.		1
3180	Landa Lake	Bryo-2	2024-06-12	16	Etheostoma fonticola	30	1
3180	Landa Lake	Bryo-2	2024-06-12	17	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	1	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	2	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	3	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	4	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	5	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	6	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	7	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	8	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	9	No fish collected		
3181	Landa Lake	Open-1	2024-06-12	10	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	1	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	2	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	3	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	4	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	5	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	6	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	7	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	8	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	9	No fish collected		
3182	Landa Lake	Open-2	2024-06-12	10	No fish collected		
3183	Landa Lake	Val-1	2024-06-12	1	Palaemonetes sp.		2
3183	Landa Lake	Val-1	2024-06-12	1	Procambarus sp.		1
3183	Landa Lake	Val-1	2024-06-12	1	Dionda nigrotaeniata	35	1
3183	Landa Lake	Val-1	2024-06-12	1	Astyanax mexicanus	48	1
3183	Landa Lake	Val-1	2024-06-12	2	Dionda nigrotaeniata	45	1
3183	Landa Lake	Val-1	2024-06-12	2	Dionda nigrotaeniata	35	1

3183	Landa Lake	Val-1	2024-06-12	2	Dionda nigrotaeniata	40	1
3183	Landa Lake	Val-1	2024-06-12	2	Dionda nigrotaeniata	40	1
3183	Landa Lake	Val-1	2024-06-12	2	Dionda nigrotaeniata	42	1
3183	Landa Lake	Val-1	2024-06-12	2	Dionda nigrotaeniata	38	1
3183	Landa Lake	Val-1	2024-06-12	2	Astyanax mexicanus	41	1
3183	Landa Lake	Val-1	2024-06-12	2	Astyanax mexicanus	47	1
3183	Landa Lake	Val-1	2024-06-12	2	Procambarus sp.		4
3183	Landa Lake	Val-1	2024-06-12	2	Lepomis miniatus	35	1
3183	Landa Lake	Val-1	2024-06-12	3	Procambarus sp.		2
3183	Landa Lake	Val-1	2024-06-12	3	Lepomis miniatus	36	1
3183	Landa Lake	Val-1	2024-06-12	3	Lepomis miniatus	42	1
3183	Landa Lake	Val-1	2024-06-12	3	Lepomis miniatus	30	1
3183	Landa Lake	Val-1	2024-06-12	3	Dionda nigrotaeniata	31	1
3183	Landa Lake	Val-1	2024-06-12	3	Dionda nigrotaeniata	29	1
3183	Landa Lake	Val-1	2024-06-12	3	Astyanax mexicanus	50	1
3183	Landa Lake	Val-1	2024-06-12	3	Astyanax mexicanus	44	1
3183	Landa Lake	Val-1	2024-06-12	3	Etheostoma fonticola	26	1
3183	Landa Lake	Val-1	2024-06-12	3	Etheostoma fonticola	29	1
3183	Landa Lake	Val-1	2024-06-12	4	Procambarus sp.		3
3183	Landa Lake	Val-1	2024-06-12	4	Lepomis miniatus	85	1
3183	Landa Lake	Val-1	2024-06-12	4	Lepomis miniatus	42	1
3183	Landa Lake	Val-1	2024-06-12	4	Astyanax mexicanus	45	1
3183	Landa Lake	Val-1	2024-06-12	4	Astyanax mexicanus	42	1
3183	Landa Lake	Val-1	2024-06-12	4	Dionda nigrotaeniata	43	1
3183	Landa Lake	Val-1	2024-06-12	4	Etheostoma fonticola	19	1
3183	Landa Lake	Val-1	2024-06-12	5	Procambarus sp.		1
3183	Landa Lake	Val-1	2024-06-12	5	Dionda nigrotaeniata	42	1
3183	Landa Lake	Val-1	2024-06-12	5	Dionda nigrotaeniata	35	1
3183	Landa Lake	Val-1	2024-06-12	5	Dionda nigrotaeniata	40	1
3183	Landa Lake	Val-1	2024-06-12	5	Astyanax mexicanus	46	1

3183	Landa Lake	Val-1	2024-06-12	5	Astyanax mexicanus	45	1
3183	Landa Lake	Val-1	2024-06-12	5	Astyanax mexicanus	51	1
3183	Landa Lake	Val-1	2024-06-12	5	Lepomis miniatus		3
3183	Landa Lake	Val-1	2024-06-12	5	Etheostoma fonticola	19	1
3183	Landa Lake	Val-1	2024-06-12	5	Etheostoma fonticola	29	1
3183	Landa Lake	Val-1	2024-06-12	6	Procambarus sp.		1
3183	Landa Lake	Val-1	2024-06-12	6	Astyanax mexicanus	50	1
3183	Landa Lake	Val-1	2024-06-12	6	Dionda nigrotaeniata	33	1
3183	Landa Lake	Val-1	2024-06-12	7	Procambarus sp.		4
3183	Landa Lake	Val-1	2024-06-12	7	Lepomis miniatus	89	1
3183	Landa Lake	Val-1	2024-06-12	7	Lepomis miniatus	54	1
3183	Landa Lake	Val-1	2024-06-12	7	Etheostoma fonticola	18	1
3183	Landa Lake	Val-1	2024-06-12	7	Etheostoma fonticola	15	1
3183	Landa Lake	Val-1	2024-06-12	7	Etheostoma fonticola	30	1
3183	Landa Lake	Val-1	2024-06-12	8	Lepomis miniatus	35	1
3183	Landa Lake	Val-1	2024-06-12	8	Lepomis miniatus	29	1
3183	Landa Lake	Val-1	2024-06-12	8	Procambarus sp.		1
3183	Landa Lake	Val-1	2024-06-12	8	Etheostoma fonticola	18	1
3183	Landa Lake	Val-1	2024-06-12	9	Dionda nigrotaeniata	34	1
3183	Landa Lake	Val-1	2024-06-12	9	Procambarus sp.		1
3183	Landa Lake	Val-1	2024-06-12	9	Etheostoma fonticola	26	1
3183	Landa Lake	Val-1	2024-06-12	9	Etheostoma fonticola	25	1
3183	Landa Lake	Val-1	2024-06-12	10	Procambarus sp.		1
3183	Landa Lake	Val-1	2024-06-12	10	Etheostoma fonticola	24	1
3183	Landa Lake	Val-1	2024-06-12	10	Lepomis miniatus	35	1
3183	Landa Lake	Val-1	2024-06-12	10	Palaemonetes sp.		1
3183	Landa Lake	Val-1	2024-06-12	11	Procambarus sp.		1
3183	Landa Lake	Val-1	2024-06-12	12	Lepomis miniatus	42	1
3183	Landa Lake	Val-1	2024-06-12	12	Etheostoma fonticola	30	1
3183	Landa Lake	Val-1	2024-06-12	13	Procambarus sp.		1

3183	Landa Lake	Val-1	2024-06-12	13	Dionda nigrotaeniata	36	1
3183	Landa Lake	Val-1	2024-06-12	14	Procambarus sp.		1
3183	Landa Lake	Val-1	2024-06-12	15	Astyanax mexicanus	52	1
3183	Landa Lake	Val-1	2024-06-12	15	Dionda nigrotaeniata	39	1
3183	Landa Lake	Val-1	2024-06-12	15	Palaemonetes sp.		1
3183	Landa Lake	Val-1	2024-06-12	15	Etheostoma fonticola	24	1
3183	Landa Lake	Val-1	2024-06-12	15	Procambarus sp.		1
3183	Landa Lake	Val-1	2024-06-12	16	Astyanax mexicanus	47	1
3183	Landa Lake	Val-1	2024-06-12	16	Dionda nigrotaeniata	42	1
3184	Landa Lake	Val-2	2024-06-12	1	Lepomis sp.	19	1
3184	Landa Lake	Val-2	2024-06-12	1	Lepomis miniatus	33	1
3184	Landa Lake	Val-2	2024-06-12	1	Lepomis miniatus	54	1
3184	Landa Lake	Val-2	2024-06-12	1	Palaemonetes sp.		10
3184	Landa Lake	Val-2	2024-06-12	2	Lepomis miniatus	100	1
3184	Landa Lake	Val-2	2024-06-12	2	Etheostoma fonticola	12	1
3184	Landa Lake	Val-2	2024-06-12	2	Etheostoma fonticola	26	1
3184	Landa Lake	Val-2	2024-06-12	2	Gambusia sp.	12	1
3184	Landa Lake	Val-2	2024-06-12	2	Gambusia sp.	10	1
3184	Landa Lake	Val-2	2024-06-12	2	Palaemonetes sp.		4
3184	Landa Lake	Val-2	2024-06-12	3	Palaemonetes sp.		4
3184	Landa Lake	Val-2	2024-06-12	3	Lepomis miniatus	36	1
3184	Landa Lake	Val-2	2024-06-12	3	Etheostoma fonticola	32	1
3184	Landa Lake	Val-2	2024-06-12	3	Gambusia sp.	10	1
3184	Landa Lake	Val-2	2024-06-12	3	Procambarus sp.		1
3184	Landa Lake	Val-2	2024-06-12	4	Palaemonetes sp.		13
3184	Landa Lake	Val-2	2024-06-12	4	Etheostoma fonticola	29	1
3184	Landa Lake	Val-2	2024-06-12	4	Etheostoma fonticola	26	1
3184	Landa Lake	Val-2	2024-06-12	4	Etheostoma fonticola	26	1
3184	Landa Lake	Val-2	2024-06-12	4	Etheostoma fonticola	25	1
3184	Landa Lake	Val-2	2024-06-12	5	Astyanax mexicanus	60	1

3184	Landa Lake	Val-2	2024-06-12	5	Etheostoma fonticola	29	1
3184	Landa Lake	Val-2	2024-06-12	5	Etheostoma fonticola	22	1
3184	Landa Lake	Val-2	2024-06-12	5	Etheostoma fonticola	24	1
3184	Landa Lake	Val-2	2024-06-12	5	Etheostoma fonticola	24	1
3184	Landa Lake	Val-2	2024-06-12	5	Palaemonetes sp.		5
3184	Landa Lake	Val-2	2024-06-12	6	Micropterus salmoides	95	1
3184	Landa Lake	Val-2	2024-06-12	6	Procambarus sp.		1
3184	Landa Lake	Val-2	2024-06-12	6	Palaemonetes sp.		2
3184	Landa Lake	Val-2	2024-06-12	6	Etheostoma fonticola	32	1
3184	Landa Lake	Val-2	2024-06-12	6	Gambusia sp.	10	1
3184	Landa Lake	Val-2	2024-06-12	7	Etheostoma fonticola	32	1
3184	Landa Lake	Val-2	2024-06-12	7	Etheostoma fonticola	29	1
3184	Landa Lake	Val-2	2024-06-12	7	Etheostoma fonticola	28	1
3184	Landa Lake	Val-2	2024-06-12	7	Palaemonetes sp.		2
3184	Landa Lake	Val-2	2024-06-12	7	Lepomis miniatus	33	1
3184	Landa Lake	Val-2	2024-06-12	8	Palaemonetes sp.		1
3184	Landa Lake	Val-2	2024-06-12	9	Palaemonetes sp.		2
3184	Landa Lake	Val-2	2024-06-12	10	Palaemonetes sp.		2
3184	Landa Lake	Val-2	2024-06-12	10	Etheostoma fonticola	33	1
3184	Landa Lake	Val-2	2024-06-12	11	Palaemonetes sp.		1
3184	Landa Lake	Val-2	2024-06-12	11	Etheostoma fonticola	27	1
3184	Landa Lake	Val-2	2024-06-12	12	Micropterus salmoides	85	1
3184	Landa Lake	Val-2	2024-06-12	12	Palaemonetes sp.		1
3184	Landa Lake	Val-2	2024-06-12	13	No fish collected		
3184	Landa Lake	Val-2	2024-06-12	14	Palaemonetes sp.		2
3184	Landa Lake	Val-2	2024-06-12	15	No fish collected		
3185	Old Channel Reach	Bryo-1	2024-06-11	1	Etheostoma fonticola	23	1
3185	Old Channel Reach	Bryo-1	2024-06-11	1	Etheostoma fonticola	28	1
3185	Old Channel Reach	Bryo-1	2024-06-11	1	Etheostoma fonticola	24	1
3185	Old Channel Reach	Bryo-1	2024-06-11	1	Etheostoma fonticola	15	1

3185	Old Channel Reach	Bryo-1	2024-06-11	2	Procambarus sp.		2
3185	Old Channel Reach	Bryo-1	2024-06-11	2	Etheostoma fonticola	30	1
3185	Old Channel Reach	Bryo-1	2024-06-11	2	Etheostoma fonticola	11	1
3185	Old Channel Reach	Bryo-1	2024-06-11	3	Etheostoma fonticola	28	1
3185	Old Channel Reach	Bryo-1	2024-06-11	3	Gambusia sp.	9	1
3185	Old Channel Reach	Bryo-1	2024-06-11	3	Notropis amabilis	13	1
3185	Old Channel Reach	Bryo-1	2024-06-11	3	Notropis amabilis	13	1
3185	Old Channel Reach	Bryo-1	2024-06-11	4	Etheostoma fonticola	20	1
3185	Old Channel Reach	Bryo-1	2024-06-11	4	Etheostoma fonticola	28	1
3185	Old Channel Reach	Bryo-1	2024-06-11	5	Procambarus sp.		1
3185	Old Channel Reach	Bryo-1	2024-06-11	6	Procambarus sp.		2
3185	Old Channel Reach	Bryo-1	2024-06-11	6	Etheostoma fonticola	28	1
3185	Old Channel Reach	Bryo-1	2024-06-11	7	Etheostoma fonticola	30	1
3185	Old Channel Reach	Bryo-1	2024-06-11	7	Procambarus sp.		1
3185	Old Channel Reach	Bryo-1	2024-06-11	8	No fish collected		
3185	Old Channel Reach	Bryo-1	2024-06-11	9	Etheostoma fonticola	27	1
3185	Old Channel Reach	Bryo-1	2024-06-11	10	Etheostoma fonticola	28	1
3185	Old Channel Reach	Bryo-1	2024-06-11	11	No fish collected		
3185	Old Channel Reach	Bryo-1	2024-06-11	12	Procambarus sp.		1
3185	Old Channel Reach	Bryo-1	2024-06-11	13	No fish collected		
3185	Old Channel Reach	Bryo-1	2024-06-11	14	No fish collected		
3185	Old Channel Reach	Bryo-1	2024-06-11	15	No fish collected		
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	28	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	27	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	25	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	30	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	25	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	30	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	30	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	19	1

3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	25	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	26	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Etheostoma fonticola	25	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Procambarus sp.		5
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	8	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	8	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	5	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	7	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	5	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	9	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	7	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	8	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	10	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	9	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	8	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	9	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	9	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	10	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	8	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	8	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	7	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	8	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	7	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	6	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	7	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.	7	1
3186	Old Channel Reach	Bryo-2	2024-06-11	1	Lepomis sp.		54
3186	Old Channel Reach	Bryo-2	2024-06-11	2	Procambarus sp.		6
3186	Old Channel Reach	Bryo-2	2024-06-11	2	Etheostoma fonticola	26	1
3186	Old Channel Reach	Bryo-2	2024-06-11	2	Etheostoma fonticola	30	1

3186	Old Channel Reach	Bryo-2	2024-06-11	2	Etheostoma fonticola	30	1
3186	Old Channel Reach	Bryo-2	2024-06-11	2	Etheostoma fonticola	29	1
3186	Old Channel Reach	Bryo-2	2024-06-11	2	Etheostoma fonticola	28	1
3186	Old Channel Reach	Bryo-2	2024-06-11	2	Lepomis sp.		33
3186	Old Channel Reach	Bryo-2	2024-06-11	3	Etheostoma fonticola	31	1
3186	Old Channel Reach	Bryo-2	2024-06-11	3	Etheostoma fonticola	26	1
3186	Old Channel Reach	Bryo-2	2024-06-11	3	Etheostoma fonticola	30	1
3186	Old Channel Reach	Bryo-2	2024-06-11	3	Etheostoma fonticola	29	1
3186	Old Channel Reach	Bryo-2	2024-06-11	3	Etheostoma fonticola	27	1
3186	Old Channel Reach	Bryo-2	2024-06-11	3	Etheostoma fonticola	14	1
3186	Old Channel Reach	Bryo-2	2024-06-11	3	Lepomis sp.		6
3186	Old Channel Reach	Bryo-2	2024-06-11	4	Etheostoma fonticola	26	1
3186	Old Channel Reach	Bryo-2	2024-06-11	4	Etheostoma fonticola	28	1
3186	Old Channel Reach	Bryo-2	2024-06-11	4	Procambarus sp.		1
3186	Old Channel Reach	Bryo-2	2024-06-11	5	Procambarus sp.		1
3186	Old Channel Reach	Bryo-2	2024-06-11	5	Etheostoma fonticola	25	1
3186	Old Channel Reach	Bryo-2	2024-06-11	5	Lepomis sp.		2
3186	Old Channel Reach	Bryo-2	2024-06-11	6	Procambarus sp.		2
3186	Old Channel Reach	Bryo-2	2024-06-11	6	Lepomis sp.		1
3186	Old Channel Reach	Bryo-2	2024-06-11	7	Lepomis sp.		3
3186	Old Channel Reach	Bryo-2	2024-06-11	8	Etheostoma fonticola	22	1
3186	Old Channel Reach	Bryo-2	2024-06-11	8	Etheostoma fonticola	30	1
3186	Old Channel Reach	Bryo-2	2024-06-11	8	Procambarus sp.		2
3186	Old Channel Reach	Bryo-2	2024-06-11	9	Etheostoma fonticola	29	1
3186	Old Channel Reach	Bryo-2	2024-06-11	9	Procambarus sp.		1
3186	Old Channel Reach	Bryo-2	2024-06-11	9	Lepomis sp.		2
3186	Old Channel Reach	Bryo-2	2024-06-11	10	Procambarus sp.		1
3186	Old Channel Reach	Bryo-2	2024-06-11	10	Lepomis sp.		2
3186	Old Channel Reach	Bryo-2	2024-06-11	11	Procambarus sp.		1
3186	Old Channel Reach	Bryo-2	2024-06-11	11	Lepomis sp.		1

3186	Old Channel Reach	Bryo-2	2024-06-11	12	Procambarus sp.		1
3186	Old Channel Reach	Bryo-2	2024-06-11	13	Procambarus sp.		1
3186	Old Channel Reach	Bryo-2	2024-06-11	14	Lepomis sp.		1
3186	Old Channel Reach	Bryo-2	2024-06-11	15	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	25	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	30	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	33	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	25	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	27	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	25	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	32	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	27	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	30	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	28	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	30	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	26	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	31	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	24	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	30	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	29	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	29	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	21	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis amabilis	21	1
3187	Old Channel Reach	Open-1	2024-06-11	1	Notropis volucellus	28	1
3187	Old Channel Reach	Open-1	2024-06-11	2	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	3	Notropis amabilis	25	1
3187	Old Channel Reach	Open-1	2024-06-11	3	Notropis amabilis		8
3187	Old Channel Reach	Open-1	2024-06-11	4	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	5	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	6	No fish collected		

3187	Old Channel Reach	Open-1	2024-06-11	7	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	8	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	9	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	10	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	11	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	12	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	13	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	14	No fish collected		
3187	Old Channel Reach	Open-1	2024-06-11	15	No fish collected		
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis cyanellus	60	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1

3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	1	Lepomis sp.	7	1
3188	Old Channel Reach	Open-2	2024-06-11	2	Lepomis sp.		30
3188	Old Channel Reach	Open-2	2024-06-11	3	Lepomis sp.		5
3188	Old Channel Reach	Open-2	2024-06-11	4	Lepomis sp.		12
3188	Old Channel Reach	Open-2	2024-06-11	5	No fish collected		
3188	Old Channel Reach	Open-2	2024-06-11	6	No fish collected		
3188	Old Channel Reach	Open-2	2024-06-11	7	No fish collected		
3188	Old Channel Reach	Open-2	2024-06-11	8	Lepomis sp.		5
3188	Old Channel Reach	Open-2	2024-06-11	9	Lepomis sp.		18
3188	Old Channel Reach	Open-2	2024-06-11	10	Lepomis sp.		9
3188	Old Channel Reach	Open-2	2024-06-11	11	Lepomis sp.		11
3188	Old Channel Reach	Open-2	2024-06-11	12	No fish collected		
3188	Old Channel Reach	Open-2	2024-06-11	13	Lepomis sp.		1
3188	Old Channel Reach	Open-2	2024-06-11	14	No fish collected		
3188	Old Channel Reach	Open-2	2024-06-11	15	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	1	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	2	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	3	Etheostoma fonticola	25	1
3189	Old Channel Reach	Lud-1	2024-06-11	4	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	5	Procambarus sp.		1
3189	Old Channel Reach	Lud-1	2024-06-11	5	Lepomis sp.	10	1
3189	Old Channel Reach	Lud-1	2024-06-11	6	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	7	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	8	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	9	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	10	No fish collected		

3189	Old Channel Reach	Lud-1	2024-06-11	11	Lepomis sp.	7	1
3189	Old Channel Reach	Lud-1	2024-06-11	12	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	13	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	14	No fish collected		
3189	Old Channel Reach	Lud-1	2024-06-11	15	No fish collected		
3190	Old Channel Reach	Lud-2	2024-06-11	1	Procambarus sp.		3
3190	Old Channel Reach	Lud-2	2024-06-11	1	Palaemonetes sp.		5
3190	Old Channel Reach	Lud-2	2024-06-11	1	Etheostoma fonticola	22	1
3190	Old Channel Reach	Lud-2	2024-06-11	1	Etheostoma fonticola	30	1
3190	Old Channel Reach	Lud-2	2024-06-11	1	Etheostoma fonticola	21	1
3190	Old Channel Reach	Lud-2	2024-06-11	1	Etheostoma fonticola	28	1
3190	Old Channel Reach	Lud-2	2024-06-11	1	Etheostoma fonticola	15	1
3190	Old Channel Reach	Lud-2	2024-06-11	1	Etheostoma fonticola	22	1
3190	Old Channel Reach	Lud-2	2024-06-11	1	Etheostoma fonticola	21	1
3190	Old Channel Reach	Lud-2	2024-06-11	2	Etheostoma fonticola	22	1
3190	Old Channel Reach	Lud-2	2024-06-11	2	Etheostoma fonticola	32	1
3190	Old Channel Reach	Lud-2	2024-06-11	2	Etheostoma fonticola	23	1
3190	Old Channel Reach	Lud-2	2024-06-11	2	Procambarus sp.		9
3190	Old Channel Reach	Lud-2	2024-06-11	2	Palaemonetes sp.		6
3190	Old Channel Reach	Lud-2	2024-06-11	3	Palaemonetes sp.		1
3190	Old Channel Reach	Lud-2	2024-06-11	3	Etheostoma fonticola	25	1
3190	Old Channel Reach	Lud-2	2024-06-11	3	Etheostoma fonticola	20	1
3190	Old Channel Reach	Lud-2	2024-06-11	3	Procambarus sp.		2
3190	Old Channel Reach	Lud-2	2024-06-11	4	Procambarus sp.		1
3190	Old Channel Reach	Lud-2	2024-06-11	5	Procambarus sp.		5
3190	Old Channel Reach	Lud-2	2024-06-11	5	Etheostoma fonticola	35	1
3190	Old Channel Reach	Lud-2	2024-06-11	5	Etheostoma fonticola	25	1
3190	Old Channel Reach	Lud-2	2024-06-11	5	Palaemonetes sp.		1
3190	Old Channel Reach	Lud-2	2024-06-11	6	Etheostoma fonticola	29	1
3190	Old Channel Reach	Lud-2	2024-06-11	6	Etheostoma fonticola	21	1

3190	Old Channel Reach	Lud-2	2024-06-11	6	Etheostoma fonticola	25	1
3190	Old Channel Reach	Lud-2	2024-06-11	6	Etheostoma fonticola	22	1
3190	Old Channel Reach	Lud-2	2024-06-11	6	Palaemonetes sp.		3
3190	Old Channel Reach	Lud-2	2024-06-11	6	Procambarus sp.		2
3190	Old Channel Reach	Lud-2	2024-06-11	7	Etheostoma fonticola	24	1
3190	Old Channel Reach	Lud-2	2024-06-11	7	Etheostoma fonticola	27	1
3190	Old Channel Reach	Lud-2	2024-06-11	7	Etheostoma fonticola	28	1
3190	Old Channel Reach	Lud-2	2024-06-11	7	Etheostoma fonticola	32	1
3190	Old Channel Reach	Lud-2	2024-06-11	7	Etheostoma fonticola	22	1
3190	Old Channel Reach	Lud-2	2024-06-11	7	Procambarus sp.		6
3190	Old Channel Reach	Lud-2	2024-06-11	8	Procambarus sp.		3
3190	Old Channel Reach	Lud-2	2024-06-11	9	Procambarus sp.		1
3190	Old Channel Reach	Lud-2	2024-06-11	10	Procambarus sp.		2
3190	Old Channel Reach	Lud-2	2024-06-11	11	No fish collected		
3190	Old Channel Reach	Lud-2	2024-06-11	12	Procambarus sp.		3
3190	Old Channel Reach	Lud-2	2024-06-11	12	Etheostoma fonticola	21	1
3190	Old Channel Reach	Lud-2	2024-06-11	13	Procambarus sp.		1
3190	Old Channel Reach	Lud-2	2024-06-11	13	Etheostoma fonticola	35	1
3190	Old Channel Reach	Lud-2	2024-06-11	13	Etheostoma fonticola	26	1
3190	Old Channel Reach	Lud-2	2024-06-11	13	Etheostoma fonticola	26	1
3190	Old Channel Reach	Lud-2	2024-06-11	13	Etheostoma fonticola	22	1
3190	Old Channel Reach	Lud-2	2024-06-11	13	Gambusia sp.	10	1
3190	Old Channel Reach	Lud-2	2024-06-11	14	No fish collected		
3190	Old Channel Reach	Lud-2	2024-06-11	15	Procambarus sp.		1
3190	Old Channel Reach	Lud-2	2024-06-11	15	Palaemonetes sp.		1
3191	Upper New Channel Reach	Open-1	2024-06-17	1	No fish collected		
3191	Upper New Channel Reach	Open-1	2024-06-17	2	No fish collected		
3191	Upper New Channel Reach	Open-1	2024-06-17	3	No fish collected		
3191	Upper New Channel Reach	Open-1	2024-06-17	4	No fish collected		
3191	Upper New Channel Reach	Open-1	2024-06-17	5	No fish collected		

3191	Upper New Channel Reach	Open-1	2024-06-17	6	No fish collected		
3191	Upper New Channel Reach	Open-1	2024-06-17	7	No fish collected		
3191	Upper New Channel Reach	Open-1	2024-06-17	8	No fish collected		
3191	Upper New Channel Reach	Open-1	2024-06-17	9	No fish collected		
3191	Upper New Channel Reach	Open-1	2024-06-17	10	No fish collected		
3192	Upper New Channel Reach	Hyg-1	2024-06-17	1	Dionda nigrotaeniata	45	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	1	Procambarus sp.		2
3192	Upper New Channel Reach	Hyg-1	2024-06-17	1	Palaemonetes sp.		3
3192	Upper New Channel Reach	Hyg-1	2024-06-17	1	Lepomis gulosus	50	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	1	Herichthys cyanoguttatus	35	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	1	Lepomis cyanellus	43	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	2	Procambarus sp.		6
3192	Upper New Channel Reach	Hyg-1	2024-06-17	2	Herichthys cyanoguttatus	31	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	2	Herichthys cyanoguttatus	28	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	2	Herichthys cyanoguttatus	35	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	2	Ameiurus natalis	84	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	3	Procambarus sp.		4
3192	Upper New Channel Reach	Hyg-1	2024-06-17	3	Lepomis cyanellus	70	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	3	Palaemonetes sp.		2
3192	Upper New Channel Reach	Hyg-1	2024-06-17	4	No fish collected		
3192	Upper New Channel Reach	Hyg-1	2024-06-17	5	Herichthys cyanoguttatus	23	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	6	Procambarus sp.		1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	6	Palaemonetes sp.		2
3192	Upper New Channel Reach	Hyg-1	2024-06-17	7	Procambarus sp.		2
3192	Upper New Channel Reach	Hyg-1	2024-06-17	8	Procambarus sp.		1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	8	Lepomis miniatus	64	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	9	Lepomis gulosus	56	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	9	Herichthys cyanoguttatus	21	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	10	Procambarus sp.		1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	11	Dionda nigrotaeniata	45	1

3192	Upper New Channel Reach	Hyg-1	2024-06-17	11	Procambarus sp.		1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	12	Etheostoma fonticola	29	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	13	No fish collected		
3192	Upper New Channel Reach	Hyg-1	2024-06-17	14	Procambarus sp.		1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	14	Etheostoma fonticola	26	1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	14	Palaemonetes sp.		1
3192	Upper New Channel Reach	Hyg-1	2024-06-17	15	No fish collected		
3193	Upper New Channel Reach	Cab-1	2024-06-17	1	Palaemonetes sp.		1
3193	Upper New Channel Reach	Cab-1	2024-06-17	1	Lepomis miniatus	62	1
3193	Upper New Channel Reach	Cab-1	2024-06-17	1	Procambarus sp.		1
3193	Upper New Channel Reach	Cab-1	2024-06-17	2	Procambarus sp.		4
3193	Upper New Channel Reach	Cab-1	2024-06-17	2	Palaemonetes sp.		2
3193	Upper New Channel Reach	Cab-1	2024-06-17	3	Procambarus sp.		2
3193	Upper New Channel Reach	Cab-1	2024-06-17	4	No fish collected		
3193	Upper New Channel Reach	Cab-1	2024-06-17	5	No fish collected		
3193	Upper New Channel Reach	Cab-1	2024-06-17	6	Procambarus sp.		2
3193	Upper New Channel Reach	Cab-1	2024-06-17	6	Lepomis miniatus	50	1
3193	Upper New Channel Reach	Cab-1	2024-06-17	7	Procambarus sp.		2
3193	Upper New Channel Reach	Cab-1	2024-06-17	7	Palaemonetes sp.		1
3193	Upper New Channel Reach	Cab-1	2024-06-17	8	Procambarus sp.		1
3193	Upper New Channel Reach	Cab-1	2024-06-17	9	Procambarus sp.		3
3193	Upper New Channel Reach	Cab-1	2024-06-17	10	Procambarus sp.		1
3193	Upper New Channel Reach	Cab-1	2024-06-17	10	Herichthys cyanoguttatus	12	1
3193	Upper New Channel Reach	Cab-1	2024-06-17	11	Procambarus sp.		2
3193	Upper New Channel Reach	Cab-1	2024-06-17	12	Procambarus sp.		4
3193	Upper New Channel Reach	Cab-1	2024-06-17	12	Ambloplites rupestris	39	1
3193	Upper New Channel Reach	Cab-1	2024-06-17	13	No fish collected		
3193	Upper New Channel Reach	Cab-1	2024-06-17	14	Procambarus sp.		1
3193	Upper New Channel Reach	Cab-1	2024-06-17	15	Procambarus sp.		2
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Procambarus sp.		4

3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	30	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Herichthys cyanoguttatus		104
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Lepomis cyanellus	45	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	1	Palaemonetes sp.		5
3194	Upper New Channel Reach	Cab-2	2024-06-17	2	Procambarus sp.		2
3194	Upper New Channel Reach	Cab-2	2024-06-17	2	Palaemonetes sp.		3
3194	Upper New Channel Reach	Cab-2	2024-06-17	2	Herichthys cyanoguttatus		56
3194	Upper New Channel Reach	Cab-2	2024-06-17	3	Lepomis gulosus	59	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	3	Lepomis gulosus	65	1

3194	Upper New Channel Reach	Cab-2	2024-06-17	3	Lepomis cyanellus	52	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	3	Lepomis miniatus	55	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	3	Procambarus sp.		2
3194	Upper New Channel Reach	Cab-2	2024-06-17	3	Palaemonetes sp.		4
3194	Upper New Channel Reach	Cab-2	2024-06-17	3	Herichthys cyanoguttatus		52
3194	Upper New Channel Reach	Cab-2	2024-06-17	4	Lepomis miniatus	65	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	4	Procambarus sp.		4
3194	Upper New Channel Reach	Cab-2	2024-06-17	4	Palaemonetes sp.		1
3194	Upper New Channel Reach	Cab-2	2024-06-17	4	Herichthys cyanoguttatus		44
3194	Upper New Channel Reach	Cab-2	2024-06-17	5	Procambarus sp.		3
3194	Upper New Channel Reach	Cab-2	2024-06-17	5	Lepomis miniatus	74	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	5	Lepomis miniatus	72	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	5	Herichthys cyanoguttatus		41
3194	Upper New Channel Reach	Cab-2	2024-06-17	6	Procambarus sp.		1
3194	Upper New Channel Reach	Cab-2	2024-06-17	6	Palaemonetes sp.		3
3194	Upper New Channel Reach	Cab-2	2024-06-17	6	Herichthys cyanoguttatus		20
3194	Upper New Channel Reach	Cab-2	2024-06-17	7	Procambarus sp.		1
3194	Upper New Channel Reach	Cab-2	2024-06-17	7	Palaemonetes sp.		1
3194	Upper New Channel Reach	Cab-2	2024-06-17	7	Herichthys cyanoguttatus		18
3194	Upper New Channel Reach	Cab-2	2024-06-17	8	Procambarus sp.		4
3194	Upper New Channel Reach	Cab-2	2024-06-17	8	Lepomis miniatus	73	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	8	Palaemonetes sp.		1
3194	Upper New Channel Reach	Cab-2	2024-06-17	8	Herichthys cyanoguttatus		13
3194	Upper New Channel Reach	Cab-2	2024-06-17	9	Lepomis gulosus	70	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	9	Procambarus sp.		2
3194	Upper New Channel Reach	Cab-2	2024-06-17	9	Lepomis sp.	15	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	9	Herichthys cyanoguttatus		5
3194	Upper New Channel Reach	Cab-2	2024-06-17	10	Procambarus sp.		1
3194	Upper New Channel Reach	Cab-2	2024-06-17	10	Herichthys cyanoguttatus		24
3194	Upper New Channel Reach	Cab-2	2024-06-17	11	Procambarus sp.		4

3194	Upper New Channel Reach	Cab-2	2024-06-17	11	Herichthys cyanoguttatus		8
3194	Upper New Channel Reach	Cab-2	2024-06-17	12	Procambarus sp.		1
3194	Upper New Channel Reach	Cab-2	2024-06-17	12	Palaemonetes sp.		1
3194	Upper New Channel Reach	Cab-2	2024-06-17	12	Herichthys cyanoguttatus		8
3194	Upper New Channel Reach	Cab-2	2024-06-17	13	Procambarus sp.		2
3194	Upper New Channel Reach	Cab-2	2024-06-17	13	Herichthys cyanoguttatus		11
3194	Upper New Channel Reach	Cab-2	2024-06-17	14	Herichthys cyanoguttatus		5
3194	Upper New Channel Reach	Cab-2	2024-06-17	15	Procambarus sp.		3
3194	Upper New Channel Reach	Cab-2	2024-06-17	15	Lepomis miniatus	75	1
3194	Upper New Channel Reach	Cab-2	2024-06-17	15	Herichthys cyanoguttatus		5
3195	Upper New Channel Reach	Hyg-2	2024-06-17	1	Herichthys cyanoguttatus	58	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	1	Herichthys cyanoguttatus	20	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	1	Procambarus sp.		2
3195	Upper New Channel Reach	Hyg-2	2024-06-17	1	Palaemonetes sp.		6
3195	Upper New Channel Reach	Hyg-2	2024-06-17	2	Procambarus sp.		3
3195	Upper New Channel Reach	Hyg-2	2024-06-17	2	Lepomis gulosus	61	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	2	Lepomis gulosus	74	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	2	Herichthys cyanoguttatus	64	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	2	Palaemonetes sp.		8
3195	Upper New Channel Reach	Hyg-2	2024-06-17	3	Procambarus sp.		4
3195	Upper New Channel Reach	Hyg-2	2024-06-17	3	Palaemonetes sp.		1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	4	Procambarus sp.		7
3195	Upper New Channel Reach	Hyg-2	2024-06-17	4	Lepomis gulosus	52	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	4	Lepomis miniatus	56	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	4	Palaemonetes sp.		3
3195	Upper New Channel Reach	Hyg-2	2024-06-17	5	Palaemonetes sp.		1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	5	Procambarus sp.		4
3195	Upper New Channel Reach	Hyg-2	2024-06-17	6	Procambarus sp.		2
3195	Upper New Channel Reach	Hyg-2	2024-06-17	6	Palaemonetes sp.		1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	7	Procambarus sp.		1

3195	Upper New Channel Reach	Hyg-2	2024-06-17	7	Palaemonetes sp.		2
3195	Upper New Channel Reach	Hyg-2	2024-06-17	7	Lepomis gulosus	82	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	7	Lepomis gulosus	78	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	8	Lepomis miniatus	56	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	9	Procambarus sp.		2
3195	Upper New Channel Reach	Hyg-2	2024-06-17	9	Palaemonetes sp.		1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	10	Procambarus sp.		1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	11	No fish collected		
3195	Upper New Channel Reach	Hyg-2	2024-06-17	12	Procambarus sp.		1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	13	Lepomis gulosus	87	1
3195	Upper New Channel Reach	Hyg-2	2024-06-17	13	Procambarus sp.		3
3195	Upper New Channel Reach	Hyg-2	2024-06-17	14	No fish collected		
3195	Upper New Channel Reach	Hyg-2	2024-06-17	15	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	1	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	2	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	3	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	4	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	5	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	6	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	7	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	8	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	9	No fish collected		
3196	Upper New Channel Reach	Open-2	2024-06-17	10	No fish collected		
3225	Upper Spring Run	Chara-1	2024-10-29	1	Astyanax mexicanus	19	1
3225	Upper Spring Run	Chara-1	2024-10-29	1	Astyanax mexicanus	15	1
3225	Upper Spring Run	Chara-1	2024-10-29	1	Lepomis sp.	20	1
3225	Upper Spring Run	Chara-1	2024-10-29	1	Lepomis sp.	14	1
3225	Upper Spring Run	Chara-1	2024-10-29	1	Lepomis sp.	10	1
3225	Upper Spring Run	Chara-1	2024-10-29	2	Herichthys cyanoguttatus	47	1
3225	Upper Spring Run	Chara-1	2024-10-29	3	Lepomis miniatus	103	1

3225	Upper Spring Run	Chara-1	2024-10-29	3	Etheostoma fonticola	25	1
3225	Upper Spring Run	Chara-1	2024-10-29	4	Etheostoma fonticola	32	1
3225	Upper Spring Run	Chara-1	2024-10-29	4	Lepomis sp.	19	1
3225	Upper Spring Run	Chara-1	2024-10-29	5	Lepomis sp.	20	1
3225	Upper Spring Run	Chara-1	2024-10-29	5	Lepomis miniatus	30	1
3225	Upper Spring Run	Chara-1	2024-10-29	6	Lepomis miniatus	105	1
3225	Upper Spring Run	Chara-1	2024-10-29	7	Lepomis miniatus	28	1
3225	Upper Spring Run	Chara-1	2024-10-29	8	No fish collected		
3225	Upper Spring Run	Chara-1	2024-10-29	9	No fish collected		
3225	Upper Spring Run	Chara-1	2024-10-29	10	No fish collected		
3225	Upper Spring Run	Chara-1	2024-10-29	11	No fish collected		
3225	Upper Spring Run	Chara-1	2024-10-29	12	No fish collected		
3225	Upper Spring Run	Chara-1	2024-10-29	13	Lepomis miniatus	98	1
3225	Upper Spring Run	Chara-1	2024-10-29	14	No fish collected		
3225	Upper Spring Run	Chara-1	2024-10-29	15	No fish collected		
3226	Upper Spring Run	Chara-2	2024-10-29	1	Astyanax mexicanus	19	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Palaemonetes sp.		2
3226	Upper Spring Run	Chara-2	2024-10-29	2	Astyanax mexicanus	15	1
3226	Upper Spring Run	Chara-2	2024-10-29	3	Procambarus sp.		1
3226	Upper Spring Run	Chara-2	2024-10-29	3	Astyanax mexicanus	15	1
3226	Upper Spring Run	Chara-2	2024-10-29	3	Astyanax mexicanus	20	1
3226	Upper Spring Run	Chara-2	2024-10-29	4	Palaemonetes sp.		1
3226	Upper Spring Run	Chara-2	2024-10-29	5	Palaemonetes sp.		1
3226	Upper Spring Run	Chara-2	2024-10-29	5	Astyanax mexicanus	22	1
3226	Upper Spring Run	Chara-2	2024-10-29	5	Astyanax mexicanus	22	1
3226	Upper Spring Run	Chara-2	2024-10-29	5	Astyanax mexicanus	11	1
3226	Upper Spring Run	Chara-2	2024-10-29	5	Astyanax mexicanus	10	1
3226	Upper Spring Run	Chara-2	2024-10-29	5	Astyanax mexicanus	18	1
3226	Upper Spring Run	Chara-2	2024-10-29	5	Lepomis sp.	30	1
3226	Upper Spring Run	Chara-2	2024-10-29	6	Astyanax mexicanus	16	1

3226	Upper Spring Run	Chara-2	2024-10-29	6	Astyanax mexicanus	20	1
3226	Upper Spring Run	Chara-2	2024-10-29	6	Dionda nigrotaeniata	22	1
3226	Upper Spring Run	Chara-2	2024-10-29	6	Palaemonetes sp.		1
3226	Upper Spring Run	Chara-2	2024-10-29	7	Palaemonetes sp.		1
3226	Upper Spring Run	Chara-2	2024-10-29	7	Etheostoma fonticola	28	1
3226	Upper Spring Run	Chara-2	2024-10-29	7	Lepomis sp.	10	1
3226	Upper Spring Run	Chara-2	2024-10-29	8	Astyanax mexicanus	10	1
3226	Upper Spring Run	Chara-2	2024-10-29	8	Palaemonetes sp.		1
3226	Upper Spring Run	Chara-2	2024-10-29	9	Lepomis sp.	20	1
3226	Upper Spring Run	Chara-2	2024-10-29	10	Lepomis miniatus	86	1
3226	Upper Spring Run	Chara-2	2024-10-29	10	Astyanax mexicanus	22	1
3226	Upper Spring Run	Chara-2	2024-10-29	10	Astyanax mexicanus		1
3226	Upper Spring Run	Chara-2	2024-10-29	10	Lepomis sp.	10	1
3226	Upper Spring Run	Chara-2	2024-10-29	10	Lepomis sp.	10	1
3226	Upper Spring Run	Chara-2	2024-10-29	10	Palaemonetes sp.		1
3226	Upper Spring Run	Chara-2	2024-10-29	11	Lepomis miniatus	54	1
3226	Upper Spring Run	Chara-2	2024-10-29	11	Astyanax mexicanus		1
3226	Upper Spring Run	Chara-2	2024-10-29	11	Palaemonetes sp.		1
3226	Upper Spring Run	Chara-2	2024-10-29	12	Etheostoma fonticola	35	1
3226	Upper Spring Run	Chara-2	2024-10-29	13	Astyanax mexicanus		1
3226	Upper Spring Run	Chara-2	2024-10-29	14	Lepomis sp.	7	1
3226	Upper Spring Run	Chara-2	2024-10-29	15	Palaemonetes sp.		1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Lepomis miniatus	25	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Lepomis sp.	20	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Lepomis sp.	10	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Lepomis sp.	20	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Lepomis sp.	19	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Astyanax mexicanus	14	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Astyanax mexicanus	25	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Astyanax mexicanus	22	1

3226	Upper Spring Run	Chara-2	2024-10-29	1	Astyanax mexicanus	18	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Astyanax mexicanus	28	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Astyanax mexicanus	22	1
3226	Upper Spring Run	Chara-2	2024-10-29	1	Astyanax mexicanus	20	1
3227	Upper Spring Run	Bryo-1	2024-10-29	1	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	2	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	3	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	4	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	5	Etheostoma fonticola	12	1
3227	Upper Spring Run	Bryo-1	2024-10-29	5	Lepomis sp.	8	1
3227	Upper Spring Run	Bryo-1	2024-10-29	6	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	7	Etheostoma fonticola	22	1
3227	Upper Spring Run	Bryo-1	2024-10-29	7	Lepomis sp.	18	1
3227	Upper Spring Run	Bryo-1	2024-10-29	8	Procambarus sp.		1
3227	Upper Spring Run	Bryo-1	2024-10-29	8	Etheostoma fonticola	18	1
3227	Upper Spring Run	Bryo-1	2024-10-29	9	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	10	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	11	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	12	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	13	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	14	No fish collected		
3227	Upper Spring Run	Bryo-1	2024-10-29	15	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	1	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	2	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	3	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	4	Etheostoma fonticola	20	1
3228	Upper Spring Run	Bryo-2	2024-10-29	5	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	6	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	7	Etheostoma fonticola	25	1
3228	Upper Spring Run	Bryo-2	2024-10-29	7	Etheostoma fonticola	18	1

3228	Upper Spring Run	Bryo-2	2024-10-29	8	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	9	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	10	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	11	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	12	Etheostoma fonticola	22	1
3228	Upper Spring Run	Bryo-2	2024-10-29	13	Etheostoma fonticola	30	1
3228	Upper Spring Run	Bryo-2	2024-10-29	14	No fish collected		
3228	Upper Spring Run	Bryo-2	2024-10-29	15	No fish collected		
3229	Upper Spring Run	Open-1	2024-10-29	1	No fish collected		
3229	Upper Spring Run	Open-1	2024-10-29	2	No fish collected		
3229	Upper Spring Run	Open-1	2024-10-29	3	Procambarus sp.		1
3229	Upper Spring Run	Open-1	2024-10-29	4	No fish collected		
3229	Upper Spring Run	Open-1	2024-10-29	5	No fish collected		
3229	Upper Spring Run	Open-1	2024-10-29	6	No fish collected		
3229	Upper Spring Run	Open-1	2024-10-29	7	No fish collected		
3229	Upper Spring Run	Open-1	2024-10-29	8	No fish collected		
3229	Upper Spring Run	Open-1	2024-10-29	9	No fish collected		
3229	Upper Spring Run	Open-1	2024-10-29	10	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	1	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	2	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	3	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	4	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	5	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	6	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	7	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	8	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	9	No fish collected		
3230	Upper Spring Run	Open-2	2024-10-29	10	No fish collected		
3231	Old Channel Reach	Bryo-1	2024-10-29	1	Lepomis miniatus	35	1
3231	Old Channel Reach	Bryo-1	2024-10-29	1	Palaemonetes sp.		9

3231	Old Channel Reach	Bryo-1	2024-10-29	1	Etheostoma fonticola	30	1
3231	Old Channel Reach	Bryo-1	2024-10-29	1	Etheostoma fonticola	9	1
3231	Old Channel Reach	Bryo-1	2024-10-29	2	Palaemonetes sp.		6
3231	Old Channel Reach	Bryo-1	2024-10-29	3	Palaemonetes sp.		6
3231	Old Channel Reach	Bryo-1	2024-10-29	4	Palaemonetes sp.		2
3231	Old Channel Reach	Bryo-1	2024-10-29	5	Palaemonetes sp.		1
3231	Old Channel Reach	Bryo-1	2024-10-29	6	No fish collected		
3231	Old Channel Reach	Bryo-1	2024-10-29	7	Palaemonetes sp.		5
3231	Old Channel Reach	Bryo-1	2024-10-29	7	Etheostoma fonticola	31	1
3231	Old Channel Reach	Bryo-1	2024-10-29	7	Etheostoma fonticola	32	1
3231	Old Channel Reach	Bryo-1	2024-10-29	8	Palaemonetes sp.		3
3231	Old Channel Reach	Bryo-1	2024-10-29	9	Lepomis miniatus	60	1
3231	Old Channel Reach	Bryo-1	2024-10-29	9	Etheostoma fonticola	28	1
3231	Old Channel Reach	Bryo-1	2024-10-29	10	Etheostoma fonticola	34	1
3231	Old Channel Reach	Bryo-1	2024-10-29	11	No fish collected		
3231	Old Channel Reach	Bryo-1	2024-10-29	12	No fish collected		
3231	Old Channel Reach	Bryo-1	2024-10-29	13	No fish collected		
3231	Old Channel Reach	Bryo-1	2024-10-29	14	No fish collected		
3231	Old Channel Reach	Bryo-1	2024-10-29	15	Palaemonetes sp.		1
3232	Old Channel Reach	Bryo-2	2024-10-29	1	Etheostoma fonticola	31	1
3232	Old Channel Reach	Bryo-2	2024-10-29	1	Etheostoma fonticola	9	1
3232	Old Channel Reach	Bryo-2	2024-10-29	1	Etheostoma fonticola	10	1
3232	Old Channel Reach	Bryo-2	2024-10-29	1	Etheostoma fonticola	12	1
3232	Old Channel Reach	Bryo-2	2024-10-29	1	Palaemonetes sp.		5
3232	Old Channel Reach	Bryo-2	2024-10-29	2	Procambarus sp.		1
3232	Old Channel Reach	Bryo-2	2024-10-29	2	Palaemonetes sp.		8
3232	Old Channel Reach	Bryo-2	2024-10-29	2	Lepomis miniatus	34	1
3232	Old Channel Reach	Bryo-2	2024-10-29	3	Ameiurus natalis	42	1
3232	Old Channel Reach	Bryo-2	2024-10-29	3	Palaemonetes sp.		3
3232	Old Channel Reach	Bryo-2	2024-10-29	3	Procambarus sp.		1

3232	Old Channel Reach	Bryo-2	2024-10-29	4	Palaemonetes sp.		2
3232	Old Channel Reach	Bryo-2	2024-10-29	4	Procambarus sp.		2
3232	Old Channel Reach	Bryo-2	2024-10-29	5	Procambarus sp.		3
3232	Old Channel Reach	Bryo-2	2024-10-29	6	No fish collected		
3232	Old Channel Reach	Bryo-2	2024-10-29	7	Herichthys cyanoguttatus	34	1
3232	Old Channel Reach	Bryo-2	2024-10-29	7	Procambarus sp.		5
3232	Old Channel Reach	Bryo-2	2024-10-29	8	Procambarus sp.		5
3232	Old Channel Reach	Bryo-2	2024-10-29	8	Palaemonetes sp.		1
3232	Old Channel Reach	Bryo-2	2024-10-29	9	Palaemonetes sp.		1
3232	Old Channel Reach	Bryo-2	2024-10-29	10	No fish collected		
3232	Old Channel Reach	Bryo-2	2024-10-29	11	Procambarus sp.		5
3232	Old Channel Reach	Bryo-2	2024-10-29	11	Ameiurus natalis	55	1
3232	Old Channel Reach	Bryo-2	2024-10-29	12	Procambarus sp.		1
3232	Old Channel Reach	Bryo-2	2024-10-29	13	No fish collected		
3232	Old Channel Reach	Bryo-2	2024-10-29	14	No fish collected		
3232	Old Channel Reach	Bryo-2	2024-10-29	15	No fish collected		
3232	Old Channel Reach	Bryo-2	2024-10-29				
3233	Old Channel Reach	Lud-1	2024-10-29	1	Palaemonetes sp.		1
3233	Old Channel Reach	Lud-1	2024-10-29	2	Etheostoma fonticola	25	1
3233	Old Channel Reach	Lud-1	2024-10-29	3	Lepomis miniatus	39	1
3233	Old Channel Reach	Lud-1	2024-10-29	4	Etheostoma fonticola	15	1
3233	Old Channel Reach	Lud-1	2024-10-29	5	Palaemonetes sp.		1
3233	Old Channel Reach	Lud-1	2024-10-29	5	Herichthys cyanoguttatus	38	1
3233	Old Channel Reach	Lud-1	2024-10-29	5	Herichthys cyanoguttatus	28	1
3233	Old Channel Reach	Lud-1	2024-10-29	6	No fish collected		
3233	Old Channel Reach	Lud-1	2024-10-29	7	No fish collected		
3233	Old Channel Reach	Lud-1	2024-10-29	8	No fish collected		
3233	Old Channel Reach	Lud-1	2024-10-29	9	Herichthys cyanoguttatus	40	1
3233	Old Channel Reach	Lud-1	2024-10-29	10	Etheostoma fonticola	15	1
3233	Old Channel Reach	Lud-1	2024-10-29	11	No fish collected		

3233	Old Channel Reach	Lud-1	2024-10-29	12	No fish collected		
3233	Old Channel Reach	Lud-1	2024-10-29	13	No fish collected		
3233	Old Channel Reach	Lud-1	2024-10-29	14	No fish collected		
3233	Old Channel Reach	Lud-1	2024-10-29	15	No fish collected		
3234	Old Channel Reach	Lud-2	2024-10-29	1	Herichthys cyanoguttatus	21	1
3234	Old Channel Reach	Lud-2	2024-10-29	1	Lepomis miniatus	43	1
3234	Old Channel Reach	Lud-2	2024-10-29	1	Palaemonetes sp.		17
3234	Old Channel Reach	Lud-2	2024-10-29	1	Procambarus sp.		4
3234	Old Channel Reach	Lud-2	2024-10-29	2	Procambarus sp.		3
3234	Old Channel Reach	Lud-2	2024-10-29	2	Lepomis miniatus	57	1
3234	Old Channel Reach	Lud-2	2024-10-29	2	Lepomis miniatus	42	1
3234	Old Channel Reach	Lud-2	2024-10-29	2	Etheostoma fonticola	30	1
3234	Old Channel Reach	Lud-2	2024-10-29	2	Palaemonetes sp.		4
3234	Old Channel Reach	Lud-2	2024-10-29	3	Procambarus sp.		1
3234	Old Channel Reach	Lud-2	2024-10-29	3	Palaemonetes sp.		8
3234	Old Channel Reach	Lud-2	2024-10-29	4	Procambarus sp.		1
3234	Old Channel Reach	Lud-2	2024-10-29	4	Palaemonetes sp.		6
3234	Old Channel Reach	Lud-2	2024-10-29	5	No fish collected		
3234	Old Channel Reach	Lud-2	2024-10-29	6	Palaemonetes sp.		1
3234	Old Channel Reach	Lud-2	2024-10-29	7	Palaemonetes sp.		1
3234	Old Channel Reach	Lud-2	2024-10-29	8	No fish collected		
3234	Old Channel Reach	Lud-2	2024-10-29	9	No fish collected		
3234	Old Channel Reach	Lud-2	2024-10-29	10	Etheostoma fonticola	35	1
3234	Old Channel Reach	Lud-2	2024-10-29	10	Palaemonetes sp.		2
3234	Old Channel Reach	Lud-2	2024-10-29	11	Palaemonetes sp.		1
3234	Old Channel Reach	Lud-2	2024-10-29	12	Lepomis miniatus	46	1
3234	Old Channel Reach	Lud-2	2024-10-29	12	Palaemonetes sp.		2
3234	Old Channel Reach	Lud-2	2024-10-29	12	Procambarus sp.		2
3234	Old Channel Reach	Lud-2	2024-10-29	13	Palaemonetes sp.		1
3234	Old Channel Reach	Lud-2	2024-10-29	14	Palaemonetes sp.		1

3234	Old Channel Reach	Lud-2	2024-10-29	15	No fish collected		
3234	Old Channel Reach	Lud-2	2024-10-29	1	Lepomis miniatus	55	1
3235	Old Channel Reach	Open-1	2024-10-29	1	No fish collected		
3235	Old Channel Reach	Open-1	2024-10-29	2	No fish collected		
3235	Old Channel Reach	Open-1	2024-10-29	3	No fish collected		
3235	Old Channel Reach	Open-1	2024-10-29	4	No fish collected		
3235	Old Channel Reach	Open-1	2024-10-29	5	No fish collected		
3235	Old Channel Reach	Open-1	2024-10-29	6	No fish collected		
3235	Old Channel Reach	Open-1	2024-10-29	7	No fish collected		
3235	Old Channel Reach	Open-1	2024-10-29	8	No fish collected		
3235	Old Channel Reach	Open-1	2024-10-29	9	No fish collected		
3235	Old Channel Reach	Open-1	2024-10-29	10	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	1	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	2	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	3	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	4	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	5	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	6	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	7	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	8	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	9	No fish collected		
3236	Old Channel Reach	Open-2	2024-10-29	10	No fish collected		
3237	Landa Lake	Val-1	2024-10-30	1	Procambarus sp.		1
3237	Landa Lake	Val-1	2024-10-30	1	Astyanax mexicanus	69	1
3237	Landa Lake	Val-1	2024-10-30	1	Astyanax mexicanus	68	1
3237	Landa Lake	Val-1	2024-10-30	1	Astyanax mexicanus	63	1
3237	Landa Lake	Val-1	2024-10-30	1	Astyanax mexicanus	71	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	36	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	20	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	20	1

3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	25	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	25	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	28	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	24	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	35	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	27	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	15	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	9	1
3237	Landa Lake	Val-1	2024-10-30	1	Gambusia sp.	14	1
3237	Landa Lake	Val-1	2024-10-30	2	Gambusia sp.	20	1
3237	Landa Lake	Val-1	2024-10-30	2	Gambusia sp.	25	1
3237	Landa Lake	Val-1	2024-10-30	2	Gambusia sp.	36	1
3237	Landa Lake	Val-1	2024-10-30	2	Gambusia sp.	25	1
3237	Landa Lake	Val-1	2024-10-30	2	Gambusia sp.	17	1
3237	Landa Lake	Val-1	2024-10-30	2	Gambusia sp.	25	1
3237	Landa Lake	Val-1	2024-10-30	3	Astyanax mexicanus	72	1
3237	Landa Lake	Val-1	2024-10-30	3	Gambusia sp.	22	1
3237	Landa Lake	Val-1	2024-10-30	3	Gambusia sp.	27	1
3237	Landa Lake	Val-1	2024-10-30	4	Gambusia sp.		4
3237	Landa Lake	Val-1	2024-10-30	5	No fish collected		
3237	Landa Lake	Val-1	2024-10-30	6	No fish collected		
3237	Landa Lake	Val-1	2024-10-30	7	No fish collected		
3237	Landa Lake	Val-1	2024-10-30	8	Astyanax mexicanus	64	1
3237	Landa Lake	Val-1	2024-10-30	9	No fish collected		
3237	Landa Lake	Val-1	2024-10-30	10	Procambarus sp.		1
3237	Landa Lake	Val-1	2024-10-30	11	No fish collected		
3237	Landa Lake	Val-1	2024-10-30	12	No fish collected		
3237	Landa Lake	Val-1	2024-10-30	13	No fish collected		
3237	Landa Lake	Val-1	2024-10-30	14	No fish collected		
3237	Landa Lake	Val-1	2024-10-30	15	Gambusia sp.		1

3238	Landa Lake	Val-2	2024-10-30	1	Dionda nigrotaeniata	65	1
3238	Landa Lake	Val-2	2024-10-30	2	Dionda nigrotaeniata	54	1
3238	Landa Lake	Val-2	2024-10-30	2	Procambarus sp.		1
3238	Landa Lake	Val-2	2024-10-30	3	Etheostoma fonticola	30	1
3238	Landa Lake	Val-2	2024-10-30	3	Etheostoma fonticola	32	1
3238	Landa Lake	Val-2	2024-10-30	3	Etheostoma fonticola	28	1
3238	Landa Lake	Val-2	2024-10-30	3	Procambarus sp.		1
3238	Landa Lake	Val-2	2024-10-30	4	Dionda nigrotaeniata	59	1
3238	Landa Lake	Val-2	2024-10-30	4	Dionda nigrotaeniata	60	1
3238	Landa Lake	Val-2	2024-10-30	5	No fish collected		
3238	Landa Lake	Val-2	2024-10-30	6	No fish collected		
3238	Landa Lake	Val-2	2024-10-30	7	No fish collected		
3238	Landa Lake	Val-2	2024-10-30	8	Dionda nigrotaeniata	61	1
3238	Landa Lake	Val-2	2024-10-30	8	Etheostoma fonticola	32	1
3238	Landa Lake	Val-2	2024-10-30	9	No fish collected		
3238	Landa Lake	Val-2	2024-10-30	10	Etheostoma fonticola	25	1
3238	Landa Lake	Val-2	2024-10-30	10	Etheostoma fonticola	25	1
3238	Landa Lake	Val-2	2024-10-30	10	Procambarus sp.		2
3238	Landa Lake	Val-2	2024-10-30	11	Procambarus sp.		1
3238	Landa Lake	Val-2	2024-10-30	12	No fish collected		
3238	Landa Lake	Val-2	2024-10-30	13	No fish collected		
3238	Landa Lake	Val-2	2024-10-30	14	No fish collected		
3238	Landa Lake	Val-2	2024-10-30	15	No fish collected		
3239	Landa Lake	Bryo-1	2024-10-30	1	Procambarus sp.		7
3239	Landa Lake	Bryo-1	2024-10-30	2	Etheostoma fonticola	30	1
3239	Landa Lake	Bryo-1	2024-10-30	2	Etheostoma fonticola	25	1
3239	Landa Lake	Bryo-1	2024-10-30	2	Etheostoma fonticola	25	1
3239	Landa Lake	Bryo-1	2024-10-30	2	Procambarus sp.		5
3239	Landa Lake	Bryo-1	2024-10-30	3	Etheostoma fonticola	27	1
3239	Landa Lake	Bryo-1	2024-10-30	3	Etheostoma fonticola	30	1

3239	Landa Lake	Bryo-1	2024-10-30	3	Etheostoma fonticola	32	1
3239	Landa Lake	Bryo-1	2024-10-30	4	No fish collected		
3239	Landa Lake	Bryo-1	2024-10-30	5	Etheostoma fonticola	31	1
3239	Landa Lake	Bryo-1	2024-10-30	5	Etheostoma fonticola	30	1
3239	Landa Lake	Bryo-1	2024-10-30	5	Etheostoma fonticola	32	1
3239	Landa Lake	Bryo-1	2024-10-30	5	Etheostoma fonticola	30	1
3239	Landa Lake	Bryo-1	2024-10-30	6	No fish collected		
3239	Landa Lake	Bryo-1	2024-10-30	7	Etheostoma fonticola	29	1
3239	Landa Lake	Bryo-1	2024-10-30	8	Etheostoma fonticola	35	1
3239	Landa Lake	Bryo-1	2024-10-30	8	Etheostoma fonticola	29	1
3239	Landa Lake	Bryo-1	2024-10-30	8	Procambarus sp.		1
3239	Landa Lake	Bryo-1	2024-10-30	9	No fish collected		
3239	Landa Lake	Bryo-1	2024-10-30	10	No fish collected		
3239	Landa Lake	Bryo-1	2024-10-30	11	No fish collected		
3239	Landa Lake	Bryo-1	2024-10-30	12	No fish collected		
3239	Landa Lake	Bryo-1	2024-10-30	13	No fish collected		
3239	Landa Lake	Bryo-1	2024-10-30	14	No fish collected		
3239	Landa Lake	Bryo-1	2024-10-30	15	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	1	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	2	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	3	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	4	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	5	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	6	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	7	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	8	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	9	No fish collected		
3240	Landa Lake	Open-1	2024-10-30	10	No fish collected		
3241	Landa Lake	Open-2	2024-10-30	1	No fish collected		
3241	Landa Lake	Open-2	2024-10-30	2	No fish collected		

3241	Landa Lake	Open-2	2024-10-30	3	No fish collected		
3241	Landa Lake	Open-2	2024-10-30	4	No fish collected		
3241	Landa Lake	Open-2	2024-10-30	5	No fish collected		
3241	Landa Lake	Open-2	2024-10-30	6	No fish collected		
3241	Landa Lake	Open-2	2024-10-30	7	No fish collected		
3241	Landa Lake	Open-2	2024-10-30	8	No fish collected		
3241	Landa Lake	Open-2	2024-10-30	9	No fish collected		
3241	Landa Lake	Open-2	2024-10-30	10	No fish collected		
3242	Landa Lake	Bryo-2	2024-10-30	2	Palaemonetes sp.		4
3242	Landa Lake	Bryo-2	2024-10-30	3	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	3	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	3	Etheostoma fonticola	9	1
3242	Landa Lake	Bryo-2	2024-10-30	3	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	4	Palaemonetes sp.		1
3242	Landa Lake	Bryo-2	2024-10-30	4	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	4	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	4	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	5	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	5	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	5	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	5	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	6	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	6	Etheostoma fonticola	9	1
3242	Landa Lake	Bryo-2	2024-10-30	6	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	14	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	29	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	15	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	25	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	19	1

3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	18	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Etheostoma fonticola	10	1
3242	Landa Lake	Bryo-2	2024-10-30	7	Procambarus sp.		1
3242	Landa Lake	Bryo-2	2024-10-30	8	Etheostoma fonticola	25	1
3242	Landa Lake	Bryo-2	2024-10-30	8	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	8	Etheostoma fonticola	15	1
3242	Landa Lake	Bryo-2	2024-10-30	8	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	8	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	8	Etheostoma fonticola	8	1
3242	Landa Lake	Bryo-2	2024-10-30	8	Etheostoma fonticola	9	1
3242	Landa Lake	Bryo-2	2024-10-30	8	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	8	Dionda nigrotaeniata	15	1
3242	Landa Lake	Bryo-2	2024-10-30	9	Etheostoma fonticola	10	1
3242	Landa Lake	Bryo-2	2024-10-30	9	Etheostoma fonticola	9	1
3242	Landa Lake	Bryo-2	2024-10-30	9	Etheostoma fonticola	15	1
3242	Landa Lake	Bryo-2	2024-10-30	9	Etheostoma fonticola	10	1
3242	Landa Lake	Bryo-2	2024-10-30	9	Procambarus sp.		1
3242	Landa Lake	Bryo-2	2024-10-30	10	Etheostoma fonticola	15	1
3242	Landa Lake	Bryo-2	2024-10-30	10	Etheostoma fonticola	15	1
3242	Landa Lake	Bryo-2	2024-10-30	11	Etheostoma fonticola	34	1
3242	Landa Lake	Bryo-2	2024-10-30	11	Etheostoma fonticola	10	1
3242	Landa Lake	Bryo-2	2024-10-30	11	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	11	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	11	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	12	Procambarus sp.		1
3242	Landa Lake	Bryo-2	2024-10-30	12	Etheostoma fonticola	33	1
3242	Landa Lake	Bryo-2	2024-10-30	12	Etheostoma fonticola	23	1
3242	Landa Lake	Bryo-2	2024-10-30	12	Etheostoma fonticola	11	1

3242	Landa Lake	Bryo-2	2024-10-30	12	Etheostoma fonticola	15	1
3242	Landa Lake	Bryo-2	2024-10-30	12	Etheostoma fonticola	14	1
3242	Landa Lake	Bryo-2	2024-10-30	12	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	13	Etheostoma fonticola	7	1
3242	Landa Lake	Bryo-2	2024-10-30	14	Etheostoma fonticola	10	1
3242	Landa Lake	Bryo-2	2024-10-30	15	No fish collected		
3242	Landa Lake	Bryo-2	2024-10-30	1	Procambarus sp.		4
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	22	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	32	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	22	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	29	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	14	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	10	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Etheostoma fonticola	9	1
3242	Landa Lake	Bryo-2	2024-10-30	1	Palaemonetes sp.		3
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	30	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	32	1

3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	9	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	10	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	30	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	15	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	14	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	12	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	10	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	13	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	11	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	10	1
3242	Landa Lake	Bryo-2	2024-10-30	2	Etheostoma fonticola	12	1
3221	Upper Spring Run	Sag-1	2024-10-29	1	No fish collected		
3221	Upper Spring Run	Sag-1	2024-10-29	2	Micropterus salmoides	111	1
3221	Upper Spring Run	Sag-1	2024-10-29	3	Lepomis miniatus	72	1
3221	Upper Spring Run	Sag-1	2024-10-29	4	No fish collected		
3221	Upper Spring Run	Sag-1	2024-10-29	5	Procambarus sp.		1
3221	Upper Spring Run	Sag-1	2024-10-29	6	No fish collected		
3221	Upper Spring Run	Sag-1	2024-10-29	7	Lepomis miniatus	55	1
3221	Upper Spring Run	Sag-1	2024-10-29	7	Lepomis miniatus	65	1
3221	Upper Spring Run	Sag-1	2024-10-29	8	No fish collected		
3221	Upper Spring Run	Sag-1	2024-10-29	9	Lepomis miniatus	56	1
3221	Upper Spring Run	Sag-1	2024-10-29	10	No fish collected		
3221	Upper Spring Run	Sag-1	2024-10-29	11	Procambarus sp.		1
3221	Upper Spring Run	Sag-1	2024-10-29	12	No fish collected		
3221	Upper Spring Run	Sag-1	2024-10-29	13	No fish collected		
3221	Upper Spring Run	Sag-1	2024-10-29	14	No fish collected		
3221	Upper Spring Run	Sag-1	2024-10-29	15	Procambarus sp.		1
3243	Landa Lake	Sag-1	2024-10-30	1	No fish collected		

3243	Landa Lake	Sag-1	2024-10-30	2	Procambarus sp.		1
3243	Landa Lake	Sag-1	2024-10-30	2	Lepomis miniatus	27	1
3243	Landa Lake	Sag-1	2024-10-30	3	Lepomis miniatus	46	1
3243	Landa Lake	Sag-1	2024-10-30	3	Procambarus sp.		2
3243	Landa Lake	Sag-1	2024-10-30	3	Etheostoma fonticola	34	1
3243	Landa Lake	Sag-1	2024-10-30	3	Etheostoma fonticola	28	1
3243	Landa Lake	Sag-1	2024-10-30	4	Procambarus sp.		1
3243	Landa Lake	Sag-1	2024-10-30	5	Palaemonetes sp.		2
3243	Landa Lake	Sag-1	2024-10-30	6	Procambarus sp.		1
3243	Landa Lake	Sag-1	2024-10-30	7	Procambarus sp.		1
3243	Landa Lake	Sag-1	2024-10-30	7	Etheostoma fonticola	18	1
3243	Landa Lake	Sag-1	2024-10-30	8	Procambarus sp.		1
3243	Landa Lake	Sag-1	2024-10-30	9	Dionda nigrotaeniata	55	1
3243	Landa Lake	Sag-1	2024-10-30	10	Procambarus sp.		1
3243	Landa Lake	Sag-1	2024-10-30	11	No fish collected		
3243	Landa Lake	Sag-1	2024-10-30	12	Herichthys cyanoguttatus	44	1
3243	Landa Lake	Sag-1	2024-10-30	13	Procambarus sp.		1
3243	Landa Lake	Sag-1	2024-10-30	14	Procambarus sp.		1
3243	Landa Lake	Sag-1	2024-10-30	15	Ameiurus natalis	113	1
3243	Landa Lake	Sag-1	2024-10-30	15	Procambarus sp.		1
3244	Landa Lake	Sag-2	2024-10-30	1	Lepomis miniatus	125	1
3244	Landa Lake	Sag-2	2024-10-30	1	Procambarus sp.		1
3244	Landa Lake	Sag-2	2024-10-30	2	Procambarus sp.		3
3244	Landa Lake	Sag-2	2024-10-30	3	Procambarus sp.		1
3244	Landa Lake	Sag-2	2024-10-30	4	No fish collected		
3244	Landa Lake	Sag-2	2024-10-30	5	Procambarus sp.		1
3244	Landa Lake	Sag-2	2024-10-30	6	Herichthys cyanoguttatus	24	1
3244	Landa Lake	Sag-2	2024-10-30	6	Procambarus sp.		1
3244	Landa Lake	Sag-2	2024-10-30	6	Ameiurus natalis	63	1
3244	Landa Lake	Sag-2	2024-10-30	7	Procambarus sp.		2

3244	Landa Lake	Sag-2	2024-10-30	8	No fish collected		
3244	Landa Lake	Sag-2	2024-10-30	9	Procambarus sp.		1
3244	Landa Lake	Sag-2	2024-10-30	10	Procambarus sp.		1
3244	Landa Lake	Sag-2	2024-10-30	11	Procambarus sp.		3
3244	Landa Lake	Sag-2	2024-10-30	12	No fish collected		
3244	Landa Lake	Sag-2	2024-10-30	13	Procambarus sp.		1
3244	Landa Lake	Sag-2	2024-10-30	14	No fish collected		
3244	Landa Lake	Sag-2	2024-10-30	15	Procambarus sp.		1
3245	Landa Lake	Lud-1	2024-10-30	1	Procambarus sp.		4
3245	Landa Lake	Lud-1	2024-10-30	2	No fish collected		
3245	Landa Lake	Lud-1	2024-10-30	3	Procambarus sp.		2
3245	Landa Lake	Lud-1	2024-10-30	4	Etheostoma fonticola	27	1
3245	Landa Lake	Lud-1	2024-10-30	4	Etheostoma fonticola	26	1
3245	Landa Lake	Lud-1	2024-10-30	4	Etheostoma fonticola	31	1
3245	Landa Lake	Lud-1	2024-10-30	4	Etheostoma fonticola	31	1
3245	Landa Lake	Lud-1	2024-10-30	4	Dionda nigrotaeniata	31	1
3245	Landa Lake	Lud-1	2024-10-30	5	Etheostoma fonticola	31	1
3245	Landa Lake	Lud-1	2024-10-30	5	Etheostoma fonticola	24	1
3245	Landa Lake	Lud-1	2024-10-30	5	Etheostoma fonticola	28	1
3245	Landa Lake	Lud-1	2024-10-30	5	Lepomis sp.	11	1
3245	Landa Lake	Lud-1	2024-10-30	6	No fish collected		
3245	Landa Lake	Lud-1	2024-10-30	7	Palaemonetes sp.		1
3245	Landa Lake	Lud-1	2024-10-30	8	Lepomis miniatus	65	1
3245	Landa Lake	Lud-1	2024-10-30	8	Dionda nigrotaeniata	62	1
3245	Landa Lake	Lud-1	2024-10-30	8	Etheostoma fonticola	25	1
3245	Landa Lake	Lud-1	2024-10-30	9	Procambarus sp.		2
3245	Landa Lake	Lud-1	2024-10-30	10	No fish collected		
3245	Landa Lake	Lud-1	2024-10-30	11	Procambarus sp.		1
3245	Landa Lake	Lud-1	2024-10-30	12	No fish collected		
3245	Landa Lake	Lud-1	2024-10-30	13	No fish collected		

3245	Landa Lake	Lud-1	2024-10-30	14	Palaemonetes sp.		1
3245	Landa Lake	Lud-1	2024-10-30	15	No fish collected		
3246	Landa Lake	Cab-1	2024-10-30	1	Etheostoma fonticola	33	1
3246	Landa Lake	Cab-1	2024-10-30	1	Procambarus sp.		1
3246	Landa Lake	Cab-1	2024-10-30	1	Palaemonetes sp.		2
3246	Landa Lake	Cab-1	2024-10-30	2	Procambarus sp.		2
3246	Landa Lake	Cab-1	2024-10-30	2	Palaemonetes sp.		1
3246	Landa Lake	Cab-1	2024-10-30	2	Etheostoma fonticola	30	1
3246	Landa Lake	Cab-1	2024-10-30	2	Etheostoma fonticola	33	1
3246	Landa Lake	Cab-1	2024-10-30	3	Procambarus sp.		1
3246	Landa Lake	Cab-1	2024-10-30	3	Etheostoma fonticola	33	1
3246	Landa Lake	Cab-1	2024-10-30	3	Etheostoma fonticola	28	1
3246	Landa Lake	Cab-1	2024-10-30	3	Etheostoma fonticola	28	1
3246	Landa Lake	Cab-1	2024-10-30	3	Etheostoma fonticola	30	1
3246	Landa Lake	Cab-1	2024-10-30	3	Lepomis miniatus	77	1
3246	Landa Lake	Cab-1	2024-10-30	3	Palaemonetes sp.		1
3246	Landa Lake	Cab-1	2024-10-30	3	Lepomis sp.	15	1
3246	Landa Lake	Cab-1	2024-10-30	4	No fish collected		
3246	Landa Lake	Cab-1	2024-10-30	5	Palaemonetes sp.		1
3246	Landa Lake	Cab-1	2024-10-30	6	No fish collected		
3246	Landa Lake	Cab-1	2024-10-30	7	Etheostoma fonticola	20	1
3246	Landa Lake	Cab-1	2024-10-30	8	No fish collected		
3246	Landa Lake	Cab-1	2024-10-30	9	Astyanax mexicanus	14	1
3246	Landa Lake	Cab-1	2024-10-30	10	No fish collected		
3246	Landa Lake	Cab-1	2024-10-30	11	No fish collected		
3246	Landa Lake	Cab-1	2024-10-30	12	Procambarus sp.		1
3246	Landa Lake	Cab-1	2024-10-30	13	No fish collected		
3246	Landa Lake	Cab-1	2024-10-30	14	No fish collected		
3246	Landa Lake	Cab-1	2024-10-30	15	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	1	Lepomis miniatus	87	1

3247	Landa Lake	Cab-2	2024-10-30	1	Etheostoma fonticola	30	1
3247	Landa Lake	Cab-2	2024-10-30	1	Etheostoma fonticola	34	1
3247	Landa Lake	Cab-2	2024-10-30	1	Etheostoma fonticola	27	1
3247	Landa Lake	Cab-2	2024-10-30	1	Palaemonetes sp.		6
3247	Landa Lake	Cab-2	2024-10-30	1	Procambarus sp.		1
3247	Landa Lake	Cab-2	2024-10-30	2	Procambarus sp.		1
3247	Landa Lake	Cab-2	2024-10-30	3	Lepomis miniatus	35	1
3247	Landa Lake	Cab-2	2024-10-30	3	Palaemonetes sp.		2
3247	Landa Lake	Cab-2	2024-10-30	4	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	5	Lepomis miniatus	48	1
3247	Landa Lake	Cab-2	2024-10-30	5	Etheostoma fonticola	32	1
3247	Landa Lake	Cab-2	2024-10-30	6	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	7	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	8	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	9	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	10	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	11	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	12	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	13	No fish collected		
3247	Landa Lake	Cab-2	2024-10-30	14	Palaemonetes sp.		1
3247	Landa Lake	Cab-2	2024-10-30	15	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	1	Lepomis miniatus	30	1
3248	Landa Lake	Lud-2	2024-10-30	1	Lepomis sp.	12	1
3248	Landa Lake	Lud-2	2024-10-30	1	Palaemonetes sp.		1
3248	Landa Lake	Lud-2	2024-10-30	2	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	2	Etheostoma fonticola	32	1
3248	Landa Lake	Lud-2	2024-10-30	3	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	3	Etheostoma fonticola	14	1
3248	Landa Lake	Lud-2	2024-10-30	4	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	4	Etheostoma fonticola	29	1

3248	Landa Lake	Lud-2	2024-10-30	4	Etheostoma fonticola	31	1
3248	Landa Lake	Lud-2	2024-10-30	4	Palaemonetes sp.		1
3248	Landa Lake	Lud-2	2024-10-30	5	Micropterus salmoides	50	1
3248	Landa Lake	Lud-2	2024-10-30	6	Procambarus sp.		2
3248	Landa Lake	Lud-2	2024-10-30	6	Etheostoma fonticola	30	1
3248	Landa Lake	Lud-2	2024-10-30	7	Dionda nigrotaeniata	54	1
3248	Landa Lake	Lud-2	2024-10-30	7	Etheostoma fonticola	32	1
3248	Landa Lake	Lud-2	2024-10-30	7	Ameiurus natalis	14	1
3248	Landa Lake	Lud-2	2024-10-30	7	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	8	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	9	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	10	Procambarus sp.		2
3248	Landa Lake	Lud-2	2024-10-30	11	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	12	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	12	Lepomis miniatus	30	1
3248	Landa Lake	Lud-2	2024-10-30	13	Procambarus sp.		1
3248	Landa Lake	Lud-2	2024-10-30	13	Etheostoma fonticola	29	1
3248	Landa Lake	Lud-2	2024-10-30	14	Procambarus sp.		2
3248	Landa Lake	Lud-2	2024-10-30	14	Etheostoma fonticola	31	1
3248	Landa Lake	Lud-2	2024-10-30	15	Procambarus sp.		2
3248	Landa Lake	Lud-2	2024-10-30	15	Etheostoma fonticola	28	1
3248	Landa Lake	Lud-2	2024-10-30	16	Etheostoma fonticola	31	1
3248	Landa Lake	Lud-2	2024-10-30	17	No fish collected		
3249	Upper New Channel Reach	Open-1	2024-10-31	1	No fish collected		
3249	Upper New Channel Reach	Open-1	2024-10-31	2	No fish collected		
3249	Upper New Channel Reach	Open-1	2024-10-31	3	No fish collected		
3249	Upper New Channel Reach	Open-1	2024-10-31	4	No fish collected		
3249	Upper New Channel Reach	Open-1	2024-10-31	5	No fish collected		
3249	Upper New Channel Reach	Open-1	2024-10-31	6	No fish collected		
3249	Upper New Channel Reach	Open-1	2024-10-31	7	No fish collected		

3249	Upper New Channel Reach	Open-1	2024-10-31	8	No fish collected		
3249	Upper New Channel Reach	Open-1	2024-10-31	9	No fish collected		
3249	Upper New Channel Reach	Open-1	2024-10-31	10	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	1	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	2	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	3	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	4	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	5	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	6	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	7	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	8	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	9	No fish collected		
3250	Upper New Channel Reach	Open-2	2024-10-31	10	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	1	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	2	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	3	Lepomis miniatus	59	1
3222	Upper Spring Run	Sag-2	2024-10-29	4	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	5	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	6	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	7	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	8	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	9	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	10	Procambarus sp.		1
3222	Upper Spring Run	Sag-2	2024-10-29	11	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	12	No fish collected		
3222	Upper Spring Run	Sag-2	2024-10-29	13	No fish collected		
3223	Upper Spring Run	Cab-1	2024-10-29	1	No fish collected		
3223	Upper Spring Run	Cab-1	2024-10-29	2	Procambarus sp.		1
3223	Upper Spring Run	Cab-1	2024-10-29	3	Etheostoma lepidum	61	1
3223	Upper Spring Run	Cab-1	2024-10-29	3	Herichthys cyanoguttatus	45	1

3223	Upper Spring Run	Cab-1	2024-10-29	3	Palaemonetes sp.		1
3223	Upper Spring Run	Cab-1	2024-10-29	4	Procambarus sp.		1
3223	Upper Spring Run	Cab-1	2024-10-29	5	Lepomis sp.	16	1
3223	Upper Spring Run	Cab-1	2024-10-29	5	Lepomis sp.	18	1
3223	Upper Spring Run	Cab-1	2024-10-29	5	Lepomis sp.	11	1
3223	Upper Spring Run	Cab-1	2024-10-29	5	Procambarus sp.		1
3223	Upper Spring Run	Cab-1	2024-10-29	6	No fish collected		
3223	Upper Spring Run	Cab-1	2024-10-29	7	No fish collected		
3223	Upper Spring Run	Cab-1	2024-10-29	8	Lepomis miniatus	28	1
3223	Upper Spring Run	Cab-1	2024-10-29	9	Lepomis miniatus	66	1
3223	Upper Spring Run	Cab-1	2024-10-29	10	Etheostoma lepidum	38	1
3223	Upper Spring Run	Cab-1	2024-10-29	10	Procambarus sp.		1
3223	Upper Spring Run	Cab-1	2024-10-29	11	Lepomis miniatus	79	1
3223	Upper Spring Run	Cab-1	2024-10-29	12	Procambarus sp.		1
3223	Upper Spring Run	Cab-1	2024-10-29	13	No fish collected		
3223	Upper Spring Run	Cab-1	2024-10-29	14	No fish collected		
3223	Upper Spring Run	Cab-1	2024-10-29	15	Procambarus sp.		1
3224	Upper Spring Run	Cab-2	2024-10-29	1	Lepomis miniatus	104	1
3224	Upper Spring Run	Cab-2	2024-10-29	1	Astyanax mexicanus	42	1
3224	Upper Spring Run	Cab-2	2024-10-29	2	Procambarus sp.		1
3224	Upper Spring Run	Cab-2	2024-10-29	2	Micropterus salmoides	70	1
3224	Upper Spring Run	Cab-2	2024-10-29	3	Herichthys cyanoguttatus	130	1
3224	Upper Spring Run	Cab-2	2024-10-29	3	Astyanax mexicanus	35	1
3224	Upper Spring Run	Cab-2	2024-10-29	3	Procambarus sp.		1
3224	Upper Spring Run	Cab-2	2024-10-29	4	No fish collected		
3224	Upper Spring Run	Cab-2	2024-10-29	5	Lepomis miniatus	110	1
3224	Upper Spring Run	Cab-2	2024-10-29	5	Lepomis sp.	15	1
3224	Upper Spring Run	Cab-2	2024-10-29	6	Lepomis sp.	11	1
3224	Upper Spring Run	Cab-2	2024-10-29	7	Lepomis miniatus	59	1
3224	Upper Spring Run	Cab-2	2024-10-29	8	Micropterus salmoides	57	1

3224	Upper Spring Run	Cab-2	2024-10-29	9	Lepomis miniatus	71	1
3224	Upper Spring Run	Cab-2	2024-10-29	9	Lepomis miniatus	95	1
3224	Upper Spring Run	Cab-2	2024-10-29	9	Lepomis sp.	10	1
3224	Upper Spring Run	Cab-2	2024-10-29	9	Procambarus sp.		2
3224	Upper Spring Run	Cab-2	2024-10-29	10	No fish collected		
3224	Upper Spring Run	Cab-2	2024-10-29	11	No fish collected		
3224	Upper Spring Run	Cab-2	2024-10-29	12	No fish collected		
3224	Upper Spring Run	Cab-2	2024-10-29	13	No fish collected		
3224	Upper Spring Run	Cab-2	2024-10-29	14	No fish collected		
3224	Upper Spring Run	Cab-2	2024-10-29	15	No fish collected		
3251	Upper New Channel Reach	Hyg-1	2024-10-31	1	Lepomis miniatus	72	1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	1	Palaemonetes sp.		2
3251	Upper New Channel Reach	Hyg-1	2024-10-31	1	Gambusia sp.	24	1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	1	Gambusia sp.	25	1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	2	Astyanax mexicanus	70	1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	3	Palaemonetes sp.		1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	4	Procambarus sp.		1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	4	Palaemonetes sp.		1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	5	Astyanax mexicanus	41	1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	6	Lepomis cyanellus	75	1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	7	Palaemonetes sp.		1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	8	Palaemonetes sp.		1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	9	No fish collected		
3251	Upper New Channel Reach	Hyg-1	2024-10-31	10	Lepomis sp.	18	1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	11	Lepomis miniatus	50	1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	12	No fish collected		
3251	Upper New Channel Reach	Hyg-1	2024-10-31	13	No fish collected		
3251	Upper New Channel Reach	Hyg-1	2024-10-31	14	Palaemonetes sp.		1
3251	Upper New Channel Reach	Hyg-1	2024-10-31	15	Lepomis cyanellus		75
3252	Upper New Channel Reach	Hyg-2	2024-10-31	1	Palaemonetes sp.		1

3252	Upper New Channel Reach	Hyg-2	2024-10-31	2	No fish collected		
3252	Upper New Channel Reach	Hyg-2	2024-10-31	3	No fish collected		
3252	Upper New Channel Reach	Hyg-2	2024-10-31	4	Procambarus sp.		1
3252	Upper New Channel Reach	Hyg-2	2024-10-31	4	Herichthys cyanoguttatus	38	1
3252	Upper New Channel Reach	Hyg-2	2024-10-31	5	No fish collected		
3252	Upper New Channel Reach	Hyg-2	2024-10-31	6	No fish collected		
3252	Upper New Channel Reach	Hyg-2	2024-10-31	7	Procambarus sp.		1
3252	Upper New Channel Reach	Hyg-2	2024-10-31	8	Procambarus sp.		1
3252	Upper New Channel Reach	Hyg-2	2024-10-31	9	No fish collected		
3252	Upper New Channel Reach	Hyg-2	2024-10-31	10	No fish collected		
3252	Upper New Channel Reach	Hyg-2	2024-10-31	11	No fish collected		
3252	Upper New Channel Reach	Hyg-2	2024-10-31	12	Procambarus sp.		1
3252	Upper New Channel Reach	Hyg-2	2024-10-31	13	No fish collected		
3252	Upper New Channel Reach	Hyg-2	2024-10-31	14	No fish collected		
3252	Upper New Channel Reach	Hyg-2	2024-10-31	15	Procambarus sp.		1
3253	Upper New Channel Reach	Cab-1	2024-10-31	1	Lepomis miniatus	72	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	1	Poecilia latipinna	66	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	2	Lepomis miniatus	100	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	2	Lepomis gulosus	74	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	2	Herichthys cyanoguttatus	45	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	3	Lepomis miniatus	85	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	3	Lepomis miniatus	84	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	3	Lepomis miniatus	25	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	4	No fish collected		
3253	Upper New Channel Reach	Cab-1	2024-10-31	5	Lepomis cyanellus	80	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	6	Gambusia sp.	16	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	6	Lepomis miniatus	88	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	6	Procambarus sp.		1
3253	Upper New Channel Reach	Cab-1	2024-10-31	7	No fish collected		
3253	Upper New Channel Reach	Cab-1	2024-10-31	8	Procambarus sp.		2

3253	Upper New Channel Reach	Cab-1	2024-10-31	9	Herichthys cyanoguttatus	30	1
3253	Upper New Channel Reach	Cab-1	2024-10-31	10	No fish collected		
3253	Upper New Channel Reach	Cab-1	2024-10-31	11	No fish collected		
3253	Upper New Channel Reach	Cab-1	2024-10-31	12	Procambarus sp.		1
3253	Upper New Channel Reach	Cab-1	2024-10-31	13	No fish collected		
3253	Upper New Channel Reach	Cab-1	2024-10-31	14	No fish collected		
3253	Upper New Channel Reach	Cab-1	2024-10-31	15	No fish collected		
3254	Upper New Channel Reach	Cab-2	2024-10-31	1	Procambarus sp.		1
3254	Upper New Channel Reach	Cab-2	2024-10-31	2	Procambarus sp.		1
3254	Upper New Channel Reach	Cab-2	2024-10-31	3	Procambarus sp.		1
3254	Upper New Channel Reach	Cab-2	2024-10-31	3	Dionda nigrotaeniata	25	1
3254	Upper New Channel Reach	Cab-2	2024-10-31	3	Gambusia sp.	19	1
3254	Upper New Channel Reach	Cab-2	2024-10-31	4	No fish collected		
3254	Upper New Channel Reach	Cab-2	2024-10-31	5	Lepomis sp.	21	1
3254	Upper New Channel Reach	Cab-2	2024-10-31	6	No fish collected		
3254	Upper New Channel Reach	Cab-2	2024-10-31	7	No fish collected		
3254	Upper New Channel Reach	Cab-2	2024-10-31	8	Lepomis miniatus	30	1
3254	Upper New Channel Reach	Cab-2	2024-10-31	9	Lepomis gulosus	78	1
3254	Upper New Channel Reach	Cab-2	2024-10-31	10	Procambarus sp.		1
3254	Upper New Channel Reach	Cab-2	2024-10-31	11	Lepomis cyanellus	52	1
3254	Upper New Channel Reach	Cab-2	2024-10-31	12	No fish collected		
3254	Upper New Channel Reach	Cab-2	2024-10-31	13	No fish collected		
3254	Upper New Channel Reach	Cab-2	2024-10-31	14	No fish collected		
3254	Upper New Channel Reach	Cab-2	2024-10-31	15	No fish collected		

APPENDIX H: FOUNTAIN DARTER HABITAT SUITABILITY ANALYTICAL FRAMEWORK

OBJECTIVES

The goal of this analysis was to develop an index to quantify Fountain Darter habitat suitability within biological monitoring study reaches based on aquatic vegetation composition. Specific objectives included: (1) build Habitat Suitability Criteria (HSC) for each vegetation taxa; (2) use HSC to calculate an Overall Habitat Suitability Index (OHSI) based on vegetation community composition mapped at a given study reach during each monitoring event; (3) evaluate the efficacy of OHSI as a measure of Fountain Darter habitat suitability by testing whether Fountain Darter occurrence can be predicted based on OHSI.

METHODS

Habitat Suitability Criteria

HSC are a form of resource selection function (RSF) defined as any function that is proportional to the probability of use by an organism (Manly et al. 1993). HSC were built separately for the Comal and San Marcos river/springs systems using logistic regression based on random-station dip-net data and drop-net data converted to presence/absence. Logistic regression is a form of classification model that uses presence/absence data to predict probabilities based on a set of covariates (Hastie et al. 2009). The response variable for this analysis, probability of darter occurrence, was used to quantify criteria for each vegetation type, ranging from 0 (i.e., not suitable) to 1 (i.e., most suitable) (Figure H1).

OHSI Calculation

To calculate the OHSI for each monitoring event, HSC values for each vegetation strata were first multiplied by the areal coverage of that vegetation strata, and these values were summed across all vegetation strata within each study reach, to generate a Weighted Usable Area (WUA) of vegetation only as follows:

Eq. 1
$$WUA = \sum_{i=1}^{N} (A_i \ x \ HSC_i)$$

where N is the total number of vegetation types, A_i is the areal coverage of a single vegetation type, and HSC_i is the habitat suitability criteria of that single vegetation type (Yao & Bamal 2014).

This WUA was then divided by the total wetted area within the reach to generate OHSI, as follows:

Eq. 2
$$OHSI = \frac{WUA}{\sum_{i=1}^{N} (A_i)}$$

In this way, OHSI can also be thought of as the proportion of weighted usable area (Yao & Bamal 2014), ranging from 0 (unsuitable overall habitat) to 1 (most suitable overall habitat). Standardizing by reach size allows for a comparison of habitat quality between reaches of different sizes.

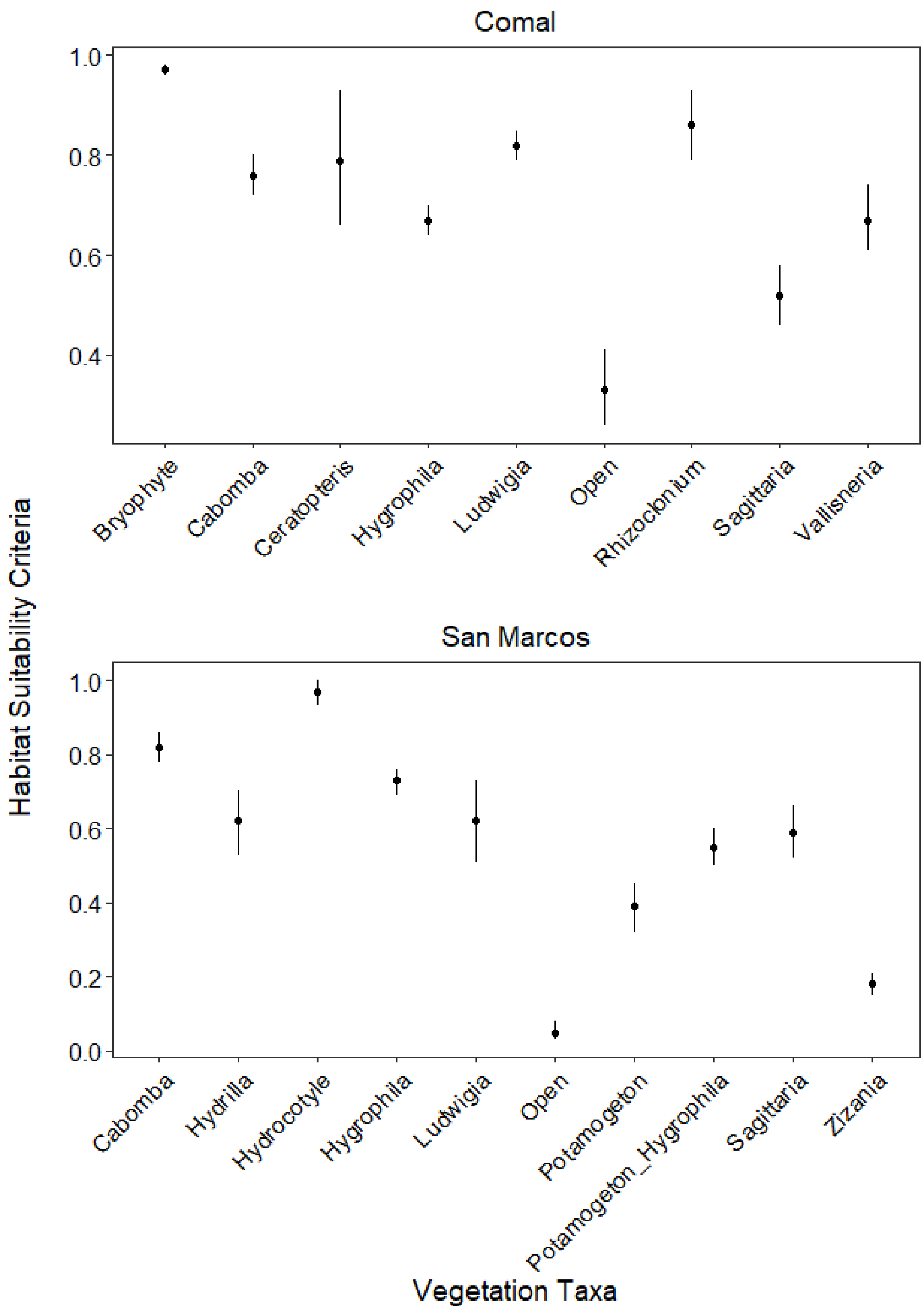

Figure H1. **Aquatic vegetation habitat suitability criteria (±95% CI) built with drop-net and random dip-net datasets using logistic regression.**

OHSI Evaluation

OHSI Evaluation Methods

To examine the relationship between OHSI and Fountain Darter population metrics, random-station dip-net data from 2017-2020 was organized in a way that treats each monitoring event per study reach as independent. This results in the response variable quantified as the proportional occurrence of Fountain Darters per reach at a given monitoring event based on the independent variable OHSI.

To predict Fountain Darter occurrence, two modeling approaches that are able to analyze proportions were used, which included: (1) GLM with a binomial distribution and (2) Random Forest Regression (RF). RF is an ensemble learning technique that builds many decision trees to predict a response variable (Breiman et al. 1984). Each decision tree of the "forest" is built by selecting a random subset of the dataset with replacement and a random set of covariates (Liaw & Wiener 2002). RF are considered more advantageous compared to traditional decision tree models and GLM because they correct for overfitting (Breiman 2001) and can provide more accurate predictions with many covariates (Cutler et al. 2007). For this analysis, we built RF models with 500 trees.

GLMs and RFs were built separately for the Comal and San Marcos systems. First, 50% of each dataset was randomly selected to train each model. Second, 5-fold cross validation (CV) was used to independently test the predictive performance of each model with the remaining 50% of the dataset (i.e., test data). Predictive performance was compared among models based on the correlation (R) and deviance (D) between observed and predicted values. Mean CV R ± standard error (SE) and CV D ± SE were calculated based on predictions from the 5 CV folds. Models with the highest CV R were considered as the best models for making predictions and elaborated on further in the results.

Lastly, figures were built to display fitted predictions across observed OHSI values to examine if there was a positive relationship between Fountain Darter occurrence and OHSI. Fitted predictions were also presented with a LOWESS smoothed function to visualize if trends of OHSI are linear or nonlinear (Milborrow 2020). In sum, if the models displayed strong predictive power and Fountain Darter occurrence showed a positive relationship with OHSI, then OHSI was considered a useful measurement of habitat suitability for Fountain Darters.

OHSI Evaluation Results

Predictive performance for the Comal models showed that RF (0.81 ± 0.18) predictions were more accurate than GLM (0.62 ± 0.20). San Marcos models were similar, showing better predictive accuracy for RF (0.97 ± 0.02) compared to GLM (0.93 ± 0.06) (Table H1). Comparisons between observed vs. predicted occurrence for the RF 5-fold CV demonstrated lowest predictive accuracy at observed proportions about 0.20 or less for the Comal and San Marcos (Figure H2).

Fitted predictions of occurrence as a function of OHSI showed that occurrence increased with increasing OHSI for the Comal and San Marcos. In the Comal, LOWESS smoothed predictions exhibited a non-linear asymptotic trend. Occurrence increased about 0.60 to 0.80 when OHSI increased from about 0.65 to 0.75 and remained around 0.80 at OHSI values >0.75. In the San Marcos, LOWESS smoothed predictions exhibited a more linear trend compared to the Comal and occurrence increased from about 0.25 to 0.55 as OHSI increased from 0.25 to 0.60 (Figure H3).

Table H1. Summary model performance statistics for predicting Fountain Darter occurrence based on OHSI. Summary statistics includes deviance (D) and correlation (R) for training data and 5-fold cross-validation (SE).

	Comal		San Marcos	
	GLM	RF	GLM	RF
Training Data				
Deviance	1.10	1.03	1.23	1.20
Correlation	0.48	0.77	0.70	0.89
Cross-Validation				
Deviance	1.12 (0.05)	1.05 (0.06)	1.24 (0.07)	1.21 (0.05)
Correlation	0.62 (0.20)	0.81 (0.18)	0.93 (0.06)	0.97 (0.02)

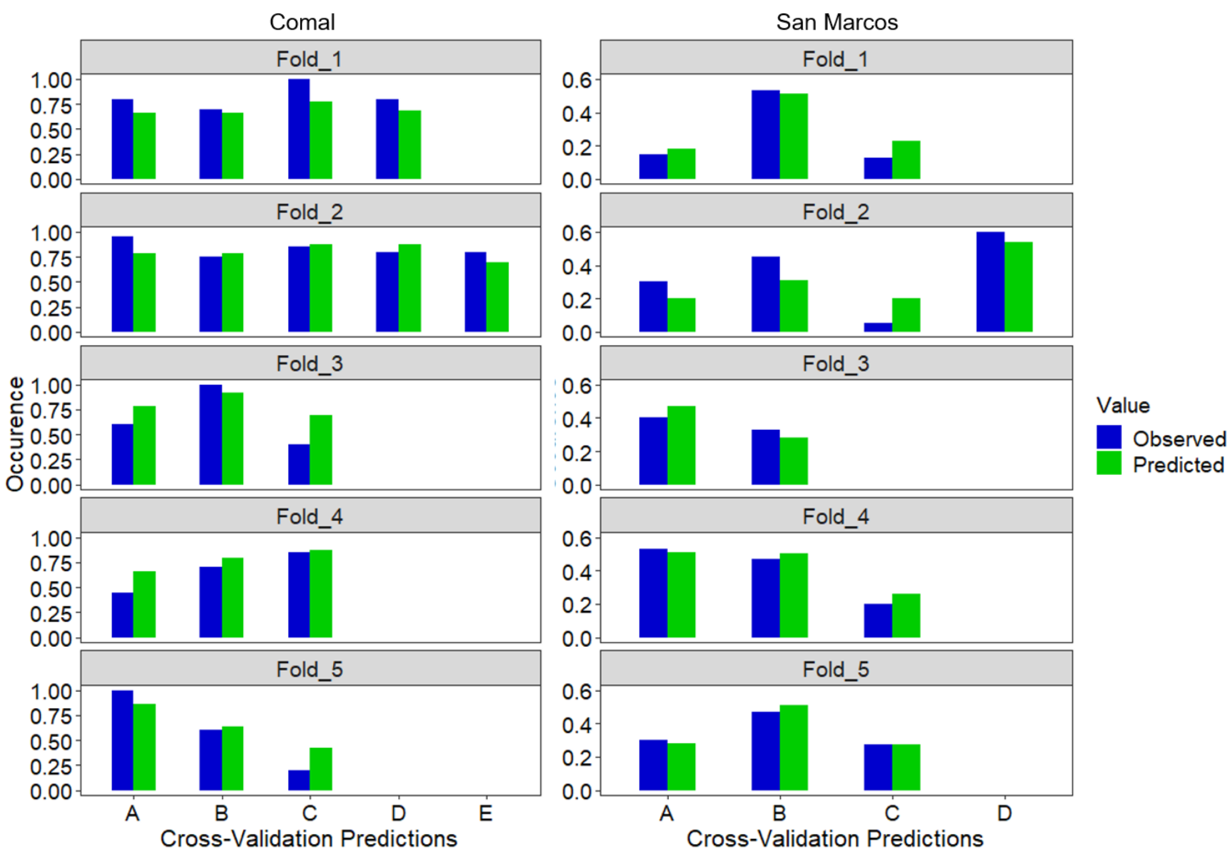

Figure H2. Observed vs. predicted Fountain Darter occurrence in relationship to OHSI from Random Forest 5-fold cross-validation.

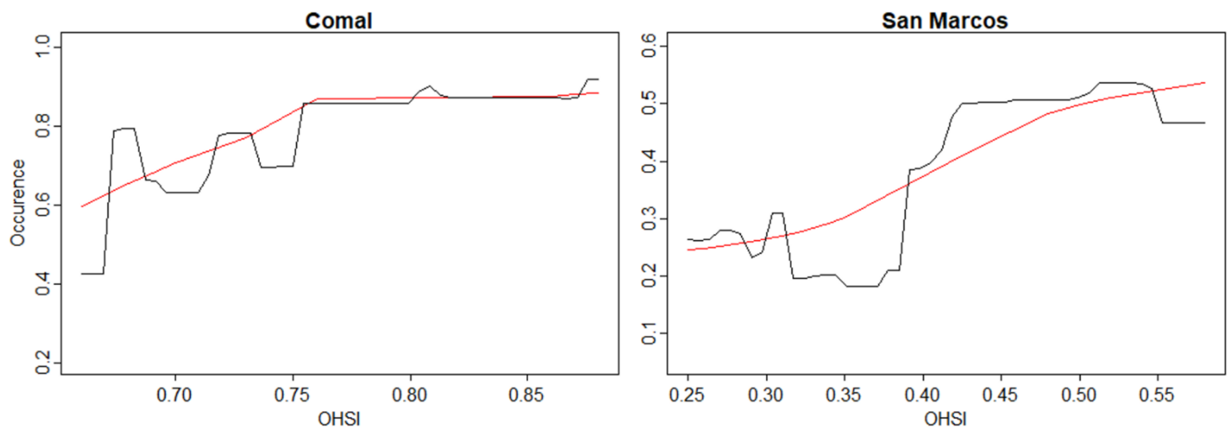

Figure H3. **Fitted occurrence predictions for OHSI in the Comal Springs/River and San Marcos River. The red lines are LOWESS smoothed fitted predictions used to visualize nonlinear trends.**

OHSI EVALUATION DISCUSSION

Model CV R >0.80 for all RFs demonstrate good model performance and that Fountain Darter occurrence can be accurately predicted based on OHSI. Further, similar performance statistics for training data and test data via cross-validation indicated that the training models were not overfit and can reliably predict independent observations in the future. That being said, predictions were least accurate at observed occurrence values about 0.20 or less, which is likely due to smaller sample sizes in this range. As random station dip-net sampling continues during future biomonitoring activities, predictions at these lower occurrence values will likely improve. Fountain Darter occurrence also increased with increasing OHSI. The positive relationship between occurrence and OHSI and good model performance supports that OHSI is an ecologically relevant index for evaluating Fountain Darter habitat suitability based on vegetation community composition.

In sum, this analysis demonstrated that OHSI based on vegetation-specific HSC and reach-level vegetation composition data can accurately predict Fountain Darter occurrence and is a useful measurement for quantifying habitat suitability. However, additional data collection can assist in addressing multiple limitations of this analysis. Firstly, random station dip-net data with simple random sampling is only available from about 2017-2020, which limits the ability to predict occurrence from historical observations. Further, model performance would likely improve at lower occurrence values as additional data are collected and a more robust dataset is generated. Secondly, this analysis assumed that vegetation alone determines Fountain Darter occurrence. For example, decreased predictive accuracy at lower darter occurrence values may be due to other habitat factors (e.g., depth-flow conditions, river discharge) or biotic factors (e.g., competition, predation) rather than due to smaller sample sizes of lower occurrence values; however, a multi-factor ecological model is beyond the scope of this work. In addition, OHSI can only be assessed for vegetation taxa that have been sampled previously and building HSC for rare vegetation taxa not represented may improve predictions. That being said, RF models demonstrated that occurrence can be predicted accurately without including additional habitat variables or vegetation types, supporting that this assumption does not hinder this analysis and does not appear to restrict the inference value of OHSI.

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Appendix F4 | **San Marcos Biological Monitoring Report**

HABITAT CONSERVATION PLAN

BIOLOGICAL MONITORING PROGRAM

San Marcos Springs/River Aquatic Ecosystem

ANNUAL REPORT

December 2024

Prepared for:

Edwards Aquifer Authority
900 East Quincy
San Antonio, Texas 78215

Prepared by:

BIO-WEST, Inc.
1812 Central Commerce Court
Round Rock, Texas 78664

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EXECUTIVE SUMMARY

The Edwards Aquifer Habitat Conservation Plan (EAHCP) Biological Monitoring Program continued to track biota and habitat conditions of the San Marcos Springs/River ecosystem in 2024 through monitoring activities outlined in this report. Monitoring in the San Marcos system consisted of routine surveys specific to EAHCP Covered Species: Fountain Darter (*Etheostoma fonticola*), Texas Wild-rice (*Zizania texana*), and San Marcos Salamander (*Eurycea nana*). Community-level monitoring data were also collected on aquatic vegetation, fish, and benthic macroinvertebrates. In addition, reduced river discharge triggered species-specific low-flow sampling events starting in spring. The results from 2024 biological monitoring provide valuable data to further assess spatiotemporal trends of aquatic biota in the San Marcos Springs/River ecosystem, as well as an opportunity to better understand ecological responses to low-flow conditions sustained for several years.

In 2024, central Texas, including the San Marcos Springs/River ecosystem, experienced continued extreme drought conditions with low precipitation and higher than normal ambient temperatures. The year began under low-flow conditions until rain at the end of January increased total system discharge, resulting in two months of approximately historical median flows in February and March. However, flows steadily declined until October when flows were near 10^{th} percentile conditions. Flows decreased to 120 cubic feet per second (cfs) in May triggering species-specific Texas Wild-rice physical measurements and continued to decline to ~85 cfs in September triggering a Critical Period event which was coupled with routine fall sampling. Annual median daily mean discharge was higher in 2024 (112 cfs) than in 2023 (88 cfs) and more similar to previous low-flow monitoring events in 2006 (116 cfs), 2009 (96 cfs), 2011 (117 cfs), and 2022 (119 cfs).

Vegetation coverage among the study reaches remained similar from 2020 to 2024, whereas coverages among specific taxa changed. Within the study reaches in 2024, total aquatic vegetation coverage declined from spring to fall at Spring Lake Dam and City Park but increased at I-35. Declines in vegetation coverage at the two upstream reaches were mainly attributed to decreased coverage of Texas Wild-rice due to low flows and recreation. In October 2023, Texas Wild-rice had decreased to the lowest coverage mapped since 2016; however, by August 2024, Texas Wild-rice coverage increased to levels similar to August 2023 and were still considerably above pre-EAHCP levels. Impacts of low flows were notable in the I-35 reach as reductions in wetted habitat resulted in a large dewatered area near Snake Island. More amphibious species like *Hygrophila* outcompeted Texas Wild-rice, surviving as emergent in the shallowest areas. *Hygrophila* coverage also increased in the main river channel, contributing to the increase in vegetation from spring to fall despite the large dewatered area. Deeper areas also provided ecological refugia for Texas Wild-rice to survive and expand. Continued monitoring of Texas Wild-rice will provide insight into the species response to the ongoing drought.

In addition to Texas Wild-rice, the influence of low springflows was also evident on abiotic habitat and aquatic vegetation conditions that influence Fountain Darter populations. Increases in *Cabomba* coverage in City Park and the presence of bryophytes intermixed with other vegetation taxa in riverine reaches contributed to higher Fountain Darter density estimates. Overall habitat suitability indices generally showed an increase in habitat conditions compared to 2023.

However, since these indices are based on long-term taxa-specific suitability values, they don't capture increases in habitat complexity provided by bryophytes in 2023 and 2024.

Water temperatures remained consistent in spring areas but were elevated relative to typical years in downstream areas. Under these low-flow conditions, the optimal water temperature threshold for Fountain Darter egg production (26 °C) was exceeded at City Park, Rio Vista, I-35, Thompson Island, and Wastewater Treatment Plant more commonly and for longer durations than in previous years (i.e., 2020-2021). Despite this, Fountain Darter population metrics indicated increased densities at the City Park study reach and approximated historical median densities at the I-35 study reaches in both spring and fall. This could suggest that exceedance of these laboratory-derived temperature thresholds may not be a strong predictor of wild Fountain Darter population performance. However, the health and condition of individual Fountain Darters was not analyzed, and application of laboratory derived temperature thresholds to wild populations is nuanced for several reasons. For example, although McDonald et al. (2007) did vary temperature for their laboratory trials, those temperature fluctuations do not exactly match natural diel patterns observed in the wild. Given availability of a tremendous amount of water temperature data in these systems, additional research is needed to evaluate the influence of naturally occurring diel temperature fluctuations on wild Fountain Darter population dynamics while accounting for variation in habitat quality and quantity.

Trends in San Marcos Salamander densities were variable among sites in 2024 and over the past five years. However, only Spring Lake Dam showed substantially lower densities in 2024. At a community scale, fish and macroinvertebrate community-level responses to low flows were not readily apparent. In general, no long-term temporal trends in overall or spring-associated fish diversity, richness, and relative density are evident from fish community monitoring data. Macroinvertebrate Index of Biotic Integrity (IBI) scores were generally consistent with past years.

Overall, 2024 biological monitoring provided insights into the current condition of the EAHCP Covered Species in the San Marcos Springs/River, as well as flow-ecology relationships of the broader aquatic community. Following 2023, which recorded the lowest flow conditions observed since 1956, observations from 2024 suggest the system proved resilient. Reductions in wetted habitats did not negatively impact Fountain Darter population metrics, as catch rates and percent occurrence were generally comparable to previous data and densities increased in recent years. San Marcos Salamander densities declined in Spring Lake and Spring Lake Dam in fall 2024, therefore additional monitoring is needed to examine future trends. Fish community and macroinvertebrate bioassessments revealed a healthy riverine community with a diversity of taxa similar to previous years. In summary, results from 2024 demonstrated resilience of aquatic communities and Covered Species populations to the continued low-flow conditions observed. Subsequent monitoring efforts will provide opportunities to better understand the dynamics of this complex ecological system and further examine responses to varying hydrologic conditions.

INTRODUCTION

The Edwards Aquifer Habitat Conservation Plan (EAHCP) was established in 2012 and supports the issuance of an Incidental Take Permit that allows the "incidental take" of threatened and endangered species (i.e., Covered Species) (Table 1) from otherwise lawful activities in the San Marcos Springs/River. Section 6.3.1 of the HCP established a continuation of biological monitoring in the San Marcos Springs/River. This biological monitoring program was first established in 2000 (formerly known as the Edwards Aquifer Authority [EAA] Variable Flow Study) and its original purpose was to evaluate the effects of variable flow on the biological resources, with an emphasis on threatened and endangered species. However, the utility of the HCP biological monitoring program has surpassed its initial purpose (EAHCP 2012), and biological data collected since the implementation of this monitoring program (BIO-WEST 2001–2024) now serves as the foundation for several underlying sections in the HCP, which include: (1) long-term biological goals (LTBGs) and management objectives (Section 4.1); (2) determination of potential impacts to Covered Species, "incidental take" assessment, and Environmental Impact Statement alternatives (Section 4.2); and (3) establishment of core adaptive-management activities for triggered monitoring and adaptive-management response actions (Section 6.4.4). As the HCP proceeds, biological monitoring program data, in conjunction with other available information, are essential to adaptive management. Current and future data collection will help assess the effectiveness and efficiency of certain HCP mitigation and restoration activities conducted in the San Marcos Springs/River and calculate the HCP habitat baseline and net disturbance determination and annual "incidental take" estimate (EAHCP 2012).

Table 1. Covered Species directly sampled for under the Edwards Aquifer Habitat Conservation Plan in the San Marcos Springs/River ecosystem.

SCIENTIFIC NAME	COMMON NAME	ESA STATUS
Plants		
Zizania texana	Texas Wild-rice	Endangered
Amphibians		
Eurycea nana	San Marcos Salamander	Threatened
Fish		
Etheostoma fonticola	Fountain Darter	Endangered

This report provides the methodology and results for biological monitoring activities conducted in 2024 within the San Marcos Springs/River ecosystem. In addition to routine monitoring, Critical Period and species-specific low-flow sampling was triggered. The results include summaries of current physiochemical conditions, as well as current conditions of floral and faunal communities, all of which encompasses both routine and low-flow sampling. For all aquatic organisms, historic observations (BIO-WEST 2001–2023) are also used to provide context to current conditions.

METHODS

Study Location

The upper San Marcos River (San Marcos, Hays County, Texas) is fed by the Edwards Aquifer and originates at a series of spring upwellings in Spring Lake, which was impounded in the mid-1800s (Bousman and Nickels 2003). From the headwaters, the river flows about eight kilometers (km) before its confluence with the Blanco River, traversing two additional impoundments, Rio Vista Dam and Capes Dam. The upper San Marcos River watershed is dominated by urban landcover and is subjected to recreational use. Spring inputs from the Edwards Aquifer provide stable physiochemical conditions, and springflow conditions are dictated by aquifer recharge and human water use (Sung and Li 2010). The upper San Marcos River maintains diverse assemblages of floral and faunal communities (Bowles and Arsuffi 1993; Owens et al. 2001) that include multiple endemic organisms, such as Texas Wild-rice, Comal Springs Riffle Beetle (*Heterelmis comalensis*), San Marcos Salamander, and Fountain Darter among others.

Sampling Strategy

Based on the long-term biological goals (LTBGs), and management objectives outlined in the HCP, study areas were established to conduct long-term monitoring and quantify population trends of the Covered Species (EAHCP 2012). The sampling locations selected are designed to cover the entire extent of Covered Species habitats, but they also allow for holistic ecological interpretation while maximizing resources (Figures 1–3). Comprehensive sampling within the established study area varies temporally and spatially among Covered Species. The current sampling strategy includes five spatial resolutions:

1. System-wide sampling
    a. Texas Wild-rice mapping: 1 event/year (summer)
    b. Aquatic vegetation mapping: 5-year intervals (spring)
2. Select longitudinal locations
    a. Water temperature: assessed year-round at permanent monitoring stations
3. Reach sampling
    a. Aquatic vegetation mapping: 2 events/year (spring, fall)
    b. Fountain Darter drop-net sampling: 2 events/year (spring, fall)
    c. Fountain Darter random-station dip-net surveys: 3 events/year (spring, summer, fall)
4. Springs Sampling
    a. San Marcos Salamander surveys: 2 events/year (spring, fall)
5. River section/segment
    a. Fountain Darter timed dip-net surveys: 3 events/year (spring, summer, fall)
    b. Fish community surveys: 2 events/year (spring, fall)
    c. Macroinvertebrate community sampling: 2 events/year (spring, fall)

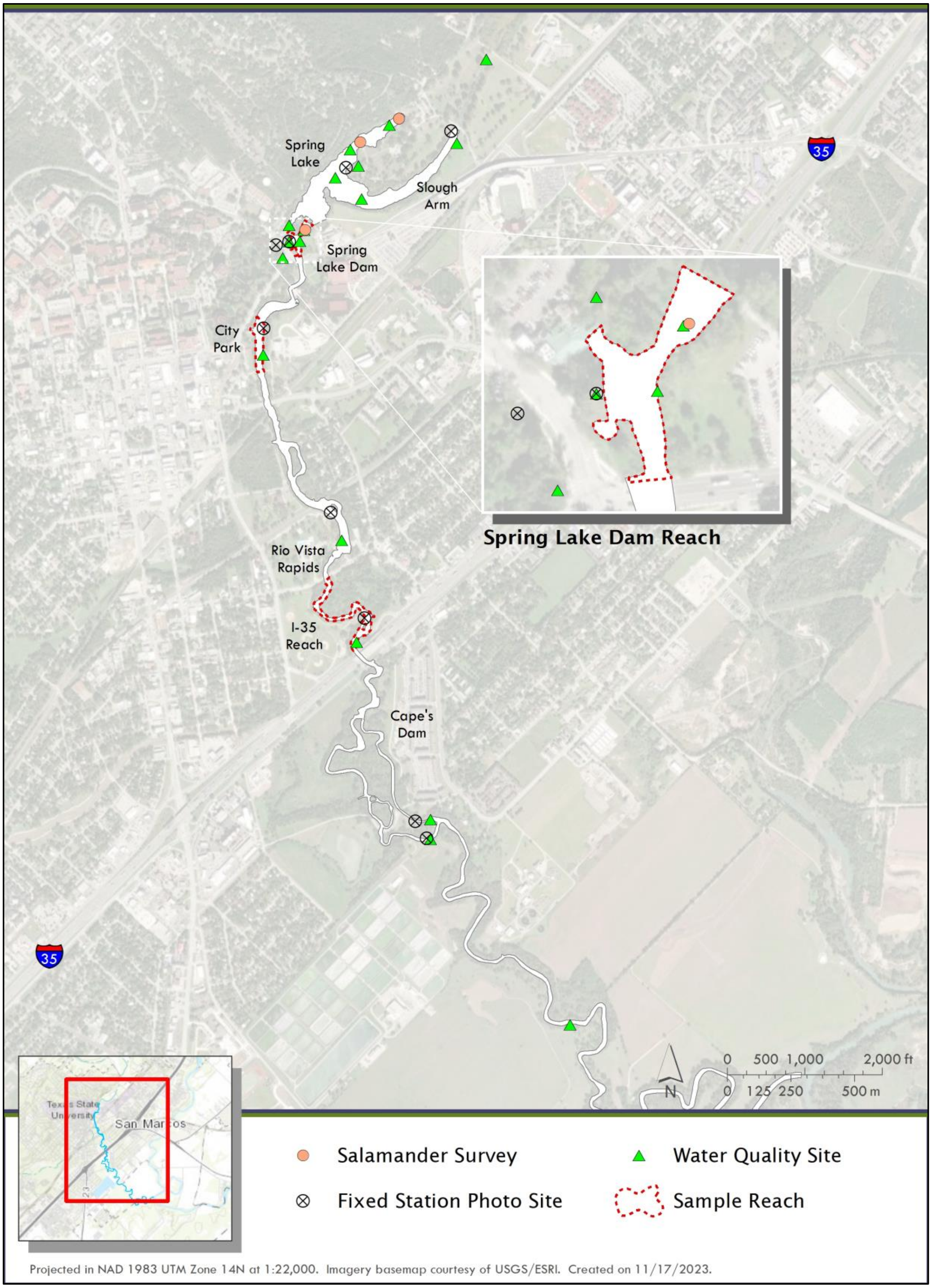

Figure 1. Upper San Marcos River sample reaches, San Marcos Salamander survey sites, water quality sampling sites, and fixed-station photography sites.

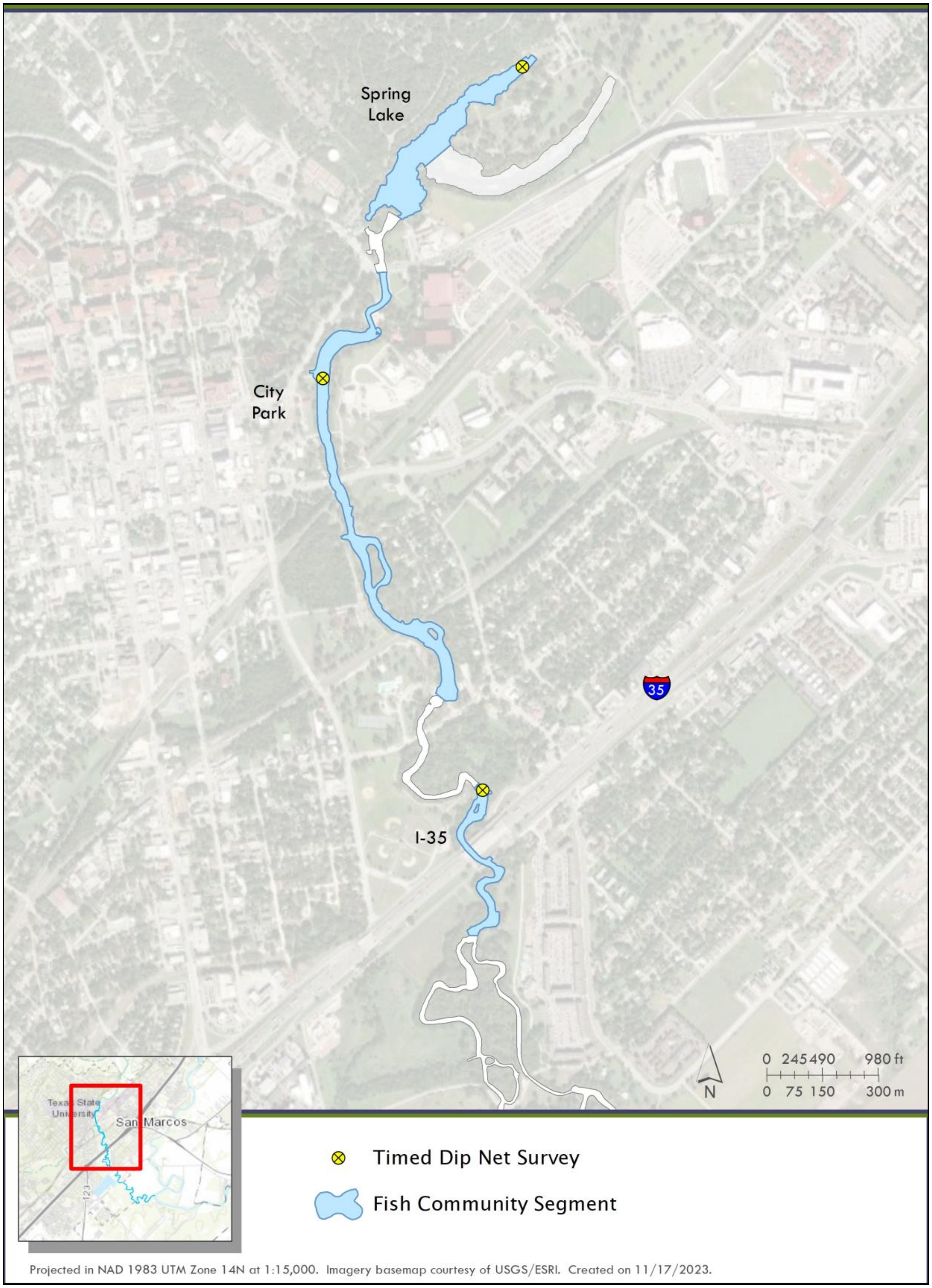

Figure 2. Fish community sampling segments and dip-net timed survey sections for the upper San Marcos River.

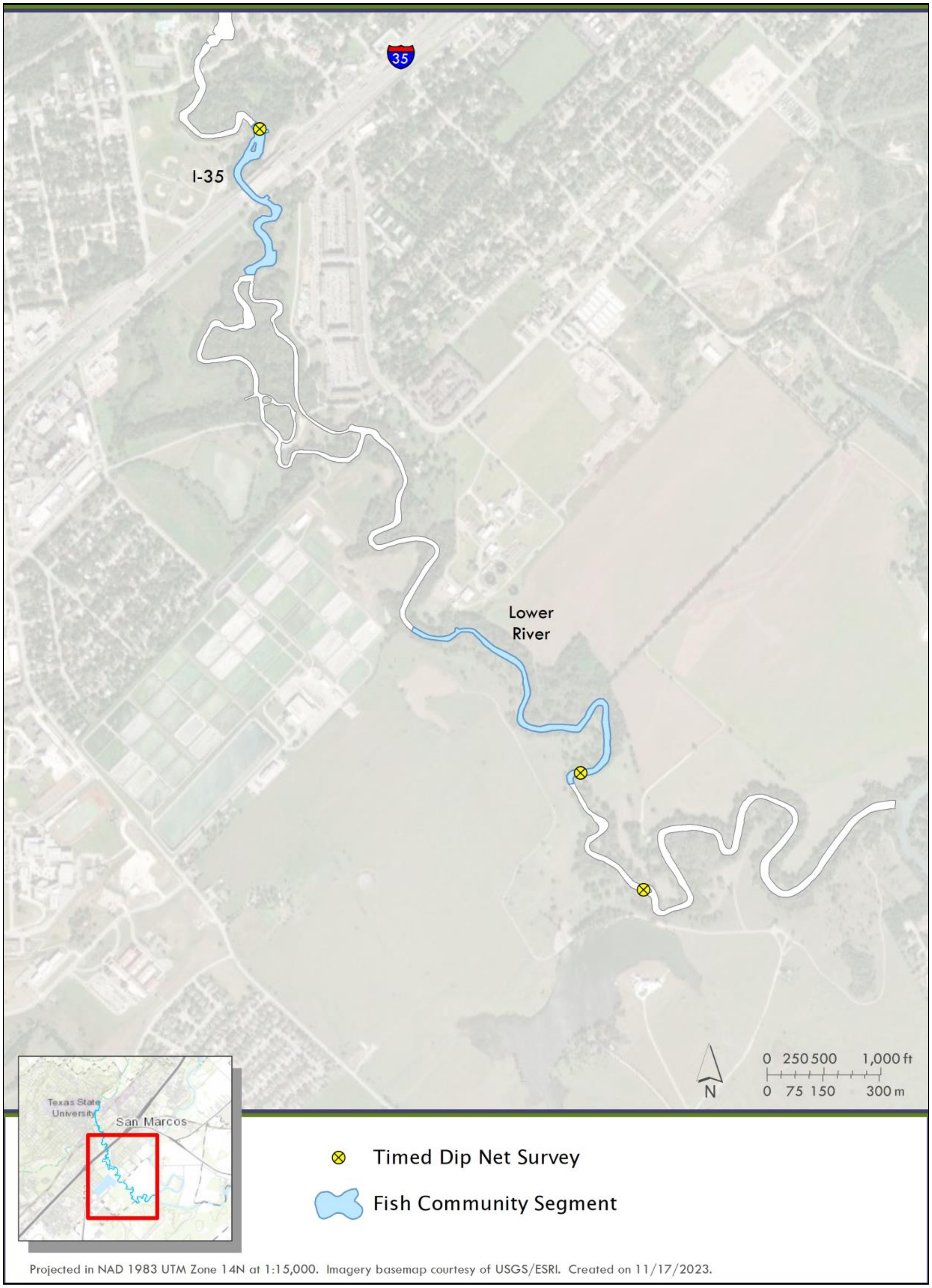

Figure 3. Fish community sampling segments and dip-net survey sections for the lower San Marcos River.

In addition to annual comprehensive sampling outlined above, low-flow sampling may also be conducted, but is dependent on HCP flow triggers, which include Critical Period low-flow sampling and species-specific sampling (EAHCP 2012). Due to decreased flows, one Critical Period monitoring event (< 85 cfs) was triggered and coupled with routine fall monitoring in October. Several species-specific, Texas Wild-rice physical measurements, were triggered in January and again from May through November. As total system discharge decreased below 120 cfs, the river was evaluated at approximately 5 cfs intervals to monitor low-flow conditions and ensure adequate habitat was maintained. In addition, thermistors were downloaded at regular intervals to monitor temperatures as flows declined.

The remaining methods sections provide brief descriptions of the procedures utilized for comprehensive routine, Critical Period, and species-specific sampling efforts. A more-detailed description of the gear types used, methodologies employed, and specific GPS coordinates can be found in the Standard Operating Procedures Manual for the HCP biological monitoring program for the San Marcos Springs/River ecosystem (EAA 2017).

San Marcos River Discharge

River hydrology in 2024 was assessed using U.S. Geological Survey (USGS) stream gage data from January 1 through October 31. Mean daily discharge expressed in cubic feet per second (cfs) was acquired from USGS gage #08170500, which represents cumulative river discharge that encompasses springflow and local runoff contributions from the Sink Creek drainage. It should be noted that some of these data are provisional and are subject to revision at a later date (USGS 2024). The annual distribution of mean daily discharge was compared for the past 5 years using boxplots. The distribution of 2024 mean daily discharge was also summarized by month using boxplots. Monthly discharge levels were compared with long-term (1956, 1994–present) 10th, 50th (i.e., median), and 90th percentiles.

Water Temperature

Spatiotemporal trends in water temperature (°C) were assessed using temperature data loggers (HOBO Tidbit v2 Temp Loggers) at the 11 permanent monitoring stations established in 2000. Data loggers recorded water temperature every 10 minutes and were downloaded at regular intervals. Prior to analysis, data processing was conducted to locate potential data logger errors per station by comparing time-series for the current year with previous years. Timeframes displaying temperatures that deviated substantially from historical data and didn't exhibit ecologically rational trends (e.g., discontinuities, ascending drift) were considered unreliable and omitted from the dataset. For analysis, the distribution of water temperatures for the current year was assessed among stations based on 4-hour intervals and summarized using boxplots. Data from the current year were also compared to their 5-year and long-term trends. Water temperatures were also compared with maximum optimal temperature requirements for Fountain Darter larval (≥25 °C) and egg (≥26 °C) production (McDonald et al. 2007). Further, 25 °C is also the designated water temperature threshold within the HCP Fountain Darter LTBG study reaches (Spring Lake Dam, City Park, I-35) (EAHCP 2012). In the case of stations that surpassed either water temperature threshold during the year, the general timeframes in which those exceedances occurred are discussed in the text.

Aquatic Vegetation

Mapping

The team used a kayak for visual observations to complete aquatic vegetation mapping in sample reaches during the spring routine monitoring and fall low-flow/routine monitoring events. A Trimble GPS unit and external Tempest antenna set on the bow of the kayak was used to collect high accuracy (10–60 centimeter [cm]) geospatial data. A data dictionary with pre-determined attributes was loaded into the GPS unit for data collection in the field. Discrete patch dimensions and the type and density of vegetation were recorded from the kayak. In some instances, an accompanying free diver was used to provide additional detail and to verify surface observations. The discreteness of an individual vegetation patch was determined by the dominant species located within the patch compared to surrounding vegetation. Once a patch of vegetation was visually delineated, the kayak was maneuvered around the perimeter of the vegetation patch to collect geospatial data with the GPS unit, thus creating a vegetation polygon. Attributes assigned to each polygon included species type and percent cover of each of the four most-dominant species. The type of substrate (silt, sand, gravel, cobble, organic) was identified if substrate was a dominant feature within the patch. Rooted aquatic vegetation, floating aquatic vegetation, bryophytes, and algae were mapped as separate features. Only aquatic vegetation patches 1 meter (m) in diameter or larger were mapped as polygons. However, all Texas Wild-rice was recorded, with individual Texas Wild-rice plants too small to delineate as polygons mapped as points instead.

Data Processing and Analysis

During data processing, Microsoft Pathfinder was used to correct spatial data and create shapefiles. Spatial data were projected using the Projected Coordinate System NAD 1983 Zone 14N. Post processing was conducted to clean polygon intersections, check for and correct errors, and calculate cover for individual discrete polygons as well as totals for all encountered aquatic plant species.

Vegetation types are described in the Results and Discussion sections by genus, except for Texas Wild-rice for which the common name is used. Vegetation community composition among taxa and grouped by native vs. invasive taxa are compared for the last five years using stacked bar graphs. Total surface area of aquatic vegetation, measured in square meters (m^2), is presented for each season using bar graphs and is compared with long-term averages (2001–present) from spring, fall, high-flow events, and low-flow events. Since the I-35 study reach was expanded in 2014, the long-term averages for this reach were calculated from 2014-2024 to exclude years prior to the reach expansion. High-flow and low-flow averages were calculated from Critical Period events. These events are based on predetermined river discharge triggers (Appendix A), which result in additional mapping events to assess flow-related impacts to the vegetation community. All total coverages were calculated solely based on rooted plant taxa.

Texas Wild-rice Annual Observations

Mapping and Physical Observations

In addition to aquatic vegetation mapping in the LTBG study reaches, Texas Wild-rice was mapped within Spring Lake and eight river segments using the same methods described above during routine summer mapping in July/August (Figure 4). Moreover, physical measurements were quantified during routine monitoring in spring and fall. Eight additional sampling events occurred during species-specific events triggered in January (n = 1), May (n = 1), June (n = 2), July (n=1), August (n = 1), and September (n = 2).

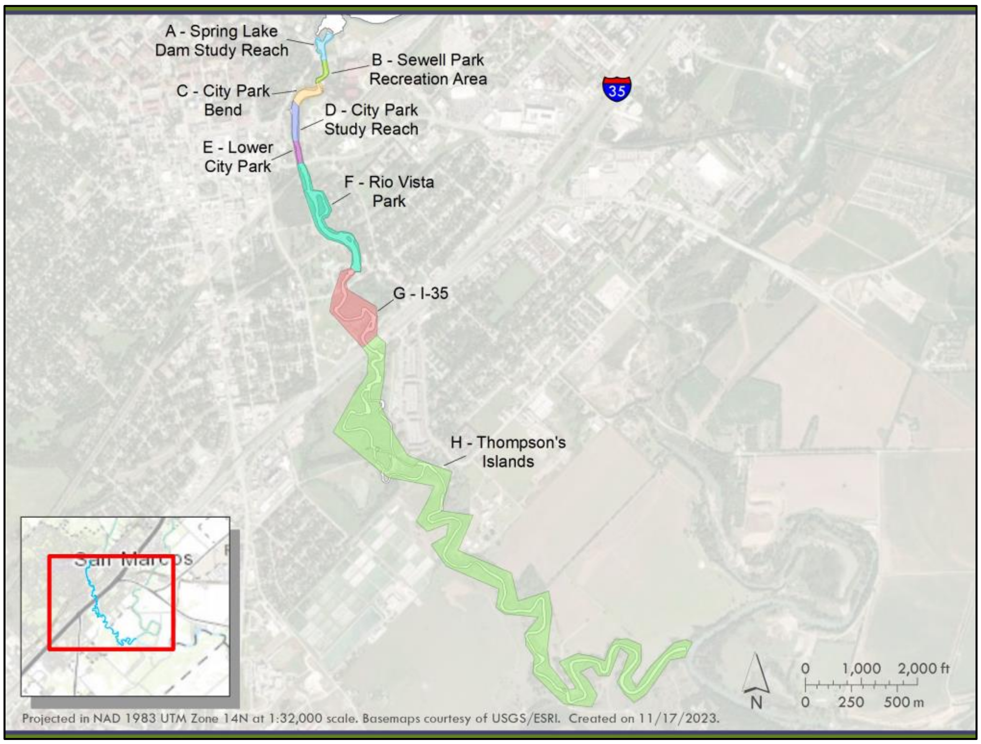

Figure 4. Designated river segments for monitoring Texas Wild-rice coverage.

At the beginning of the initial sampling activities in 2000, Texas Wild-rice stands throughout the San Marcos River were assessed and documented as being in "vulnerable" areas if they possessed one or more of the following characteristics: (1) occurred in shallow water (<0.5 feet); (2) revealed extreme root exposure because of substrate scouring; or (3) generally appeared to be in poor condition. The areal coverage of Texas Wild-rice stands in vulnerable locations were determined in 2024 by GPS mapping (see Aquatic Vegetation Mapping for details) in most instances. However, areal coverage of some smaller stands was measured using a method originally developed by the Texas Parks and Wildlife Department (J. Poole, pers. comm.). To do this, maximum length and maximum width were measured. The length measurement was taken at the water surface parallel to streamflow and included the distance between the bases of the roots to the tip of the longest leaf. The width was measured at the widest point perpendicular to the stream current. Percent cover was then estimated within the rectangle formed from the maximum length and maximum width measurements. The total area of the rectangle was then multiplied by the percent cover to estimate the areal coverage for each small stand.

Data Processing and Analysis

Annual trends in total Texas Wild-rice coverage (m^2) within Spring Lake and all river segments are presented from 2001–present. The conditions of vulnerable Texas Wild-rice stands were assessed by combining quantitative and qualitative observational measurements from the following metrics: (1) percent of stand that was emergent, (2) percent of emergent portions that were seeding, (3) percent of stand covered with vegetation mats or algae buildup, and (4) categorical estimation of root exposure. Water depth was measured in feet (ft) at the shallowest point in the Texas Wild-rice stand and velocity in feet per second (ft/s) was measured at the upstream edge of each stand. All results from the physical observations and vulnerable stands monitoring can be found in Appendix C.

Fountain Darter

Drop-Net Sampling

Drop-net sampling was utilized to quantify Fountain Darter densities and habitat utilization during the spring and fall monitoring events at established sample reaches (Figure 1). Drop-net stations were selected using a random-stratified design. In each study reach, two sample stations per vegetation strata were randomly selected based on dominant aquatic vegetation (including open areas) mapped prior to sampling (see Aquatic Vegetation Mapping for details). At each sample station, all organisms were first trapped using a 2 m^2 drop-net. Organisms were then collected by sweeping a 1 m^2 dip-net along the river bottom within the drop-net. If no fish were collected after the first ten dip-net sweeps, the station was considered complete, and if fish were collected, an additional five sweeps were conducted. If any Fountain Darters were collected on sweep 15, additional sweeps were conducted until no Fountain Darters were collected.

Most fishes collected were identified to species and enumerated. Two morphologically similar species, Western Mosquitofish (*Gambusia affinis*) and Largespring Gambusia (*Gambusia geiseri*), which are known to hybridize, were classified by genus (*Gambusia* sp.). Larval and juvenile fishes too small to confidently identify to species in the field were also classified by genus. All Fountain Darters and the first 25 individuals of other fish taxa were measured (total length expressed in millimeters [mm]).

Physiochemical habitat data were collected at each drop-net location. Water depth (ft) and velocity (ft/s) data were collected at the upstream end of drop-net samples using a HACH FH90 flowmeter and adjustable wading rod. Water-velocity measurements were collected at 15 cm above the river bottom to characterize flows that directly influence Fountain Darters. Mean-column velocity was measured at 60% of water depth when depths were less than three feet. At depths of three feet or greater, water velocities were measured at 20% and 80% of depth and averaged to estimate mean column velocity. Water quality was measured within each drop-net using a HydroTech multiprobe, which included water temperature (degrees Celsius [°C]), pH, dissolved oxygen (milligrams per liter [mg/L], percent saturation), and specific conductance (microsiemens per centimeter [µs/cm]). Mid-column water quality was measured at water depths less than three feet, whereas bottom and surface values were measured and averaged at depths of three feet or greater. Lastly, vegetation composition (%) was visually estimated and dominant substrate type was recorded within each drop-net sample.

Dip-Net Sampling
Dip-net sampling was used to provide additional metrics for assessing Fountain Darter population trends and included qualitative timed surveys and random-station presence/absence surveys. All sampling was conducted using a 40x40 cm (1.6-mm-mesh) dip-net, and surveys for both methods were conducted in spring, summer, and fall.

Timed dip-net sampling was conducted to examine patterns in Fountain Darter catch rates and size structure along a more extensive longitudinal gradient compared to drop-net sampling. Surveys were conducted within established survey sections and for a fixed amount of search effort (Spring Lake: 0.5 hour, City Park: 1.0 hour, I-35: 1.0 hour, Cypress Tree: 0.5 hour, Todd Island: 0.5 hour) (Figures 2 and 3). In each study reach, a single surveyor used a dip-net to collect Fountain Darters in a downstream to upstream fashion. Collection efforts mainly focused on suitable Fountain Darter habitat, specifically in areas with dense aquatic vegetation. Non-wadeable habitats (>1.4 m) were not sampled. All Fountain Darters collected were enumerated, measured (mm), and returned to the river at point of collection.

Random-station presence/absence surveys were implemented to assess Fountain Darter occurrence. During each monitoring event, sample stations were randomly selected within the vegetated area of each reach (Spring Lake: 10, Spring Lake Dam: 15, City Park: 20, I-35: 15) (Figure 1). At each random-station, presence/absence was recorded during four independent dips. To avoid recapture, collected Fountain Darters were returned to the river in areas adjacent to the random station being sampled. Habitat variables recorded at each station included dominant aquatic vegetation and presence/absence of bryophytes and algae.

Data Analysis
Key demographic parameters used to evaluate Fountain Darter observations included population performance, size structure, and recruitment. Population performance was assessed using drop-net, timed dip-net, and random dip-net data. Counts of darters per drop-net sample were standardized as density (darters/m^2). Timed dip-net total darter counts per study reach were standardized as catch-per-unit-effort (CPUE; darters/person-hour [p-h]) for each sampling event. Random dip-net occurrence per station was based on whether or not a Fountain Darter was observed during any of the four dips and percent occurrence was calculated per sampling event at each reach as: (sum[darter presence]/sum[random stations])*100. Fountain Darter density, CPUE, and occurrence were compared among seasons using boxplots. In addition, density and CPUE seasonal observations were compared to the past five years and long-term observations (2001–present). Occurrence values were only compared to observations from the past five years due to the fact that Texas Wild-rice was excluded from sampling prior to 2017. Lastly, temporal trends in Fountain Darter density were assessed per sampling event for each study reach for the past five years using boxplots and compared to their respective long-term (2001–present) medians and quartiles (25th and 75th percentile).
Size structure and recruitment were assessed among seasons. Fall and spring were assessed by combining drop-net and timed dip-net data, and summer was assessed using timed dip-net data only. Boxplots coupled with violin plots were used to display the distribution of darter lengths per sampling event for each season for the past five years. Boxplots show basic length-distribution statistics (i.e., median, quartiles, range) and violin plots visually display the full distribution of lengths relative to each sampling event using kernel probability density estimation

(Hintze and Nelson 1998). Recruitment was quantified as the percent of darters ≤20 mm during each sampling event. Based on a linear model built by Brandt et al. (1993) that looked at age-length relationships of laboratory-reared Fountain Darters, individuals of this size are likely less than 3 months old and not sexually mature (Brandt et al. 1993; Schenck and Whiteside 1976). Percent recruitment ±95% confidence intervals (beta distribution percentiles; McDonald 2014) were shown for the past five years by season and compared to their respective long-term averages.

Habitat use was assessed based on population performance and size structure among vegetation strata using drop-net and random station dip-net observations. Fountain Darter density by vegetation taxa was compared based on current, five-year, and long-term (2001–present) observations using boxplots. Long-term comparisons of Texas Wild-rice were not provided since 2020 was the first year this species was sampled via drop-netting. In addition, Texas Wild-rice was not sampled during fall drop-netting due to river discharge dropping below 120 cfs. Proportion of occurrence was also calculated among vegetation types sampled during random-station dip-netting for the current year. Lastly, boxplots coupled with violin plots were used to display the distribution of darter lengths by vegetation taxa using drop-net data to examine habitat use among size classes for the current year. Open habitats and Texas Wild-rice were omitted from analysis due to limited darter counts (i.e., less than 3 darters total).

Habitat suitability was quantified to examine reach-level changes in habitat quality for Fountain Darters through time. First, Habitat Suitability Criteria (HSC) ranging from 0 (unsuitable habitat) to 1 (most suitable habitat) were built based on occurrence data for all vegetation types (including open habitat) that have been sampled using logistic regression (Manly et al. 1993). Resulting HSC were then multiplied by the areal coverage of each vegetation strata mapped during a biomonitoring event, and results were summed across vegetation strata to calculate a weighted usable area for each reach. To make data comparable between reaches of different sizes, the total weighted usable area of each reach was then divided by the total area of the reach, resulting in an Overall Habitat Suitability Index (OHSI) for each reach during each sampling event. Following this method, temporal trends of Fountain Darter OHSI ±95% CI were calculated per sampling event for each study reach (Spring Lake Dam, City Park, I-35) for the past five years. Long-term (2003–present) OHSI and 95% CI averages were also calculated to provide historical context to recent observations. Specific details on the analytical framework used for developing OHSI and evaluating its efficacy as a Fountain Darter habitat index, including methods to build HSC, can be found in Appendix G.

Fish Community

Mesohabitat, Microhabitat, and Seine Sampling

Fish community sampling was conducted in the spring and fall monitoring events to quantify fish assemblage composition/structure and to assess Fountain Darters in river segments and habitats (e.g., deeper areas) not sampled during drop-net and timed dip-net surveys. The following nine monitoring segments were sampled: Spring Lake, Sewell Park, Veterans Plaza, Rio Vista Park, Crooks Park, I-35, Thompson Island, Wastewater Treatment Plant, and Smith Property (Figures 2 and 3). Deeper habitats were sampled using visual transect surveys, and shallow habitats were sampled via seining.

A total of three mesohabitat transects were sampled at each segment during visual surveys. At each transect, four divers swam from bank-to-bank at approximately mid-column depth, enumerating all fishes observed and identifying them to species. After each mesohabitat transect was completed, microhabitat sampling was also conducted along four, five-meter-long PVC pipe segments (micro-transect pipes) placed on the stream bottom and spaced evenly along the original transect. Divers started at the downstream end and swam up the pipe searching through the vegetation, if present, and substrate within approximately 1 m of the pipe. All fishes observed were identified to species and enumerated. For both surveys, any individuals that could not be identified to species were classified by genus. At each micro-transect-pipe, total area surveyed (m^2), aquatic vegetation composition (%), and substrate composition (%) were recorded. Water depth (ft) and velocity (ft/s) data were collected in the middle of each micro-transect-pipe using a Marsh McBirney Model 2000 portable flowmeter and adjustable wading rod. At each micro-transect pipe, water-velocity measurements were taken 15 cm from the bottom, mid-column, and at the surface. Standard water-quality parameters were also recorded once at each transect using a handheld water-quality sonde.

In shallow habitats, at least three transects were sampled within each monitoring segment (except Spring Lake) via seining. At each of these, multiple seine hauls were pulled until the entire wadeable area had been covered. After each seine haul, fish were identified, measured (mm), and enumerated. To prevent recapture on subsequent seine hauls, captured fish were placed in a holding bucket containing river water. After completion of the transect, all fish were released from holding buckets. Total area surveyed (m^2) was visually estimated for each seining transect. Habitat data from each seine haul location included substrate and vegetation composition (%); water depth (ft); and velocity (ft/s) measured at 15 cm above the river bottom, at mid-column, and at the surface. Fish taxonomy herein follows the most recent guide published by the American Fisheries Society (AFS 2023).

Data Analysis

To evaluate fish community results, all analyses were conducted using fishes identified to species; fishes identified to genus or family were excluded. Total counts of species from independent samples were first quantified as density (fish/m^2) to standardize abundance among the three gear types used. Results from multiple sites were combined to assess spatial longitudinal differences between Spring Lake, Upper River (Sewell Park, Veterans Plaza), Middle River (Rio Vista Park, Crooks Park, I-35), and Lower River (Thompson Island, Wastewater Treatment Plant, Smith Property) (hereafter 'study segments').

Based on microhabitat sampling, temporal trends in Fountain Darter density were assessed per sampling event for each study reach for the past five years using boxplots and compared to their respective long-term (2014–present) medians and quartiles. Overall species richness and diversity using the Shannon's diversity index (Spellerberg and Fedor 2003) for each study segment was assessed for the past five years and plotted with bar graphs. Richness and relative density (%; [sum(species *x* density)/sum(all species density)]*100) of spring-associated fishes (Table 2) were also quantified and presented in the same manner as species richness and diversity.

Table 2. Spring-associated fishes within the San Marcos Springs system based on Craig et al. (2016).

SCIENTIFIC NAME	COMMON NAME
Dionda nigrotaeniata	Guadalupe Roundnose Minnow
Notropis amabilis	Texas Shiner
Alburnops chalybaeus	Ironcolor Shiner
Astyanax argentatus	Texas Tetra
Gambusia geiseri	Largespring Gambusia
Etheostoma fonticola	Fountain Darter
Percina apristis	Guadalupe Darter
Percina carbonaria	Texas Logperch

San Marcos Salamander

Visual Surveys

Salamander surveys were conducted during the spring and fall monitoring events at three sites within Spring Lake and the San Marcos River (Figure 1), which were previously described as habitat for San Marcos Salamander (Nelson 1993). Two of the sites are located within Spring Lake: the Hotel Site is adjacent to the old hotel, and the Riverbed Site was located across from the former Aquarena Springs boat dock. The third survey area, called the Spring Lake Dam Site, is located in the main river channel immediately downstream of Spring Lake Dam in the eastern spillway. This site is subdivided into three smaller areas to allow greater coverage of suitable salamander habitat.

SCUBA gear was used to sample habitats in Spring Lake, while a mask and snorkel were used in the site below Spring Lake Dam. For each sample, an area of macrophyte-free rock was outlined using flagging tape, and three timed surveys (five minutes each) were conducted by overturning rocks >5 cm wide and counting the number of San Marcos Salamanders observed underneath. Following each timed search, the total number of rocks surveyed was recorded to estimate the number of San Marcos Salamanders per rock in the area searched. The three surveys were averaged to yield the number of San Marcos Salamanders per rock. Densities of suitably sized rocks at each sampling site were determined using quadrats (0.25 m^2). Three random samples were taken in each area by randomly throwing the quadrat into the sampling area and counting the number of appropriately sized rocks. The three samples were then averaged to yield a density estimate of the number of suitable rocks in the sampling area. The area of each site was determined by measuring each sampling area with a tape measure.

Data Analysis

Salamander densities (salamanders/m^2) are presented for each season using bar graphs and are compared with long-term (2001–present) spring, fall, high-flow event, and low-flow event averages. High-flow and low-flow averages were calculated from Critical Period events. These events are based on predetermined river discharge triggers (Appendix A), which result in additional survey events to assess flow-related impacts to the San Marcos Salamander population. Temporal trends in salamander density were also assessed per sampling event for each study site for the past five years using bar graphs.

Macroinvertebrates

Rapid Bioassessment Sampling

Rapid Bioassessment Protocols (RBPs) are tools for evaluating biotic integrity and overall habitat health, based on the community of organisms present (Barbour et al. 1999). Macroinvertebrates are the most frequently used biological units for RBPs because they are ubiquitous, diverse, and there is an acceptable working knowledge of their taxonomy and life histories (Poff et al. 2006, Merritt et al. 2008).

BIO-WEST performed sampling and processing of freshwater benthic macroinvertebrates, following Texas RBP standards (TCEQ 2014). Macroinvertebrates were sampled with a D-frame kick net (mesh size 500 micrometers [µm]) by disturbing riffle or run habitat (consisting primarily of cobble-gravel substrate) for five minutes while moving in a zig-zag fashion up-stream. Invertebrates were then randomly distributed in a tray and subsamples were taken by scooping out random portions of material and placing them into a separate sorting tray.

All macroinvertebrates were picked from the tray before another subsample was taken. This process was continued until a minimum of 140 individuals were picked to represent a sample. If the entire sample did not contain 140 individuals, the process was repeated again until this minimum count was reached. Macroinvertebrates were collected in this fashion from Spring Lake, Spring Lake Dam, City Park, and I-35 reaches, during spring and fall sampling (Figure 1).

Sample Processing and Data Analysis

Picked samples were preserved in 80% denatured ethanol, returned to the laboratory, and identified to TCEQ-recommended taxonomic levels (TCEQ 2014). This is usually genus, though members of the family Chironomidae (non-biting midges) and class Oligochaeta (worms) were retained at those taxonomic levels. The 12 ecological measures or metrics of the Texas RBP benthic index of biotic integrity (B-IBI) were calculated for each sample. Each metric represents a functional aspect of the macroinvertebrate community, related to ecosystem health, and sample values are scored from 1 to 4 based on benchmarks set by reference condition streams for the state of Texas. The aggregate of all 12 metric scores for a sample represent the B-IBI score for the reach that sample was taken from. The B-IBI point-scores for each sample are compared to benchmark ranges and are described as having aquatic-life-uses as “Exceptional”, “High”, “Intermediate”, or “Limited”. In this way, point-scores were calculated and the aquatic-life-use for each sample reach was evaluated. Temporal trends in B-IBI scores were assessed per sampling event for each study site for the past five years using bar graphs.

RESULTS and DISCUSSION

In 2024, central Texas continued to experience low precipitation and higher ambient temperatures similar to conditions observed in 2022 and 2023. Drought conditions throughout most of the Texas Hill Country deteriorated during the year, worsening to Extreme conditions (as designated by the National Weather Service [NWS]) in October. As described in the next section, river discharge in the San Marcos River increased in magnitude at the beginning of the year as regional and local rain increased springflow contributions, resulting in approximately median historical discharge in February and March. However, discharge declined well below median historical conditions through the remainder of the year. While 2024 represented another low-flow year, changes in habitat conditions and species metrics were less severe or even improved compared to 2023, a year in which the lowest flows since 1956 were observed and flows were below median historical expectations the entire year. Median mean daily discharge was higher in 2024 (112) than in 2023 (88 cfs). It was similar to previous low-flow years in 2006 (116 cfs), 2009 (96 cfs), 2011 (117 cfs), and 2022 (119 cfs). However, unlike previous low-flow years, flows did not return to normal levels by fall but actually decreased to the lowest point in October (87 cfs).

Although conditions were below long-term expectations for most of the year, impacts to habitat were not as drastic as in 2023. Habitat quality documented for the Covered Species varied spatially over the year as flows declined. Despite declining flows, habitat quality remained suitable for the San Marcos Salamander in Spring Lake and Spring Lake Dam. Suitable Fountain Darter habitat persisted at all three study reaches and was benefitted by prevalence of bryophytes intermixed with other vegetation taxa. Texas Wild-rice coverage was reduced within the study reaches under these drought conditions due to reductions in wetted area and competition with terrestrial competitors in shallow areas, though survival and even expansion was noted in deeper habitats. Warmer water temperatures above 25 °C were documented infrequently, mostly during the late spring and summer months, at all stations from Spring Lake Dam and below.

In summary, 2024 represented a third consecutive year of prolonged low flows in the San Marcos River System. Although flows were below historical expectations for most of 2024, results suggest that an increase in discharge early in the year helped maintain habitat conditions and promoted opportunities for improvement. It remains important to keep tracking the system-wide conditions for the Covered Species as these lower-than average discharge levels continue to persist. The remaining sections in the Results and Discussion describe observed patterns in river discharge, water temperature, Covered Species populations, and select floral and faunal communities through the San Marcos Springs/River system during this low-flow year.

River Discharge

Over the last five years, median annual mean daily discharge exhibited a declining trend from 2020 (149 cfs) to 2024 (112 cfs), representing a decline from ~41st to ~22nd percentile magnitudes, respectively. Minimum discharge also showed a decreasing trend from 2020 (119 cfs) to 2024 (82 cfs), but maximum discharge did not decrease substantially over the past five years. Maximum annual discharge was highest in 2021 (579 cfs), representing a >99th percentile event, and was lowest in 2023 (132 cfs). The maximum discharge in 2021 was the only time during the last five years when a >300 cfs high pulse event occurred. Variation in mean daily discharge (i.e., interquartile range) did not display any strong trends, but was highest from 2021–2022 (57–60 cfs) and lowest in 2023 (8 cfs). Despite the overall decreasing trend in annual discharge patterns, median, upper quartile, and maximum discharge increased to magnitudes >100 cfs from 2023 to 2024 (Figure 5A).

Monthly river discharge in 2024 showed an increase in magnitude at the beginning of the year that was followed by a decline. High variability in river discharge observed in January (76 cfs) indicated an increase in springflow (+ ~75 cfs; USGS 2024), which was likely explained by increased springflow contributions from both regional (J-17 Index Well: + ~9 ft; EAA 2024) and local (Blanco River gage #08171300: + ~400 cfs; USGS 2024) sources within the recharge zone. That said, local contributions from the Blanco River have minimal effects on long-term springflow trends relative to regional recharge sources (Smith et al. 2015). As such, monthly patterns reflected this short-term recharge increase early in the year. Specifically, median discharge increased from January (89 cfs) to March (157 cfs), with medians in February (170 cfs) and March representing the only months that approximated their respective long-term medians. Following March, median discharge declined the rest of the year and was roughly equal to the long-term 10th percentile magnitude by October (87 cfs) (Figure 5B).

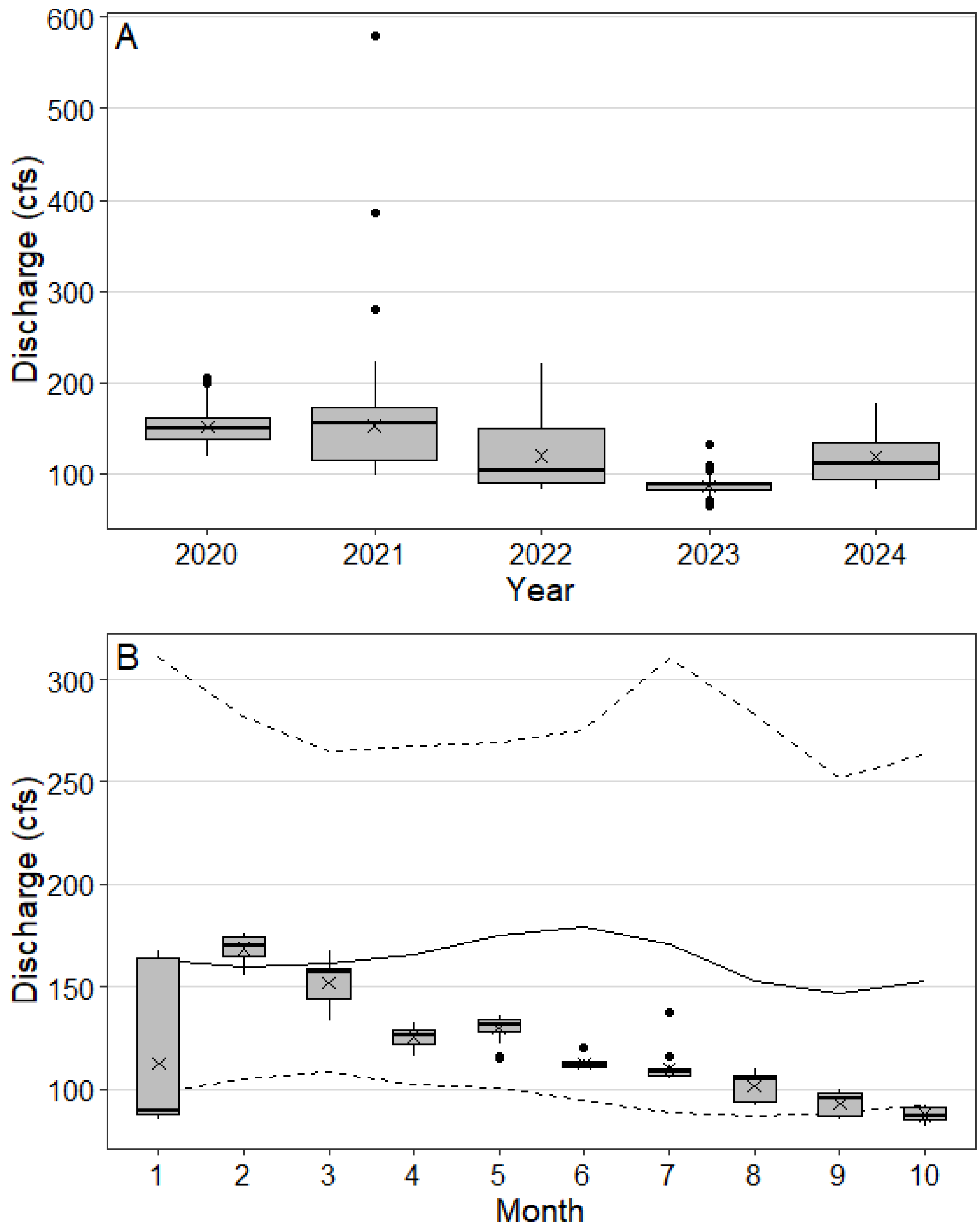

Figure 5. **Boxplots displaying San Marcos River mean daily discharge annually from 2020–2024 (A) and among months (January–October) in 2024 (B). Each month is compared to the 10th percentile (lower dashed line), median (solid line), and 90th percentile (upper dashed line) of their historical (1956, 1994–2024) daily means. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range, and outliers beyond this are designated with solid black circles.**

Water Temperature

Median water temperature did not display a longitudinal trend and was stable from Spring Lake stations (21.9–22.4 °C) to Wastewater Treatment Plant (22.8 °C). Instead, water temperature illustrated a variability (i.e., interquartile range) gradient, increasing from < 1 °C in spring habitats to a maximum of ~ 3 °C at stations farthest downstream (Figure 6). This longitudinal gradient in 2024 matched 5-year and long-term data trends and is typical within spring-associated ecosystems, where water temperatures increase in magnitude and variation with increasing distance from spring inputs (Kollaus and Bonner 2012). This pattern of greater variation with increasing distance downstream coincided with more frequent measurements > 25 °C. Water temperature was never above 25 °C at Spring Lake Deep, Spring Lake, and Chute, and rarely exceeded this temperature at Spring Lake Dam. Water temperature exceeded 26 °C at the remaining stations. Measurements > 26 °C were generally rare at these stations but were most frequent at Thompson Island Artificial and Wastewater Treatment Plant (Figure 6).

The Fountain Darter larval production threshold (25 °C) was exceeded for at least one day from April to October at all riverine stations. At Spring Lake Dam, this occurred for nine days in May. For other stations, the number of days of larval temperature threshold exceedance ranged from one to ~25 days per month. Thompson Island Natural and Wastewater Treatment Plant were the only two stations where larval exceedance was > 20 days for a given month. In general, frequency of exceedance increased from April to September and decreased by October. The number of 4-hour measurements exceeding the threshold were mostly 1–2 per day, rarely increasing to 3 per day, though they were relatively more frequent at both Thompson Island stations and Wastewater Treatment Plant.

Monthly patterns in exceedance of the optimal egg production threshold (26 °C) were less frequent than the larval threshold and generally occurred from June to October at City Park and downstream. Exceedances occurred from 5–12 days/month at City Park from June to September. Egg production threshold exceedance only occurred in September at Rio Vista Park (3 days) and in July at I-35 (1 day). Temperatures above 26 °C at Thomspon Island were measured in June (1 day) and August (6 days). At Thompson Island Artificial and Wastewater Treatment Plant, the frequency of egg production temperature exceedance increased from June (~6 days) to September (~13 days), followed by a decreased frequency in October (0–5 days).

Fountain Darter reproductive thresholds within the study reaches were exceeded more frequently in low-flow years (i.e., 2022-2024) than in higher flow years (i.e., 2020-2021). For example, the egg production threshold at City Park was not exceeded in 2020 or 2021, but was exceeded for 31 days in 2022, 8 days in 2023, and 12 days in 2024. Temperature exceedances were lower in 2024 than in 2023 for some reaches. At Spring Lake Dam, the larval production threshold was exceeded for 11 fewer days in 2024. At I-35, the egg production threshold was exceeded for 13 days in 2023 but for one day in 2024. Based on patterns in Fountain Darter population demography within each of the drop-net study reaches, peak periods of elevated water temperatures in summer 2024 did not have a strong negative affect on overall population condition or recruitment rates (see subsequent sections for more details).

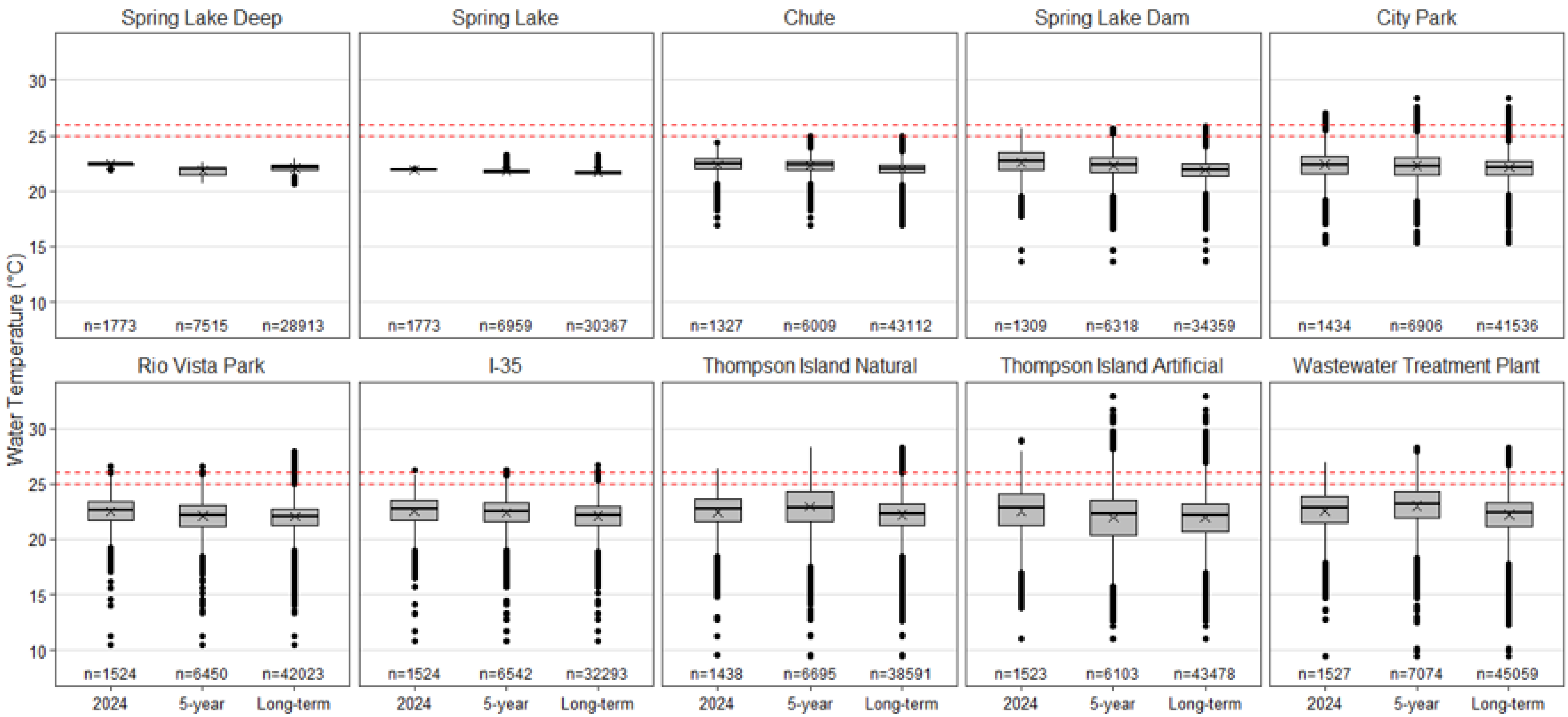

Figure 6. **Boxplots displaying 2024, 5-year (2020–2024), and long-term (2020–2024) water temperature trends in the San Marcos Springs/River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range, and outliers beyond this are designated with solid black circles. The "n" values along the x-axis represent the number of individual temperature measurements in each category. The lower and upper red dashed lines indicate maximum optimal temperatures for Fountain Darter larval (≥25 °C) and egg (≥26 °C) production (McDonald et al. 2007), respectively.**

Aquatic Vegetation

Spring Lake Dam Reach

Aquatic vegetation in the Spring Lake Dam reach remained relatively stable during 2024 compared to previous low-flow years. Total vegetation decreased in spring from 1,460 m^2 to 1,314 m^2 in the fall, with the majority of vegetation loss from Texas Wild-rice near the recreational access point. The spring total coverage was similar to the long-term average (1,486 m^2), while fall coverage was greater than the long-term average (1,202 m^2; Figure 7). Texas Wild-rice was the dominant vegetation across both seasons (85%) with other taxa, including *Potamogeton* and *Hydrocotyle*, comprising 221 m^2 (15%) in the spring and 204 m^2 (15%) in the fall (Figure 8). Vegetation loss from spring to fall was likely a combined result of both recreation and flow reduction as summer progressed. The Spring Lake Dam reach has been a popular recreation area over the past decade, when access is allowed. Low flows in the summer of 2024 produced shallower depths and slower velocities which intensified recreational impacts. However, the addition of recreation barriers around the eastern spillway presumably decreased wading in the area and protected the largest stands of Texas Wild-rice in the reach.

City Park Reach

Total vegetation coverage in this reach was lower than long-term averages in the spring and fall. Spring vegetation totaled 3,399 m^2 with Texas Wild-rice accounting for 93% (Figure 7). By fall, vegetation coverage receded to 2,510 m^2 with Texas Wild-rice representing 92%. Other taxa including *Cabomba*, *Sagittaria*, and *Ludwigia* accounted for about 200 m^2 (6-7%) in both seasons (Figure 8). *Cabomba*, which has been observed to increase in both Comal and San Marcos systems during low flows, was the second most dominant taxa throughout the year and has remained persistent in a few areas outside of the main flow path and away from heavy recreation. The bryophytes that persisted in this reach in 2023 were absent by spring 2024. However, as flows decreased throughout the year, small individual bryophyte patches and bryophytes intermixed with other taxa were observed by fall. While the City Park reach maintains the most vegetation relative to Spring Lake Dam or I-35, it also receives the most recreational impacts from wading, swimming, and tubing. As such, large seasonal fluctuations in vegetation from spring to fall have been a consistent long-term pattern observed in this reach (Figure 8). That said, the change in total coverage from spring to fall (889 m^2) was less than in 2023 (1,548 m^2). In contrast to 2023 when the lowest flows coincided with peak summer recreation, flows in 2024 did not decrease drastically until mid-August when recreation tapered off.

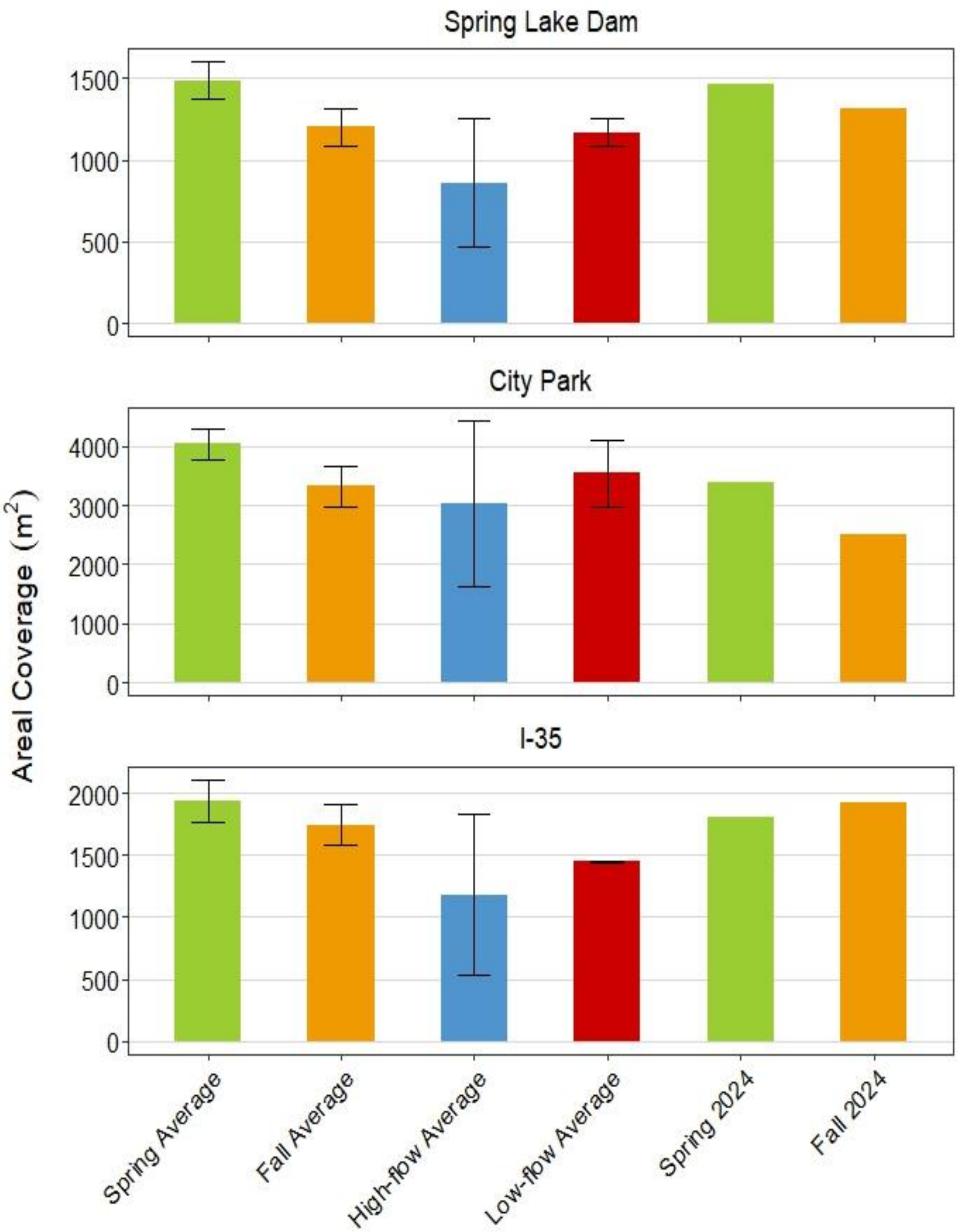

Figure 7. **Areal Coverage (m^2) of aquatic vegetation among study reaches in the San Marcos River. Long-term study averages were calculated from 2000-2024 for Spring Lake Dam and City Park and from 2014-2024 for I-35. Long-term study averages are provided with error bars representing 95% confidence intervals.**

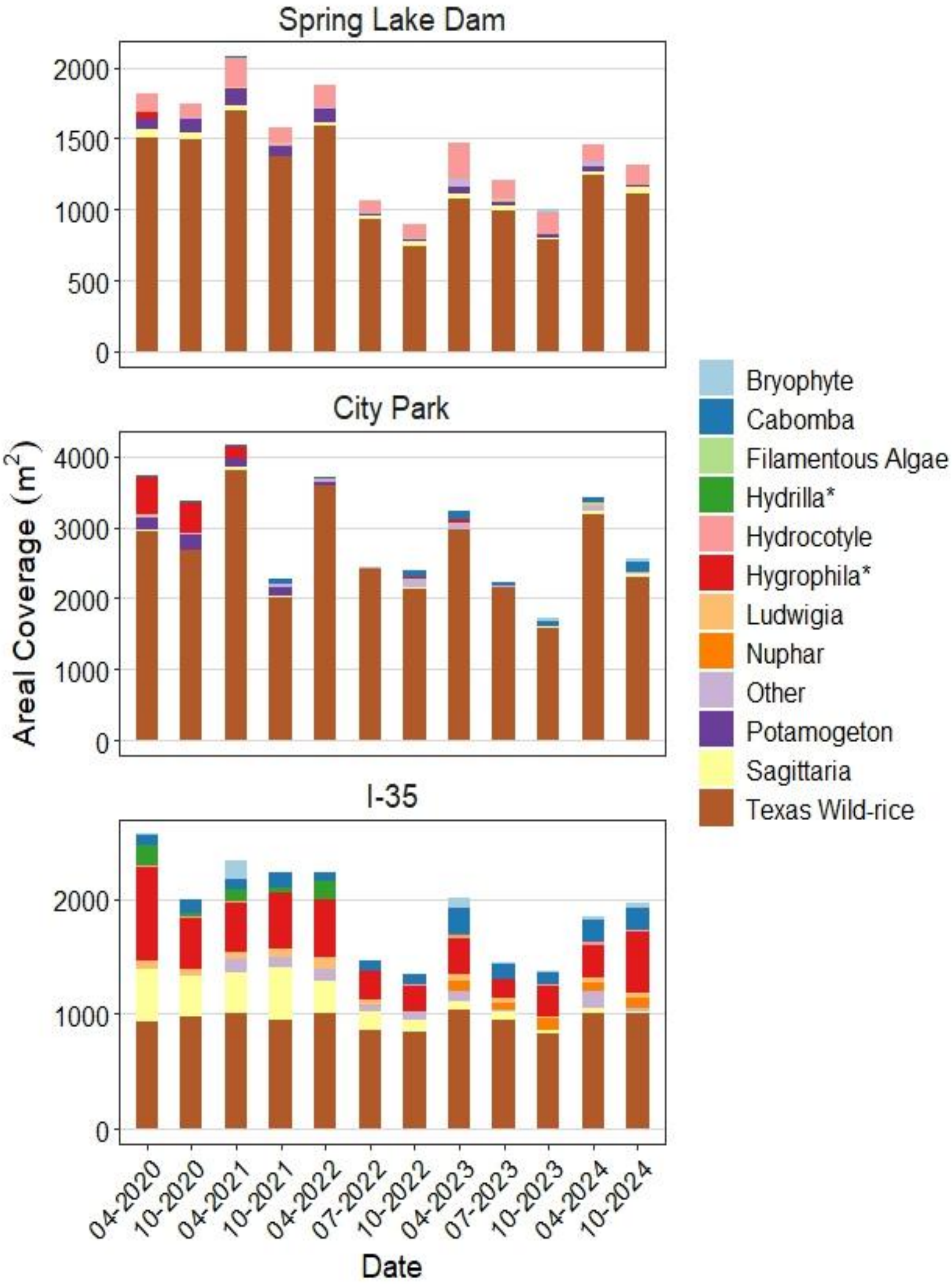

Figure 8. **Aquatic vegetation (m^2) composition among taxa (top row) from 2020–2024 in the San Marcos River. (*) in the legend denote non-native taxa.**

I-35 Reach

Total vegetation coverage at I-35 was similar to the long-term average in spring and was slightly higher than the long-term average in fall. Of the three study reaches, I-35 was the only one to show an increase in vegetation from spring to fall (Figure 7). In spring, total vegetation coverage was 1,809 m^2 and rose to 1,917 m^2 by fall. Texas Wild-rice was the most dominant taxa in the spring (56%; 1,008 m^2) and fall (53%; 1,012 m^2). Expansion of *Hygrophila* accounted for a majority of the increase in vegetation between spring and fall events as it increased from 280 m^2 (15%) in the spring to 518 m^2 (27%) in the fall (Figure 8). I-35 remains the most diverse reach with Texas Wild-rice, *Hygrophila*, *Cabomba*, *Sagittaria,* and *Nuphar* very abundant (Figure 8). Several other taxa were present in smaller abundances including *Hydrocotyle* and *Ludwigia*. Additionally, bryophytes persisted in both spring and fall in greater abundances than in higher flow years (e.g., 2019-2021). River morphology has changed in this reach over the past couple of years due to sustained low flows. In the lower half of the reach, the majority of flow has now been diverted to river right, leaving a large dewatered area on river left near Snake Island. This has allowed for littoral and terrestrial taxa to establish. Amphibious taxa such as *Hygrophila* and *Sagittaria* continued to survive as emergent plants in this area, while taxa such as *Cabomba* and Texas Wild-rice shifted to deeper water for survival. In addition to the expansion of *Hygrophila* in shallow areas along the bank, coverage of this taxa also increased in deeper areas within the main river channel, contributing to the higher vegetation coverage in fall.

Texas Wild-rice

Texas Wild-rice Mapping

In 2024, Texas Wild-rice was mapped once from Spring Lake to the confluence of the Blanco River during the annual summer mapping event in July/August. Flows decreased below 100 cfs in August and remained below 90 cfs through October (Figure 5B). The lowest flows occurred in October when total discharge decreased to about 82 cfs. Full system maps are located in Appendix B. Total coverage of Texas Wild-rice was 11,272 m^2 in 2024, a substantial increase from the September low-flow event in 2023 (8,211 m^2) but similar to the previous annual summer mapping event in 2023 (11,820 m^2; Figure 9). This increase is in part attributed to expansion below Cheatham Street bridge and areas around Purgatory Creek and Hopkins Bridge which have been cleared of *Hydrilla*. Impacts to the physical structure of Texas Wild-rice (e.g., root exposure, thickness) were observed in 2024 and most noticeable in areas adjacent to public access points in Spring Lake Dam and City Park reaches where recreation is high. However, less impacts to the structure and coverage of Texas Wild-rice stands were observed in 2024 compared to 2023 when low flows were sustained throughout the entire year. Over the long-term, coverage since 2018 has fluctuated around 10,000-15,000 m^2, approximately 2-3 times pre-HCP levels.

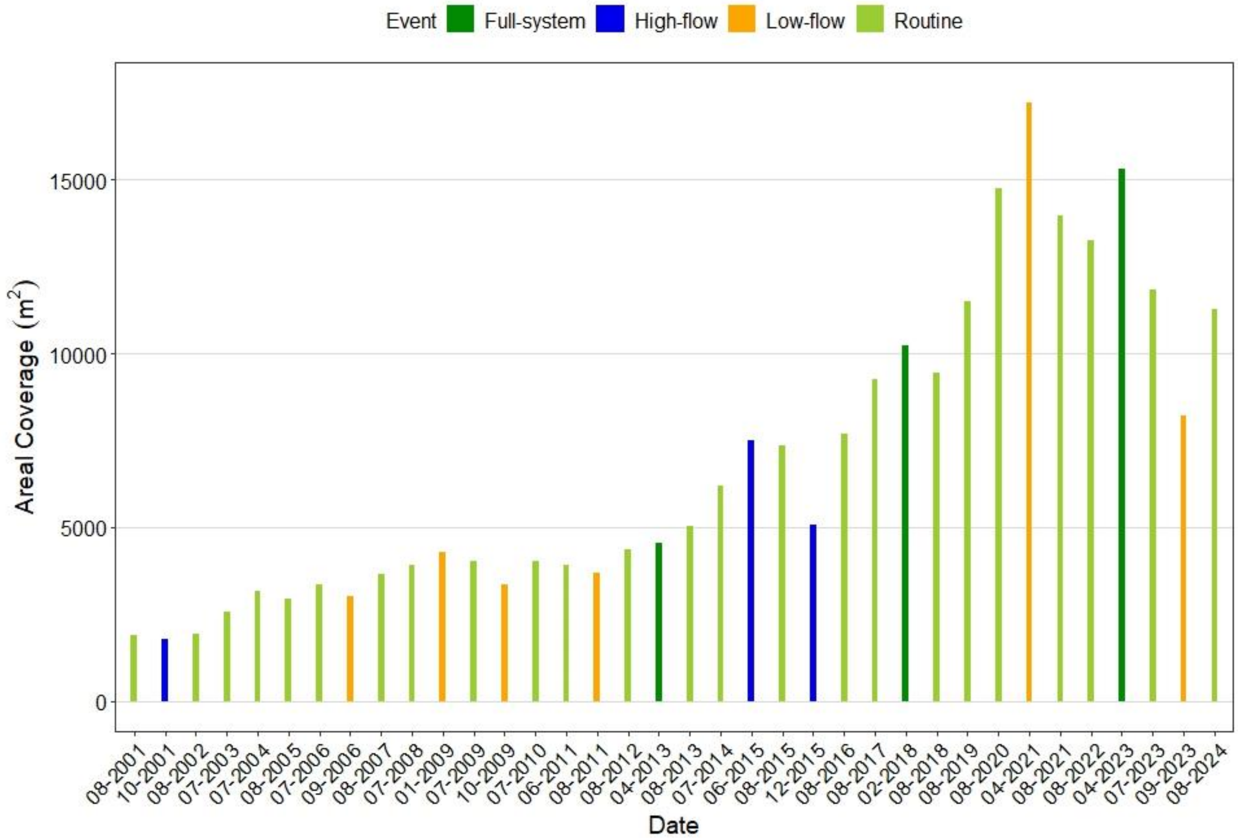

Figure 9. **Texas Wild-rice areal coverage (m^2) from 2001–2024 in the upper San Marcos River.**

Between July/August 2023 and July/August 2024, Texas Wild-rice coverage was approximately the same with changes varying by river segment (Table 3). Texas Wild-rice decreased in Segments B, C, and E. The largest loss of Texas Wild-rice occurred in Segment C (City Park Bend), with a decrease of over 1,000 m^2 since the 2023 annual mapping event. A large area has been dewatered in this segment with Texas Wild-rice remaining only in the wetted thalweg. Texas Wild-rice in Segment B, Sewell Park, continued to be outcompeted by terrestrial vegetation which expanded in exposed sediments that are typically submerged. Decreases in Segment E, Lower City Park, are attributed to recreational traffic that thins or uproots the plants.

Increases in Texas Wild-rice were observed in Segments A, D, F, G, and H (Table 3). One of the largest increases occurred in Segment F, Veramendi Park to Rio Vista Park, with 563 m^2 more Texas Wild-rice in 2024 than in July/August 2023. Expansion of Texas Wild-rice throughout this segment was aided by removal of *Hydrilla* and some planting efforts. Texas Wild-rice also increased in Segment H, below I-35, which is largely a result of natural expansion above Cape's Dam. The continued increasing trend in this segment in recent years can also be attributed to the limited nature of large flow pulses over the past few years. Exclusion zones in Segment A, Spring Lake Dam Study reach, allowed Texas Wild-rice to persist near the eastern spillway.

The Texas wild-rice population has continued to adapt to low-flow conditions which have been ongoing for three years. As the river morphology has adjusted to prolonged low flows, the deepened river channel and increase in pool habitats allowed Texas Wild-rice to persist and even expand in some areas. However, development of weedy riparian vegetation in shallow areas along the bank has outcompeted emergent Texas Wild-rice (Figure 10). If drought conditions extend beyond 2024, it is likely Texas Wild-rice colonies will persist more in the deeper areas of the river and the occurrence of emergent Texas Wild-rice along stream edges will be less common.

Table 3. Change in coverage (m^2) of Texas Wild-rice between July/August 2023 and July/August 2024 annual mapping.

RIVER SEGMENT	JULY/AUGUST 2023 COVERAGE	JULY/AUGUST 2024 COVERAGE	COVERAGE CHANGE	PERCENT CHANGE
A. Spring Lake Dam Study Reach	1,033	1,063	+30	+3
B. Sewell Park	946	732	-214	-29
C. City Park bend	3,276	2,159	-1,117	-51
D. City Park Study Reach	2,172	2,344	+172	+7
E. Lower City Park	1,223	1,095	-128	-12
F. Veramendi Park to Rio Vista Park	1,626	2,189	+563	+26
G. I-35 Study Reach	954	986	+32	+3
H. Below I-35	502	571	+69	+12
Spring Lake	88	133	+45	+34

Figure 10. **(A) A large stand of emergent Texas Wild-rice at upper City Park in May 2019. (B) The same area at upper City Park in October 2024, after dewatering led to its replacement by terrestrial vegetation (*Ceratopteris thalictroides* and *Bacopa monnieri*) in shallow areas.**

Fountain Darter

A total of 1,025 Fountain Darters were observed at 54 drop-net samples in 2024. Drop-net densities ranged from 0.00–55.50 darters/m^2. Community summaries and raw drop-net data are included in Appendix D and Appendix F, respectively. Habitat conditions observed during drop-netting are summarized in Table 4. Texas Wild-rice was only sampled in spring 2024 because river discharge decreased below 120 cfs by fall.

Table 4. Habitat conditions observed during 2024 drop-net sampling. Physical habitat parameters include counts of dominant vegetation (median % composition) and dominant substrate type sampled. Depth-velocity and water quality parameters include medians (min-max) of each variable among all drop-net samples.

HABITAT PARAMETERS	SLD	CP	I-35
Vegetation			
Cabomba[1]	0	4 (100%)	4 (100%)
Hydrocotyle[1]	4 (85%)	0	4 (75%
Hygrophila[1]	0	0	4 (98%)
Ludwigia[1]	0	4 (85%)	2 (88%)
Open	4 (100%)	4 (100%)	4 (100%)
Potamogeton[2]	4 (85%)	0	0
Sagittaria[2]	4 (95%)	2 (98%)	0
Texas Wild-rice[2]	2 (93%)	2 (85%)	2 (93%)
Substrate			
Cobble	10	2	0
Gravel	4	2	4
Sand	1	0	10
Silt	3	12	6
Depth-velocity			
Water depth (ft)	1.1 (0.4–2.3)	1.6 (0.8–2.8)	1.2 (0.4–2.7)
Mean column velocity (ft/s)	0.1 (0.0–1.6)	0.1 (0.0–0.8)	0.2 (0.0–1.1)
15-cm column velocity (ft/s)	0.1 (0.0–1.4)	0.1 (0.0–0.8)	0.3 (0.0–1.0)
Water quality			
Water temperature (°C)	22.2 (21.6–22.7)	22.7 (21.2–23.9)	22.3 (20.3–23.7)
DO (ppm)	7.8 (7.3–8.3)	8.8 (7.5–10.2)	9.0 (7.1–11.0)
DO % saturation	91.4 (82.7–96.4)	101.8 (84.4–120.2)	104.0 (79.6–129.5)
pH	7.3 (7.3–7.4)	7.5 (7.3–7.9)	8.6 (8.1–8.9)
Specific conductance (µs/cm)	648 (646–662)	647 (584–650)	643 (611–647)

[1]Denotes ornate vegetation taxa with physical characteristics that create complex structure
[2]Denotes long broad or ribbon-like, austere-leaved vegetation taxa

Timed dip-netting resulted in a total of 540 Fountain Darters during 10.50 person-hours (p-h) of effort. Site CPUE ranged from 2–102 darters/p-h. Fountain Darters were present at 68 out of 180 (38%) random-stations. Reach-level percent occurrence among monitoring events ranged from 0–87%. A summary of occurrences per reach and vegetation taxa can be found in Table 5.

Table 5. Summary of vegetation types sampled among reaches during 2024 random-station surveys in the San Marcos Springs/River and the percent occurrence of Fountain Darters in each reach and vegetation type. Raw numbers represent the sum of detections per reach-vegetation type combination and '-' denotes that the vegetation type was not sampled.

VEGETATION TYPE	SL	SLD	CP	I-35	Total	Total Samples	Occurrence (%)
Bacopa[1]	-	-	1	-	**1**	**2**	**50.0**
Bryophyte[1]	-	-	2	-	**2**	**2**	**100**
Cabomba[1]	3	-	2	3	**8**	**12**	**66.7**
Ceratophyllum[1]	2	-	-	-	**2**	**2**	**100**
Graminoid[2]	-	0	-	1	**1**	**2**	**50.0**
Heteranthera[1]	-	0	1	-	**1**	**2**	**50.0**
Hydrocotyle[1]	-	7	-	-	**7**	**8**	**87.5**
Hygrophila[1]	-	-	-	20	**20**	**22**	**90.9**
Ludwigia[1]	-	1	-	2	**3**	**3**	**100**
Myriophyllum[1]	0	-	-	-	**0**	**1**	**0.0**
Nuphar[2]	-	-	-	0	**0**	**2**	**0.0**
Sagittaria[2]	1	2	1	-	**4**	**23**	**17.4**
Texas Wild-Rice[2]	-	2	14	3	**19**	**99**	**19.2**
Total	**6**	**12**	**21**	**29**	**68**	**180**	**37.8**
Total samples	**30**	**45**	**60**	**45**	**-**	**-**	**-**
Occurrence	**20.0**	**26.7**	**35.0**	**64.4**	**-**	**-**	**-**

[1]Denotes ornate vegetation taxa with physical characteristics that create complex structure
[2]Denotes long broad or ribbon-like, austere-leaved vegetation taxa

Population Demography

Seasonal population trends

Median Fountain Darter density in 2024 increased from spring (1.75 darters/m^2) to fall (2.25 darters/m^2). Upper quartiles and variability (i.e., interquartile range) were similar between seasons (~15.00 darters/m^2) (Figure 11A). Timed and random dip-netting illustrated inverse seasonal trends in 2024. Median catch rates were highest in spring (53 darters/p-h) and decreased to equal rates in summer and fall (30 darters/p-h). Median occurrence in contrast was lowest in spring (20%) and increased in summer (43%) and fall (34%) (Figure 11B, 11C). Boxplot statistics in 2024 mostly aligned with 5-year and long-term trends across indices, though several notable discrepancies were apparent. First, upper quartile densities were ~2–3 times higher than historical upper quartiles, which supports densities were higher than expected at multiple sampling locations (Figure 11A). Increased frequency of high-density samples was ubiquitous across study reaches and can at least be partially explained by higher prevalence of bryophytes within the vegetation taxa sampled in 2024 (see next section for further discussion). Second, catch rates in summer and occurrences in spring were lower than expected, with medians being more similar to their respective lower quartiles (Figure 11B, 11C). Lower values of these seasonal indices may be influenced by several factors which are discussed below.

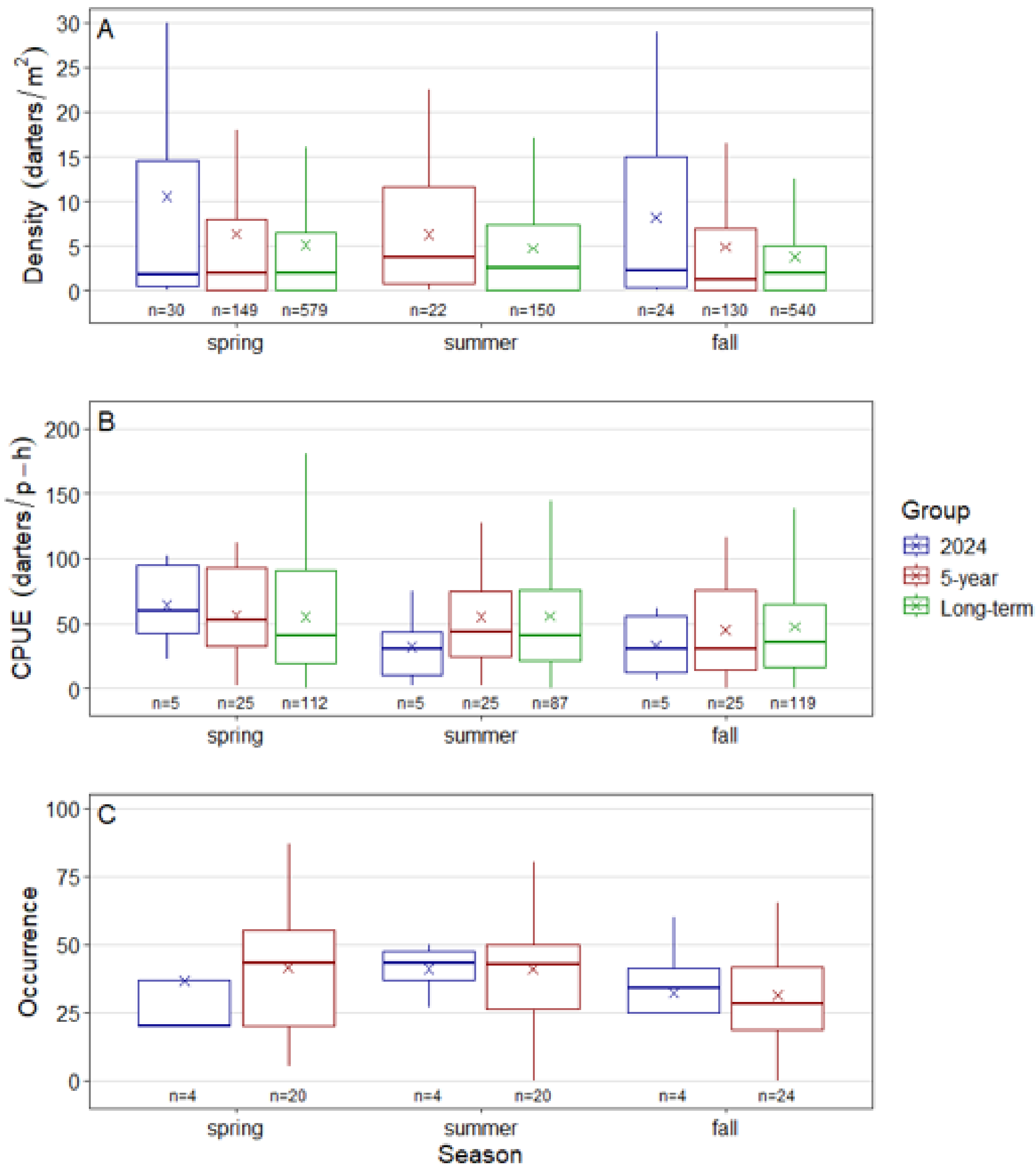

Figure 11. **Boxplots comparing Fountain Darter density from drop-net sampling (A), catch-per-unit-effort (CPUE) from timed dip-netting (B), and proportional occurrence from random-station dip-netting (C) among seasons in the San Marcos Springs/River. Temporal groups include 2024, 5-year (2020–2024), and long-term (2001–2024) observations. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent the number of discrete samples per category.**

Catch rates and occurrences in Spring Lake were lower in 2023 and 2024 than in previous higher flow years (2017-2021), suggesting that the littoral zone around the lake perimeter has provided suboptimal habitat conditions during extended durations of reduced springflow. Fish community sampling in contrast, has shown no detectable decreases in Fountain Darter density, suggesting the local population within the lake has not experienced a declining trend and darters are instead utilizing deeper habitats (BIO-WEST 2023, 2024). Additionally, ~80% of occurrence samples at Spring Lake Dam and City Park were within Texas Wild-rice. This taxon has been found to only provide suitable Fountain Darter habitat when bryophytes increase structural complexity (Alexander and Phillips 2012; Edwards and Bonner 2022). While bryophytes were observed within most Texas Wild-rice samples at these reaches, they were mostly accumulated near the water's surface rather than the riverbed. Given that Texas Wild-rice accounts for >70% of vegetation assemblages within these reaches, lower prevalence of darters during a given season should not be viewed as an unexpected phenomenon. Additionally, given the low occurrence and occasional high densities in spring, it is possible that smaller darters aggregated in more suitable habitat such as *Sagittaria* with bryophytes which was accounted for in drop-net sampling but not random-station dip-net sampling. Regardless, values of both indices returned to more historical levels during the subsequent season.

Drop-net sampling density trends

Temporal trends in Fountain Darter density from 2020–2024 varied across reaches. Median densities over time were not strongly correlated ($r < 0.7$) between reaches, suggesting spatially asynchronous dynamics over the past five years. From 2020–2023, all reaches generally displayed cyclical changes in median density that fluctuated around their respective long-term medians. In 2024, median densities at Spring Lake Dam (0.75–2.00 darters/m^2) and I-35 (1.75–2.00 darters/m^2) approximated their long-term medians. City Park, however, illustrated increased median densities in 2024 (10.75–11.75 darters/m^2) which exceeded the long-term upper quartile. Further, City Park upper quartiles have mostly increased from 2020–2024 (3.50–16.00 darters/m^2). Upper quartile densities at I-35 (9.25–12.75 darters/m^2) were also above the long-term values this year. At Spring Lake Dam, upper quartile density increased from spring (3.38 darters/m^2) to fall (9.00 darters/m^2), when it was 2.25 times greater than the long-term value (Figure 12).

Similar to 2023, results from this year suggest that the prolonged period of reduced flows since 2022 have not had an apparent negative effect on temporal patterns of Fountain Darter density in the upper San Marcos River. In fact, higher densities observed in 2024, along with relatively stable occurrence and catch rates, provide supporting evidence that population condition has improved the past five years. Data collected in 2024 demonstrated medians and upper quartiles that consistently met or exceeded long-term values across reaches. This illustrates that high-density samples were more frequent in these reaches, likely due to improved habitat quality in certain areas. For example, densities in *Sagittaria* at Spring Lake Dam in fall 2024 (25.5–39.00 darters/m^2) were 10–15 times higher than this vegetation taxon's long-term median in this reach. This substantial increase can be best explained by increased structural complexity due to higher prevalence of bryophytes (50–70%) (Alexander and Phillips 2012; Edwards and Bonner 2022). Moreover, density patterns have steadily increased at City Park since 2022. Similar to other reaches, habitat quality appears to have benefitted from increased prevalence of bryophytes. The establishment of persistent patches of *Cabomba* since 2019 is also likely an important driver of the increasing density trend at City Park. A 300% increase in *Cabomba* coverage in the reach since 2020 may have resulted in an increase in reach-level carrying capacity at City Park (Dennis et al. 2006; Boettiger 2018).

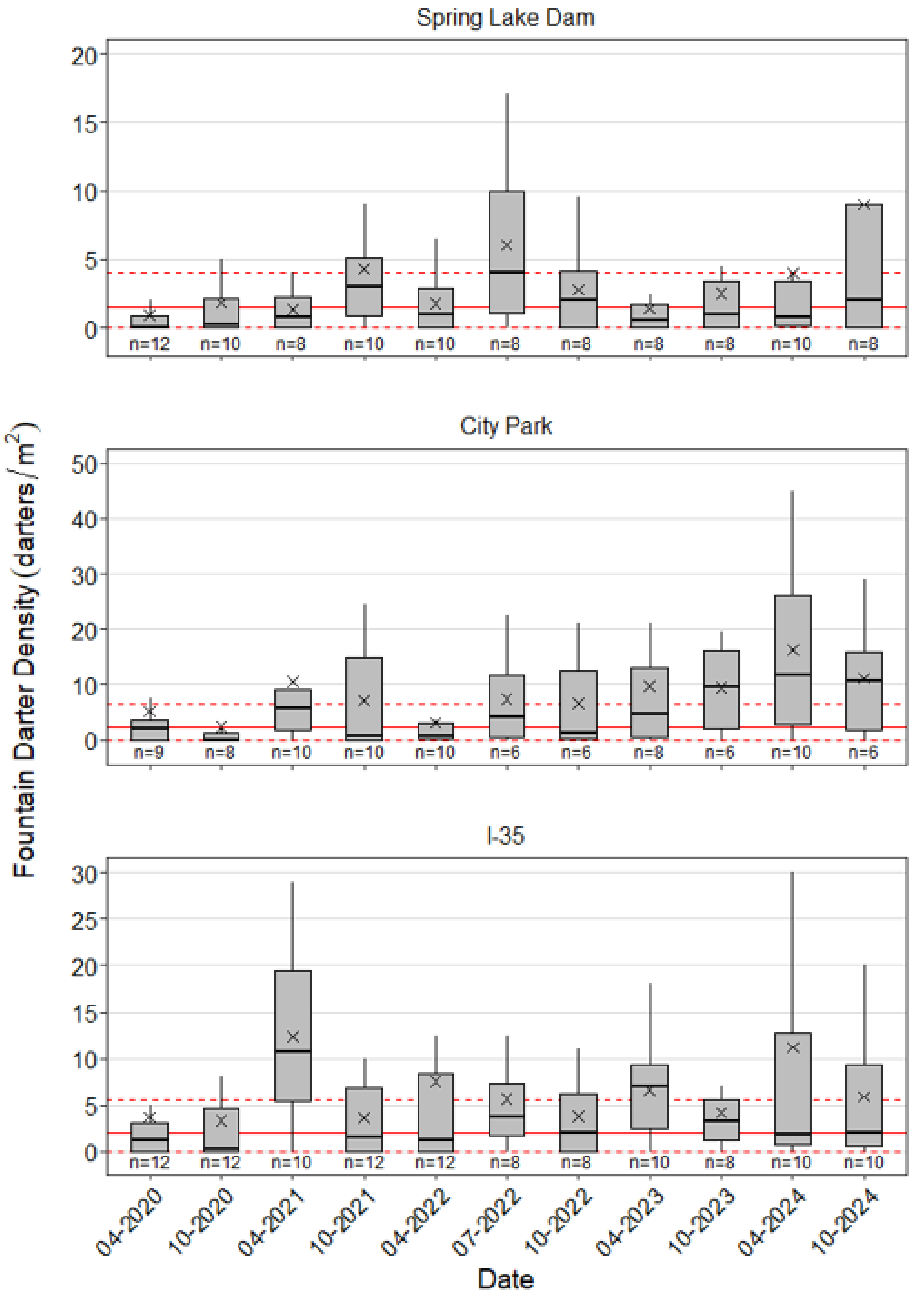

Figure 12. **Boxplots displaying temporal trends in Fountain Darter density (darters/m^2) among study reaches from 2020–2024 during drop-net sampling in the San Marcos River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent the number of drop-net samples in each category. Solid and dashed red lines denote long-term (2001–2024) medians and interquartile ranges, respectively.**

Size structure and recruitment trends

Five-year trends in Fountain Darter size structure and recruitment mostly demonstrated consistent seasonal patterns. In general, smaller darters were more frequent during peak reproduction in spring. This pattern is illustrated by lower median lengths in spring (19–21 mm) and higher prevalence of recruits (46.5–59.5%). Patterns in size structure aligned with long-term trends in spring 2024.

Median lengths were greater in summer (25–27 mm) and fall (24–29 mm) and recruitment levels were typically ~20%. Both Fountain Darter size structure and recruitment in 2024 were similar to long-term expectations across seasons. Recruitment also never dropped to meaningful levels below long-term values, though it was greater than expected during several years. In particular, recruitment in fall 2022 (39.2%) was two times greater than expected (Figure 13). This high recruitment was potentially due to low and stable flows throughout 2022, though mechanisms behind this are unclear.

Similar to five-year density trends, size structure and recruitment results do not provide evidence that the continuation of low flows altered size structure or suppressed recruitment of darters. Instead, observed data suggest that recruitment was either consistent with expectations or actually increased under low-flow conditions. Consistent patterns in size structure indicates Fountain Darter growth was not reduced in 2024. Previous studies on other riverine darters have shown reduced growth rates during periods of extreme low flows (Marsh-Matthews and Matthews 2010, Katz and Freeman 2015). Incongruency between these studies and the Fountain Darter is likely at least partially explained by the stable water temperatures in the spring-dominated upper San Marcos River, which have generally been maintained at suitable levels for the species despite prolonged low flows during this period. Fountain Darter recruitment rates were substantially higher than expected in 2022 and fell back to normal levels in 2023 and 2024, yet densities increased overall during this time period.

Potential mechanisms driving observed patterns in recruitment are poorly understood for Fountain Darters. Long-term monitoring data does illustrate higher density of recent recruits within complex vegetation, as well as the potential for greater recruitment than typical during low and stable flows (BIO-WEST 2023, 2024). That said, it remains unknown what density-independent and/or -dependent factors influence survival of recent recruits from juvenile/sub-adult life stages to sexually mature adults. Despite this lack of mechanistic knowledge, it is clear that maintaining large patches of suitable habitat is important for Fountain Darter population persistence (Duncan et al. 2016; Dunn and Angermeier 2019).

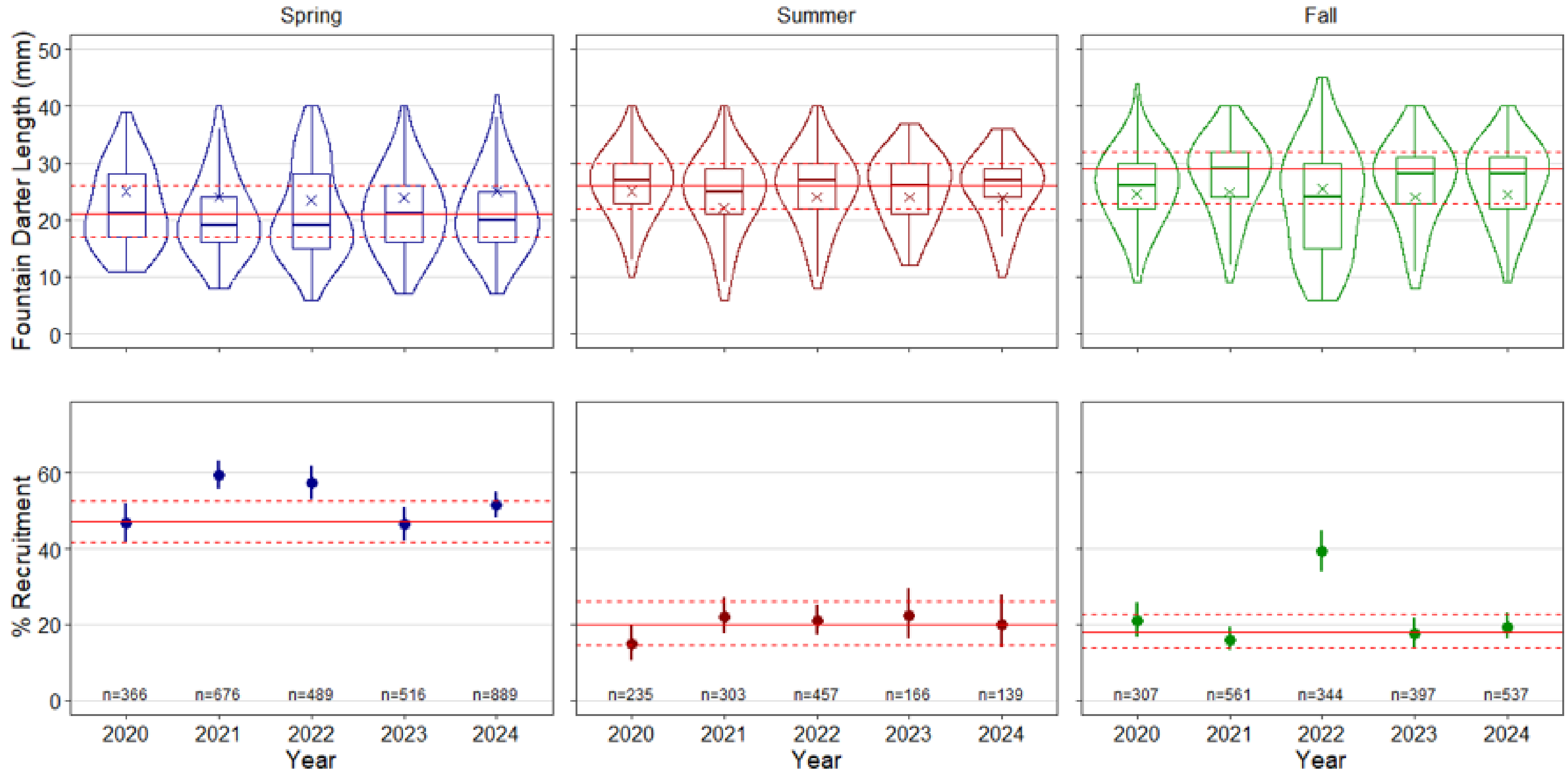

Figure 13. **Seasonal trends of Fountain Darter size structure (mm; top row) and percent recruitment (bottom row) in the San Marcos River from 2020–2024. Spring and fall are based on drop-net and timed dip-net data in aggregate, whereas summer values are based on timed dip-net data only. Size structure is displayed with boxplots (median, quartiles, range) and violin plots (probability density; polygons outlining boxplots). The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axis of the top row represent the number of Fountain Darter length measurements in each distribution. Recruitment is the percent relative abundance (± 95% CI) of darters ≤20 mm. Long-term (2001–2024) values of size structure are represented by median (solid red line) and interquartile range (dashed red lines). Recruitment is compared to the long-term mean percentage (solid red line) and 95% CI (dashed red lines).**

Habitat Use and Suitability

Density trends among vegetation taxa

Median densities in 2024 were highest in *Cabomba* (24.50 darters/m^2) and *Sagittaria* (19.75 darters/m^2). Taxa with intermediate median estimates included *Ludwigia* (10.00 darters/m^2) and *Hygrophila* (6.50 darters/m^2). Estimates were lowest within Texas Wild-rice (2.33 darters/m^2), *Hydrocotyle* (2.00 darters/m^2), *Potamogeton* (1.00 darters/m^2), and open (0.08 darters/m^2). Fountain Darter densities within *Cabomba* and *Sagittaria* this year were substantially higher compared to historical data. Furthermore, densities within *Hygrophila* and *Ludwigia* in 2024 aligned with recent five-year values, which both exceeded long-term expectations. The remaining taxa generally aligned with historical expectations, though slightly increased 2024 median density in Texas Wild-rice was notable (>0.00 darters/m^2; Figure 14).

Current patterns of vegetation use continue to generally support previous research, showing that higher Fountain Darter densities occur within ornate vegetation which provides complex structure near the benthos (Schenck and Whiteside 1976; Linam et al. 1993; Alexander and Phillips 2012; Edwards and Bonner 2022). As described in previous sections, substantial deviations in taxa-specific densities from historical data in *Cabomba* and *Sagittaria* were likely related to greater structural complexity provided by bryophytes, and possibly due to increases in *Cabomba* coverage at City Park and I-35 (Alexander and Phillips 2012; Duncan et al. 2016; Dunn and Angermeier 2019; Edwards and Bonner 2022). Reduced current velocities due to persistent low flows have allowed unrooted bryophytes to proliferate in riverine areas where they are typically limited, and have also likely facilitated the expansion of *Cabomba*, which grows best in slow-moving water.

Size structure among vegetation taxa

Boxplot summary statistics and violin plots showed that Fountain Darter size structure varied among vegetation taxa sampled in 2024. The lowest median lengths occurred in open (15 mm), Texas Wild-rice (18 mm), and *Cabomba* (21 mm), were intermediate in *Hygrophila* (23 mm) and *Ludwigia* (24 mm), and highest in *Sagittaria* (25 mm), *Potamogeton* (26 mm), and *Hydrocotyle* (29 mm). Size structure distributions for *Cabomba*, *Hygrophila*, and Texas Wild-rice demonstrated greater prevalence of smaller lengths, which suggests these taxa were important habitat for recent recruits (Figure 15). This observation was surprising for Texas Wild-rice, but further demonstrates that simple-leafed taxa can provide habitat suitable for juveniles when bryophytes are present to increase complexity (Edwards and Bonner 2022). Greater number of smaller darters were observed in *Hygrophila* in 2024 compared to 2023. As in previous years, *Cabomba* continued to provide important habitat for both recruits and adults (BIO-WEST 2024). Likewise, *Ludwigia* illustrated a bimodal distribution, with peaks ~18 mm and ~30 mm, indicating it provided habitat for both recruits and adults in 2024. This size pattern aligns with observations in 2022 and 2023 in which *Ludwigia* yielded greater proportions of smaller recruits in 2022 and larger adults in 2023. The remaining taxa generally aligned with past observations (Figure 15) (BIO-WEST 2023, 2024). In summary, size structure among vegetation taxa in 2024 showed both similarities and differences compared to previous years. Differences are likely attributed to bryophyte prevalence, spatial variation in hydraulic conditions, or other stochastic processes unaccounted for.

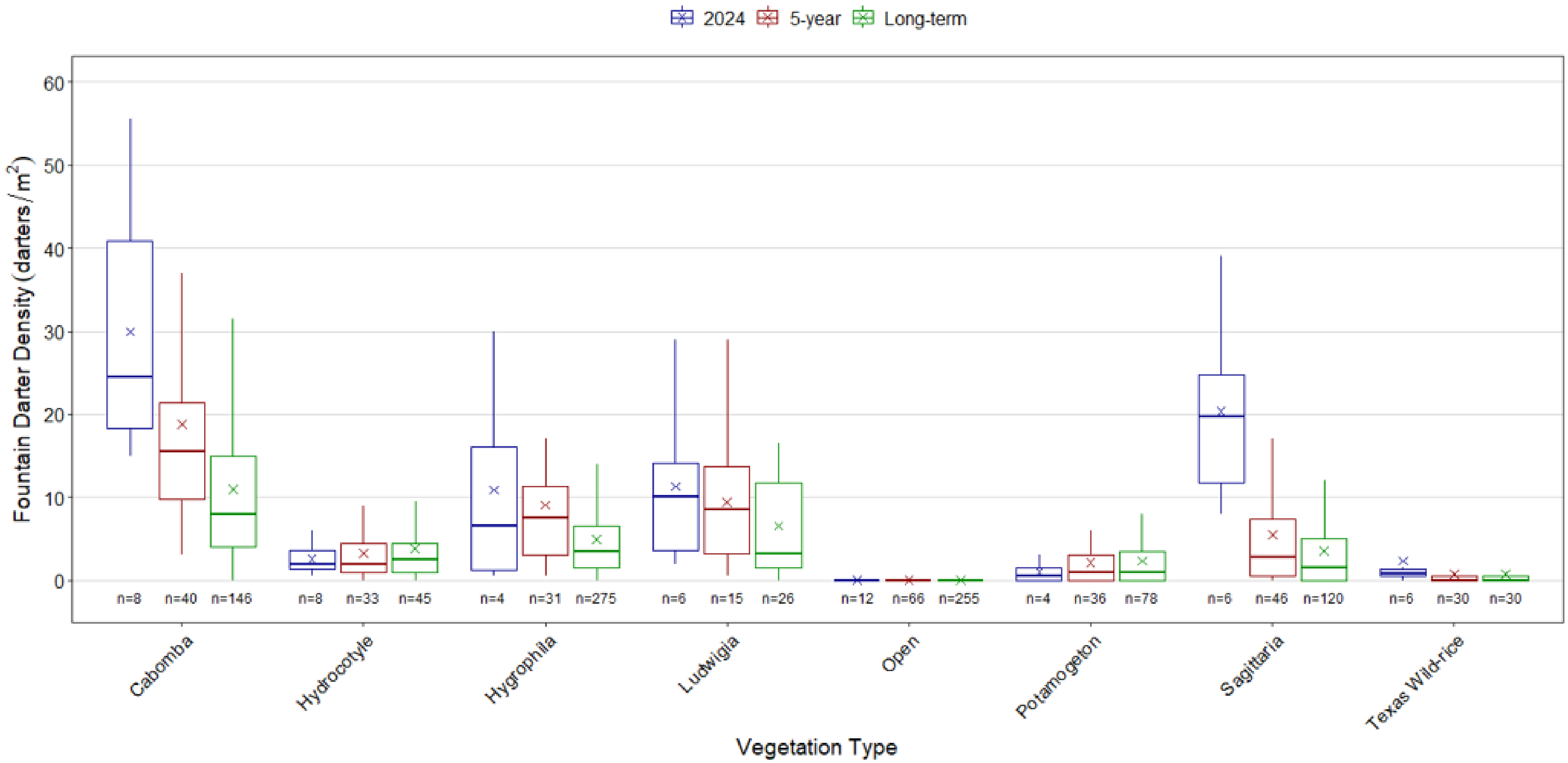

Figure 14. **Boxplots displaying 2024, 5-year (2020–2024), and long-term (2001–2024) drop-net Fountain Darter density (darters/m²) among vegetation types in the San Marcos River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent drop-net sample sizes per group.**

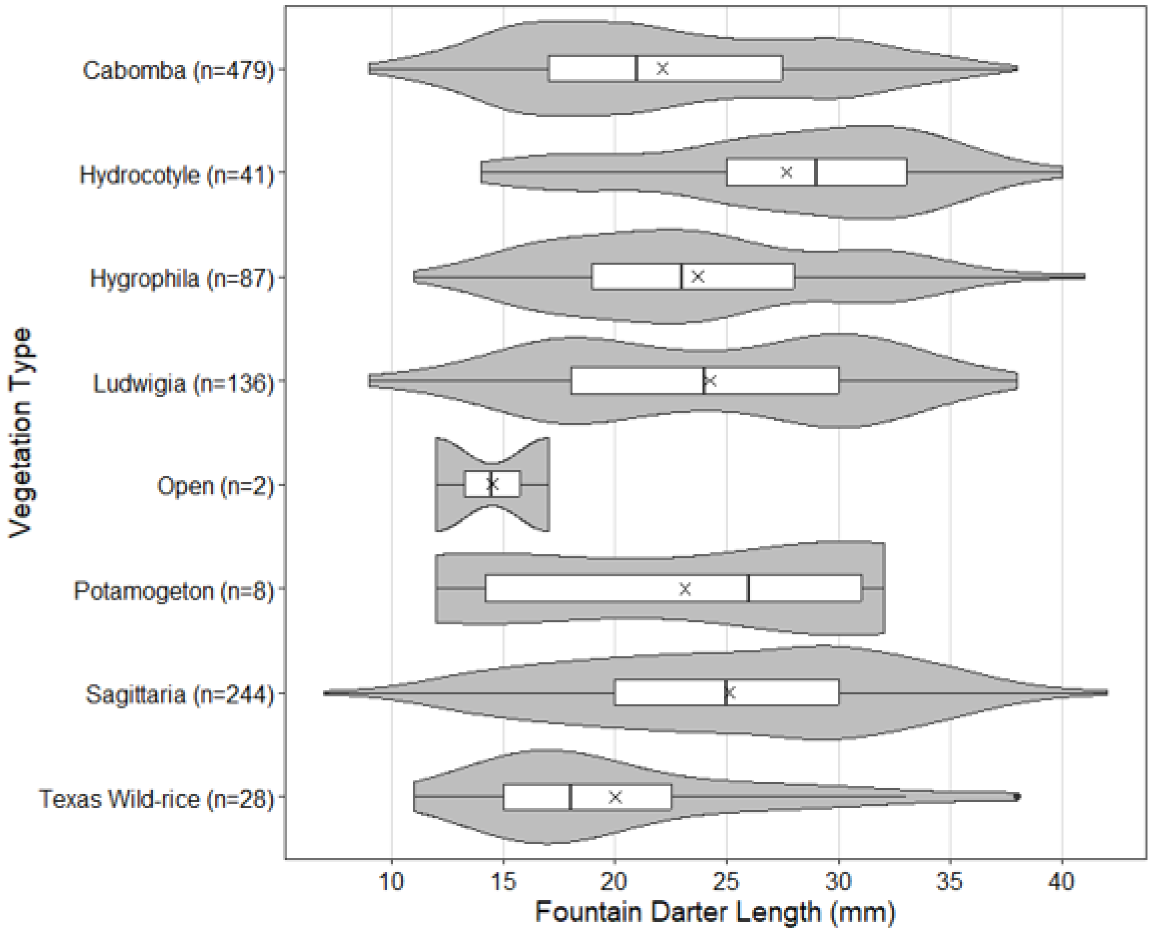

Figure 15. Boxplots and violin plots (grey polygons) displaying Fountain Darter lengths among dominant vegetation types during 2024 drop-net sampling in the San Marcos River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range, and outliers beyond this are designated with solid black circles. The "n" values represent the number of Fountain Darter length measurements per vegetation type.

Habitat suitability

Temporal trends in the Fountain Darter Overall Habitat Suitability Index (OHSI) from 2020–2024 were similar among reaches. Estimated OHSI were highly correlated ($r > 0.7$) between reaches, indicating spatially consistent patterns in habitat conditions the past five years. From 2020–2022, all reaches showed general declining trends in OHSI. Subsequent increases occurred in spring 2023, which were immediately followed by another decrease in summer 2023. OHSI displayed small to moderate increases for the remainder of the time-series. In addition, OHSI and associated confidence intervals at Spring Lake Dam and I-35 were within the bounds of their respective long-term expectations. OHSI at City Park, in contrast, remained below the lower boundary of its 95% confidence interval (Figure 16). OHSI at City Park began decreasing around 2013 and has remained below the lower boundary of its 95% confidence interval since 2016 (Appendix D, Figure D10). This is likely driven by the increase in Texas Wild-rice which began in 2013 due to planting efforts and implementation of conservation measures.

Despite the consistent trends in OHSI observed the past five years, changes in OHSI and changes in vegetation taxa coverages showed some differences among reaches. OHSI values were strongly associated with *Hydrocotyle* at Spring Lake Dam compared to *Potamogeton* and *Hygrophila* at City Park. OHSI at Spring Lake Dam and City Park was also more influenced by increases in Texas Wild-rice coverage than OHSI at I-35. Instead, changes in OHSI at I-35 were mainly due to fluctuations in coverages of *Hygrophila* and *Ludwigia*. Although increases in intermixed bryophytes resulted in increased Fountain Darter densities in 2023 and 2024, this is not captured by the OHSI which assigns long-term taxa-specific suitability criteria based on dominant vegetation. For example, a patch of *Sagittaria* with intermixed bryophytes (and thus high Fountain Darter density, as seen at Spring Lake Dam in 2024) would be assigned the long-term *Sagittaria* suitability criteria (0.59 ± 0.07) for OHSI calculations. As a result, the current OHSI framework does not accurately reflect the increased habitat structure at these microhabitat spatial resolutions. Increasing model complexity for OHSI estimates by incorporating other environmental factors (such as bryophyte presence) could provide better realizations of spatial variation in habitat suitability, both within and among reaches.

Drop-net results demonstrated darters are consistently spatially clustered within smaller patches of more suitable habitat. However, less suitable taxa may still provide important habitat to help fulfill life history requirements, such as providing dispersal corridors that facilitate connectivity among suitable habitat patches (Fagan 2002). In total, this suggests management strategies should consider expanding coverages of suitable taxa while maintaining diverse vegetation assemblages to enhance resistance and resilience during and after environmental disturbances (Duncan et al. 2016, Dunn and Angermeier 2018).

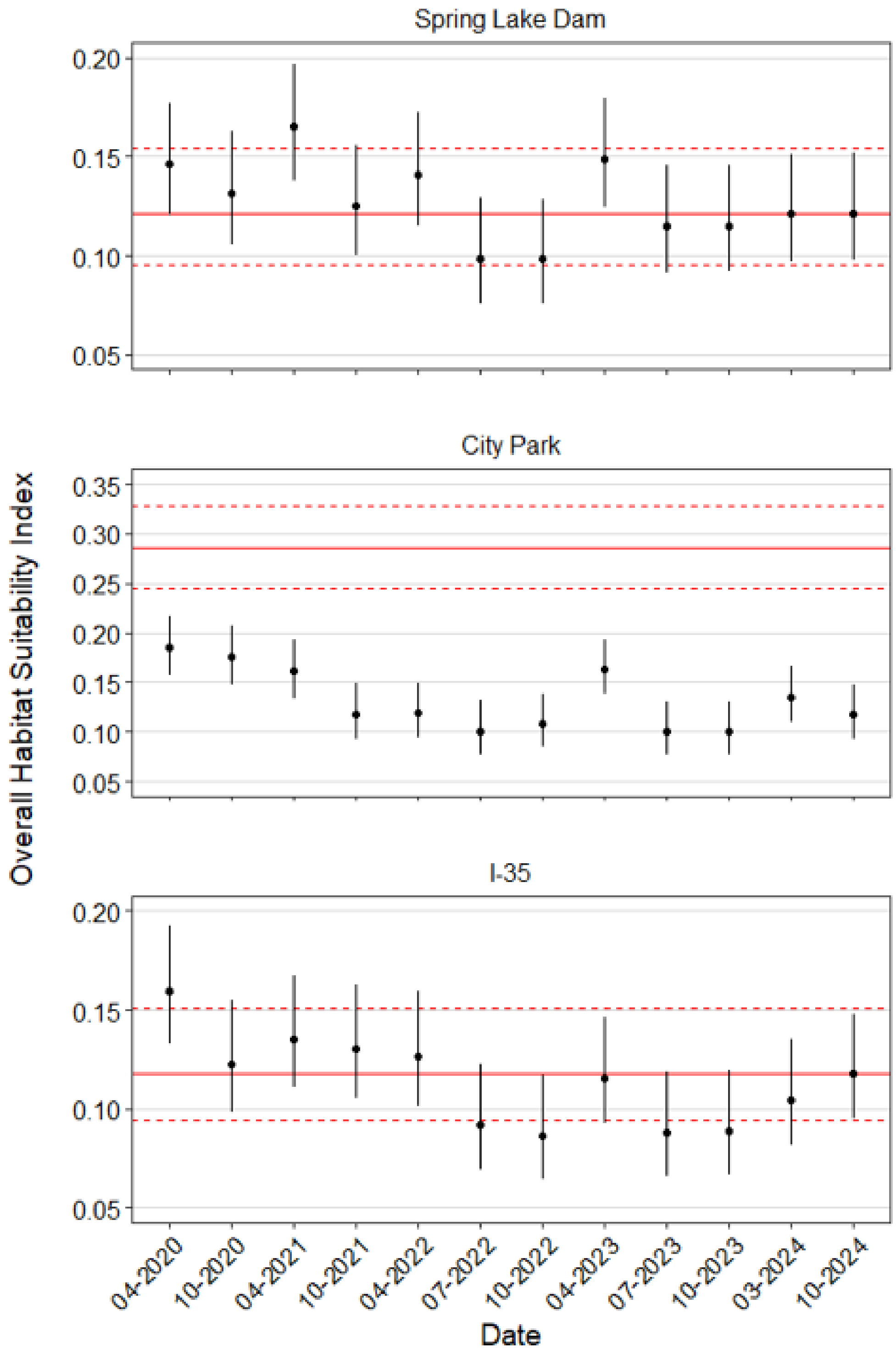

Figure 16. **Overall Habitat Suitability Index (OHSI) (±95% CI) from 2020–2024 among study reaches in the San Marcos River. Solid and dashed red lines denote means of long-term (2003–2024) OHSI and 95% CI, respectively.**

Fish Community

A total of 9,667 fishes represented by 10 families and 34 unique species were observed in the San Marcos Springs system during 2024 sampling. Mosquitofish (*Gambusia* spp.) or Largespring Gambusia (*Gambusia geiseri*) were among the top five dominant taxa in every reach, ranging from 6.5% in Lower River to 44.0% in Upper River (Appendix D, Table D2). In Spring Lake, the assemblage also primarily consisted of pelagic species such as Texas Tetra (*Astyanax argentatus;* 27.5%) and Guadalupe Roundnose Minnow (*Dionda nigrotaeniata*; 25.7%). Fountain Darter was ranked third in abundance in Upper River (9.9%) and Middle River (11.7%). The Lower River assemblage was dominated by pelagic minnows: Texas Shiner (*Notropis amabilis*; 29.9%) and Mimic Shiner (*Paranotropis volucellus*; 20.0%).

Patterns in species richness and diversity varied between and within study segments. Species richness increased at Spring Lake, Upper River, and Lower River over the course of 2024. In general, species richness and diversity were highest at Lower River. Species richness was also high at Upper River, though diversity was lower and more similar to that of Spring Lake. Middle River displayed intermediate species richness and diversity. Diversity at Middle River was fairly stable until it declined sharply in spring 2023, though it increased in fall 2024 to more typical levels. Community-based metrics at Spring Lake were lower than other segments and were generally more stable over time (Figure 17).

Spring fishes' species richness and relative density observations were incongruent with community-level observations. Spring fishes' richness was high and stable at the Upper River and Middle River. Total number of spring fish species was also stable at Spring Lake, though richness did not exceed three species. Spring fishes' richness at Lower River was more variable than upstream river segments with the most species observed in summer and fall 2022. Relative density of spring fishes was high and stable in the upstream reaches of Spring Lake and Upper River. At Middle River, relative density was also high but more variable than upstream segments. However, variability in this segment has been more stable since spring 2023 which is likely a result of prolonged low flows. Spring fishes' relative density was reduced at Lower River but accounted for 60-80% of the assemblage in fall 2021 and summer 2022 (Figure 18). Additionally, relative density has increased since fall 2023 with spring fishes accounting for nearly 60% of the assemblage in fall 2024. Decreases in total species and relative density of spring fishes with increasing distance from springflow influence is well documented (Hubbs 1995; Kollaus and Bonner 2012; Craig et al. 2016).

Temporal trends in Fountain Darter density from 2020–2024 were based on microhabitat sampling data. Median density at Spring Lake was below long-term expectations since fall 2022 but increased at or above the long-term median in 2024 (Figure 19). Variation in density (i.e., interquartile range) has decreased since spring 2022 when the upper quartile was substantially higher. At Middle River, median density was above long-term expectations in spring and fall with greater variability in the spring. Lastly, median Fountain Darter density in 2024 at Upper River and Lower River continued to show typical historical patterns with densities at or close to zero (Figure 19).

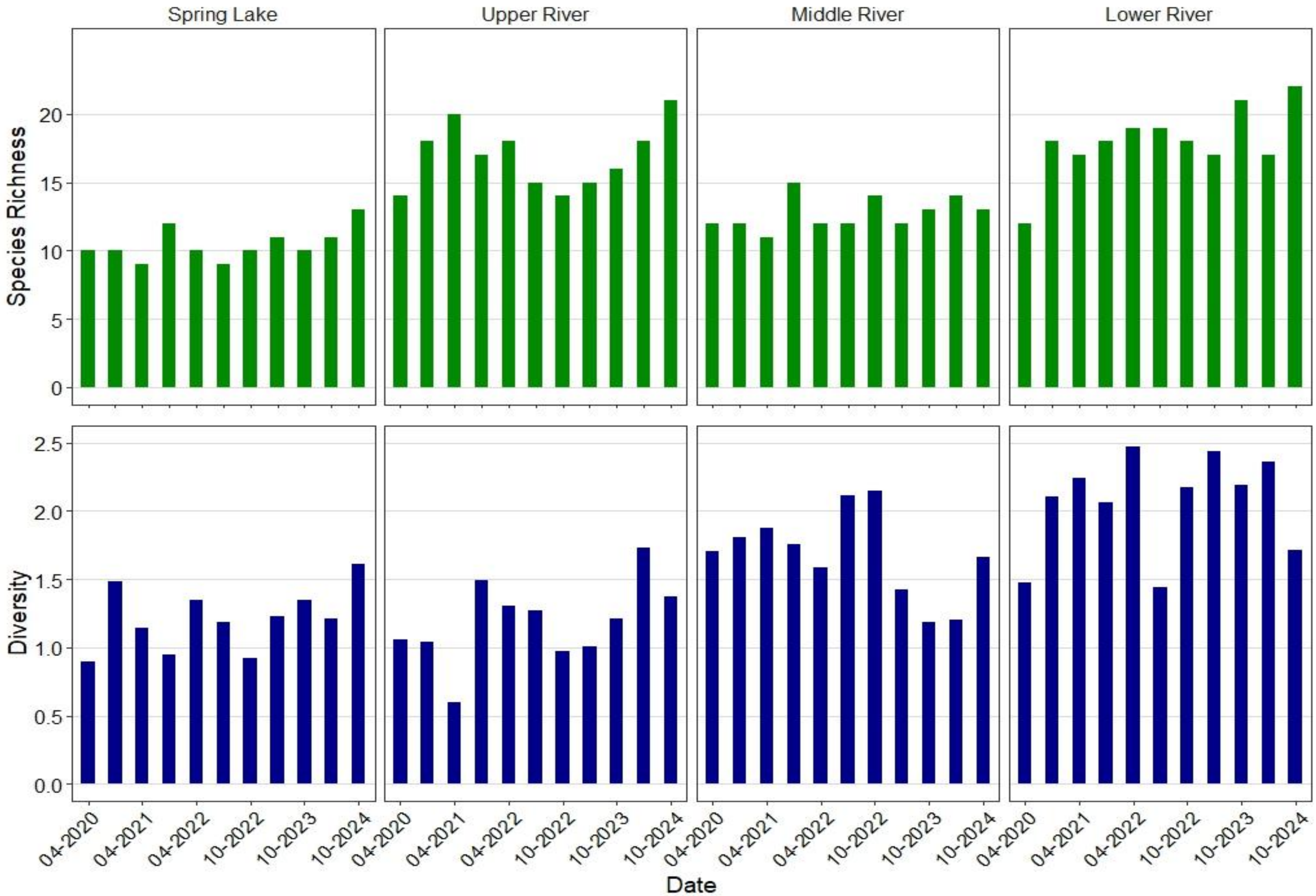

Figure 17. **Bar graphs displaying species richness (top row) and diversity (bottom row) from 2020–2024 based on all three fish community sampling methods in the San Marcos Springs/River.**

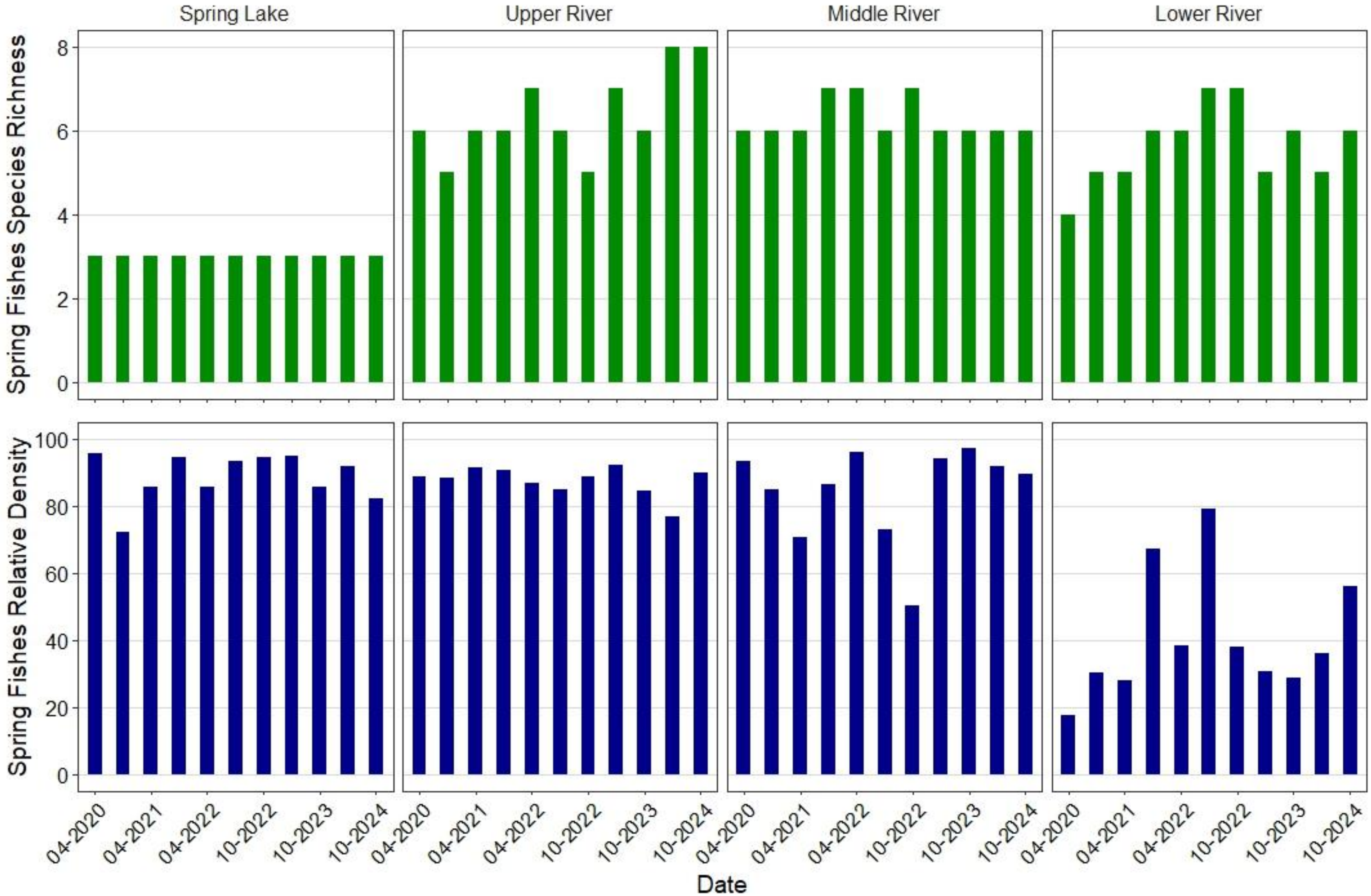

Figure 18. **Bar graphs displaying spring fish richness (top row) and relative density (RD; %) (bottom row) from 2020–2024 based on all three fish community sampling methods in the upper San Marcos Springs/River.**

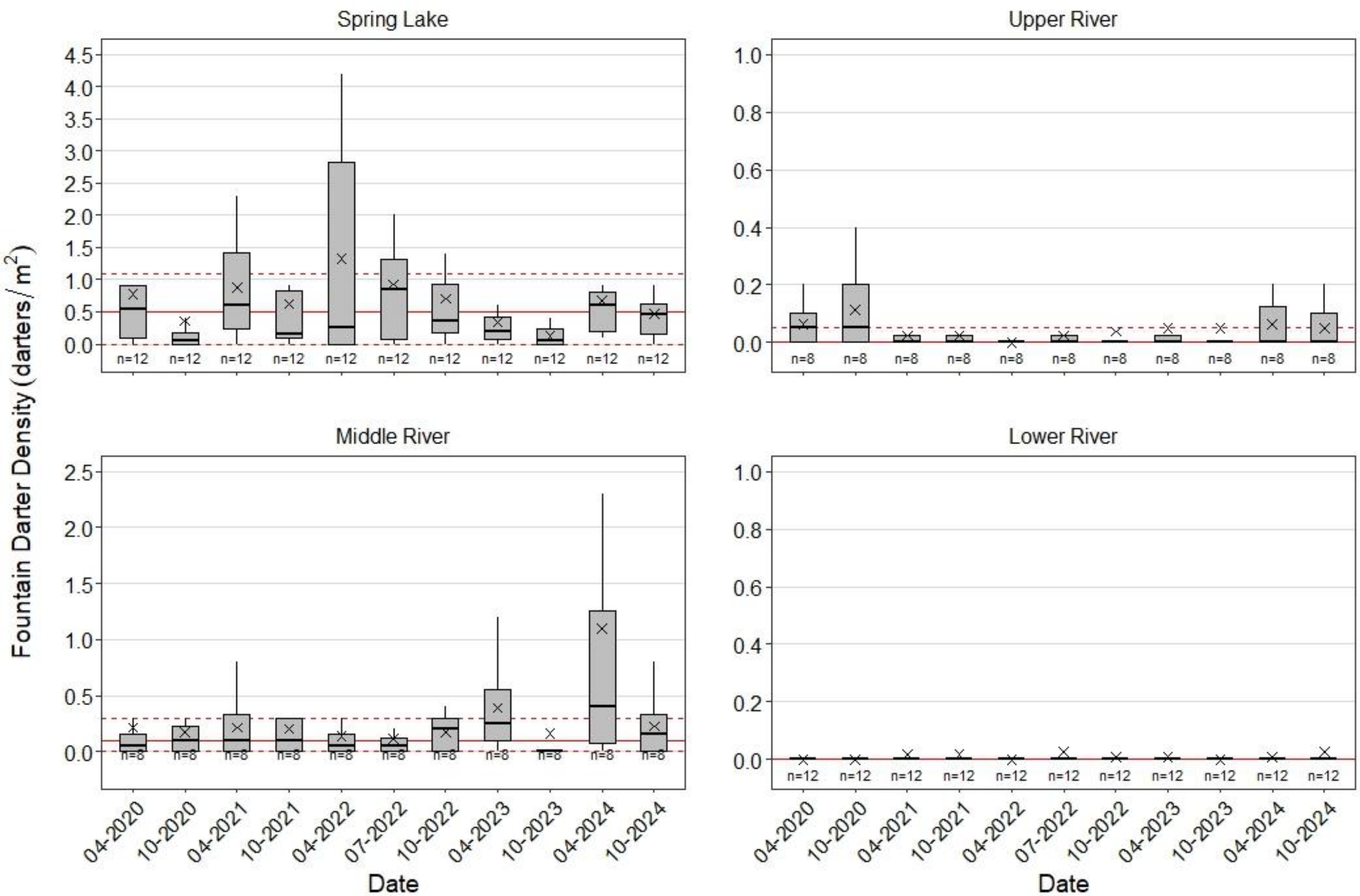

Figure 19. **Boxplots displaying temporal trends in Fountain Darter density (darters/m^2) among study reaches from 2020–2024 during fish community microhabitat sampling in the San Marcos Springs/River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. The "n" values along the x-axes represent the number of microhabitat samples per category. Solid and dashed red lines denote long-term (2014–2024) medians and interquartile ranges, respectively.**

Macroinvertebrates

Benthic Macroinvertebrate Rapid Bioassessment

Benthic macroinvertebrate rapid bioassessment data was collected during both the spring and fall sampling events in 2024 (raw data presented in Appendix E). At Spring Lake, habitats sampled this year included emergent vegetation, root wads, and sand. Similar habitats were sampled at City Park, with the addition of debris jams. Cobble/gravel habitats were sampled at Spring Lake Dam and I-35 in addition to what was sampled at City Park. No supplemental snag samples were taken. A total of 908 and 658 individual macroinvertebrates, representing 31 and 35 unique taxa were sampled in spring and fall, respectively. Metric scoring criteria for calculating the B-IBI can be found in Table 6. The cumulative scores and corresponding aquatic-life-use designations are displayed in Figure 20. Altogether, 41 unique taxa were represented among all samples from 2024. Overall scores and aquatic-life-use designations in 2024 generally aligned with the previous four years and indicate stable patterns among benthic macroinvertebrate communities. Scores at three out of four sites were consistent across both seasons. Spring Lake was described as "Intermediate", Spring Lake Dam was described as "High", and I-35 was described as "Exceptional". Aquatic-life-use at City Park was "Limited" in spring and "Intermediate" in fall (Figure 20).

Table 6. Metric value scoring ranges for calculating the Texas RBP B-IBI (TCEQ 2014).

METRIC	SCORING CRITERIA			
	4	3	2	1
Taxa richness	>21	15–21	8–14	<8
EPT taxa abundance	>9	7–9	4–6	<4
Biotic index (HBI)	<3.77	3.77–4.52	4.56–5.27	>5.27
% Chironomidae	0.79–4.10	4.11–9.48	9.49–16.19	<0.79 or >16.19
% Dominant taxon	<22.15	22.15–31.01	31.02–39.88	>39.88
% Dominant FFG	<36.50	36.50–45.30	45.31–54.12	>54.12
% Predators	4.73–15.20	15.21–25.67	25.68–36.14	<4.73 or >36.14
Ratio of intolerant: tolerant taxa	>4.79	3.21–4.79	1.63–3.20	<1.63
% of total Trichoptera as Hydropsychidae	<25.50	25.51–50.50	50.51–75.50	>75.50 or no Trichoptera
# of non–insect taxa	>5	4–5	2–3	<2
% Collector–gatherers	8.00–19.23	19.24–30.46	30.47–41.68	<8.00 or >41.68
% of total number as Elmidae	0.88–10.04	10.05–20.08	20.09–30.12	<0.88 or >30.12

Spring Lake and City Park scored lower than the other sites, likely due to differences in available habitats. Lower scores were expected at Spring Lake as these lentic communities are naturally different compared to swift flowing "least-disturbed reference streams". At City Park, lower scores in fall compared to Spring Lake Dam and I-35 were also not surprising. Of the three riverine sites, City Park has consistently scored the lowest over the past five years, likely due to differences in habitat and recreation. Lotic habitats at City Park consist of runs, whereas lotic habitats at Spring Lake Dam and I-35 consist of riffles with cobble and gravel substrates more similar to reference streams. Higher scores at Spring Lake Dam and I-35 are best explained by greater prevalence of fluvial specialists, resulting in greater taxa diversity overall. Additionally, most reference streams do not exhibit the stenothermal conditions present within the upper San Marcos River which may contribute to differing community composition. As such, patterns of results per reach over time in the spring-fed San Marcos River are more important than the level of score. Continued monitoring will create a robust reference dataset and allow for the development of scoring criteria specific to this unique ecosystem, providing a more accurate realization of ecological health through time.

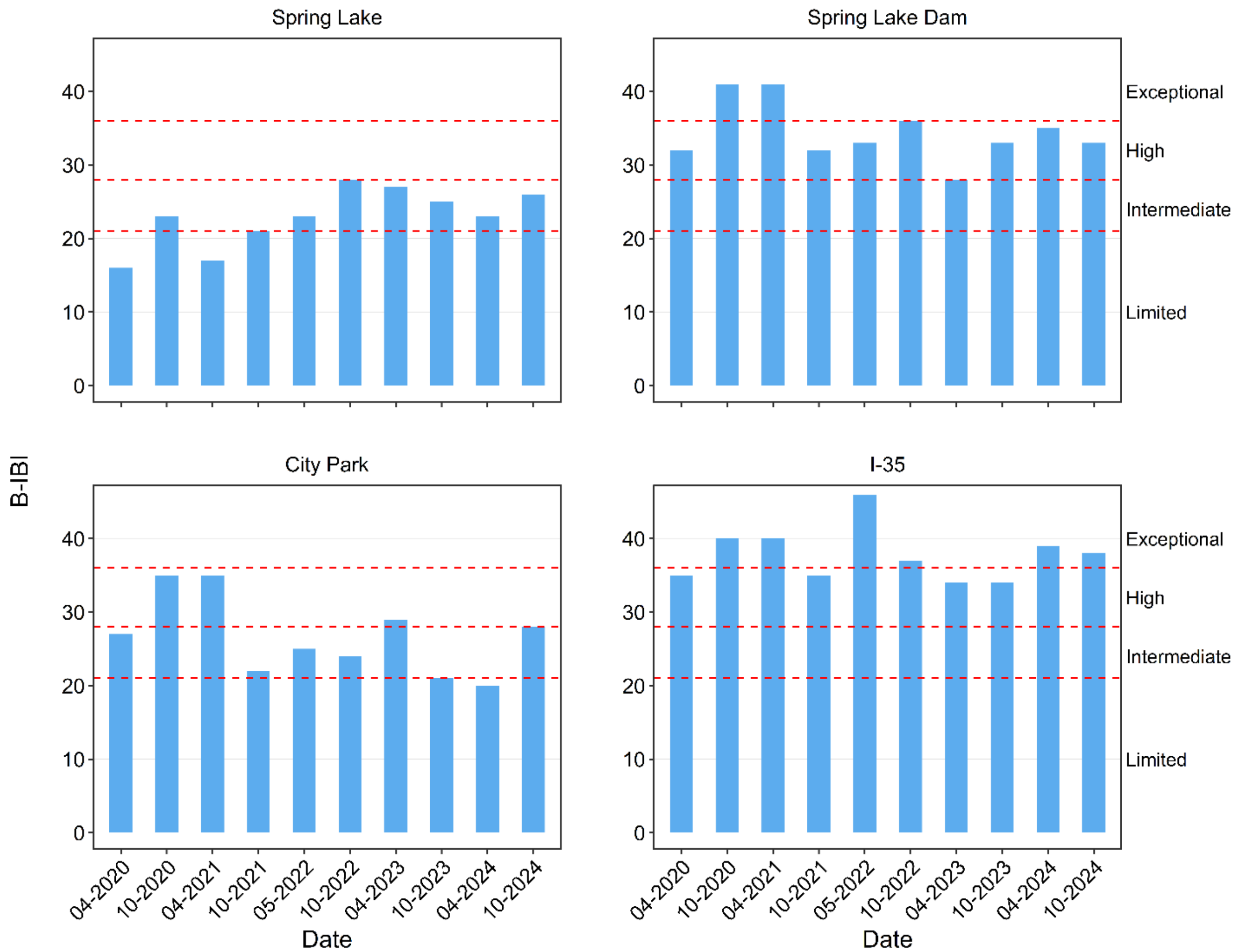

Figure 20. Benthic macroinvertebrate Index of Biotic Integrity (B-IBI) scores and aquatic-life-use categories from 2020–2024 in the San Marcos Springs/River.

San Marcos Salamander

A total of 394 salamanders were observed in spring (200 salamanders) and fall (194 salamanders) during routine monitoring events in 2024. Salamander densities ranged from 1.62–16.87 salamanders/m^2 (Figure 21). Salamander densities decreased from spring to fall at Hotel and Spring Lake Dam sites but increased at Riverbed. At Hotel, spring salamander densities (14.8 salamanders/m^2) were similar to long-term expectations (15.5 salamanders/m^2); whereas, fall densities (8.5 salamanders/m^2) were well below the long-term average (14.4 salamanders/m^2). Fall 2024 density observations at Hotel fell outside the confidence interval boundary, suggesting a meaningful difference. In contrast, spring salamander densities at Riverbed (12.0 salamanders/m^2) were lower than the long-term average (14.5 salamanders/m^2), while fall densities (16.9 salamanders/m^2) exceeded expectations (12.6 salamanders/m^2). Both spring and fall 2024 densities fell outside the confidence interval boundaries at Riverbed. At Spring Lake Dam in 2024, densities in spring (3.61 salamanders/m^2) and fall (1.62 salamanders/m^2) were lower than the respective long-term averages (Figure 21).

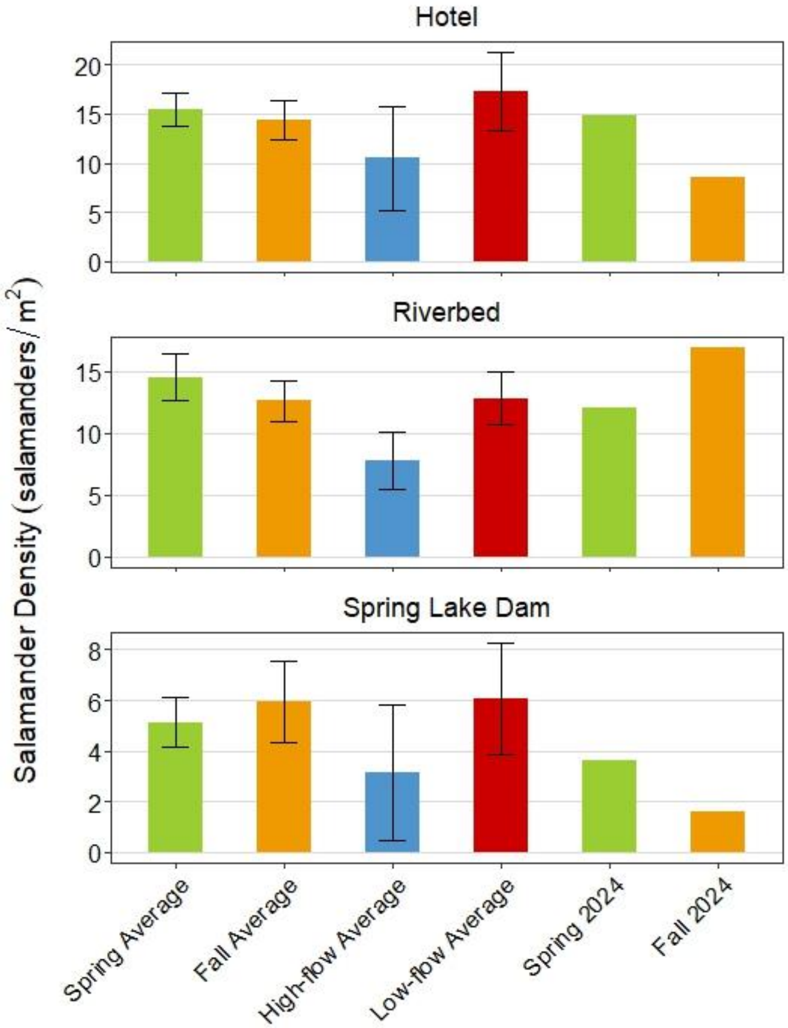

Figure 21. **San Marcos Salamander density (salamanders/m^2) among sites in 2024, with the long-term (2001–2024) average for each sampling event. Error bars for long-term averages represent 95% confidence intervals.**

Five-year trends at Hotel demonstrated decreasing densities beginning in fall 2020, followed by a noticeable increase during the last two events in 2022. After this increase, densities in 2023 decreased again and generally remained lower than the previous five years. At Riverbed, density was variable. The fall 2023 event had the lowest densities observed over the past five years; however, densities increased to more typical levels in 2024. Density at Spring Lake Dam demonstrated a cyclical but decreasing pattern over the past five years (Figure 22). Subsequent monitoring will help provide insights on how salamander densities change following the low flows in fall 2024.

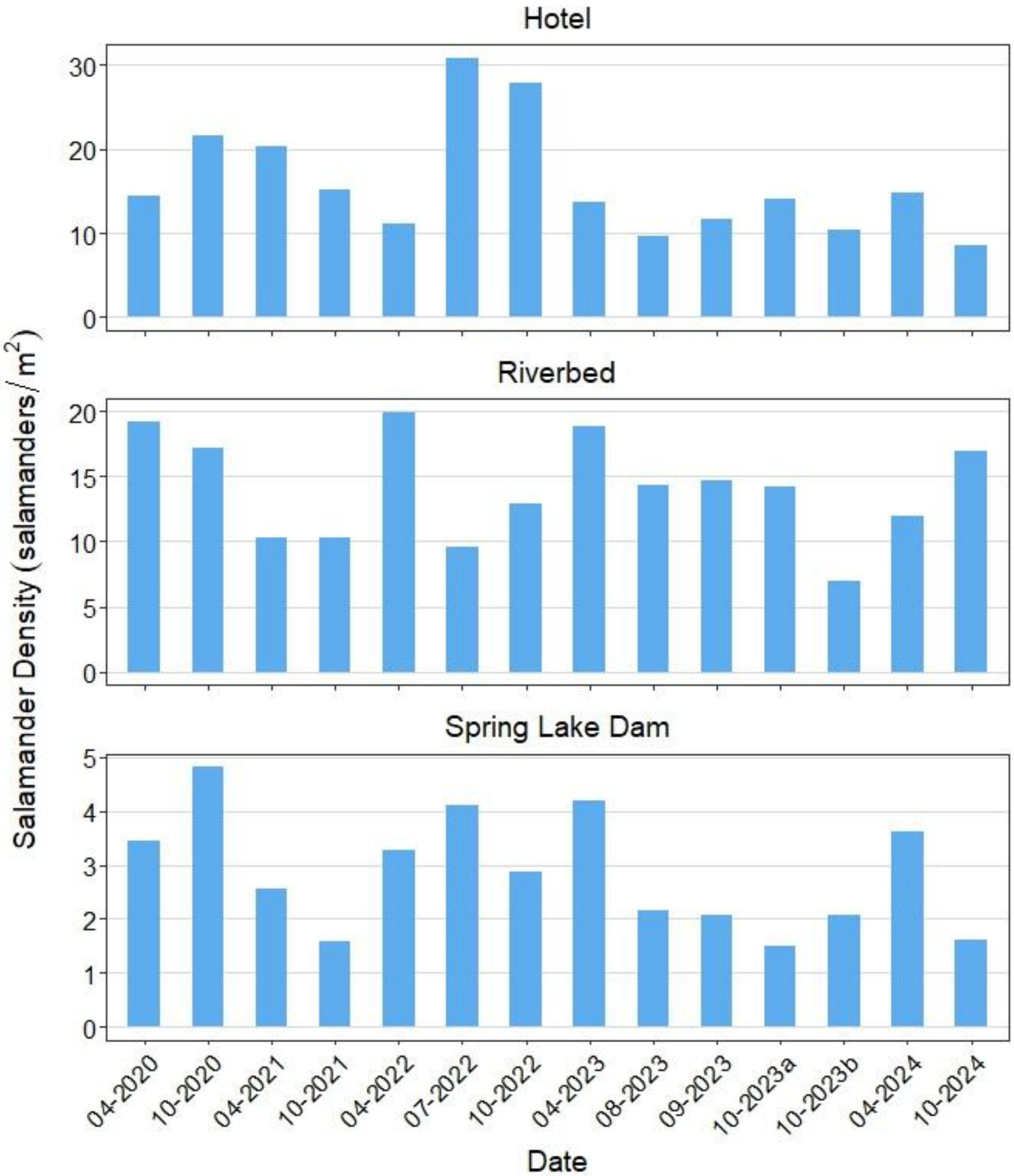

Figure 22. **San Marcos Salamander density (salamanders/m^2) among sites from 2020–2024 in the San Marcos Springs/River.**

CONCLUSION

Results from the 2024 biological monitoring in the San Marcos Springs/River system indicated overall declining trends in discharge and variable trends in Covered Species population metrics. Based on monthly analysis of daily mean discharge, the system was near historical median flow conditions early in the year but declined near 10th percentile flow conditions by October. Low variation in water temperature continued to occur at reaches closer to springs (i.e., Spring Lake), whereas higher variation occurred at reaches farther downstream (i.e., Wastewater Treatment Plant). Although exceedance frequency and duration of Fountain Darter larval and egg production thresholds increased throughout the summer, impacts to Fountain Darter population metrics were not observed.

Total aquatic vegetation coverage declined from spring to fall at Spring Lake Dam and City Park but increased at I-35. Declines in the two upstream reaches were mainly attributed to decreased coverage of Texas Wild-rice due to low flows and recreation. At I-35, however, increases in vegetation can be attributed to both the expansion of amphibious species (e.g., *Sagittaria*) that could survive as emergent and outcompete other taxa in the shallowest areas and expansion of slackwater tolerant species (e.g., *Hygrophila*) in the main river channel. Texas Wild-rice continued to dominate assemblage structure throughout the upper reaches of the system, and full-system coverage recovered from September 2023 when the lowest coverage since 2016 was observed. Reduced river discharge led to some Texas Wild-rice becoming dewatered and outcompeted by terrestrial vegetation, yet Texas Wild-rice survived and expanded in deeper areas. Vegetation varied at City Park as established patches of *Cabomba* persisted throughout the year and bryophyte abundance increased as flows declined, resulting in enhanced habitat and contributing to higher Fountain Darter density estimates. Likewise, higher prevalence of bryophytes associated with *Sagittaria* in Spring Lake Dam contributed to substantially higher darter densities than previously observed in *Sagittaria*. However, overall habitat suitability indices did not pick up on this observed habitat improvement, since they are based on long-term taxa-specific suitability indices. San Marcos Salamander densities were variable among sites in 2024 and over the past five years, but the species persists within all monitored habitats.

Overall, 2024 biological monitoring captured the response of the San Marcos Springs/River aquatic community to a third year of sustained low flows. Results indicated that the San Marcos Springs/River was resilient to the low-flow conditions, with some Covered Species showing improvements from 2023. Texas Wild-rice coverage remains well above pre-HCP levels despite reduced wetted habitat and alterations in river morphology. Vegetation coverage varied throughout the system, yet low flows allowed patches of *Cabomba* to persist and bryophytes to establish throughout rooted vegetation and along the benthos. This increased benthic habitat complexity provided by bryophytes positively impacted Fountain Darter density estimates over the past two years. With some minor deviations, Fountain Darter catch rates and percent occurrence were comparable to previous years. No obvious trends in salamanders, fish assemblage composition, spring fishes, or macroinvertebrates were noted. Despite declines in flow throughout the year, populations persist and demonstrate the potential for improvement when typical flows return. Subsequent monitoring efforts will provide opportunities to better understand the dynamics of this complex ecological system and how it responds to future hydrologic conditions.

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APPENDIX A: CRITICAL PERIOD MONITORING SCHEDULE

SAN MARCOS RIVER/SPRINGS
Critical Period Low-Flow Sampling – Schedule and Parameters

FLOW TRIGGER (+ or - 5 cfs)	PARAMETERS
120 cfs	Wild-Rice vulnerable stands - Every 5 cfs decline (maximum weekly)
100 cfs	Full Sampling Event
100 - 85 cfs	Habitat Evaluations - Every 5 cfs decline (maximum weekly)
85 cfs	Full Sampling Event
85 - 60 cfs	Habitat Evaluations - Every 5 cfs decline (maximum weekly)
60 cfs	Full Sampling Event
60 - 25 cfs	Habitat Evaluations - Every 5 cfs decline (maximum weekly)
25 cfs	Full Sampling Event
25 - 0 cfs	Habitat Evaluations - Every 5 cfs decline (maximum weekly)
10 - 0 cfs	Full Sampling Event
RECOVERY	
25 - 85 cfs	Full Sampling Event (dependent on flow stabilization)
85 - 125 cfs	Full Sampling Event (dependent on flow stabilization)

PARAMETER DESCRIPTION

Wild-Rice Monitoring	Physical changes vulnerable stands
Fall Sampling Event	Aquatic Vegetation Mapping - including Texas Wild-Rice Fountain Darter Sampling Drop Net, Dip net (Presence/Absence), and Visual Parasite evaluations Fish Community Sampling Salamander Sampling - Visual Fish Sampling - Exotics/Predation (85 cfs and below) Water Quality - Suite I and Suite II
Habitat Evaluations	Photographs

SAN MARCOS RIVER/SPRINGS
Species-Specific Triggered Sampling

FLOW RATE (+ or – 10 cfs)	SPECIES	FREQUENCY	PARAMETERS
≤80 cfs or ≥ 50 cfs continuing until flow rate restores to ≥100 cfs	Fountain Darter	Every other month	Aquatic vegetation mapping at Spring Lake Dam reach, City Park reach, and IH-35 reach
≤80 cfs or ≥ 50 cfs continuing until flow rate restores to ≥100 cfs	Fountain Darter	Every other month	Conduct dip net sampling/visual parasite evaluations at 50 sites in high quality habitat to include fifteen (15) sites in Spring Lake Dam reach; twenty (20) sites in City Park reach, and fifteen (15) sites in IH-35 reach.
≤50 cfs	Fountain Darter	Monthly	Aquatic vegetation mapping at Spring Lake Dam reach, City Park reach, and IH-35 reach
≤50 cfs	Fountain Darter	Weekly	Conduct dip net sampling/visual parasite evaluations at 50 sites in high quality habitat to include fifteen (15) sites in Spring Lake Dam reach; twenty (20) sites in City Park reach, and fifteen (15) sites in IH-35 reach.
≤80 cfs or ≥ 50 cfs	San Marcos Salamander	Every other week	Salamander surveys (SCUBA and snorkel) will be conducted at the Hotel Area, Riverbed area, and eastern spillway of Spring Lake Dam
<50 cfs	San Marcos Salamander	Weekly	Salamander surveys (SCUBA and snorkel) will be conducted at the Hotel Area, Riverbed area, and eastern spillway of Spring Lake Dam
100 cfs	Texas Wild-Rice	Once	Mapping of Texas Wild-Rice coverage for the entire San Marcos River will be conducted
≤100 cfs or ≥60 cfs	Texas Wild-Rice	Every other week	Physical parameters of Texas Wild-Rice will be monitored in designated "vulnerable" areas
<80 cfs	Texas Wild-Rice	Monthly	Mapping of Texas Wild-Rice coverage for the entire San Marcos River will be conducted
<80 cfs	Texas Wild-Rice	Weekly	Physical visual observations of Texas Wild-Rice will occur

APPENDIX B: AQUATIC VEGETATION MAPS

Long-term Biological Goals Study Reaches

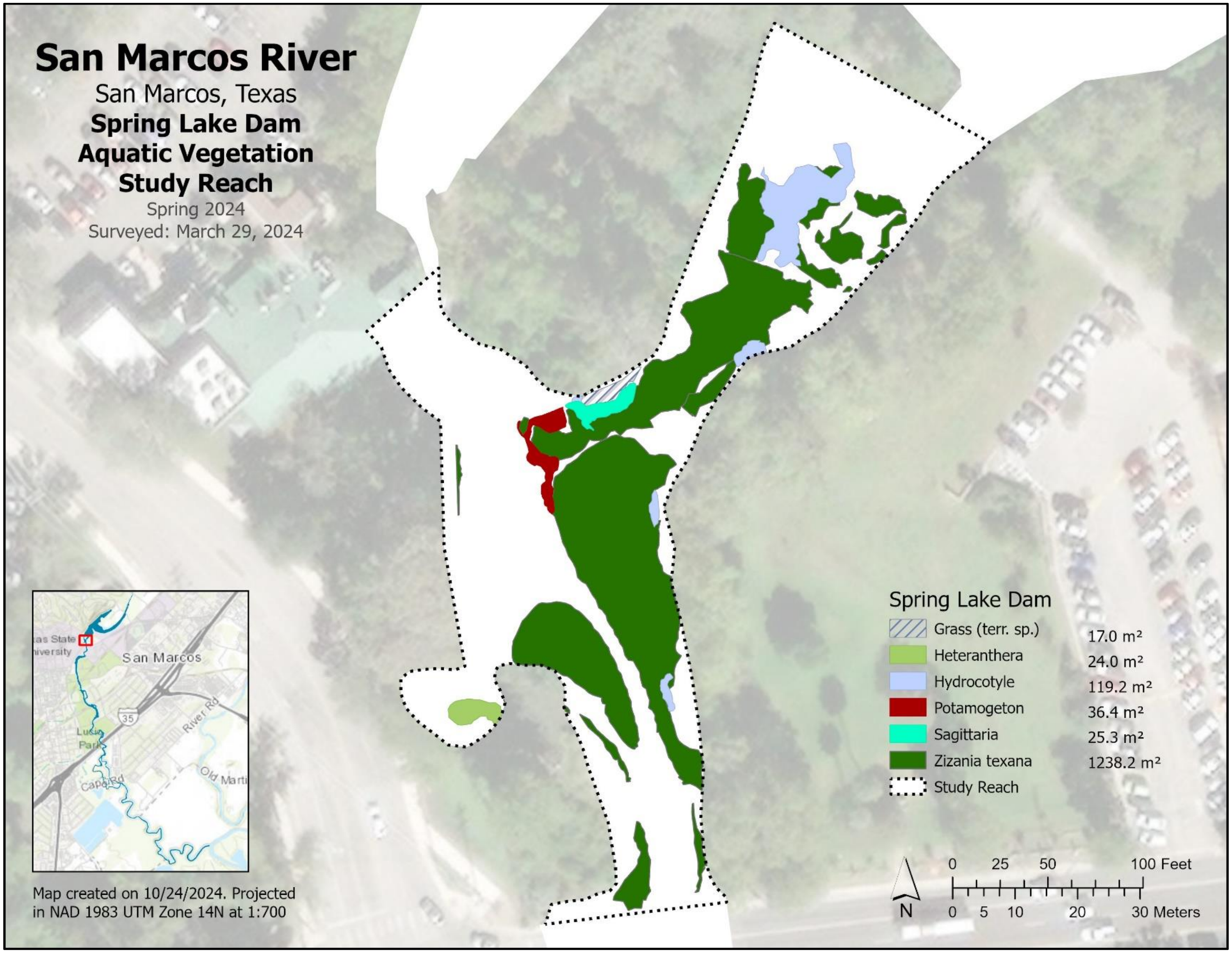

Figure C1. **Map of aquatic vegetation coverage at Spring Lake Dam Study Reach in spring 2024.**

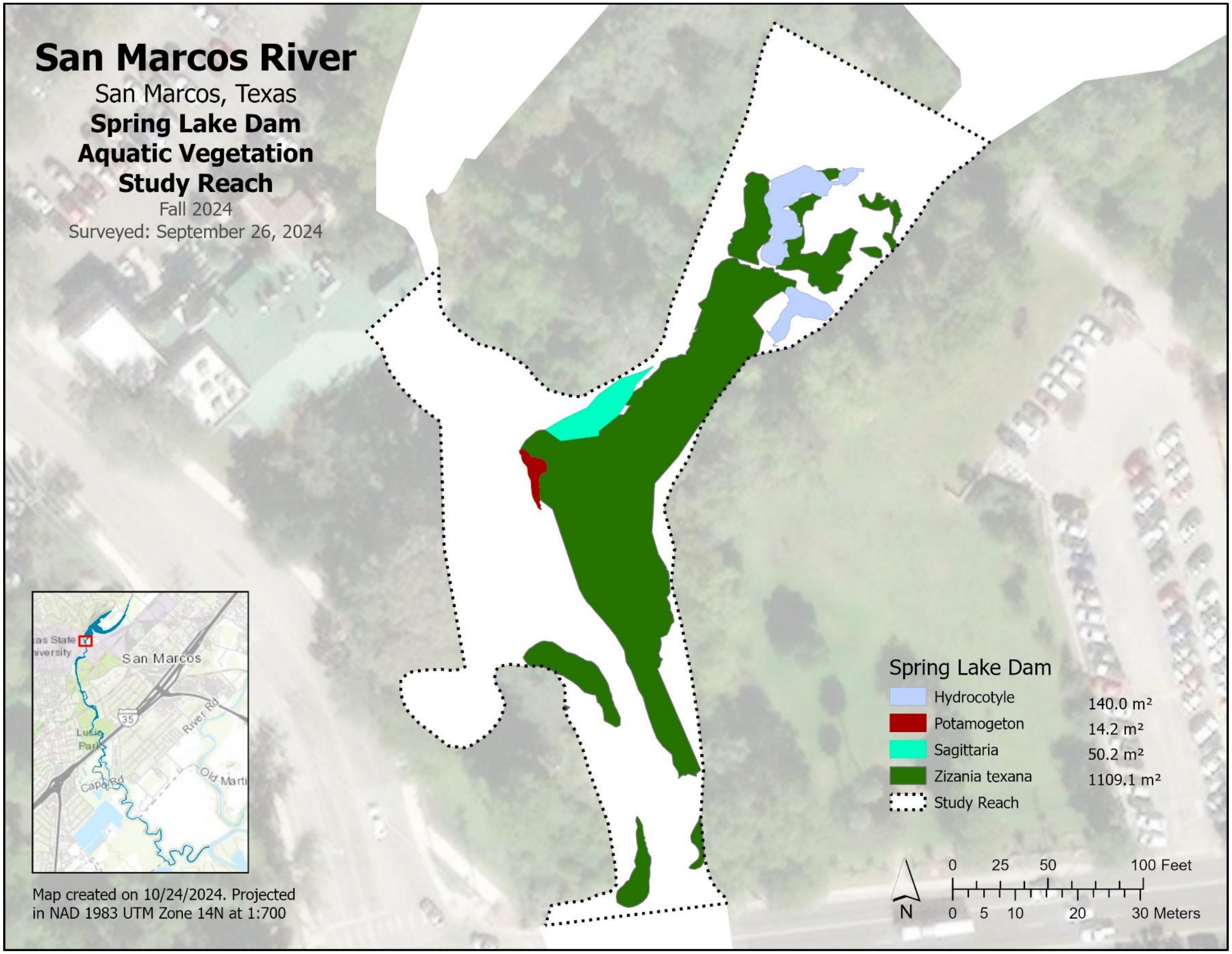

Figure C2. **Map of aquatic vegetation coverage at Spring Lake Dam Study Reach in fall 2024.**

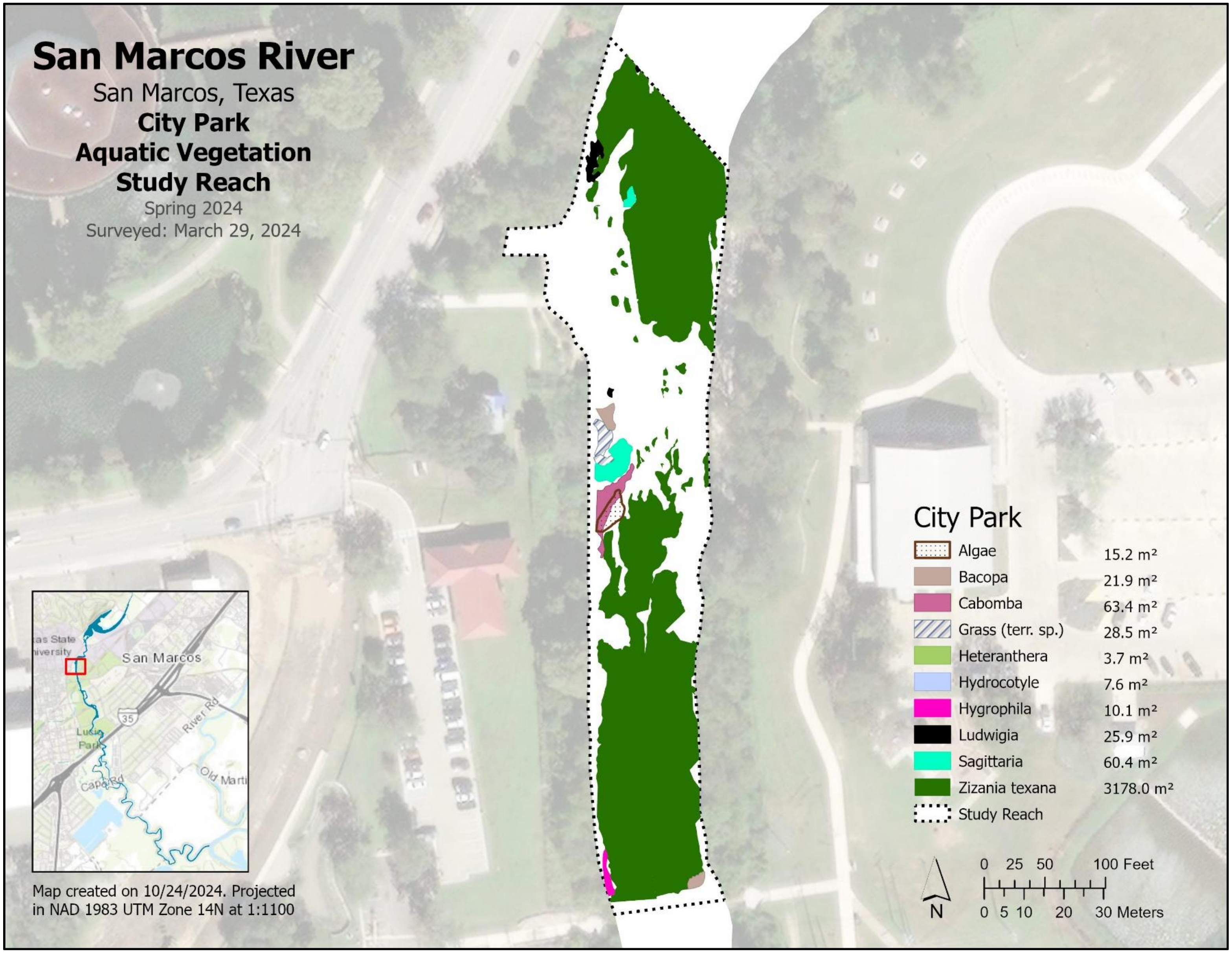

Figure C3. Map of aquatic vegetation coverage at City Park Study Reach in spring 2024.

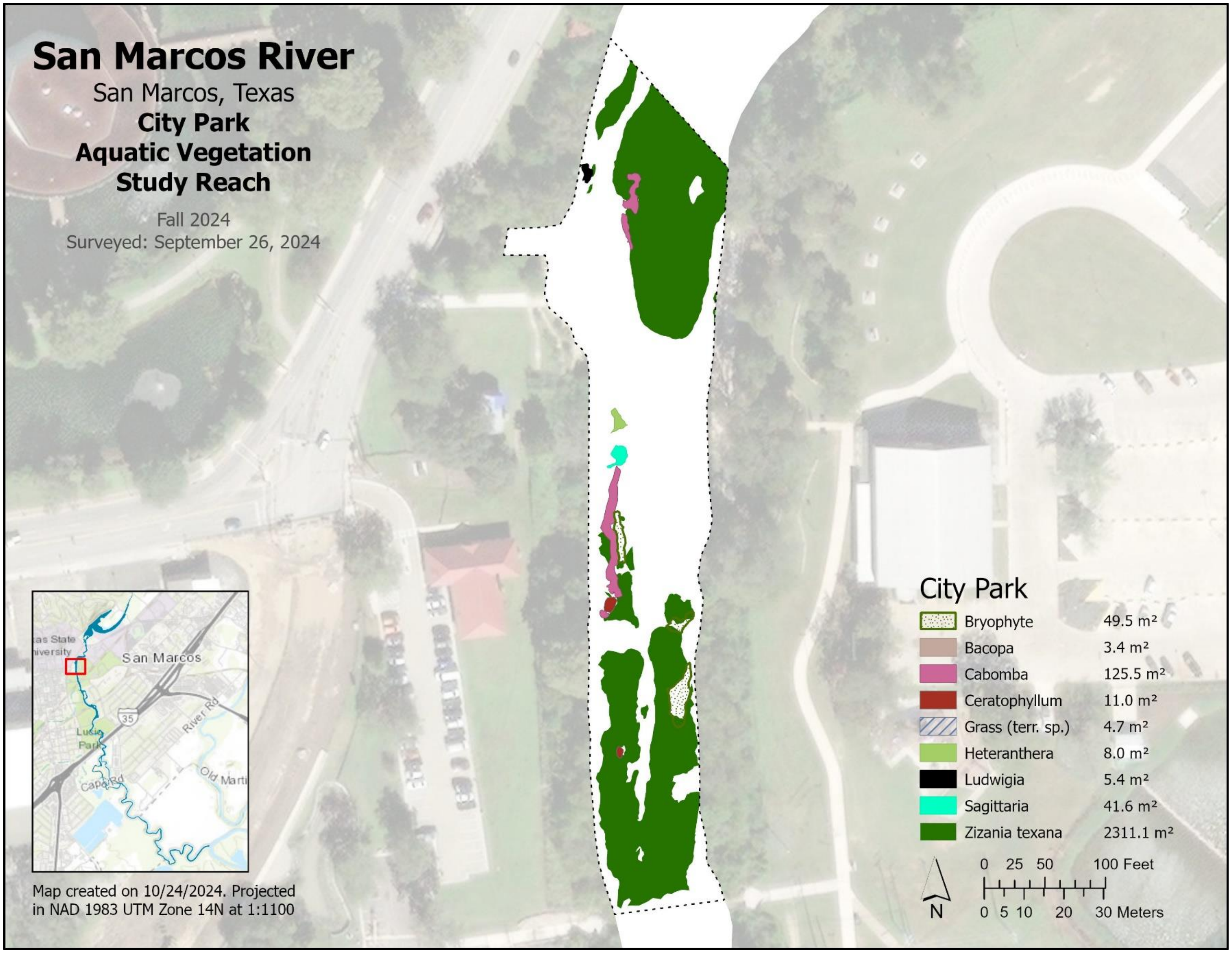

Figure C4. **Map of aquatic vegetation coverage at City Park Study Reach in fall 2024.**

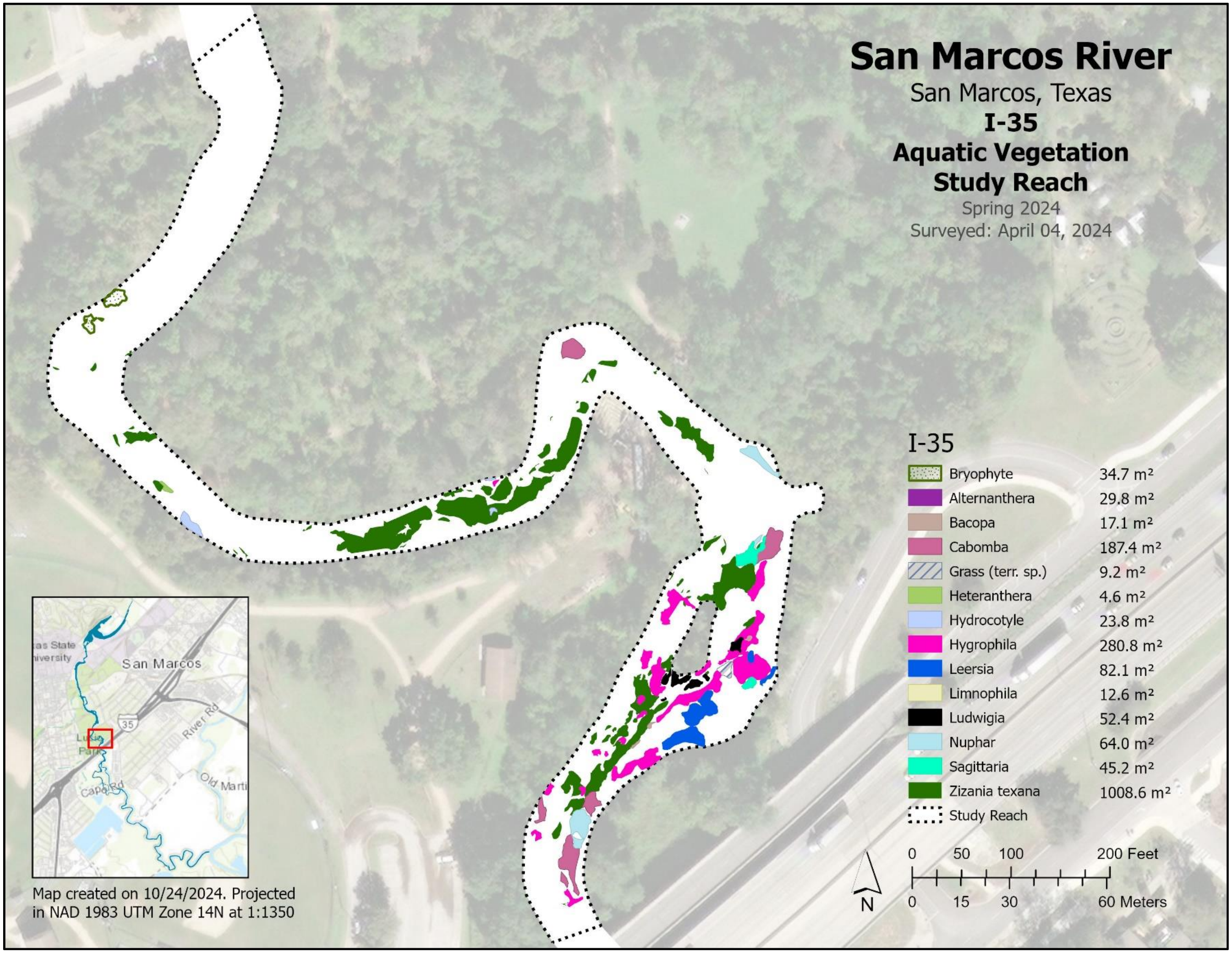

Figure C5. Map of aquatic vegetation coverage at I-35 Study Reach in spring 2024.

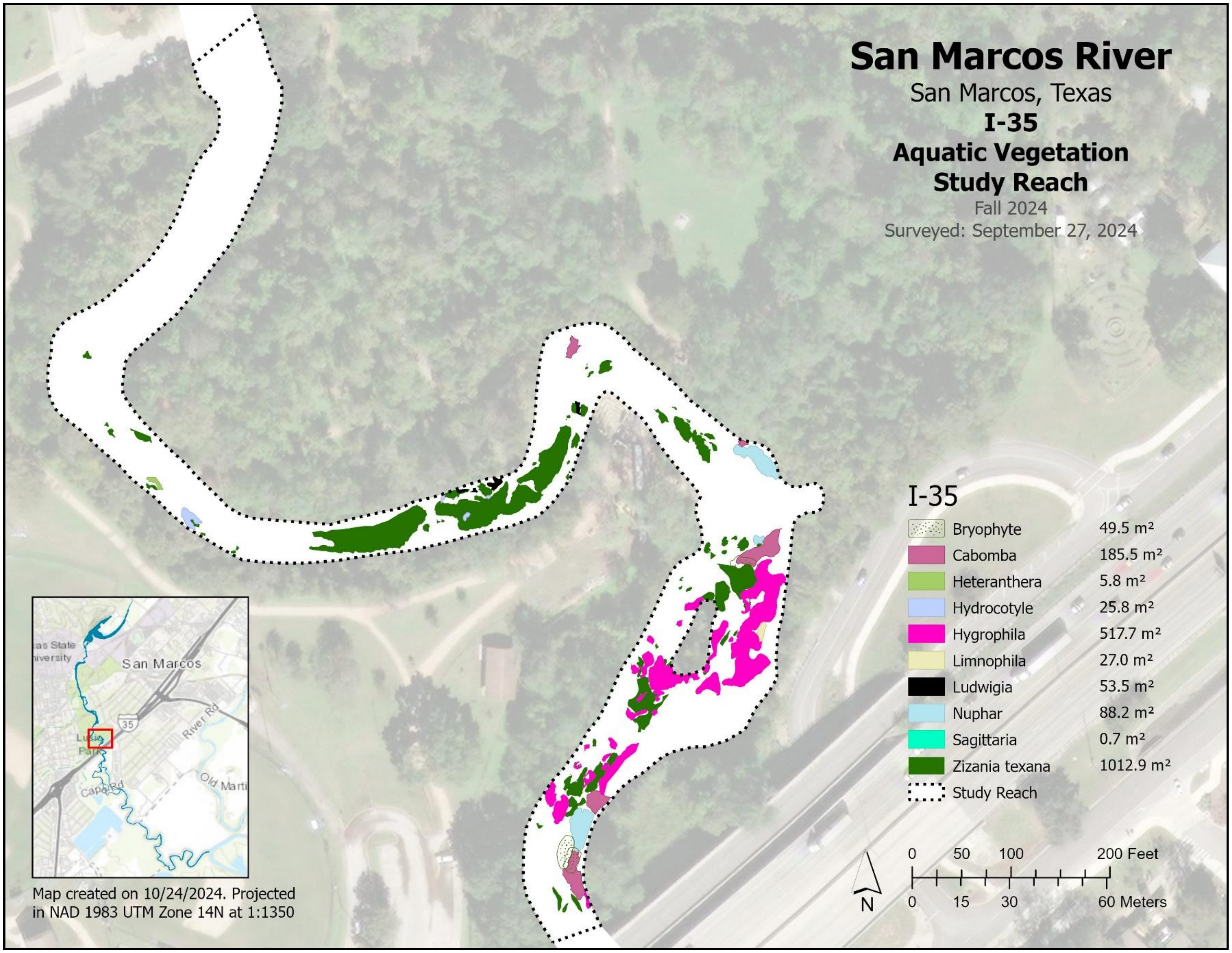

Figure C6. Map of aquatic vegetation coverage at I-35 Study Reach in fall 2024.

Texas Wild-rice Annual Mapping

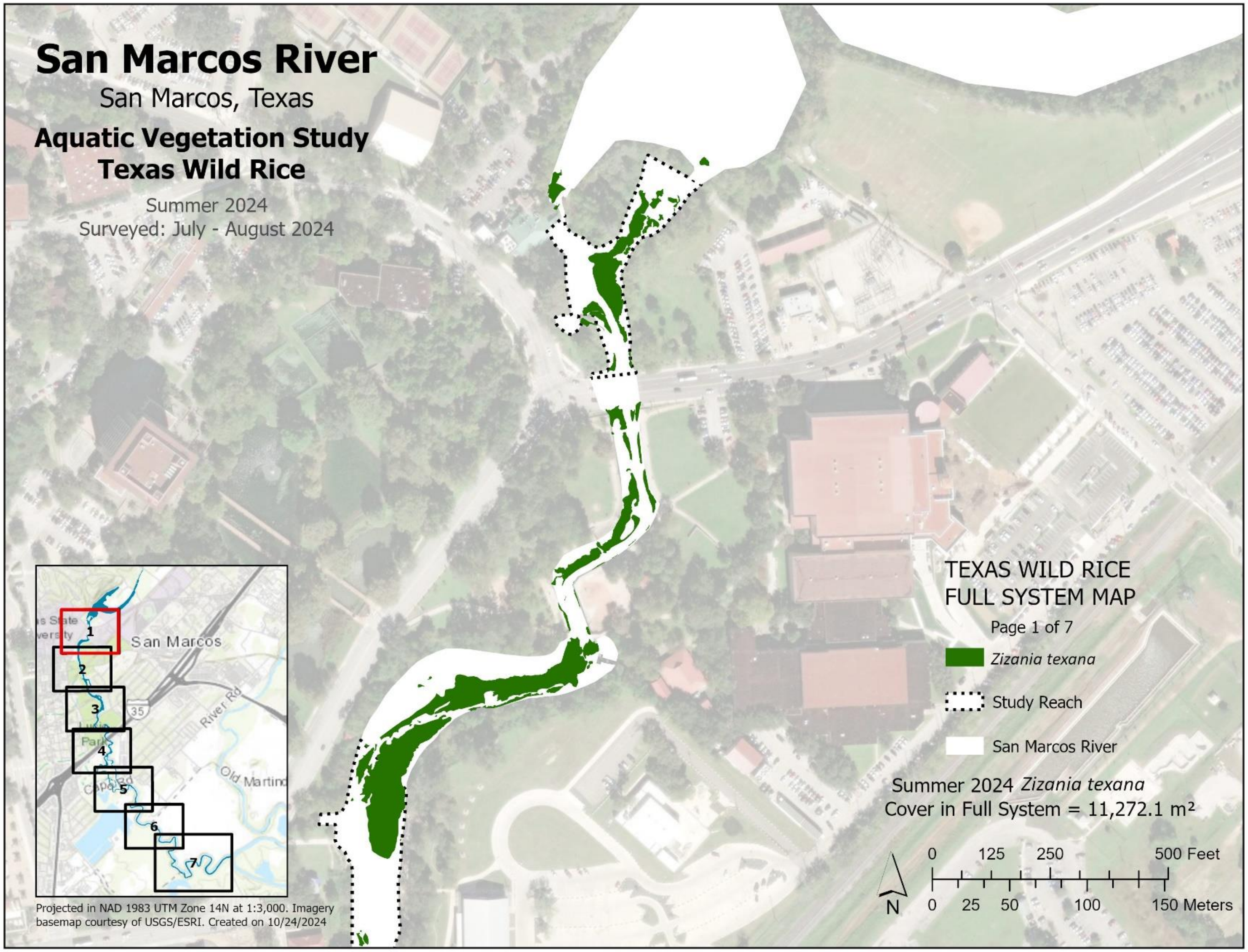

Figure C7. Map of Texas Wild-rice coverage from Spring Lake to City Park in summer 2024.

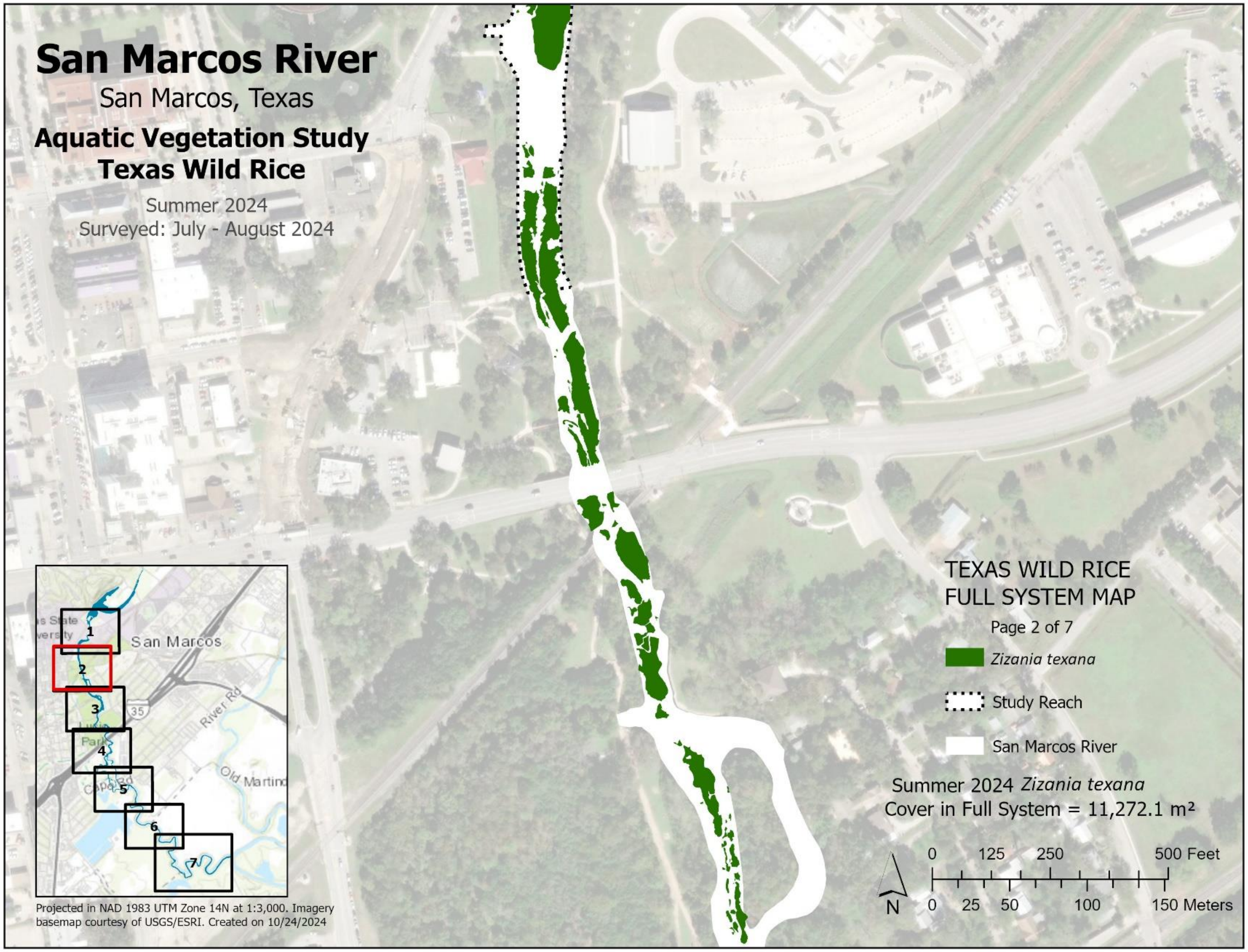

Figure C8. Map of Texas Wild-rice coverage from City Park to Cheatham Street in summer 2024.

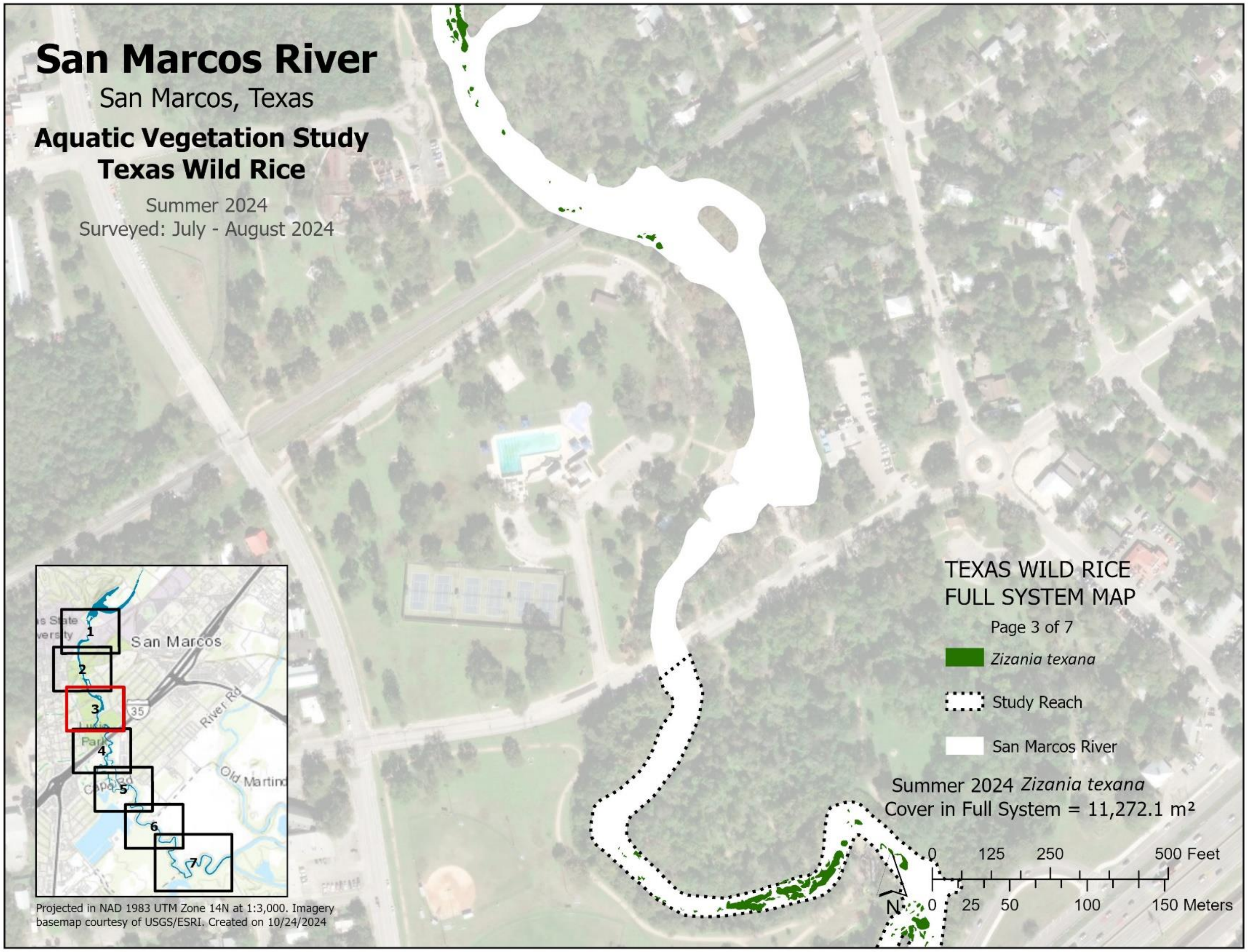

Figure C9. **Map of Texas Wild-rice coverage from Cheatham Street to I-35 in summer 2024.**

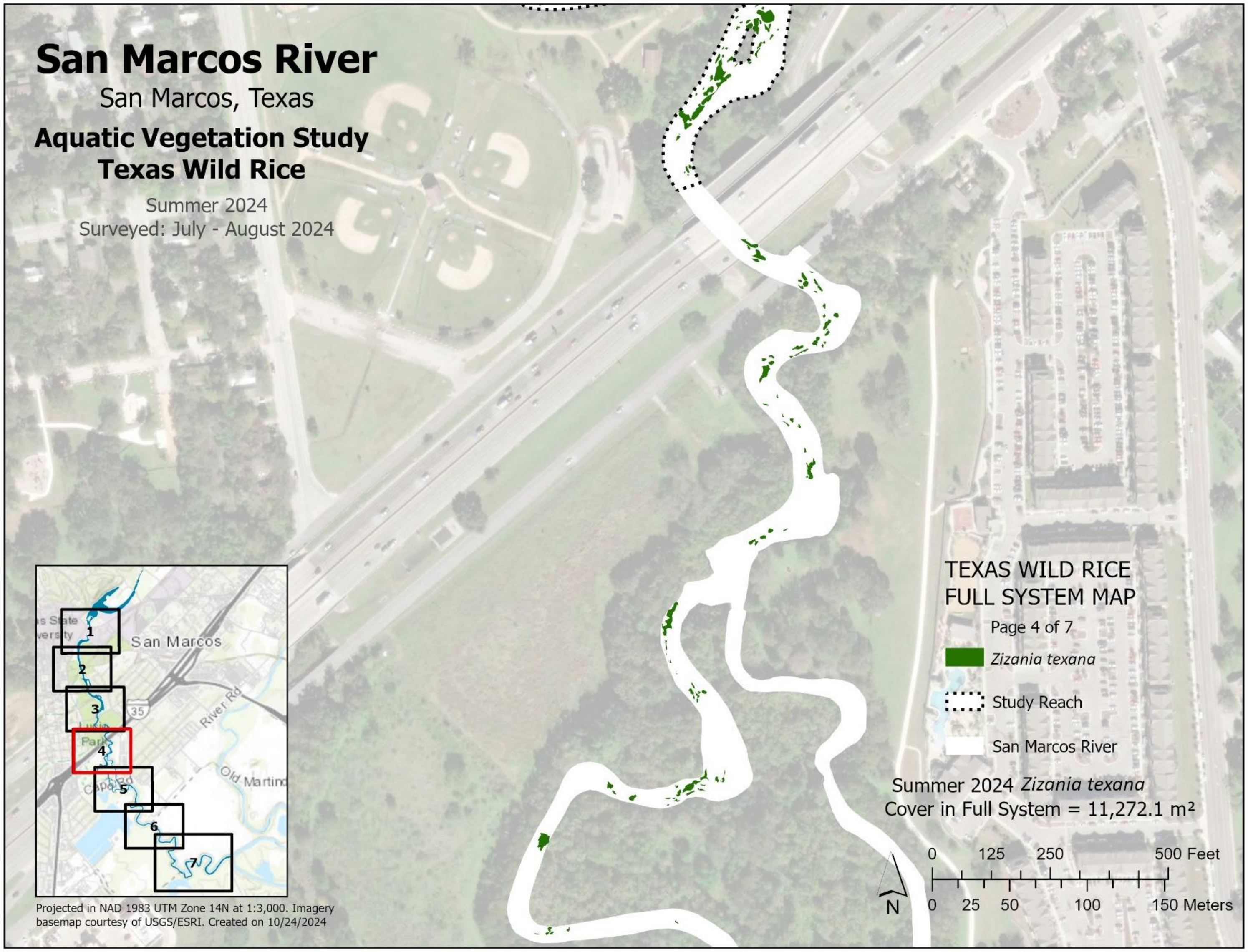

Figure C10. **Map of Texas Wild-rice coverage from Cheatham Street to about Stokes Park in summer 2024.**

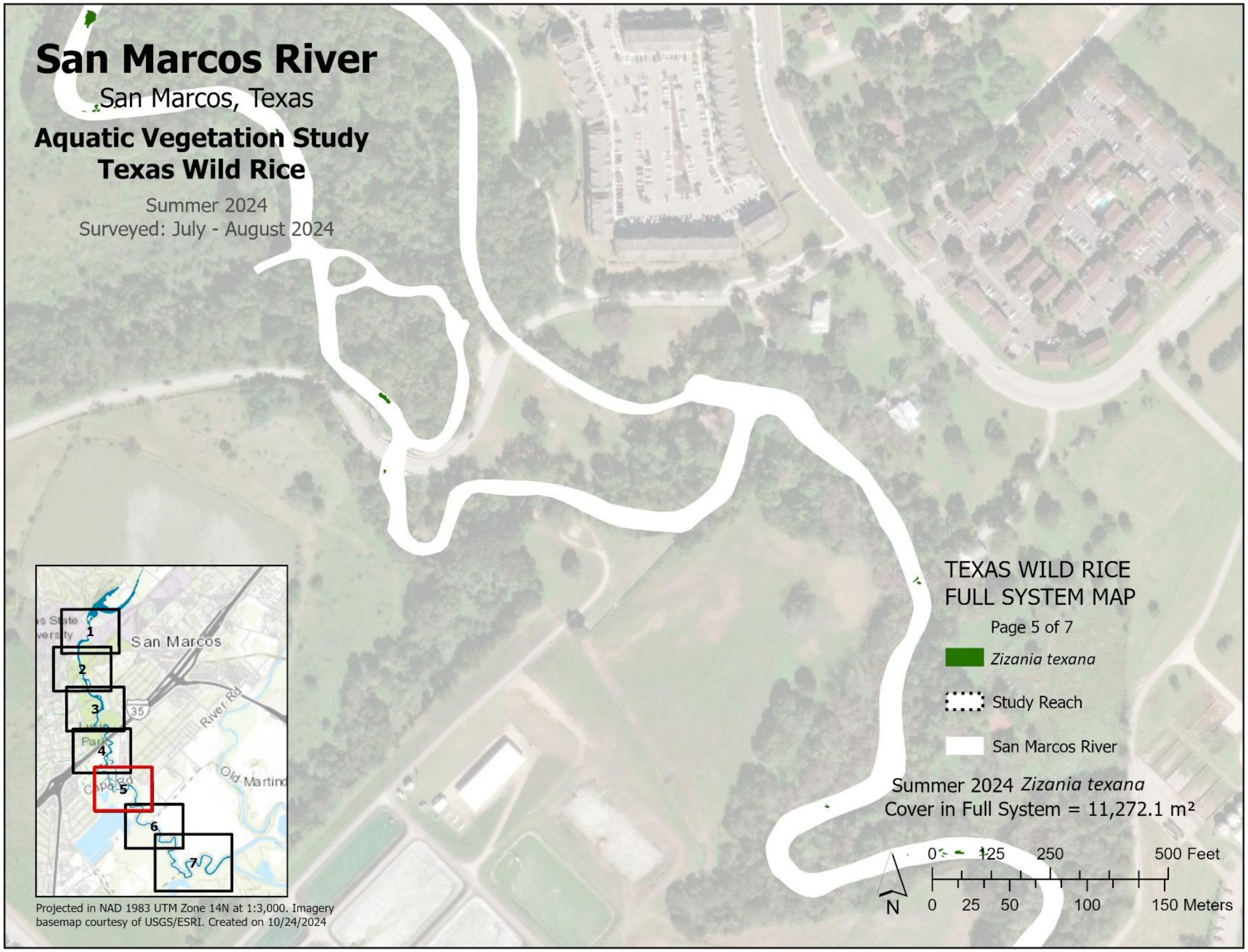

Figure C11. Map of Texas Wild-rice coverage from about Stokes Park to Wastewater Treatment Plant in summer 2024.

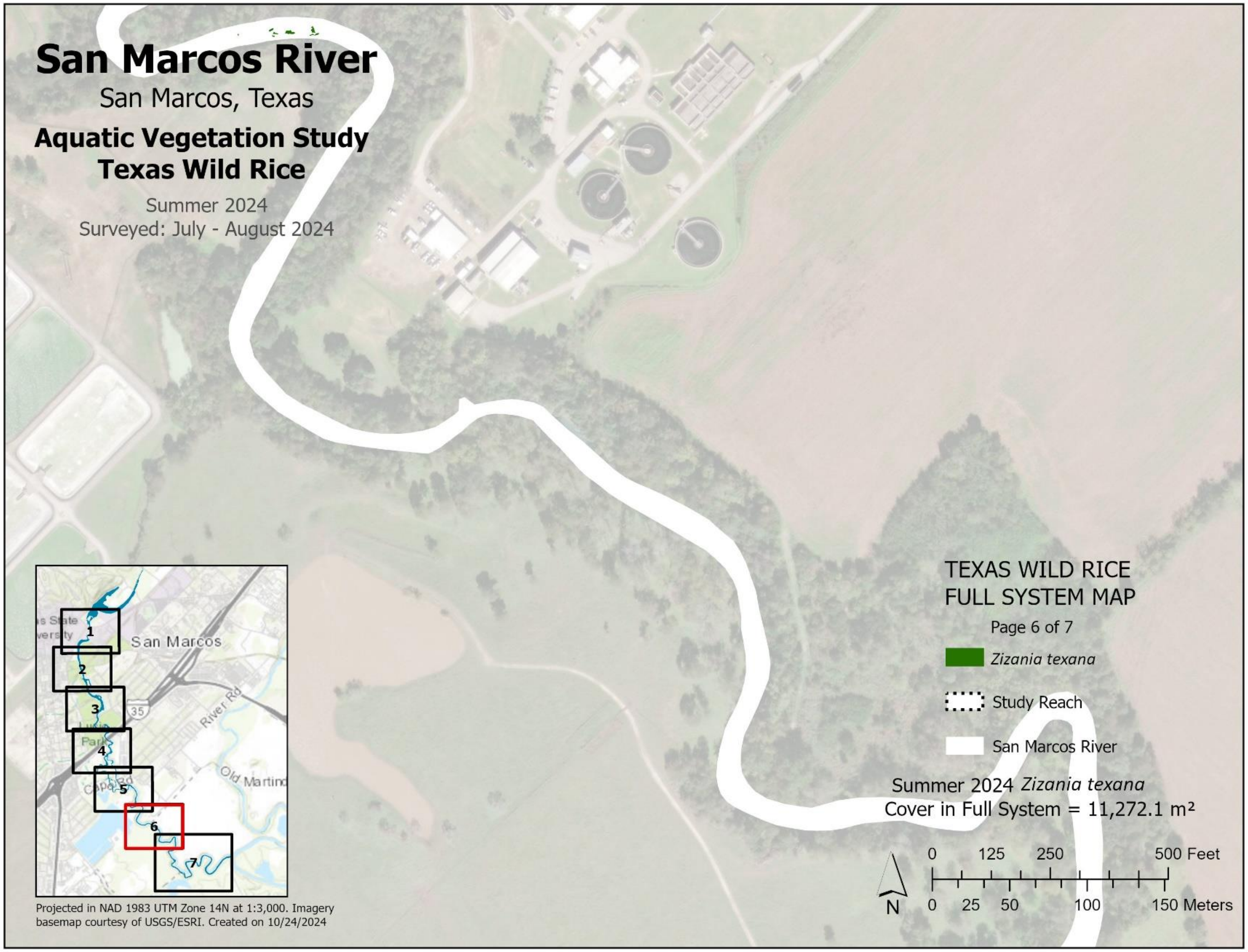

Figure C12. **Map of Texas Wild-rice coverage from Wastewater Treatment Plant to about Cypress Tree Island in summer 2024.**

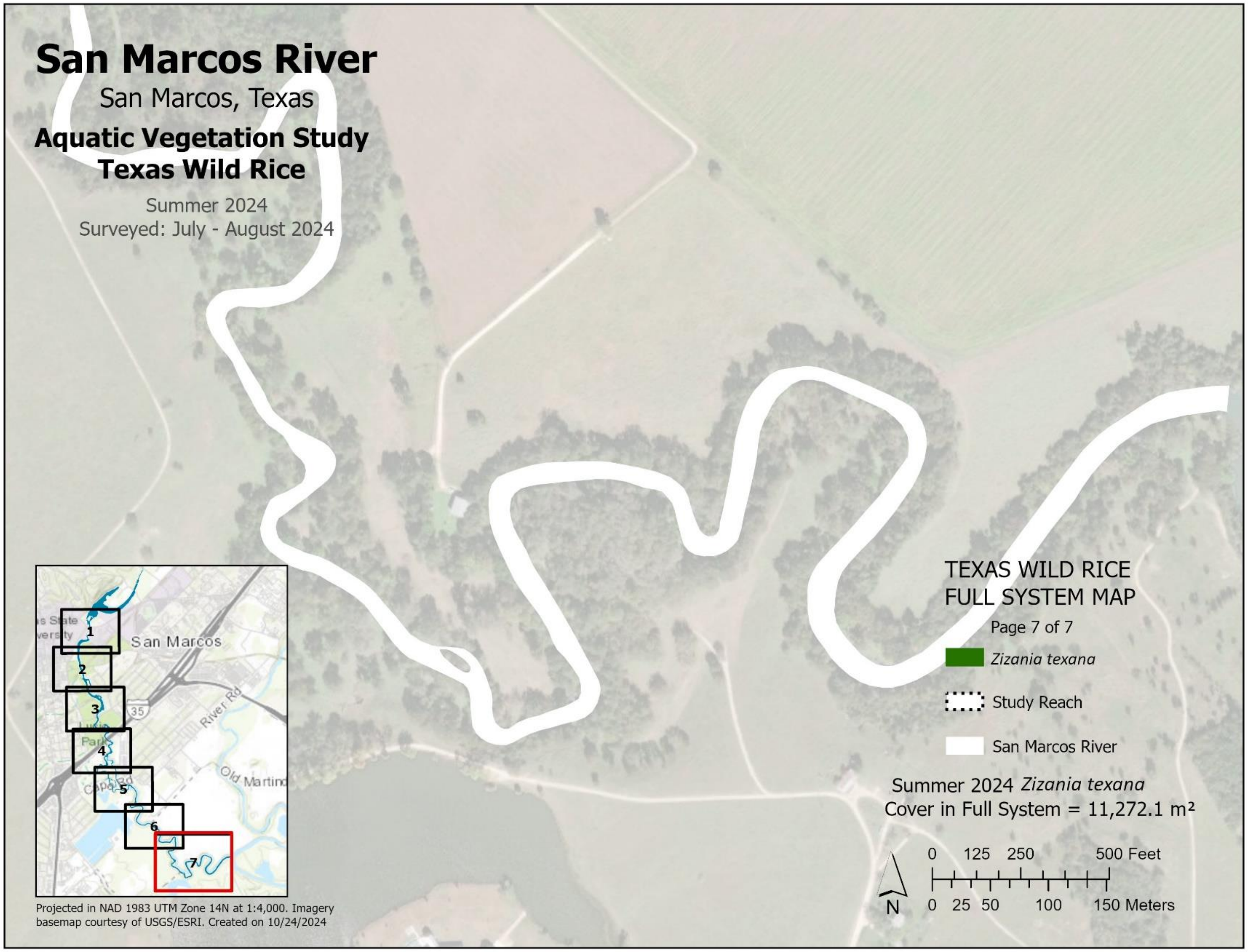

Figure C13. Map of Texas Wild-rice coverage from about Cypress Tree to the Blanco River confluence in summer 2024.

APPENDIX C: TEXAS WILD-RICE PHYSICAL OBSERVATIONS

For the 2024 annual mapping event, 289 stands and 281 points of Texas Wild-rice (TWR) were mapped. The extent of Texas Wild-rice was unchanged compared to previous years and the most downstream extent of rice was located at the power line right-of-way as it crosses the river at A.E. Wood State Fish Hatchery (29.8664456N; -97.9271326W). The majority (53%) of Texas Wild-rice stands were documented at water depths ≥ 3 ft. Texas Wild-rice stands were found at similar frequencies between 0 to 2.9 ft (Table D1). Approximately 28% of Texas Wild-rice stands were found to be associated with another aquatic plant species, which was lower compared to the previous year (37%). One non-native aquatic plant species, *Hygrophila polysperma*, and one native aquatic plant species, *Cabomba caroliniana*, were the most commonly associated taxa with Texas Wild-rice (Table D2). Plant community associations have changed considerably over the last few years, as native plants have become more widespread throughout the river. Lastly, there were 22 Texas Wild-rice stands in bloom at the time of mapping and bloom percentage ranged from 10 to 100%.

Table D1. Distribution of Texas Wild-rice stands based on water depth (n=289) during annual mapping in July/August 2024.

WATER DEPTH (ft)	# OF TWR STANDS	FREQUENCY (%)
0 to 0.9	48	17
1.0-1.9	48	17
2.0-2.9	40	13
3.0 +	153	53

Table D2. Associated species found with Texas Wild-rice stands (n=80) during annual mapping in July/August 2024.

SPECIES	# OF TWR STANDS	FREQUENCY (%)
Hygrophila polysperma	34	43
Cabomba caroliniana	17	21
Sagittaria platyphylla	7	9
Heteranthera dubia	6	7
Other species	16	20

Observations for vulnerable Texas Wild-rice stands were conducted 10 times during 2024 (Table D3). These qualitative measurements included the following categories: 1) the percent of the stand that was emergent (including the percent with seed or flower); and 2) the percent covered with vegetation mats or algae buildup and a categorical estimation of root exposure. Rectangular study plots, established around chosen vulnerable stands in GIS were used to locate and identify vulnerable Texas Wild-rice stands for sampling. Individual stands are mapped in GIS to provide length, width, and cover estimates. Water depth and flow measurements were taken at the upstream edge of each Texas Wild-rice stand. San Marcos River mean daily discharge during the monitoring events ranged from 131 cfs in the spring to 82 cfs in the fall. Although discharge during both events was still below the historical mean daily discharge (186 cfs), conditions through most of 2024 were better than 2023 until August (Table D3).

As in the previous year, physical observations were made for vulnerable Texas Wild-rice stands within three general study areas: 1) Spring Lake Dam / Sewell Park; 2) Veramendi Park; and 3) I-35. These study areas are heavily trafficked with river recreation due to their location near river access points that allow recreationists to enter, exit or linger for the duration of a given day. Therefore, during peak recreation season, Texas Wild-rice patches at these locations are typically subjected to harsher disturbances compared to patches located in other reaches of the river. At the end of this appendix, coverage of each vulnerable stand, percent of stands at water depths less than 0.50 feet (ft), and index of root exposure for stands can be found in Table D4, Figure D4, and Figure D5, respectively.

Table D3. The dates of Texas Wild-rice observations conducted in 2024 with corresponding average daily discharge in the San Marcos River.

PHYSICAL OBSERVATIONS EVENT	EVENT TYPE	DATE	MEAN DAILY DISCHARGE (cfs)
1	Low Flow Physical Observation	January 11	90
2	Spring Biological Monitoring	May 3	131*
3	Low Flow Physical Observation	May 8	129*
4	Low Flow Physical Observation	June 10	112
5	Low Flow Physical Observation	June 21	112
6	Low Flow Physical Observation	July 3	114
7	Low Flow Physical Observation	August 23	93
8	Low Flow Physical Observation	September 3	95
9	Low Flow Physical Observation	September 27	85
10	Fall Biological Monitoring	November 8	82

http://nwis.waterdata.usgs.gov/tx *Discharge was calibrated to above 120 cfs after sampling event.

Spring Lake Dam/Sewell Park Reach

The Texas Wild-rice stands in this reach varied in coverage and health throughout 2024, with the highest total coverage noted during low flow event 8 (165 m^2; Table D4). In general, Texas Wild-rice stands in this reach were negatively impacted primarily by foot traffic followed by silt accretion and dewatering. In January, Texas Wild-rice was mostly emergent with large amounts of mature seeds. As the year progressed, stands became less dense and eventually completely fragmented by foot traffic. One stand on river right completely disappeared by fall (Figure D2). Stand #7 had large percentages of the stand elevated above the water surface causing the stand to perish as flows continued to decrease. This stand was highly eroded along the long edge with clear walking paths throughout (Figure D2). Stands that were not in the path of recreation (e.g., stand #2 and stand #4/5) maintained their footprint.

During low flow event 1, velocity at individual stands ranged from 0.14 to 1.03 ft/s. All stands were in water depths greater than 0.5 ft except Stand #8 in which about 80% of the stand was in water less than 0.50 ft. Root exposure from scouring was noted in this section, with heavy scouring at stand #4/5 and #7. Fall sampling velocity ranged from 0.54 to 1.95 ft/s. By this time, Stand #8 was very thin and mostly in less than 0.50 ft of water. Root exposure was extreme around all stands except for stand #1 (Figure D1). Additionally, this reach had the most vegetation mat cover compared to all other reaches.

Figure D1. Event 6 2024 (left); Event 8 2024 (middle); fall biological monitoring event (right) vulnerable Texas Wild-rice plots in the Spring Lake dam / Sewell Park location. Yellow rectangles indicate stand plots. Red polygons indicate individual Texas Wild-rice stands.

Veramendi Park

Total cover of vulnerable Texas Wild-rice stands in Veramendi Park was highest in event 10 (fall biological monitoring). Stand #1 was absent from sampling events early in the year but re-established by event 6. This stand is typically located in the footpath of recreationists. Although flows decreased through the late summer and fall, all other stands maintained their footprint throughout the year.

During low flow event 1, velocities ranged from 0.16 to 0.78 ft/s. All stands occurred in water depths greater than 0.50 ft. Root exposure was moderate across all stands and blooming was minimal. During the fall biological monitoring event, sampling velocities ranged from 0.30 to 1.48 ft/s. No stands occurred in water less than 0.50 ft in water depth. Root exposure ranged from moderate to extreme. Stand #2, located away from the main channel and recreational pathway, was maintained through most of the year and Stand #3 expanded into the river channel (Figure D2).

Figure D2. **Event 6 2024 (left); Event 8 2024 (middle); fall biological monitoring event (right) vulnerable Texas wild-rice plots in the Veramendi Park area. Yellow rectangles indicate stand plots. Red polygons indicate individual Texas Wild-rice stands.**

I-35 Reach

The coverages of vulnerable Texas Wild-rice stands in this reach varied throughout the year. Coverage was lowest during low flow event 6, increased during low flow event 8 and decreased again during fall (Figure D3). The vulnerable stands were more impacted by recreational wading compared to previous years as more people utilize William & Eleanor Crook Park for river access. Texas Wild-rice stands in deeper pools were less impacted.

Current velocities during low flow event 1 in January ranged from 0.0 to 1.54 ft/s. Stand #3 was the only stand observed in water depths 0.50 ft or less. On average, root exposure was moderate around all stands. During fall sampling, velocities ranged from 0.13 to 1.52 ft/s. Root exposure was noted as moderate across all stands except for stand #8 in which most roots were entirely exposed. Additionally, stand #5 was completely dewatered during fall sampling. Flowering was minimal in both spring and fall sampling.

Figure D3. **Event 6 2024 (left); Event 8 2024 (middle); fall biological monitoring event (right) vulnerable Texas wild-rice plots in the I-35 area. Yellow rectangles indicate stand plots. Red polygons indicate individual Texas Wild-rice stands.**

Table D4. **Cover (m^2) of individual vulnerable Texas Wild-rice stands during selected sampling events throughout 2024. Sites labeled 'Gone' denotes vulnerable stands were absent and 'Point' denotes vulnerable stands were present, but cover was not large enough to calculate an area.**

LOCATION	LOW-FLOW EVENT VI	LOW-FLOW EVENT VIII	FALL 2024
Sewell Park 1	65	82	68
Sewell Park 2	7	11	7
Sewell Park 3	Gone	Gone	Gone
Sewell Park 4/5	29	23	31
Sewell Park 6	Gone	Gone	Gone
Sewell Park 7	33	41	17
Sewell Park 8	4	8	11
Sum of Cover	**138**	**165**	**134**
Veramendi 1	4	3	9
Veramendi 2	42	37	34
Veramendi 3	48	41	59
Sum of Cover	**94**	**81**	**102**
I-35-1	4	8	5
I-35-2	0	4	2
I-35-3	0	0	2
I-35-4	82	119	88
I-35-5	2	1	1
I-35-6	3	8	Point
I-35-7	Gone	Gone	Gone
I-35-8	23	7	18
I-35-9	Gone	1	Gone
I-35-10	Gone	Gone	Gone
Sum of Cover	**114**	**148**	**116**

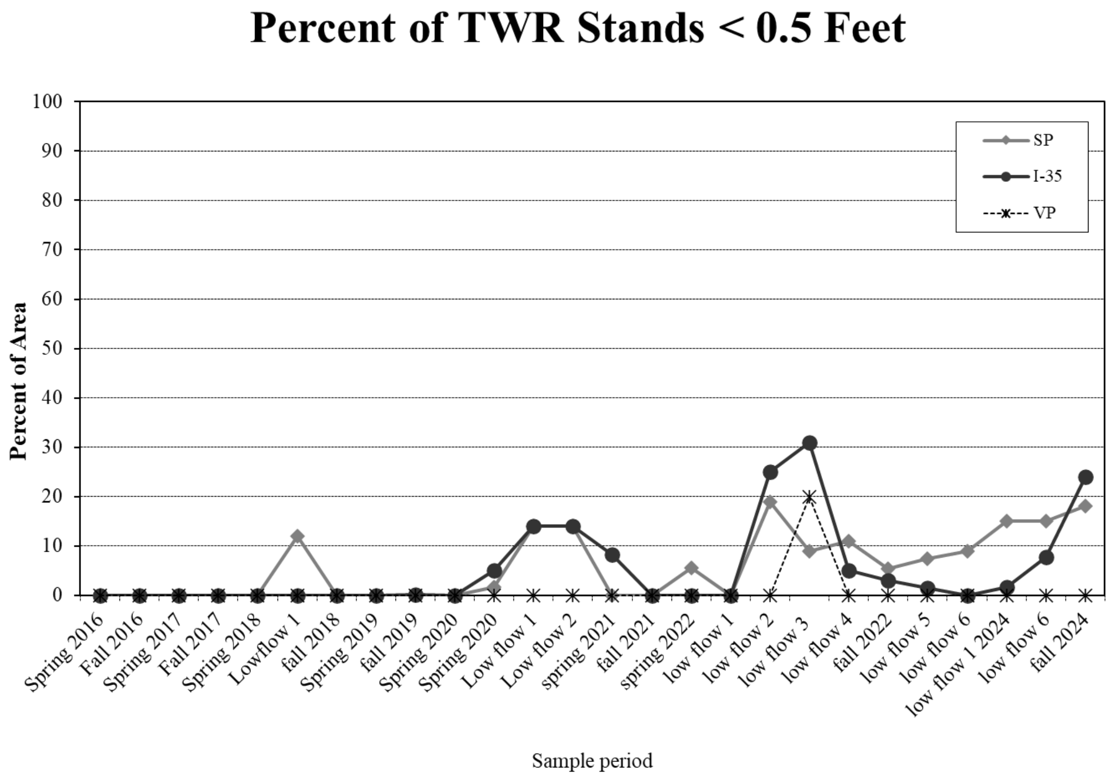

Figure D4. Percent of Texas Wild-rice stands at water depths less than 0.5 feet 2016–2024.

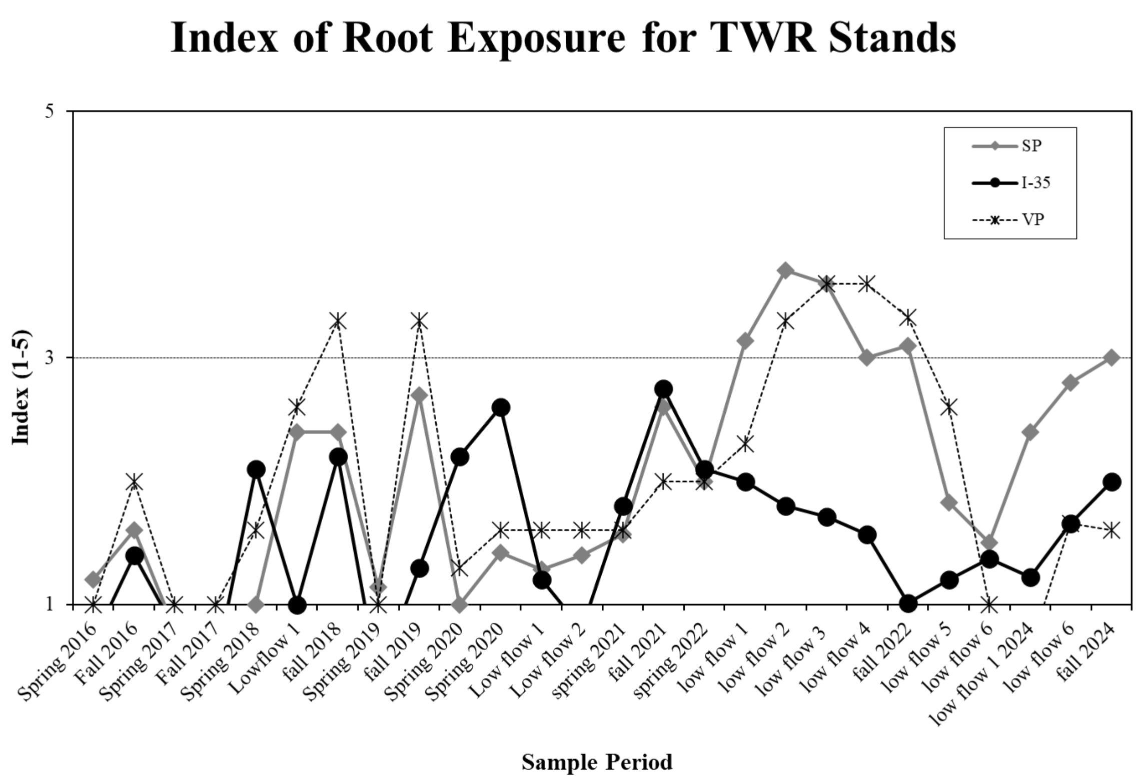

Figure D5. Index for root exposure of Texas Wild-rice stands from 2016–2024.

APPENDIX D: TABLES AND FIGURES

Fish Assemblage Results:
Drop-Net and Fish Community Sampling

Table E1. **Overall number (#) and percent relative abundance (%) of fishes collected from the three long-term biological goals study reaches during drop-net sampling in 2024.**

TAXA	SPRING LAKE DAM		CITY PARK		I-35	
	#	%	#	%	#	%
Lepisosteidae						
Lepisosteus oculatus	0	0.00	0	0.00	1	0.13
Leuciscidae						
Alburnops chalybaeus	0	0.00	26	1.75	2	0.25
Dionda nigrotaeniata	2	0.35	0	0.00	3	0.38
Notropis amabilis	0	0.00	0	0.00	26	3.26
Characidae						
*Astyanax argentatus**	0	0.00	3	0.20	0	0.00
Ictaluridae						
Ameiurus natalis	1	0.17	0	0.00	5	0.63
Loricariidae						
*Hypostomus plecostomus**	0	0.00	0	0.00	6	0.75
Fundulidae						
Fundulus chrysotus	0	0.00	0	0.00	1	0.13
Poeciliidae						
Gambusia sp.	329	56.82	992	66.67	337	42.28
Centrarchidae						
*Ambloplites rupestris**	3	0.52	1	0.07	11	1.38
Lepomis cyanellus	0	0.00	0	0.00	1	0.13
Lepomis gulosus	1	0.17	0	0.00	1	0.13
Lepomis miniatus	10	1.73	4	0.27	14	1.76
Lepomis sp.	3	0.52	2	0.13	40	5.02
Micropterus salmoides	1	0.17	0	0.00	3	0.38
Percidae						
Etheostoma fonticola	224	38.69	460	30.91	341	42.79
Percina apristis	0	0.00	0	0.00	1	0.13
Cichlidae						
*Herichthys cyanoguttatus**	5	0.86	0	0.00	4	0.50
TOTAL	**579**		**1488**		**797**	

Asterisks (*) denotes introduced species

Table E2. Overall number (#) and percent relative abundance (%) of fishes collected during fish community sampling in 2024.

TAXA	SPRING LAKE		UPPER RIVER		MIDDLE RIVER		LOWER RIVER	
	#	%	#	%	#	%	#	%
Lepisosteidae								
Lepisosteus oculatus	3	0.1	0	0.0	0	0.0	0	0.0
Leuciscidae								
*Alburnops chalybaeus**	0	0.0	6	0.3	10	0.7	0	0.0
Cyprinella venusta	0	0.0	0	0.0	0	0.0	26	2.8
Dionda nigrotaeniata	1451	25.7	75	4.2	141	10.5	2	0.2
Pimephales vigilax	0	0.0	0	0.0	0	0.0	2	0.2
Notropis amabilis	0	0.0	24	1.4	103	7.7	275	29.9
Paranotropis volucellus	0	0.0	0	0.0	0	0.0	184	20.0
Characidae								
*Astyanax argentatus**	1552	27.5	92	5.2	16	1.2	9	1.0
Ictaluridae								
Ameiurus natalis	0	0.0	4	0.2	0	0.0	0	0.0
Ictalurus punctatus	0	0.0	0	0.0	0	0.0	1	0.1
Loricariidae								
Loricariidae sp.	0	0.0	9	0.5	10	0.7	43	4.7
Fundulidae								
Fundulus notatus	0	0.0	0	0.0	0	0.0	1	0.1
Poeciliidae								
Gambusia affinis	0	0.0	57	3.2	17	1.3	9	1.0
Gambusia geiseri	0	0.0	781	44.0	433	32.3	0	0.0
Gambusia sp.	1782	31.6	3	0.2	265	19.8	60	6.5
*Poecilia latipinna**	0	0.0	2	0.1	4	0.3	0	0.0
Centrarchidae								
*Ambloplites rupestris**	0	0.0	2	0.1	2	0.1	7	0.8
*Lepomis auritus**	49	0.9	213	12.0	67	5.0	51	5.5
Lepomis cyanellus	32	0.6	0	0.0	0	0.0	0	0.0
Lepomis gulosus	0	0.0	0	0.0	0	0.0	1	0.1
Lepomis macrochirus	56	1.0	3	0.2	0	0.0	47	5.1
Lepomis megalotis	34	0.6	21	1.2	1	0.1	2	0.2
Lepomis microlophus	150	2.7	4	0.2	1	0.1	4	0.4
Lepomis miniatus	42	0.7	70	3.9	22	1.6	8	0.9
Lepomis sp.	141	2.5	138	7.8	32	2.4	36	3.9
Micropterus punctatus	3	0.1	0	0.0	0	0.0	2	0.2
Micropterus salmoides	191	3.4	56	3.2	45	3.4	16	1.7
Micropterus treculii	0	0.0	0	0.0	0	0.0	1	0.1
Micropterus sp.	0	0.0	0	0.0	1	0.1	0	0.0
Percidae								

Etheostoma fonticola	136	2.4	176	9.9	157	11.7	38	4.1
Etheostoma spectabile	0	0.0	0	0.0	0	0.0	30	3.3
Etheostoma sp.	0	0.0	0	0.0	0	0.0	1	0.1
Percina aptristis	0	0.0	18	1.0	11	0.8	54	5.9
Percina carbonaria	0	0.0	4	0.2	0	0.0	6	0.7
Cichlidae								
*Herichthys cyanoguttatus**	13	0.2	5	0.3	3	0.2	3	0.3
*Oreochromis aureus**	7	0.1	2	0.1	0	0.0	0	0.0
Total	**5,642**		**1,765**		**1,341**		**919**	

Asterisks (*) denotes introduced species

FIGURES

Aquatic Vegetation

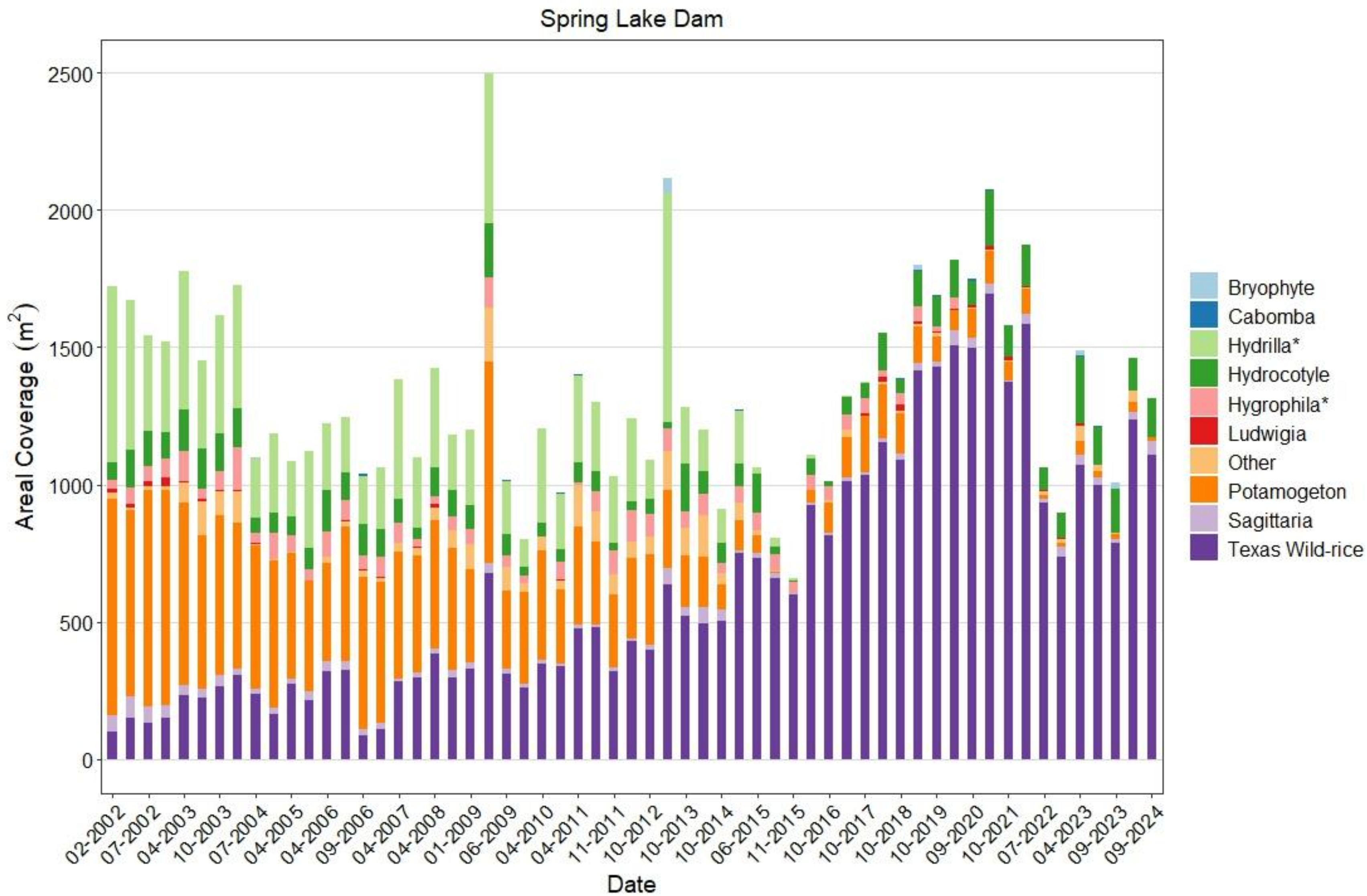

Figure E1. **Aquatic vegetation composition (m^2) among select taxa from 2002–2024 at Spring Lake Dam.**

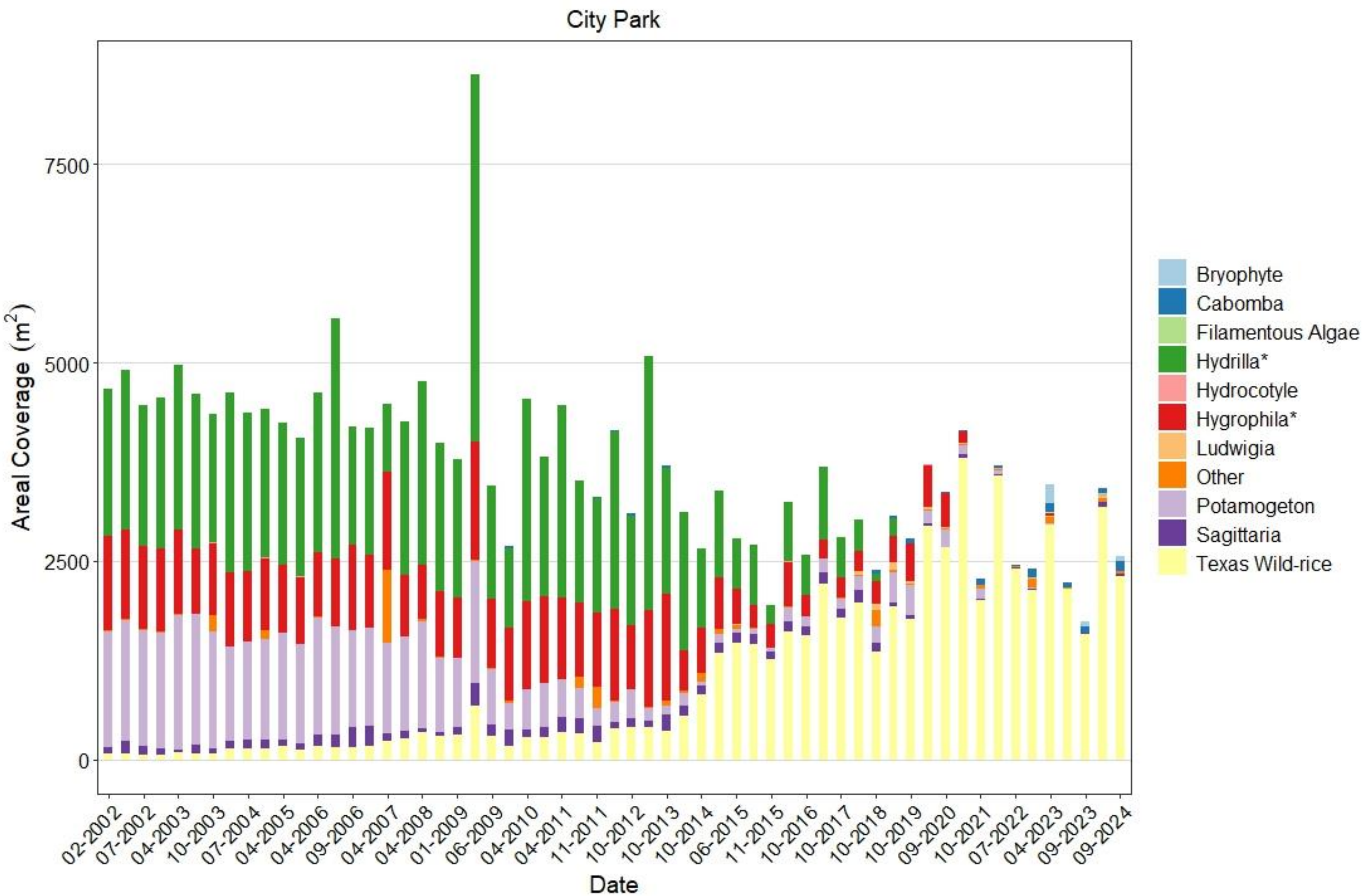

Figure E2. **Aquatic vegetation composition (m^2) among select taxa from 2002–2024 at City Park.**

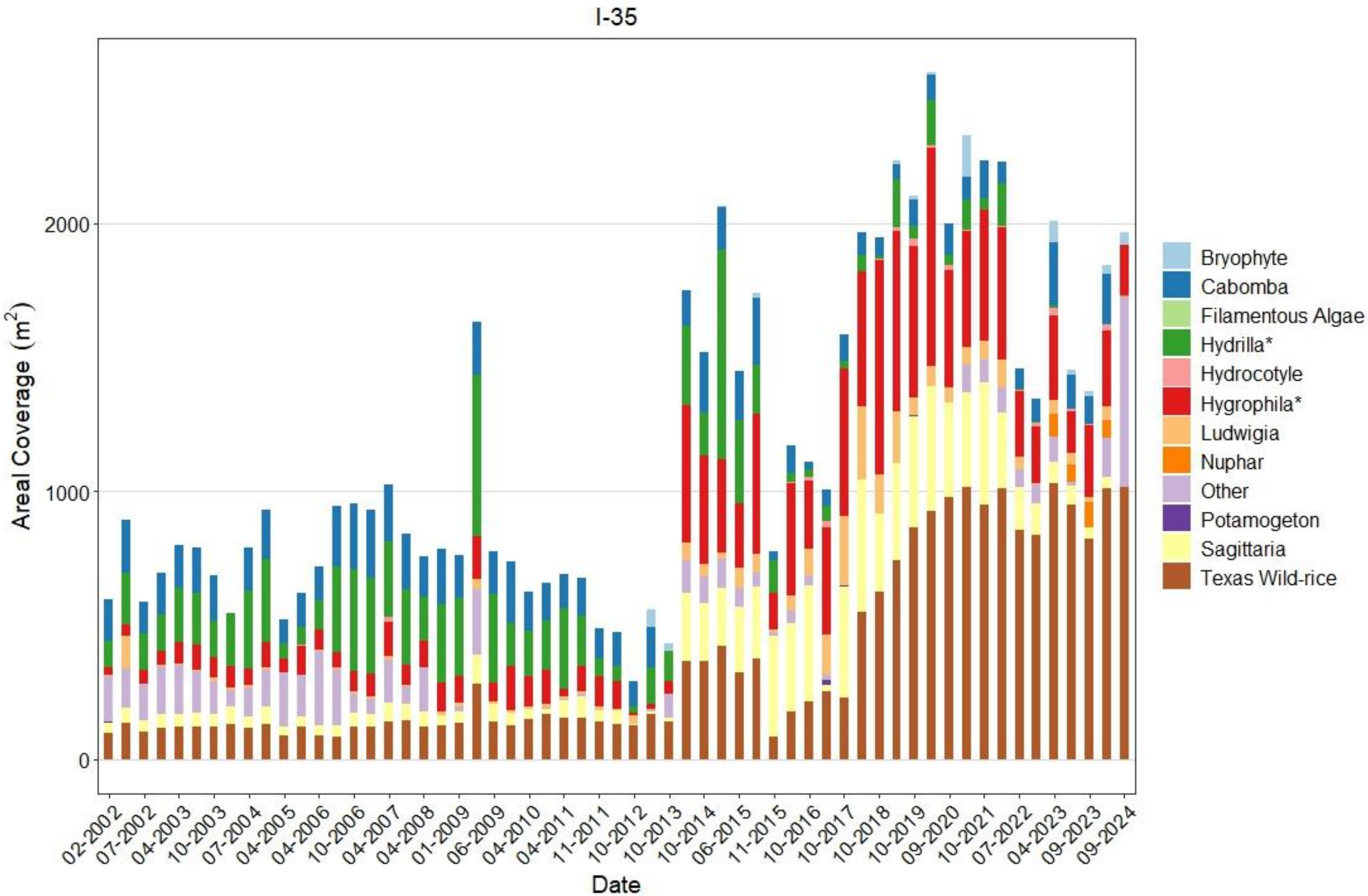

Figure E3. **Aquatic vegetation composition (m^2) among select taxa from 2002–2024 at I-35.**

Fountain Darter

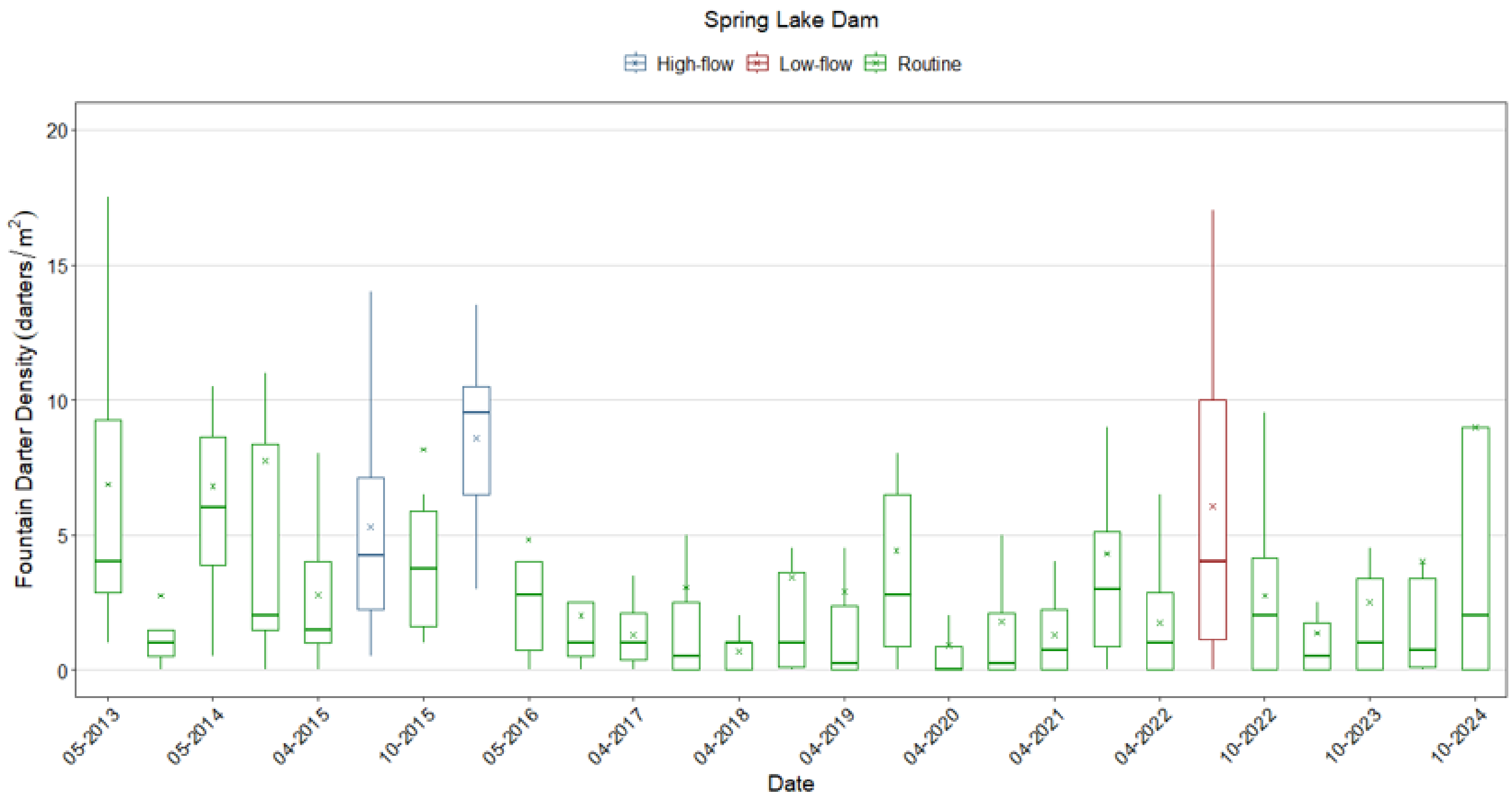

Figure E4. **Boxplots displaying temporal trends in Fountain Darter density (darters/m^2) from 2013–2024 during drop-net sampling at Spring Lake Dam. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.**

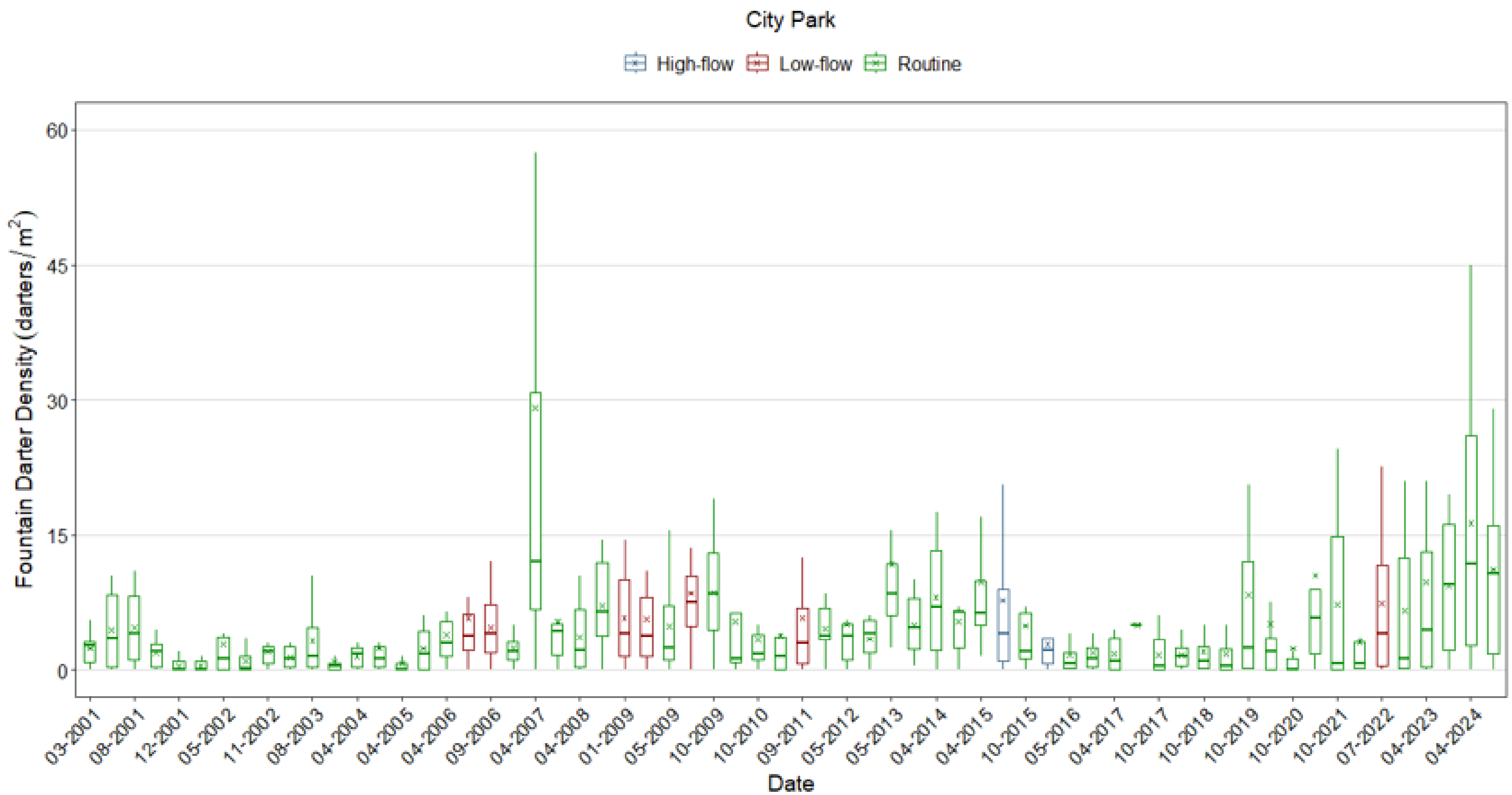

Figure E5. **Boxplots displaying temporal trends in Fountain Darter density (darters/m^2) from 2001–2024 during drop-net sampling at City Park. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.**

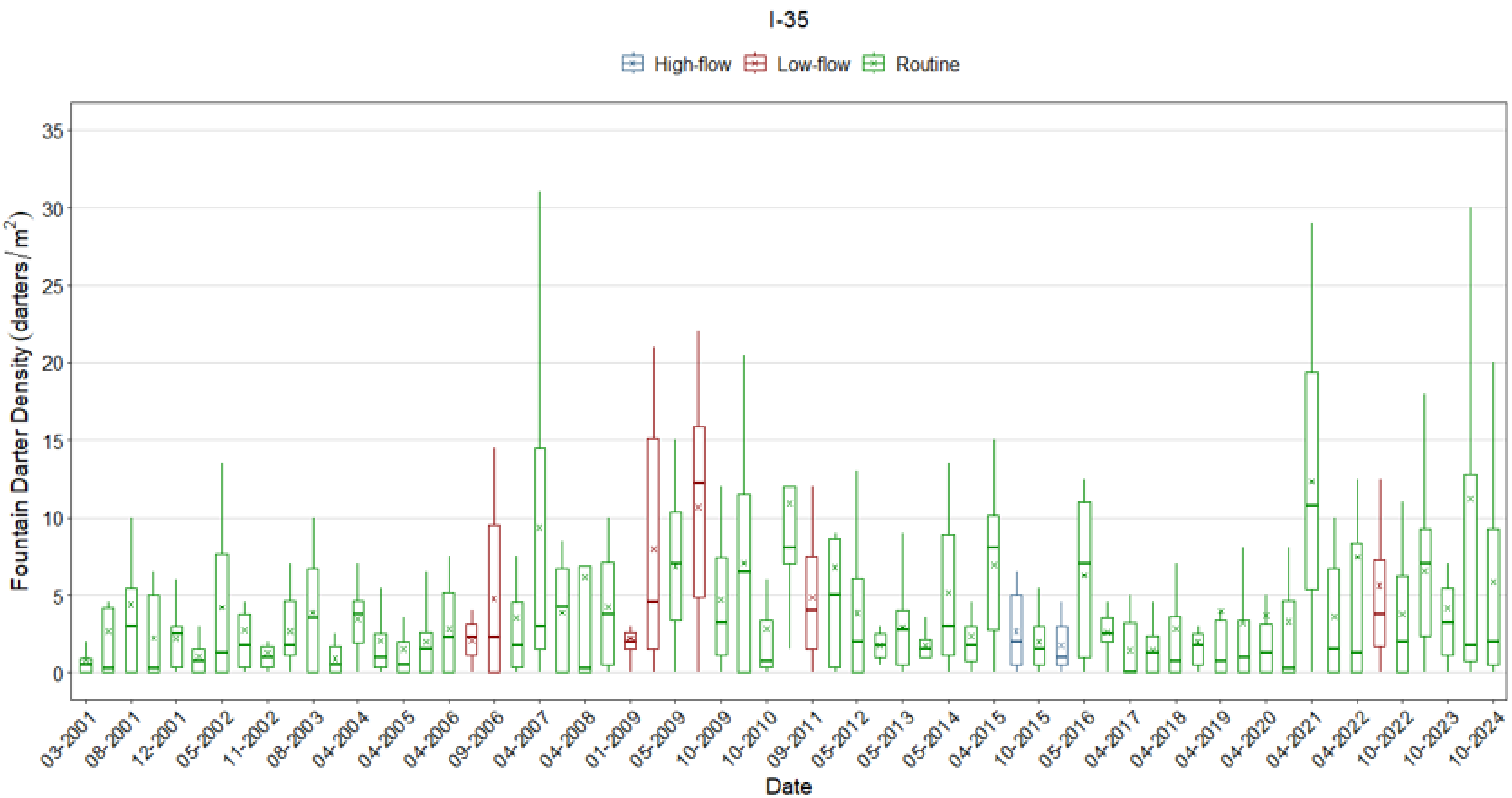

Figure E6. **Boxplots displaying temporal trends in Fountain Darter density (darters/m^2) from 2001–2024 during drop-net sampling at I-35. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.**

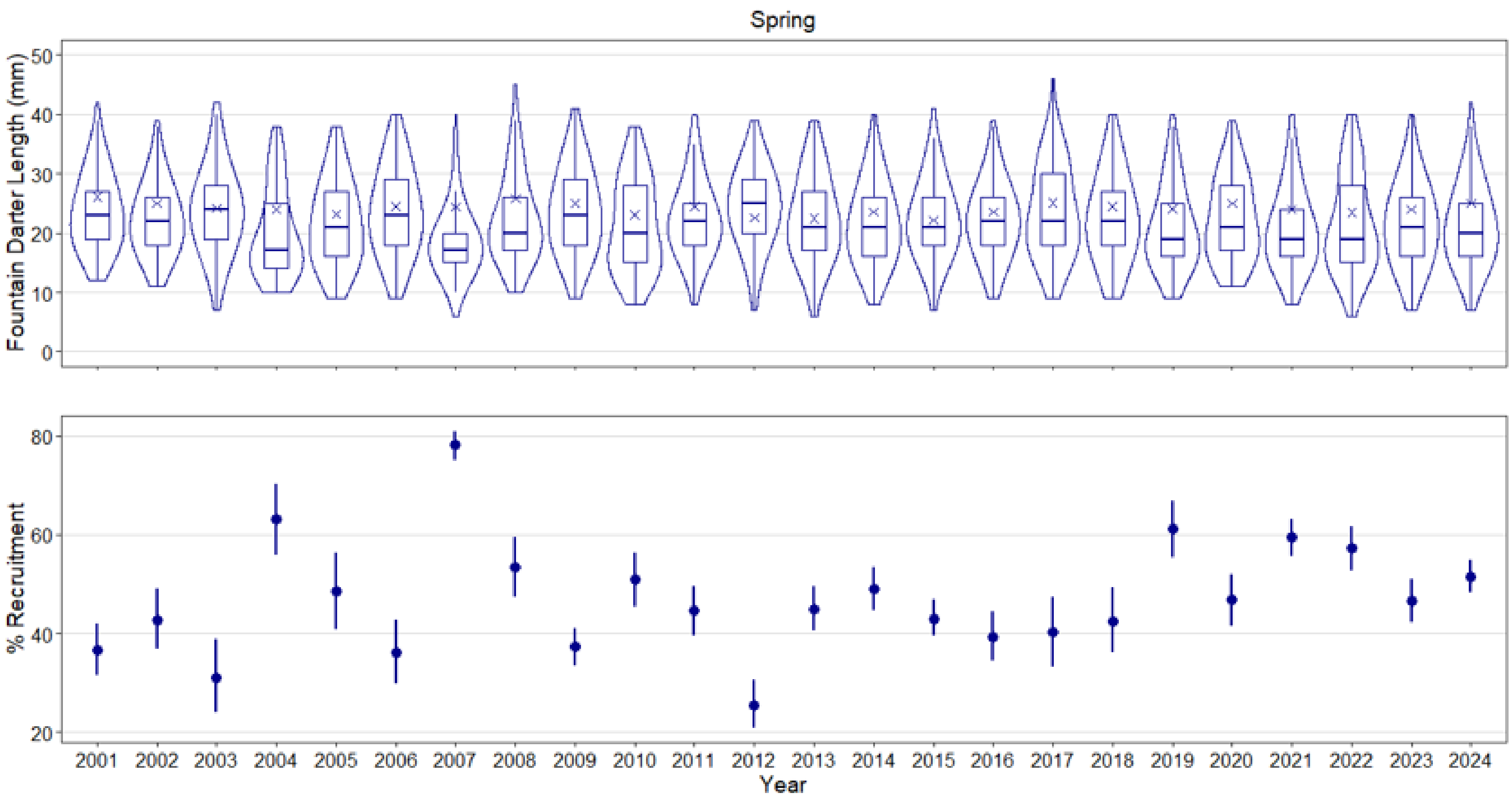

Figure E7. **Fountain Darter size structure (mm; top row) and percent recruitment (bottom row) in the San Marcos Springs and River during spring sampling (i.e., drop-net and timed dip-net data) events from 2001–2024. Size structure is displayed with boxplots (median, quartiles, range) and violin plots (probability density; polygons outlining boxplots). The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. Recruitment is the percent relative abundance (± 95% CI) of darters ≤20 mm.**

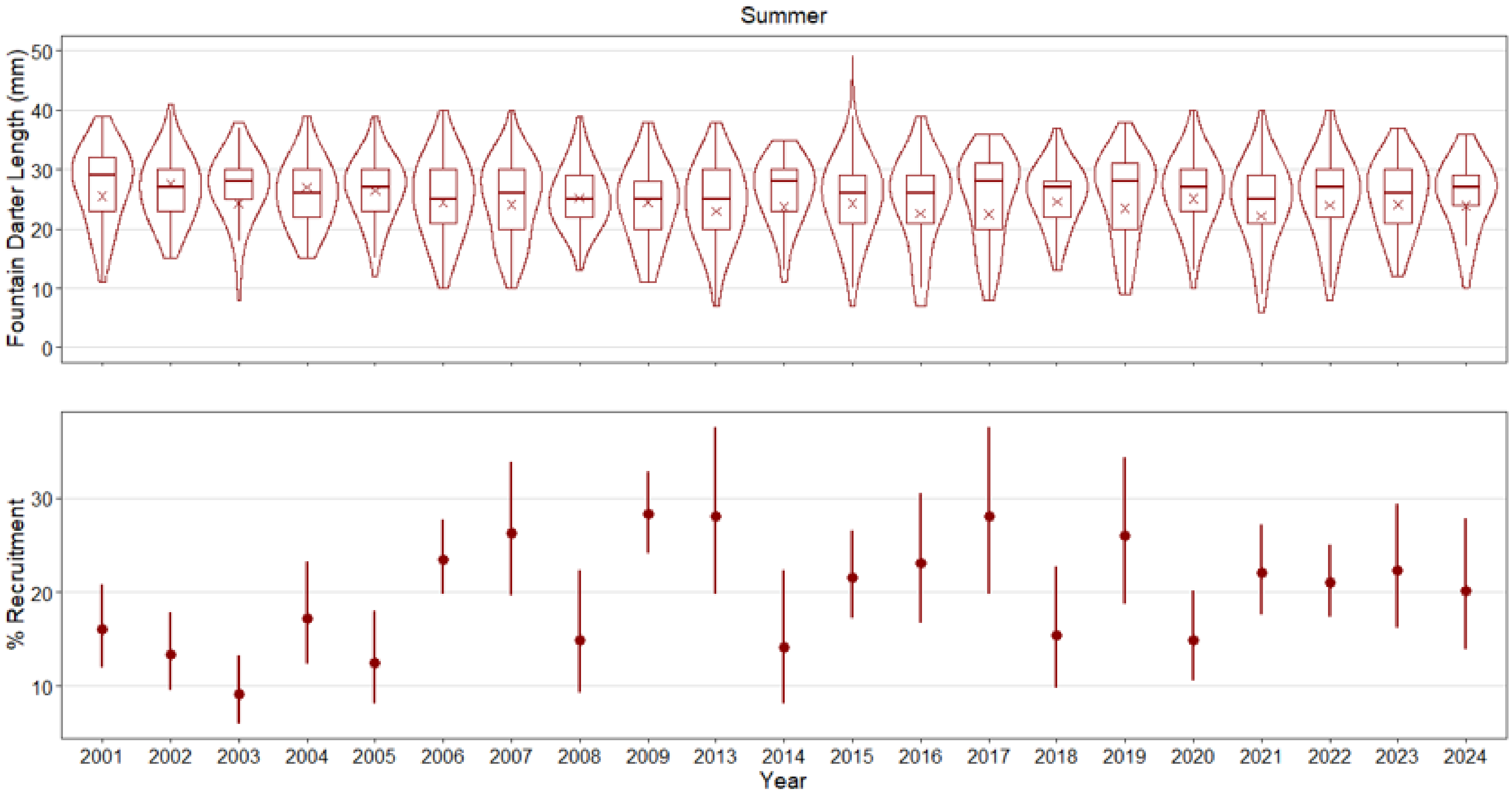

Figure E8. **Fountain Darter size structure (mm; top row) and percent recruitment (bottom row) in the San Marcos Springs and River during summer sampling (i.e., drop-net and timed dip-net data) events from 2001–2024. Size structure is displayed with boxplots (median, quartiles, range) and violin plots (probability density; polygons outlining boxplots). The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. Recruitment is the percent relative abundance (± 95% CI) of darters ≤20 mm.**

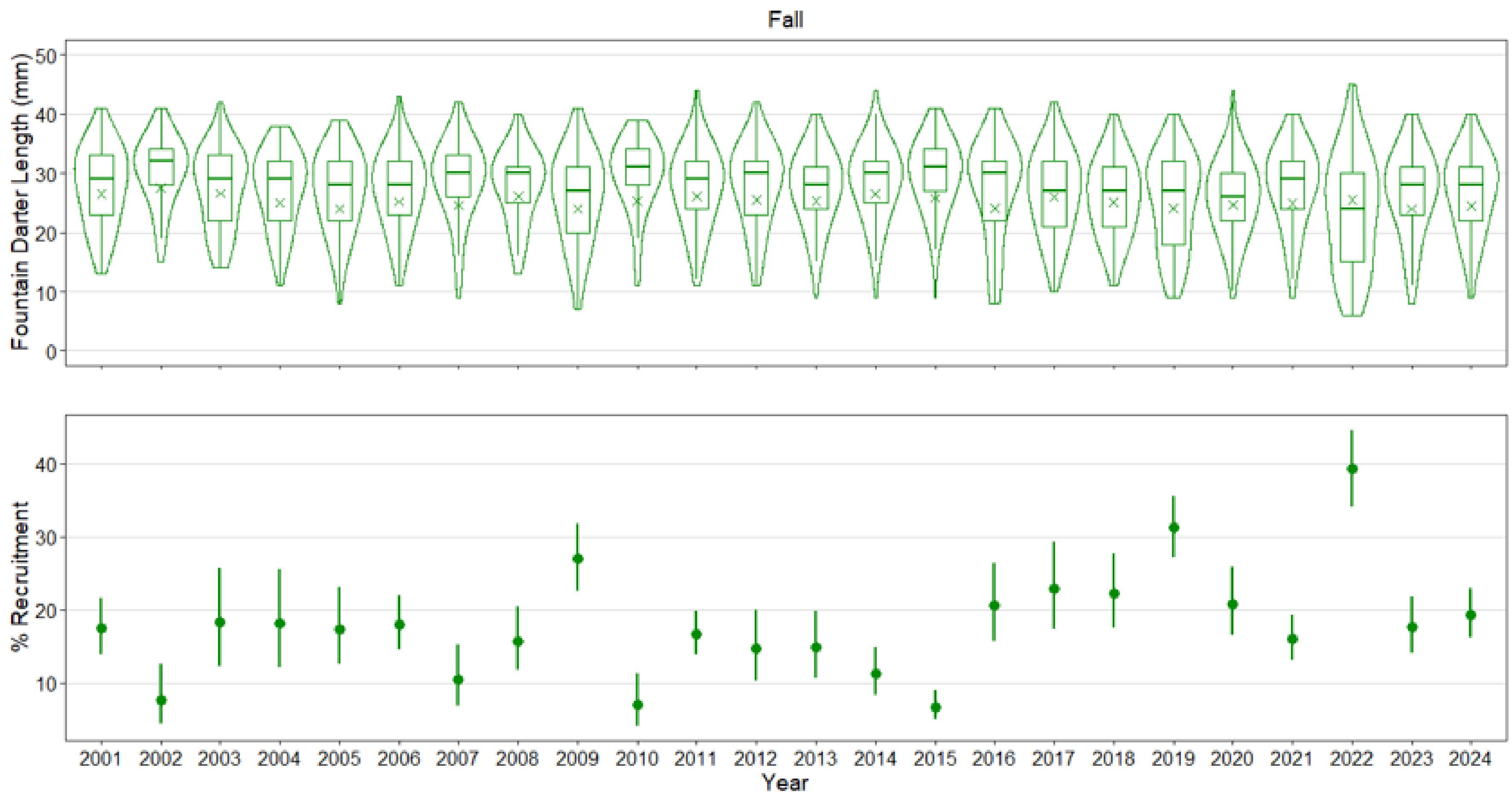

Figure E9. **Fountain Darter size structure (mm; top row) and percent recruitment (bottom row) in the San Marcos Springs and River during fall sampling (i.e., drop-net and timed dip-net data) events from 2001–2024. Size structure is displayed with boxplots (median, quartiles, range) and violin plots (probability density; polygons outlining boxplots). The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range. Recruitment is the percent relative abundance (± 95% CI) of darters ≤20 mm.**

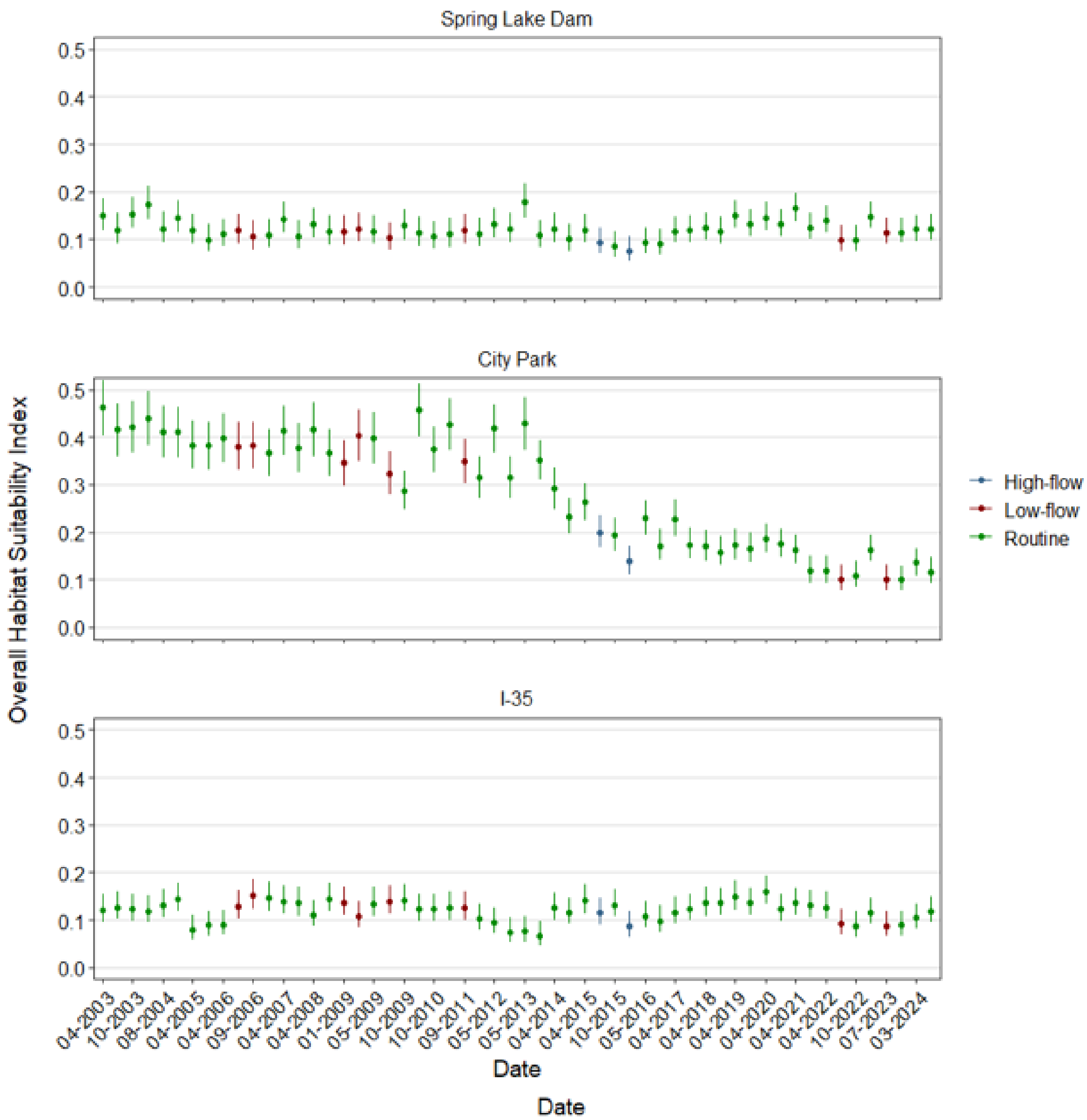

Figure E10. **Overall Habitat Suitability Index (OHSI) (±95% CI) from 2003–2024 among study reaches in the San Marcos River.**

Fish Community

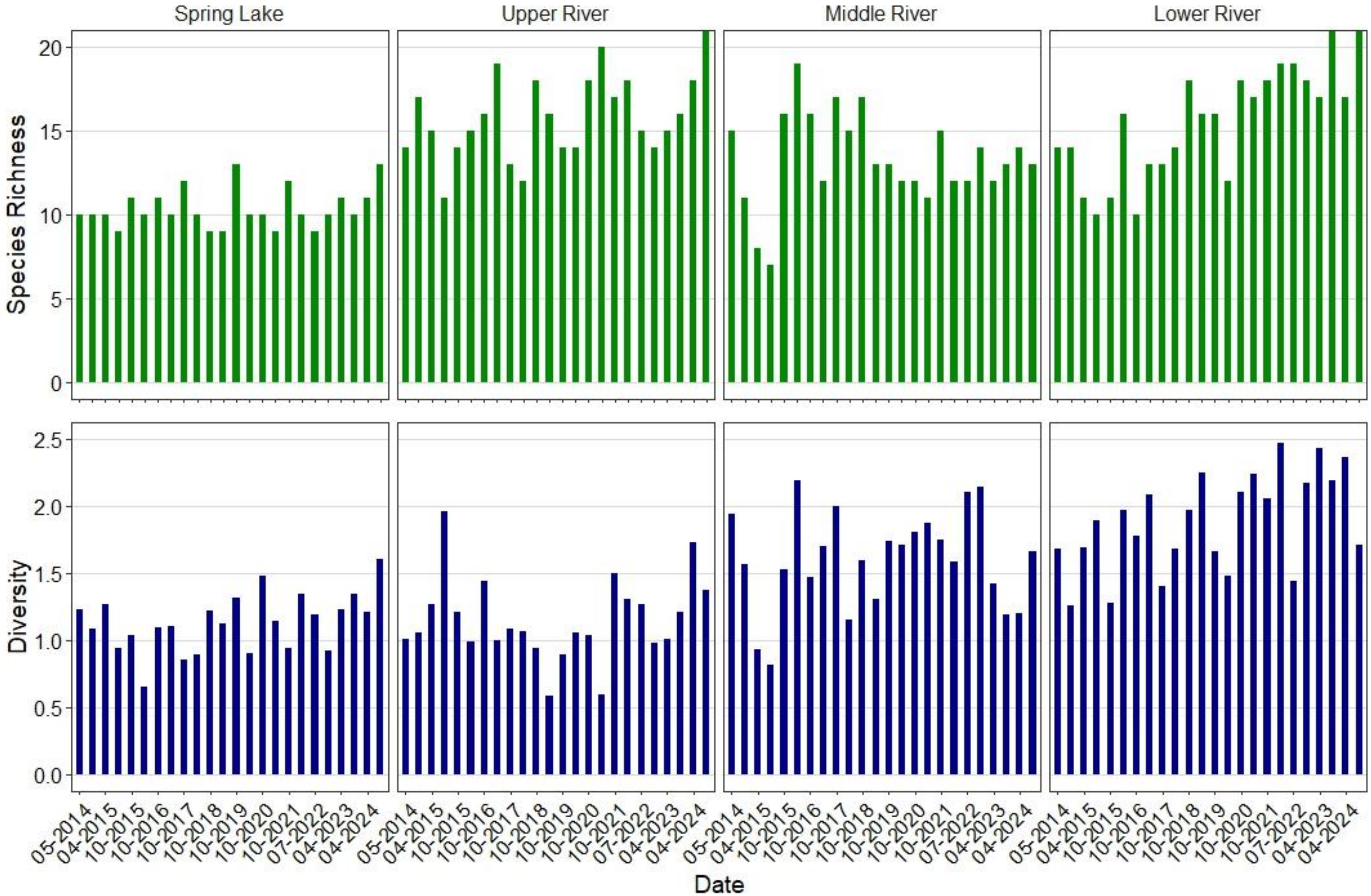

Figure E11. **Bar graphs displaying temporal trends in species richness and diversity among study reaches from 2014–2024 during fish community sampling in the San Marcos Springs/River.**

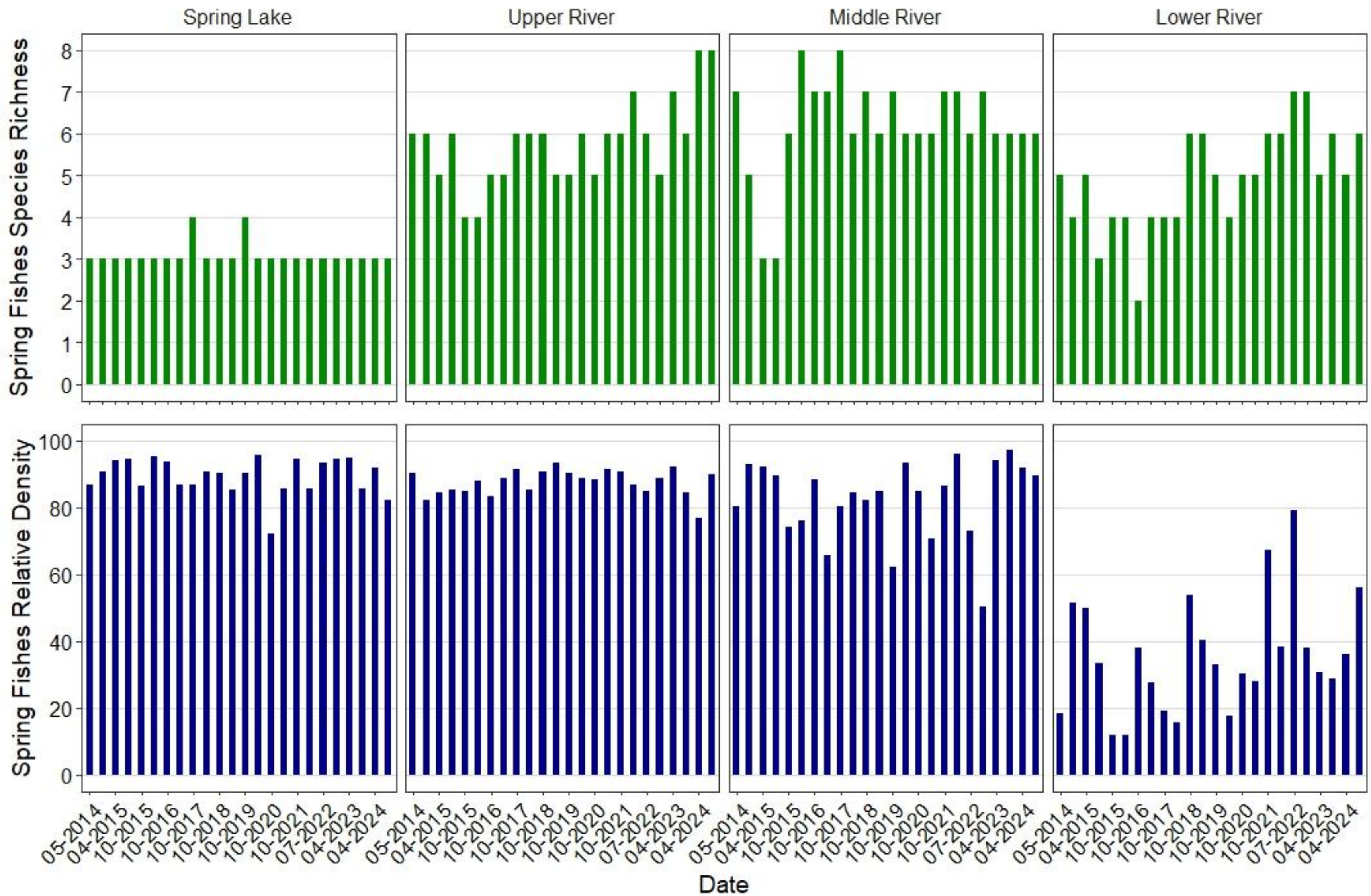

Figure E12. **Bar graphs displaying temporal trends in spring fishes species richness and percent relative density among study reaches from 2014–2024 during fish community sampling in the San Marcos Springs/River.**

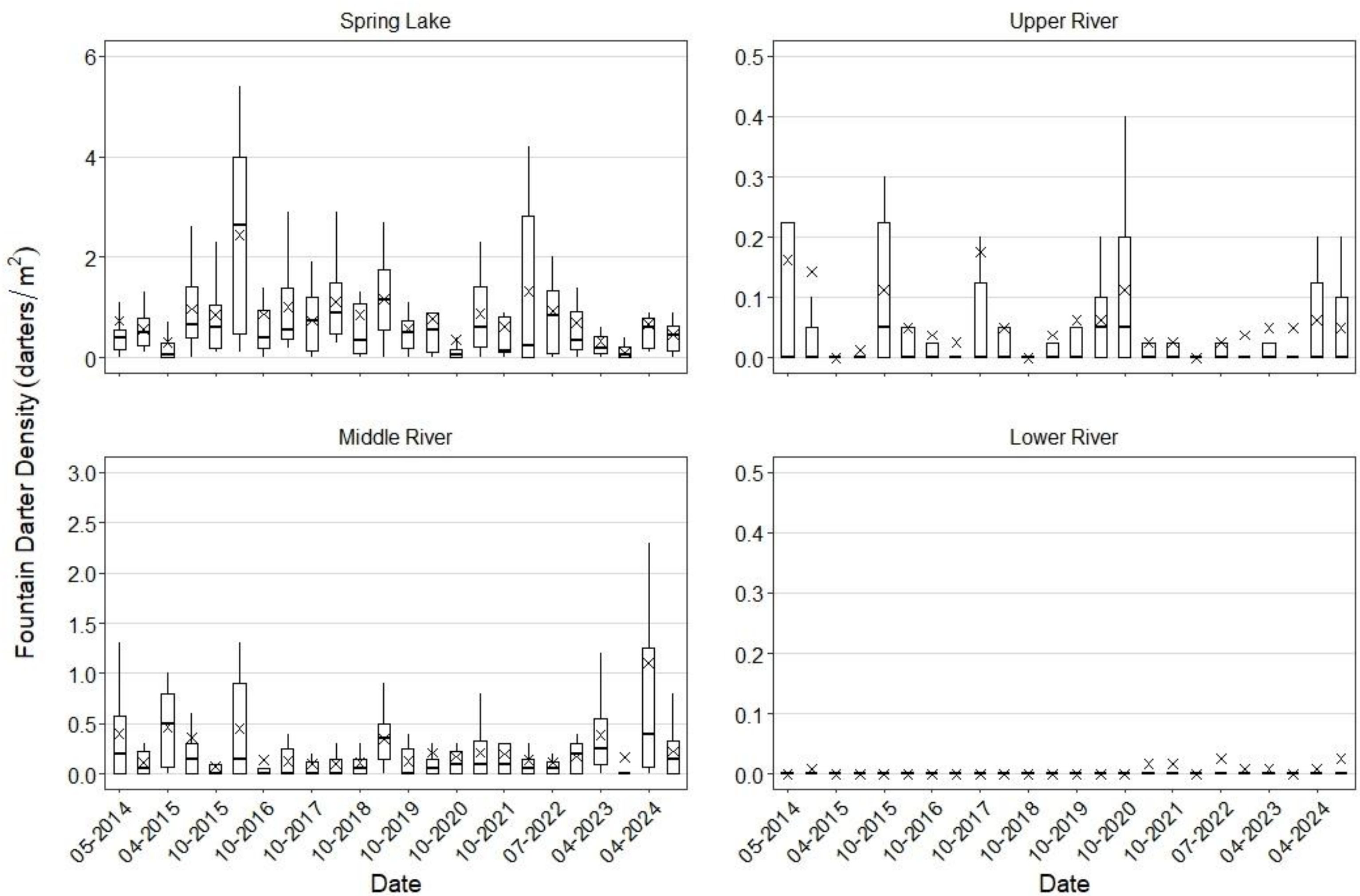

Figure E13. Boxplots displaying temporal trends in Fountain Darter density (darters/m²) among study reaches from 2014–2024 during fish community microhabitat sampling in the San Marcos Springs/River. The thick horizontal line in each box is the median, x represents the mean, and the upper/lower bounds of each box represents the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range.

San Marcos Salamander

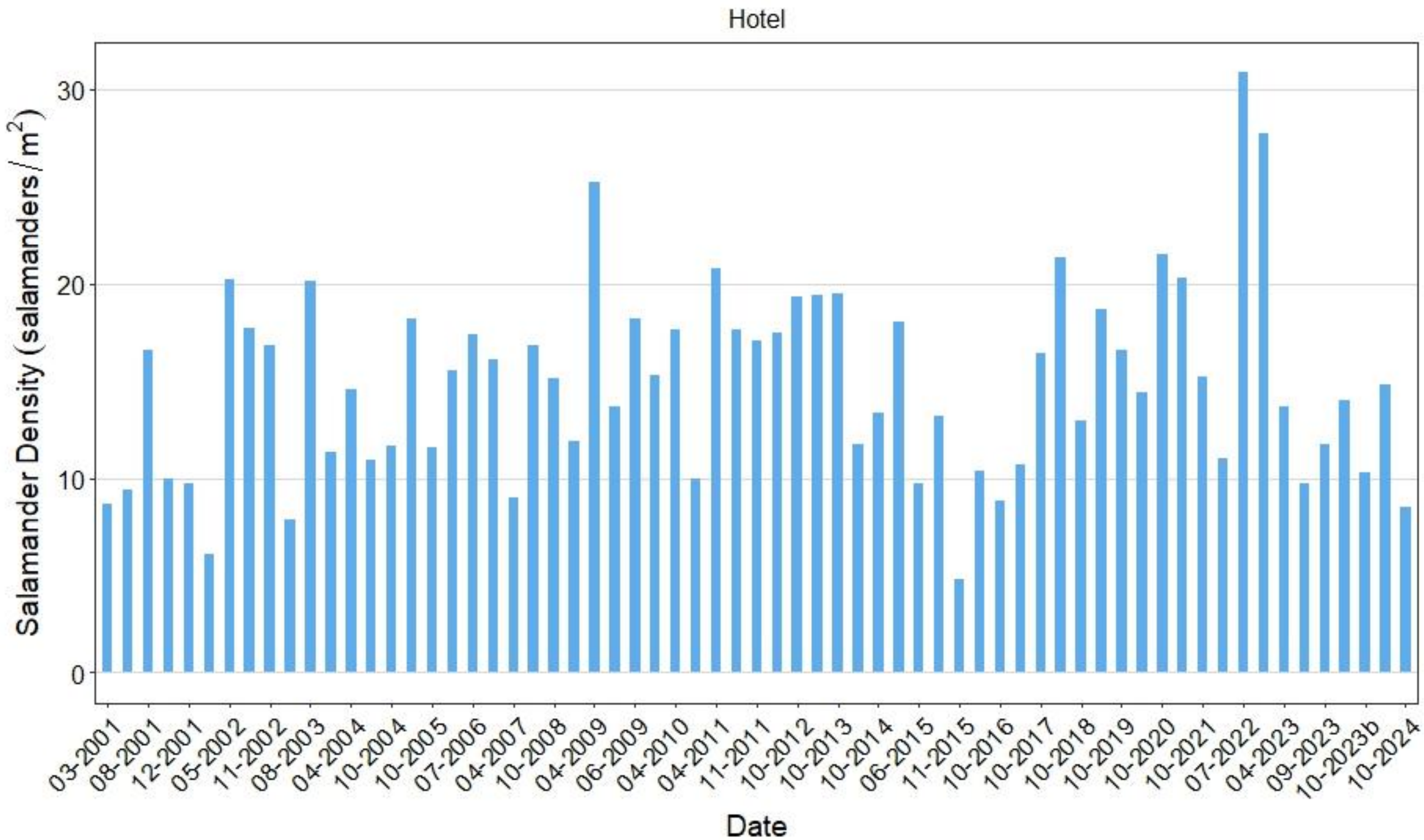

Figure E14. **San Marcos Salamander density from 2001–2024 at the Hotel Site.**

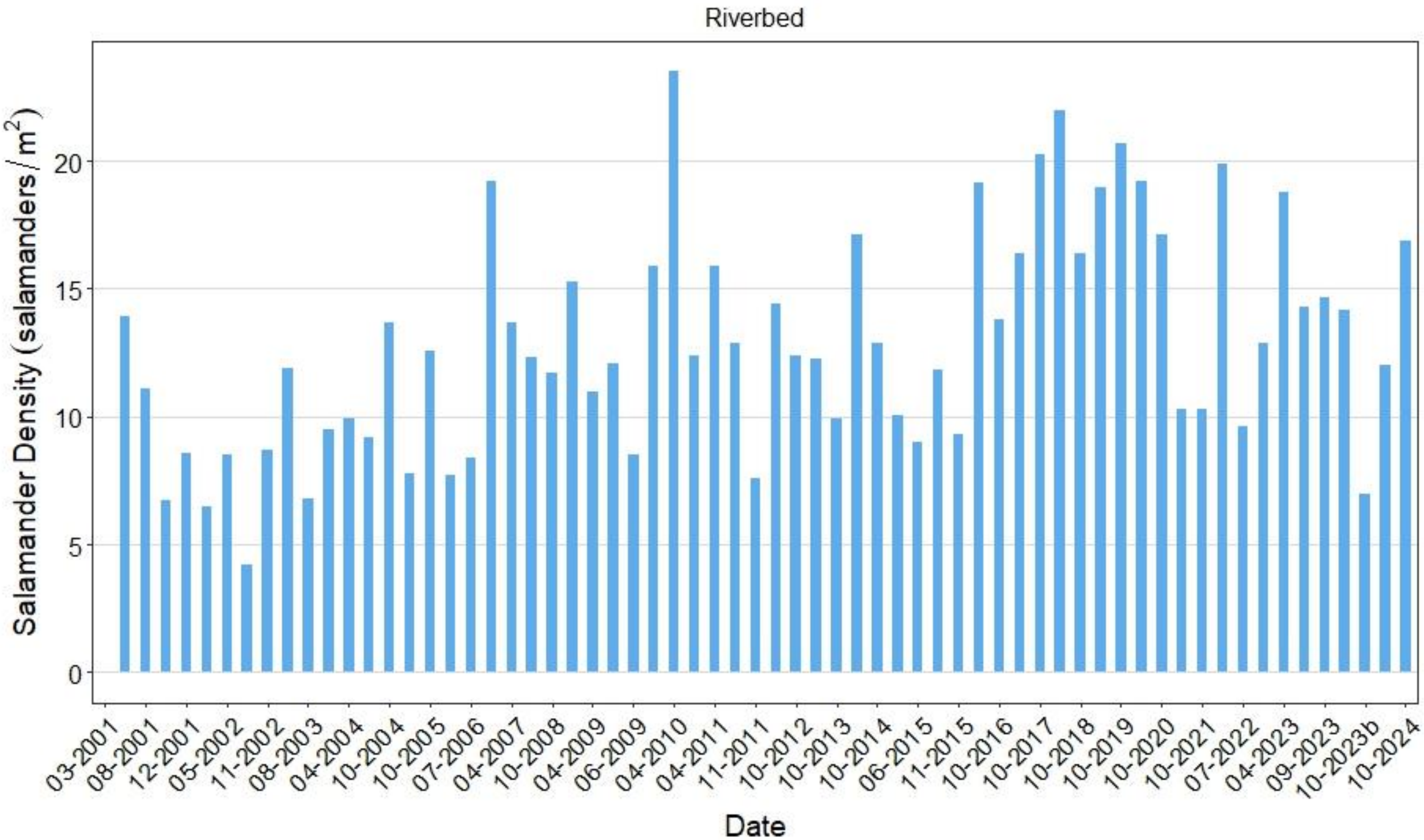

Figure E15. **San Marcos Salamander density from 2001–2024 at the Riverbed Site.**

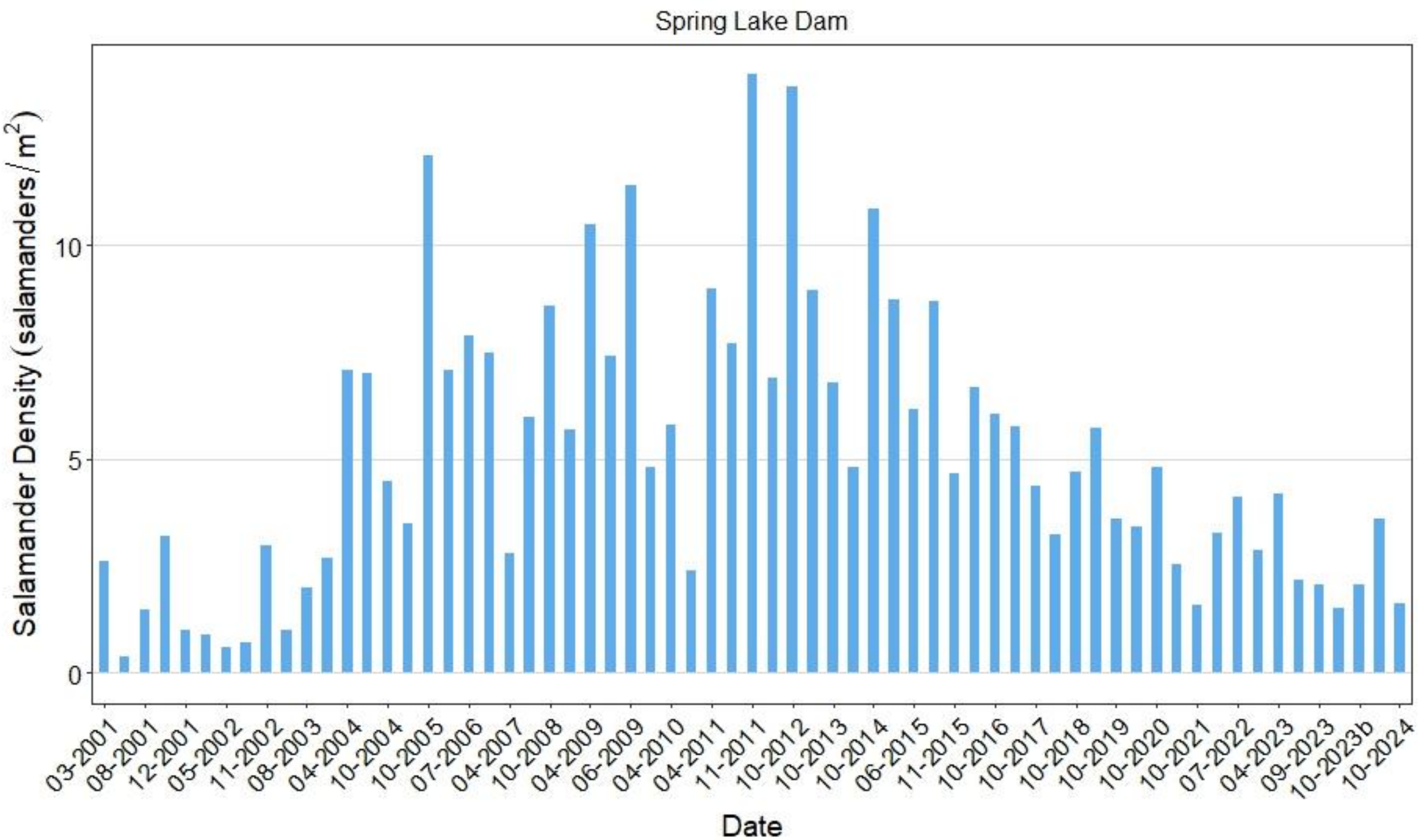

Figure E16. **San Marcos Salamander density from 2001–2024 at the Spring Lake Dam Site.**

APPENDIX E: MACROINVERTEBRATE RAW DATA

Site	Date	Season	Class	Order	Family	FinalID	Counts
Spring Lake	4/24/2024	Spring	Malacostraca	Amphipoda	Hyalellidae	Hyalella	321
Spring Lake	4/24/2024	Spring	Insecta	Coleoptera	Psephenidae	Psephenus texanus	2
Spring Lake	4/24/2024	Spring	Insecta	Ephemeroptera	Baetidae	Callibaetis	2
Spring Lake	4/24/2024	Spring	Insecta	Ephemeroptera	Heptageniidae	Stenonema	1
Spring Lake	4/24/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	7
Spring Lake	4/24/2024	Spring	Insecta	Hemiptera	Naucoridae	Ambrysus	1
Spring Lake	4/24/2024	Spring	Insecta	Odonata	Coenagrionidae	Enallagma	2
Spring Lake	4/24/2024	Spring	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	4
Spring Lake	4/24/2024	Spring	Insecta	Trichoptera	Leptoceridae	Nectopsyche	1
Spring Lake	4/24/2024	Spring		Tricladida	Dugesiidae	Dugesia	1
Spring Lake	4/24/2024	Spring	Gastropoda		Pleuroceridae	Elimia	3
Spring Lake	4/24/2024	Spring	Clitellata			Hirudinea	1
Spring Lake	4/24/2024	Spring	Clitellata			Oligochaeta	10
Spring Lake	10/21/2024	Fall	Malacostraca	Amphipoda	Hyalellidae	Hyalella	94
Spring Lake	10/21/2024	Fall	Malacostraca	Decapoda	Cambaridae	Cambaridae	7
Spring Lake	10/21/2024	Fall	Insecta	Diptera	Chironomidae	Chironomidae	5
Spring Lake	10/21/2024	Fall	Insecta	Ephemeroptera	Baetidae	Callibaetis	10
Spring Lake	10/21/2024	Fall	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	21
Spring Lake	10/21/2024	Fall	Insecta	Hemiptera	Naucoridae	Ambrysus	1
Spring Lake	10/21/2024	Fall	Annelida	Hirudinea	Glossosiphonidae	Glossosiphonidae	1
Spring Lake	10/21/2024	Fall	Insecta	Odonata	Coenagrionidae	Enallagma	2
Spring Lake	10/21/2024	Fall	Insecta	Odonata	Corduliidae	Epitheca	1
Spring Lake	10/21/2024	Fall	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	1
Spring Lake	10/21/2024	Fall		Tricladida	Dugesiidae	Dugesia	2
Spring Lake	10/21/2024	Fall	Gastropoda		Pleuroceridae	Elimia	7
Spring Lake	10/21/2024	Fall	Clitellata			Oligochaeta	5
Spring Lake Dam	4/24/2024	Spring	Malacostraca	Amphipoda	Hyalellidae	Hyalella	30
Spring Lake Dam	4/24/2024	Spring	Insecta	Coleoptera	Elmidae	Macrelmis	1
Spring Lake Dam	4/24/2024	Spring	Insecta	Coleoptera	Psephenidae	Psephenus texanus	5

Spring Lake Dam	4/24/2024	Spring	Insecta	Decapoda	Simuliidae	Simulium	29
Spring Lake Dam	4/24/2024	Spring	Insecta	Diptera	Chironomidae	Chironomidae	1
Spring Lake Dam	4/24/2024	Spring	Insecta	Diptera	Stratiomyidae	Euparyphus	1
Spring Lake Dam	4/24/2024	Spring	Insecta	Ephemeroptera	Baetidae	Baetodes	2
Spring Lake Dam	4/24/2024	Spring	Insecta	Ephemeroptera	Baetidae	Fallceon	6
Spring Lake Dam	4/24/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Leptohyphes	50
Spring Lake Dam	4/24/2024	Spring	Insecta	Ephemeroptera	Leptophlebiidae	Thraulodes	12
Spring Lake Dam	4/24/2024	Spring	Insecta	Hemiptera	Naucoridae	Ambrysus	21
Spring Lake Dam	4/24/2024	Spring	Insecta	Odonata	Calopterygidae	Hetaerina	1
Spring Lake Dam	4/24/2024	Spring	Insecta	Odonata	Coenagrionidae	Argia	1
Spring Lake Dam	4/24/2024	Spring	Insecta	Odonata	Coenagrionidae	Enallagma	1
Spring Lake Dam	4/24/2024	Spring	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	4
Spring Lake Dam	4/24/2024	Spring	Insecta	Trichoptera	Hydropsychidae	Smicridea	4
Spring Lake Dam	4/24/2024	Spring	Insecta	Trichoptera	Leptoceridae	Nectopsyche	2
Spring Lake Dam	4/24/2024	Spring	Insecta	Trichoptera	Philopotamidae	Chimarra	12
Spring Lake Dam	4/24/2024	Spring		Tricladida	Dugesiidae	Dugesia	11
Spring Lake Dam	4/24/2024	Spring	Gastropoda		Planorbidae	Planorbella	1
Spring Lake Dam	4/24/2024	Spring	Gastropoda		Pleuroceridae	Elimia	4
Spring Lake Dam	4/24/2024	Spring	Clitellata			Hirudinea	1
Spring Lake Dam	4/24/2024	Spring	Clitellata			Oligochaeta	4
Spring Lake Dam	10/21/2024	Fall	Malacostraca	Amphipoda	Hyalellidae	Hyalella	4
Spring Lake Dam	10/21/2024	Fall	Insecta	Coleoptera	Elmidae	Macrelmis	1
Spring Lake Dam	10/21/2024	Fall	Insecta	Coleoptera	Psephenidae	Psephenus texanus	2
Spring Lake Dam	10/21/2024	Fall	Insecta	Decapoda	Simuliidae	Simulium	18
Spring Lake Dam	10/21/2024	Fall	Insecta	Diptera	Chironomidae	Chironomidae	1
Spring Lake Dam	10/21/2024	Fall	Insecta	Ephemeroptera	Baetidae	Baetis	2
Spring Lake Dam	10/21/2024	Fall	Insecta	Ephemeroptera	Baetidae	Baetodes	7
Spring Lake Dam	10/21/2024	Fall	Insecta	Ephemeroptera	Baetidae	Fallceon	2
Spring Lake Dam	10/21/2024	Fall	Insecta	Ephemeroptera	Leptohyphidae	Leptohyphes	10
Spring Lake Dam	10/21/2024	Fall	Insecta	Ephemeroptera	Leptophlebiidae	Thraulodes	4

Spring Lake Dam	10/21/2024	Fall	Insecta	Hemiptera	Naucoridae	Ambrysus	17
Spring Lake Dam	10/21/2024	Fall	Insecta	Megaloptera	Corydalidae	Corydalus	8
Spring Lake Dam	10/21/2024	Fall	Insecta	Odonata	Calopterygidae	Hetaerina	2
Spring Lake Dam	10/21/2024	Fall	Insecta	Odonata	Coenagrionidae	Argia	6
Spring Lake Dam	10/21/2024	Fall	Insecta	Odonata	Libellulidae	Brechmorhoga	9
Spring Lake Dam	10/21/2024	Fall	Insecta	Trichoptera	Glossosomatidae	Protoptila	1
Spring Lake Dam	10/21/2024	Fall	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	8
Spring Lake Dam	10/21/2024	Fall	Insecta	Trichoptera	Hydropsychidae	Smicridea	1
Spring Lake Dam	10/21/2024	Fall	Insecta	Trichoptera	Leptoceridae	Nectopsyche	1
Spring Lake Dam	10/21/2024	Fall	Insecta	Trichoptera	Philopotamidae	Chimarra	46
Spring Lake Dam	10/21/2024	Fall		Tricladida	Dugesiidae	Dugesia	9
Spring Lake Dam	10/21/2024	Fall	Gastropoda		Pleuroceridae	Elimia	9
Spring Lake Dam	10/21/2024	Fall	Gastropoda		Thiaridae	Melanoides tuberculata	2
Spring Lake Dam	10/21/2024	Fall	Clitellata			Oligochaeta	16
City Park	4/24/2024	Spring	Malacostraca	Amphipoda	Hyalellidae	Hyalella	57
City Park	4/24/2024	Spring	Insecta	Ephemeroptera	Baetidae	Fallceon	2
City Park	4/24/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	42
City Park	4/24/2024	Spring	Insecta	Odonata	Coenagrionidae	Argia	1
City Park	4/24/2024	Spring	Insecta	Trichoptera	Glossosomatidae	Protoptila	4
City Park	4/24/2024	Spring	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	2
City Park	4/24/2024	Spring	Insecta	Trichoptera	Leptoceridae	Nectopsyche	24
City Park	4/24/2024	Spring	Gastropoda		Pleuroceridae	Elimia	19
City Park	4/24/2024	Spring	Gastropoda		Thiaridae	Melanoides tuberculata	13
City Park	4/24/2024	Spring	Clitellata			Hirudinea	3
City Park	4/24/2024	Spring	Clitellata			Oligochaeta	4
City Park	10/21/2024	Fall	Malacostraca	Amphipoda	Hyalellidae	Hyalella	33
City Park	10/21/2024	Fall	Insecta	Diptera	Chironomidae	Chironomidae	2
City Park	10/21/2024	Fall	Insecta	Ephemeroptera	Baetidae	Baetis	7
City Park	10/21/2024	Fall	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	53
City Park	10/21/2024	Fall	Insecta	Hemiptera	Corixidae	Trichocorixa	1

City Park	10/21/2024	Fall	Annelida	Hirudinea	Glossosiphonidae	Glossosiphonidae	3
City Park	10/21/2024	Fall	Insecta	Odonata	Aeshnidae	Aeshnidae	4
City Park	10/21/2024	Fall	Insecta	Trichoptera	Glossosomatidae	Protoptila	1
City Park	10/21/2024	Fall	Insecta	Trichoptera	Leptoceridae	Nectopsyche	7
City Park	10/21/2024	Fall		Tricladida	Dugesiidae	Dugesia	1
City Park	10/21/2024	Fall	Gastropoda		Pleuroceridae	Elimia	26
City Park	10/21/2024	Fall	Gastropoda		Thiaridae	Melanoides tuberculata	19
I-35	4/24/2024	Spring	Malacostraca	Amphipoda	Hyalellidae	Hyalella	4
I-35	4/24/2024	Spring	Insecta	Coleoptera	Elmidae	Macrelmis	1
I-35	4/24/2024	Spring	Insecta	Coleoptera	Elmidae	Stenelmis	1
I-35	4/24/2024	Spring	Insecta	Ephemeroptera	Baetidae	Fallceon	1
I-35	4/24/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Leptohyphes	1
I-35	4/24/2024	Spring	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	1
I-35	4/24/2024	Spring	Insecta	Ephemeroptera	Leptophlebiidae	Thraulodes	17
I-35	4/24/2024	Spring	Insecta	Hemiptera	Naucoridae	Ambrysus	1
I-35	4/24/2024	Spring	Insecta	Hemiptera	Naucoridae	Limnocoris lutzi	5
I-35	4/24/2024	Spring	Insecta	Trichoptera	Glossosomatidae	Protoptila	35
I-35	4/24/2024	Spring	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	45
I-35	4/24/2024	Spring	Insecta	Trichoptera	Leptoceridae	Nectopsyche	6
I-35	4/24/2024	Spring	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	2
I-35	4/24/2024	Spring		Tricladida	Dugesiidae	Dugesia	6
I-35	4/24/2024	Spring	Gastropoda		Pleuroceridae	Elimia	20
I-35	4/24/2024	Spring	Gastropoda		Thiaridae	Melanoides tuberculata	28
I-35	4/24/2024	Spring	Clitellata			Hirudinea	1
I-35	4/24/2024	Spring	Clitellata			Oligochaeta	2
I-35	10/21/2024	Fall	Malacostraca	Amphipoda	Hyalellidae	Hyalella	2
I-35	10/21/2024	Fall	Malacostraca	Decapoda	Cambaridae	Cambaridae	2
I-35	10/21/2024	Fall	Insecta	Diptera	Chironomidae	Chironomidae	2
I-35	10/21/2024	Fall	Insecta	Ephemeroptera	Baetidae	Baetis	1
I-35	10/21/2024	Fall	Insecta	Ephemeroptera	Leptophlebiidae	Thraulodes	15

I-35	10/21/2024	Fall	Insecta	Hemiptera	Naucoridae	Ambrysus	1
I-35	10/21/2024	Fall	Insecta	Hemiptera	Naucoridae	Limnocoris lutzi	13
I-35	10/21/2024	Fall	Annelida	Hirudinea	Glossosiphonidae	Glossosiphonidae	1
I-35	10/21/2024	Fall	Insecta	Odonata	Gomphidae	Hagenius brevistylus	1
I-35	10/21/2024	Fall	Insecta	Trichoptera	Glossosomatidae	Protoptila	13
I-35	10/21/2024	Fall	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	47
I-35	10/21/2024	Fall	Insecta	Trichoptera	Hydroptilidae	Hydroptila	1
I-35	10/21/2024	Fall	Insecta	Trichoptera	Leptoceridae	Nectopsyche	9
I-35	10/21/2024	Fall	Insecta	Trichoptera	Philopotamidae	Chimarra	1
I-35	10/21/2024	Fall		Tricladida	Dugesiidae	Dugesia	5
I-35	10/21/2024	Fall	Gastropoda		Pleuroceridae	Elimia	23
I-35	10/21/2024	Fall	Gastropoda		Thiaridae	Melanoides tuberculata	20
I-35	10/21/2024	Fall	Clitellata			Oligochaeta	1

APPENDIX F: DROP-NET RAW DATA

SiteCode	Reach	Site_No	Date	Dip_Net	Species	Length	Count
3103	Spring Lake Dam	Open-1	2024-04-17	1	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	2	Etheostoma fonticola	12	1
3103	Spring Lake Dam	Open-1	2024-04-17	3	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	4	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	5	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	6	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	7	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	8	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	9	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	10	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	11	No fish collected		
3103	Spring Lake Dam	Open-1	2024-04-17	12	No fish collected		
3104	Spring Lake Dam	Ziz-1	2024-04-17	1	No fish collected		
3104	Spring Lake Dam	Ziz-1	2024-04-17	2	Gambusia sp.	33	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	3	No fish collected		
3104	Spring Lake Dam	Ziz-1	2024-04-17	4	Gambusia sp.	37	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	5	Gambusia sp.	42	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	6	Gambusia sp.	38	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	6	Gambusia sp.	32	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	6	Gambusia sp.	25	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	6	Gambusia sp.	24	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	7	No fish collected		
3104	Spring Lake Dam	Ziz-1	2024-04-17	8	No fish collected		
3104	Spring Lake Dam	Ziz-1	2024-04-17	9	Gambusia sp.	26	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	9	Gambusia sp.	21	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	10	Gambusia sp.	25	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	11	No fish collected		
3104	Spring Lake Dam	Ziz-1	2024-04-17	12	Lepomis miniatus	25	1
3104	Spring Lake Dam	Ziz-1	2024-04-17	13	Gambusia sp.	30	1

3104	Spring Lake Dam	Ziz-1	2024-04-17	14	No fish collected		
3104	Spring Lake Dam	Ziz-1	2024-04-17	15	No fish collected		
3105	Spring Lake Dam	Ziz-2	2024-04-17	1	Gambusia sp.	20	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	1	Gambusia sp.	13	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	1	Gambusia sp.	24	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	1	Gambusia sp.	22	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	1	Gambusia sp.	23	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	1	Gambusia sp.	10	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	2	Gambusia sp.	33	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	2	Gambusia sp.	21	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	2	Gambusia sp.	22	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	2	Gambusia sp.	28	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	3	Gambusia sp.	15	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	4	Gambusia sp.	24	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	5	Gambusia sp.	28	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	5	Gambusia sp.	12	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	6	No fish collected		
3105	Spring Lake Dam	Ziz-2	2024-04-17	7	No fish collected		
3105	Spring Lake Dam	Ziz-2	2024-04-17	8	Etheostoma fonticola	19	1
3105	Spring Lake Dam	Ziz-2	2024-04-17	9	No fish collected		
3105	Spring Lake Dam	Ziz-2	2024-04-17	10	No fish collected		
3105	Spring Lake Dam	Ziz-2	2024-04-17	11	No fish collected		
3105	Spring Lake Dam	Ziz-2	2024-04-17	12	No fish collected		
3105	Spring Lake Dam	Ziz-2	2024-04-17	13	No fish collected		
3105	Spring Lake Dam	Ziz-2	2024-04-17	14	No fish collected		
3105	Spring Lake Dam	Ziz-2	2024-04-17	15	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	1	Gambusia sp.	18	1
3106	Spring Lake Dam	Pota-1	2024-04-17	1	Gambusia sp.	20	1
3106	Spring Lake Dam	Pota-1	2024-04-17	2	Gambusia sp.	20	1
3106	Spring Lake Dam	Pota-1	2024-04-17	3	Dionda nigrotaeniata	31	1

3106	Spring Lake Dam	Pota-1	2024-04-17	4	Gambusia sp.	40	1
3106	Spring Lake Dam	Pota-1	2024-04-17	5	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	6	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	7	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	8	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	9	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	10	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	11	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	12	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	13	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	14	No fish collected		
3106	Spring Lake Dam	Pota-1	2024-04-17	15	No fish collected		
3107	Spring Lake Dam	Pota-2	2024-04-17	1	Gambusia sp.	28	1
3107	Spring Lake Dam	Pota-2	2024-04-17	1	Gambusia sp.	30	1
3107	Spring Lake Dam	Pota-2	2024-04-17	1	Gambusia sp.	40	1
3107	Spring Lake Dam	Pota-2	2024-04-17	1	Gambusia sp.	25	1
3107	Spring Lake Dam	Pota-2	2024-04-17	1	Gambusia sp.	22	1
3107	Spring Lake Dam	Pota-2	2024-04-17	1	Etheostoma fonticola	12	1
3107	Spring Lake Dam	Pota-2	2024-04-17	2	No fish collected		
3107	Spring Lake Dam	Pota-2	2024-04-17	3	Procambarus sp.		1
3107	Spring Lake Dam	Pota-2	2024-04-17	3	Gambusia sp.	21	1
3107	Spring Lake Dam	Pota-2	2024-04-17	3	Gambusia sp.	33	1
3107	Spring Lake Dam	Pota-2	2024-04-17	4	Etheostoma fonticola	12	1
3107	Spring Lake Dam	Pota-2	2024-04-17	5	Procambarus sp.		1
3107	Spring Lake Dam	Pota-2	2024-04-17	6	No fish collected		
3107	Spring Lake Dam	Pota-2	2024-04-17	7	Gambusia sp.	25	1
3107	Spring Lake Dam	Pota-2	2024-04-17	8	Gambusia sp.	32	1
3107	Spring Lake Dam	Pota-2	2024-04-17	8	Gambusia sp.	32	1
3107	Spring Lake Dam	Pota-2	2024-04-17	9	No fish collected		
3107	Spring Lake Dam	Pota-2	2024-04-17	10	No fish collected		

3107	Spring Lake Dam	Pota-2	2024-04-17	11	No fish collected		
3107	Spring Lake Dam	Pota-2	2024-04-17	12	No fish collected		
3107	Spring Lake Dam	Pota-2	2024-04-17	13	No fish collected		
3107	Spring Lake Dam	Pota-2	2024-04-17	14	No fish collected		
3107	Spring Lake Dam	Pota-2	2024-04-17	15	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	1	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	2	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	3	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	4	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	5	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	6	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	7	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	8	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	9	No fish collected		
3108	Spring Lake Dam	Open-2	2024-04-17	10	No fish collected		
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	37	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	21	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	22	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	20	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	20	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	11	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	20	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	18	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	14	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	18	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	35	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Gambusia sp.	10	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Etheostoma fonticola	13	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Etheostoma fonticola	14	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Etheostoma fonticola	32	1

3109	Spring Lake Dam	Sag-1	2024-04-17	1	Etheostoma fonticola	25	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Etheostoma fonticola	12	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Etheostoma fonticola	15	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Etheostoma fonticola	13	1
3109	Spring Lake Dam	Sag-1	2024-04-17	1	Palaemonetes sp.		1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Gambusia sp.	22	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Gambusia sp.	13	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	29	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	19	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	15	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	16	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	31	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	13	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	25	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	18	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	12	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	16	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	11	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Etheostoma fonticola	13	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Lepomis sp.	16	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Lepomis sp.	10	1
3109	Spring Lake Dam	Sag-1	2024-04-17	2	Palaemonetes sp.		1
3109	Spring Lake Dam	Sag-1	2024-04-17	3	Gambusia sp.	16	1
3109	Spring Lake Dam	Sag-1	2024-04-17	3	Gambusia sp.	10	1
3109	Spring Lake Dam	Sag-1	2024-04-17	3	Etheostoma fonticola	18	1
3109	Spring Lake Dam	Sag-1	2024-04-17	3	Etheostoma fonticola	24	1
3109	Spring Lake Dam	Sag-1	2024-04-17	3	Etheostoma fonticola	22	1
3109	Spring Lake Dam	Sag-1	2024-04-17	3	Etheostoma fonticola	18	1
3109	Spring Lake Dam	Sag-1	2024-04-17	3	Etheostoma fonticola	12	1
3109	Spring Lake Dam	Sag-1	2024-04-17	3	Palaemonetes sp.		1

3109	Spring Lake Dam	Sag-1	2024-04-17	4	Etheostoma fonticola	35	1
3109	Spring Lake Dam	Sag-1	2024-04-17	4	Etheostoma fonticola	28	1
3109	Spring Lake Dam	Sag-1	2024-04-17	4	Etheostoma fonticola	20	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Gambusia sp.	22	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Lepomis miniatus	28	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Etheostoma fonticola	40	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Etheostoma fonticola	32	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Etheostoma fonticola	19	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Etheostoma fonticola	19	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Etheostoma fonticola	12	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Etheostoma fonticola	32	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Etheostoma fonticola	16	1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Procambarus sp.		1
3109	Spring Lake Dam	Sag-1	2024-04-17	5	Lepomis sp.	16	1
3109	Spring Lake Dam	Sag-1	2024-04-17	6	Gambusia sp.	25	1
3109	Spring Lake Dam	Sag-1	2024-04-17	6	Etheostoma fonticola	42	1
3109	Spring Lake Dam	Sag-1	2024-04-17	7	Procambarus sp.		1
3109	Spring Lake Dam	Sag-1	2024-04-17	7	Etheostoma fonticola	25	1
3109	Spring Lake Dam	Sag-1	2024-04-17	7	Gambusia sp.	15	1
3109	Spring Lake Dam	Sag-1	2024-04-17	8	No fish collected		
3109	Spring Lake Dam	Sag-1	2024-04-17	9	Procambarus sp.		1
3109	Spring Lake Dam	Sag-1	2024-04-17	9	Etheostoma fonticola	20	1
3109	Spring Lake Dam	Sag-1	2024-04-17	9	Etheostoma fonticola	19	1
3109	Spring Lake Dam	Sag-1	2024-04-17	9	Etheostoma fonticola	33	1
3109	Spring Lake Dam	Sag-1	2024-04-17	9	Etheostoma fonticola	26	1
3109	Spring Lake Dam	Sag-1	2024-04-17	10	Etheostoma fonticola	29	1
3109	Spring Lake Dam	Sag-1	2024-04-17	10	Etheostoma fonticola	28	1
3109	Spring Lake Dam	Sag-1	2024-04-17	10	Gambusia sp.	37	1
3109	Spring Lake Dam	Sag-1	2024-04-17	10	Lepomis miniatus	60	1
3109	Spring Lake Dam	Sag-1	2024-04-17	11	Procambarus sp.		1

3109	Spring Lake Dam	Sag-1	2024-04-17	11	Etheostoma fonticola	23	1
3109	Spring Lake Dam	Sag-1	2024-04-17	12	Gambusia sp.	25	1
3109	Spring Lake Dam	Sag-1	2024-04-17	13	No fish collected		
3109	Spring Lake Dam	Sag-1	2024-04-17	14	No fish collected		
3109	Spring Lake Dam	Sag-1	2024-04-17	15	Etheostoma fonticola	30	1
3109	Spring Lake Dam	Sag-1	2024-04-17	15	Etheostoma fonticola	21	1
3109	Spring Lake Dam	Sag-1	2024-04-17	16	No fish collected		
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	32	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	35	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	10	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	21	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	32	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	22	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	15	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	25	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	18	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	12	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	21	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	15	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	32	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	32	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	30	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	20	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	35	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	15	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	22	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.	27	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1

3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Procambarus sp.		7
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Etheostoma fonticola	31	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Etheostoma fonticola	26	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Etheostoma fonticola	16	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Etheostoma fonticola	9	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Ambloplites rupestris	21	1
3110	Spring Lake Dam	Sag-2	2024-04-17	1	Dionda nigrotaeniata	21	1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Procambarus sp.		3
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Gambusia sp.		1

3110	Spring Lake Dam	Sag-2	2024-04-17	2	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Etheostoma fonticola	15	1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Etheostoma fonticola	39	1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Etheostoma fonticola	35	1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Etheostoma fonticola	15	1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Etheostoma fonticola	34	1
3110	Spring Lake Dam	Sag-2	2024-04-17	2	Etheostoma fonticola	16	1
3110	Spring Lake Dam	Sag-2	2024-04-17	3	Procambarus sp.		6
3110	Spring Lake Dam	Sag-2	2024-04-17	3	Palaemonetes sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	3	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	3	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	3	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	3	Etheostoma fonticola	36	1
3110	Spring Lake Dam	Sag-2	2024-04-17	4	Etheostoma fonticola	29	1
3110	Spring Lake Dam	Sag-2	2024-04-17	4	Etheostoma fonticola	15	1
3110	Spring Lake Dam	Sag-2	2024-04-17	4	Procambarus sp.		4
3110	Spring Lake Dam	Sag-2	2024-04-17	4	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	4	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	4	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	5	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	5	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	5	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	5	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	5	Etheostoma fonticola	29	1
3110	Spring Lake Dam	Sag-2	2024-04-17	5	Etheostoma fonticola	14	1
3110	Spring Lake Dam	Sag-2	2024-04-17	5	Procambarus sp.		2
3110	Spring Lake Dam	Sag-2	2024-04-17	6	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	6	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	7	Gambusia sp.		1

3110	Spring Lake Dam	Sag-2	2024-04-17	7	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	7	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	7	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	7	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	8	Procambarus sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	8	Palaemonetes sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	9	Procambarus sp.		2
3110	Spring Lake Dam	Sag-2	2024-04-17	9	Lepomis miniatus	85	1
3110	Spring Lake Dam	Sag-2	2024-04-17	9	Etheostoma fonticola	28	1
3110	Spring Lake Dam	Sag-2	2024-04-17	10	Procambarus sp.		3
3110	Spring Lake Dam	Sag-2	2024-04-17	10	Etheostoma fonticola	33	1
3110	Spring Lake Dam	Sag-2	2024-04-17	11	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	12	Procambarus sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	13	Etheostoma fonticola	32	1
3110	Spring Lake Dam	Sag-2	2024-04-17	13	Etheostoma fonticola	33	1
3110	Spring Lake Dam	Sag-2	2024-04-17	13	Etheostoma fonticola	25	1
3110	Spring Lake Dam	Sag-2	2024-04-17	13	Gambusia sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	14	Procambarus sp.		1
3110	Spring Lake Dam	Sag-2	2024-04-17	15	No fish collected		
3111	Spring Lake Dam	Hydro-1	2024-04-17	1	Gambusia sp.	26	1
3111	Spring Lake Dam	Hydro-1	2024-04-17	1	Procambarus sp.		1
3111	Spring Lake Dam	Hydro-1	2024-04-17	1	Etheostoma fonticola	34	1
3111	Spring Lake Dam	Hydro-1	2024-04-17	1	Etheostoma fonticola	27	1
3111	Spring Lake Dam	Hydro-1	2024-04-17	2	No fish collected		
3111	Spring Lake Dam	Hydro-1	2024-04-17	3	Procambarus sp.		3
3111	Spring Lake Dam	Hydro-1	2024-04-17	3	Gambusia sp.	22	1
3111	Spring Lake Dam	Hydro-1	2024-04-17	4	No fish collected		
3111	Spring Lake Dam	Hydro-1	2024-04-17	5	Gambusia sp.	19	1
3111	Spring Lake Dam	Hydro-1	2024-04-17	6	No fish collected		
3111	Spring Lake Dam	Hydro-1	2024-04-17	7	Procambarus sp.		2

3111	Spring Lake Dam	Hydro-1	2024-04-17	8	No fish collected		
3111	Spring Lake Dam	Hydro-1	2024-04-17	9	Etheostoma fonticola	19	1
3111	Spring Lake Dam	Hydro-1	2024-04-17	10	No fish collected		
3111	Spring Lake Dam	Hydro-1	2024-04-17	11	No fish collected		
3111	Spring Lake Dam	Hydro-1	2024-04-17	12	Procambarus sp.		2
3111	Spring Lake Dam	Hydro-1	2024-04-17	13	Procambarus sp.		1
3111	Spring Lake Dam	Hydro-1	2024-04-17	14	No fish collected		
3111	Spring Lake Dam	Hydro-1	2024-04-17	15	Gambusia sp.	42	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	1	Gambusia sp.	21	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	1	Gambusia sp.	20	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	1	Gambusia sp.	26	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	1	Etheostoma fonticola	30	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	1	Etheostoma fonticola	19	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	2	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	3	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	4	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	5	Etheostoma fonticola	18	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	6	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	7	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	8	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	9	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	10	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	11	Etheostoma fonticola	16	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	11	Etheostoma fonticola	29	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	11	Etheostoma fonticola	32	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	12	Etheostoma fonticola	35	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	12	Etheostoma fonticola	14	1
3112	Spring Lake Dam	Hydro-2	2024-04-17	13	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	14	No fish collected		
3112	Spring Lake Dam	Hydro-2	2024-04-17	15	No fish collected		

3113	City Park	Open-1	2024-04-17	1	No fish collected		
3113	City Park	Open-1	2024-04-17	2	No fish collected		
3113	City Park	Open-1	2024-04-17	3	No fish collected		
3113	City Park	Open-1	2024-04-17	4	No fish collected		
3113	City Park	Open-1	2024-04-17	5	No fish collected		
3113	City Park	Open-1	2024-04-17	6	No fish collected		
3113	City Park	Open-1	2024-04-17	7	No fish collected		
3113	City Park	Open-1	2024-04-17	8	No fish collected		
3113	City Park	Open-1	2024-04-17	9	No fish collected		
3113	City Park	Open-1	2024-04-17	10	No fish collected		
3114	City Park	Open-2	2024-04-17	1	No fish collected		
3114	City Park	Open-2	2024-04-17	2	No fish collected		
3114	City Park	Open-2	2024-04-17	3	No fish collected		
3114	City Park	Open-2	2024-04-17	4	No fish collected		
3114	City Park	Open-2	2024-04-17	5	No fish collected		
3114	City Park	Open-2	2024-04-17	6	No fish collected		
3114	City Park	Open-2	2024-04-17	7	No fish collected		
3114	City Park	Open-2	2024-04-17	8	No fish collected		
3114	City Park	Open-2	2024-04-17	9	No fish collected		
3114	City Park	Open-2	2024-04-17	10	No fish collected		
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	25	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	26	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	32	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	30	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	27	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	26	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	20	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	25	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	17	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	10	1

3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	10	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	15	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	21	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	20	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	25	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	21	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	21	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	10	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	24	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.	25	1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1

3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	26	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	19	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	10	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	16	1

3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	10	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	21	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	15	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	17	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	24	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	28	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	23	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	24	1
3115	City Park	Cab-1	2024-04-17	1	Etheostoma fonticola	12	1
3115	City Park	Cab-1	2024-04-17	1	Notropis chalybaeus	21	1
3115	City Park	Cab-1	2024-04-17	1	Notropis chalybaeus	16	1
3115	City Park	Cab-1	2024-04-17	1	Notropis chalybaeus	25	1
3115	City Park	Cab-1	2024-04-17	1	Notropis chalybaeus	18	1
3115	City Park	Cab-1	2024-04-17	1	Palaemonetes sp.		2
3115	City Park	Cab-1	2024-04-17	1	Procambarus sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	30	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	27	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	17	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	21	1

3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	26	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	25	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	29	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	33	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	27	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	24	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	22	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	24	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	20	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	12	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	25	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	19	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	17	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	20	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	20	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	15	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	17	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	24	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	12	1
3115	City Park	Cab-1	2024-04-17	2	Etheostoma fonticola	12	1
3115	City Park	Cab-1	2024-04-17	2	Procambarus sp.		1
3115	City Park	Cab-1	2024-04-17	2	Palaemonetes sp.		2
3115	City Park	Cab-1	2024-04-17	2	Notropis chalybaeus	21	1
3115	City Park	Cab-1	2024-04-17	3	Etheostoma fonticola	14	1
3115	City Park	Cab-1	2024-04-17	3	Etheostoma fonticola	23	1
3115	City Park	Cab-1	2024-04-17	3	Etheostoma fonticola	25	1
3115	City Park	Cab-1	2024-04-17	3	Etheostoma fonticola	18	1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1

3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	3	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	4	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	4	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	4	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	4	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	4	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	4	Procambarus sp.		3
3115	City Park	Cab-1	2024-04-17	4	Etheostoma fonticola	20	1
3115	City Park	Cab-1	2024-04-17	4	Etheostoma fonticola	27	1
3115	City Park	Cab-1	2024-04-17	4	Etheostoma fonticola	12	1
3115	City Park	Cab-1	2024-04-17	5	Etheostoma fonticola	21	1
3115	City Park	Cab-1	2024-04-17	5	Etheostoma fonticola	22	1
3115	City Park	Cab-1	2024-04-17	5	Etheostoma fonticola	30	1
3115	City Park	Cab-1	2024-04-17	5	Notropis chalybaeus	20	1
3115	City Park	Cab-1	2024-04-17	6	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	6	Etheostoma fonticola	15	1
3115	City Park	Cab-1	2024-04-17	6	Etheostoma fonticola	19	1
3115	City Park	Cab-1	2024-04-17	6	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	6	Etheostoma fonticola	18	1

3115	City Park	Cab-1	2024-04-17	6	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	7	Procambarus sp.		1
3115	City Park	Cab-1	2024-04-17	7	Lepomis miniatus	56	1
3115	City Park	Cab-1	2024-04-17	7	Etheostoma fonticola	24	1
3115	City Park	Cab-1	2024-04-17	7	Etheostoma fonticola	35	1
3115	City Park	Cab-1	2024-04-17	7	Etheostoma fonticola	28	1
3115	City Park	Cab-1	2024-04-17	8	Etheostoma fonticola	15	1
3115	City Park	Cab-1	2024-04-17	8	Etheostoma fonticola	15	1
3115	City Park	Cab-1	2024-04-17	8	Etheostoma fonticola	22	1
3115	City Park	Cab-1	2024-04-17	8	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	8	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	9	Etheostoma fonticola	22	1
3115	City Park	Cab-1	2024-04-17	9	Etheostoma fonticola	11	1
3115	City Park	Cab-1	2024-04-17	9	Etheostoma fonticola	15	1
3115	City Park	Cab-1	2024-04-17	9	Etheostoma fonticola	25	1
3115	City Park	Cab-1	2024-04-17	9	Etheostoma fonticola	18	1
3115	City Park	Cab-1	2024-04-17	10	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	10	Etheostoma fonticola	15	1
3115	City Park	Cab-1	2024-04-17	11	Etheostoma fonticola	22	1
3115	City Park	Cab-1	2024-04-17	11	Etheostoma fonticola	31	1
3115	City Park	Cab-1	2024-04-17	11	Etheostoma fonticola	31	1
3115	City Park	Cab-1	2024-04-17	11	Etheostoma fonticola	25	1
3115	City Park	Cab-1	2024-04-17	11	Etheostoma fonticola	29	1
3115	City Park	Cab-1	2024-04-17	11	Etheostoma fonticola	18	1
3115	City Park	Cab-1	2024-04-17	11	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	12	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	13	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	13	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	14	Etheostoma fonticola	29	1
3115	City Park	Cab-1	2024-04-17	14	Gambusia sp.		1

3115	City Park	Cab-1	2024-04-17	15	Etheostoma fonticola	26	1
3115	City Park	Cab-1	2024-04-17	15	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	15	Etheostoma fonticola	20	1
3115	City Park	Cab-1	2024-04-17	15	Etheostoma fonticola	14	1
3115	City Park	Cab-1	2024-04-17	15	Etheostoma fonticola	19	1
3115	City Park	Cab-1	2024-04-17	15	Etheostoma fonticola	20	1
3115	City Park	Cab-1	2024-04-17	15	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	15	Gambusia sp.		1
3115	City Park	Cab-1	2024-04-17	16	Etheostoma fonticola	33	1
3115	City Park	Cab-1	2024-04-17	16	Etheostoma fonticola	12	1
3115	City Park	Cab-1	2024-04-17	16	Etheostoma fonticola	19	1
3115	City Park	Cab-1	2024-04-17	17	Etheostoma fonticola	17	1
3115	City Park	Cab-1	2024-04-17	18	Etheostoma fonticola	16	1
3115	City Park	Cab-1	2024-04-17	19	Etheostoma fonticola	17	1
3115	City Park	Cab-1	2024-04-17	20	Etheostoma fonticola	26	1
3115	City Park	Cab-1	2024-04-17	21	No fish collected		
3116	City Park	Cab-2	2024-04-17	1	Etheostoma fonticola	31	1
3116	City Park	Cab-2	2024-04-17	1	Etheostoma fonticola	16	1
3116	City Park	Cab-2	2024-04-17	1	Etheostoma fonticola	14	1
3116	City Park	Cab-2	2024-04-17	1	Etheostoma fonticola	19	1
3116	City Park	Cab-2	2024-04-17	1	Etheostoma fonticola	18	1
3116	City Park	Cab-2	2024-04-17	1	Etheostoma fonticola	11	1
3116	City Park	Cab-2	2024-04-17	1	Etheostoma fonticola	14	1
3116	City Park	Cab-2	2024-04-17	1	Notropis chalybaeus	18	1
3116	City Park	Cab-2	2024-04-17	1	Notropis chalybaeus	21	1
3116	City Park	Cab-2	2024-04-17	1	Notropis chalybaeus	12	1
3116	City Park	Cab-2	2024-04-17	1	Notropis chalybaeus	13	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	26	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	23	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	20	1

3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	22	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	20	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	12	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	19	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	24	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	13	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	10	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	12	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	11	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	10	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	10	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	10	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	9	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	10	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	12	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	12	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.	10	1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	1	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	20	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	18	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	19	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	31	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	22	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	26	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	17	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	17	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	20	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	19	1

3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	16	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	15	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	19	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	21	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	15	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	21	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	18	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	22	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	16	1
3116	City Park	Cab-2	2024-04-17	2	Etheostoma fonticola	20	1
3116	City Park	Cab-2	2024-04-17	2	Notropis chalybaeus	20	1
3116	City Park	Cab-2	2024-04-17	2	Notropis chalybaeus	17	1
3116	City Park	Cab-2	2024-04-17	2	Notropis chalybaeus	18	1
3116	City Park	Cab-2	2024-04-17	2	Notropis chalybaeus	20	1
3116	City Park	Cab-2	2024-04-17	2	Notropis chalybaeus	20	1
3116	City Park	Cab-2	2024-04-17	2	Notropis chalybaeus	16	1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1

3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1

3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	2	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Etheostoma fonticola	24	1
3116	City Park	Cab-2	2024-04-17	3	Etheostoma fonticola	16	1
3116	City Park	Cab-2	2024-04-17	3	Etheostoma fonticola	19	1
3116	City Park	Cab-2	2024-04-17	3	Etheostoma fonticola	12	1
3116	City Park	Cab-2	2024-04-17	3	Etheostoma fonticola	12	1
3116	City Park	Cab-2	2024-04-17	3	Etheostoma fonticola	15	1
3116	City Park	Cab-2	2024-04-17	3	Etheostoma fonticola	14	1
3116	City Park	Cab-2	2024-04-17	3	Etheostoma fonticola	13	1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1

3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1

3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	3	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Etheostoma fonticola	26	1
3116	City Park	Cab-2	2024-04-17	4	Etheostoma fonticola	20	1
3116	City Park	Cab-2	2024-04-17	4	Etheostoma fonticola	22	1
3116	City Park	Cab-2	2024-04-17	4	Etheostoma fonticola	22	1
3116	City Park	Cab-2	2024-04-17	4	Etheostoma fonticola	30	1
3116	City Park	Cab-2	2024-04-17	4	Etheostoma fonticola	17	1
3116	City Park	Cab-2	2024-04-17	4	Etheostoma fonticola	21	1
3116	City Park	Cab-2	2024-04-17	4	Etheostoma fonticola	15	1
3116	City Park	Cab-2	2024-04-17	4	Etheostoma fonticola	17	1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1

3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	4	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	5	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	5	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	5	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	5	Etheostoma fonticola	30	1
3116	City Park	Cab-2	2024-04-17	5	Etheostoma fonticola	21	1
3116	City Park	Cab-2	2024-04-17	5	Etheostoma fonticola	33	1
3116	City Park	Cab-2	2024-04-17	5	Etheostoma fonticola	18	1
3116	City Park	Cab-2	2024-04-17	5	Etheostoma fonticola	13	1
3116	City Park	Cab-2	2024-04-17	5	Etheostoma fonticola	13	1
3116	City Park	Cab-2	2024-04-17	5	Etheostoma fonticola	16	1
3116	City Park	Cab-2	2024-04-17	5	Etheostoma fonticola	18	1
3116	City Park	Cab-2	2024-04-17	5	Procambarus sp.		1
3116	City Park	Cab-2	2024-04-17	6	Astyanax mexicanus	22	1
3116	City Park	Cab-2	2024-04-17	6	Etheostoma fonticola	20	1
3116	City Park	Cab-2	2024-04-17	6	Etheostoma fonticola	23	1
3116	City Park	Cab-2	2024-04-17	6	Etheostoma fonticola	14	1
3116	City Park	Cab-2	2024-04-17	6	Etheostoma fonticola	18	1
3116	City Park	Cab-2	2024-04-17	6	Etheostoma fonticola	17	1

3116	City Park	Cab-2	2024-04-17	6	Etheostoma fonticola	20	1
3116	City Park	Cab-2	2024-04-17	6	Etheostoma fonticola	20	1
3116	City Park	Cab-2	2024-04-17	6	Etheostoma fonticola	11	1
3116	City Park	Cab-2	2024-04-17	6	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	6	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	6	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	6	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	6	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	6	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	7	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	7	Etheostoma fonticola	17	1
3116	City Park	Cab-2	2024-04-17	8	Etheostoma fonticola	20	1
3116	City Park	Cab-2	2024-04-17	8	Etheostoma fonticola	24	1
3116	City Park	Cab-2	2024-04-17	8	Etheostoma fonticola	11	1
3116	City Park	Cab-2	2024-04-17	8	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	9	Etheostoma fonticola	15	1
3116	City Park	Cab-2	2024-04-17	9	Etheostoma fonticola	14	1
3116	City Park	Cab-2	2024-04-17	9	Etheostoma fonticola	17	1
3116	City Park	Cab-2	2024-04-17	9	Etheostoma fonticola	15	1
3116	City Park	Cab-2	2024-04-17	9	Etheostoma fonticola	15	1
3116	City Park	Cab-2	2024-04-17	9	Etheostoma fonticola	12	1
3116	City Park	Cab-2	2024-04-17	9	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	9	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	9	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	10	Etheostoma fonticola	19	1
3116	City Park	Cab-2	2024-04-17	10	Etheostoma fonticola	17	1
3116	City Park	Cab-2	2024-04-17	10	Etheostoma fonticola	12	1
3116	City Park	Cab-2	2024-04-17	11	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	11	Etheostoma fonticola	12	1
3116	City Park	Cab-2	2024-04-17	12	Etheostoma fonticola	26	1

3116	City Park	Cab-2	2024-04-17	12	Etheostoma fonticola	11	1
3116	City Park	Cab-2	2024-04-17	13	Etheostoma fonticola	18	1
3116	City Park	Cab-2	2024-04-17	14	No fish collected		
3116	City Park	Cab-2	2024-04-17	15	Gambusia sp.		1
3116	City Park	Cab-2	2024-04-17	15	Etheostoma fonticola	22	1
3116	City Park	Cab-2	2024-04-17	15	Etheostoma fonticola	15	1
3116	City Park	Cab-2	2024-04-17	16	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	1	Etheostoma fonticola	24	1
3117	City Park	Lud-1	2024-04-17	1	Etheostoma fonticola	28	1
3117	City Park	Lud-1	2024-04-17	1	Etheostoma fonticola	24	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	23	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	12	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	22	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	11	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	10	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	10	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	12	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	12	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	10	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	10	1
3117	City Park	Lud-1	2024-04-17	1	Gambusia sp.	11	1
3117	City Park	Lud-1	2024-04-17	1	Procambarus sp.		1
3117	City Park	Lud-1	2024-04-17	2	Gambusia sp.	20	1
3117	City Park	Lud-1	2024-04-17	2	Gambusia sp.	15	1
3117	City Park	Lud-1	2024-04-17	2	Gambusia sp.	30	1
3117	City Park	Lud-1	2024-04-17	2	Gambusia sp.	36	1
3117	City Park	Lud-1	2024-04-17	2	Gambusia sp.	28	1
3117	City Park	Lud-1	2024-04-17	2	Gambusia sp.	22	1
3117	City Park	Lud-1	2024-04-17	2	Gambusia sp.	12	1
3117	City Park	Lud-1	2024-04-17	2	Gambusia sp.	10	1

3117	City Park	Lud-1	2024-04-17	2	Etheostoma fonticola	23	1
3117	City Park	Lud-1	2024-04-17	2	Etheostoma fonticola	24	1
3117	City Park	Lud-1	2024-04-17	2	Procambarus sp.		1
3117	City Park	Lud-1	2024-04-17	3	Gambusia sp.	25	1
3117	City Park	Lud-1	2024-04-17	3	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	3	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	3	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	4	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	4	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	4	Procambarus sp.		1
3117	City Park	Lud-1	2024-04-17	4	Astyanax mexicanus	30	1
3117	City Park	Lud-1	2024-04-17	5	Procambarus sp.		1
3117	City Park	Lud-1	2024-04-17	5	Etheostoma fonticola	13	1
3117	City Park	Lud-1	2024-04-17	6	Procambarus sp.		2
3117	City Park	Lud-1	2024-04-17	6	Etheostoma fonticola	31	1
3117	City Park	Lud-1	2024-04-17	6	Etheostoma fonticola	29	1
3117	City Park	Lud-1	2024-04-17	6	Etheostoma fonticola	27	1
3117	City Park	Lud-1	2024-04-17	6	Etheostoma fonticola	29	1
3117	City Park	Lud-1	2024-04-17	6	Etheostoma fonticola	28	1
3117	City Park	Lud-1	2024-04-17	6	Etheostoma fonticola	23	1
3117	City Park	Lud-1	2024-04-17	6	Etheostoma fonticola	31	1
3117	City Park	Lud-1	2024-04-17	6	Etheostoma fonticola	15	1
3117	City Park	Lud-1	2024-04-17	6	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	6	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	7	Lepomis miniatus	89	1
3117	City Park	Lud-1	2024-04-17	7	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	7	Etheostoma fonticola	20	1
3117	City Park	Lud-1	2024-04-17	7	Etheostoma fonticola	22	1
3117	City Park	Lud-1	2024-04-17	7	Etheostoma fonticola	12	1
3117	City Park	Lud-1	2024-04-17	8	Procambarus sp.		1

3117	City Park	Lud-1	2024-04-17	8	Etheostoma fonticola	15	1
3117	City Park	Lud-1	2024-04-17	8	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	8	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	9	Procambarus sp.		1
3117	City Park	Lud-1	2024-04-17	9	Etheostoma fonticola	30	1
3117	City Park	Lud-1	2024-04-17	10	Etheostoma fonticola	37	1
3117	City Park	Lud-1	2024-04-17	10	Etheostoma fonticola	31	1
3117	City Park	Lud-1	2024-04-17	10	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	11	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	11	Etheostoma fonticola	30	1
3117	City Park	Lud-1	2024-04-17	11	Etheostoma fonticola	18	1
3117	City Park	Lud-1	2024-04-17	12	Gambusia sp.		1
3117	City Park	Lud-1	2024-04-17	13	Etheostoma fonticola	18	1
3117	City Park	Lud-1	2024-04-17	13	Procambarus sp.		1
3117	City Park	Lud-1	2024-04-17	14	Procambarus sp.		2
3117	City Park	Lud-1	2024-04-17	15	Etheostoma fonticola	31	1
3117	City Park	Lud-1	2024-04-17	15	Etheostoma fonticola	34	1
3117	City Park	Lud-1	2024-04-17	16	No fish collected		
3118	City Park	Lud-2	2024-04-17	1	Lepomis miniatus	107	1
3118	City Park	Lud-2	2024-04-17	1	Ambloplites rupestris	30	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	10	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	26	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	35	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	28	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	24	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	15	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	24	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	15	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	18	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	32	1

3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	23	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	18	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	12	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	27	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	24	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	20	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	12	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	13	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	10	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	15	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.	24	1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	1	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	17	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	33	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	16	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	27	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	20	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	19	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	15	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	26	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	26	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	20	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	28	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	19	1

3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	12	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	15	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	30	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	35	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	23	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	15	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	29	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	34	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	19	1
3118	City Park	Lud-2	2024-04-17	1	Etheostoma fonticola	18	1
3118	City Park	Lud-2	2024-04-17	1	Procambarus sp.		7
3118	City Park	Lud-2	2024-04-17	2	Etheostoma fonticola	30	1
3118	City Park	Lud-2	2024-04-17	2	Etheostoma fonticola	15	1
3118	City Park	Lud-2	2024-04-17	2	Etheostoma fonticola	17	1
3118	City Park	Lud-2	2024-04-17	2	Etheostoma fonticola	18	1
3118	City Park	Lud-2	2024-04-17	2	Etheostoma fonticola	18	1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	2	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	3	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	3	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	3	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	3	Gambusia sp.		1

3118	City Park	Lud-2	2024-04-17	3	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	3	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	3	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	3	Etheostoma fonticola	29	1
3118	City Park	Lud-2	2024-04-17	3	Etheostoma fonticola	22	1
3118	City Park	Lud-2	2024-04-17	3	Procambarus sp.		5
3118	City Park	Lud-2	2024-04-17	4	Procambarus sp.		4
3118	City Park	Lud-2	2024-04-17	4	Etheostoma fonticola	38	1
3118	City Park	Lud-2	2024-04-17	4	Etheostoma fonticola	19	1
3118	City Park	Lud-2	2024-04-17	4	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	4	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	4	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	4	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	4	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	4	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	5	Procambarus sp.		2
3118	City Park	Lud-2	2024-04-17	5	Etheostoma fonticola	16	1
3118	City Park	Lud-2	2024-04-17	5	Etheostoma fonticola	18	1
3118	City Park	Lud-2	2024-04-17	5	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	6	No fish collected		
3118	City Park	Lud-2	2024-04-17	7	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	8	Procambarus sp.		1
3118	City Park	Lud-2	2024-04-17	8	Etheostoma fonticola	32	1
3118	City Park	Lud-2	2024-04-17	9	Procambarus sp.		1
3118	City Park	Lud-2	2024-04-17	9	Etheostoma fonticola	33	1
3118	City Park	Lud-2	2024-04-17	10	Etheostoma fonticola	29	1
3118	City Park	Lud-2	2024-04-17	10	Etheostoma fonticola	18	1
3118	City Park	Lud-2	2024-04-17	10	Etheostoma fonticola	17	1
3118	City Park	Lud-2	2024-04-17	10	Etheostoma fonticola	16	1
3118	City Park	Lud-2	2024-04-17	11	Procambarus sp.		2

3118	City Park	Lud-2	2024-04-17	11	Etheostoma fonticola	32	1
3118	City Park	Lud-2	2024-04-17	11	Etheostoma fonticola	32	1
3118	City Park	Lud-2	2024-04-17	11	Etheostoma fonticola	20	1
3118	City Park	Lud-2	2024-04-17	11	Etheostoma fonticola	20	1
3118	City Park	Lud-2	2024-04-17	11	Etheostoma fonticola	24	1
3118	City Park	Lud-2	2024-04-17	11	Etheostoma fonticola	18	1
3118	City Park	Lud-2	2024-04-17	11	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	12	Etheostoma fonticola	29	1
3118	City Park	Lud-2	2024-04-17	12	Gambusia sp.		1
3118	City Park	Lud-2	2024-04-17	13	Etheostoma fonticola	31	1
3118	City Park	Lud-2	2024-04-17	13	Etheostoma fonticola	23	1
3118	City Park	Lud-2	2024-04-17	13	Procambarus sp.		1
3118	City Park	Lud-2	2024-04-17	14	Procambarus sp.		3
3118	City Park	Lud-2	2024-04-17	14	Etheostoma fonticola	21	1
3118	City Park	Lud-2	2024-04-17	14	Etheostoma fonticola	25	1
3118	City Park	Lud-2	2024-04-17	14	Etheostoma fonticola	15	1
3118	City Park	Lud-2	2024-04-17	15	Procambarus sp.		1
3118	City Park	Lud-2	2024-04-17	15	Etheostoma fonticola	33	1
3118	City Park	Lud-2	2024-04-17	15	Etheostoma fonticola	29	1
3118	City Park	Lud-2	2024-04-17	15	Etheostoma fonticola	34	1
3118	City Park	Lud-2	2024-04-17	15	Etheostoma fonticola	26	1
3118	City Park	Lud-2	2024-04-17	15	Etheostoma fonticola	22	1
3118	City Park	Lud-2	2024-04-17	16	Procambarus sp.		1
3118	City Park	Lud-2	2024-04-17	16	Etheostoma fonticola	14	1
3118	City Park	Lud-2	2024-04-17	16	Etheostoma fonticola	29	1
3118	City Park	Lud-2	2024-04-17	17	No fish collected		
3118	City Park	Lud-2	2024-04-17				
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	22	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	21	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	12	1

3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	16	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	20	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	22	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	15	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	10	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	12	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	22	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	22	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	10	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	20	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	18	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	10	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	12	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	15	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	12	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	22	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.	28	1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1

3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	1	Notropis chalybaeus	16	1
3119	City Park	Sag-1	2024-04-18	1	Notropis chalybaeus	13	1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1

3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	2	Lepomis sp.	16	1
3119	City Park	Sag-1	2024-04-18	2	Notropis chalybaeus	14	1
3119	City Park	Sag-1	2024-04-18	3	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	3	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	3	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	3	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	3	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	3	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	3	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	4	Etheostoma fonticola	19	1
3119	City Park	Sag-1	2024-04-18	4	Etheostoma fonticola	25	1

3119	City Park	Sag-1	2024-04-18	4	Etheostoma fonticola	22	1
3119	City Park	Sag-1	2024-04-18	4	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	4	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	4	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	4	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	4	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	4	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	4	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	5	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	6	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	6	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	6	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	6	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	6	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	6	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	6	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	6	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	7	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	7	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	7	Gambusia sp.		1

3119	City Park	Sag-1	2024-04-18	7	Astyanax mexicanus	20	1
3119	City Park	Sag-1	2024-04-18	8	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	8	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	8	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	8	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	8	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	8	Etheostoma fonticola	17	1
3119	City Park	Sag-1	2024-04-18	8	Etheostoma fonticola	24	1
3119	City Park	Sag-1	2024-04-18	8	Etheostoma fonticola	12	1
3119	City Park	Sag-1	2024-04-18	9	Procambarus sp.		1
3119	City Park	Sag-1	2024-04-18	10	Lepomis sp.	17	1
3119	City Park	Sag-1	2024-04-18	11	Etheostoma fonticola	28	1
3119	City Park	Sag-1	2024-04-18	11	Etheostoma fonticola	24	1
3119	City Park	Sag-1	2024-04-18	11	Etheostoma fonticola	17	1
3119	City Park	Sag-1	2024-04-18	11	Procambarus sp.		1
3119	City Park	Sag-1	2024-04-18	11	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	12	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	12	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	13	Procambarus sp.		1
3119	City Park	Sag-1	2024-04-18	13	Etheostoma fonticola	17	1
3119	City Park	Sag-1	2024-04-18	13	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	13	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	14	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	14	Etheostoma fonticola	24	1
3119	City Park	Sag-1	2024-04-18	14	Etheostoma fonticola	23	1
3119	City Park	Sag-1	2024-04-18	14	Etheostoma fonticola	19	1
3119	City Park	Sag-1	2024-04-18	15	Gambusia sp.		1
3119	City Park	Sag-1	2024-04-18	15	Etheostoma fonticola	24	1
3119	City Park	Sag-1	2024-04-18	15	Etheostoma fonticola	18	1
3119	City Park	Sag-1	2024-04-18	15	Etheostoma fonticola	18	1

3119	City Park	Sag-1	2024-04-18	16	No fish collected		
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	32	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	27	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	15	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	20	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	21	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	20	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	24	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	18	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	24	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	23	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	22	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	20	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	15	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	25	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	16	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	28	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	17	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	19	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	32	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.	22	1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1

3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1

3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	1	Procambarus sp.		1
3120	City Park	Sag-2	2024-04-18	1	Etheostoma fonticola	30	1
3120	City Park	Sag-2	2024-04-18	1	Etheostoma fonticola	28	1
3120	City Park	Sag-2	2024-04-18	1	Etheostoma fonticola	21	1
3120	City Park	Sag-2	2024-04-18	1	Etheostoma fonticola	28	1
3120	City Park	Sag-2	2024-04-18	1	Etheostoma fonticola	21	1
3120	City Park	Sag-2	2024-04-18	1	Etheostoma fonticola	25	1
3120	City Park	Sag-2	2024-04-18	1	Notropis chalybaeus	15	1
3120	City Park	Sag-2	2024-04-18	2	Etheostoma fonticola	16	1
3120	City Park	Sag-2	2024-04-18	2	Etheostoma fonticola	19	1
3120	City Park	Sag-2	2024-04-18	2	Notropis chalybaeus	20	1
3120	City Park	Sag-2	2024-04-18	2	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	2	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	2	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	2	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	2	Gambusia sp.		1

3120	City Park	Sag-2	2024-04-18	2	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	2	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	2	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	2	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	3	Procambarus sp.		1
3120	City Park	Sag-2	2024-04-18	3	Notropis chalybaeus	20	1
3120	City Park	Sag-2	2024-04-18	3	Notropis chalybaeus	22	1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1

3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	4	Procambarus sp.		1
3120	City Park	Sag-2	2024-04-18	4	Etheostoma fonticola	7	1
3120	City Park	Sag-2	2024-04-18	4	Etheostoma fonticola	18	1
3120	City Park	Sag-2	2024-04-18	4	Etheostoma fonticola	14	1
3120	City Park	Sag-2	2024-04-18	4	Notropis chalybaeus	19	1
3120	City Park	Sag-2	2024-04-18	4	Notropis chalybaeus	24	1
3120	City Park	Sag-2	2024-04-18	5	Procambarus sp.		1
3120	City Park	Sag-2	2024-04-18	5	Etheostoma fonticola	29	1
3120	City Park	Sag-2	2024-04-18	5	Etheostoma fonticola	13	1
3120	City Park	Sag-2	2024-04-18	5	Etheostoma fonticola	13	1
3120	City Park	Sag-2	2024-04-18	5	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	5	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	6	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	6	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	6	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	6	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	6	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	6	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	6	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	6	Procambarus sp.		1
3120	City Park	Sag-2	2024-04-18	6	Etheostoma fonticola	27	1
3120	City Park	Sag-2	2024-04-18	6	Etheostoma fonticola	16	1
3120	City Park	Sag-2	2024-04-18	6	Etheostoma fonticola	18	1
3120	City Park	Sag-2	2024-04-18	7	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	7	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	7	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	7	Gambusia sp.		1

3120	City Park	Sag-2	2024-04-18	7	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	7	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	7	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	7	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	7	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	8	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	8	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	8	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	8	Etheostoma fonticola	25	1
3120	City Park	Sag-2	2024-04-18	8	Etheostoma fonticola	18	1
3120	City Park	Sag-2	2024-04-18	9	Procambarus sp.		2
3120	City Park	Sag-2	2024-04-18	9	Notropis chalybaeus	25	1
3120	City Park	Sag-2	2024-04-18	9	Etheostoma fonticola	28	1
3120	City Park	Sag-2	2024-04-18	9	Etheostoma fonticola	15	1
3120	City Park	Sag-2	2024-04-18	9	Etheostoma fonticola	14	1
3120	City Park	Sag-2	2024-04-18	9	Etheostoma fonticola	22	1
3120	City Park	Sag-2	2024-04-18	9	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	9	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	9	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	9	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	9	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	9	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	9	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	9	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	10	Procambarus sp.		2
3120	City Park	Sag-2	2024-04-18	10	Etheostoma fonticola	12	1
3120	City Park	Sag-2	2024-04-18	10	Etheostoma fonticola	20	1
3120	City Park	Sag-2	2024-04-18	10	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	10	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	10	Gambusia sp.		1

3120	City Park	Sag-2	2024-04-18	11	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	11	Etheostoma fonticola	16	1
3120	City Park	Sag-2	2024-04-18	12	Etheostoma fonticola	20	1
3120	City Park	Sag-2	2024-04-18	12	Etheostoma fonticola	16	1
3120	City Park	Sag-2	2024-04-18	12	Etheostoma fonticola	26	1
3120	City Park	Sag-2	2024-04-18	12	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	12	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	13	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	14	Etheostoma fonticola	25	1
3120	City Park	Sag-2	2024-04-18	15	Etheostoma fonticola	16	1
3120	City Park	Sag-2	2024-04-18	15	Etheostoma fonticola	24	1
3120	City Park	Sag-2	2024-04-18	15	Etheostoma fonticola	28	1
3120	City Park	Sag-2	2024-04-18	16	Procambarus sp.		1
3120	City Park	Sag-2	2024-04-18	16	Etheostoma fonticola	39	1
3120	City Park	Sag-2	2024-04-18	16	Gambusia sp.		1
3120	City Park	Sag-2	2024-04-18	17	No fish collected		
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	10	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	20	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	10	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	22	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	20	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	22	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	28	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	31	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	10	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	30	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	29	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	24	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	28	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	20	1

3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	19	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	22	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	32	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	22	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	14	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.	10	1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	1	Etheostoma fonticola	18	1
3121	City Park	Ziz-1	2024-04-18	1	Procambarus sp.		2
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1

3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	2	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	3	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	3	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	3	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	3	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	3	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	3	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	4	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	5	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	5	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	5	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	6	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	6	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	7	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	7	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	8	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	8	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	9	No fish collected		
3121	City Park	Ziz-1	2024-04-18	10	Gambusia sp.		1

3121	City Park	Ziz-1	2024-04-18	10	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	10	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	10	Etheostoma fonticola	15	1
3121	City Park	Ziz-1	2024-04-18	11	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	12	No fish collected		
3121	City Park	Ziz-1	2024-04-18	13	No fish collected		
3121	City Park	Ziz-1	2024-04-18	14	Gambusia sp.		1
3121	City Park	Ziz-1	2024-04-18	15	No fish collected		
3122	City Park	Ziz-2	2024-04-18	1	Etheostoma fonticola	16	1
3122	City Park	Ziz-2	2024-04-18	1	Gambusia sp.	33	1
3122	City Park	Ziz-2	2024-04-18	1	Gambusia sp.	21	1
3122	City Park	Ziz-2	2024-04-18	1	Gambusia sp.	15	1
3122	City Park	Ziz-2	2024-04-18	1	Gambusia sp.	12	1
3122	City Park	Ziz-2	2024-04-18	1	Gambusia sp.	10	1
3122	City Park	Ziz-2	2024-04-18	2	Gambusia sp.	15	1
3122	City Park	Ziz-2	2024-04-18	2	Gambusia sp.	10	1
3122	City Park	Ziz-2	2024-04-18	2	Gambusia sp.	11	1
3122	City Park	Ziz-2	2024-04-18	2	Gambusia sp.	18	1
3122	City Park	Ziz-2	2024-04-18	2	Etheostoma fonticola	22	1
3122	City Park	Ziz-2	2024-04-18	3	Gambusia sp.	28	1
3122	City Park	Ziz-2	2024-04-18	3	Gambusia sp.	24	1
3122	City Park	Ziz-2	2024-04-18	3	Gambusia sp.	24	1
3122	City Park	Ziz-2	2024-04-18	3	Gambusia sp.	13	1
3122	City Park	Ziz-2	2024-04-18	3	Gambusia sp.	25	1
3122	City Park	Ziz-2	2024-04-18	3	Gambusia sp.	22	1
3122	City Park	Ziz-2	2024-04-18	3	Etheostoma fonticola	15	1
3122	City Park	Ziz-2	2024-04-18	3	Etheostoma fonticola	30	1
3122	City Park	Ziz-2	2024-04-18	3	Etheostoma fonticola	15	1
3122	City Park	Ziz-2	2024-04-18	4	Etheostoma fonticola	20	1
3122	City Park	Ziz-2	2024-04-18	4	Etheostoma fonticola	18	1

3122	City Park	Ziz-2	2024-04-18	4	Gambusia sp.	23	1
3122	City Park	Ziz-2	2024-04-18	4	Gambusia sp.	24	1
3122	City Park	Ziz-2	2024-04-18	4	Gambusia sp.	12	1
3122	City Park	Ziz-2	2024-04-18	4	Gambusia sp.	12	1
3122	City Park	Ziz-2	2024-04-18	5	Etheostoma fonticola	22	1
3122	City Park	Ziz-2	2024-04-18	5	Etheostoma fonticola	26	1
3122	City Park	Ziz-2	2024-04-18	5	Etheostoma fonticola	38	1
3122	City Park	Ziz-2	2024-04-18	5	Etheostoma fonticola	20	1
3122	City Park	Ziz-2	2024-04-18	5	Gambusia sp.	28	1
3122	City Park	Ziz-2	2024-04-18	5	Gambusia sp.	32	1
3122	City Park	Ziz-2	2024-04-18	6	Etheostoma fonticola	11	1
3122	City Park	Ziz-2	2024-04-18	7	No fish collected		
3122	City Park	Ziz-2	2024-04-18	8	Etheostoma fonticola	29	1
3122	City Park	Ziz-2	2024-04-18	9	Procambarus sp.		2
3122	City Park	Ziz-2	2024-04-18	9	Etheostoma fonticola	18	1
3122	City Park	Ziz-2	2024-04-18	9	Etheostoma fonticola	18	1
3122	City Park	Ziz-2	2024-04-18	10	Gambusia sp.	25	1
3122	City Park	Ziz-2	2024-04-18	10	Gambusia sp.	20	1
3122	City Park	Ziz-2	2024-04-18	10	Etheostoma fonticola	15	1
3122	City Park	Ziz-2	2024-04-18	10	Etheostoma fonticola	18	1
3122	City Park	Ziz-2	2024-04-18	11	Etheostoma fonticola	33	1
3122	City Park	Ziz-2	2024-04-18	11	Etheostoma fonticola	11	1
3122	City Park	Ziz-2	2024-04-18	11	Gambusia sp.	20	1
3122	City Park	Ziz-2	2024-04-18	11	Gambusia sp.		1
3122	City Park	Ziz-2	2024-04-18	12	No fish collected		
3122	City Park	Ziz-2	2024-04-18	13	Procambarus sp.		1
3122	City Park	Ziz-2	2024-04-18	13	Etheostoma fonticola	15	1
3122	City Park	Ziz-2	2024-04-18	14	Etheostoma fonticola	15	1
3122	City Park	Ziz-2	2024-04-18	15	No fish collected		
3123	I-35	Cab-1	2024-04-18	1	Procambarus sp.		4

3123	I-35	Cab-1	2024-04-18	1	Ambloplites rupestris	28	1
3123	I-35	Cab-1	2024-04-18	1	Ambloplites rupestris	21	1
3123	I-35	Cab-1	2024-04-18	1	Gambusia sp.	29	1
3123	I-35	Cab-1	2024-04-18	1	Gambusia sp.	11	1
3123	I-35	Cab-1	2024-04-18	1	Gambusia sp.	38	1
3123	I-35	Cab-1	2024-04-18	1	Gambusia sp.	13	1
3123	I-35	Cab-1	2024-04-18	1	Gambusia sp.	10	1
3123	I-35	Cab-1	2024-04-18	1	Lepomis sp.	18	1
3123	I-35	Cab-1	2024-04-18	1	Dionda nigrotaeniata	25	1
3123	I-35	Cab-1	2024-04-18	1	Dionda nigrotaeniata	12	1
3123	I-35	Cab-1	2024-04-18	1	Etheostoma fonticola	24	1
3123	I-35	Cab-1	2024-04-18	1	Etheostoma fonticola	18	1
3123	I-35	Cab-1	2024-04-18	1	Etheostoma fonticola	18	1
3123	I-35	Cab-1	2024-04-18	2	Procambarus sp.		1
3123	I-35	Cab-1	2024-04-18	2	Lepomis sp.	15	1
3123	I-35	Cab-1	2024-04-18	2	Etheostoma fonticola	22	1
3123	I-35	Cab-1	2024-04-18	2	Etheostoma fonticola	11	1
3123	I-35	Cab-1	2024-04-18	2	Gambusia sp.	11	1
3123	I-35	Cab-1	2024-04-18	2	Ambloplites rupestris	11	1
3123	I-35	Cab-1	2024-04-18	3	Gambusia sp.	28	1
3123	I-35	Cab-1	2024-04-18	3	Gambusia sp.	36	1
3123	I-35	Cab-1	2024-04-18	3	Gambusia sp.	10	1
3123	I-35	Cab-1	2024-04-18	3	Gambusia sp.	20	1
3123	I-35	Cab-1	2024-04-18	3	Procambarus sp.		1
3123	I-35	Cab-1	2024-04-18	4	Lepomis sp.	21	1
3123	I-35	Cab-1	2024-04-18	4	Lepomis sp.	15	1
3123	I-35	Cab-1	2024-04-18	4	Lepomis sp.	12	1
3123	I-35	Cab-1	2024-04-18	4	Etheostoma fonticola	33	1
3123	I-35	Cab-1	2024-04-18	4	Etheostoma fonticola	22	1
3123	I-35	Cab-1	2024-04-18	4	Etheostoma fonticola	21	1

3123	I-35	Cab-1	2024-04-18	4	Etheostoma fonticola	12	1
3123	I-35	Cab-1	2024-04-18	4	Gambusia sp.	10	1
3123	I-35	Cab-1	2024-04-18	5	Gambusia sp.	33	1
3123	I-35	Cab-1	2024-04-18	5	Gambusia sp.	10	1
3123	I-35	Cab-1	2024-04-18	5	Gambusia sp.	15	1
3123	I-35	Cab-1	2024-04-18	5	Gambusia sp.	11	1
3123	I-35	Cab-1	2024-04-18	5	Gambusia sp.	11	1
3123	I-35	Cab-1	2024-04-18	5	Ambloplites rupestris	25	1
3123	I-35	Cab-1	2024-04-18	5	Etheostoma fonticola	23	1
3123	I-35	Cab-1	2024-04-18	5	Etheostoma fonticola	16	1
3123	I-35	Cab-1	2024-04-18	6	Gambusia sp.	30	1
3123	I-35	Cab-1	2024-04-18	6	Gambusia sp.	13	1
3123	I-35	Cab-1	2024-04-18	6	Gambusia sp.	10	1
3123	I-35	Cab-1	2024-04-18	6	Procambarus sp.		4
3123	I-35	Cab-1	2024-04-18	6	Etheostoma fonticola	16	1
3123	I-35	Cab-1	2024-04-18	6	Etheostoma fonticola	22	1
3123	I-35	Cab-1	2024-04-18	6	Etheostoma fonticola	31	1
3123	I-35	Cab-1	2024-04-18	6	Etheostoma fonticola	10	1
3123	I-35	Cab-1	2024-04-18	6	Etheostoma fonticola	22	1
3123	I-35	Cab-1	2024-04-18	6	Lepomis sp.	11	1
3123	I-35	Cab-1	2024-04-18	7	Gambusia sp.	11	1
3123	I-35	Cab-1	2024-04-18	7	Procambarus sp.		1
3123	I-35	Cab-1	2024-04-18	8	Procambarus sp.		2
3123	I-35	Cab-1	2024-04-18	8	Etheostoma fonticola	22	1
3123	I-35	Cab-1	2024-04-18	8	Etheostoma fonticola	28	1
3123	I-35	Cab-1	2024-04-18	8	Etheostoma fonticola	29	1
3123	I-35	Cab-1	2024-04-18	8	Etheostoma fonticola	18	1
3123	I-35	Cab-1	2024-04-18	8	Etheostoma fonticola	22	1
3123	I-35	Cab-1	2024-04-18	8	Etheostoma fonticola	17	1
3123	I-35	Cab-1	2024-04-18	8	Etheostoma fonticola	15	1

3123	I-35	Cab-1	2024-04-18	8	Lepomis sp.	11	1
3123	I-35	Cab-1	2024-04-18	8	Lepomis sp.	15	1
3123	I-35	Cab-1	2024-04-18	8	Lepomis sp.	12	1
3123	I-35	Cab-1	2024-04-18	8	Ameiurus natalis	19	1
3123	I-35	Cab-1	2024-04-18	9	Gambusia sp.		1
3123	I-35	Cab-1	2024-04-18	9	Gambusia sp.		1
3123	I-35	Cab-1	2024-04-18	9	Gambusia sp.		1
3123	I-35	Cab-1	2024-04-18	9	Gambusia sp.		1
3123	I-35	Cab-1	2024-04-18	9	Lepomis sp.	10	1
3123	I-35	Cab-1	2024-04-18	10	Procambarus sp.		1
3123	I-35	Cab-1	2024-04-18	10	Etheostoma fonticola	27	1
3123	I-35	Cab-1	2024-04-18	10	Lepomis sp.	12	1
3123	I-35	Cab-1	2024-04-18	11	Etheostoma fonticola	20	1
3123	I-35	Cab-1	2024-04-18	11	Etheostoma fonticola	20	1
3123	I-35	Cab-1	2024-04-18	11	Procambarus sp.		1
3123	I-35	Cab-1	2024-04-18	11	Lepomis sp.	15	1
3123	I-35	Cab-1	2024-04-18	12	No fish collected		
3123	I-35	Cab-1	2024-04-18	13	No fish collected		
3123	I-35	Cab-1	2024-04-18	14	Etheostoma fonticola	28	1
3123	I-35	Cab-1	2024-04-18	14	Etheostoma fonticola	21	1
3123	I-35	Cab-1	2024-04-18	14	Etheostoma fonticola	26	1
3123	I-35	Cab-1	2024-04-18	14	Etheostoma fonticola	21	1
3123	I-35	Cab-1	2024-04-18	14	Ameiurus natalis	18	1
3123	I-35	Cab-1	2024-04-18	15	No fish collected		
3124	I-35	Hyg-1	2024-04-18	1	Procambarus sp.		13
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	18	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	17	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	23	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	14	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	26	1

3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	19	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	19	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	25	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	17	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	23	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	21	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	26	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	16	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	16	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	15	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	23	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	22	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	23	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	22	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	23	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	21	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	17	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	22	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	13	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	22	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	20	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	31	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	22	1
3124	I-35	Hyg-1	2024-04-18	1	Etheostoma fonticola	15	1
3124	I-35	Hyg-1	2024-04-18	1	Gambusia sp.	16	1
3124	I-35	Hyg-1	2024-04-18	1	Gambusia sp.	22	1
3124	I-35	Hyg-1	2024-04-18	1	Gambusia sp.	24	1
3124	I-35	Hyg-1	2024-04-18	1	Gambusia sp.	20	1
3124	I-35	Hyg-1	2024-04-18	1	Gambusia sp.	13	1
3124	I-35	Hyg-1	2024-04-18	2	Gambusia sp.	40	1

3124	I-35	Hyg-1	2024-04-18	2	Gambusia sp.	10	1
3124	I-35	Hyg-1	2024-04-18	2	Gambusia sp.	15	1
3124	I-35	Hyg-1	2024-04-18	2	Gambusia sp.	17	1
3124	I-35	Hyg-1	2024-04-18	2	Gambusia sp.	16	1
3124	I-35	Hyg-1	2024-04-18	2	Gambusia sp.	17	1
3124	I-35	Hyg-1	2024-04-18	2	Procambarus sp.		3
3124	I-35	Hyg-1	2024-04-18	2	Etheostoma fonticola	17	1
3124	I-35	Hyg-1	2024-04-18	2	Etheostoma fonticola	20	1
3124	I-35	Hyg-1	2024-04-18	2	Etheostoma fonticola	19	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	23	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	17	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	22	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	19	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	23	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	15	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	16	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	16	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	23	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	25	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	18	1
3124	I-35	Hyg-1	2024-04-18	3	Etheostoma fonticola	11	1
3124	I-35	Hyg-1	2024-04-18	3	Gambusia sp.	25	1
3124	I-35	Hyg-1	2024-04-18	3	Gambusia sp.	21	1
3124	I-35	Hyg-1	2024-04-18	3	Procambarus sp.		5
3124	I-35	Hyg-1	2024-04-18	4	Procambarus sp.		2
3124	I-35	Hyg-1	2024-04-18	4	Etheostoma fonticola	26	1
3124	I-35	Hyg-1	2024-04-18	4	Gambusia sp.	20	1
3124	I-35	Hyg-1	2024-04-18	5	Procambarus sp.		3
3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	18	1
3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	41	1

3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	31	1
3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	21	1
3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	19	1
3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	21	1
3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	25	1
3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	20	1
3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	25	1
3124	I-35	Hyg-1	2024-04-18	5	Etheostoma fonticola	21	1
3124	I-35	Hyg-1	2024-04-18	6	Procambarus sp.		5
3124	I-35	Hyg-1	2024-04-18	7	Etheostoma fonticola	28	1
3124	I-35	Hyg-1	2024-04-18	8	Etheostoma fonticola	25	1
3124	I-35	Hyg-1	2024-04-18	8	Etheostoma fonticola	16	1
3124	I-35	Hyg-1	2024-04-18	8	Procambarus sp.		1
3124	I-35	Hyg-1	2024-04-18	9	Procambarus sp.		3
3124	I-35	Hyg-1	2024-04-18	9	Etheostoma fonticola	24	1
3124	I-35	Hyg-1	2024-04-18	10	Etheostoma fonticola	16	1
3124	I-35	Hyg-1	2024-04-18	10	Procambarus sp.		1
3124	I-35	Hyg-1	2024-04-18	11	Procambarus sp.		1
3124	I-35	Hyg-1	2024-04-18	12	Procambarus sp.		1
3124	I-35	Hyg-1	2024-04-18	13	No fish collected		
3124	I-35	Hyg-1	2024-04-18	14	Procambarus sp.		1
3124	I-35	Hyg-1	2024-04-18	15	Procambarus sp.		1
3125	I-35	Hyg-2	2024-04-18	1	Etheostoma fonticola	25	1
3125	I-35	Hyg-2	2024-04-18	1	Etheostoma fonticola	19	1
3125	I-35	Hyg-2	2024-04-18	1	Hypostomus plecostomus	25	1
3125	I-35	Hyg-2	2024-04-18	1	Procambarus sp.		1
3125	I-35	Hyg-2	2024-04-18	1	Gambusia sp.	25	1
3125	I-35	Hyg-2	2024-04-18	2	Gambusia sp.	26	1
3125	I-35	Hyg-2	2024-04-18	3	No fish collected		
3125	I-35	Hyg-2	2024-04-18	4	No fish collected		

3125	I-35	Hyg-2	2024-04-18	5	No fish collected		
3125	I-35	Hyg-2	2024-04-18	6	Hypostomus plecostomus	26	1
3125	I-35	Hyg-2	2024-04-18	7	No fish collected		
3125	I-35	Hyg-2	2024-04-18	8	Lepomis miniatus	89	1
3125	I-35	Hyg-2	2024-04-18	8	Procambarus sp.		1
3125	I-35	Hyg-2	2024-04-18	9	No fish collected		
3125	I-35	Hyg-2	2024-04-18	10	No fish collected		
3125	I-35	Hyg-2	2024-04-18	11	Etheostoma fonticola	25	1
3125	I-35	Hyg-2	2024-04-18	12	No fish collected		
3125	I-35	Hyg-2	2024-04-18	13	No fish collected		
3125	I-35	Hyg-2	2024-04-18	14	No fish collected		
3125	I-35	Hyg-2	2024-04-18	15	Gambusia sp.	21	1
3126	I-35	Open-1	2024-04-18	1	No fish collected		
3126	I-35	Open-1	2024-04-18	2	No fish collected		
3126	I-35	Open-1	2024-04-18	3	No fish collected		
3126	I-35	Open-1	2024-04-18	4	No fish collected		
3126	I-35	Open-1	2024-04-18	5	No fish collected		
3126	I-35	Open-1	2024-04-18	6	No fish collected		
3126	I-35	Open-1	2024-04-18	7	No fish collected		
3126	I-35	Open-1	2024-04-18	8	No fish collected		
3126	I-35	Open-1	2024-04-18	9	No fish collected		
3126	I-35	Open-1	2024-04-18	10	No fish collected		
3127	I-35	Cab-2	2024-04-18	1	Etheostoma fonticola	22	1
3127	I-35	Cab-2	2024-04-18	1	Etheostoma fonticola	30	1
3127	I-35	Cab-2	2024-04-18	1	Etheostoma fonticola	22	1
3127	I-35	Cab-2	2024-04-18	1	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	1	Etheostoma fonticola	16	1
3127	I-35	Cab-2	2024-04-18	1	Etheostoma fonticola	16	1
3127	I-35	Cab-2	2024-04-18	1	Etheostoma fonticola	19	1
3127	I-35	Cab-2	2024-04-18	1	Micropterus salmoides	26	1

3127	I-35	Cab-2	2024-04-18	1	Unidentified fish	61	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	29	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	22	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	8	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	12	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	20	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	10	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	10	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	11	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	10	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	11	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	10	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	10	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	10	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	12	1
3127	I-35	Cab-2	2024-04-18	1	Gambusia sp.	9	1
3127	I-35	Cab-2	2024-04-18	1	Lepomis sp.	10	1
3127	I-35	Cab-2	2024-04-18	1	Lepomis sp.	14	1
3127	I-35	Cab-2	2024-04-18	1	Lepomis sp.	15	1
3127	I-35	Cab-2	2024-04-18	1	Lepomis sp.	10	1
3127	I-35	Cab-2	2024-04-18	1	Dionda nigrotaeniata	34	1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.	28	1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.	21	1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.	44	1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.	33	1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.	30	1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1

3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	2	Etheostoma fonticola	16	1
3127	I-35	Cab-2	2024-04-18	2	Etheostoma fonticola	17	1
3127	I-35	Cab-2	2024-04-18	2	Etheostoma fonticola	23	1
3127	I-35	Cab-2	2024-04-18	2	Etheostoma fonticola	22	1
3127	I-35	Cab-2	2024-04-18	2	Etheostoma fonticola	14	1
3127	I-35	Cab-2	2024-04-18	2	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	35	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	23	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	16	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	19	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	22	1

3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	25	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	17	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	25	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	14	1
3127	I-35	Cab-2	2024-04-18	3	Etheostoma fonticola	18	1
3127	I-35	Cab-2	2024-04-18	3	Lepomis sp.	12	1
3127	I-35	Cab-2	2024-04-18	3	Lepomis sp.	20	1
3127	I-35	Cab-2	2024-04-18	3	Lepomis sp.	9	1
3127	I-35	Cab-2	2024-04-18	3	Lepomis sp.	10	1
3127	I-35	Cab-2	2024-04-18	3	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	3	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	3	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	3	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	4	Lepomis sp.	12	1
3127	I-35	Cab-2	2024-04-18	4	Lepomis sp.	19	1
3127	I-35	Cab-2	2024-04-18	4	Lepomis sp.	15	1
3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	22	1
3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	21	1
3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	21	1

3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	16	1
3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	18	1
3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	4	Etheostoma fonticola	13	1
3127	I-35	Cab-2	2024-04-18	4	Palaemonetes sp.		2
3127	I-35	Cab-2	2024-04-18	5	Procambarus sp.		1
3127	I-35	Cab-2	2024-04-18	5	Lepomis sp.	12	1
3127	I-35	Cab-2	2024-04-18	5	Lepomis sp.	19	1
3127	I-35	Cab-2	2024-04-18	5	Lepomis sp.	15	1
3127	I-35	Cab-2	2024-04-18	5	Etheostoma fonticola	19	1
3127	I-35	Cab-2	2024-04-18	5	Etheostoma fonticola	22	1
3127	I-35	Cab-2	2024-04-18	5	Etheostoma fonticola	36	1
3127	I-35	Cab-2	2024-04-18	5	Etheostoma fonticola	30	1
3127	I-35	Cab-2	2024-04-18	5	Etheostoma fonticola	19	1
3127	I-35	Cab-2	2024-04-18	5	Etheostoma fonticola	23	1
3127	I-35	Cab-2	2024-04-18	5	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	5	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	5	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	5	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	5	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	5	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	5	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	5	Ambloplites rupestris	17	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	29	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	21	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	15	1

3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	22	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	14	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	21	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	14	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	16	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	21	1
3127	I-35	Cab-2	2024-04-18	6	Etheostoma fonticola	17	1
3127	I-35	Cab-2	2024-04-18	6	Lepomis sp.	20	1
3127	I-35	Cab-2	2024-04-18	6	Lepomis sp.	10	1
3127	I-35	Cab-2	2024-04-18	7	Notropis chalybaeus	55	1
3127	I-35	Cab-2	2024-04-18	7	Etheostoma fonticola	27	1
3127	I-35	Cab-2	2024-04-18	7	Etheostoma fonticola	27	1
3127	I-35	Cab-2	2024-04-18	7	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	7	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	7	Etheostoma fonticola	16	1
3127	I-35	Cab-2	2024-04-18	7	Etheostoma fonticola	22	1
3127	I-35	Cab-2	2024-04-18	7	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	7	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	7	Etheostoma fonticola	22	1
3127	I-35	Cab-2	2024-04-18	7	Lepomis sp.	18	1
3127	I-35	Cab-2	2024-04-18	7	Lepomis sp.	12	1
3127	I-35	Cab-2	2024-04-18	7	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	7	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	7	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	7	Gambusia sp.		1

3127	I-35	Cab-2	2024-04-18	8	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	8	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	8	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	8	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	8	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	8	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	8	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	8	Procambarus sp.		1
3127	I-35	Cab-2	2024-04-18	8	Lepomis sp.	12	1
3127	I-35	Cab-2	2024-04-18	8	Lepomis sp.	15	1
3127	I-35	Cab-2	2024-04-18	8	Lepomis sp.	16	1
3127	I-35	Cab-2	2024-04-18	8	Lepomis sp.	22	1
3127	I-35	Cab-2	2024-04-18	8	Etheostoma fonticola	21	1
3127	I-35	Cab-2	2024-04-18	8	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	8	Etheostoma fonticola	25	1
3127	I-35	Cab-2	2024-04-18	8	Etheostoma fonticola	22	1
3127	I-35	Cab-2	2024-04-18	9	Lepisosteus sp.	780	1
3127	I-35	Cab-2	2024-04-18	9	Etheostoma fonticola	21	1
3127	I-35	Cab-2	2024-04-18	9	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	9	Etheostoma fonticola	25	1
3127	I-35	Cab-2	2024-04-18	9	Etheostoma fonticola	21	1
3127	I-35	Cab-2	2024-04-18	9	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	9	Etheostoma fonticola	21	1
3127	I-35	Cab-2	2024-04-18	9	Etheostoma fonticola	14	1
3127	I-35	Cab-2	2024-04-18	9	Lepomis sp.	16	1
3127	I-35	Cab-2	2024-04-18	9	Procambarus sp.		1
3127	I-35	Cab-2	2024-04-18	10	Etheostoma fonticola	18	1
3127	I-35	Cab-2	2024-04-18	10	Etheostoma fonticola	30	1
3127	I-35	Cab-2	2024-04-18	10	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	10	Etheostoma fonticola	21	1

3127	I-35	Cab-2	2024-04-18	10	Etheostoma fonticola	32	1
3127	I-35	Cab-2	2024-04-18	10	Etheostoma fonticola	30	1
3127	I-35	Cab-2	2024-04-18	10	Etheostoma fonticola	23	1
3127	I-35	Cab-2	2024-04-18	10	Lepomis gulosus	169	1
3127	I-35	Cab-2	2024-04-18	10	Lepomis sp.	16	1
3127	I-35	Cab-2	2024-04-18	10	Gambusia sp.		1
3127	I-35	Cab-2	2024-04-18	11	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	11	Etheostoma fonticola	26	1
3127	I-35	Cab-2	2024-04-18	11	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	11	Etheostoma fonticola	18	1
3127	I-35	Cab-2	2024-04-18	11	Etheostoma fonticola	19	1
3127	I-35	Cab-2	2024-04-18	11	Etheostoma fonticola	25	1
3127	I-35	Cab-2	2024-04-18	12	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	12	Etheostoma fonticola	26	1
3127	I-35	Cab-2	2024-04-18	12	Etheostoma fonticola	18	1
3127	I-35	Cab-2	2024-04-18	12	Etheostoma fonticola	16	1
3127	I-35	Cab-2	2024-04-18	12	Etheostoma fonticola	29	1
3127	I-35	Cab-2	2024-04-18	12	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	12	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	12	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	12	Lepomis miniatus	82	1
3127	I-35	Cab-2	2024-04-18	12	Procambarus sp.		1
3127	I-35	Cab-2	2024-04-18	13	Lepomis miniatus	46	1
3127	I-35	Cab-2	2024-04-18	13	Lepomis sp.	12	1
3127	I-35	Cab-2	2024-04-18	13	Lepomis sp.	13	1
3127	I-35	Cab-2	2024-04-18	13	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	13	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	13	Etheostoma fonticola	16	1
3127	I-35	Cab-2	2024-04-18	14	Etheostoma fonticola	27	1
3127	I-35	Cab-2	2024-04-18	15	Etheostoma fonticola	19	1

3127	I-35	Cab-2	2024-04-18	15	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	16	Etheostoma fonticola	23	1
3127	I-35	Cab-2	2024-04-18	17	Lepomis miniatus	86	1
3127	I-35	Cab-2	2024-04-18	17	Etheostoma fonticola	15	1
3127	I-35	Cab-2	2024-04-18	17	Etheostoma fonticola	30	1
3127	I-35	Cab-2	2024-04-18	17	Etheostoma fonticola	24	1
3127	I-35	Cab-2	2024-04-18	17	Etheostoma fonticola	18	1
3127	I-35	Cab-2	2024-04-18	17	Etheostoma fonticola	21	1
3127	I-35	Cab-2	2024-04-18	17	Etheostoma fonticola	20	1
3127	I-35	Cab-2	2024-04-18	18	Etheostoma fonticola	17	1
3127	I-35	Cab-2	2024-04-18	19	No fish collected		
3128	I-35	Ziz-1	2024-04-18	1	Procambarus sp.		1
3128	I-35	Ziz-1	2024-04-18	1	Ambloplites rupestris	23	1
3128	I-35	Ziz-1	2024-04-18	1	Etheostoma fonticola	26	1
3128	I-35	Ziz-1	2024-04-18	1	Gambusia sp.	26	1
3128	I-35	Ziz-1	2024-04-18	1	Gambusia sp.	20	1
3128	I-35	Ziz-1	2024-04-18	1	Gambusia sp.	12	1
3128	I-35	Ziz-1	2024-04-18	2	Micropterus salmoides	51	1
3128	I-35	Ziz-1	2024-04-18	3	Notropis chalybaeus	60	1
3128	I-35	Ziz-1	2024-04-18	4	No fish collected		
3128	I-35	Ziz-1	2024-04-18	5	Etheostoma fonticola	24	1
3128	I-35	Ziz-1	2024-04-18	6	Lepomis sp.	7	1
3128	I-35	Ziz-1	2024-04-18	7	No fish collected		
3128	I-35	Ziz-1	2024-04-18	8	No fish collected		
3128	I-35	Ziz-1	2024-04-18	9	Procambarus sp.		1
3128	I-35	Ziz-1	2024-04-18	10	Etheostoma fonticola	15	1
3128	I-35	Ziz-1	2024-04-18	11	No fish collected		
3128	I-35	Ziz-1	2024-04-18	12	Gambusia sp.	9	1
3128	I-35	Ziz-1	2024-04-18	13	No fish collected		
3128	I-35	Ziz-1	2024-04-18	14	No fish collected		

3128	I-35	Ziz-1	2024-04-18	15	No fish collected		
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	20	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	29	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	18	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	8	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	9	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	14	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	10	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	19	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	13	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	10	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	9	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	10	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	10	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	21	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	10	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	11	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	10	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	8	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	10	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.	10	1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	1	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	1	Lepomis miniatus	83	1
3129	I-35	Ziz-2	2024-04-18	1	Procambarus sp.		1
3129	I-35	Ziz-2	2024-04-18	2	Ambloplites rupestris	21	1

3129	I-35	Ziz-2	2024-04-18	2	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	2	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	2	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	2	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	2	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	2	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	2	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	2	Procambarus sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	3	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	4	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	5	Lepomis miniatus	80	1
3129	I-35	Ziz-2	2024-04-18	5	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	5	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	5	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	6	Procambarus sp.		1
3129	I-35	Ziz-2	2024-04-18	6	Lepomis sp.	15	1
3129	I-35	Ziz-2	2024-04-18	7	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	7	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	8	Ambloplites rupestris	18	1
3129	I-35	Ziz-2	2024-04-18	8	Gambusia sp.		1

3129	I-35	Ziz-2	2024-04-18	9	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	9	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	10	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	11	No fish collected		
3129	I-35	Ziz-2	2024-04-18	12	No fish collected		
3129	I-35	Ziz-2	2024-04-18	13	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	13	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	13	Gambusia sp.		1
3129	I-35	Ziz-2	2024-04-18	13	Etheostoma fonticola	18	1
3129	I-35	Ziz-2	2024-04-18	14	No fish collected		
3129	I-35	Ziz-2	2024-04-18	15	No fish collected		
3130	I-35	Hyd-1	2024-04-18	1	Procambarus sp.		5
3130	I-35	Hyd-1	2024-04-18	1	Gambusia sp.	15	1
3130	I-35	Hyd-1	2024-04-18	1	Gambusia sp.	12	1
3130	I-35	Hyd-1	2024-04-18	1	Gambusia sp.	9	1
3130	I-35	Hyd-1	2024-04-18	1	Etheostoma fonticola	20	1
3130	I-35	Hyd-1	2024-04-18	1	Etheostoma fonticola	15	1
3130	I-35	Hyd-1	2024-04-18	2	Etheostoma fonticola	26	1
3130	I-35	Hyd-1	2024-04-18	2	Procambarus sp.		5
3130	I-35	Hyd-1	2024-04-18	2	Gambusia sp.	15	1
3130	I-35	Hyd-1	2024-04-18	3	Etheostoma fonticola	25	1
3130	I-35	Hyd-1	2024-04-18	3	Etheostoma fonticola	26	1
3130	I-35	Hyd-1	2024-04-18	3	Hypostomus plecostomus	25	1
3130	I-35	Hyd-1	2024-04-18	3	Procambarus sp.		5
3130	I-35	Hyd-1	2024-04-18	3	Gambusia sp.	16	1
3130	I-35	Hyd-1	2024-04-18	4	Procambarus sp.		3
3130	I-35	Hyd-1	2024-04-18	5	Procambarus sp.		5
3130	I-35	Hyd-1	2024-04-18	5	Etheostoma fonticola	22	1
3130	I-35	Hyd-1	2024-04-18	6	Etheostoma fonticola	30	1
3130	I-35	Hyd-1	2024-04-18	6	Etheostoma fonticola	25	1

3130	I-35	Hyd-1	2024-04-18	6	Procambarus sp.		2
3130	I-35	Hyd-1	2024-04-18	7	Procambarus sp.		1
3130	I-35	Hyd-1	2024-04-18	7	Etheostoma fonticola	25	1
3130	I-35	Hyd-1	2024-04-18	8	Etheostoma fonticola	30	1
3130	I-35	Hyd-1	2024-04-18	9	No fish collected		
3130	I-35	Hyd-1	2024-04-18	10	Procambarus sp.		2
3130	I-35	Hyd-1	2024-04-18	10	Etheostoma fonticola	31	1
3130	I-35	Hyd-1	2024-04-18	11	Procambarus sp.		2
3130	I-35	Hyd-1	2024-04-18	12	Procambarus sp.		1
3130	I-35	Hyd-1	2024-04-18	13	No fish collected		
3130	I-35	Hyd-1	2024-04-18	14	Procambarus sp.		3
3130	I-35	Hyd-1	2024-04-18	15	Procambarus sp.		4
3130	I-35	Hyd-1	2024-04-18	15	Gambusia sp.	14	1
3130	I-35	Hyd-1	2024-04-18	15	Etheostoma fonticola	25	1
3130	I-35	Hyd-1	2024-04-18	16	Procambarus sp.		1
3131	I-35	Hyd-2	2024-04-18	1	No fish collected		
3131	I-35	Hyd-2	2024-04-18	2	Etheostoma fonticola	34	1
3131	I-35	Hyd-2	2024-04-18	2	Etheostoma fonticola	34	1
3131	I-35	Hyd-2	2024-04-18	3	Procambarus sp.		1
3131	I-35	Hyd-2	2024-04-18	4	Procambarus sp.		1
3131	I-35	Hyd-2	2024-04-18	4	Etheostoma fonticola	26	1
3131	I-35	Hyd-2	2024-04-18	5	Etheostoma fonticola	35	1
3131	I-35	Hyd-2	2024-04-18	6	No fish collected		
3131	I-35	Hyd-2	2024-04-18	7	Percina apristis	80	1
3131	I-35	Hyd-2	2024-04-18	8	No fish collected		
3131	I-35	Hyd-2	2024-04-18	9	No fish collected		
3131	I-35	Hyd-2	2024-04-18	10	No fish collected		
3131	I-35	Hyd-2	2024-04-18	11	No fish collected		
3131	I-35	Hyd-2	2024-04-18	12	No fish collected		
3131	I-35	Hyd-2	2024-04-18	13	No fish collected		

3131	I-35	Hyd-2	2024-04-18	14	No fish collected		
3131	I-35	Hyd-2	2024-04-18	15	No fish collected		
3132	I-35	Open-2	2024-04-18	1	No fish collected		
3132	I-35	Open-2	2024-04-18	2	No fish collected		
3132	I-35	Open-2	2024-04-18	3	No fish collected		
3132	I-35	Open-2	2024-04-18	4	No fish collected		
3132	I-35	Open-2	2024-04-18	5	No fish collected		
3132	I-35	Open-2	2024-04-18	6	No fish collected		
3132	I-35	Open-2	2024-04-18	7	No fish collected		
3132	I-35	Open-2	2024-04-18	8	No fish collected		
3132	I-35	Open-2	2024-04-18	9	No fish collected		
3132	I-35	Open-2	2024-04-18	10	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	1	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	2	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	3	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	4	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	5	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	6	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	7	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	8	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	9	No fish collected		
3197	Spring Lake Dam	Open-1	2024-10-15	10	No fish collected		
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	38	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	36	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	21	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	39	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	42	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	31	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	20	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	19	1

3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	19	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	25	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	24	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	25	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	24	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	12	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	21	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	18	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	11	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Gambusia sp.	18	1
3198	Spring Lake Dam	Pota-1	2024-10-15	1	Procambarus sp.		3
3198	Spring Lake Dam	Pota-1	2024-10-15	2	Gambusia sp.	25	1
3198	Spring Lake Dam	Pota-1	2024-10-15	2	Gambusia sp.	29	1
3198	Spring Lake Dam	Pota-1	2024-10-15	2	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	2	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	2	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	2	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	2	Procambarus sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	3	Procambarus sp.		2
3198	Spring Lake Dam	Pota-1	2024-10-15	3	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	4	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	5	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	5	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	5	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	5	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	6	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	7	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	8	No fish collected		
3198	Spring Lake Dam	Pota-1	2024-10-15	9	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	10	No fish collected		

3198	Spring Lake Dam	Pota-1	2024-10-15	11	Gambusia sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	12	Procambarus sp.		1
3198	Spring Lake Dam	Pota-1	2024-10-15	13	No fish collected		
3198	Spring Lake Dam	Pota-1	2024-10-15	14	No fish collected		
3198	Spring Lake Dam	Pota-1	2024-10-15	15	No fish collected		
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Ameiurus natalis	65	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Herichthys cyanoguttatus	46	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	35	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	24	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	31	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	25	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	28	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	15	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	20	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	28	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	28	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	18	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	20	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	25	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	15	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	18	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	35	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	22	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	20	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	25	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	21	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.	20	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1

3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Etheostoma fonticola	15	1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Procambarus sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	1	Palaemonetes sp.		2
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Etheostoma fonticola	31	1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1

3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	2	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	3	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	3	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	3	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	3	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	3	Procambarus sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Etheostoma fonticola	30	1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Etheostoma fonticola	22	1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Etheostoma fonticola	32	1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Herichthys cyanoguttatus	49	1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1

3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Procambarus sp.		4
3199	Spring Lake Dam	Pota-2	2024-10-15	4	Palaemonetes sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	5	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	5	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	6	Etheostoma fonticola	31	1
3199	Spring Lake Dam	Pota-2	2024-10-15	6	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	6	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	6	Gambusia sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	7	No fish collected		
3199	Spring Lake Dam	Pota-2	2024-10-15	8	No fish collected		
3199	Spring Lake Dam	Pota-2	2024-10-15	9	No fish collected		
3199	Spring Lake Dam	Pota-2	2024-10-15	10	Procambarus sp.		1
3199	Spring Lake Dam	Pota-2	2024-10-15	11	No fish collected		
3199	Spring Lake Dam	Pota-2	2024-10-15	12	No fish collected		
3199	Spring Lake Dam	Pota-2	2024-10-15	13	No fish collected		
3199	Spring Lake Dam	Pota-2	2024-10-15	14	No fish collected		
3199	Spring Lake Dam	Pota-2	2024-10-15	15	No fish collected		
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	22	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	30	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	23	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	34	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	36	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	35	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	29	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	21	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	19	1

3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	25	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	21	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	20	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Etheostoma fonticola	20	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	42	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	25	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	9	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	18	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	15	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	38	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	24	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	16	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	16	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	15	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	17	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	21	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	16	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	20	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	14	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	10	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Gambusia sp.	10	1
3200	Spring Lake Dam	Sag-1	2024-10-15	1	Procambarus sp.		11
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	30	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	30	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	30	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	30	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	28	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	34	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	30	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	35	1

3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	26	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	36	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	29	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	34	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	32	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	21	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	24	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	23	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	24	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	19	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	33	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	29	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Etheostoma fonticola	26	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Gambusia sp.	21	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Gambusia sp.	18	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Gambusia sp.	12	1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Procambarus sp.		7
3200	Spring Lake Dam	Sag-1	2024-10-15	2	Palaemonetes sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	28	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	30	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	34	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	31	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	35	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	22	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	32	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	33	1

3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	31	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	25	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Etheostoma fonticola	34	1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	3	Procambarus sp.		7
3200	Spring Lake Dam	Sag-1	2024-10-15	4	Etheostoma fonticola	30	1
3200	Spring Lake Dam	Sag-1	2024-10-15	4	Etheostoma fonticola	31	1
3200	Spring Lake Dam	Sag-1	2024-10-15	4	Etheostoma fonticola	26	1
3200	Spring Lake Dam	Sag-1	2024-10-15	4	Etheostoma fonticola	18	1
3200	Spring Lake Dam	Sag-1	2024-10-15	4	Etheostoma fonticola	24	1
3200	Spring Lake Dam	Sag-1	2024-10-15	4	Etheostoma fonticola	25	1
3200	Spring Lake Dam	Sag-1	2024-10-15	4	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	4	Procambarus sp.		6
3200	Spring Lake Dam	Sag-1	2024-10-15	4	Palaemonetes sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Etheostoma fonticola	36	1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Etheostoma fonticola	22	1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Etheostoma fonticola	35	1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Etheostoma fonticola	22	1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Etheostoma fonticola	26	1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Etheostoma fonticola	21	1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Etheostoma fonticola	24	1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	5	Procambarus sp.		9
3200	Spring Lake Dam	Sag-1	2024-10-15	6	Etheostoma fonticola	22	1
3200	Spring Lake Dam	Sag-1	2024-10-15	6	Etheostoma fonticola	27	1
3200	Spring Lake Dam	Sag-1	2024-10-15	6	Gambusia sp.		1

3200	Spring Lake Dam	Sag-1	2024-10-15	6	Procambarus sp.		5
3200	Spring Lake Dam	Sag-1	2024-10-15	7	Etheostoma fonticola	28	1
3200	Spring Lake Dam	Sag-1	2024-10-15	7	Etheostoma fonticola	36	1
3200	Spring Lake Dam	Sag-1	2024-10-15	7	Etheostoma fonticola	31	1
3200	Spring Lake Dam	Sag-1	2024-10-15	7	Procambarus sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	8	Etheostoma fonticola	32	1
3200	Spring Lake Dam	Sag-1	2024-10-15	8	Etheostoma fonticola	28	1
3200	Spring Lake Dam	Sag-1	2024-10-15	8	Etheostoma fonticola	34	1
3200	Spring Lake Dam	Sag-1	2024-10-15	8	Etheostoma fonticola	21	1
3200	Spring Lake Dam	Sag-1	2024-10-15	8	Etheostoma fonticola	23	1
3200	Spring Lake Dam	Sag-1	2024-10-15	8	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	8	Gambusia sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	8	Procambarus sp.		5
3200	Spring Lake Dam	Sag-1	2024-10-15	9	Etheostoma fonticola	28	1
3200	Spring Lake Dam	Sag-1	2024-10-15	9	Etheostoma fonticola	34	1
3200	Spring Lake Dam	Sag-1	2024-10-15	9	Etheostoma fonticola	24	1
3200	Spring Lake Dam	Sag-1	2024-10-15	9	Etheostoma fonticola	28	1
3200	Spring Lake Dam	Sag-1	2024-10-15	9	Etheostoma fonticola	34	1
3200	Spring Lake Dam	Sag-1	2024-10-15	9	Procambarus sp.		3
3200	Spring Lake Dam	Sag-1	2024-10-15	10	Etheostoma fonticola	35	1
3200	Spring Lake Dam	Sag-1	2024-10-15	11	No fish collected		
3200	Spring Lake Dam	Sag-1	2024-10-15	12	Procambarus sp.		5
3200	Spring Lake Dam	Sag-1	2024-10-15	13	Etheostoma fonticola	31	1
3200	Spring Lake Dam	Sag-1	2024-10-15	13	Procambarus sp.		1
3200	Spring Lake Dam	Sag-1	2024-10-15	14	Etheostoma fonticola	25	1
3200	Spring Lake Dam	Sag-1	2024-10-15	15	Procambarus sp.		2
3200	Spring Lake Dam	Sag-1	2024-10-15	15	Etheostoma fonticola	30	1
3200	Spring Lake Dam	Sag-1	2024-10-15	15	Etheostoma fonticola	28	1
3200	Spring Lake Dam	Sag-1	2024-10-15	16	Procambarus sp.		1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	20	1

3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	36	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	30	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	36	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	30	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	22	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	21	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	32	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	22	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	22	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	15	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Etheostoma fonticola	28	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Lepomis miniatus	32	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Lepomis miniatus	48	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Lepomis miniatus	40	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Gambusia sp.	10	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Gambusia sp.	9	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Gambusia sp.	10	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Herichthys cyanoguttatus	44	1
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Procambarus sp.		22
3201	Spring Lake Dam	Sag-2	2024-10-15	1	Palaemonetes sp.		1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Procambarus sp.		5
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Palaemonetes sp.		1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	27	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	32	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	22	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	37	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	30	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	16	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	28	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	20	1

3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	20	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Etheostoma fonticola	18	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Gambusia sp.	10	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Gambusia sp.	24	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Gambusia sp.	8	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Gambusia sp.	10	1
3201	Spring Lake Dam	Sag-2	2024-10-15	2	Lepomis miniatus	28	1
3201	Spring Lake Dam	Sag-2	2024-10-15	3	Procambarus sp.		10
3201	Spring Lake Dam	Sag-2	2024-10-15	3	Herichthys cyanoguttatus	36	1
3201	Spring Lake Dam	Sag-2	2024-10-15	3	Herichthys cyanoguttatus	30	1
3201	Spring Lake Dam	Sag-2	2024-10-15	3	Etheostoma fonticola	32	1
3201	Spring Lake Dam	Sag-2	2024-10-15	3	Etheostoma fonticola	29	1
3201	Spring Lake Dam	Sag-2	2024-10-15	3	Etheostoma fonticola	33	1
3201	Spring Lake Dam	Sag-2	2024-10-15	4	Etheostoma fonticola	33	1
3201	Spring Lake Dam	Sag-2	2024-10-15	4	Etheostoma fonticola	28	1
3201	Spring Lake Dam	Sag-2	2024-10-15	4	Etheostoma fonticola	28	1
3201	Spring Lake Dam	Sag-2	2024-10-15	4	Etheostoma fonticola	26	1
3201	Spring Lake Dam	Sag-2	2024-10-15	4	Procambarus sp.		1
3201	Spring Lake Dam	Sag-2	2024-10-15	5	Procambarus sp.		7
3201	Spring Lake Dam	Sag-2	2024-10-15	5	Etheostoma fonticola	24	1
3201	Spring Lake Dam	Sag-2	2024-10-15	5	Etheostoma fonticola	30	1
3201	Spring Lake Dam	Sag-2	2024-10-15	5	Etheostoma fonticola	29	1
3201	Spring Lake Dam	Sag-2	2024-10-15	5	Etheostoma fonticola	38	1
3201	Spring Lake Dam	Sag-2	2024-10-15	6	Procambarus sp.		4
3201	Spring Lake Dam	Sag-2	2024-10-15	6	Etheostoma fonticola	24	1
3201	Spring Lake Dam	Sag-2	2024-10-15	6	Etheostoma fonticola	32	1
3201	Spring Lake Dam	Sag-2	2024-10-15	6	Etheostoma fonticola	31	1
3201	Spring Lake Dam	Sag-2	2024-10-15	6	Gambusia sp.	10	1
3201	Spring Lake Dam	Sag-2	2024-10-15	6	Gambusia sp.	7	1
3201	Spring Lake Dam	Sag-2	2024-10-15	7	Procambarus sp.		6

3201	Spring Lake Dam	Sag-2	2024-10-15	7	Etheostoma fonticola	25	1
3201	Spring Lake Dam	Sag-2	2024-10-15	7	Etheostoma fonticola	30	1
3201	Spring Lake Dam	Sag-2	2024-10-15	7	Etheostoma fonticola	32	1
3201	Spring Lake Dam	Sag-2	2024-10-15	7	Gambusia sp.	10	1
3201	Spring Lake Dam	Sag-2	2024-10-15	8	Ambloplites rupestris	76	1
3201	Spring Lake Dam	Sag-2	2024-10-15	8	Ambloplites rupestris	83	1
3201	Spring Lake Dam	Sag-2	2024-10-15	8	Procambarus sp.		4
3201	Spring Lake Dam	Sag-2	2024-10-15	9	Micropterus salmoides	136	1
3201	Spring Lake Dam	Sag-2	2024-10-15	9	Procambarus sp.		2
3201	Spring Lake Dam	Sag-2	2024-10-15	10	Procambarus sp.		3
3201	Spring Lake Dam	Sag-2	2024-10-15	10	Etheostoma fonticola	25	1
3201	Spring Lake Dam	Sag-2	2024-10-15	11	Etheostoma fonticola	22	1
3201	Spring Lake Dam	Sag-2	2024-10-15	11	Etheostoma fonticola	31	1
3201	Spring Lake Dam	Sag-2	2024-10-15	11	Etheostoma fonticola	18	1
3201	Spring Lake Dam	Sag-2	2024-10-15	11	Etheostoma fonticola	29	1
3201	Spring Lake Dam	Sag-2	2024-10-15	11	Etheostoma fonticola	33	1
3201	Spring Lake Dam	Sag-2	2024-10-15	11	Etheostoma fonticola	24	1
3201	Spring Lake Dam	Sag-2	2024-10-15	11	Lepomis miniatus	28	1
3201	Spring Lake Dam	Sag-2	2024-10-15	11	Lepomis miniatus	107	1
3201	Spring Lake Dam	Sag-2	2024-10-15	11	Procambarus sp.		3
3201	Spring Lake Dam	Sag-2	2024-10-15	12	Procambarus sp.		3
3201	Spring Lake Dam	Sag-2	2024-10-15	12	Etheostoma fonticola	37	1
3201	Spring Lake Dam	Sag-2	2024-10-15	13	Procambarus sp.		2
3201	Spring Lake Dam	Sag-2	2024-10-15	13	Etheostoma fonticola	28	1
3201	Spring Lake Dam	Sag-2	2024-10-15	13	Etheostoma fonticola	28	1
3201	Spring Lake Dam	Sag-2	2024-10-15	14	Procambarus sp.		3
3201	Spring Lake Dam	Sag-2	2024-10-15	14	Etheostoma fonticola	33	1
3201	Spring Lake Dam	Sag-2	2024-10-15	14	Etheostoma fonticola	30	1
3201	Spring Lake Dam	Sag-2	2024-10-15	15	Procambarus sp.		2
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Lepomis gulosus	190	1

3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	35	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	30	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	25	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	10	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	38	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	15	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	28	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	23	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	23	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	39	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	22	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	39	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	19	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	10	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Gambusia sp.	10	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	1	Etheostoma fonticola	36	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Gambusia sp.	32	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Gambusia sp.	25	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Gambusia sp.	22	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Gambusia sp.	21	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Gambusia sp.	22	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Gambusia sp.	20	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Gambusia sp.	20	1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Procambarus sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	2	Palaemonetes sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	3	Procambarus sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	3	Palaemonetes sp.		3
3202	Spring Lake Dam	Hydro-1	2024-10-15	4	Etheostoma fonticola	18	1

3202	Spring Lake Dam	Hydro-1	2024-10-15	4	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	4	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	4	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	5	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	5	Palaemonetes sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	6	No fish collected		
3202	Spring Lake Dam	Hydro-1	2024-10-15	7	Palaemonetes sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	7	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	8	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	9	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	9	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	9	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	10	Gambusia sp.		1
3202	Spring Lake Dam	Hydro-1	2024-10-15	11	No fish collected		
3202	Spring Lake Dam	Hydro-1	2024-10-15	12	No fish collected		
3202	Spring Lake Dam	Hydro-1	2024-10-15	13	No fish collected		
3202	Spring Lake Dam	Hydro-1	2024-10-15	14	No fish collected		
3202	Spring Lake Dam	Hydro-1	2024-10-15	15	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15	6	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15	7	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15	8	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15	9	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15	10	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15				
3203	Spring Lake Dam	Open-2	2024-10-15	1	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15	2	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15	3	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15	4	No fish collected		
3203	Spring Lake Dam	Open-2	2024-10-15	5	No fish collected		
3206	City Park	Open-2	2024-10-16	1	No fish collected		

3206	City Park	Open-2	2024-10-16	2	No fish collected		
3206	City Park	Open-2	2024-10-16	3	No fish collected		
3206	City Park	Open-2	2024-10-16	4	No fish collected		
3206	City Park	Open-2	2024-10-16	5	No fish collected		
3206	City Park	Open-2	2024-10-16	6	No fish collected		
3206	City Park	Open-2	2024-10-16	7	No fish collected		
3206	City Park	Open-2	2024-10-16	8	No fish collected		
3206	City Park	Open-2	2024-10-16	9	No fish collected		
3206	City Park	Open-2	2024-10-16	10	No fish collected		
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	10	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	12	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	25	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	15	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	20	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	10	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	10	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	10	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	15	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	24	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	16	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	13	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	13	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	17	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	10	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	10	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	15	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	20	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	15	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.	10	1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1

3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	27	1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	31	1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	30	1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	31	1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	28	1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	25	1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	31	1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	27	1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	29	1

3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	28	1
3207	City Park	Cab-1	2024-10-16	1	Palaemonetes sp.		4
3207	City Park	Cab-1	2024-10-16	1	Procambarus sp.		16
3207	City Park	Cab-1	2024-10-16	2	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	2	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	2	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	2	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	2	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	2	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	2	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	2	Etheostoma fonticola	30	1
3207	City Park	Cab-1	2024-10-16	2	Etheostoma fonticola	26	1
3207	City Park	Cab-1	2024-10-16	2	Etheostoma fonticola	28	1
3207	City Park	Cab-1	2024-10-16	2	Etheostoma fonticola	14	1
3207	City Park	Cab-1	2024-10-16	2	Procambarus sp.		1
3207	City Park	Cab-1	2024-10-16	2	Palaemonetes sp.		1
3207	City Park	Cab-1	2024-10-16	3	Procambarus sp.		5
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	1	Etheostoma fonticola	30	1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1

3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	3	Etheostoma fonticola	35	1
3207	City Park	Cab-1	2024-10-16	3	Etheostoma fonticola	30	1
3207	City Park	Cab-1	2024-10-16	3	Etheostoma fonticola	13	1
3207	City Park	Cab-1	2024-10-16	4	Procambarus sp.		4
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1

3207	City Park	Cab-1	2024-10-16	4	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	4	Etheostoma fonticola	34	1
3207	City Park	Cab-1	2024-10-16	4	Etheostoma fonticola	31	1
3207	City Park	Cab-1	2024-10-16	4	Etheostoma fonticola	34	1
3207	City Park	Cab-1	2024-10-16	4	Etheostoma fonticola	16	1
3207	City Park	Cab-1	2024-10-16	5	Etheostoma fonticola	28	1
3207	City Park	Cab-1	2024-10-16	5	Etheostoma fonticola	30	1
3207	City Park	Cab-1	2024-10-16	5	Etheostoma fonticola	32	1
3207	City Park	Cab-1	2024-10-16	5	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	5	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	5	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	5	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	5	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	5	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	5	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	5	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	5	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	5	Palaemonetes sp.		1
3207	City Park	Cab-1	2024-10-16	5	Procambarus sp.		4
3207	City Park	Cab-1	2024-10-16	6	Lepomis miniatus	99	1
3207	City Park	Cab-1	2024-10-16	6	Procambarus sp.		3
3207	City Park	Cab-1	2024-10-16	6	Etheostoma fonticola	20	1
3207	City Park	Cab-1	2024-10-16	6	Etheostoma fonticola	31	1
3207	City Park	Cab-1	2024-10-16	6	Etheostoma fonticola	30	1
3207	City Park	Cab-1	2024-10-16	6	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	6	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	6	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	6	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	6	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	6	Gambusia sp.		1

3207	City Park	Cab-1	2024-10-16	6	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	7	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	8	Procambarus sp.		1
3207	City Park	Cab-1	2024-10-16	8	Etheostoma fonticola	36	1
3207	City Park	Cab-1	2024-10-16	9	Procambarus sp.		1
3207	City Park	Cab-1	2024-10-16	9	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	9	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	9	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	9	Etheostoma fonticola	32	1
3207	City Park	Cab-1	2024-10-16	10	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	11	Procambarus sp.		2
3207	City Park	Cab-1	2024-10-16	12	Etheostoma fonticola	32	1
3207	City Park	Cab-1	2024-10-16	12	Etheostoma fonticola	25	1
3207	City Park	Cab-1	2024-10-16	13	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	14	Etheostoma fonticola	30	1
3207	City Park	Cab-1	2024-10-16	14	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	14	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	14	Gambusia sp.		1
3207	City Park	Cab-1	2024-10-16	14	Palaemonetes sp.		1
3207	City Park	Cab-1	2024-10-16	15	No fish collected		
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1

3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1

3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Etheostoma fonticola	10	1
3208	City Park	Lud-1	2024-10-16	1	Etheostoma fonticola	18	1
3208	City Park	Lud-1	2024-10-16	1	Procambarus sp.		1
3208	City Park	Lud-1	2024-10-16	2	Procambarus sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	2	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	3	Etheostoma fonticola	35	1
3208	City Park	Lud-1	2024-10-16	3	Etheostoma fonticola	28	1

3208	City Park	Lud-1	2024-10-16	3	Etheostoma fonticola	15	1
3208	City Park	Lud-1	2024-10-16	3	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	3	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	3	Procambarus sp.		2
3208	City Park	Lud-1	2024-10-16	4	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	4	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	4	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	4	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	5	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	6	Etheostoma fonticola	34	1
3208	City Park	Lud-1	2024-10-16	6	Etheostoma fonticola	30	1
3208	City Park	Lud-1	2024-10-16	7	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	7	Etheostoma fonticola	9	1
3208	City Park	Lud-1	2024-10-16	8	Etheostoma fonticola	34	1
3208	City Park	Lud-1	2024-10-16	8	Etheostoma fonticola	26	1
3208	City Park	Lud-1	2024-10-16	8	Etheostoma fonticola	18	1
3208	City Park	Lud-1	2024-10-16	8	Etheostoma fonticola	22	1
3208	City Park	Lud-1	2024-10-16	8	Procambarus sp.		1
3208	City Park	Lud-1	2024-10-16	9	No fish collected		
3208	City Park	Lud-1	2024-10-16	10	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	11	Gambusia sp.		1

3208	City Park	Lud-1	2024-10-16	12	Procambarus sp.		1
3208	City Park	Lud-1	2024-10-16	12	Etheostoma fonticola	32	1
3208	City Park	Lud-1	2024-10-16	13	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	13	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	14	No fish collected		
3208	City Park	Lud-1	2024-10-16	15	No fish collected		
3208	City Park	Lud-1	2024-10-16	1	Etheostoma fonticola	26	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	26	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	18	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	15	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	35	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	22	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	22	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	20	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	33	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	15	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	17	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	38	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	26	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	26	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	28	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	20	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	30	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	22	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	22	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	32	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.	32	1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1

3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3208	City Park	Lud-1	2024-10-16	1	Gambusia sp.		1
3209	City Park	Lud-2	2024-10-16	1	Procambarus sp.		4
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	24	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	30	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	21	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	31	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	28	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	18	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	17	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	18	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	12	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	20	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	10	1
3209	City Park	Lud-2	2024-10-16	1	Etheostoma fonticola	17	1
3209	City Park	Lud-2	2024-10-16	1	Gambusia sp.	10	1
3209	City Park	Lud-2	2024-10-16	1	Gambusia sp.	12	1
3209	City Park	Lud-2	2024-10-16	1	Gambusia sp.	10	1
3209	City Park	Lud-2	2024-10-16	2	Procambarus sp.		6
3209	City Park	Lud-2	2024-10-16	2	Etheostoma fonticola	33	1
3209	City Park	Lud-2	2024-10-16	2	Etheostoma fonticola	16	1
3209	City Park	Lud-2	2024-10-16	2	Gambusia sp.	10	1
3209	City Park	Lud-2	2024-10-16	2	Gambusia sp.	10	1
3209	City Park	Lud-2	2024-10-16	2	Gambusia sp.	10	1
3209	City Park	Lud-2	2024-10-16	3	Etheostoma fonticola	28	1
3209	City Park	Lud-2	2024-10-16	3	Etheostoma fonticola	31	1
3209	City Park	Lud-2	2024-10-16	3	Etheostoma fonticola	32	1
3209	City Park	Lud-2	2024-10-16	3	Gambusia sp.	12	1
3209	City Park	Lud-2	2024-10-16	3	Gambusia sp.	10	1

3209	City Park	Lud-2	2024-10-16	3	Gambusia sp.	10	1
3209	City Park	Lud-2	2024-10-16	4	Etheostoma fonticola	27	1
3209	City Park	Lud-2	2024-10-16	4	Etheostoma fonticola	31	1
3209	City Park	Lud-2	2024-10-16	4	Procambarus sp.		1
3209	City Park	Lud-2	2024-10-16	5	Etheostoma fonticola	28	1
3209	City Park	Lud-2	2024-10-16	5	Etheostoma fonticola	31	1
3209	City Park	Lud-2	2024-10-16	5	Procambarus sp.		2
3209	City Park	Lud-2	2024-10-16	6	Procambarus sp.		2
3209	City Park	Lud-2	2024-10-16	6	Etheostoma fonticola	22	1
3209	City Park	Lud-2	2024-10-16	6	Etheostoma fonticola	30	1
3209	City Park	Lud-2	2024-10-16	6	Gambusia sp.	15	1
3209	City Park	Lud-2	2024-10-16	7	Etheostoma fonticola	20	1
3209	City Park	Lud-2	2024-10-16	7	Etheostoma fonticola	25	1
3209	City Park	Lud-2	2024-10-16	8	Procambarus sp.		2
3209	City Park	Lud-2	2024-10-16	9	Etheostoma fonticola	18	1
3209	City Park	Lud-2	2024-10-16	9	Etheostoma fonticola	19	1
3209	City Park	Lud-2	2024-10-16	10	Procambarus sp.		2
3209	City Park	Lud-2	2024-10-16	11	Etheostoma fonticola	19	1
3209	City Park	Lud-2	2024-10-16	12	Procambarus sp.		2
3209	City Park	Lud-2	2024-10-16	13	Procambarus sp.		2
3209	City Park	Lud-2	2024-10-16	14	Etheostoma fonticola	22	1
3209	City Park	Lud-2	2024-10-16	15	Procambarus sp.		1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	35	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	27	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	31	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	26	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	23	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	22	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	34	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	27	1

3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	16	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	29	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	33	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	28	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	30	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	27	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	29	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	20	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	28	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	30	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	12	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	25	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	28	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	26	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	30	1
3210	City Park	Cab-2	2024-10-16	1	Etheostoma fonticola	19	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	10	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	25	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	10	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	10	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	32	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	31	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	14	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	10	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	18	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	12	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	12	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	10	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	15	1
3210	City Park	Cab-2	2024-10-16	1	Procambarus sp.		12

3210	City Park	Cab-2	2024-10-16	2	Etheostoma fonticola	34	1
3210	City Park	Cab-2	2024-10-16	2	Etheostoma fonticola	21	1
3210	City Park	Cab-2	2024-10-16	2	Etheostoma fonticola	35	1
3210	City Park	Cab-2	2024-10-16	2	Etheostoma fonticola	30	1
3210	City Park	Cab-2	2024-10-16	2	Etheostoma fonticola	16	1
3210	City Park	Cab-2	2024-10-16	2	Etheostoma fonticola	29	1
3210	City Park	Cab-2	2024-10-16	2	Gambusia sp.	25	1
3210	City Park	Cab-2	2024-10-16	2	Gambusia sp.	13	1
3210	City Park	Cab-2	2024-10-16	2	Gambusia sp.	10	1
3210	City Park	Cab-2	2024-10-16	2	Gambusia sp.	10	1
3210	City Park	Cab-2	2024-10-16	2	Gambusia sp.	15	1
3210	City Park	Cab-2	2024-10-16	2	Gambusia sp.	13	1
3210	City Park	Cab-2	2024-10-16	2	Procambarus sp.		5
3210	City Park	Cab-2	2024-10-16	3	Procambarus sp.		3
3210	City Park	Cab-2	2024-10-16	3	Gambusia sp.	10	1
3210	City Park	Cab-2	2024-10-16	3	Gambusia sp.		1
3210	City Park	Cab-2	2024-10-16	3	Gambusia sp.		1
3210	City Park	Cab-2	2024-10-16	3	Etheostoma fonticola	29	1
3210	City Park	Cab-2	2024-10-16	3	Etheostoma fonticola	20	1
3210	City Park	Cab-2	2024-10-16	3	Etheostoma fonticola	15	1
3210	City Park	Cab-2	2024-10-16	4	Procambarus sp.		3
3210	City Park	Cab-2	2024-10-16	4	Etheostoma fonticola	24	1
3210	City Park	Cab-2	2024-10-16	4	Gambusia sp.		1
3210	City Park	Cab-2	2024-10-16	5	Procambarus sp.		9
3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	28	1
3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	30	1
3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	31	1
3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	24	1
3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	24	1
3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	22	1

3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	10	1
3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	19	1
3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	9	1
3210	City Park	Cab-2	2024-10-16	5	Etheostoma fonticola	15	1
3210	City Park	Cab-2	2024-10-16	5	Gambusia sp.		1
3210	City Park	Cab-2	2024-10-16	6	Etheostoma fonticola	34	1
3210	City Park	Cab-2	2024-10-16	6	Etheostoma fonticola	24	1
3210	City Park	Cab-2	2024-10-16	6	Etheostoma fonticola	25	1
3210	City Park	Cab-2	2024-10-16	1	Gambusia sp.	10	1
3210	City Park	Cab-2	2024-10-16	7	Procambarus sp.		3
3210	City Park	Cab-2	2024-10-16	8	Procambarus sp.		1
3210	City Park	Cab-2	2024-10-16	8	Etheostoma fonticola	31	1
3210	City Park	Cab-2	2024-10-16	8	Etheostoma fonticola	25	1
3210	City Park	Cab-2	2024-10-16	8	Etheostoma fonticola	19	1
3210	City Park	Cab-2	2024-10-16	9	Etheostoma fonticola	31	1
3210	City Park	Cab-2	2024-10-16	9	Etheostoma fonticola	32	1
3210	City Park	Cab-2	2024-10-16	9	Etheostoma fonticola	28	1
3210	City Park	Cab-2	2024-10-16	9	Etheostoma fonticola	25	1
3210	City Park	Cab-2	2024-10-16	9	Procambarus sp.		1
3210	City Park	Cab-2	2024-10-16	10	Etheostoma fonticola	21	1
3210	City Park	Cab-2	2024-10-16	10	Etheostoma fonticola	32	1
3210	City Park	Cab-2	2024-10-16	10	Procambarus sp.		1
3210	City Park	Cab-2	2024-10-16	11	Etheostoma fonticola	26	1
3210	City Park	Cab-2	2024-10-16	11	Procambarus sp.		2
3210	City Park	Cab-2	2024-10-16	12	Procambarus sp.		1
3210	City Park	Cab-2	2024-10-16	13	Procambarus sp.		1
3210	City Park	Cab-2	2024-10-16	14	Procambarus sp.		2
3210	City Park	Cab-2	2024-10-16	15	Gambusia sp.		1
3210	City Park	Cab-2	2024-10-16	15	Etheostoma fonticola	27	1
3210	City Park	Cab-2	2024-10-16	16	No fish collected		

3211	I-35	Hyg-1	2024-10-17	1	Procambarus sp.		7
3211	I-35	Hyg-1	2024-10-17	1	Gambusia sp.	22	1
3211	I-35	Hyg-1	2024-10-17	2	Gambusia sp.	22	1
3211	I-35	Hyg-1	2024-10-17	2	Gambusia sp.	18	1
3211	I-35	Hyg-1	2024-10-17	2	Gambusia sp.	22	1
3211	I-35	Hyg-1	2024-10-17	2	Gambusia sp.	20	1
3211	I-35	Hyg-1	2024-10-17	3	Gambusia sp.	18	1
3211	I-35	Hyg-1	2024-10-17	3	Procambarus sp.		1
3211	I-35	Hyg-1	2024-10-17	4	Procambarus sp.		5
3211	I-35	Hyg-1	2024-10-17	4	Ameiurus natalis	15	1
3211	I-35	Hyg-1	2024-10-17	4	Gambusia sp.	10	1
3211	I-35	Hyg-1	2024-10-17	5	Etheostoma fonticola	34	1
3211	I-35	Hyg-1	2024-10-17	6	No fish collected		
3211	I-35	Hyg-1	2024-10-17	7	Procambarus sp.		1
3211	I-35	Hyg-1	2024-10-17	8	Gambusia sp.	28	1
3211	I-35	Hyg-1	2024-10-17	9	No fish collected		
3211	I-35	Hyg-1	2024-10-17	10	Gambusia sp.	22	1
3211	I-35	Hyg-1	2024-10-17	11	No fish collected		
3211	I-35	Hyg-1	2024-10-17	12	No fish collected		
3211	I-35	Hyg-1	2024-10-17	13	No fish collected		
3211	I-35	Hyg-1	2024-10-17	14	No fish collected		
3211	I-35	Hyg-1	2024-10-17	15	No fish collected		
3212	I-35	Hyg-2	2024-10-17	1	Procambarus sp.		6
3212	I-35	Hyg-2	2024-10-17	1	Etheostoma fonticola	34	1
3212	I-35	Hyg-2	2024-10-17	1	Etheostoma fonticola	33	1
3212	I-35	Hyg-2	2024-10-17	1	Etheostoma fonticola	34	1
3212	I-35	Hyg-2	2024-10-17	1	Etheostoma fonticola	32	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	24	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	28	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	15	1

3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	17	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	20	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	24	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	15	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	15	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	15	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	18	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	18	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	15	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	16	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	11	1
3212	I-35	Hyg-2	2024-10-17	1	Gambusia sp.	18	1
3212	I-35	Hyg-2	2024-10-17	1	Hypostomus plecostomus	26	1
3212	I-35	Hyg-2	2024-10-17	2	Etheostoma fonticola	35	1
3212	I-35	Hyg-2	2024-10-17	2	Etheostoma fonticola	28	1
3212	I-35	Hyg-2	2024-10-17	2	Etheostoma fonticola	37	1
3212	I-35	Hyg-2	2024-10-17	2	Etheostoma fonticola	31	1
3212	I-35	Hyg-2	2024-10-17	2	Etheostoma fonticola	24	1
3212	I-35	Hyg-2	2024-10-17	2	Etheostoma fonticola	25	1
3212	I-35	Hyg-2	2024-10-17	2	Etheostoma fonticola	31	1
3212	I-35	Hyg-2	2024-10-17	2	Etheostoma fonticola	25	1
3212	I-35	Hyg-2	2024-10-17	2	Procambarus sp.		4
3212	I-35	Hyg-2	2024-10-17	2	Gambusia sp.	20	1
3212	I-35	Hyg-2	2024-10-17	2	Gambusia sp.	21	1
3212	I-35	Hyg-2	2024-10-17	2	Gambusia sp.	18	1
3212	I-35	Hyg-2	2024-10-17	2	Gambusia sp.	15	1
3212	I-35	Hyg-2	2024-10-17	2	Gambusia sp.	22	1
3212	I-35	Hyg-2	2024-10-17	3	Procambarus sp.		2
3212	I-35	Hyg-2	2024-10-17	3	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	3	Etheostoma fonticola	29	1

3212	I-35	Hyg-2	2024-10-17	4	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	4	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	4	Procambarus sp.		8
3212	I-35	Hyg-2	2024-10-17	4	Etheostoma fonticola	33	1
3212	I-35	Hyg-2	2024-10-17	4	Etheostoma fonticola	32	1
3212	I-35	Hyg-2	2024-10-17	4	Etheostoma fonticola	27	1
3212	I-35	Hyg-2	2024-10-17	5	Etheostoma fonticola	31	1
3212	I-35	Hyg-2	2024-10-17	5	Procambarus sp.		10
3212	I-35	Hyg-2	2024-10-17	5	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	5	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	5	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	6	Procambarus sp.		8
3212	I-35	Hyg-2	2024-10-17	7	Etheostoma fonticola	33	1
3212	I-35	Hyg-2	2024-10-17	7	Etheostoma fonticola	32	1
3212	I-35	Hyg-2	2024-10-17	7	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	7	Procambarus sp.		2
3212	I-35	Hyg-2	2024-10-17	8	Etheostoma fonticola	31	1
3212	I-35	Hyg-2	2024-10-17	8	Etheostoma fonticola	30	1
3212	I-35	Hyg-2	2024-10-17	8	Etheostoma fonticola	28	1
3212	I-35	Hyg-2	2024-10-17	8	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	8	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	8	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	9	No fish collected		
3212	I-35	Hyg-2	2024-10-17	10	Gambusia sp.		1
3212	I-35	Hyg-2	2024-10-17	11	Procambarus sp.		2
3212	I-35	Hyg-2	2024-10-17	11	Etheostoma fonticola	32	1
3212	I-35	Hyg-2	2024-10-17	12	Procambarus sp.		1
3212	I-35	Hyg-2	2024-10-17	13	Procambarus sp.		2
3212	I-35	Hyg-2	2024-10-17	14	Procambarus sp.		2
3212	I-35	Hyg-2	2024-10-17	15	Procambarus sp.		1

3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	44	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	35	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	35	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	20	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	24	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	30	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	25	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	21	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	34	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	25	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	25	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	17	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	16	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	18	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	10	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	23	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	24	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	18	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	10	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	19	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	17	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	20	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.	12	1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1

3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	1	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	2	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	3	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	3	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	3	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	4	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	4	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	4	Gambusia sp.		1

3213	I-35	Open-1	2024-10-17	4	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	4	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	5	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	5	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	5	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	6	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	6	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	7	No fish collected		
3213	I-35	Open-1	2024-10-17	8	No fish collected		
3213	I-35	Open-1	2024-10-17	9	No fish collected		
3213	I-35	Open-1	2024-10-17	10	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	11	No fish collected		
3213	I-35	Open-1	2024-10-17	12	No fish collected		
3213	I-35	Open-1	2024-10-17	13	No fish collected		
3213	I-35	Open-1	2024-10-17	14	Gambusia sp.		1
3213	I-35	Open-1	2024-10-17	15	No fish collected		
3214	I-35	Open-2	2024-10-17	1	Gambusia sp.	20	1
3214	I-35	Open-2	2024-10-17	2	No fish collected		
3214	I-35	Open-2	2024-10-17	3	Gambusia sp.	12	1
3214	I-35	Open-2	2024-10-17	4	No fish collected		
3214	I-35	Open-2	2024-10-17	5	No fish collected		
3214	I-35	Open-2	2024-10-17	6	No fish collected		
3214	I-35	Open-2	2024-10-17	7	No fish collected		
3214	I-35	Open-2	2024-10-17	8	No fish collected		
3214	I-35	Open-2	2024-10-17	9	No fish collected		
3214	I-35	Open-2	2024-10-17	10	No fish collected		
3214	I-35	Open-2	2024-10-17	11	No fish collected		
3214	I-35	Open-2	2024-10-17	12	No fish collected		
3214	I-35	Open-2	2024-10-17	13	Gambusia sp.	32	1
3214	I-35	Open-2	2024-10-17	14	Gambusia sp.	37	1

3214	I-35	Open-2	2024-10-17	15	Etheostoma fonticola	17	1
3214	I-35	Open-2	2024-10-17	16	No fish collected		
3215	I-35	Cab-1	2024-10-17	4	Palaemonetes sp.		1
3215	I-35	Cab-1	2024-10-17	5	Ambloplites rupestris	66	1
3215	I-35	Cab-1	2024-10-17	5	Etheostoma fonticola	32	1
3215	I-35	Cab-1	2024-10-17	5	Etheostoma fonticola	30	1
3215	I-35	Cab-1	2024-10-17	5	Etheostoma fonticola	26	1
3215	I-35	Cab-1	2024-10-17	5	Etheostoma fonticola	38	1
3215	I-35	Cab-1	2024-10-17	5	Etheostoma fonticola	32	1
3215	I-35	Cab-1	2024-10-17	5	Etheostoma fonticola	32	1
3215	I-35	Cab-1	2024-10-17	5	Herichthys cyanoguttatus	38	1
3215	I-35	Cab-1	2024-10-17	5	Procambarus sp.		5
3215	I-35	Cab-1	2024-10-17	6	Micropterus salmoides	45	1
3215	I-35	Cab-1	2024-10-17	6	Ameiurus natalis	42	1
3215	I-35	Cab-1	2024-10-17	6	Etheostoma fonticola	28	1
3215	I-35	Cab-1	2024-10-17	6	Etheostoma fonticola	35	1
3215	I-35	Cab-1	2024-10-17	6	Etheostoma fonticola	35	1
3215	I-35	Cab-1	2024-10-17	6	Etheostoma fonticola	30	1
3215	I-35	Cab-1	2024-10-17	6	Procambarus sp.		2
3215	I-35	Cab-1	2024-10-17	6	Gambusia sp.	16	1
3215	I-35	Cab-1	2024-10-17	6	Gambusia sp.	12	1
3215	I-35	Cab-1	2024-10-17	7	Etheostoma fonticola	35	1
3215	I-35	Cab-1	2024-10-17	7	Etheostoma fonticola	36	1
3215	I-35	Cab-1	2024-10-17	7	Etheostoma fonticola	12	1
3215	I-35	Cab-1	2024-10-17	7	Etheostoma fonticola	14	1
3215	I-35	Cab-1	2024-10-17	7	Procambarus sp.		2
3215	I-35	Cab-1	2024-10-17	8	Procambarus sp.		6
3215	I-35	Cab-1	2024-10-17	8	Etheostoma fonticola	16	1
3215	I-35	Cab-1	2024-10-17	8	Etheostoma fonticola	34	1
3215	I-35	Cab-1	2024-10-17	8	Etheostoma fonticola	18	1

3215	I-35	Cab-1	2024-10-17	8	Etheostoma fonticola	17	1
3215	I-35	Cab-1	2024-10-17	9	Etheostoma fonticola	32	1
3215	I-35	Cab-1	2024-10-17	9	Etheostoma fonticola	20	1
3215	I-35	Cab-1	2024-10-17	9	Etheostoma fonticola	20	1
3215	I-35	Cab-1	2024-10-17	9	Procambarus sp.		1
3215	I-35	Cab-1	2024-10-17	9	Gambusia sp.	11	1
3215	I-35	Cab-1	2024-10-17	10	Procambarus sp.		3
3215	I-35	Cab-1	2024-10-17	10	Etheostoma fonticola	19	1
3215	I-35	Cab-1	2024-10-17	10	Gambusia sp.	15	1
3215	I-35	Cab-1	2024-10-17	11	Procambarus sp.		2
3215	I-35	Cab-1	2024-10-17	12	Lepomis miniatus	65	1
3215	I-35	Cab-1	2024-10-17	12	Etheostoma fonticola	28	1
3215	I-35	Cab-1	2024-10-17	12	Etheostoma fonticola	17	1
3215	I-35	Cab-1	2024-10-17	12	Etheostoma fonticola	10	1
3215	I-35	Cab-1	2024-10-17	12	Procambarus sp.		2
3215	I-35	Cab-1	2024-10-17	13	Procambarus sp.		1
3215	I-35	Cab-1	2024-10-17	13	Etheostoma fonticola	18	1
3215	I-35	Cab-1	2024-10-17	14	Procambarus sp.		1
3215	I-35	Cab-1	2024-10-17	15	Etheostoma fonticola	28	1
3215	I-35	Cab-1	2024-10-17	15	Gambusia sp.	11	1
3215	I-35	Cab-1	2024-10-17	15	Procambarus sp.		1
3215	I-35	Cab-1	2024-10-17	16	No fish collected		
3215	I-35	Cab-1	2024-10-17	1	Etheostoma fonticola	34	1
3215	I-35	Cab-1	2024-10-17	1	Etheostoma fonticola	16	1
3215	I-35	Cab-1	2024-10-17	1	Etheostoma fonticola	17	1
3215	I-35	Cab-1	2024-10-17	1	Etheostoma fonticola	16	1
3215	I-35	Cab-1	2024-10-17	1	Gambusia sp.	19	1
3215	I-35	Cab-1	2024-10-17	1	Gambusia sp.	16	1
3215	I-35	Cab-1	2024-10-17	1	Palaemonetes sp.		1
3215	I-35	Cab-1	2024-10-17	1	Procambarus sp.		6

3215	I-35	Cab-1	2024-10-17	2	Lepomis cyanellus	56	1
3215	I-35	Cab-1	2024-10-17	2	Etheostoma fonticola	32	1
3215	I-35	Cab-1	2024-10-17	2	Etheostoma fonticola	27	1
3215	I-35	Cab-1	2024-10-17	2	Etheostoma fonticola	19	1
3215	I-35	Cab-1	2024-10-17	2	Etheostoma fonticola	16	1
3215	I-35	Cab-1	2024-10-17	2	Etheostoma fonticola	15	1
3215	I-35	Cab-1	2024-10-17	2	Gambusia sp.	17	1
3215	I-35	Cab-1	2024-10-17	2	Gambusia sp.	16	1
3215	I-35	Cab-1	2024-10-17	2	Gambusia sp.	8	1
3215	I-35	Cab-1	2024-10-17	2	Gambusia sp.	12	1
3215	I-35	Cab-1	2024-10-17	2	Gambusia sp.	11	1
3215	I-35	Cab-1	2024-10-17	2	Gambusia sp.	10	1
3215	I-35	Cab-1	2024-10-17	2	Procambarus sp.		3
3215	I-35	Cab-1	2024-10-17	3	Procambarus sp.		2
3215	I-35	Cab-1	2024-10-17	3	Etheostoma fonticola	28	1
3215	I-35	Cab-1	2024-10-17	4	Etheostoma fonticola	33	1
3215	I-35	Cab-1	2024-10-17	4	Etheostoma fonticola	31	1
3215	I-35	Cab-1	2024-10-17	4	Etheostoma fonticola	31	1
3215	I-35	Cab-1	2024-10-17	4	Procambarus sp.		3
3216	I-35	Cab-2	2024-10-17	1	Herichthys cyanoguttatus	35	1
3216	I-35	Cab-2	2024-10-17	1	Herichthys cyanoguttatus	55	1
3216	I-35	Cab-2	2024-10-17	1	Lepomis miniatus	64	1
3216	I-35	Cab-2	2024-10-17	1	Ambloplites rupestris	35	1
3216	I-35	Cab-2	2024-10-17	1	Etheostoma fonticola	36	1
3216	I-35	Cab-2	2024-10-17	1	Etheostoma fonticola	18	1
3216	I-35	Cab-2	2024-10-17	1	Etheostoma fonticola	21	1
3216	I-35	Cab-2	2024-10-17	1	Etheostoma fonticola	30	1
3216	I-35	Cab-2	2024-10-17	1	Etheostoma fonticola	26	1
3216	I-35	Cab-2	2024-10-17	1	Gambusia sp.	15	1
3216	I-35	Cab-2	2024-10-17	1	Gambusia sp.	18	1

3216	I-35	Cab-2	2024-10-17	1	Procambarus sp.		6
3216	I-35	Cab-2	2024-10-17	2	Lepomis miniatus	122	1
3216	I-35	Cab-2	2024-10-17	2	Lepomis miniatus	85	1
3216	I-35	Cab-2	2024-10-17	2	Etheostoma fonticola	31	1
3216	I-35	Cab-2	2024-10-17	2	Etheostoma fonticola	28	1
3216	I-35	Cab-2	2024-10-17	2	Etheostoma fonticola	32	1
3216	I-35	Cab-2	2024-10-17	2	Etheostoma fonticola	18	1
3216	I-35	Cab-2	2024-10-17	2	Etheostoma fonticola	14	1
3216	I-35	Cab-2	2024-10-17	2	Gambusia sp.	10	1
3216	I-35	Cab-2	2024-10-17	2	Procambarus sp.		5
3216	I-35	Cab-2	2024-10-17	3	Procambarus sp.		4
3216	I-35	Cab-2	2024-10-17	3	Etheostoma fonticola	29	1
3216	I-35	Cab-2	2024-10-17	3	Etheostoma fonticola	26	1
3216	I-35	Cab-2	2024-10-17	3	Etheostoma fonticola	21	1
3216	I-35	Cab-2	2024-10-17	3	Etheostoma fonticola	22	1
3216	I-35	Cab-2	2024-10-17	4	Procambarus sp.		6
3216	I-35	Cab-2	2024-10-17	4	Etheostoma fonticola	19	1
3216	I-35	Cab-2	2024-10-17	4	Etheostoma fonticola	34	1
3216	I-35	Cab-2	2024-10-17	4	Etheostoma fonticola	15	1
3216	I-35	Cab-2	2024-10-17	4	Gambusia sp.	17	1
3216	I-35	Cab-2	2024-10-17	5	Procambarus sp.		2
3216	I-35	Cab-2	2024-10-17	5	Gambusia sp.	17	1
3216	I-35	Cab-2	2024-10-17	5	Etheostoma fonticola	35	1
3216	I-35	Cab-2	2024-10-17	5	Etheostoma fonticola	30	1
3216	I-35	Cab-2	2024-10-17	5	Etheostoma fonticola	15	1
3216	I-35	Cab-2	2024-10-17	5	Etheostoma fonticola	18	1
3216	I-35	Cab-2	2024-10-17	6	Procambarus sp.		2
3216	I-35	Cab-2	2024-10-17	6	Lepomis miniatus	34	1
3216	I-35	Cab-2	2024-10-17	6	Etheostoma fonticola	31	1
3216	I-35	Cab-2	2024-10-17	6	Etheostoma fonticola	21	1

3216	I-35	Cab-2	2024-10-17	6	Etheostoma fonticola	29	1
3216	I-35	Cab-2	2024-10-17	6	Gambusia sp.	16	1
3216	I-35	Cab-2	2024-10-17	7	Procambarus sp.		5
3216	I-35	Cab-2	2024-10-17	7	Etheostoma fonticola	23	1
3216	I-35	Cab-2	2024-10-17	7	Etheostoma fonticola	34	1
3216	I-35	Cab-2	2024-10-17	7	Etheostoma fonticola	22	1
3216	I-35	Cab-2	2024-10-17	7	Etheostoma fonticola	33	1
3216	I-35	Cab-2	2024-10-17	8	Lepomis miniatus	52	1
3216	I-35	Cab-2	2024-10-17	8	Etheostoma fonticola	18	1
3216	I-35	Cab-2	2024-10-17	8	Etheostoma fonticola	31	1
3216	I-35	Cab-2	2024-10-17	9	No fish collected		
3216	I-35	Cab-2	2024-10-17	10	Procambarus sp.		2
3216	I-35	Cab-2	2024-10-17	10	Etheostoma fonticola	19	1
3216	I-35	Cab-2	2024-10-17	11	Etheostoma fonticola	18	1
3216	I-35	Cab-2	2024-10-17	11	Procambarus sp.		1
3216	I-35	Cab-2	2024-10-17	12	No fish collected		
3216	I-35	Cab-2	2024-10-17	13	Lepomis miniatus	105	1
3216	I-35	Cab-2	2024-10-17	13	Lepomis miniatus	124	1
3216	I-35	Cab-2	2024-10-17	13	Procambarus sp.		3
3216	I-35	Cab-2	2024-10-17	14	Procambarus sp.		1
3216	I-35	Cab-2	2024-10-17	15	Procambarus sp.		2
3216	I-35	Cab-2	2024-10-17	15	Etheostoma fonticola	35	1
3216	I-35	Cab-2	2024-10-17	15	Etheostoma fonticola	29	1
3216	I-35	Cab-2	2024-10-17	15	Etheostoma fonticola	18	1
3216	I-35	Cab-2	2024-10-17	15	Etheostoma fonticola	35	1
3216	I-35	Cab-2	2024-10-17	15	Etheostoma fonticola	21	1
3216	I-35	Cab-2	2024-10-17	15	Etheostoma fonticola	19	1
3216	I-35	Cab-2	2024-10-17	16	Procambarus sp.		4
3217	I-35	Lud-1	2024-10-17	1	Hypostomus plecostomus	18	1
3217	I-35	Lud-1	2024-10-17	1	Gambusia sp.	25	1

3217	I-35	Lud-1	2024-10-17	1	Gambusia sp.	20	1
3217	I-35	Lud-1	2024-10-17	1	Gambusia sp.	20	1
3217	I-35	Lud-1	2024-10-17	1	Gambusia sp.	10	1
3217	I-35	Lud-1	2024-10-17	1	Gambusia sp.	20	1
3217	I-35	Lud-1	2024-10-17	1	Gambusia sp.	10	1
3217	I-35	Lud-1	2024-10-17	1	Gambusia sp.	9	1
3217	I-35	Lud-1	2024-10-17	1	Procambarus sp.		3
3217	I-35	Lud-1	2024-10-17	2	Etheostoma fonticola	31	1
3217	I-35	Lud-1	2024-10-17	2	Procambarus sp.		1
3217	I-35	Lud-1	2024-10-17	2	Gambusia sp.	10	1
3217	I-35	Lud-1	2024-10-17	3	Etheostoma fonticola	28	1
3217	I-35	Lud-1	2024-10-17	3	Etheostoma fonticola	31	1
3217	I-35	Lud-1	2024-10-17	3	Etheostoma fonticola	37	1
3217	I-35	Lud-1	2024-10-17	3	Procambarus sp.		2
3217	I-35	Lud-1	2024-10-17	3	Herichthys cyanoguttatus	28	1
3217	I-35	Lud-1	2024-10-17	4	No fish collected		
3217	I-35	Lud-1	2024-10-17	5	Procambarus sp.		2
3217	I-35	Lud-1	2024-10-17	6	No fish collected		
3217	I-35	Lud-1	2024-10-17	7	Procambarus sp.		1
3217	I-35	Lud-1	2024-10-17	8	No fish collected		
3217	I-35	Lud-1	2024-10-17	9	Etheostoma fonticola	15	1
3217	I-35	Lud-1	2024-10-17	9	Procambarus sp.		1
3217	I-35	Lud-1	2024-10-17	10	Ameiurus natalis	50	1
3217	I-35	Lud-1	2024-10-17	11	Procambarus sp.		1
3217	I-35	Lud-1	2024-10-17	12	No fish collected		
3217	I-35	Lud-1	2024-10-17	13	Procambarus sp.		1
3217	I-35	Lud-1	2024-10-17	14	No fish collected		
3217	I-35	Lud-1	2024-10-17	15	No fish collected		
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	48	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	50	1

3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	51	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	45	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	55	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	37	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	50	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	45	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	45	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	45	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	54	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	28	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	36	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	40	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	32	1
3218	I-35	Hydro-1	2024-10-17	1	Notropis amabilis	40	1
3218	I-35	Hydro-1	2024-10-17	2	Notropis amabilis	40	1
3218	I-35	Hydro-1	2024-10-17	2	Notropis amabilis	50	1
3218	I-35	Hydro-1	2024-10-17	2	Notropis amabilis	32	1
3218	I-35	Hydro-1	2024-10-17	2	Notropis amabilis	35	1
3218	I-35	Hydro-1	2024-10-17	2	Notropis amabilis	35	1
3218	I-35	Hydro-1	2024-10-17	2	Notropis amabilis	40	1
3218	I-35	Hydro-1	2024-10-17	2	Notropis amabilis	41	1
3218	I-35	Hydro-1	2024-10-17	2	Etheostoma fonticola	31	1
3218	I-35	Hydro-1	2024-10-17	2	Procambarus sp.		1
3218	I-35	Hydro-1	2024-10-17	3	Notropis amabilis	33	1
3218	I-35	Hydro-1	2024-10-17	4	Procambarus sp.		1
3218	I-35	Hydro-1	2024-10-17	5	No fish collected		
3218	I-35	Hydro-1	2024-10-17	6	Procambarus sp.		2
3218	I-35	Hydro-1	2024-10-17	7	Procambarus sp.		1
3218	I-35	Hydro-1	2024-10-17	7	Notropis amabilis		1
3218	I-35	Hydro-1	2024-10-17	8	No fish collected		

3218	I-35	Hydro-1	2024-10-17	9	No fish collected		
3218	I-35	Hydro-1	2024-10-17	10	Notropis amabilis		1
3218	I-35	Hydro-1	2024-10-17	11	Procambarus sp.		1
3218	I-35	Hydro-1	2024-10-17	12	No fish collected		
3218	I-35	Hydro-1	2024-10-17	13	No fish collected		
3218	I-35	Hydro-1	2024-10-17	14	Procambarus sp.		2
3218	I-35	Hydro-1	2024-10-17	15	No fish collected		
3219	I-35	Lud-2	2024-10-17	1	Ambloplites rupestris	69	1
3219	I-35	Lud-2	2024-10-17	1	Gambusia sp.	15	1
3219	I-35	Lud-2	2024-10-17	1	Gambusia sp.	22	1
3219	I-35	Lud-2	2024-10-17	1	Gambusia sp.	14	1
3219	I-35	Lud-2	2024-10-17	1	Gambusia sp.	10	1
3219	I-35	Lud-2	2024-10-17	1	Gambusia sp.	15	1
3219	I-35	Lud-2	2024-10-17	1	Gambusia sp.	10	1
3219	I-35	Lud-2	2024-10-17	1	Gambusia sp.	10	1
3219	I-35	Lud-2	2024-10-17	1	Procambarus sp.		8
3219	I-35	Lud-2	2024-10-17	2	Procambarus sp.		7
3219	I-35	Lud-2	2024-10-17	2	Gambusia sp.	24	1
3219	I-35	Lud-2	2024-10-17	2	Gambusia sp.	15	1
3219	I-35	Lud-2	2024-10-17	2	Gambusia sp.	15	1
3219	I-35	Lud-2	2024-10-17	3	Procambarus sp.		3
3219	I-35	Lud-2	2024-10-17	4	Procambarus sp.		17
3219	I-35	Lud-2	2024-10-17	4	Etheostoma fonticola	32	1
3219	I-35	Lud-2	2024-10-17	4	Gambusia sp.	10	1
3219	I-35	Lud-2	2024-10-17	5	Procambarus sp.		3
3219	I-35	Lud-2	2024-10-17	5	Etheostoma fonticola	30	1
3219	I-35	Lud-2	2024-10-17	5	Gambusia sp.	10	1
3219	I-35	Lud-2	2024-10-17	6	Etheostoma fonticola	35	1
3219	I-35	Lud-2	2024-10-17	6	Etheostoma fonticola	36	1
3219	I-35	Lud-2	2024-10-17	6	Procambarus sp.		4

3219	I-35	Lud-2	2024-10-17	7	No fish collected		
3219	I-35	Lud-2	2024-10-17	8	Procambarus sp.		2
3219	I-35	Lud-2	2024-10-17	9	No fish collected		
3219	I-35	Lud-2	2024-10-17	10	Procambarus sp.		4
3219	I-35	Lud-2	2024-10-17	11	No fish collected		
3219	I-35	Lud-2	2024-10-17	12	Procambarus sp.		1
3219	I-35	Lud-2	2024-10-17	13	No fish collected		
3219	I-35	Lud-2	2024-10-17	14	Procambarus sp.		9
3219	I-35	Lud-2	2024-10-17	15	No fish collected		
3220	I-35	Hydro-2	2024-10-17	1	Procambarus sp.		2
3220	I-35	Hydro-2	2024-10-17	2	Etheostoma fonticola	34	1
3220	I-35	Hydro-2	2024-10-17	2	Procambarus sp.		1
3220	I-35	Hydro-2	2024-10-17	3	Gambusia sp.	25	1
3220	I-35	Hydro-2	2024-10-17	3	Etheostoma fonticola	25	1
3220	I-35	Hydro-2	2024-10-17	3	Procambarus sp.		1
3220	I-35	Hydro-2	2024-10-17	4	Procambarus sp.		1
3220	I-35	Hydro-2	2024-10-17	5	Procambarus sp.		1
3220	I-35	Hydro-2	2024-10-17	5	Hypostomus plecostomus	21	1
3220	I-35	Hydro-2	2024-10-17	6	Procambarus sp.		1
3220	I-35	Hydro-2	2024-10-17	7	No fish collected		
3220	I-35	Hydro-2	2024-10-17	8	Procambarus sp.		1
3220	I-35	Hydro-2	2024-10-17	9	Etheostoma fonticola	28	1
3220	I-35	Hydro-2	2024-10-17	10	No fish collected		
3220	I-35	Hydro-2	2024-10-17	11	Procambarus sp.		1
3220	I-35	Hydro-2	2024-10-17	12	No fish collected		
3220	I-35	Hydro-2	2024-10-17	13	Procambarus sp.		1
3220	I-35	Hydro-2	2024-10-17	14	Etheostoma fonticola	33	1
3220	I-35	Hydro-2	2024-10-17	14	Procambarus sp.		1
3220	I-35	Hydro-2	2024-10-17	15	No fish collected		
3204	Spring Lake Dam	Hydro-2	2024-10-15	1	Etheostoma fonticola	30	1

3204	Spring Lake Dam	Hydro-2	2024-10-15	1	Gambusia sp.	20	1
3204	Spring Lake Dam	Hydro-2	2024-10-15	2	Etheostoma fonticola	33	1
3204	Spring Lake Dam	Hydro-2	2024-10-15	2	Etheostoma fonticola	32	1
3204	Spring Lake Dam	Hydro-2	2024-10-15	2	Procambarus sp.		1
3204	Spring Lake Dam	Hydro-2	2024-10-15	3	Etheostoma fonticola	31	1
3204	Spring Lake Dam	Hydro-2	2024-10-15	3	Procambarus sp.		1
3204	Spring Lake Dam	Hydro-2	2024-10-15	4	Etheostoma fonticola	29	1
3204	Spring Lake Dam	Hydro-2	2024-10-15	5	No fish collected		
3204	Spring Lake Dam	Hydro-2	2024-10-15	6	Procambarus sp.		2
3204	Spring Lake Dam	Hydro-2	2024-10-15	7	No fish collected		
3204	Spring Lake Dam	Hydro-2	2024-10-15	8	No fish collected		
3204	Spring Lake Dam	Hydro-2	2024-10-15	9	Etheostoma fonticola	33	1
3204	Spring Lake Dam	Hydro-2	2024-10-15	10	No fish collected		
3204	Spring Lake Dam	Hydro-2	2024-10-15	11	Etheostoma fonticola	40	1
3204	Spring Lake Dam	Hydro-2	2024-10-15	12	Procambarus sp.		1
3204	Spring Lake Dam	Hydro-2	2024-10-15	13	No fish collected		
3204	Spring Lake Dam	Hydro-2	2024-10-15	14	No fish collected		
3204	Spring Lake Dam	Hydro-2	2024-10-15	15	No fish collected		
3205	City Park	Open-1	2024-10-16	1	No fish collected		
3205	City Park	Open-1	2024-10-16	2	No fish collected		
3205	City Park	Open-1	2024-10-16	3	No fish collected		
3205	City Park	Open-1	2024-10-16	4	No fish collected		
3205	City Park	Open-1	2024-10-16	5	No fish collected		
3205	City Park	Open-1	2024-10-16	6	No fish collected		
3205	City Park	Open-1	2024-10-16	7	No fish collected		
3205	City Park	Open-1	2024-10-16	8	No fish collected		
3205	City Park	Open-1	2024-10-16	9	No fish collected		
3205	City Park	Open-1	2024-10-16	10	No fish collected		

APPENDIX G: FOUNTAIN DARTER HABITAT SUITABILITY ANALYTICAL FRAMEWORK

OBJECTIVES

The goal of this analysis was to develop an index to quantify Fountain Darter habitat suitability within biological monitoring study reaches based on aquatic vegetation composition. Specific objectives included: (1) build Habitat Suitability Criteria (HSC) for each vegetation taxa; (2) use HSC to calculate an Overall Habitat Suitability Index (OHSI) based on vegetation community composition mapped at a given study reach during each monitoring event; (3) evaluate the efficacy of OHSI as a measure of Fountain Darter habitat suitability by testing whether Fountain Darter occurrence can be predicted based on OHSI.

METHODS

Habitat Suitability Criteria

HSC are a form of resource selection function (RSF) defined as any function that is proportional to the probability of use by an organism (Manly et al. 1993). HSC were built separately for the Comal and San Marcos river/springs systems using logistic regression based on random-station dip-net data and drop-net data converted to presence/absence. Logistic regression is a form of classification model that uses presence/absence data to predict probabilities based on a set of covariates (Hastie et al. 2009). The response variable for this analysis, probability of darter occurrence, was used to quantify criteria for each vegetation type, ranging from 0 (i.e., not suitable) to 1 (i.e., most suitable) (Figure G1).

OHSI Calculation

To calculate the OHSI for each monitoring event, HSC values for each vegetation strata were first multiplied by the areal coverage of that vegetation strata, and these values were summed across all vegetation strata within each study reach, to generate a Weighted Usable Area (WUA) of vegetation only as follows:

Eq. 1
$$WUA = \sum_{i=1}^{N}(A_i \ x \ HSC_i)$$

where N is the total number of vegetation types, A_i is the areal coverage of a single vegetation type, and HSC_i is the habitat suitability criteria of that single vegetation type (Yao & Bamal 2014).

This WUA was then divided by the total wetted area within the reach to generate OHSI, as follows:

Eq. 2
$$OHSI = \frac{WUA}{\sum_{i=1}^{N}(A_i)}$$

In this way, OHSI can also be thought of as the proportion of weighted usable area (Yao & Bamal 2014), ranging from 0 (unsuitable overall habitat) to 1 (most suitable overall habitat). Standardizing by reach size allows for a comparison of habitat quality between reaches of different sizes.

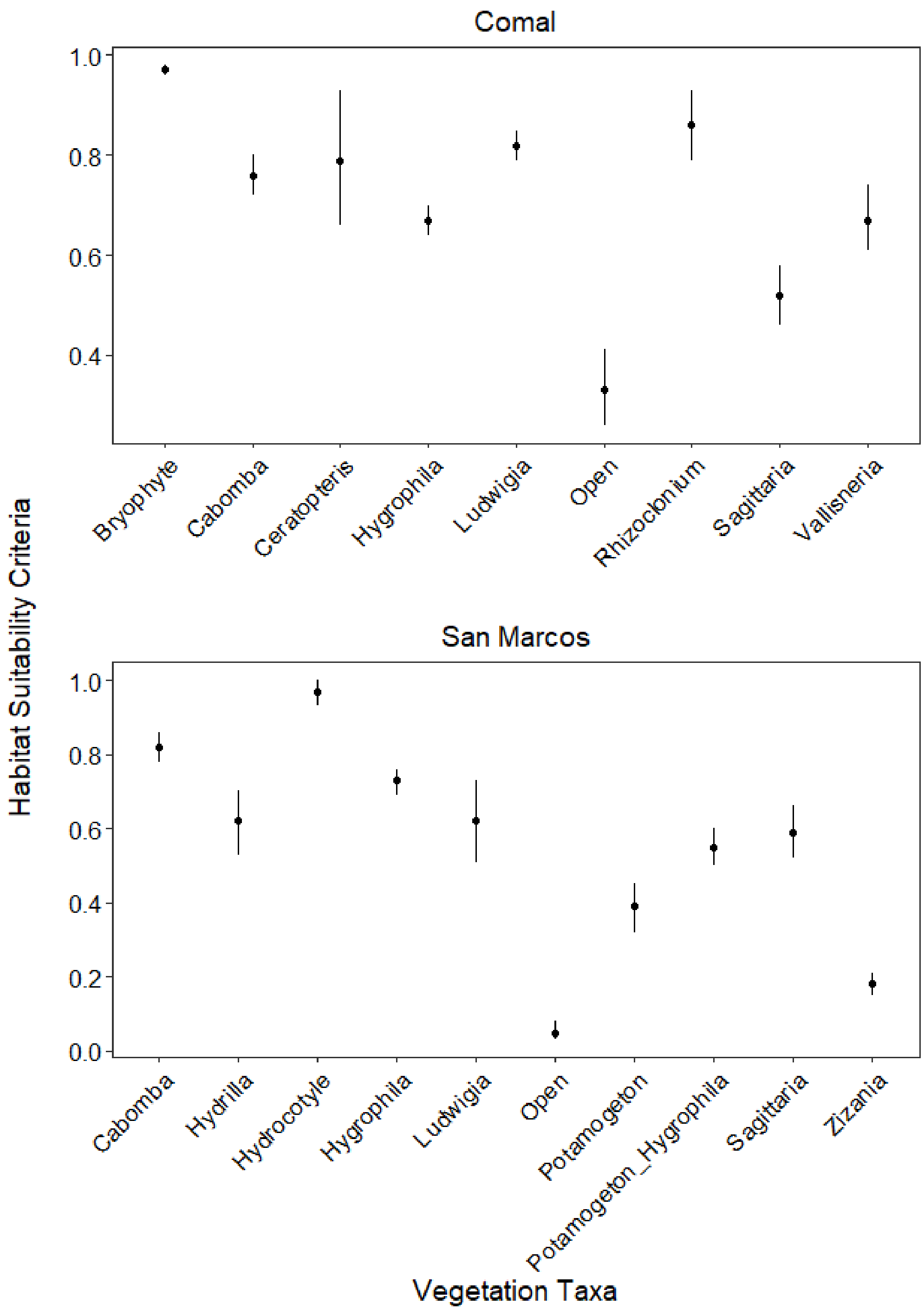

Figure H1. **Aquatic vegetation habitat suitability criteria (±95% CI) built with drop-net and random dip-net datasets using logistic regression.**

OHSI Evaluation

OHSI Evaluation Methods

To examine the relationship between OHSI and Fountain Darter population metrics, random-station dip-net data from 2017-2020 was organized in a way that treats each monitoring event per study reach as independent. This results in the response variable quantified as the proportional occurrence of Fountain Darters per reach at a given monitoring event based on the independent variable OHSI.

To predict Fountain Darter occurrence, two modeling approaches that are able to analyze proportions were used, which included: (1) GLM with a binomial distribution and (2) Random Forest Regression (RF). RF is an ensemble learning technique that builds many decision trees to predict a response variable (Breiman et al. 1984). Each decision tree of the "forest" is built by selecting a random subset of the dataset with replacement and a random set of covariates (Liaw & Wiener 2002). RF are considered more advantageous compared to traditional decision tree models and GLM because they correct for overfitting (Breiman 2001) and can provide more accurate predictions with many covariates (Cutler et al. 2007). For this analysis, we built RF models with 500 trees.

GLMs and RFs were built separately for the Comal and San Marcos systems. First, 50% of each dataset was randomly selected to train each model. Second, 5-fold cross validation (CV) was used to independently test the predictive performance of each model with the remaining 50% of the dataset (i.e., test data). Predictive performance was compared among models based on the correlation (R) and deviance (D) between observed and predicted values. Mean CV R ± standard error (SE) and CV D ± SE were calculated based on predictions from the 5 CV folds. Models with the highest CV R were considered as the best models for making predictions and elaborated on further in the results.

Lastly, figures were built to display fitted predictions across observed OHSI values to examine if there was a positive relationship between Fountain Darter occurrence and OHSI. Fitted predictions were also presented with a LOWESS smoothed function to visualize if trends of OHSI are linear or nonlinear (Milborrow 2020). In sum, if the models displayed strong predictive power and Fountain Darter occurrence showed a positive relationship with OHSI, then OHSI was considered a useful measurement of habitat suitability for Fountain Darters.

OHSI Evaluation Results

Predictive performance for the Comal models showed that RF (0.81 ± 0.18) predictions were more accurate than GLM (0.62 ± 0.20). San Marcos models were similar, showing better predictive accuracy for RF (0.97 ± 0.02) compared to GLM (0.93 ± 0.06) (Table G1). Comparisons between observed vs. predicted occurrence for the RF 5-fold CV demonstrated lowest predictive accuracy at observed proportions about 0.20 or less for the Comal and San Marcos (Figure G2).

Fitted predictions of occurrence as a function of OHSI showed that occurrence increased with increasing OHSI for the Comal and San Marcos. In the Comal, LOWESS smoothed predictions exhibited a non-linear asymptotic trend. Occurrence increased about 0.60 to 0.80 when OHSI increased from about 0.65 to 0.75 and remained around 0.80 at OHSI values >0.75. In the San Marcos, LOWESS smoothed predictions exhibited a more linear trend compared to the Comal and occurrence increased from about 0.25 to 0.55 as OHSI increased from 0.25 to 0.60 (Figure G3).

Table H1. Summary model performance statistics for predicting Fountain Darter occurrence based on OHSI. Summary statistics includes deviance (D) and correlation (R) for training data and 5-fold cross-validation (SE).

	Comal		San Marcos	
	GLM	RF	GLM	RF
Training Data				
Deviance	1.10	1.03	1.23	1.20
Correlation	0.48	0.77	0.70	0.89
Cross-Validation				
Deviance	1.12 (0.05)	1.05 (0.06)	1.24 (0.07)	1.21 (0.05)
Correlation	0.62 (0.20)	0.81 (0.18)	0.93 (0.06)	0.97 (0.02)

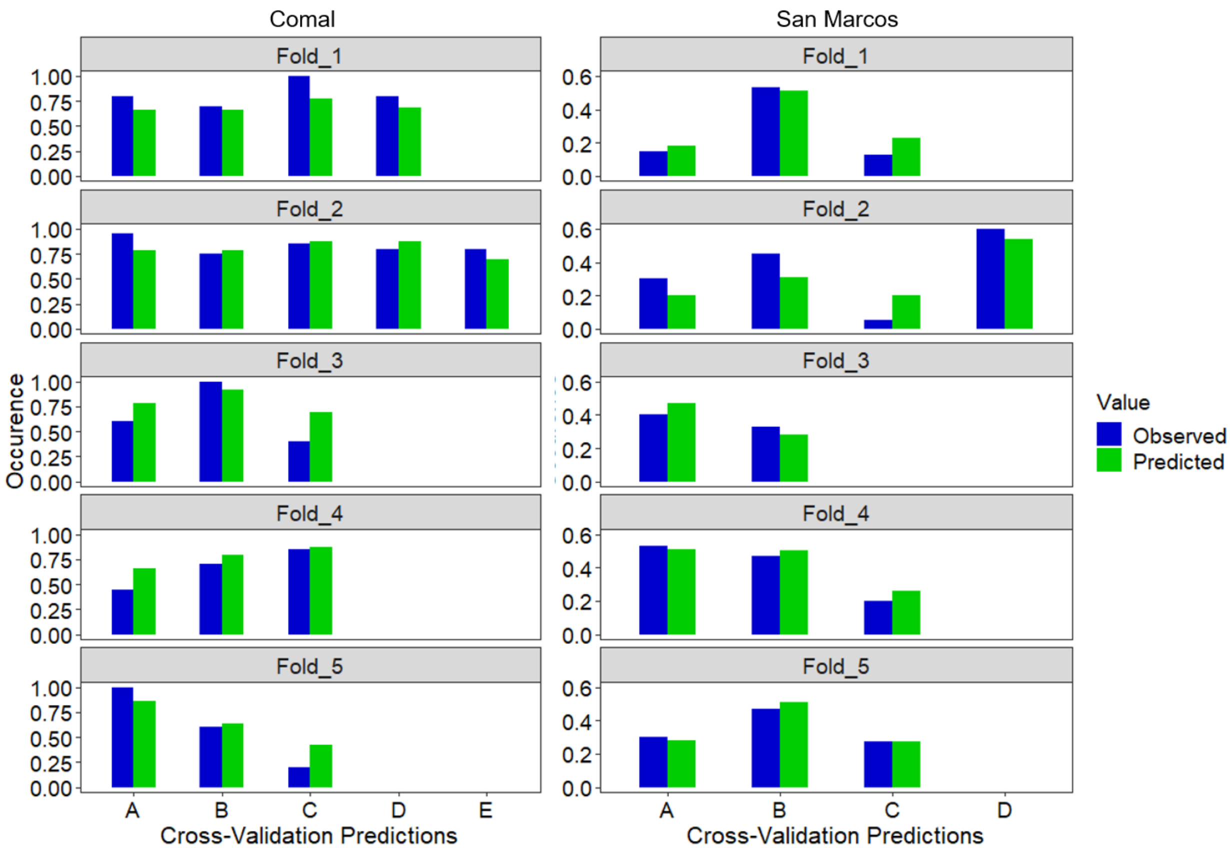

Figure H2. Observed vs. predicted Fountain Darter occurrence in relationship to OHSI from Random Forest 5-fold cross-validation.

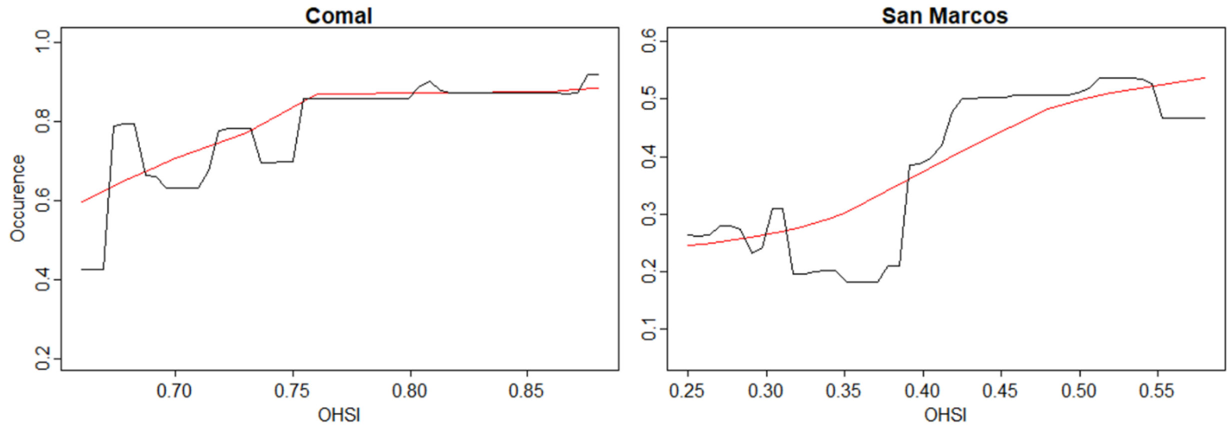

Figure H3. Fitted occurrence predictions for OHSI in the Comal Springs/River and San Marcos River. The red lines are LOWESS smoothed fitted predictions used to visualize nonlinear trends.

OHSI EVALUATION DISCUSSION

Model CV R >0.80 for all RFs demonstrate good model performance and that Fountain Darter occurrence can be accurately predicted based on OHSI. Further, similar performance statistics for training data and test data via cross-validation indicated that the training models were not overfit and can reliably predict independent observations in the future. That being said, predictions were least accurate at observed occurrence values about 0.20 or less, which is likely due to smaller sample sizes in this range. As random station dip-net sampling continues during future biomonitoring activities, predictions at these lower occurrence values will likely improve. Fountain Darter occurrence also increased with increasing OHSI. The positive relationship between occurrence and OHSI and good model performance supports that OHSI is an ecologically relevant index for evaluating Fountain Darter habitat suitability based on vegetation community composition.

In sum, this analysis demonstrated that OHSI based on vegetation-specific HSC and reach-level vegetation composition data can accurately predict Fountain Darter occurrence and is a useful measurement for quantifying habitat suitability. However, additional data collection can assist in addressing multiple limitations of this analysis. Firstly, random station dip-net data with simple random sampling is only available from about 2017-2020, which limits the ability to predict occurrence from historical observations. Further, model performance would likely improve at lower occurrence values as additional data are collected and a more robust dataset is generated. Secondly, this analysis assumed that vegetation alone determines Fountain Darter occurrence. For example, decreased predictive accuracy at lower darter occurrence values may be due to other habitat factors (e.g., depth-flow conditions, river discharge) or biotic factors (e.g., competition, predation) rather than due to smaller sample sizes of lower occurrence values; however, a multi-factor ecological model is beyond the scope of this work. In addition, OHSI can only be assessed for vegetation taxa that have been sampled previously and building HSC for rare vegetation taxa not represented may improve predictions. That being said, RF models demonstrated that occurrence can be predicted accurately without including additional habitat variables or vegetation types, supporting that this assumption does not hinder this analysis and does not appear to restrict the inference value of OHSI.

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Appendix F5 | **Permit Renewal Work Plan**

EAHCP Work Plan Versioning Table		
Version #	Date	Summary of Changes
1.0	07/19/2022	First draft
2.0	1/24/2023	Updated Figure 2-1 (org chart) and Figure 4-1 (project schedule). Revisions to address EAHCP staff comments.
3.0	4/26/2023	Updated Figure 2-1 and removed Subtask 5.4, Foreseeable Future and Climate Vulnerability Assessment. Analyses regarding the foreseeable future (e.g., future groundwater pumping projections) and climate conditions (e.g., temperature, precipitation) will be conducted as part of Task 6, Modeling Projections.
4.0	3/11/2024	Updates to Figure 2-1 and the list of deliverables under Task 5, including revisions to Table 3-2. Revised Task 6, including updating description to note that EAA Aquifer Science team will be conducting modeling and combining Recharge, Pumping, and MODFLOW tasks into Task 6.2.

Work Plan

Permit Renewal for the Edwards Aquifer Habitat Conservation Plan

Prepared for:

Edwards Aquifer Authority

Prepared by:

ICF

March 2024

Contents

Tables and Figures

Chapter 1
Introduction

1.1 Program Overview

In 1996, the Texas Legislature passed the Edwards Aquifer Authority Act, which created the Edwards Aquifer Authority (EAA) to regulate pumping from the aquifer and pursue a program "to ensure that the continuous minimum springflows of the Comal Springs and the San Marcos Springs are maintained to protect endangered and threatened species to the extent required by federal law" (EAA Act § 1.14). The Texas Legislature amended the EAA Act in 2007 to form the Edwards Aquifer Recovery Implementation Program (EARIP) and directed the EARIP to work with the U.S. Fish and Wildlife Service (USFWS) to prepare the *Edwards Aquifer Recovery Implementation Program Habitat Conservation Plan* (EAHCP or Plan). The EARIP process, including years of negotiations among the eventual Permittees and with many stakeholders, led to the completion of the EAHCP in 2013.

The EAHCP has been highly effective in conserving the Covered Species and the ecosystems on which they depend. Activities covered include groundwater pumping from the Edwards Aquifer, surface water management, aquatic and riparian habitat management, and recreational use in the aboveground springs fed by the aquifer in the Cities of New Braunfels and San Marcos. Its implementation has greatly expanded what is understood about the life histories of many of its Covered Species. The EAHCP's committees—formed during the EARIP process—have also demonstrated the ability to use the Plan's adaptive management process to make necessary and important changes to Conservation Measures to improve their overall feasibility and effectiveness.

The EAHCP has a relatively short permit term (15 years), expiring on March 31, 2028. The Permittees are now looking ahead to the end of the permit term and are proceeding with an Incidental Take Permit (ITP) renewal process to continue the program beyond 2028. The primary goal of this renewal process is extending the duration of ITP, but in the process the Permittees will also look to improve the EAHCP to set the stage for its long-term success.

There are three comprehensive goals for the permit renewal of the EAHCP. These goals pertain to the renewal process, renewed permit, and implementation and are as follows:

1. Renewal Process: To have an efficient and transparent permit renewal process that considers stakeholder input and results in an ITP renewal prior to the expiration of the current permit in 2028.
2. Renewed Permit: Renew the permit in ways that will continue to set up the plan for long-term success by reinforcing the plan's many accomplishments and adjusting what has not worked well.
3. Implementation: Enhance the flexibility and clarity of the plan to make implementation easier, more efficient, and more cost-effective for the long term.

The EAA began identifying potential changes to the EAHCP through the Permit Options Report, which ICF completed in 2020. Potential changes identified to be considered by the Permittees included the following:

- Add Covered Species or Covered Activities.
- Restructure biological goals and objectives for listed Covered Species and add biological goals and objectives for unlisted Covered Species.
- Adjust Conservation Measures and monitoring to improve implementation and effectiveness tracking.
- Separate the EAHCP and the Funding and Management Agreement.
- Simplify processes for administrative and adaptive management changes.
- Evaluate the potential effects of climate change and extend the duration of the ITP well beyond 2028.

Many of these changes would require an amendment to the EAHCP, which will be part of the ITP renewal process. This amendment would require National Environmental Policy Act (NEPA) review by the USFWS through an environmental assessment (EA) or environmental impact statement (EIS). The program under which these efforts will be completed is termed the *Permit Renewal for the Edwards Aquifer Habitat Conservation Plan* (PREAHCP).

1.2 Work Plan Overview

This document will guide the work to be conducted as part of the PREAHCP. It covers the following:

- **Team Organization and Communication.** Identifies team members and roles and specifies communication protocols.
- **Tasks and Quality Control.** Describes each task to be conducted as part of the PREAHCP, including deliverables and assumptions, and summarizes ICF’s process for quality control.
- **Schedule.** Outlines the phases of the PREAHCP, based on a detailed project schedule.
- **Amended EAHCP Outline.** Summarizes the organization of the Amended EAHCP.

This work plan is intended to be flexible to respond to new issues and will be modified upon agreement with EAHCP staff.

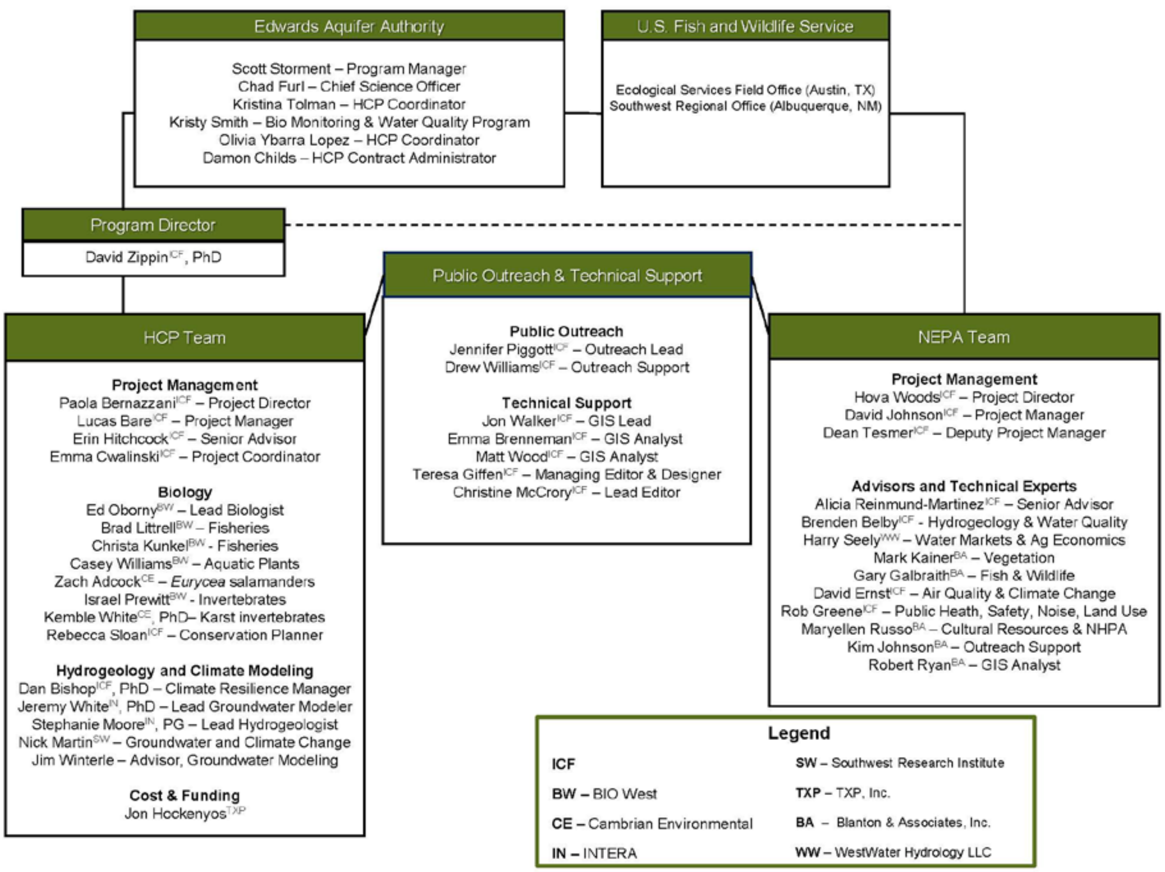
Chapter 2
Team Organization and Communication

Effective organization and communication will be key to the success of the PREAHCP. Shared understanding of roles and responsibilities and clear communication throughout the life of the project will be critical to completing project deliverables on schedule and within budget. The following sections describe the team's organization and communication protocols.

2.1 Team Organization

Figure 2-1 illustrates the PREAHCP team organization, including EAHCP staff, the HCP team, and the NEPA team. EAHCP staff will direct the work of the HCP team. The U.S. Fish and Wildlife Service (USFWS) will direct the work of the NEPA team. ICF's program director serves as the connection between the HCP team and the NEPA team for contract and management purposes.

Figure 2-1. Organizational Chart



2.2 Communication

A detailed list of all staff, roles, and contact information will be housed in the project's document library accessible to the EAHCP staff and HCP team and provided by ICF upon request.

The HCP team will communicate directly with EAHCP staff, while the NEPA team will communicate directly with USFWS and with EAHCP staff and the HCP team as authorized by USFWS. Regularly scheduled meetings will serve as a primary communication means for the PREAHCP. HCP team meetings are described below in Section 3.2, Task 2: Meetings. NEPA team meetings are described under the respective NEPA tasks in Sections 3.8, 3.10, 3.11, and 3.13.

Below is a list of communication best practices that will ensure appropriate information is being communicated to the right parties:

- **Include the ICF, HCP or NEPA project manager and on all communications**. The relevant project manager should be copied on every message related to the project to facilitate progress tracking, resolution of issues, and escalation of concerns as needed.
- **Precede email subject lines with "PREAHCP**." Email communication will have in the subject line "PREAHCP – [email subject]" in order to easily identify communication for this project.
- **Keep decision makers informed**. Identifying and keeping the appropriate decision-making authorities informed throughout the project duration will be critical to its success.
- **Maintain action item list**. ICF will track action items and will read them at the end of each meeting to establish and confirm common understanding of responsibilities and expectations.
- **Communicate meeting objectives**. Prior to beginning meetings, ICF and EAA should clearly state the objectives for each meeting and the end-goal, so participants have a common understanding of what needs to be achieved.
- **Coordinate in advance on deliverables**. Prior to starting work on each deliverable, ICF will coordinate with EAA regarding the outline, content, and format to ensure common understanding of the work product and establish expectations. When submitting each deliverable, ICF will provide written directions to reviewers about how they should comment (see Section 3.14, "Quality Control," for more procedures related to deliverables).
- **GIS**. EAA and ICF will agree to an approach to delivery and sharing of PREAHCP GIS data and maps between EAA and the HCP team.
- **External stakeholder engagement**. EAHCP staff will be responsible for all external written communication, including with EAHCP committees, the public, and the USFWS. The HCP team will conduct external communication only as directed by EAHCP staff.

2.3 SharePoint

Microsoft SharePoint will be used to store and share all project files. ICF will maintain the SharePoint site. ICF will establish separate document libraries to organize files and administer appropriate permissions to share files with various users. Master project files, including working versions of all documents, should be stored on the project SharePoint site at all times to avoid version control issues. If master documents are to be downloaded and "checked out" of SharePoint the user must notify the ICF Project Manager. The following are best practices when using SharePoint:

- Do NOT "check out" the document. This will prevent others from simultaneously editing and will create version control issues.
- Use current version of Microsoft Word when possible and always save as a .docx.
- Click on the link and enable the edit function (open in the traditional MS Word software and NOT the web app).
- Activate track changes.
- Use “AutoSave” or save frequently when editing in SharePoint, and always save and exit the document when you leave your computer (even for a brief break).
- If you see sections where others are reviewing, SharePoint will prevent two reviewers from editing the same paragraph at any one time. Return to these sections later or communicate with the other reviewer to discuss.
- Do not accept track changes when multiple users are in the file.
- Do not attempt major formatting for the document.
- Do not make any changes to the entire text (i.e., changing the font using CTRL+A).
- Do not do a global Find and Replace.
- Co-authoring works best where there are at most five people in the document at a given time.

Chapter 3
Tasks and Quality Control

Below are the tasks to be performed under the PREAHCP effort. ICF will work with the EAHCP staff to avoid unnecessary delays in the project due to requested changes, and ICF will not perform work outside the current contract scope of work without written authorization from EAA.

3.1 Task 1: Program Management

3.1.1 Task Description

ICF will be responsible for managing all ICF staff and subcontractor staff in the execution of the scope of work over the period of performance. ICF will manage different teams for development of the HCP and NEPA documents and will provide technical expertise to perform studies to renew the ITP. The HCP will be developed for the ITP Permittees, and the NEPA document will be developed for the USFWS.

ICF will draft a project work plan and schedule to complete the Amended HCP to discuss at the kickoff meeting (Task 2). We will update the project work plan and schedule as needed through the period of performance to complete the ITP renewal process. The work plan will address the preparation of the NEPA documents generally, acknowledging that more specific planning will be conducted in coordination with the USFWS at the appropriate time, as part of Task 8. ICF will also set up an electronic file sharing site to be maintained and updated through the period of performance.

ICF will create, manage, and distribute any necessary templates in Microsoft Word and PowerPoint and will maintain a list of terms and abbreviations to ensure consistency across all contract deliverables. ICF will also develop an ITP renewal process logo for branding purposes. Templates, the logo, and list of terms and abbreviations will be used for all contract deliverables by the HCP team.

The ICF program director, David, will oversee the HCP and NEPA project directors, Paola and Hova, respectively. The program and project directors will be responsible for setting the tone and approach for the program, guiding the schedule and technical analyses, troubleshooting difficult stakeholder and technical issues, and performing senior review. The project managers, supported by HCP and NEPA deputy project managers, respectively, will oversee authors and technical analyses, be responsible for managing the deliverable and meeting schedule, perform senior review, and serve as the point of contact for EAA, including for invoicing and contractual purposes.

3.1.2 Deliverables

- Draft work plan
- Updated work plan as needed
- Draft schedule

- Updated schedule as needed
- Draft electronic file sharing site
- Updated electronic file sharing site as needed
- Draft Microsoft Word templates
- Standard PowerPoint style incorporating PREAHCP logo for presentations
- Second draft Microsoft Word and PowerPoint templates
- Final Microsoft Word and PowerPoint templates
- Draft PREAHCP logo
- Second draft PREAHCP logo
- Final PREAHCP logo
- List of terms and abbreviations
- Updated list of terms and abbreviations as needed
- Monthly invoices

3.1.3 Assumptions

- SharePoint will be used for all document storage/sharing.
- Microsoft Project will be used to create and maintain a detailed project schedule.
- ICF will update the work plan, schedule, and list of terms and abbreviations periodically throughout the life of the project as needed.

3.2 Task 2: Meetings

3.2.1 Task Description

Meetings are the framework within which important decisions will be made throughout the permit renewal process. The management approach and meeting breakdown described in this section will support work under all HCP tasks. NEPA meeting tasks are described under Tasks 8, 10, 11, and 13.

The following components outline the HCP team's plan for conducting meetings.

- **Regularly scheduled meetings**. We will use regularly scheduled or standing meetings whenever possible.
- **Attendees**. The HCP project manager and HCP deputy project manager will plan to attend all coordination meetings for continuity. Additional HCP team staff will attend meetings on an as-needed basis depending on active project tasks and necessary technical or strategic expertise, determined in coordination with EAHCP staff.
- **Agendas and agenda management.** The HCP team will propose an agenda prior to each coordination meeting. Having an agenda for each meeting is key to ensuring that meetings

achieve their intended objectives and that all topics needing discussion and decisions are addressed.

- **Screen sharing**. Screen sharing during meetings is a valuable tool to bolster engagement and understanding of issues being discussed and to facilitate reaching consensus efficiently. Sharing notes and tasks on screen ensures they are correct and limits the need for post-meeting corrections.
- **Review material**. The HCP team will distribute review material to be discussed in meetings in advance of the meeting when feasible.
- **Notes, decisions, and action items**. The HCP team will distribute notes after each meeting. Distributing notes post-meeting ensures everyone on the team concurs with the meeting outcome. ICF will track key decisions and action items for ease of reference. These tools capture the evolution of the project and can be particularly important on longer projects where there may be staff turnover. Assigning action items to individuals or organizations, providing due dates, and then following up with reminders are all tactics the HCP team will use to facilitate accountability and ensure the project stays on schedule.

In addition to the project kickoff meeting, the project will consist of four other meeting types: regularly scheduled coordination meetings (approximately 1 hour), in-person meetings (approximately a full workday), virtual meetings (approximately a half workday), and virtual presentations at the request of the EAHCP management team (likely corresponding with committee or EAA board meetings). Coordination meetings every 2 weeks will be used to track decisions and technical tasks, prepare for upcoming deliverables, debrief from past meetings, plan for future meetings, and check in on program status with respect to the schedule. **Table 3-1** lists the meetings planned to support all HCP tasks, including those allocated under other tasks. Specifically, the table approximates how the in-person and virtual meetings will be allocated amongst HCP development tasks.

ICF will be responsible for meeting coordination and will work with EAHCP staff to identify attendees, set agendas, and manage meeting notes and the decision record.

Table 3-1. HCP Team Meetings[1] by Task in Support of the Permit Renewal for the EAHCP

Task	In-Person Meetings	Virtual Meetings	Virtual Presentations[2]	Regular Coordination Meetings[3]
Task 2, Kickoff Meeting	1	--	--	--
Task 3, Listen and Learn	See Task 3[4]	--	1	16
Task 4, Operating Agreements	--	2	--	2
Task 5, HCP Planning and Alternative Development	6	10	10	42
Task 6, Modeling	2	2	1	12
Task 7, Draft HCP	2	6	1	18
Task 8, Draft NEPA	NEPA Team Meetings Funded Under Task 8			
Task 9, ITP Application	--	--	--	2

Task	In-Person Meetings	Virtual Meetings	Virtual Presentations[2]	Regular Coordination Meetings[3]
Task 10, Public Scoping	NEPA Team Meetings Funded Under Task 10			
Task 11, Draft EIS Public Meetings	NEPA Team Meetings Funded Under Task 11			
Task 12, Final HCP	1	2	1	8
Task 13, Final NEPA Document	NEPA Team Meetings Funded Under Task 13			
Total Meetings Funded Under Task 2	**12**	**22**	**14**	**116**

[1]NEPA team meetings are not included in Task 2, but are included in the NEPA Tasks 8, 10, 11, and 13 to facilitate a separation of the HCP and NEPA teams (i.e., NEPA team staff and HCP team staff work should be conducted on separate tasks).

[2]Assumes that the HCP team would be requested to provide up to 14 virtual presentations over the course of the ITP renewal process.

[3]Assumes regularly scheduled coordination meetings between the HCP team and EAHCP staff approximately twice per month. The number of these meetings for each task is approximated based on the estimated task duration.

[4]Listen and Learn in-person workshops are allocated under Task 3. Coordination meetings and virtual presentations that may occur during this phase of the project are included under Task 2.

3.2.2 Deliverables

- Kickoff meeting agenda
- Coordination of regularly scheduled status meetings
- Attendance and/or facilitation at up to 12 in-person meetings
- Attendance and/or facilitation at up to 22 virtual meetings
- Virtual presentations at the request of the EAHCP project manager

3.2.3 Assumptions

- Up to 4 HCP team members will attend approximately 12 in-person meetings and facilitate approximately 22 virtual meetings.
- The HCP team will be requested to provide up to 14 virtual presentations over the course of the ITP renewal process.
- In-person meetings will be up to 8 hours in duration.
- Virtual meetings will be up to 4 hours in duration.
- Virtual meetings will be conducted via Microsoft Teams.

3.3 Task 3: Listen and Learn Workshops

3.3.1 Task Description

The HCP team will prepare, conduct, and facilitate four 1-day workshops to get input and data sources from community stakeholders. EAHCP staff will collaborate with the HCP team to focus the content for each workshop. An open-house style meeting will be held for each topic, with each meeting lasting up to 8 hours in duration.

Designing and implementing a successful Listen and Learn workshop process requires strong public meeting design skills, clear intent, and a well-constructed plan for incorporating information gathered from the workshops into the permit renewal process. The HCP team and ICF's public outreach staff will work closely with EAHCP staff and the HCP management team to set goals for the Listen and Learn workshops, outline the best approach for interfacing with stakeholders, and create a list of proposed workshop materials.

Up to four HCP team and public outreach staff persons will attend each workshop. Feedback will be collected on the topic and requests for existing data on the topic will be made electronically before and after each workshop and in-person at each workshop. The outcome of each workshop will be a summary of all the feedback received. EAHCP staff will collaborate with the HCP team in advance to identify stakeholders not yet on the EAHCP mailing list to include on future communications and to invite to the workshops. The four workshop topics to be conducted are outlined below.

3.3.1.1 Workshop 1: Recommended ITP Approach

The purpose of this workshop is to collect feedback on the following items:

- Permit renewal options
  - Covered Activities
  - Covered Species
  - Mitigation and Management Measures
  - Other ITP conditions
- Length of the permit term
- Administrative changes

3.3.1.2 Workshop 2: Biological Goals and Objectives

The purpose of this workshop is to collect feedback on the biological goals and objectives of the EAHCP:

- Define goals for species, habitat, or ecosystems
- What the new goals and objectives might be
- How objectives define success
- What tools may help evaluate success

3.3.1.3 Workshop 3: Climate Change and System Vulnerabilities

Climate is a fundamental component to the future management of the conservation measures implemented in the EAHCP. Understanding the direction/focus of the biological goals and objectives will help to refine a climate vulnerability assessment. Building on the outcome of the first two workshops, the purpose of this workshop is to collect feedback on the following topics regarding climate change.

- The effect of climate change on covered species, habitat, or ecosystem
- The sensitivity, exposure, and adaptive capacity of the spring systems and the Edwards Aquifer

3.3.1.4 Workshop 4: Conservation Measures

The EAHCP defines measures to conserve federally listed species that live in the Edwards Aquifer and the Comal and San Marcos springs through implementation of Minimization and Mitigation Measures (Conservation Measures). The activities defined in the EAHCP have changed via adaptive management or due to the lack of necessity. The purpose of this workshop is to collect feedback on the EAHCP Conservation Measures and determine if changes should be made to the following items.

- Details of the Conservation Measures
- Implementation efforts

ICF will be responsible for the following Listen and Learn workshop components.

- Workshop logistics
- Meeting materials (presentations, brochures, fact sheets, display boards, comment forms, and/or sign-in sheets)
- Participation at meetings
- Collecting public comments using various methods (paper forms and electronic)

ICF will conduct a dry run of the first workshop for the EAHCP staff and Permittees prior to the first workshop. After the four workshops have been conducted, ICF will summarize the feedback received in a draft and final report for EAHCP staff. ICF will coordinate with EAHCP staff to develop recommendations for next steps based on the data received.

3.3.2 Deliverables

- Attendance at up to five in-person meetings
- Draft workshop materials (electronic for each workshop)
- Administrative draft workshop materials (electronic for each workshop)
- Administrative draft workshop materials (printed for dry run)
- Final electronic and printed workshop materials (for each workshop)
- Draft Listen and Learn Workshop Report
- Final Listen and Learn Workshop Report

3.3.3 Assumptions

- To reduce travel costs, ICF will conduct the dry run of the first workshop on the same trip as Workshop 1 (e.g., 1–2 days prior to Workshop 1).
- Up to four HCP team members will attend each Listen and Learn workshop.
- EAHCP staff will be responsible for maintaining the mailing list or public notice of workshops.

3.4 Task 4: Operating Agreements

3.4.1 Task Description

The HCP team management and program director will review existing operating agreements and make recommendations for future changes. This task may require interviewing EAHCP staff, Permittees, and other Committee members. The HCP team will conduct interviews virtually unless conducted concurrently with other in-person meetings under Task 2. The HCP team will also review EAHCP-related Interlocal Agreements between the Permittees. The HCP Team will make recommendations for changes to the following documents.

- *Funding and Management Agreement* (January 2012)
- *Operational Procedures of the Implementing Committee of the Edwards Aquifer Habitat Conservation Plan Program* (March 2012)
- *Parliamentary Rules of Conduct of the Implementing Committee of the Edwards Aquifer Habitat Conservation Plan Program* (March 2012)
- *Program Operational Rules for EAHCP Program Adaptive Management Stakeholder Committee Members and Participants* (May 2022)
- *Operational Procedures of the Science Committee of the Edwards Aquifer Habitat Conservation Plan Program* (April 2014).

As part of this task, the HCP team will conduct a thorough review of all relevant operating agreements listed above to answer the following questions.

- Do any provisions of these agreements need to change to align to the proposed amendments to the EAHCP?
- Should any provisions of these agreements be changed to improve the efficiency and effectiveness of EAHCP implementation?
- Can any of these agreements be separated from the EAHCP and ITP to provide the Permittees with more flexibility in implementation?

3.4.2 Deliverables

- Recommended tracked change revisions to the following.
    - *The Funding and Management Agreement*
    - *Operational Procedures of the Implementing Committee of the Edwards Aquifer Habitat Conservation Plan Program* (March 2012)
    - *Parliamentary Rules of Conduct of the Implementing Committee of the Edwards Aquifer Habitat Conservation Plan Program* (March 2012)
    - *Program Operational Rules for EAHCP Program Adaptive Management Stakeholder Committee Members and Participants* (May 2022)
    - *Operational Procedures of the Science Committee of the Edwards Aquifer Habitat Conservation Plan Program* (April 2014)

- Documented justification for recommended changes provided in a memorandum format and/or in comments in the reviewed documents.

3.4.3 Assumptions

- The HCP team will conduct interviews with EAHCP staff, Permittees, and other Committee members to obtain information on recommendations for operating agreement changes virtually unless conducted concurrently with other in-person meetings under Task 2.
- The HCP team will provide documented justification for required recommended changes to operating agreements in a memorandum format and/or in comments in the reviewed documents.

3.5 Task 5: HCP Planning and Alternative Development

3.5.1 Task Description

The HCP team will perform planning and technical studies to support the permit renewal for the EAHCP. The HCP team may also use these studies to identify data gaps and additional studies, if any, are needed to inform development of the HCP. These analyses should include the projected level of effort in both cost and time needed for proposed studies. The HCP team will provide any resource tools (i.e., Geographic Information System files, spreadsheets, etc.) created in the development of their work.

This task includes much of the essential content that will make up Chapters 2–7 of the HCP Amendment described under Task 7 (**Figure 3-1**). As with all writing tasks, the HCP team will begin with existing HCP text where useful and relevant. Subtasks 5.4, Define Biological Goals and Objectives, through 5.9, Monitoring Plan, will be informed by Task 6, Modeling Projections. All subtask deliverables will be overseen by the HCP team management staff, drawing on the HCP team's technical experts as noted below.

Technical memos or short technical reports will be used as the way to solicit early feedback from EAHCP staff and the USFWS on the foundational elements of the HCP. Two or three versions of each memo will be developed with review from (a) EAHCP staff, (b) the USFWS and EAHCP committee members, and (c) receive a directive to proceed from the Implementing Committee. We will coordinate with EAHCP staff to determine a draft development and review process for each memo, but **Table 3-2** provides the assumed approach to deliverables under this task.

Table 3-2. Task 5 Deliverables

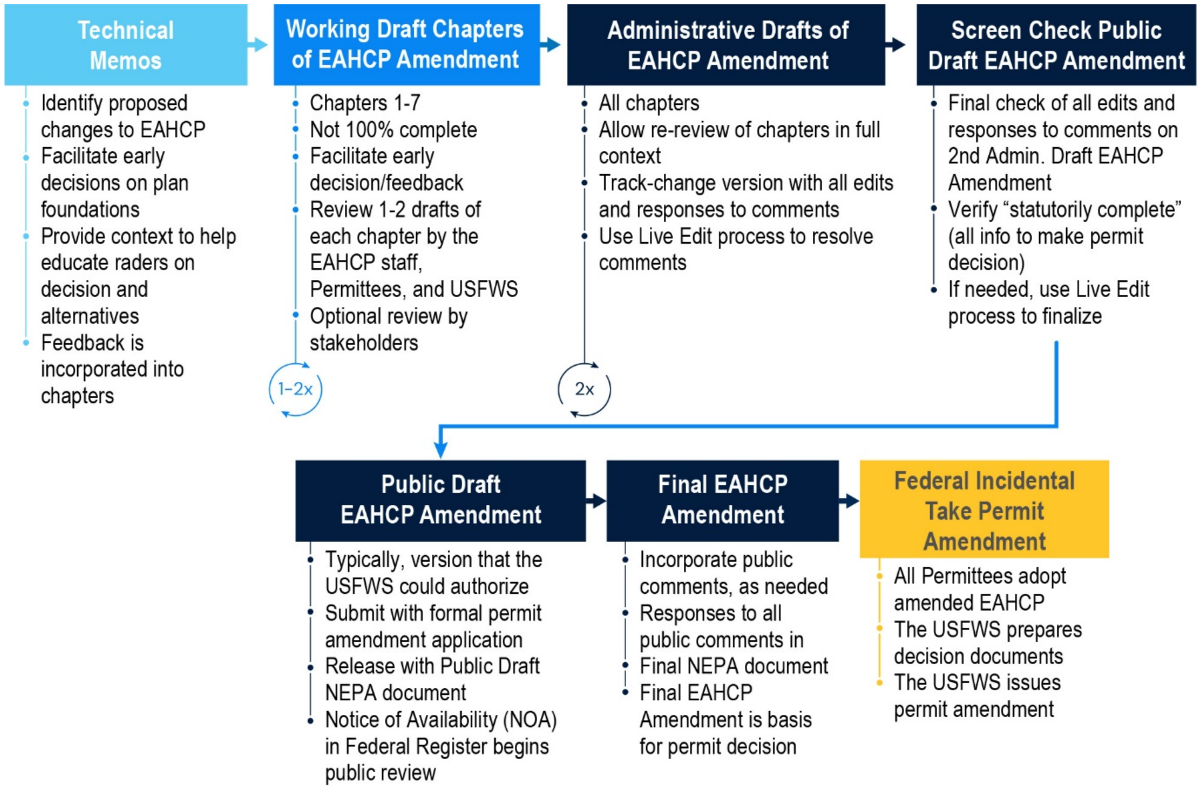
Deliverable[ab]		# of Drafts	Notes and Next Steps
1a-c	Draft Covered Species Memo	3[a]	Incorporate into Amended HCP Chapter 3, "Existing Conditions," and HCP appendix to document covered species selection process (Task 7)
2a-c	Draft Covered Activities Memo	3[a]	Incorporate into Amended HCP Chapter 2, "Covered Activities" (Task 7)

Deliverable[ab]		# of Drafts	Notes and Next Steps
3a-c	Update to Environmental Setting and Baseline Conditions Chapter	3[a]	Update to EAHCP Chapter 3, “Existing Conditions” (Task 7)
4a-c	Draft Biological Goals and Objectives Memo	3[a]	Consider Biological Goals and Objectives Subcommittees’ recommendations. Incorporate into Amended HCP Chapter 5, “Conservation Strategy” (Task 7)
5a-c	Draft Preliminary Conservation Strategy Changes Memo	3[a]	Incorporate into Amended HCP Chapter 5, “Conservation Strategy” (Task 7)
6a-b 7a-b	Habitat Suitability Analysis and Take Assessment Memo	2[b]	Incorporate into Amended HCP Chapter 4, “Effects Analysis.” Final document as EAHCP appendix (Task 7)
8a-b	Draft Monitoring Plan Updates Memo	2[b]	Incorporate into Amended HCP Chapter 6, Sections 6.2 and 6.3 (Task 7)
9a-c	Draft Preliminary Costs Memo	3[a]	Incorporate into Amended HCP Chapter 7, “Cost and Funding” (Task 7)
	Total	22	

[a] Assumes (a) first draft reviewed by EAHCP staff, (b) second draft reviewed by the USFWS and committee members, and (c) third draft reviewed and approved by the Implementing Committee.

[b] Assumes that the Draft Habitat Suitability Analysis and Take Assessment Memo and the Draft Monitoring Plan Memo will not require Implementing Committee approval at this stage, so only two drafts will be prepared per memo.

Figure 3-1. Document Review Process



Once approved by the Implementing Committee, most technical memo recommendations would be applied to the first draft of the relevant Amended HCP chapter (Task 7) (exceptions to this, where a technical memo is assumed to be an appendix to the HCP, are noted in **Table 3-2**). It is important that material be maintained as a "working draft" up until the Public Draft Amended HCP. The technical memo format helps to convey the working draft status. In cases where the technical material will become an appendix to the HCP, a standalone report is appropriate. In other cases, avoiding a report or memo altogether is preferrable so that reviews can be focused on the Amended HCP chapters.

In all cases, technical memos and technical reports in this task will assess and identify important data gaps that may be relevant to the Amended HCP. For each data gap we will identify the following.

- Relevance or importance to completing the Amended HCP
- Risk to the Amended HCP of not addressing the data gap
- Analysis or study required to address the data gap and estimated time and cost (if necessary, analysis to completely address the data gap is unknown, a scoping phase will be described)
- Options to address the data gap during HCP implementation should it not be addressed during the Amended HCP

The following subtasks will be conducted under this task.

3.5.1.1 Subtask 5.1: Define Covered Species

The HCP team will use information collected during the Listen and Learn workshops, information from USFWS, and the results of previous deliverables to recommend what Covered Species should be included in the renewed ITP. ICF will coordinate closely with EAHCP staff in finalizing recommendations presented to Permittees. This work plan assumes the removal of the San Marcos gambusia (proposed extinct) and removal of unlisted Covered Species that are no longer petitioned.

The HCP team's technical staff will carefully evaluate species for coverage. ICF uses the following criteria to evaluate whether a species should be covered under an HCP.

- **Listing status.** Is the species currently listed as threatened or endangered? If not, considering its status and threats to the species, what is the likelihood that the species will be listed during the permit term?
- **Range.** Is the species known to occur or expected to occur within the Plan Area based on best available data and professional expertise? If not currently known or expected to occur, is it expected to move into the Plan Area during the permit term?
- **Impact.** Will the species or its habitat be affected by Covered Activities at a level that may result in take?
- **Species data.** Is there sufficient scientific data on the species life history, habitat requirements, and occurrence in the Plan Area to allow for adequate evaluation of impacts on the species and the development of Conservation Measures to mitigate those impacts?

Detailed information on the following topics will be included for the species recommended for coverage: listing status, historical and current range, habitat description, habitat extent in the Plan Area, presence in the Plan Area, and threats. Covered Species reports are typically captured, in full, as an appendix to Chapter 3, "Environmental Setting and Baseline Conditions," described under Task 7. The report for each species, often referred to as a species account or species profile, will be authored by a HCP team biology technical expert.

3.5.1.2 Subtask 5.2: Define Covered Activities

The HCP team will use information collected during the Listen and Learn workshops, the results of previous deliverables, text in the existing HCP, and information from annual reports documenting the HCP's Conservation Measures, to recommend what Covered Activities should be included in the renewed ITP. We will coordinate closely with EAHCP staff in finalizing recommendations presented to Permittees.

The HCP team will use the following criteria as a starting point to evaluate whether activities warrant coverage, which can be adapted as needed.

- **Location.** The project and/or activity occurs in the Plan Area.
- **Timing.** Construction of the project or operational or maintenance activities will occur during the permit term.
- **Impact.** The project or activity has a reasonable potential or likelihood to result in take of a Covered Species.

- **Definition.** The location, size, and other relevant aspects of the project or activity can be defined sufficiently such that direct and indirect impacts on Covered Species can be evaluated and Conservation Measures developed to mitigate those impacts.
- **Practicability.** Inclusion of the project and/or activity as a Covered Activity will not result in undue delays or substantial additional cost to HCP development and permitting processes relative to the benefit of including the project, activity, or service in the permit. In other words, it will be more cost-effective to provide endangered species permits for the project, activity, or service through the HCP rather than separately. Impractical Covered Activities include ones that, on their own, would add additional Covered Species, generate substantial controversy, or significantly complicate the impact analysis.

3.5.1.3 Subtask 5.3: Existing Conditions

The HCP team will use information collected during the Listen and Learn workshops, best available science, and the existing EAHCP Chapter 3, "Environmental Setting and Baseline Conditions," to evaluate how the chapter needs to be updated given what conditions have changed since the EAHCP was approved.

Updated existing conditions is an important input to the permit renewal process that will inform the EAHCP effects analysis, conservation strategy, and monitoring and adaptive management plan. The HCP team will start with the existing EAHCP Chapter 3, "Environmental Setting and Baseline Conditions," and evaluate how the chapter needs to be updated given what conditions have changed since the EAHCP was approved and amended last. We will also consider which changes might be considered for the EAHCP, drawing from the *EAHCP Permit Options Report* and information gathered in the Listen and Learn phase, and determine whether additional analysis of existing conditions on any topics or resource areas that were not addressed in the original EAHCP is required. Sources for information will include the EAHCP and its annual reports and biological monitoring reports, *Review of the Edwards Aquifer Habitat Conservation Plan, Report 3* and the *EAHCP Permit Options Report*. In particular, this subtask will focus on the topics necessary to inform the Amended HCP, including the following.

- Climate, including temperature, precipitation, and drought projections
- Hydrology, including the Edwards Aquifer and aquifer-fed springs in the Plan Area
- Updates to species data for each Covered Species, including new data for Covered Species added to the EAHCP

All relevant text from the EAHCP will be used whenever possible. Some content in Chapter 3 of the EAHCP may need to be updated after completing the remaining Task 5 subtasks. These updates will be made in the Draft HCP (Task 7).

3.5.1.4 Subtask 5.4: Define Biological Goals and Objectives

The HCP team will use information collected during the Listen and Learn workshops, historical data and studies, recommendations from the Biological Goals and Objectives subcommittees, and the results of previous deliverables to recommend the biological goals and objectives that should be included in the renewed ITP. The HCP team will coordinate closely with EAHCP staff in finalizing recommendations presented to Permittees.

The existing biological goals and objectives for EAHCP Covered Species will serve as a starting point for the biological goals and objectives to be included in the Amended HCP. New biological goals and objectives will need to be developed for added Covered Species. The HCP team will use a collaborative approach to develop biological goals and objectives, including discussions with USFWS staff, Permittees, the HCP management team, and species experts. Species experts are crucial to informing the discussion on what are and are not reasonable expectations for species outcomes, which helps frame discussions with the USFWS to reach biological goals and objectives that result in beneficial conservation outcomes for species while also driving practicable Conservation Measures.

3.5.1.5 Subtask 5.5: Preliminary Conservation Strategy Changes

The HCP team will use information collected during the Listen and Learn workshops and recommendations from the Conservation Measures Subcommittee to recommend the mitigation and minimization measures to be included in the renewed ITP. The HCP team and EAHCP staff will coordinate closely in finalizing recommendations presented to Permittees.

This subtask will focus on identifying the options available to update the minimization and mitigation measures in the EAHCP (Chapter 5). The technical memo delivered under this task will identify the important changes to the conservation strategy that will involve deletions, additions, or major changes to existing Conservation Measures based on the following information.

- Adaptive management changes implemented by the EAA so far
- Recommendations of the *Review of the Edwards Aquifer Habitat Conservation Plan, Report 3*
- Recommendations of the *EAHCP Permit Options Report*
- Recommendations of the EAHCP Conservation Measures Subcommittee
- Additional Covered Species that may be added to the EAHCP (e.g., if existing Conservation Measures are insufficient to address the mitigation needs of these new species)
- New information that suggests new or different Conservation Measures will be more effective than existing measures
- Updated Biological Goals and Objectives
- Updated Effects Analysis and Take Assessment

Conservation Measures identified in the approved technical memo will be incorporated into a revised Amended EAHCP Chapter 5 (Task 7).

3.5.1.6 Subtask 5.6: Habitat Suitability Analysis

The HCP Team will use available tools to perform the habitat suitability analysis (HSI). Springflow, the output from MODFLOW, will be fed into the existing HSI structure for each of the modeled scenarios. The HCP team will need to review and update available tools as needed to perform the analysis. The HCP team will conduct habitat suitability analyses for fountain darter, Texas wild-rice, San Marcos salamander, and Comal Springs riffle beetle. Habitat suitability analyses for other Covered Species are not included in this scope of work.

BIO-WEST will lead the habitat suitability analysis with oversight from ICF's HCP management team and technical assistance, as needed, from Cambrian. Data and analytical tools related to habitat, water quality, and springflow are available to support habitat suitability analyses for fountain darter, Texas wild-rice, San Marcos salamander, and Comal Springs riffle beetle. Updated projections from Task 6 would also inform the springflow parameter for the analyses. The Comal Springs Riffle Beetle Population Assessment that BIO-WEST is conducting over 2022 and 2023 should also inform the habitat suitability analysis for the riffle beetle, but uncertainty in the beetle's use of subsurface habitat remains. Life history data for the Comal Springs dryopid beetle, Peck's cave amphipod, and other deep aquifer Covered Species remains insufficient to conduct habitat suitability analyses for these species. More data may be available for these species at the time this task is initiated, and the HCP team will coordinate with the EAA to determine the feasibility of habitat suitability analyses for deep aquifer Covered Species.

3.5.1.7 Subtask 5.7: HCP Effects Analysis and Take Assessment

The HCP team will document the effects analysis and take assessment for each Covered Species. The effects analyses and take assessment methods will be updated consistent with the updated Covered Species list, the revised Covered Activities, revised Conservation Measures, and changes to the biological goals and objectives. The effects analysis and take assessment methods will also be updated, as needed, to include any new or revised approaches to the adaptive management program. The effects analysis and take assessment methods will be provided to EAHCP staff and the USFWS for review prior to completing the full analysis and memo.

This subtask will document the proposed changes to the effects analysis and take assessment for each Covered Species. The effects analyses and take assessment methods will be updated consistent with the updated Covered Species list, the revised Covered Activities, and changes to the biological goals and objectives. The effects analysis and take assessment methods will also be updated, as needed, to include any new or revised approaches to the adaptive management program (that address uncertainties in the effects analysis). The effects analysis and take assessment methods will be provided to EAHCP staff and the USFWS for review prior to completing the full analysis and memo.

3.5.1.8 Subtask 5.8: Monitoring Plan

The HCP team will coordinate closely with EAHCP staff to establish and document a monitoring plan that will evaluate the effectiveness of Conservation Measures.

This subtask will focus on proposed changes to the monitoring program in Sections 6.2 and 6.3 of the EAHCP. The monitoring plan will be updated primarily in response to the best available science, changes to the Conservation Measures and the adaptive management program. Stakeholder input and lessons learned from implementation of the original HCP are also expected to inform the plan. For example, requirements for monitoring and management for gill parasites may change. Or changes to performance standards for riparian restoration may lead to changes in monitoring approach or frequency. BIO-WEST will lead the development of the monitoring plan updates memo with oversight from the HCP management team. The memo will propose additions, deletions, and changes to the long-term monitoring program and explain the rationale for these changes. Once approved, the revisions to monitoring will be incorporated into a revised monitoring chapter in Task 7.

3.5.1.9 Subtask 5.9: Preliminary Costs

The HCP team will coordinate with EAHCP staff and Permittees to establish and document costs and funding analysis consistent with USFWS guidance for inclusion in the Draft HCP.

The preliminary cost memo will identify expected cost changes because of the recommended changes to the Covered Activities, Covered Species, biological goals and objectives, Conservation Measures, and monitoring activities. ICF will use the existing EAHCP budget as a starting point for the costs analysis. The costs report may also consider changes to HCP administration as these changes could lead to adjustments in costs, specifically decreases in cost because of gained efficiency. Jon Hockenyos, HCP economic/financial analyst, will lead the preliminary costs memo.

Deliverables

Table 3-2 summarizes the deliverables under Task 5. A preliminary draft, draft, and revised memo for each of the deliverables below would be completed, except for the Monitoring Plan Updates memo, which would only have a preliminary draft and revised draft.

- Covered Species Memo
- Covered Activities Memo
- Update to Environmental Setting and Baseline Conditions chapter
- Biological Goals and Objectives Memo
- Habitat Suitability Analysis and Take Assessment Memo
- Preliminary Conservation Strategy Changes Memo
- Monitoring Plan Updates Memo
- Preliminary Costs Memo

Assumptions

- ICF will remove the San Marcos gambusia (proposed extinct) from the list of Covered Species and therefore not analyze it in the Amended HCP.
- ICF will add additional Covered Species to the list of Covered Species in the Amended HCP.
- ICF will conduct habitat suitability analyses for fountain darter, Texas wild-rice, San Marcos salamander, and Comal Springs riffle beetle. Habitat suitability analyses for other Covered Species are not included in this work plan.
- ICF will develop draft technical memos for Task 5 for EAHCP staff, USFWS and stakeholders, and committee members to review, totaling up to three versions of each memo. ICF will address comments received on the revised draft technical memos in Chapters 1–7 of the Amended HCP. Refer to **Table 3-2** for details.

3.6 Task 6: Modeling Projections

3.6.1 Task Description

The HCP team will work closely with EAA technical staff in the development of the reports described under each of the subtasks described below.

The estimation of springflow response to changes in climate and water use is a critical element of the Amended HCP. Changes in springflow quantity are one of the primary impact mechanisms to the Covered Species. Maintaining minimum springflow during droughts is a key Conservation Measure of the EAHCP that will be maintained in the Amended HCP. Accordingly, this analysis must be robust, transparent, and reproducible so that the USFWS, Permittees, and stakeholders have confidence in the results and corresponding requirements.

Projections for future surface water and groundwater conditions will be developed and evaluated during this task to assess the adequacy of current minimum springflow commitments in the EAHCP in the face of climate change. Work completed during this task provides the basis for analysis and prediction of future aquatic habitat.

Below is a summary of the deliverables and assumptions identified for this task. Additional details regarding work to be completed and associated assumptions are provided further below in following sections.

Deliverables

- Draft Temperature and Rainfall Scenarios Report
- Final Temperature and Rainfall Scenarios Report
- Draft Recharge Rates, Pumping Scenarios, and MODFLOW Springflow Projections Report
- Final Recharge Rates, Pumping Scenarios, and MODFLOW Springflow Projections Report

Assumptions

- ICF will lead the development and production of the Temperature and Rainfall Scenarios Report in coordination with EAA staff.
- EAA will lead technical components of the Recharge, Pumping, and MODFLOW Springflow Projections Report. ICF, in coordination with EAA, will produce the report, including technical editing and formatting.

3.6.1.2 Subtask 6.1: Temperature and Rainfall Scenarios

EAA staff will deliver their preferred set of downscaled future climate scenarios for more than one concentration pathway, which will already include the comparisons of the recent decadal hindcasts to measured weather. The HCP team will use the existing EAA preferred downscaled future climate scenarios. The HCP team will compare the future predicted temperature and rainfall scenarios to measured temperature and rainfall during the drought of record and other recorded significant drought periods to better understand the temporal and spatial characteristics of the predicted temperature and rainfall scenarios.

We recognize that EAA technical staff have developed downscaled and bias-corrected estimates of future precipitation and temperature conditions from CMIP5 and CMIP6 for more than one concentration pathway; we also recognize that EAA technical staff have developed approaches for estimating future potential evapotranspiration conditions. If these are the preferred future climate conditions, we will rely on these estimates directly, assuming they will be supplied by EAA technical staff. Our assumption is that the climate analyses that are currently being implemented by the EAA technical staff will include and address the following requirements.

- EAA technical staff has implemented a novel downscaling method that they deem the best available for the study region to produce downscaled climate projections of temperature and rainfall across the Edwards Aquifer Region (EAR). The EAA technical staff has already judged that this approach is recommended based on reasonably matching historical climate.
- The HCP team will use the downscaled projections produced by EAA technical staff in the analyses under the assumption that they are the EAA's preferred approach and that the EAA has implemented all comparisons that it deems necessary to validate this approach.
- The downscaled CMIP5 and CMIP6 projections of temperature and rainfall, produced by the EAA staff with their preferred downscaling method, will incorporate simulations results for more than one Representative Concentration Pathway (RCP) through 2060 across the EAR.
- The project team will produce an ensemble of temperature and rainfall time histories through 2060 across the EAR from the downscaled projections for more than one RCP that cover the entire EAR as produced by EAA technical staff.

The project team will document the future predicted temperature and rainfall scenarios produced for this task in a report (see *Deliverables* above). This approach uses all available EAA science teamwork products and requires extensive collaboration among the HCP team and the EAA science team.

3.6.1.3 Subtask 6.2: Recharge, Pumping, and MODFLOW

The HCP team will coordinate with the EAHCP team to complete a report describing recharge, pumping, and MODFLOW simulations to project future springflow. The EAA Aquifer Science Team will conduct the modeling work to project future recharge, pumping, and MODFLOW simulations. At the direction of the EAHCP team, the HCP team will produce a report describing the modeling results.

3.6.1.4 Subtask 6.3: Modeling Workshop

The HCP team will design and conduct a half-day workshop to facilitate increased understanding of ensemble-based modeling workflows for EAA staff and stakeholders. At the request of the EAHCP project manager, the HCP team will present a summary of ensemble-based modeling workflows to the EAHCP Science committee, all EAHCP committee members will be invited at attend (see **Table 3-1**).

3.7 Task 7: Draft HCP

3.7.1 Task Description

The HCP team will develop a Draft HCP consistent with USFWS guidelines in accordance with Section 10(a)(1)(B) of the ESA of 1973, as amended. The HCP team will work closely with the EAHCP staff and Permittees to document the proposed Covered Activities, environmental setting, an analysis of Covered Species, the mitigation and minimization measures, approach to adaptive management, costs and funding assurances, changed circumstances and no surprises, permit administration, and other applicable sections. The HCP team will rely on materials developed through other tasks on this contract as well as the best available data. The Amended HCP will be based on the outline included in this work plan. Draft HCP deliverables are listed below under *Deliverables*. The Implementing Committee will review and sign-off on the Final Draft HCP prior to submittal to USFWS. The HCP team will distribute electronic copies of the Final Draft HCP to the public and applicable agencies and, if requested by EAHCP staff, will produce up to 20 hardcopies of the main HCP document with appendices included as electronic files.

The Draft HCP represents the culmination of all previous efforts on the amendment from the Listen and Learn workshops to numerous meetings, assessments, drafts, and individual chapters. This task encompasses internal coordination, QA/QC, the integration of previous comments, formatting, editing, and—critically—a stepwise process for reviewing and resolving input. At the end of this task, a publication-ready Draft HCP will be released to the public (the NEPA document will be released at the same time as per Task 11) for a mandatory public review period in accordance with USFWS policy for review of draft NEPA and HCP documents.

The Amended Draft EAHCP will be assembled from all the elements developed in Tasks 3 through 6. **Table 3-3** summarizes the chapters composing the Amended HCP. A detailed Amended HCP outline is housed in the project's document library here: HCP Outline. This outline will be updated as needed throughout the analysis phase of the permit renewal process.

Table 3-3. Chapters of in the Amended HCP

Amended HCP Chapter	Original EAHCP Chapter	Corresponding Task
Chapter 1, "Introduction"	Same	Variety of sources, including Task 3 and Final Listen and Learn Session Report to summarize outreach process, and several Task 5 technical memos
Chapter 2, "Covered Activities"	Same	Task 5 and Draft Covered Activities Memo (incorporated into chapter)
Chapter 3, "Environmental Setting and Baseline Conditions"	Same	Task 5 and Update to EAHCP Chapter 3
Chapter 4, "Effects Analysis"	Same	Task 5 and Draft Effects Analysis and Take Assessment Methods Memo (incorporated into chapter), and modeling results of Task 6
Chapter 5, "Conservation Strategy"	Same	Task 5 and revised conservation strategy to address effects in Chapter 4, considering future conditions defined in Tasks 5 and 6

Amended HCP Chapter	Original EAHCP Chapter	Corresponding Task
Chapter 6, "Monitoring and Adaptive Management"	Same	Task 5, Monitoring Plan Revisions Memo
Chapter 7, "Plan Implementation"	8 and 9	Task 4 and relevant future conditions for changed circumstances
Chapter 8, "Costs and Funding"	7	Task 5, Preliminary Cost Memo and updated funding plan
Chapter 9, "Preparers and Contributors"	10	Completed as part of Task 7
Chapter 10, "Literature Cited"	12	Updated from original HCP
Appendix A: Abbreviations and Acronyms	11	Updated from original HCP
Appendix B: Glossary	New	Updated from Annual Report
Appendix C: Covered Species Memo	New	Task 5
Appendix D: Habitat Suitability Analysis	New	Task 5
Appendix E: Temperature and Rainfall Scenarios Report	New	Task 6
Appendix F: Recharge Rates, Pumping Scenarios, and MODFLOW Springflow Projections Report	New	Task 6

We will make full use of the original EAHCP by adopting its clear organization[1] and any text that still applies to the Amended HCP. However, to make it clear that the HCP is revised and updated to support a new permit application, we will update the format of the document, including font, headers, footers, the and a different cover. We will clearly indicate in the Draft HCP document and/or a summary table the changes relative to the original HCP. This approach will make clear to all reviewers, including the USFWS, what has been changed and which sections are completely new. As an amendment, it is as important to show what has not changed from the original HCP as it is to show what has changed.

During this task, close coordination and collaboration with the USFWS will be critical to rapid progress and successful completion of the Public Draft HCP. The HCP team will use several approaches to ensure productive discussion and negotiation between the EAA and the USFWS, including the following.

- Review, sort, and prioritize all comments; code comments that need discussion for ICF's proven live-edit meeting (coded comments are simply prioritized comments tagged with a key word to quickly move through a document)
- Hold in-person live-edit meetings to systematically discuss and resolve all coded comments and, when possible, edit the document on screen to reach agreement on revisions
- Clearly document all decisions made during this process to prevent renegotiating by new USFWS staff

[1] The one exception to this organization is to combine Chapter 8, "Changed Circumstances, Unforeseen Circumstances, No Surprises, and Other Federal Commitments," and Chapter 9, "Permit Administration," into one chapter called "Plan Implementation" (Table 3-1).

- For comments not adopted, explain why in the comment response
- Hold follow-up meetings as needed to resolve all comments and produce the next draft

Deliverables

- Draft Amended HCP Chapters 1–7 (see **Table 3-3**) reviewed by EAHCP staff
- Revised Draft amended HCP Chapter 1-7 reviewed by Committees and USFWS
- First Administrative Draft Amended HCP reviewed by EAHCP staff and Implementing Committee
- Second Administrative Draft Amended HCP reviewed by Committees and USFWS
- Screen-check Draft Amended HCP reviewed by EAHCP staff and Implementing Committee
- Final Draft Amended HCP for Implementing Committee Review and Sign-off
- Up to 20 hardcopies of the public draft Amended HCP with electronic appendices for distribution

Assumptions

- The HCP team will assemble the Amended HCP from all the elements developed in Tasks 3–6. We assume that compiling the Amended HCP under this task will not require any new substantive analysis in addition to what is already completed under Tasks 3–6.
- The existing EAHCP will serve as the basis for the Amended HCP. Any text that still applies will be adopted in the Amended HCP.

3.8 Task 8: Draft NEPA

3.8.1 Task Description

The USFWS's renewal of the ITP and approval of the HCP Amendment constitutes a federal action subject to compliance with NEPA. The USFWS (as the NEPA lead agency) has two important considerations for the NEPA document at the outset of the NEPA process. First, the scope of the environmental document will be based on the scope of the Amended HCP and the potential impacts of its implementation. To keep the environmental analysis focused, it will be critical for ICF to work with the USFWS to clearly define the scope of the amendment and develop a clear proposed action under NEPA. Second, it will be important to determine the level of NEPA review. As the lead federal agency responsible for NEPA compliance, the USFWS will determine whether the NEPA document will be an EA or an EIS. If the USFWS anticipates potential significant effects to the human environment due to the implementation of the HCP amendment, it may require the development of an EIS. If this is the case, the USFWS will also determine whether to prepare a supplemental EIS instead of a new EIS. This work plan assumes that USFWS will determine that an EIS is necessary. However, this work plan will be updated at the start of this task to reflect the level of NEPA review determined by USFWS, if necessary.

At the direction of the USFWS, the NEPA team will draft an EIS consistent with USFWS guidance and pursuant to provisions of NEPA (Title 42 of the United States Code (USC) Section 4321 et seq., implemented by Council on Environmental Quality Regulations). To help define project expectations and roles, the NEPA team will develop a memorandum of understanding (MOU) to outline the roles and responsibilities of EAHCP staff, the USFWS, and the NEPA team for the NEPA process. In addition, the NEPA team will develop a clear communications protocol to maintain a firewall between the HCP and NEPA teams. The NEPA team will work with the USFWS regarding any data needs from or questions directed to the HCP team, EAHCP staff, and/or Permittees per the established firewall protocol. The NEPA team will prepare a NEPA schedule with task assignments and milestones and will be responsible for meeting agendas, notetaking, and dissemination of relevant materials. The NEPA team will hold a kickoff meeting with the USFWS and regularly scheduled (approximately twice-monthly) meetings until the public draft NEPA document is completed. The NEPA team will work with USFWS to establish the administrative record protocol and begin implementation at the start of the project, although it will not be submitted in its entirety until the end of the project. The NEPA team will work closely with the USFWS, and EAHCP staff and Permittees as applicable, to document the purpose and need, alternatives considered and those not considered, the affected environment, and environmental consequences. The NEPA team will rely on materials developed through other tasks on this contract as well as the best available data. The NEPA team will perform the necessary steps to develop a Public Draft EIS.

- Submit EIS draft Chapter 1, "Purpose and Need," and Chapter 2, "Description of the Proposed Action and Alternatives," for USFWS review. The description of the proposed action will incorporate the HCP's description of the permit area, permit term, Covered Species, Covered Activities, and conservation strategy.
- Following USFWS review of EIS Chapters 1 and 2, prepare revised versions of the chapters for USFWS approval.
- Following USFWS approval of EIS Chapters 1 and 2, prepare a First Administrative Draft EIS for USFWS review.
- Address USFWS comments and prepare a Second Administrative Draft EIS for USFWS review including the USFWS Regional office and DOI Solicitor's office as appropriate.
- Address USFWS comments and prepare a Third Administrative Draft EIS (camera ready) for concurrence and approval for publication.
- Submit the Public Draft EIS to the USFWS for distribution and filing with the U.S. Environmental Protection Agency.

The HCP team will obtain data and information to characterize baseline conditions for the resource areas from publicly available data, the HCP, the previous EAHCP EIS, and the results of Tasks 5 and 6. The USFWS will ultimately determine which resources to evaluate in detail and which could be informed by early public engagement; however, based on the previous EIS, ICF's experience with similar NEPA documents, and our knowledge of the EAHCP project, we anticipate analyzing the following resources will be analyzed in detail.

- Air quality and climate
- Geology and soils
- Water resources (surface water and groundwater)
- Biological resources, including Covered Species, non-listed species in the area, and wildlife, aquatic, and vegetation

- Socioeconomics
- Environmental justice
- Land use
- Cultural and historic resources

NEPA project director, project manager, and deputy project manager will lead this task. The NEPA project director will be responsible for strategic planning and senior review, as well as ensuring the ICF NEPA team has the necessary resources to adhere to the project's schedule, scope, and budget. The NEPA project manager will be the primary point of contact with the USFWS for the EIS and overseeing the technical quality of the analyses, document preparation, project status reports, and schedule. The NEPA project manager, with the deputy project manager's assistance, will also be responsible for coordinating subject matter experts from the NEPA project team.

Deliverables

- Draft MOU
- Final MOU for execution
- Draft administrative record protocol
- Draft description of the proposed action and alternatives
- Final description of the proposed action and alternatives
- First Administrative Draft EIS
- Second Administrative Draft EIS
- Third Administrative Draft EIS
- Public Draft EIS

Assumptions

- Meetings between the NEPA team and the USFWS assume a kickoff meeting (virtual) and approximately twice-monthly coordination meetings (virtual) through the duration of the task.
- ICF will prepare a draft and final MOU to outline the roles and responsibilities of EAHCP staff, the USFWS, and the NEPA team for the NEPA process.
- The USFWS will compile and reconcile comments on the first and second administrative drafts from all reviewers in a single document.
- ICF will prepare the Draft EIS in electronic form. No hard copies will be necessary.

3.9 Task 9: ITP Application

3.9.1 Task Description

The HCP team will prepare the ITP application package and all supporting documents for submission to USFWS. EAHCP staff will coordinate with the Implementing Committee for review and sign-off of the application prior to submittal.

The HCP team will use the new online application process provided by the USFWS. This application process is expected to evolve throughout the ITP renewal process as the USFWS aims to create a better integrated approach that initiates at start-up and continues through permitting and project implementation.

The ITP application for the ITP renewal will include the draft Amended HCP, and the online application will address the following information.

- All required reports prepared under the existing valid permit
- A list of Covered Species that will be added or removed as part of the renewal, as applicable
- A description of any changes to Covered Activities and/or conservation activities, as applicable
- A description of the change in location of any proposed Covered Activities, as applicable
- A description of any additional changes or revisions to the ITP and HCP

We acknowledge that given the breadth of the changes being considered to the EAHCP, close coordination with the USFWS will be needed to ensure the ITP application meets all the agency's issuance needs.

Deliverables

- ITP application form for an ESA 10(a)(1)(b) ITP amendment.

Assumptions

- EAHCP staff will coordinate Permittee signatures and application fees.

3.10 Task 10: Public Scoping

3.10.1.1 Task Description

If an EIS is required by the USFWS, public scoping meetings will need to be held by the NEPA team. Up to six public scoping meetings will be needed throughout the Plan Area. The NEPA team will conduct a dry run of the public meeting for the USFWS, EAHCP staff, and Permittees. The NEPA team will be responsible for the following duties, which will be planned and executed in consultation with USFWS.

- Meeting logistics
- Published meeting notifications in newspapers
- Draft Notice of Intent (NOI) content for USFWS to publish in the Federal Register

- Meeting materials (presentations, brochures, fact sheets, display boards, comment forms, and/or sign-in sheets)
- Participation at meetings by up to two NEPA team staff persons
- Collect public comments using various methods (paper forms, electronic, and/or court reporters)
- Summarize public comments and the scoping process in a draft and final public scoping report

Public scoping is a required part of the EIS process that provides the opportunity for the public to be informed about the project and provide input on the scope of issues and alternatives to be considered in the NEPA analysis. Public scoping is required for an EIS; however, it is at the discretion of the USFWS to determine the level of public engagement (e.g., the number of public scoping meetings and their format).

The HCP team's Public Outreach specialists will lead the public scoping task and they will coordinate the task with the NEPA project manager and the USFWS. ICF will prepare a public scoping plan in close coordination with the USFWS to determine the right level of engagement based on stakeholder needs and public sentiment. This plan will include ICF's approach to meetings, preparation of meeting materials, preparation of the NOI for the federal register, and collection and summarization of public comments. This plan will ensure an efficient and effective public scoping process and a consistent message when engaging audiences.

Deliverables

- Attendance at up to six in-person public meetings and one dry run
- Draft Public Scoping Plan
- Final Public Scoping Plan
- Draft newspaper meeting notification
- Final newspaper meeting notification
- Publication in up to eight newspapers
- Draft NOI
- Administrative draft meeting materials as electronic files
- Administrative draft meeting materials for dry run
- Final printed and electronic meeting materials
- Draft scoping report
- Final scoping report

Assumptions

- Scoping meetings will consist of six in-person meetings and one in-person dry-run meeting. ICF will hold the six in-person meetings within 2 consecutive work weeks. Up to two staff persons, 1 based locally and one who may need to travel from out of state, will attend in-person meetings.
- Meetings would occur approximately twice-monthly coordination virtual meetings through the duration of the task.

- Meeting materials will include three drafts: administrative draft meeting materials as electronic files, administrative draft meeting materials for “dry run,” and final printed and electronic meeting materials.
- The scoping report will include two versions: draft and final.

3.11 Task 11: Draft EIS Public Meetings

3.11.1 Task Description

If an EIS is required by the USFWS, the work plan assumes that up to six public meetings will need to be held during the Draft EIS public comment period. The NEPA team will conduct a dry run of the public meeting for the USFWS, EAHCP staff, and Permittees. The NEPA team will be responsible for the following duties, which will be planned and executed in consultation with USFWS:

- Meeting logistics
- Published meeting notifications in newspapers
- Draft Notice of Availability content for USFWS to publish in the Federal Register
- Meeting materials (presentations, brochures, fact sheets, display boards, comment forms, and/or sign-in sheets)
- Participation at meetings by up to two NEPA team staff persons

Public meetings during the NEPA process provide the opportunity for the public to hear directly from the lead federal agency and provide comments on the Draft EIS and HCP. ICF’s proposed approach to the public meeting tasks will follow the same approach as Task 10, Public Scoping. ICF will prepare meeting materials and facilitate meetings. ICF’s public outreach lead will lead the task and coordinate with the NEPA project manager and the USFWS.

The USFWS will make the final decision on the number of meetings on the Draft EIS and whether they will be held in person or virtually. This work plan assumes seven in-person scoping meetings during the public comment period (one dry run and six public meetings).

Deliverables

- Published meeting notifications in newspapers
- Draft Notice of Availability content for USFWS to publish in the Federal Register
- Meeting materials (presentations, brochures, fact sheets, display boards, comment forms, and/or sign-in sheets)
- Participation at meetings by up to two NEPA team staff persons

Assumptions

- Draft EIS public meetings will consist of six in-person meetings and one in-person dry-run meeting. ICF will hold the six in-person meetings within 2 consecutive work weeks. Up to two staff persons, one based locally and one who may need to travel from out of state, will attend in-person meetings.

- Meeting would occur approximately twice-monthly coordination virtual meetings through the duration of the task.
- Meeting materials will include three drafts: administrative draft meeting materials as electronic files, administrative draft meeting materials for "dry run," and final printed and electronic meeting materials.
- Public comments will be submitted directly to the USFWS. The USFWS will provide ICF with a public comment matrix and all copies of comments received.

3.12 Task 12: Final HCP

3.12.1 Task Description

The HCP team will address any changes to the Draft HCP based on comments received during the public comment period to produce a Final HCP. The HCP team will work closely with the USFWS, and EAHCP staff and Permittees as applicable, to address comments received on the Draft HCP. The HCP team will facilitate a live-edit meeting with the USFWS, EAHCP staff, and the HCP management team. The HCP team will also support USFWS, at their request, in responding to comments on the draft NEPA document. Once responses to comments have been approved by the EAHCP staff, the HCP team will update the Draft HCP as an Administrative Final HCP with appendices for delivery to the EAHCP staff. Once the Implementing Committee approves the document revisions the HCP team will produce a Final HCP for distribution. The HCP team will provide an electronic copy of the Final HCP to EAHCP staff and the USFWS and may be required to produce up to 20 hardcopies of the main report with appendices included as electronic files.

Managing the Final HCP task requires an understanding of (1) how to provide efficient and substantive responses to comments, (2) how to coordinate the response process with the NEPA team as comments on both the HCP and the NEPA documents are received together, and (3) how to adjust the HCP document without triggering recirculation of the public draft files. The HCP management team and technical experts will work closely with the USFWS, EAHCP staff, and Permittees, as applicable, to revise the HCP in response to comments. ICF will also support the USFWS in responding to comments related to the HCP from the draft NEPA document.

The HCP team will use the following approach for responding to comments and creating the Final HCP. The NEPA team will assign HCP-specific comments to the HCP team and provide a format—approved by the USFWS—for numbering and responding to individual comments, grouped comments, or comment subcomponents (see Task 13 for NEPA team responsibilities). Once the comment response document is complete and all reviewers agree on final changes to the HCP, the ICF HCP team will prepare the Final HCP. ICF will hold a screen-check meeting with the USFWS to create the Final HCP (as described below). Both EAHCP staff and the USFWS must approve all proposed changes to the HCP. Once they approve those changes, ICF will produce a Final HCP for publication.

Deliverables

- Response to comments on Draft HCP
- Administrative Final HCP document with appendices

- Final HCP with appendices for electronic distribution
- Up to 20 hardcopies of the Final HCP with electronic appendices for distribution

Assumptions

- ICF will complete and approve revisions to the Final HCP through a live-edit meeting with the USFWS, EAHCP staff, and the HCP management team.

3.13 Task 13: Final NEPA Document

3.13.1 Task Description

The NEPA team will address any changes to the EIS document based on comments received during the public comment period to produce a Final EIS. The NEPA team will perform the necessary steps to develop a Public Final EIS:

- The NEPA team will process public comments received during the public comment period. At the direction of the USFWS, the NEPA team will identify which comments are related to the HCP and provide the comments that require input from EAHCP staff. USFWS will coordinate with EAHCP staff to develop responses to comments related to the HCP, for inclusion in the Final EIS. If needed, the NEPA team and the USFWS will meet with EAHCP staff to discuss the comments and responses. The HCP consultant team may also assist EAHCP staff in providing input for responses to public comments.
- The NEPA team will draft responses to public comments on the Draft EIS (including agency comments) and submit them to the USFWS for review. The NEPA team will make any revisions to the responses based on USFWS review.
- Following the USFWS's approval of response to comments, the NEPA team will prepare the Administrative Final EIS (with appendices) for USFWS review.
- Following USFWS review, the NEPA team will address final USFWS comments and prepare a Final EIS for electronic distribution.
- Once completed, the NEPA team will provide a draft Record of Decision (ROD) document to USFWS.

Deliverables

- Categorized comments received during the comment period on the Draft EIS and HCP
- Response to comments on the Draft EIS and HCP
- Administrative Final EIS document with appendices
- Public Final EIS document with appendices for electronic distribution
- Final electronic administrative record provided to USFWS and, with USFWS's approval, to EAHCP staff
- Draft language for the Record of Decision (ROD)

Assumptions

- Meetings would occur approximately twice-monthly coordination virtual meetings through the duration of the task.
- ICF will prepare the Final EA in electronic form. No hard copies will be necessary.
- ICF will prepare the Administrative Record and the ROD as part of this task.

3.14 Quality Control

ICF's HCP team will directly oversee all HCP tasks to ensure deliverables meet the EAHCP Program Manager's expectations and the USFWS's permit issuance criteria. The HCP team will use the following process throughout the project to ensure high-quality work products that are delivered on schedule and within budget.

- The HCP project manager and HCP project director or program director discuss each task and deliverable with EAHCP staff to establish a mutual understanding of the scope, schedule, and technical expertise that may be needed. For tasks of a more technical nature, the HCP team's technical staff may need to be involved in these early discussions to help refine the scope.
- The HCP project manager and deputy project manager develop an outline of the deliverable. The outline is reviewed by the project director or program director and then provided to EAHCP staff for review.
- EAHCP staff provide comments on the outline, and the HCP project manager and deputy project manager meet with EAHCP staff to resolve comments. The project director or program director may also be involved in this meeting, depending on the nature of the comments to resolve.
- The HCP project manager and HCP deputy project manager communicate to technical experts assignments for the deliverable, including the outline with any additional guidance, writing assignments, and schedule.
- Technical experts draft the content of the deliverable.
- The HCP deputy project manager, lead conservation planner, or QA/QC and senior regulatory advisor review the initial drafts and provide comments back to technical experts, if needed. Once the first round of internal comments is addressed, the HCP project manager reviews the deliverable and provides comments back to the deputy project manager, lead conservation planner, and/or technical experts to address.
- Once the second round of internal comments is addressed, the HCP project director or program director reviews the deliverable and provides comments back to the project manager and/or technical experts to address.
- Once the third round of internal comments is addressed, the deliverable is provided to the managing editor and designer for final technical edit and format.
- The HCP project manager resolves any comments with the managing editor and submits the deliverable to EAHCP staff and Permittees for review.

A similar process to that described above will also occur for any NEPA deliverables to the USFWS, involving the NEPA project director, NEPA project manager, NEPA deputy project manager, NEPA QA/QC and senior advisor, and subject matter experts.

Chapter 4
Schedule

The HCP team will maintain a detailed project schedule in the project's document library.

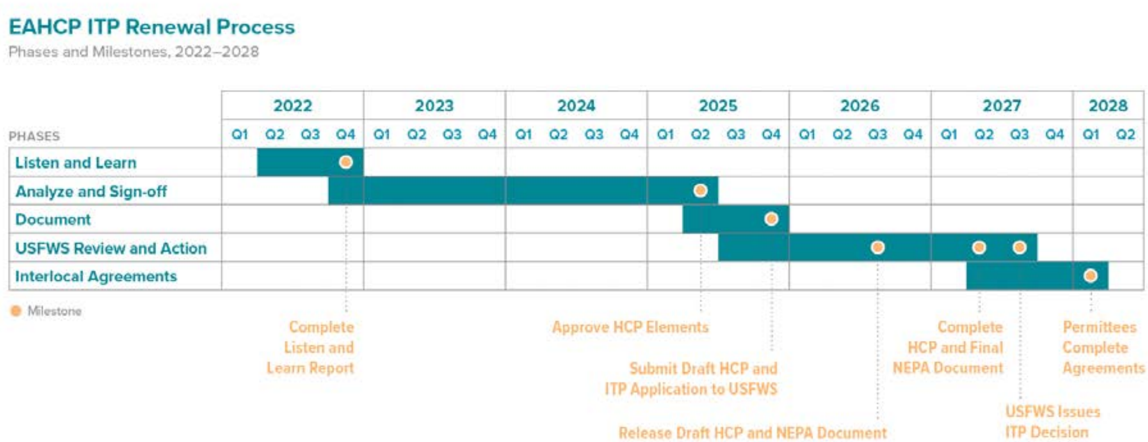
The detailed schedule includes timelines for all tasks and review periods for EAHCP staff, committees, and the USFWS. The schedule also includes the final step in 2027 of review and approval of Inter-Local Agreements with Permittees before implementation of the renewed permit can begin. Figure 4-1 provides a high-level summary schedule, based on the detailed schedule, of the permit renewal process by phase.

The detailed project schedule will be maintained in Microsoft Project throughout the permit renewal process and will be updated periodically. The ICF HCP and NEPA project managers will monitor all factors with potential to cause deviations from the approved schedule. The causes of potential schedule deviations may include changes to the scope of work that are requested by EAHCP Program Manager, factors that affect critical milestones such as granted requests for shortened or extended review periods, or delays in Federal Register publications. Such factors potentially could either shorten or lengthen either the overall schedule, or components within the schedule.

Upon recognition that the need for deviation from the approved schedule is foreseen, the ICF project manager will take the following steps:

1. Identify the proposed deviation from the schedule.
2. Discuss proposed deviation from the schedule with the EAHCP or USFWS staff including rationale, alternative approaches considered, and project implications.
3. EAHCP Program Manager decides whether to accept the proposed schedule deviation.
4. ICF addresses any related scope of work changes that may result from schedule deviations.

Figure 4-1. Permit Renewal Phase Timelines by Quarter



Chapter 5
Amended EAHCP Outline

Below is a summary outline of the Amended EAHCP. This outline will be updated periodically throughout the permit renewal process, including during Phase 1 and after the completion of Task 5 prior to initiating Phase 3, Documentation.

1. Introduction
    1.1. Background
    1.2. Permit Area
    1.3. Permit Holders and Permit Duration
    1.4. Species Proposed for Coverage under the Permit
    1.5. Regulatory Framework
    1.6. Alternatives Considered during the Development of the HCP
    1.7. Public Involvement
2. Covered Activities
    2.1. Covered Activities
    2.2. Edwards Aquifer Authority
    2.3. City of New Braunfels
    2.4. City of San Marcos
    2.5. Texas State University
    2.6. San Antonio Water System
    2.7. Texas Parks and Wildlife Department
    2.8. Adaptive Management Process
3. Environmental Setting and Baseline Conditions
    3.1. Climate
    3.2. Aquifer-fed Springs
    3.3. Edwards Aquifer
    3.4. The Edwards Aquifer, Comal Springs, and San Marcos Springs
    3.5. Covered Species
4. Effects Analysis
    4.1. Introduction
    4.2. Potential Impacts to and Incidental Take of Covered Species
5. Conservation Strategy
    5.1. Introduction
    5.2. Biological Goals and Objectives
    5.3. Minimization and Mitigation Measures
6. Monitoring and Adaptive Management
    6.1. Adaptive Management Process
    6.2. Monitoring
    6.3. Core Adaptive Management Actions
7. Plan Implementation
    7.1. Governance
    7.2. Permit Amendments
    7.3. Annual Reporting

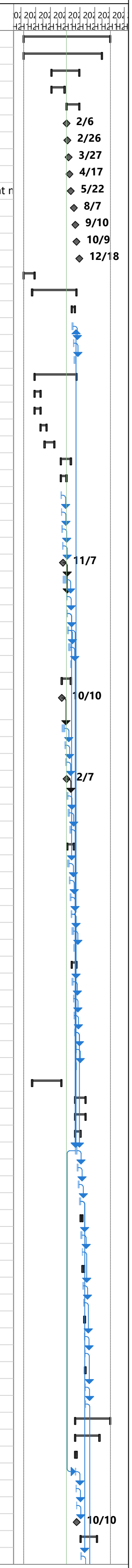
- 7.4. Changed Circumstances
- 7.5. Unforeseen Circumstances

8. Costs and Funding
   - 8.1. Cost and Benefit of the EAHCP
   - 8.2. Purpose of Cost Estimate and Annual EAHCP Implementation Budget
   - 8.3. EAHCP Cost Estimate
   - 8.4. Cost Estimate Methodology
   - 8.5. Funding Sources and Assurances
   - 8.6. EAHCP Benefits
9. Preparers and Contributors
10. Literature Cited

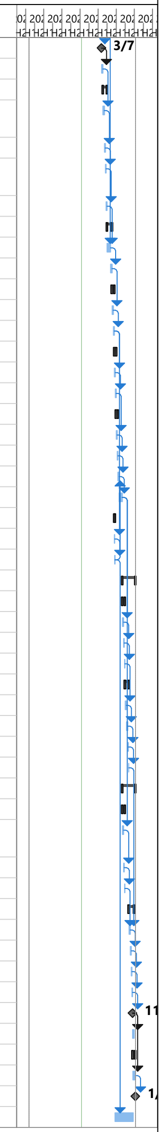
Appendix A: Abbreviations and Acronyms
Appendix B: Glossary
Appendix C: Covered Species
Appendix D: Habitat Suitability Analysis
Appendix E: Temperature and Rainfall Scenarios Report
Appendix F: Recharge Rates, Pumping Scenarios, and MODFLOW Springflow Projections Report

Appendix F6 | **Permit Renewal Detailed Schedule**

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Notes
1		**Permit Renewal for the EAHCP**	**1530 days**	**Wed 3/9/22**	**Fri 1/21/28**		
2		**1. Program Management**	**1383 days**	**Wed 3/9/22**	**Wed 6/30/27**		
18		**2. Meetings**	**490 days**	**Thu 2/1/24**	**Thu 12/18/25**		
19		**2024 Committee Meetings**	**230 days**	**Thu 2/1/24**	**Thu 12/19/24**		
30		**2025 Committee Meetings**	**225 days**	**Thu 2/6/25**	**Thu 12/18/25**		
31		Joint SH & IC	0 days	Thu 2/6/25	Thu 2/6/25		Updates on take assessment, conservation measures
32		Science	0 days	Wed 2/26/25	Wed 2/26/25		Monitoring
33		Implementing	0 days	Thu 3/27/25	Thu 3/27/25		
34		Science	0 days	Thu 4/17/25	Thu 4/17/25		
35		Implementing	0 days	Thu 5/22/25	Thu 5/22/25		Conservation Strategy Directove to proceed. Monitoring and Adaptive Management r
36		Joint SH & IC	0 days	Thu 8/7/25	Thu 8/7/25		
37		Science	0 days	Wed 9/10/25	Wed 9/10/25		
38		Implementing	0 days	Thu 10/9/25	Thu 10/9/25		Preliminary Cost evaluation.
39		Year End	0 days	Thu 12/18/25	Thu 12/18/25		
40		**Phase 1: Listen and Learn**	**191 days**	**Wed 3/9/22**	**Mon 12/5/22**		
90		**Phase 2: Analyze and Sign-off**	**786 days**	**Thu 10/6/22**	**Thu 10/9/25**		
91		**4. Operating Agreements**	**55 days**	**Mon 6/16/25**	**Fri 8/29/25**		
92		ICF Prepare Redlined Agreements & Justification	25 days	Mon 6/16/25	Fri 7/18/25	161	
93		EAHCP Staff Review	10 days	Mon 7/21/25	Fri 8/1/25	92	
94		EAHCP Permittees Review Redlined Agreements	20 days	Mon 8/4/25	Fri 8/29/25	93	
95		**5. HCP Planning and Analysis**	**743 days**	**Tue 12/6/22**	**Thu 10/9/25**		
96		**5.1. Define Covered Species**	**107 days**	**Tue 12/6/22**	**Wed 5/3/23**		
107		**5.2. Define Covered Activities**	**107 days**	**Tue 12/6/22**	**Wed 5/3/23**		
116		**5.3. Existing Conditions**	**103 days**	**Thu 5/4/23**	**Mon 9/25/23**		
123		**5.4. Define Biological Goals and Objectives**	**177 days**	**Wed 8/9/23**	**Thu 4/11/24**		
135		**5.6 & 5.7. Habitat Suitability & Take Assessment**	**176 days**	**Thu 9/19/24**	**Thu 5/22/25**		**9/27/23: Combined 5.6 & 5.7**
136		**Prepare Draft Memo**	**98 days**	**Thu 9/19/24**	**Mon 2/3/25**	**27**	
137		Prepare FWS Draft	9 days	Thu 9/19/24	Tue 10/1/24		
138		EAHCP Staff Review	5 days	Wed 10/2/24	Tue 10/8/24	137	
139		Revise Draft and Provide to FWS	13 days	Wed 10/9/24	Fri 10/25/24	138	
140		FWS Review	9 days	Mon 10/28/24	Thu 11/7/24	139	
141		FWS Meeting	0 days	Thu 11/7/24	Thu 11/7/24	140	
142		Revise to Address FWS Comments	62 days	Fri 11/8/24	Mon 2/3/25	141	1/20/25: Extended period to prepare habitat-based assessment
143		EAHCP Staff Review	10 days	Tue 2/4/25	Mon 2/17/25	141,142	
144		Revise to Address EAHCP Staff Comments	5 days	Tue 2/18/25	Mon 2/24/25	143	
145		Committees & USFWS Review	16 days	Wed 2/26/25	Wed 3/19/25	144FS+	
146		ICF & EAHCP Staff Address Comments	39 days	Thu 3/20/25	Tue 5/13/25	145	
147		IC Final Review	7 days	Wed 5/14/25	Thu 5/22/25	146	
148		**5.5 Preliminary Conservation Strategy Changes**	**161 days**	**Thu 10/10/24**	**Thu 5/22/25**		
149		ICF Team Receive Conservation Measures Subcommittee Recommendations	0 days	Thu 10/10/24	Thu 10/10/24		
150		ICF Prepare Draft Memo	50 days	Thu 10/10/24	Wed 12/18/24	149,134	Goal is CM subcommittee report by 10/10
151		EAHCP Staff Review	14 days	Thu 12/19/24	Tue 1/7/25	150	
152		ICF Prepare Revised Memo	20 days	Wed 1/8/25	Tue 2/4/25	151	
153		EAHCP Staff Distribute to Committees & USFWS	0 days	Fri 2/7/25	Fri 2/7/25	152FS+	
154		Committees & USFWS Review	20 days	Mon 2/10/25	Fri 3/7/25	153	
155		ICF & EAHCP Staff Address Comments	30 days	Mon 3/10/25	Fri 4/18/25	154	
156		IC Final Review & Directive to Proceed	24 days	Mon 4/21/25	Thu 5/22/25	155	
157		**5.8. Monitoring and Adaptive Management Plan**	**118 days**	**Tue 2/25/25**	**Thu 8/7/25**		
158		ICF Prepare Draft Memo	33 days	Tue 2/25/25	Thu 4/10/25	144	1/20/25: Adjusted to start earlier to save approx 6 weeks schedule
159		EAHCP Staff Review	15 days	Fri 4/11/25	Thu 5/1/25	158	
160		ICF Prepare Revised Draft Monitoring Plan Memo	15 days	Fri 5/2/25	Thu 5/22/25	159	
161		Committees & USFWS Review	16 days	Fri 5/23/25	Fri 6/13/25	160	
162		ICF & EAHCP Staff Address Comments	32 days	Mon 6/16/25	Tue 7/29/25	161	
163		IC Final Review	7 days	Wed 7/30/25	Thu 8/7/25	162	
164		**5.9. Preliminary Costs**	**84 days**	**Mon 6/16/25**	**Thu 10/9/25**		
165		ICF Prepare Draft Preliminary Costs	25 days	Mon 6/16/25	Fri 7/18/25	161	
166		EAHCP Staff Review	10 days	Mon 7/21/25	Fri 8/1/25	165	
167		ICF Prepare Revised Draft Memo	10 days	Mon 8/4/25	Fri 8/15/25	166	
168		Permittees Review	15 days	Mon 8/18/25	Fri 9/5/25	167	EAA Board Presentation?
169		ICF & EAHCP Staff Address Comments	17 days	Mon 9/8/25	Tue 9/30/25	168	
170		IC Final Review & Directive to Proceed	7 days	Wed 10/1/25	Thu 10/9/25	169	
171		**6. Modeling Projections**	**518 days**	**Thu 10/6/22**	**Mon 9/30/24**		
192		**Phase 3: Document**	**185 days**	**Mon 9/8/25**	**Fri 5/22/26**		
193		**7. Draft HCP**	**185 days**	**Mon 9/8/25**	**Fri 5/22/26**		
194		**Draft HCP Ch. 1-7**	**95 days**	**Mon 9/8/25**	**Fri 1/16/26**		
195		ICF Prepare Draft Amended HCP Ch. 1-7	30 days	Mon 9/8/25	Fri 10/17/25	122,168	1/20/25: Added 2 weeks
196		EAHCP Staff Review	20 days	Mon 10/20/25	Fri 11/14/25	195	1/20/25: added 1 week
197		ICF Revise Draft Amended HCP Ch. 1-7	20 days	Mon 11/17/25	Fri 12/12/25	196	1/20/25 added 1 week
198		Committees and USFWS Review Draft HCP Ch. 1-7	25 days	Mon 12/15/25	Fri 1/16/26	197	1/20/25: added 1 week over holidays
199		**First Administrative Draft HCP**	**35 days**	**Mon 1/19/26**	**Fri 3/6/26**		
200		ICF Prepare First Admin Draft HCP	25 days	Mon 1/19/26	Fri 2/20/26	198	
201		EAHCP Staff & Implementing Committee Review	10 days	Mon 2/23/26	Fri 3/6/26	200	
202		**Second Administrative Draft HCP**	**30 days**	**Mon 3/9/26**	**Fri 4/17/26**		
203		ICF Prepare Second Admin Draft	15 days	Mon 3/9/26	Fri 3/27/26	201	
204		Committees and USFWS Review	15 days	Mon 3/30/26	Fri 4/17/26	203	
205		**Screen Check Draft HCP**	**15 days**	**Mon 4/20/26**	**Fri 5/8/26**		
206		ICF Prepare Screen Check Draft	10 days	Mon 4/20/26	Fri 5/1/26	204	
207		EAHCP Staff & Implementing Committee Review	5 days	Mon 5/4/26	Fri 5/8/26	206	
208		**Final Draft HCP**	**10 days**	**Mon 5/11/26**	**Fri 5/22/26**		
209		ICF Prepare Final Draft HCP	5 days	Mon 5/11/26	Fri 5/15/26	207	
210		Implementing Committee Review and Sign-off	5 days	Mon 5/18/26	Fri 5/22/26	209	
211		**Phase 4: USFWS Review and Decision**	**620 days**	**Mon 9/8/25**	**Fri 1/21/28**		
212		**8. Draft NEPA**	**430 days**	**Mon 9/8/25**	**Fri 4/30/27**		
213		**Memorandum of Understanding**	**25 days**	**Mon 9/8/25**	**Fri 10/10/25**		
214		Draft MOU	10 days	Mon 9/8/25	Fri 9/19/25	195SS	
215		EAHCP and USFWS Review	10 days	Mon 9/22/25	Fri 10/3/25	214	
216		Final MOU	5 days	Mon 10/6/25	Fri 10/10/25	215	
217		MOU Execution	0 days	Fri 10/10/25	Fri 10/10/25	216	
218		**Draft EIS**	**291 days**	**Mon 1/19/26**	**Mon 3/1/27**		
219		Prepare Notice of Intent	14 days	Mon 1/19/26	Thu 2/5/26	198	



ID		Task Mode	Task Name	Duration	Start	Finish	Predeces	Notes
220			Publish Notice of Intent in Federal Register	0 days	Sat 3/7/26	Sat 3/7/26	219FS+	
221			Public Scoping	30 edays	Sat 3/7/26	Mon 4/6/26	220	
222			**Proposed Action & Alternatives**	**60 days**	**Tue 4/7/26**	**Mon 6/29/26**		
223			Draft Description of Proposed Action and Alternatives	20 days	Tue 4/7/26	Mon 5/4/26	221	
224			USFWS Review	15 days	Tue 5/5/26	Mon 5/25/26	223	
225			Final Description of Proposed Action and Alternatives	10 days	Tue 5/26/26	Mon 6/8/26	224	
226			USFWS Review	15 days	Tue 6/9/26	Mon 6/29/26	225	
227			**First Admin Draft EIS**	**70 days**	**Tue 6/30/26**	**Mon 10/5/26**		
228			Prepare First Draft EIS	50 days	Tue 6/30/26	Mon 9/7/26	226,210	
229			USFWS Review	20 days	Tue 9/8/26	Mon 10/5/26	228	
230			**Second Admin Draft EIS**	**35 days**	**Tue 10/6/26**	**Mon 11/23/26**		
231			Prepare Second Draft EIS	20 days	Tue 10/6/26	Mon 11/2/26	229	
232			USFWS Review	15 days	Tue 11/3/26	Mon 11/23/26	231	
233			**Third Admin Draft EIS**	**25 days**	**Tue 11/24/26**	**Mon 12/28/26**		
234			Prepare Third Draft EIS	15 days	Tue 11/24/26	Mon 12/14/26	232	
235			USFWS Review	10 days	Tue 12/15/26	Mon 12/28/26	234	
236			**Public Draft EIS**	**25 days**	**Tue 12/29/26**	**Mon 2/1/27**		
237			Draft EIS	15 days	Tue 12/29/26	Mon 1/18/27	235	
238			USFWS Review	10 days	Tue 1/19/27	Mon 2/1/27	237	
239			Final Public Draft EIS and NOA in Federal Register	20 days	Tue 2/2/27	Mon 3/1/27	238,243	
240			Public Comment Period (60 days)	60 edays	Mon 3/1/27	Fri 4/30/27	239	
241			**9. ITP Application**	**10 days**	**Tue 11/24/26**	**Mon 12/7/26**		
242			ICF Prepare ITP Application	5 days	Tue 11/24/26	Mon 11/30/26	232	
243			EAHCP Review and Submit to USFWS	5 days	Tue 12/1/26	Mon 12/7/26	242	
244			**12. Final HCP**	**190 days**	**Mon 5/3/27**	**Fri 1/21/28**		
245			**Response to Comments**	**40 days**	**Mon 5/3/27**	**Fri 6/25/27**		
246			ICF Prepare Draft Response to Comments on HCP	20 days	Mon 5/3/27	Fri 5/28/27	240	
247			EAHCP Staff Review	10 days	Mon 5/31/27	Fri 6/11/27	246	
248			Final Response to Comments to USFWS	10 days	Mon 6/14/27	Fri 6/25/27	247	
249			**Final HCP**	**55 days**	**Mon 6/28/27**	**Fri 9/10/27**		
250			ICF Prepare Admin Final HCP	20 days	Mon 6/28/27	Fri 7/23/27	248	
251			EAHCP Permittees Review	20 days	Mon 7/26/27	Fri 8/20/27	250	
252			ICF Prepare Final HCP	10 days	Mon 8/23/27	Fri 9/3/27	251	
253			Implementing Committee Review & Sign-Off	5 days	Mon 9/6/27	Fri 9/10/27	252	
254			**13. Final NEPA**	**190 days**	**Mon 5/3/27**	**Fri 1/21/28**		
255			**Response to Comments**	**40 days**	**Mon 5/3/27**	**Fri 6/25/27**		
256			ICF Prepare Draft Responses to Comments on EIS	20 days	Mon 5/3/27	Fri 5/28/27	240	
257			USFWS Review all Responses to Comments	10 days	Mon 5/31/27	Fri 6/11/27	256	
258			ICF Prepare Final Responses to Comments	10 days	Mon 6/14/27	Fri 6/25/27	257	
259			**Final EIS and Draft Record of Decision**	**75 days**	**Mon 9/13/27**	**Sun 12/26/27**		
260			ICF Prepare Admin Final EIS	20 days	Mon 9/13/27	Fri 10/8/27	258,253	
261			USFWS Review	15 days	Mon 10/11/27	Fri 10/29/27	260	
262			ICF Prepare Final EIS	10 days	Mon 11/1/27	Fri 11/12/27	261	
263			USFWS Review Final EIS	10 days	Mon 11/15/27	Fri 11/26/27	262	
264			Publish Final EIS	0 days	Fri 11/26/27	Fri 11/26/27	263	
265			30-day Period	30 edays	Fri 11/26/27	Sun 12/26/27	264	
266			**Findings, ROD, and Permit**	**40 days**	**Mon 11/29/27**	**Fri 1/21/28**		
267			ESA Findings, Biological Opinion, and ROD	8 wks	Mon 11/29/27	Fri 1/21/28	264	
268			Permit Issuance	0 days	Fri 1/21/28	Fri 1/21/28	267	
269			Phase 6: Inter-Local Agreements	365 edays	Mon 12/7/26	Tue 12/7/27	243	



Appendix F7 | **Biological Goals and Objectives Recommended for the Permit Renewal**

Memorandum

To:	Scott Storment, EAHCP Program Manager
From:	Christa Kunkel, Kyle Sullivan, Ed Oborny, Brad Littrell, Casey Williams, Matt Pintar, BIO-WEST Lucas Bare, ICF
Date:	March 7, 2024
Re:	**Revised Recommended Biological Goals and Objectives for the Permit Renewal**

1. Introduction

The Edwards Aquifer Habitat Conservation Plan (EAHCP) Permittees are preparing an application to renew their Incidental Take Permit with the U.S. Fish and Wildlife Service (USFWS). This planning process involves reassessing existing EAHCP components and identifying necessary changes to the EAHCP to include in an amended plan that will be part of the application package to USFWS. The purpose of this memorandum is to recommend new Biological Goals and Objectives for the EAHCP permit renewal. A prior version of this memorandum was distributed for review on November 15, 2023. Attachment 1 includes all comments received on the prior version of the memo, along with comment responses to the main issues raised by commenters.

Biological Goals and Objectives make up the core of a Habitat Conservation Plan's (HCP's) conservation strategy. As such, they are a focal point of the USFWS guidance for developing HCPs in the *Habitat Conservation Planning and Incidental Take Processing Handbook* (HCP Handbook) (USFWS and National Marine Fisheries Service [NMFS] 2016). Generally, Biological Goals and Objectives address each Covered Species; they can also address groups of Covered Species with similar habitat or life history traits. Biological Goals are typically broad statements that indicate future desired conditions for Covered Species or their habitat. Biological Objectives are clear, measurable statements of how the HCP will achieve its Biological Goals. The Biological Goals and Objectives recommended in this memorandum would fully replace what are called "long-term biological goals and objectives" in the current EAHCP (see Section 4.1 of the EAHCP). The original long-term Biological Goals and Objectives were developed in 2011–2012, prior to USFWS (and NMFS) updating the HCP Handbook. The new proposed Biological Goals and Objectives are designed to align better with the HCP Handbook and reflect the many lessons learned from monitoring and adaptive management under the current EAHCP. These new proposed Biological Goals and Objectives also incorporate input from EAHCP stakeholders.

2. Process for Developing Biological Goals and Objectives

The HCP Handbook defines and provides guidance for developing Biological Goals and Objectives that support an effective conservation strategy, align with the overarching purpose and vision of an HCP, and contribute to species' recovery and large-scale conservation efforts. According to the HCP Handbook, Biological Goals broadly define the overall desired future conditions of an HCP and provide guiding principles for the HCP's conservation strategy. Biological Goals should comprise four elements: a key subject of concern, an attribute of interest for that subject, the target condition for the attribute, and the action or effort proposed to achieve the target.

Biological Objectives describe the specific, incremental steps that should be taken to achieve the Biological Goals. When developing Biological Objectives, USFWS recommends considering five criteria, captured by the SMART acronym, to ensure that objectives are effective and focused. Based on these five criteria, objectives should be:

Specific—describing what, who, when, and where

Measurable—able to monitor progress toward the goal

Achievable—the permittee can control or affect the outcome

Result-oriented—descriptive of an outcome

Time-fixed—can be accomplished within the permit term

Goals are descriptive and broad, while objectives are measurable and result-oriented. Together, the goals and objectives of an HCP create an integrated framework that provides the foundation for determining conservation strategies, assessing monitoring effectiveness, and evaluating the success of actions taken.

As part of the permit renewal process, input from stakeholders was requested during workshops and EAHCP subcommittee meetings that convened to review and provide specific recommendations for Biological Goals and Objectives. Listen and Learn workshops were held in 2022 to provide stakeholders with information on the permit renewal process and an opportunity to engage and offer input on elements of the permit renewal. Listen and Learn workshop #2 (August 30, 2022) focused on Biological Goals and Objectives. Meeting attendees provided feedback on recommendations for Biological Goals and Objectives to be considered in the permit renewal.

The EAHCP convened two subcommittees to provide input to this process. Biological Goals and Biological Objectives subcommittees guided development of the goals and objectives for the permit renewal, respectively. The Biological Goals Subcommittee, consisting of Science Committee and Stakeholder Committee members, convened four times, from February 2023 to March 2023. It reviewed the current EAHCP goals and current USFWS HCP guidance and provided recommendations for Biological Goals for the permit renewal. The Biological Objectives Subcommittee, consisting of members of the Science Committee and species experts, was divided into topical areas that focused on one of three species groups: aquatic vegetation/fish, salamanders, and macroinvertebrates. Convening periodically from March 2023 to May 2023, it reviewed the EAHCP's existing Biological Objectives and proposed goals from the Biological Goals Subcommittee and considered options for updating the Biological Objectives for the permit renewal. The Biological Objectives Subcommittee's recommendations were established using baseline-scientific data and included revisions for species-specific objectives.

Other input considered in developing these Biological Goals and Objectives included the following:

- Recommendations in the *Edwards Aquifer Habitat Conservation Plan Permit Options Report* (ICF 2020), which included restructuring the Biological Goals and Objectives to align better with the HCP Handbook and increasing the flexibility in the Biological Objectives for fountain darter (*Etheostoma fonticola*) habitat, based on lessons learned from habitat management and monitoring.
- Advanced comments received from USFWS on Biological Goals and Objectives and recovery criteria for Comal Springs dryopid beetle (*Stygoparnus comalensis*), Comal Springs riffle beetle (*Heterelmis comalensis*), fountain darter, Peck's cave amphipod (*Stygobromus pecki*), Texas blind salamander (*Eurycea rathbuni*), and Texas wild-rice (*Zizania texana*).

The next steps in the process are for USFWS to review the proposed new Biological Goals and Objectives and provide comments and recommendations to EAHCP staff members. After that, EAHCP staff members will discuss USFWS comments and revise the Biological Goals and Objectives to incorporate their feedback, as appropriate. As the permit renewal process moves forward, the Biological Goals and Objectives will be used to guide the update and addition of Conservation Measures and monitoring protocols.

3. Recommended Biological Goals

The following Biological Goals were developed by the Biological Goals Subcommittee, with minor editing and renumbering for clarity.[1] We recommend that the Permittees consider these goals for inclusion in the amended EAHCP. Each of the recommended goals has as its subject Covered Species populations or the habitat or ecosystems upon which Covered Species populations depend.

Goal 1: Conserve the quality and quantity of springflow and maintain suitable ecosystems within the Plan Area to provide for the persistence and resiliency of the Covered Species.

Goal 2: Conserve habitats to support resilient populations of Texas blind salamander, Comal Springs dryopid beetle, Peck's cave amphipod, and Edwards Aquifer diving beetle (*Haidoporus texanus*) in the Plan Area.

Goal 3: Conserve habitats to support resilient Comal Springs riffle beetle populations in the Plan Area.

Goal 4: Conserve San Marcos Springs and river habitats and resilient San Marcos salamander (*Eurycea nana*) populations in the Plan Area.

Goal 5: Conserve and manage resilient Texas wild-rice populations in the San Marcos Springs and river system.

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[1] The Biological Goals Subcommittee report is available here: https://www.eahcprenewal.org/wp-content/uploads/2023/05/PREAHCP-Biological-Goals-Subcommittee-Report%E2%80%93Full-2023.pdf.

Goal 6: Conserve habitats, diverse native submerged aquatic vegetation (SAV) assemblages, and resilient fountain darter populations in the Comal and San Marcos Springs and river system.

Goal 7: Promote community engagement and awareness of the EAHCP, support land and water conservation, and mitigate anthropogenic stressors and natural disturbances within the Plan Area that will benefit the Covered Species.

4. Recommended Biological Objectives

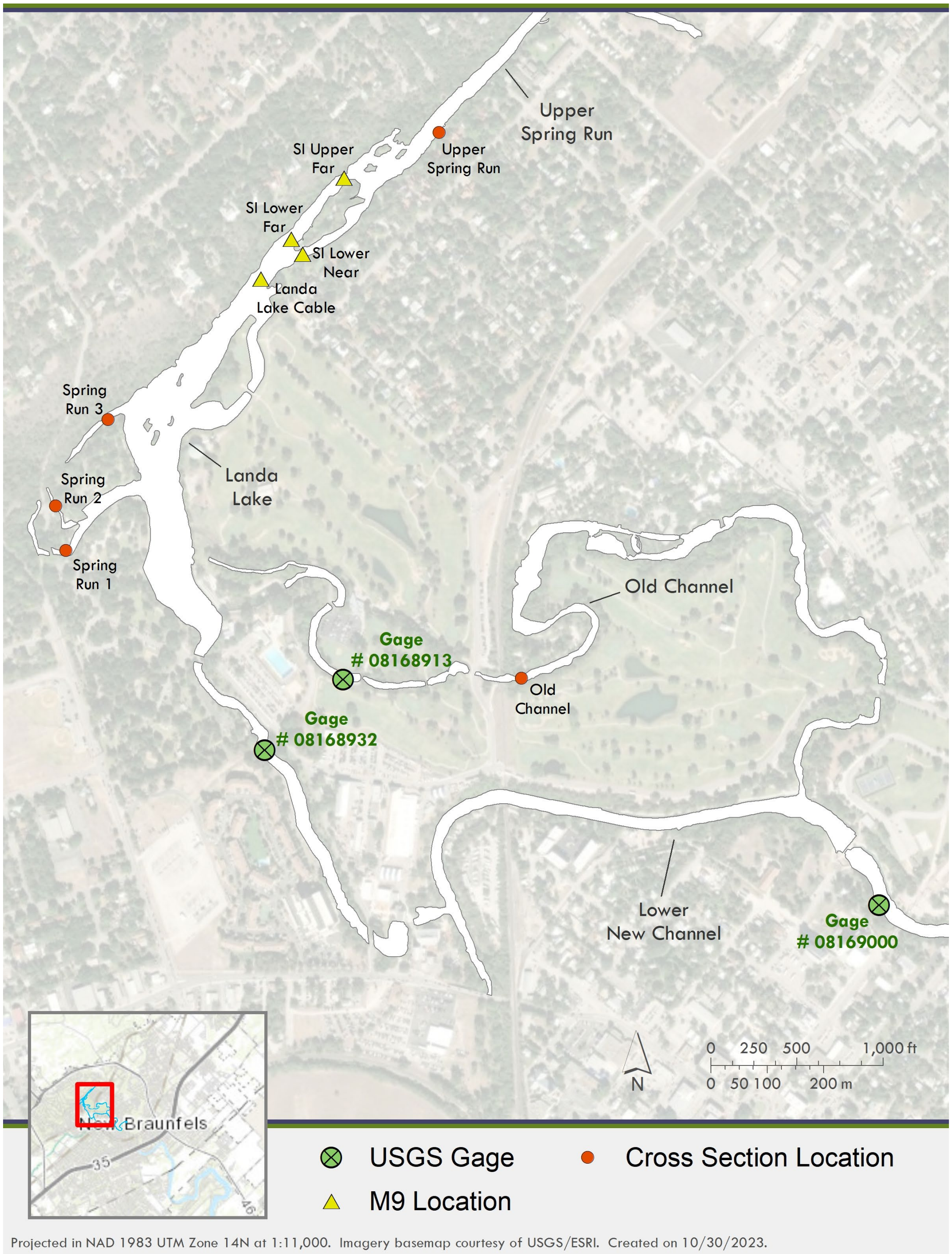
The Biological Objectives below considered input provided by the Biological Objectives Subcommittee, along with biological monitoring data collected over two decades. The objectives include measurable and achievable steps to realize the Biological Goals above. Given its broad scope and multi-faceted nature, objectives for Goal 7 have not yet been developed; therefore, this goal is not addressed further in this memo. We will consider the elements of Goal 7 when evaluating Conservation Measures to be recommended for inclusion in the renewed EAHCP.

4.1 Objectives for Springflow

Adequate springflow in both Comal and San Marcos Springs is vital to providing appropriate conditions for all of the Covered Species. The quality and quantity of available habitat is strongly influenced by springflow in dynamic spring ecosystems. Springflow objectives will continue to serve as a Biological Objective in the next iteration of the EAHCP. The springflow objectives presented below address Goal 1 directly. They also support Goals 2–6 for all Covered Species, which are addressed primarily through protection of habitat.

As part of biological monitoring, trends in river discharge are evaluated using U.S. Geological Survey (USGS) mean daily flow data in the Comal River (gage #08169000) and San Marcos River (gage #08170500). These data are used to compare monthly variations in mean daily discharge during the current monitoring year and assess recent 5-year trends. Springflow is also monitored with transects and an acoustic doppler (M9) at nine transect stations in Comal Springs, one USGS station in the New Channel (gage #08168932), and one USGS station in the Old Channel (gage #08168913) to assess spatial variation in discharge and percent contributions to total river discharge (Figure 1).

We recommend two springflow objectives for both the Comal and San Marcos systems, a minimum objective and a long-term objective. The Comal Springs minimum springflow objective links water temperature and surface habitat for fountain darter, and macroinvertebrate populations in Comal Springs habitats, which should concurrently protect subsurface habitats for subterranean species. The long-term springflow objectives link system-level springflow discharge magnitudes with long-term biological monitoring data. In addition, the Comal system will continue to employ the flow-split strategy from Landa Lake to the Old Channel by referencing real-time flow measured at the Old Channel (gage #08168913) to minimize and mitigate potential impacts during low-flow conditions. This Conservation Measure, further described in the EAHCP, is designed to preserve quality fountain darter habitat within the Old Channel over the course of the permit term. This will continue to be accomplished by providing an appropriate level of flow variability during average to high flow conditions and allowing proportionally more water to flow through the Old Channel versus the New Channel during periods of critically low flows.



Notes: SI = Spring Island. M9 is an acoustic doppler device used by the Edwards Aquifer Authority to measure springflow. Springflow calculations associated with USGS gage 08168710 described herein are based on discharge measured at USGS gage 08169000.

Figure 1. Locations of USGS Gages and Transect Stations Used to Measure Discharge in Comal Springs/River

For the San Marcos system, both objectives are based on system-level springflow discharge due to a lack of discharge data at finer spatial scales within the spring system. The San Marcos Springs objective links physical habitat availability and diverse submerged aquatic vegetation (including Texas wild-rice), wetted area, and water temperature to fountain darters, salamanders, and Texas wild-rice populations in San Marcos Springs, which should concurrently protect subsurface habitats for subterranean species. The San Marcos long-term objective links San Marcos system-level springflow discharge magnitudes with long-term biological monitoring data.

Minimum and long-term springflow objectives were based on USGS mean daily springflow data for Comal Springs (gage #08168710) and San Marcos Springs (gage #08170000), which are both quantified using discharge data for the Comal River (gage #08169000) and San Marcos River (gage #08170500). Specifically, springs discharges are calculated based on normalized flow observed at each river gage. When there is local runoff within the drainage, mean daily springflow for each gage is partitioned from inputs of the surrounding drainage using the baseflow index, separating the springs' baseflow from measured increases due to stormwater runoff.

4.1.1 Objectives for Minimum Springflow Discharge

Springflow objectives for the Comal and San Marcos systems are based on a 1-month average springflow calculated for a given year in tandem with a low-flow objective for all months.

4.1.1.1 Comal Springs

Calculations for the Comal Springs objective were made using springflow discharge measurements (cubic feet per second [cfs]) from eight of the nine biomonitoring stations (hereafter "station"; Old Channel station omitted) (2003–2023) (Figure 1) near the major springs and USGS mean daily springflow data for Comal Springs (gage #08168710 [calculated from gage #08169000, Figure 1]). The variation in station-level discharge in relation to system-level springflow conditions over a 1-month duration was assessed. For analysis, 30-day springflow moving averages (cfs) were calculated for each monitoring event at each station to approximate flow conditions at Comal Springs (gage #08168710) over a 1-month duration to establish an objective threshold.

Predictive modeling was conducted to define an objective criterion that facilitated surface habitat redundancy, which was aimed at identifying a 30-day springflow average magnitude where discharge was greater than 0 cfs at the Spring Island and Spring Run 3 stations. The term *redundancy* in this document is used to describe ecological units that occur multiple times, such as more than one area of habitat, more than one vegetation structure (complex and simple), or more than one species of vegetation. Redundancy facilitates resiliency by having multiple ecological unit buffers against the loss of any one unit.

A multilevel linear model was fit to predict spatial variation in spring discharge as a function of springflow conditions over a 1-month duration. Springflow discharge at eight of the nine stations (Old Channel omitted) per event was the response variable and 30-day springflow average at each event was the predictor variable. Regression coefficients were estimated for each station by including station as a group-level predictor (i.e., random effects) that allowed their intercepts and slopes to vary randomly. Prior to model fitting, 30-day springflow average was z-score transformed to help with model convergence and coefficient interpretation (Gelman and Hill 2007). Model performance was assessed based on root mean squared error (RMSE), R^2, and the proportion of R^2

that was explained by the station-level random effects. Prediction error was further assessed using 10-fold cross-validation repeated five times to estimate the model's ability to generalize to out-of-sample data (Hastie et al. 2009).

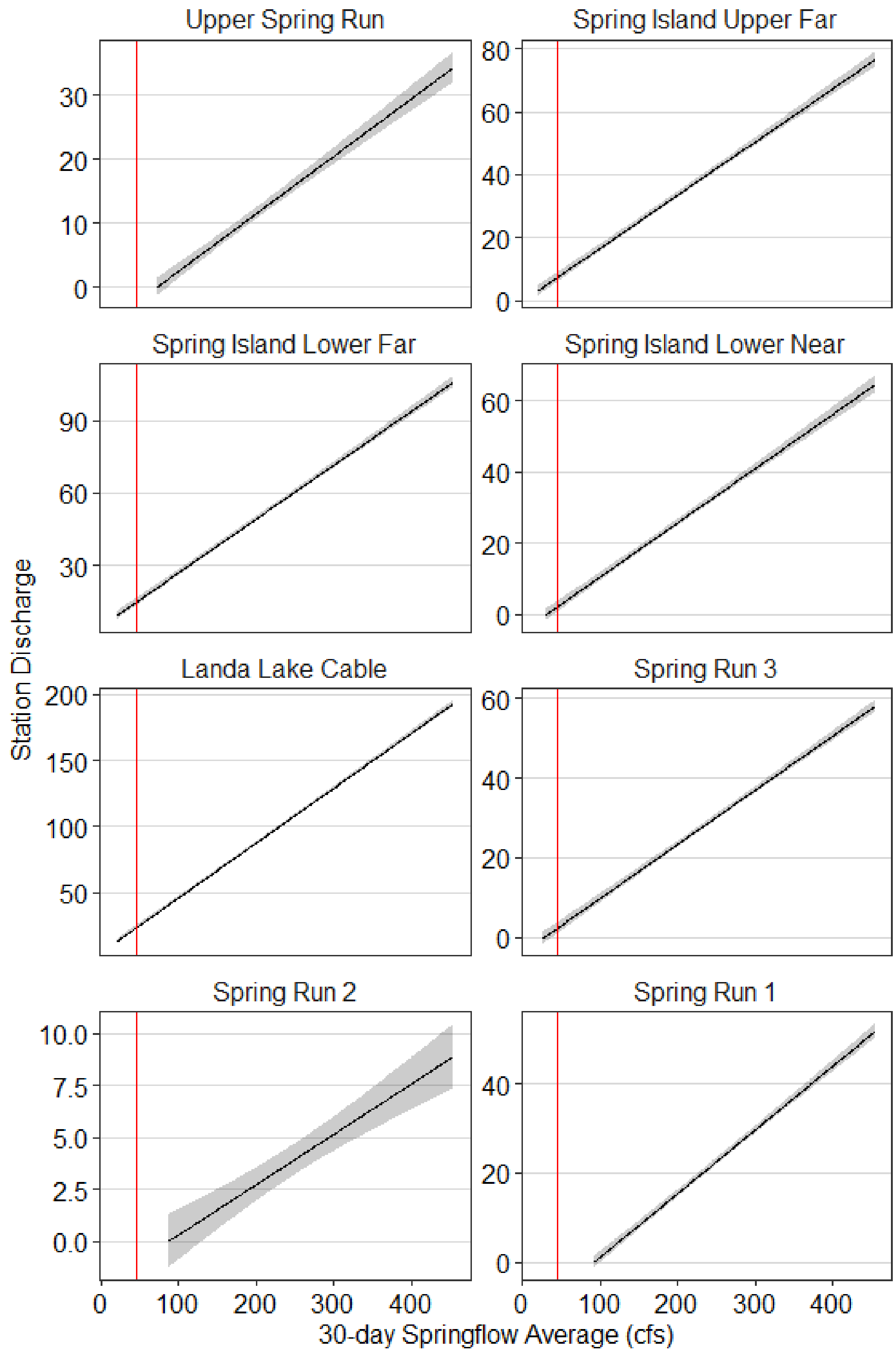
Spring discharge across stations ranged from 0 to 166 cfs (mean = 30 cfs) and 30-day spring average ranged from 64 to 454 cfs (mean = 225 cfs). The fitted multilevel model accurately predicted station-level discharge and explained a large proportion of variation in discharge, indicating high performance (RMSE = 5.04; R^2 = 0.98). Station-level R^2 contribution was 0.69, which also demonstrated that the random effects contributed to most of the variation explained by the model. Repeated cross-validation results showed mean RMSE (± standard error) and R^2 (± standard error) were very similar for both training (5.02 ± 0.02 and 0.97 ± 0.001, respectively) and test (5.24 ± 0.15 and 0.97 ± 0.001, respectively) datasets, suggesting high generalization performance. Summaries of estimated regression coefficients for each station are presented in Table 1.

Table 1. Summary of Multilevel Linear Model Coefficients among Discharge Stations in Comal Springs and River, Excluding the Old Channel Discharge Station

	Coefficients	
Station	**Intercept**	**Springflow**
Upper Spring Run	13.43	10.20
Spring Island Upper Far	37.16	19.15
Spring Island Lower Far	53.99	25.28
Spring Island Lower Near	29.05	17.29
Landa Lake Cable	96.54	47.00
Spring Run 3	26.36	15.39
Spring Run 2	3.25	2.74
Spring Run 1	18.45	16.16

High performance and ability to generalize to new data suggest that this model should be a reliable quantitative tool for selecting a 30-day average springflow objective. To do this, discharge (± standard error) was predicted through interpolation and extrapolation at each station with a 30-day average springflow ranging from 20 to 455 cfs using the fitted model. The threshold for this objective was selected at a 30-day average springflow magnitude where Spring Island stations and Spring Run 3 were predicted to remain flowing.

Predictions across all stations are displayed in Figure 2. Based on the lower bounds of standard error estimates, all stations were predicted to remain flowing at a 30-day average springflow of approximately 130 cfs. Both Spring Island Near and Spring Run 3 were predicted to be flowing when the 30-day average springflow was approximately 40–45 cfs.



Notes: Solid lines and grey polygons represent line-of-best-fit and ±1 standard error, respectively; solid red lines denote the proposed 45 cfs objective threshold.

Figure 2. Fitted Predictions of Discharge as a Function of 30-day Average Springflow across Eight Stations in the Comal System

Based on this analysis and EAHCP biological monitoring and USGS data, the recommended Comal Springs objective is:

> **Objective 1.1, Comal Springs Discharge:** *Maintain mean monthly spring discharge at Comal Springs (gage #08168710) greater than or equal to 45 cfs for at least 11 months per calendar year. Maintain daily average springflow greater than or equal to 30 cfs. This will be quantified by using mean daily springflow data to calculate average springflow for each month per year.*

At 45 cfs, five of eight stations were predicted to remain flowing, with Upper Spring Run, Spring Run 1, and Spring Run 2 not flowing (Table 2). Infrequent excursions down to a 30-cfs daily average are included in the objective, based on the model predicting four of the eight total stations and two of the three Spring Island stations still flowing (i.e., Far stations). At this magnitude, Spring Run 3 is predicted to be near zero flow. However, springs along the deeper portion of the western shoreline of Landa Lake and around Spring Island are expected to continue to support Covered Species habitat conditions. This represents two of the three historically sampled Comal invertebrate study areas, which are strongholds for the Comal Springs riffle beetle. Additionally, 45 cfs is protective of suitable flow (30 cfs) through the Old Channel, which promotes surface habitat for the fountain darter. In August 2023, a minimum mean daily flow of 55 cfs was recorded at Comal Springs. Observations at 55 cfs support model predictions of wetted habitat for Comal Springs riffle beetle at 45 cfs. Most spring runs throughout the system were largely dry from July through September, while Spring Island and Spring Run 3 remained 25–50% and 45–50% watered, respectively (BIO-WEST n.d.). Additionally, discharge through the Old Channel remained within the suitable range during the 2023 low-flow conditions.

Table 2. Fitted Predictions of Discharge (cfs) at the Proposed 30-day Average Springflow Objective Threshold of 45 cfs

	Predicted Discharge (± Standard Error)	
Station	**45 cfs**	**30 cfs**
Upper Spring Run	0.00	0.00
Spring Island Upper Far	7.34 (5.81–8.86)	4.81 (3.19–6.43)
Spring Island Lower Far	14.61 (13.04–16.17)	11.27 (9.60–12.93)
Spring Island Lower Near	2.12 (0.60–3.63)	0.00
Landa Lake Cable	23.34 (21.74–24.94)	17.13 (15.42–18.83)
Spring Run 3	2.39 (0.95–3.83)	0.35 (0.00–1.87)
Spring Run 2	0.00	0.00
Spring Run 1	0.00	0.00

4.1.1.2 San Marcos Springs

The evaluation methodology for the San Marcos Springs objective focused on EAHCP monitoring and USGS gage data with support from predictive models where monitoring data were unavailable, and historical hydrology from San Marcos Springs gage #08170000 (calculated from USGS gage #08170500; San Marcos River at San Marcos). Multiple studies have linked monitoring data to springflow or developed predictive models to determine water temperatures at varying low flows, coverage of SAV and Texas wild-rice at varying low flows, and wetted area necessary for San Marcos salamanders and vegetation (Edwards Aquifer Area Expert Science Subcommittee [EAAESS] 2009;

Hardy 2009). An objective criterion was selected that facilitated surface habitat redundancy, which was aimed at identifying a 30-day moving-average springflow magnitude where modeled water temperatures were not projected to exceed fountain darter reproductive thresholds and where wetted area for SAV and quality habitat for fountain darters and San Marcos salamanders remained at levels projected to support recovery once springflow increases (EAAESS 2009; BIO-WEST n.d.).

Based on EAHCP biological monitoring, USGS data, and water temperature modeling, the recommended San Marcos Springs objective is:

> **Objective 1.2, San Marcos Springs Discharge:** *Maintain mean monthly discharge at San Marcos Springs (gage #08170000) greater than or equal to 60 cfs for at least 11 months per calendar year. Maintain daily average springflow greater than or equal to 45 cfs. This will be quantified by using mean daily springflow data to calculate average springflow for each month per year.*

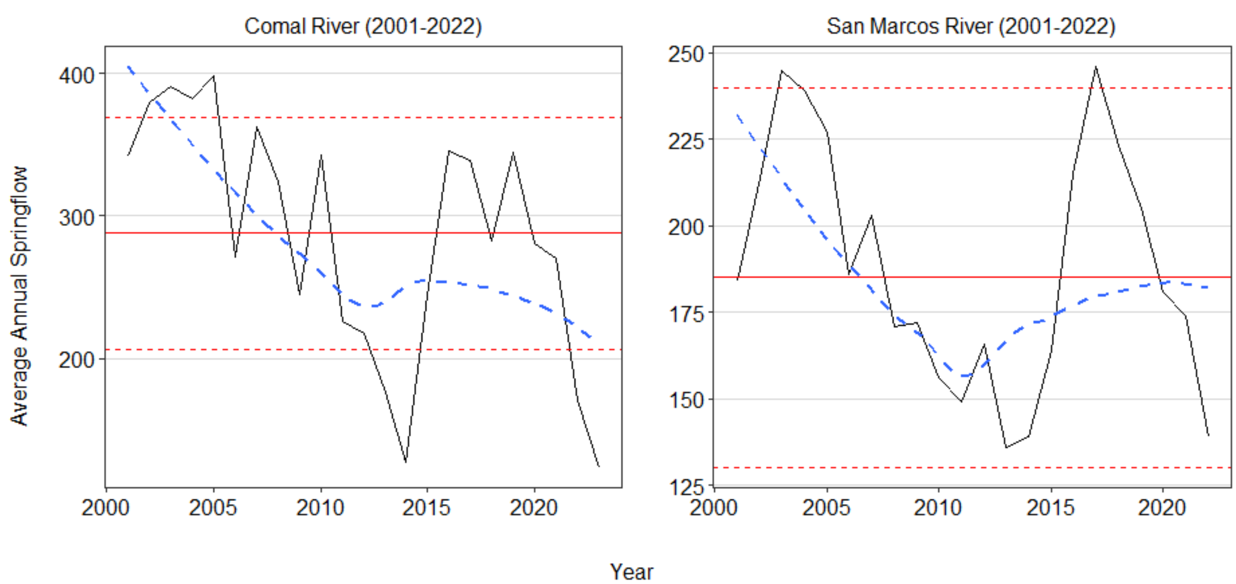
In 2023, mean daily flow was consistently below 80 cfs during August and September, with minimum mean daily flow reaching 66 cfs in August. At springflow nearing 60 cfs, algae build up and siltation increased at Spring Lake, SAV coverage in Long-Term Biological Goal (LTBG) reaches decreased with reductions in wetted width, and reproductive temperature thresholds were exceeded below Spring Lake. Although the EAAESS 2009 models predicted water temperature would remain below 25 degrees Celsius (°C), temperature exceedances above 25°C did occur during the low-flow conditions in 2023. Exceedances occurred from Spring Lake Dam (20 total days) to below Interstate (I-35) (40 total days), ranging from 4 to 8 hours in duration. The greatest impact on SAV coverage was a reduction in Texas wild-rice, yet overall Texas wild-rice areal coverage remained above the minimum 8,000 m^2 persistent coverage (see Section 4.6, *Objectives for Texas Wild-Rice*). Despite increased siltation in Spring Lake and reductions in wetted width at Spring Lake Dam, San Marcos salamanders were observed during all critical period and routine fall surveys which supports the persistence of quality habitat at conditions near 65 cfs. Likewise, fountain darter demonstrated resiliency through maintaining or exceeding long-term densities despite temperature exceedances and reduced SAV (BIO-WEST n.d.).

Infrequent reductions to the 45-cfs daily average are included in the objective because this flow still likely maintains suitable water temperatures, wetted area, and SAV habitat availability. At 45 cfs, water temperatures are likely to exceed the aforementioned reproductive threshold for short durations from Spring Lake Dam downstream to I-35, but it is anticipated that fountain darter densities would still approximate the long-term mean (BIO-WEST n.d.). At 45 cfs, SAV located in the thalweg of the river is preserved for fountain darter habitat. Thus, 45 cfs protects fountain darter reproductive capacity in reaches where fountain darter abundance is greatest.

4.1.2 Objectives for Long-Term Springflow Discharge

It is acknowledged that 2023 conditions have not been observed for an extended period (11 months) and that conditions would likely further degrade at 45 cfs in the Comal system and 60 cfs in the San Marcos system. This uncertainty was inherent in the original EAHCP springflow objectives and remains with the proposed revisions above. Hence, long-term springflow objectives were also developed to limit the occurrence and duration of minimum discharge conditions when compared to existing objectives. This reduction in duration combined with more intermittent periods between disturbance events provides opportunities for habitat conditions to recover throughout the systems, whereas increased duration of extreme low-flow events under the existing objectives limits opportunities for recovery.

Biological Objectives for long-term springflow in the Comal and San Marcos systems were quantified by relating discharge data to biological data. Over the duration of long-term monitoring (2001–2022), hydrology at Comal Springs (gage #08168710) and San Marcos Springs (gage #08170000) has varied annually, representing low-flow, high-flow, and average-flow conditions from year to year. As a simple example, Figure 3 displays a time series of average annual discharge during the monitoring period relative to one standard deviation from the long-term mean for Comal (1999–2022) and San Marcos (1994–2022) Springs. Values where springflow was greater or less than one standard deviation from the mean represent annual averages above and below typical variation, respectively. As such, it is reasonable to suggest monitoring over this time period has characterized both typical and atypical flow conditions. Biological responses show resistance and resilience during and after all low-flow years observed. For example, fountain darter populations do not show substantial declining trends in density or recruitment following periods of low flow (see Section 4.7, *Objectives for Fountain Darter*). In addition, literature supports the observation that positive and negative effects of flow on ecosystem function often involve time lags; it is recommended that these objectives use a rolling statistic to account for lag effects (Gido et al. 2010; Humphries et al. 2014). Short-term low-flow disturbance events would very likely be less severe if optimal conditions occurred prior, whereas extended durations of low flows may increase the risk of ecosystem degradation (Gido et al. 2010; Stanley et al. 2010).



Notes: The dashed blue lines denote fitted LOESS smooth functions. Dashed red lines denote one standard deviation from the long-term mean (solid red line).

Figure 3. Variation in Average Annual Springflow in the Comal and San Marcos Rivers from 2001 to 2022

Based on this, long-term objectives were quantified according to two temporal resolutions. The first objective is based on a minimum 3-year moving-average annual springflow from 2001 to 2022, which was 174 cfs in Comal Springs and 136 cfs in San Marcos Springs. The reason for using 3-year moving averages is to limit long-term environmental degradation due to low flows. The second long-term objective is based on the existing long-term (50 years) modeled average discharge objectives, which was 225 cfs in Comal Springs and 140 cfs in San Marcos Springs (Edwards Aquifer Authority [EAA] 2012).

Based on this, recommended long-term system-level objectives include:

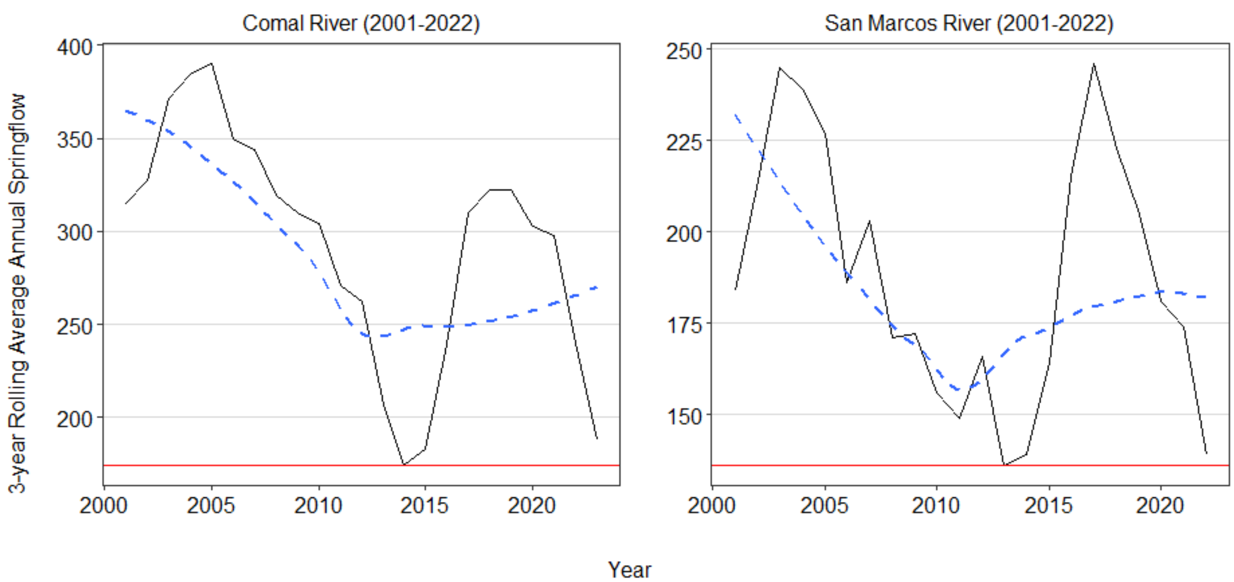
Objective 1.3, Long-Term Comal Springs Discharge:

- *Maintain a 3-year moving-average annual Comal Springs discharge (gage #08168710) above 174 cfs.*
- *Maintain a 30-year long-term average Comal Springs discharge above 225 cfs.*

Objective 1.4, Long-Term San Marcos Springs Discharge:

- *Maintain a 3-year moving-average annual San Marcos Springs discharge (gage #08170000) above 136 cfs.*
- *Maintain a 30-year long-term average San Marcos Springs discharge above 140 cfs.*

Figure 4 displays temporal trends in 3-year moving-average annual springflow from 2001 to 2022 for both systems relative to their respective thresholds. The minimum 3-year moving-average annual springflow occurred in 2014 in the Comal River and in the San Marcos River.



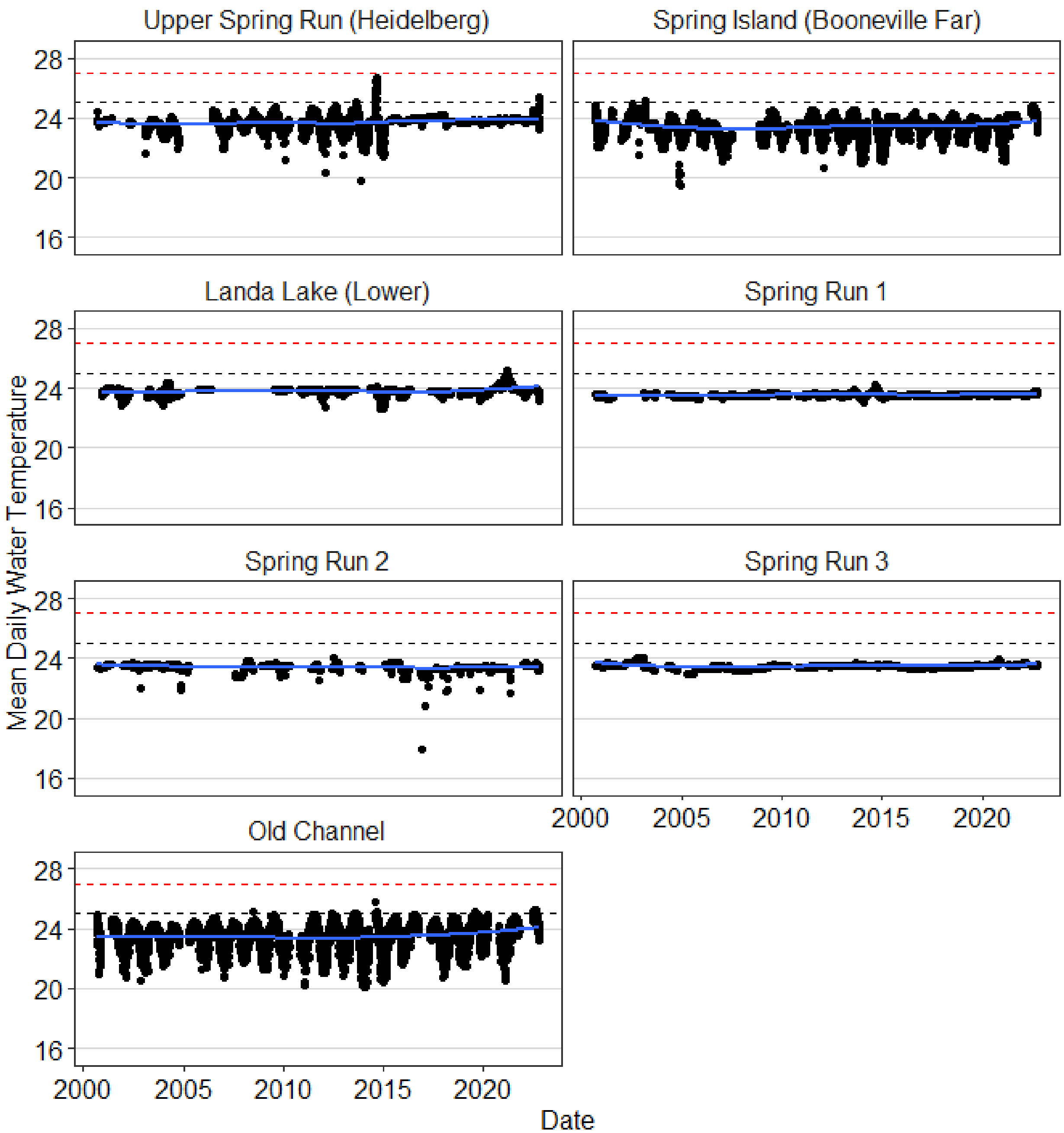
Notes: The dashed blue lines denote fitted LOESS smooth functions and the solid red lines represent the minimum observed.

Figure 4. Long-Term 3-year Average Annual Springflow Trends in the Comal and San Marcos Rivers

4.1.3 Objectives for Water Quality

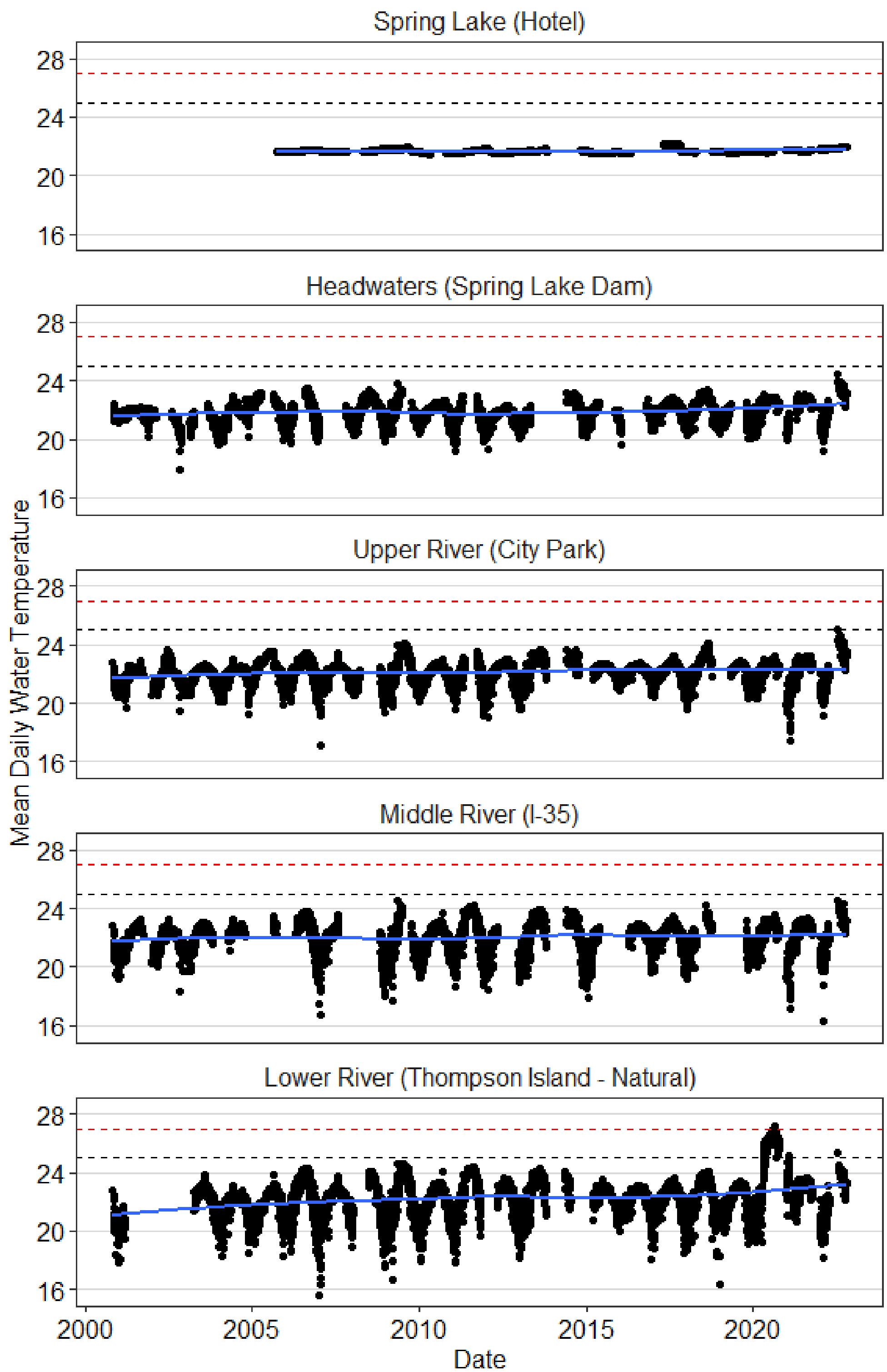
Another important reason to maintain adequate springflow is that it influences the water quality that characterizes both spring systems. Individual environmental attributes such as water temperature, dissolved oxygen, carbon dioxide, and turbidity can influence population dynamics of Covered Species; however, springflow is the driving variable for those environmental parameters. As such, maintaining appropriate springflow in both spring systems should protect suitable water quality for the Covered Species. In addition, we recommend the evaluation of water quality objectives for both systems be based on water temperature due to its direct linkage to springflow and its known physiological effects on Covered Species and their ability to fulfill life history requirements.

Water temperature objectives were established for the Covered Species in both systems and were focused on the springs and the longitudinally downstream thermally stable reaches. Maintaining a 25°C water temperature in surface habitats is considered protective of fountain darters, Comal Springs riffle beetles, and San Marcos salamanders. The temperature objective supports the maximum optimal temperature requirements for fountain darter larval (≤25°C) and egg (≤26°C) production (McDonald et al. 2007). In long-term persistent water temperature experiments (Nowlin et al. 2017), Comal Springs riffle beetles were relatively sensitive to increased temperatures when compared to the other elmid species examined in that study. Comal Springs riffle beetles exhibited around 20% greater mortality when temperatures were elevated to 26°C, and increased metabolic stress was documented at 30°C. This temperature objective is also considerably below the critical thermal maximum for the San Marcos salamander: 35.8°C and 37.3°C for juveniles and adults, respectively (Berkhouse and Fries 1995). It is assumed that water temperature in the aquifer will remain extremely stable, as evidenced by the measurements conducted over the past 20 years in the immediate spring orifices or bottom of Landa Lake and Spring Lake, respectively (Figures 5 and 6).



Notes: The solid blue lines denote fitted LOESS smooth functions. The dashed black line and dashed red line denote the 25°C and 27°C objective thresholds, respectively.

Figure 5. Mean Daily Water Temperature at Stations Chosen for Measuring Biological Objectives in the Comal Springs and River System from 2001 to 2022



Notes: The solid blue lines denote fitted LOESS smooth functions. The dashed black line and dashed red line denote the 25°C and 27°C objective thresholds, respectively.

Figure 6. Mean Daily Water Temperature at Stations Chosen for Measuring Biological Objectives in the San Marcos Springs and River System from 2001 to 2022

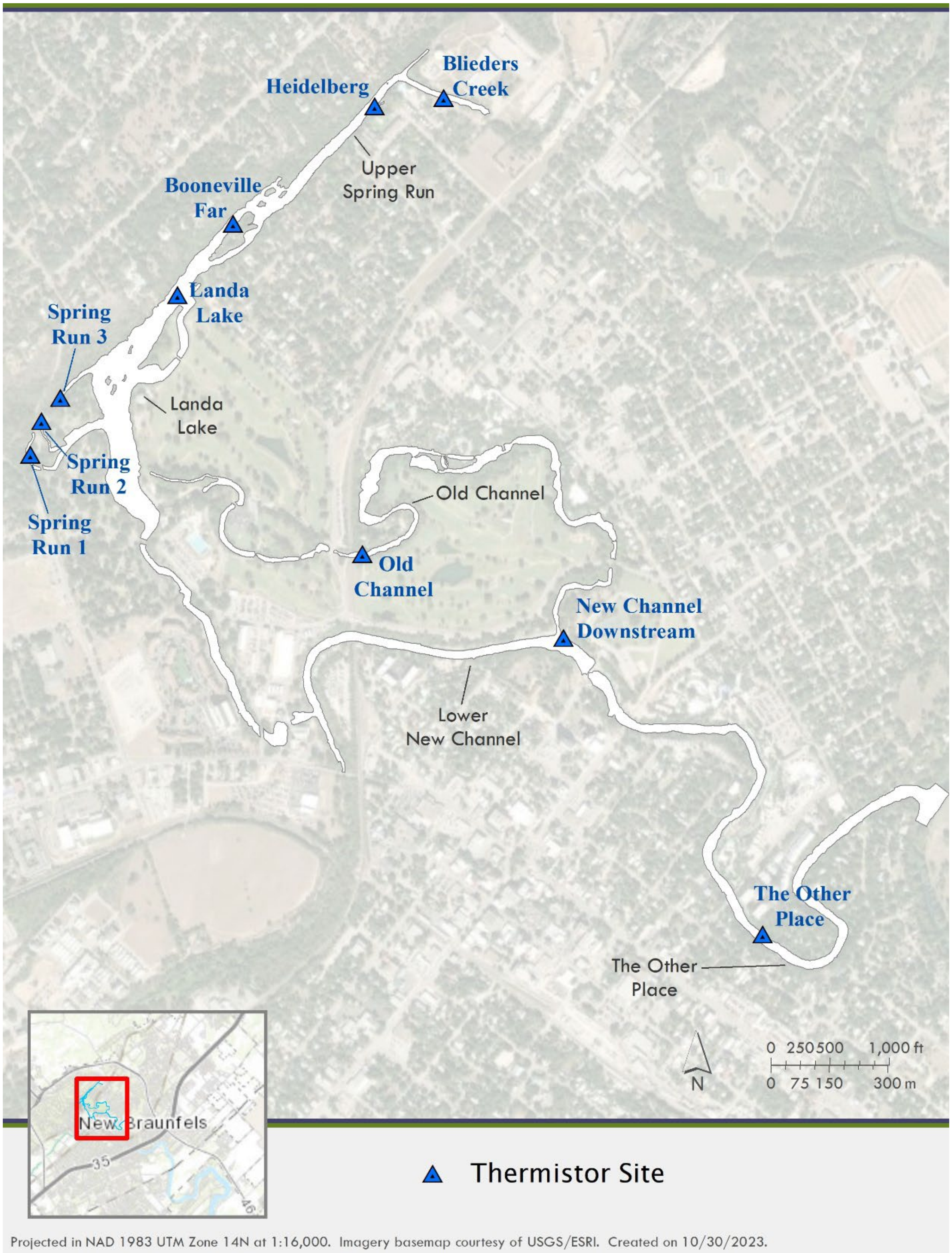
As part of biological monitoring, trends in water temperature are evaluated using temperature data loggers (HOBO Tidbit v2 Temp Loggers) at multiple permanent stations in the Comal (n = 13 stations) and San Marcos (n = 11 stations) systems. Data loggers are anchored in surface habitats near the substrate and record water temperature every 10 minutes. Each logger is downloaded at regular intervals and preprocessed prior to any analysis to remove potential measurement errors (e.g., discontinuities, ascending drift). Data based on 4-hour intervals are then used to assess spatial variation in water temperature compared with maximum optimal temperature requirements for fountain darter larval and egg production.

We recommend that water quality objectives aim to help maintain suitable thermal conditions for Covered Species that utilize subterranean and/or surface habitats. As such, two objectives are proposed for spring habitats and riverine habitats farther downstream per system due to their inherent differences in water temperature variability. Objectives will be measured using the mean daily water temperature calculated, based on 4-hour interval data at select stations, which are spatially representative of spring and riverine habitats, facilitating habitat redundancy to support population resiliency for Covered Species. Stations selected for the Comal system include Upper Spring Run (Heidelberg), Spring Island (Booneville Far), Landa Lake (lower station), Spring Run 1–3, and Old Channel (Figure 7). For the San Marcos system, stations selected include Spring Lake (Hotel), Headwaters (Spring Lake Dam), Upper River (City Park), Middle River (I-35), and Lower River (Thompson Island Natural) (Figure 8). Based on this, recommended water temperature objectives include:

> **Objective 1.5, Comal Springs and River Water Quality:** *Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C within Upper Spring Run, Spring Island, Spring Run 1–3, and Landa Lake. Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C for more than 50% of the days per year and less than or equal to 27°C within the Old Channel.*

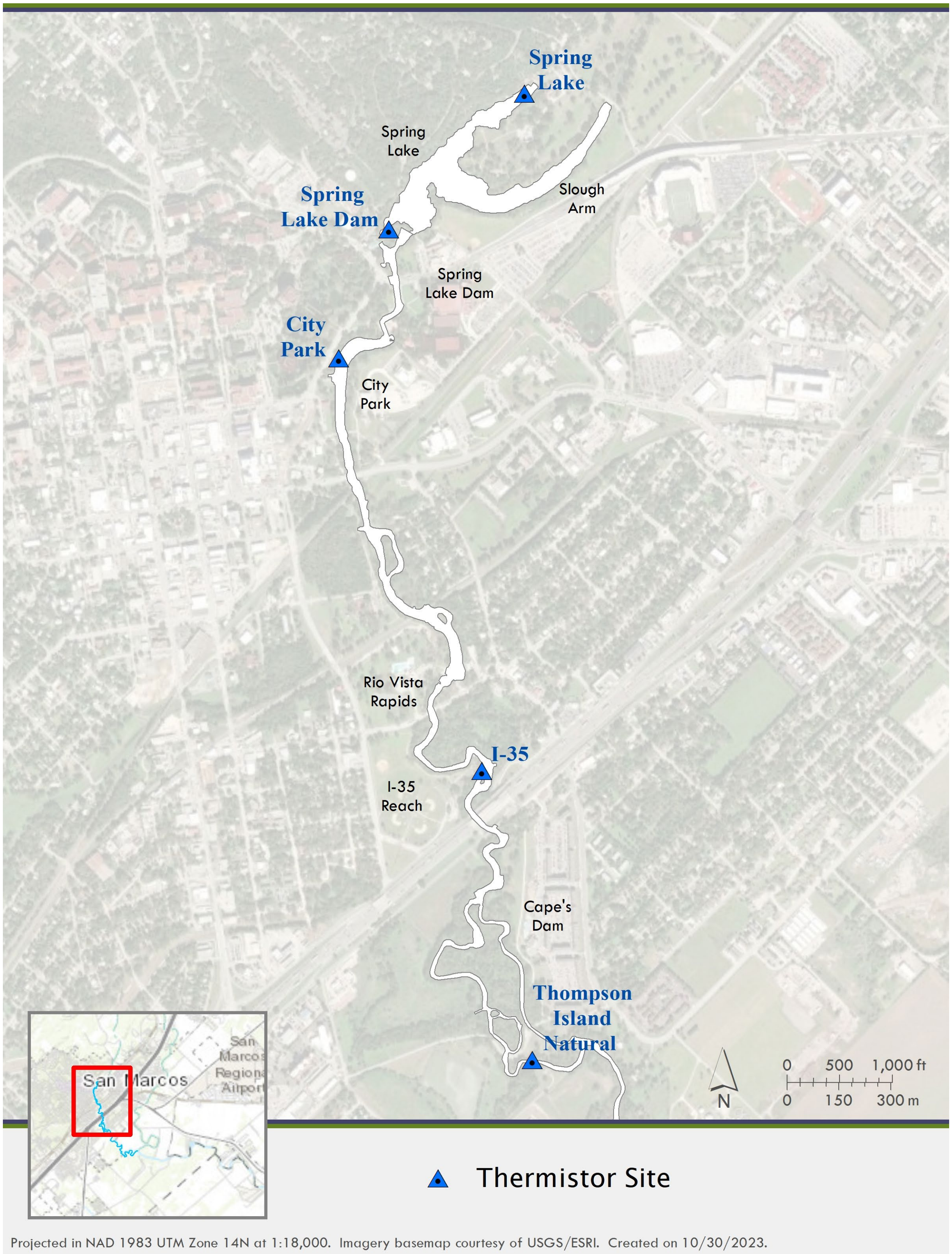
> **Objective 1.6, San Marcos Springs and River Water Quality:** *Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C within Spring Lake. Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C for more than 50% of the days per year and less than or equal to 27°C within the Headwaters, Upper River, Middle River, and Lower River.*

The proposed water temperature objectives are based on specific recommendations provided by USFWS for the Draft Recovery Plan for the Edwards Aquifer species. To exemplify how these objectives would be assessed, Figures 5 and 6 demonstrate temporal trends in water temperature for each station relative to their respective thresholds. Mean daily water temperature in spring habitats exceeded 25°C one or more days at Upper Spring Run (2013, 2014, 2022), Spring Island (2003), and Landa Lake (2021). The maximum percentage for the number of days per year when water temperature was greater than 25°C was 26% at Old Channel (Figure 5). In the San Marcos, mean daily water temperature never exceeded 25°C at Spring Lake, Headwaters, or Middle River. Water temperature at Upper River was greater than 25°C one day in 2022 (less than 1%). At Lower River, the cumulative percent of days in which mean daily water temperature exceeded 25°C was 2.8% which occurred in 2020, 2021, and 2022 (Figure 6).



Notes: Selected stations for analysis were Heidelberg (Upper Spring Run), Booneville Far (Spring Island), Landa Lake, Spring Run 1–3, and Old Channel.

Figure 7. Thermistor Station Locations throughout the Comal Springs and River System



Notes: Selected stations for analysis were Spring Lake, Spring Lake Dam (Headwaters), City Park (Upper River), I-35 (Middle River), Thompson Island Natural (Lower River).

Figure 8. Thermistor Station Locations throughout the San Marcos Springs and River System

It is acknowledged that other water quality constituents, such as contaminants, conductivity, turbidity, and pH, are factors that might affect the Covered Species. However, no quantifiable objectives are proposed for dissolved oxygen or other water quality attributes because these cannot be directly manipulated and managed. Adequate springflow is the driving variable for environmental parameters such as water temperature, dissolved oxygen, carbon dioxide, and turbidity. Due to the direct linkage between springflows and these water quality attributes, maintaining appropriate springflows (as met by the proposed objectives) is assumed protective of suitable water quality within both spring systems.

Although there is no objective for other water quality parameters, monitoring for these constituents (e.g., contaminants, dissolved oxygen, conductivity, turbidity, pH) will continue. Presently, the EAA manages six real-time water quality stations, monthly discrete sampling, low-flow water quality monitoring, and ancillary monitoring conducted by EAA Aquifer Sciences. The EAHCP, in coordination with EAA, will continue to promote best management practices over the watershed while conducting extensive water quality monitoring activities. Furthermore, existing programs in the EAHCP will continue to monitor sensitive areas under critical flow periods.

4.2 Objectives for Aquifer Species

Among the petitioned and endangered species to be covered in the permit renewal EAHCP, two are presumed to rely entirely on aquifer habitats: Texas blind salamander and Edwards Aquifer diving beetle. The Texas blind salamander has been documented in only eight well, spring, or cave locations in and near San Marcos, Texas. The Edwards Aquifer diving beetle has been collected in Comal and San Marcos Springs. However, collection of these species is rare and surface survival is low. For example, the Edwards Aquifer diving beetle has been collected only 28 times since 2003 in both spring systems (BIO-WEST n.d.). As such, demographic-specific analyses are not possible due to low abundances of these aquifer species recorded during the long-term monitoring period (2001–2022).

Biological Objectives for these two species are focused on conserving aquifer habitats and protecting water quality by maintaining suitable springflow and water temperature to ensure population resiliency (Goal 2). Therefore, the objectives in Section 4.1, *Objectives for Springflow*, support the Biological Goal for these species.

4.3 Objectives for Aquifer Species with Surface Utilization

Peck's cave amphipod and Comal Springs dryopid beetle occur in Comal Springs system headwaters and spring upwelling areas. Comal Springs dryopid beetle has been collected in the San Marcos Springs system but is more commonly found in the Comal Springs system. Both species are subterranean and rely on aquifer environments; however, both species occupy surface habitats in the Comal system. Both species are collected using drift nets in Comal Spring Runs 1, 3, and 7. They can also be found on wood throughout Landa Lake or on cotton lures. However, Peck's cave amphipod is more commonly collected than Comal Springs dryopid beetle in drift net sampling, with a total collection of 78 individuals since 2003 (BIO-WEST n.d.). Demographic-specific analyses are limited for each species due to low abundances recorded from non-targeted monitoring since 2001.

Biological Objectives for the Peck's cave amphipod and Comal Springs dryopid beetle are focused on conserving both aquifer and surface habitats by maintaining suitable springflow and water temperature to ensure population resiliency (Goal 2). Therefore, the objectives in Section 4.1, *Objectives for Springflow*, support the Biological Goal for these species.

4.4 Objectives for Comal Springs Riffle Beetle

Comal Springs riffle beetle is an aquatic beetle endemic to the springs of the Edwards Aquifer. This species occupies unembedded, gravelly spring areas in Comal Springs and has occasionally been observed in the Hotel reach of San Marcos Springs. Since 2004, the EAA has conducted regular monitoring of Comal Springs riffle beetle by sampling three areas (Spring Run 3, Landa Lake western shoreline, and Spring Island) in the Comal Springs system using the Cotton Lure standard operating procedure (EAA 2017a).

We recommend that the evaluation methodology for an abundance-specific Biological Objective seek to examine results from a system-level (across study reaches) perspective, exclusively using count data for adults. We also recommend that basis for criteria be made using data from 2013–2022 due to incongruent methods for selecting sample locations compared to 2004–2012. Lures were set in areas with quality habitats that were previously found to have high abundances from 2004–2012. From 2013–2022, lure locations varied more spatially and were also set in areas known to harbor lower beetle abundances. Based on this, data from 2013–2022 are most likely more representative of the different habitats that are available within Comal Springs and therefore should provide estimates of abundance that better generalize the overall population.

The abundance-based Biological Objective for adult Comal Springs riffle beetle was quantified according to two parameters: 1) central tendency, a value for which the results will tend to, and 2) dispersion, how far typical values range from the mean. Calculations were based on parameters from the normal distribution, mean (i.e., central tendency; μ), and standard deviation (i.e., dispersion; σ), which were used to establish objective thresholds at one standard deviation below the mean ($\mu - \sigma$). This threshold was chosen to approximate time periods when abundance is lower than the average distance from the mean, providing proximal measurements of potential system degradation.

Quantification of this objective was based on relative abundance, indexed as beetle counts per lure (counts/lure). Relative abundances were first used to calculate average counts/lure for each sampling event (n = 31 events). These averages were then used to calculate a long-term mean and standard deviation (Table 3).

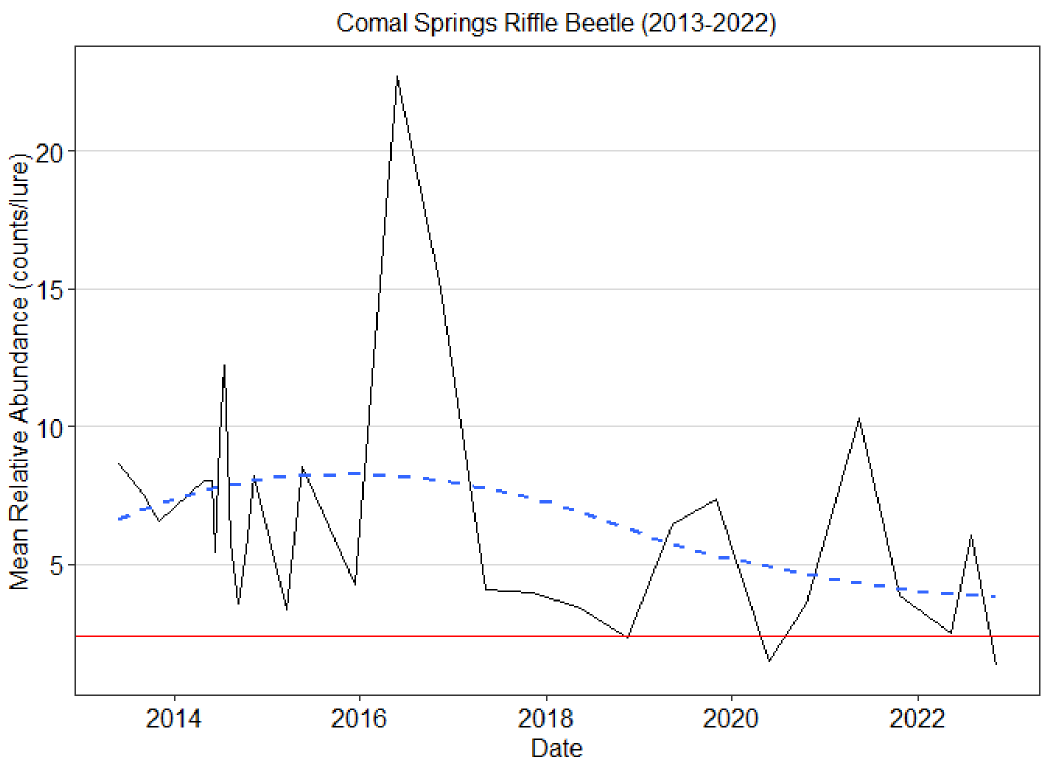
Table 3. Mean and Standard Deviation Calculations of Adult Comal Springs Riffle Beetle Counts/Lure in Comal Springs and Recommended Threshold for This Objective

Parameter	Estimate
Mean (μ)	6.7
Standard deviation (σ)	4.3
Recommended threshold for objective: One standard deviation below the mean ($\mu - \sigma$)	2.4

Biological Objectives to support conserving resilient Comal Springs riffle beetle populations (Goal 3) are focused on conserving both surface and subsurface habitats by maintaining suitable springflow and water temperature at Comal and San Marcos Springs (Section 4.1, *Objectives for Springflow*) and the following abundance objective in Comal Springs:

> **Objective 3.1, Comal Springs Riffle Beetle Relative Abundance:** *Mean Comal Springs riffle beetle relative abundance should not fall below 2.4 counts/lure for a minimum of three sampling events covering a 12-month period, as measured at long-term biological monitoring areas (Landa Lake, Western Shoreline, Spring Island, Spring Run 3).*

To exemplify how this system-level population objective would be assessed, Figure 9 displays temporal trends in mean relative abundance of Comal Springs riffle beetle compared to the objective threshold of 2.4 counts per lure. Mean relative abundance was lower than the proposed threshold at three events (10%) from 2013 to 2022; it never fell below it for more than one consecutive event.



Notes: The dashed blue lines denote fitted Loess smooth functions and the solid red lines represent one standard deviation below the mean.

Figure 9. Long-Term Trends in Mean Relative Abundance of Comal Springs Riffle Beetle

In addition to analyzing the relative abundance per lure, it is also important to protect the spatial distribution of Comal Springs riffle beetle. Therefore, a second objective was quantified based on likelihood of occurrence, which represents apparent occupancy, the proportion of lures that Comal Springs riffle beetle were detected. The response variable is a relative likelihood rather than a probability due to the fact that the true occurrence states are confounded by imperfect detection (MacKenzie et al. 2006). For this objective, likelihood of occurrence was first calculated for each sampling event as the number of lures where ≥1 beetle was detected divided by the total number of lures sampled across all sites. Likelihood of occurrence per event was then used to calculate a long-term mean and standard deviation (Table 4).

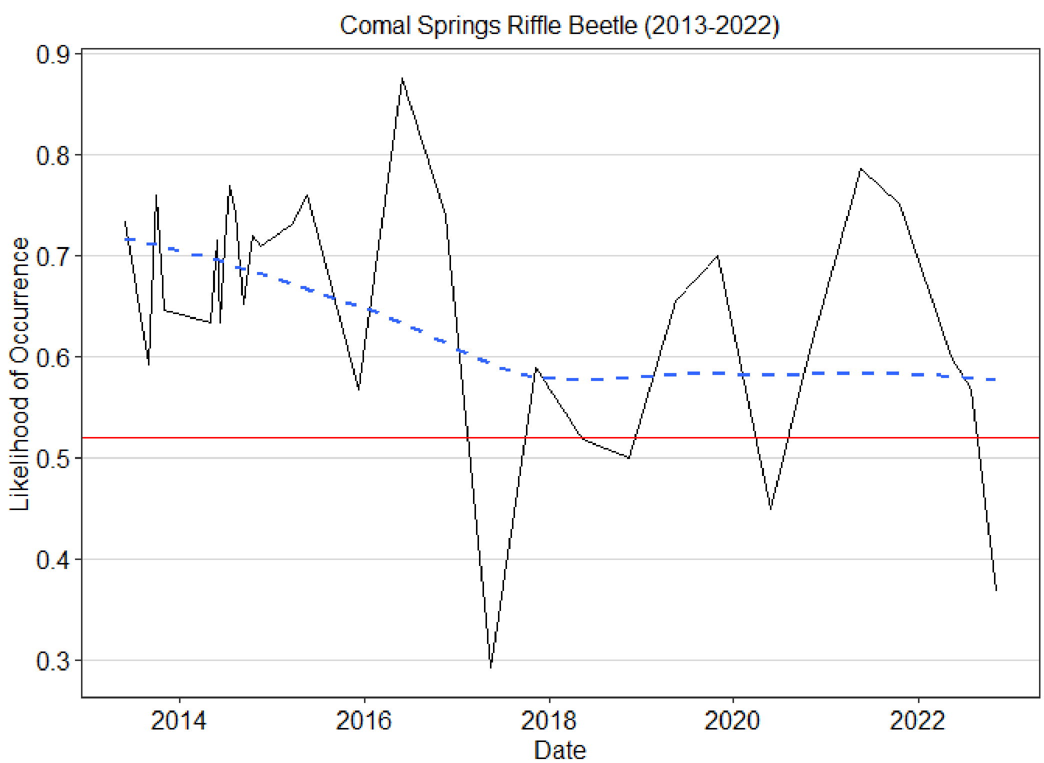
Table 4. Mean and Standard Deviation Calculations of Comal Springs Riffle Beetle Likelihood of Occurrence in Comal Springs and the Threshold for This Objective

Parameter	Comal
Mean (μ)	0.65
Standard deviation (σ)	0.13
Recommended threshold for objective: One standard deviation below the mean (μ – σ)	0.52

Based on this, a system-level objective aimed at conserving resilient Comal Springs riffle beetle populations (Goal 3) states:

> **Objective 3.2, Maintain Comal Springs Riffle Beetle Likelihood of Occurrence 0.52**. *Comal Springs riffle beetle likelihood of occurrence should not fall below 0.52 for a minimum of three sampling events covering a 12-month period.*

Figure 10 displays temporal trends in likelihood of occurrence of Comal Springs riffle beetle compared to the objective threshold of 0.52. Likelihood of occurrence was lower than the proposed threshold at four events (13%) from 2013–2022 and never fell below it for more than one consecutive sampling event.



Notes: The dashed blue lines denote fitted LOESS smooth functions, and the solid red line represents one standard deviation below the mean.

Figure 10. Long-Term Trends in Mean Likelihood of Occurrence of Adult Comal Springs Riffle Beetle

Due to the infrequent observations of Comal Springs riffle beetles in Spring Lake, this area was not included in the monitoring plan during the existing EAHCP. A quantifiable objective cannot be calculated because there has not been standardized monitoring via Cotton Lure standard operating procedure. However, it is recommended that monitoring of Comal Springs riffle beetle at the Hotel area of Spring Lake be incorporated into the monitoring plan in the EAHCP permit renewal and that an objective for Comal Springs riffle beetles in Spring Lake be evaluated as more data becomes available.

4.5 Objectives for San Marcos Salamander

The San Marcos salamander, found in Spring Lake and downstream of Spring Lake Dam, associates with rocky substrates around spring openings. Since 2001, San Marcos salamanders have been monitored at least twice per year at two sites within Spring Lake, Hotel Site and Riverbed Site, and at one site within the San Marcos River, Spring Lake Dam Site (BIO-WEST n.d.). Timed visual surveys in these three locations are conducted in quality habitat by recording the number of rocks turned and the number of salamanders observed. The National Academy of Sciences report and EAHCP Biological Objectives Subcommittee both raised concerns over the sampling methodology to calculate San Marcos salamander population metrics. As such, the project team did not use this long-term dataset to calculate density metrics. However, all three existing monitoring sites have demonstrated persistent occupancy of salamanders over the past 23 years. For example, a total of 5,154 salamanders with an average (±standard deviation) of 101.0 (±22.3) salamanders per 15-minute survey have been observed in the Hotel Reach. In the Riverbed Reach, 4,249 salamanders with an average of 83.3 (±23.4) salamanders per 15-minute survey have been observed. A total of 826 salamanders with an average of 16.2 (±7.8) salamanders per 15-minute survey have been observed in the Spring Lake Dam Reach. Consistently high salamander counts at each of these spatially diverse reaches demonstrate the presence of quality habitat. Quality surface habitat specific to these locations is defined as areas devoid of aquatic macrophytes that support clean, clear substrate conditions underneath approximately twelve to sixteen 8- to 12-centimeter-wide rocks per square meter (m^2). Subsurface use of these habitats in smaller rocks and gravels also occurs and further highlights the importance of maintaining silt-free environments.

Biological Objectives for San Marcos salamander focused on conserving areas with quality habitat demonstrated by persistent occupancy to ensure population resiliency. San Marcos salamanders from multiple size classes have occupied these quality habitats during every survey conducted in these three diverse locations over the past two decades. It is recommended that the evaluation methodology be aimed at helping maintain spatial redundancy of salamander habitat in spring and riverine environments. Therefore, separate Biological Objectives were quantified for the San Marcos Springs and River, based on two parameters: 1) central tendency, a value for which the results will tend to, and 2) dispersion, how far typical values range from the mean.

Calculations were based on monitoring data from 2001 to 2022 parameters from the normal distribution, mean (i.e., central tendency; μ), and standard deviation (i.e., dispersion; σ), which were used to establish objective thresholds at one standard deviation below the mean ($\mu - \sigma$). This threshold was chosen to approximate time periods when areas of quality habitat are lower than the average distance from the mean, providing proximal measurements of potential system degradation. Simulation analyses indicated observed habitat data did not satisfy the assumptions of normality.

That said, we believe parameters of the normal distribution still provide a useful characterization of central tendency and dispersion that is conceptually simple and easier to understand.

Objectives were quantified according to the total area of quality habitat at each site per monitoring event (n = 51 events). Quality habitat within the two most upstream riverine sites below Spring Lake Dam were combined by summing their areas into a single quantity per event. Total areas were then used to calculate long-term means and standard deviations for each site, which are presented in Table 5.

Table 5. Mean and Standard Deviation Calculations of Sampled Quality Habitat (m^2) for San Marcos Salamander at Three Sites and Thresholds for System-Level Objectives

	Sampled Site		
Parameter	**Hotel**	**Riverbed**	**Spring Lake Dam**
Mean (μ)	31.0	51.9	29.6
Standard deviation (σ)	7.63	21.6	15.8
Recommended thresholds for objective: One standard deviation below the mean (μ – σ)	23.3	30.3	13.7

Based on this information, the objectives that support conserving resilient San Marcos salamander populations (Goal 4) include the objectives for San Marcos Springs (Section 4.1, *Objectives for Springflow*) and the following habitat quality objective:

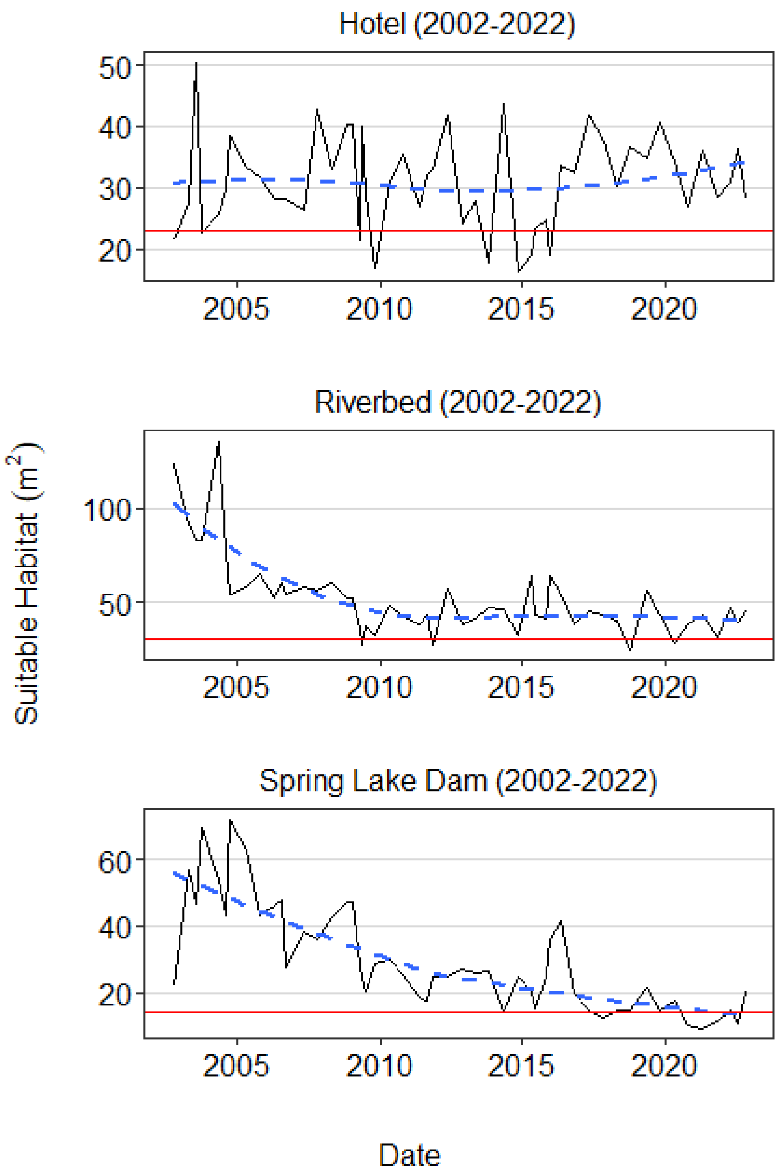
> **Objective 4.1*, San Marcos Salamander Habitat:** *Maintain total area of quality habitat above 23 m^2 at the Hotel site, above 30 m^2 at the Riverbed site, and above 14 m^2 at Spring Lake Dam. Areas of quality habitat should not fall below these values for a minimum of three sampling events covering a 12-month period.*
>
> * **Although habitat quality and protected area criteria are proposed, the San Marcos salamander biological monitoring program will be revised for the EAHCP permit renewal.**

Per recommendation of the Biological Objectives Subcommittee, an additional San Marcos salamander monitoring site at Diversion Springs will be incorporated into the long-term biological monitoring program, upon permit renewal. The inclusion of Diversion Springs as a fourth salamander monitoring area moving forward is supported by the number of San Marcos salamanders consistently observed in this location by USFWS San Marcos Aquatic Resources Center biologists. Following a few years of monitoring, it is anticipated that a habitat area objective at this fourth diverse location for the San Marcos salamander will be added to these interim criteria. To exemplify how these objectives will be assessed, Figure 11 displays temporal trends in sampled quality habitat for each site relative to their respective threshold. The threshold for quality habitat was lower than the proposed threshold at eight events (16%) at Hotel, four events (8%) at Riverbed, and five events (10%) at Spring Lake Dam. At Spring Lake Dam, quality habitat was below its proposed threshold one time during three consecutive events, which occurred from fall 2020 to fall 2021. Quality habitat was also below the threshold one time at Hotel for two consecutive events during sampling in 2014–2015.

Quality habitat in Spring Lake is dependent on human intervention from Meadows Center staff members and volunteer SCUBA divers to keep the Hotel and Riverbed sites free of aquatic macrophytes. Figure 11 highlights the consistency of this intervention since implementation of the

EAHCP. In addition, recreational activities for the general public are restricted in Spring Lake. Given the benefit that management in Spring Lake has on quality salamander habitat, it is recommended that all currently managed spring orifice locations in Spring Lake continue to be actively managed as a Conservation Measure to further enhance and protect quality San Marcos salamander habitat throughout Spring Lake.

In contrast, the Spring Lake Dam site is not actively maintained and has limited restrictions for the general public. A clear downward trend in Spring Lake Dam quality salamander habitat is evident in Figure 11. The downward trend involves more than just recreational impacts; expansion of aquatic macrophytes, such as Texas wild-rice, in this location have also led to increased sedimentation and reduction in quality salamander habitat. Active management in both the lake and the eastern spillway below Spring Lake Dam will be necessary as Conservation Measures to achieve this Biological Objective.



Notes: The dashed blue lines denote fitted LOESS smooth functions, and the solid red lines represent one standard deviation below the mean.

Figure 11. Long-Term Density Trends in Sampled Quality Habitat for San Marcos Salamander

4.6 Objectives for Texas Wild-Rice

Texas wild-rice coverage in the upper San Marcos River has greatly increased as a result of the EAHCP. Since implementation of the EAHCP in 2013, total areal coverage has increased from 4,561 m^2 in 2013 to a maximum of 17,235 m^2 in 2021, an almost fourfold increase. The areal coverage in 2021 was the highest ever recorded. This expansion was enhanced by restoration efforts that included active planting and by the lack of recreation during 2020 and 2021 due to COVID-19 restrictions. Texas wild-rice is a strong colonizer in the upper San Marcos River. It readily expands into new areas, often leading it to outcompete other SAV species. Thus, an objective was developed to balance the needs of Texas wild-rice while maintaining a diverse native SAV community. Monitoring of Texas wild-rice involves visually delineating discrete patches using kayak and collecting geospatial data for each patch. Geospatial data are then processed using GIS to construct polygons that represent discrete patches from which total areal coverage of Texas wild-rice can be quantified (EAA 2017b).

Population objectives were quantified by first determining persistent stands of Texas wild-rice over the course of the EAHCP. Summer full-system Texas wild-rice mapping data were collected from the most recent 10 years of monitoring (2013–2022) and converted to a presence/absence raster with a 25-centimeter spatial resolution. Pixel values were then summed to create a raster with values between 0 and 10, indicating years of presence per area, to demonstrate persistent coverage per location. This yielded 1,932 m^2 coverage across all 10 years. Extending persistence to 9–10 years increased coverage to 3,865 m^2; expanding persistence to 8–10 years increased coverage to 5,612.6 m^2. To illustrate how these Texas wild-rice persistent stands were assessed, Figure 12 displays temporal trends from Sewell Park to Hopkins over the course of EAHCP implementation through 2022.

Building upon persistent stands, overall Texas wild-rice areal coverage has varied between approximately 8,000 m^2 and 12,000 m^2 throughout the upper San Marcos River between 2016 and 2019, which are the years after active planting mostly stopped in reaches above I-35 and before the anomalous years during COVID-19 restrictions. This represents a period with less active control of the Texas wild-rice population while river recreation remained normal. Increasing areal coverage beyond the 5,600 m^2 of persistent stands protects the species' ability to sexually reproduce, which promotes genetic diversity and enhances resiliency. Furthermore, maintaining a spatial distribution with greater abundance in the upstream reaches while retaining some abundance in the downstream reaches also enhances population resiliency by increasing redundancy. Although the population in the Spring Lake reach is small, retaining Texas wild-rice stands in Spring Lake protects stands that have persisted for more than 20 years and are shielded from recreational impacts. Based on a total areal coverage objective of 8,000 m^2 across the upper San Marcos River, the percent of population per reach was determined from long-term monitoring (2000–2023) of Texas wild-rice and professional judgement (Table 6). Since implementation of the EAHCP, this total areal coverage and recommended spatial distribution (Figure 13) has been attainable. It represents what is assumed to be a natural spatial and longitudinal distribution of Texas wild-rice and has shown to be self-sustaining since 2016.

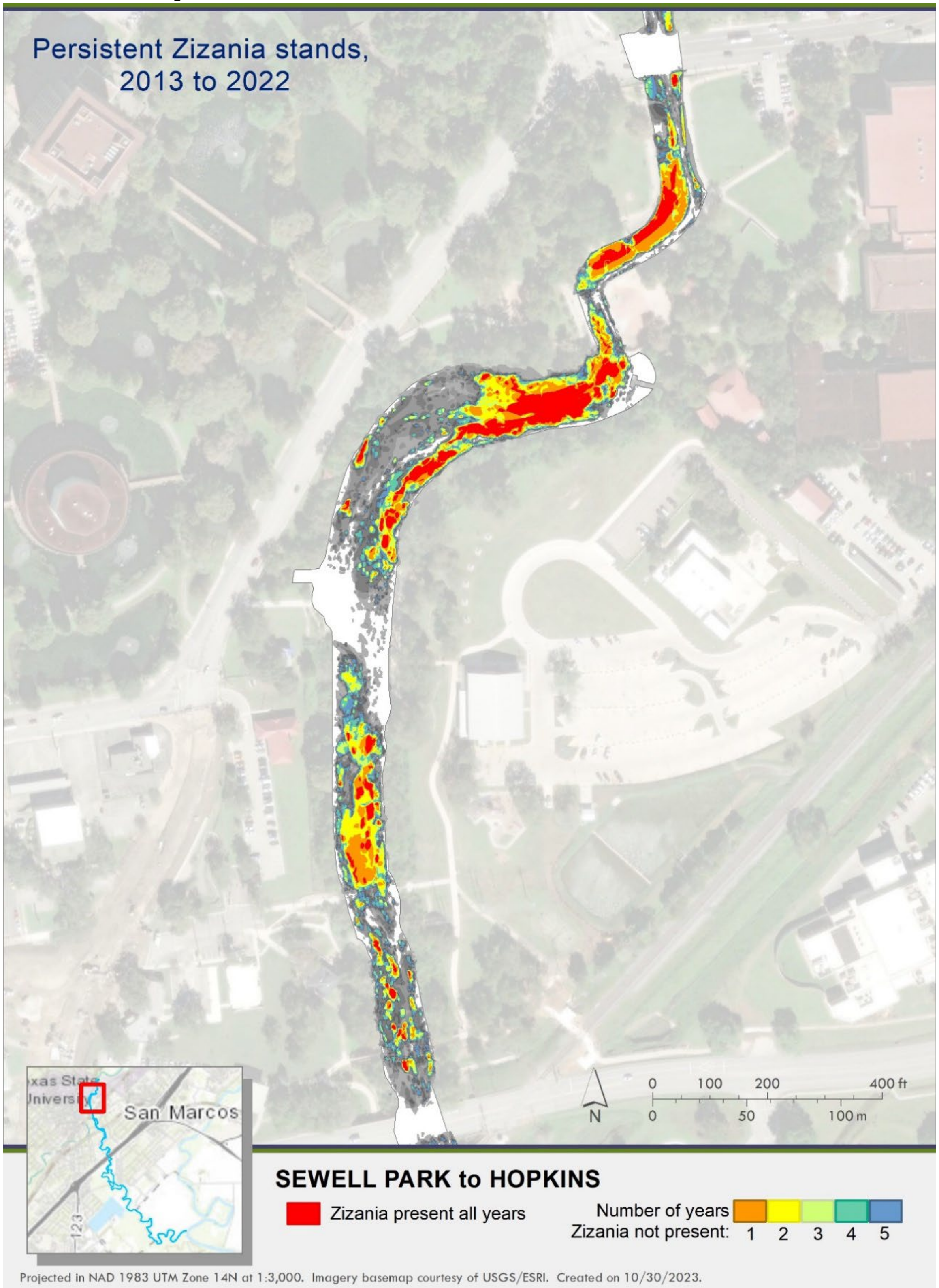


Figure 12. Texas Wild-Rice Persistent Stands from Sewell Park to Hopkins over the Course of the EAHCP

Table 6. Percent of Texas Wild-Rice Population Occurrence and Minimum Coverage Objective in Each Reach, Based on the Total Areal Coverage Objective of 8,000 m^2

Percent of Population (by area)	Reach	Coverage (m^2)
0.5	Spring Lake	40
4.5	Spring Lake Dam	360
52.5	Sewell Park to Hopkins	4,200
40.0	Hopkins to I-35	3,200
2.5	Downstream of I-35	200
100	All	8,000

Note: Reaches are shown in Figure 13.

Although there remains uncertainty regarding sexual reproduction, seed viability, and recruitment of Texas wild-rice in the San Marcos River, it has been suggested by stakeholders that preserving at least two large, contiguous stands in upper reaches might promote sexual reproduction. There is limited data on this topic available in the literature to offer guidance on the size of stand necessary; however, maintaining a few large, contiguous stands for sexual reproduction similar to what has been observed since implementation of the EAHCP (greater than 500 m^2) would likely be a benefit to this species. The objectives to conserve and manage resilient Texas wild-rice populations (Goal 5) include the San Marcos Springs objectives (Section 4.1) and the following areal coverage objectives:

Objective 5.1, Texas Wild-Rice System-Wide Areal Coverage: *Maintain a minimum coverage of 8,000 m^2 across the upper San Marcos River system. Maintain two large, contiguous stands, of greater than 500 m^2 each, in the upper reaches of the San Marcos River system.*

Objective 5.2, Texas Wild-Rice Reach-Specific Areal Coverage: *Maintain minimum coverage per reach distributed longitudinally down the San Marcos River:*

- *Spring Lake—40 m^2*
- *Spring Lake Dam—360 m^2*
- *Sewell Park to Hopkins—4,200 m^2*
- *Hopkins to I-35—3,200 m^2*
- *Downstream of I-35—200 m^2*

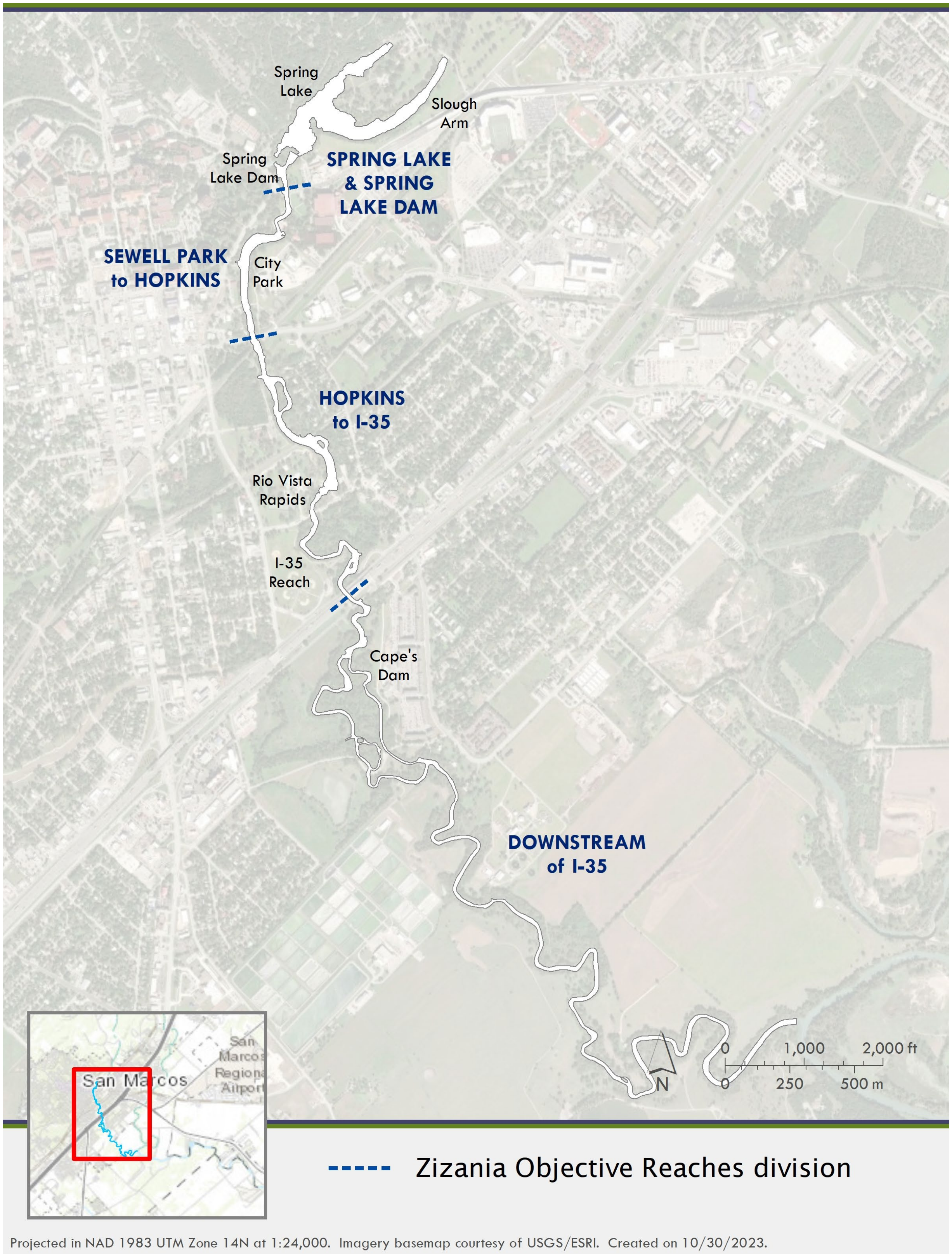


Figure 13. Locations for the Reach-Specific Texas Wild-Rice Objectives in the San Marcos River

4.7 Objectives for Fountain Darter

The fountain darter is a small-bodied fish and endemic to the spring-dominated Comal River and upper San Marcos River systems. Since 2000, the EAHCP has employed a variety of techniques, including drop-netting, dip-netting (i.e., timed, random, fixed), seining, and visual counts (i.e., SCUBA, snorkel) to monitor fountain darter abundance and occurrence indices. In addition to direct abundance and occurrence indices, the EAHCP has monitored aquatic vegetation communities biannually in LTBG reaches since 2000 and conducted full-system assessments every 5 years since 2013 (EAA 2012). As with all other Covered Species, key Biological Objectives for fountain darter are to *achieve the springflow (minimum and long-term) and water temperature objectives in both the Comal and San Marcos spring systems* (Section 4.1, *Objectives for Springflow*).

In the Comal River, reaches that are more resistant to disturbance (i.e., Landa Lake, Old Channel) maintain more stable populations compared to less-resistant reaches (i.e., Upper Spring Run, New Channel). It should not be assumed that failing to meet an abundance-based objective at some reaches reflects a lack of resiliency if other reaches remain stable; it can provide a demographic rescue to degraded areas (Van Looy et al. 2019; Larsen et al. 2021). In considering fountain darter population dynamics in the spring systems, we recommend an evaluation method for demographic-specific Biological Objectives at a broader system level (across study areas) to support populations that are resilient to variation in environmental conditions.

Specifically, we recommend linking system-level objectives to objectives that help maintain the spatial diversity of suitable habitat for fountain darters to fulfill life history requirements. As such, we recommend that SAV objectives be 1) reach specific to ensure adequate SAV coverage so suitable habitat persists throughout both systems during periods of environmental degradation, and 2) based on vegetation taxa that provide optimal habitat.

Biological Objectives for measuring population state and habitat conditions during a given monitoring event or year were quantified according to two parameters: 1) central tendency, a value for which the results will tend to, and 2) dispersion, how far typical values range from the mean. All objectives were quantified using parameters from the normal distribution, mean (i.e., central tendency; μ), and standard deviation (i.e., dispersion; σ). Objectives are intended to limit extended (i.e., 1-year) population states and habitat conditions below one standard deviation from the mean ($\mu - \sigma$). This approximates time periods when areas of suitable habitat are lower than the typical distance from the mean, providing proximal measurements of potential system degradation. Simulation analyses indicated observed SAV coverage data did not satisfy the assumptions of normality. However, parameters of the normal distribution still provide a useful characterization of central tendency and dispersion that is conceptually simple and easy to understand.

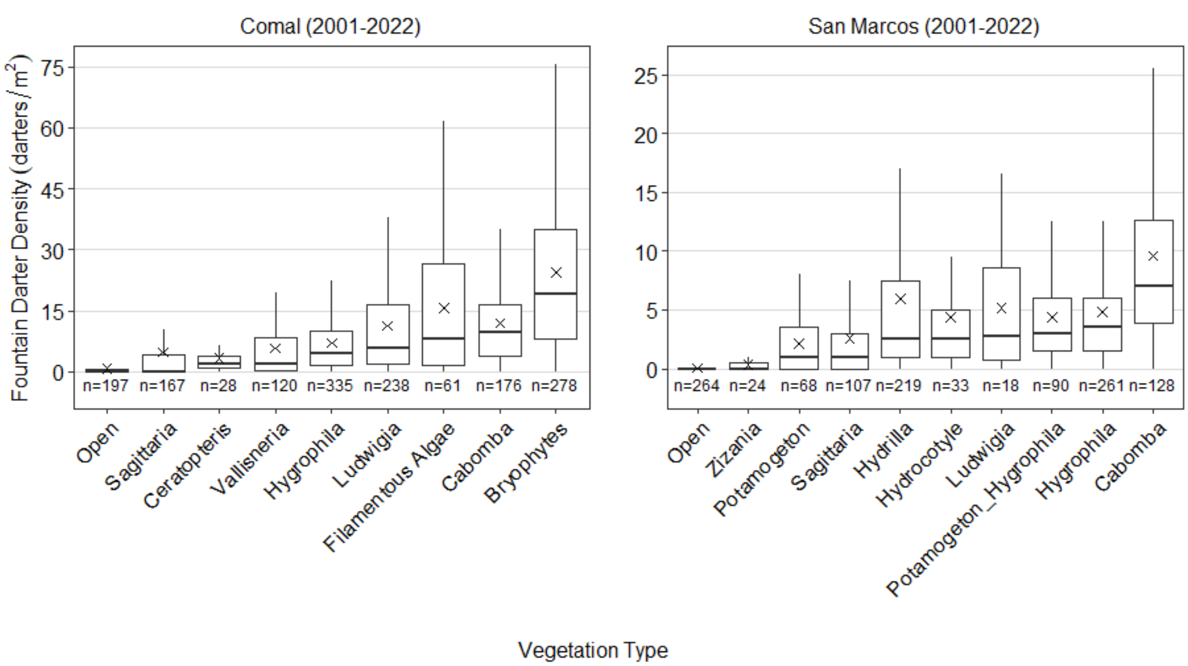
4.7.1 Fountain Darter Density

Fountain darter densities in the Comal and San Marcos Springs systems are estimated with a stratified random sampling design among wadable habitats. During each monitoring event, two sample sites are randomly selected within dominant vegetation taxa and open habitats at each LTBG reach. Densities are quantified at each site with a 2 m^2 drop-net (EAA 2017a, 2017b). Data collected during each monitoring event are used to estimate spatiotemporal trends in population demographics and habitat associations (Figure 14).

The recommended Biological Objectives evaluation methodology for fountain darter density examines results from a system-level perspective. Based on discussions at Biological Objectives Subcommittee meetings, data collected from non-vegetated (i.e., open), filamentous, and green algae taxa; *Hydrilla verticillata*; and Texas wild-rice were omitted from analysis. Density objectives were quantified by first calculating average density per sampling event (2001–2022) in the Comal (n = 60 events) and San Marcos (n = 59 events) systems. These averages were then used to calculate long-term means and standard deviations for each system (Table 7).

Table 7. Mean and Standard Deviation Calculations of Fountain Darter Densities (darters/m^2) in Both Systems and Recommended Thresholds for System-Level Objectives

Parameter	Comal	San Marcos
Mean (μ)	11.5	5.2
Standard deviation (σ)	4.9	2.9
Recommended thresholds for objective: One standard deviation below the mean (μ – σ)	6.6	2.3



Notes: The "x" denotes the mean, the thick horizontal line in each box is the median, and the upper and lower bounds of each box represent the interquartile range. Whiskers represent minimum and maximum values up to 1.5 times the interquartile range.

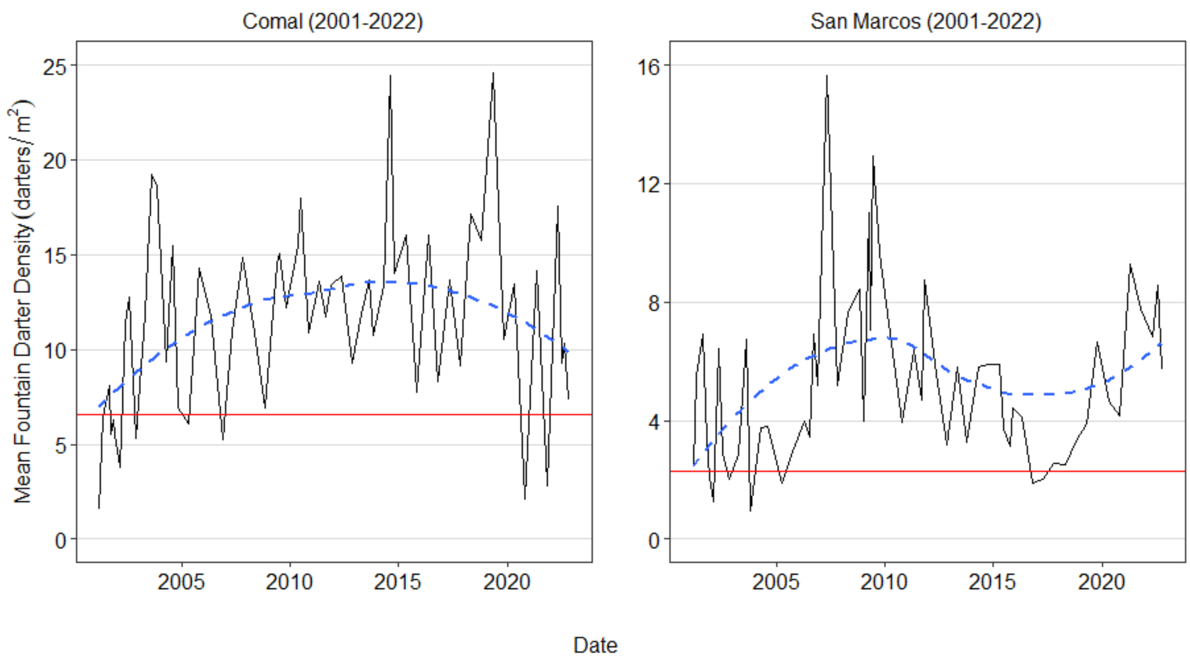
Figure 14. Boxplots Displaying Drop-Net Densities among Vegetation Types in the Comal and San Marcos Springs Systems

Based on this information, system-specific objectives aimed at conserving resilient fountain darter populations (Goal 6) include:

Objective 6.1, Comal Springs System Fountain Darter Density: *Mean fountain darter density should not fall below 6.6 darters/m^2 for a minimum of three sampling events covering a 12-month period throughout the LTBG reaches.*

Objective 6.2, San Marcos Springs System Fountain Darter Density: *Mean fountain darter density should not fall below 2.3 darters/m² for a minimum of three sampling events covering a 12-month period throughout the LTBG reaches.*

Figure 15 displays temporal trends in mean fountain darter density for both systems relative to their respective objectives threshold. Mean density was lower than the proposed threshold at 11 events (18%) in the Comal; it was also below the proposed threshold for three consecutive events conducted during October and November 2001. In the San Marcos, mean density was lower than the proposed threshold at seven events; it was never below it for three consecutive events.



Notes: The dashed blue lines denote fitted LOESS smooth functions, and the solid red lines represent one standard deviation below the mean.

Figure 15. Long-Term Density Trends in the Comal and San Marcos Spring Systems

4.7.2 Fountain Darter Recruitment Objectives

Fountain darter recruitment rates in both systems are estimated by using total length data from drop-net sampling and timed dip-netting. During each monitoring event, timed dip-net sampling is conducted within designated reaches for a fixed duration; surveyors generally target suitable habitats. All darters are measured and enumerated during sampling (EAA 2017a, 2017b). Data collected during each monitoring event are used as an additional abundance index for estimating population trends and for providing more robust assessments of recruitment.

The recommended Biological Objectives evaluation methodology for fountain darter recruitment examines results from a system-level perspective. Objectives for both systems were quantified by first calculating percent recruitment per sampling event for the Comal (n = 65 events) and San Marcos (n = 63 events) systems. To do this, raw fountain darter length frequencies from drop-net and timed dip-net datasets were aggregated for each event. Recruitment rates were calculated as the percent of darters ≤ 20 millimeters, which represents individuals that were most likely less than 3 months old and not sexually mature (Brandt et al. 1993). Average annual recruitment rates were then computed and used to calculate long-term means and standard deviations for each system, which are presented in Table 8.

Table 8. Mean and Standard Deviation Calculations of Fountain Darter Recruitment Rates (percent) in Both Systems and Recommended Thresholds for System-Level Objectives

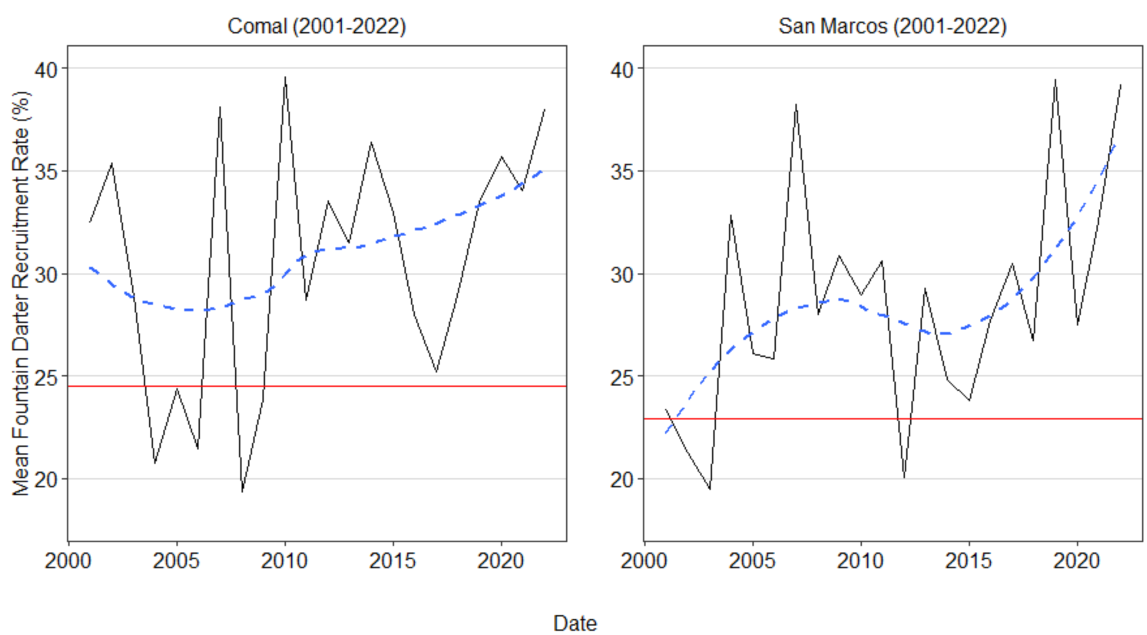
Parameter	Comal	San Marcos
Mean (μ)	30.5	28.5
Standard deviation (σ)	6.0	5.6
Recommended thresholds for objectives: One standard deviation below the mean (μ – σ)	24.5	22.9

Based on this information, objectives aimed at conserving resilient fountain darter populations (Goal 6) include:

Objective 6.3, Comal Fountain Darter Recruitment: *Mean annual recruitment should not fall below 25 percent.*

Objective 6.4, San Marcos Fountain Darter Recruitment: *Mean annual recruitment should not fall below 23 percent.*

To illustrate how these objectives would be assessed, Figure 16 displays temporal trends in mean fountain darter recruitment rates for both systems relative to their respective objectives threshold. In the Comal, mean recruitment was lower than the proposed threshold for 5 years, which occurred from 2004 to 2006 and in 2008 and 2009. In the San Marcos, mean recruitment was lower than the proposed threshold three times in 2002, 2003, and 2012.



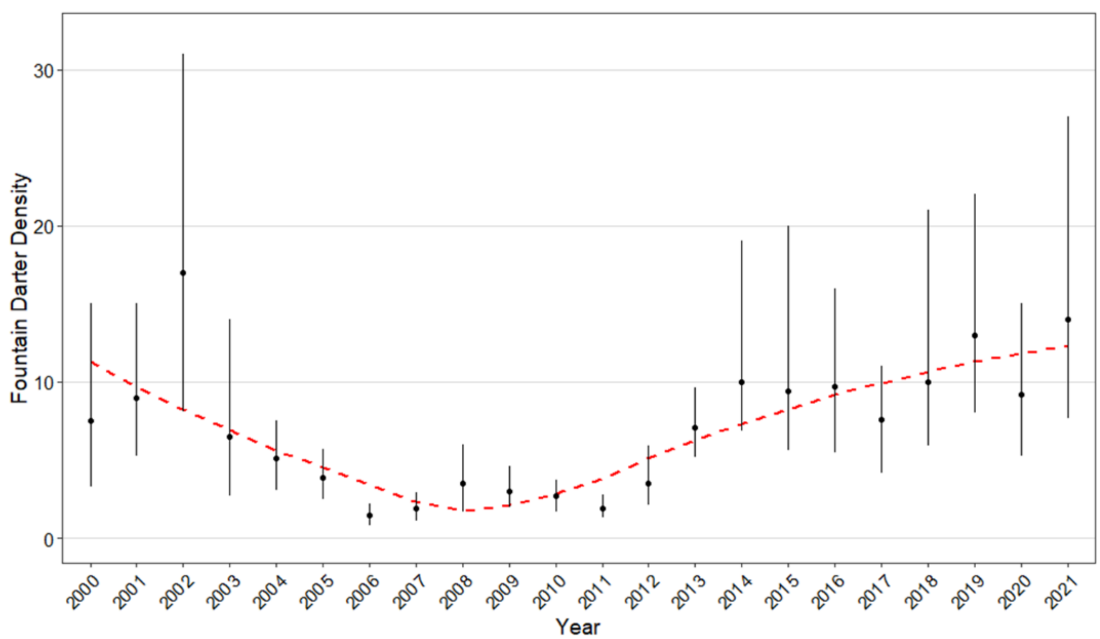
Notes: The dashed blue lines denote fitted LOESS smooth functions, and the solid red lines represent one standard deviation below the mean.

Figure 16. Long-Term Recruitment Trends in the Comal and San Marcos Spring Systems

4.7.3 Submerged Aquatic Vegetation

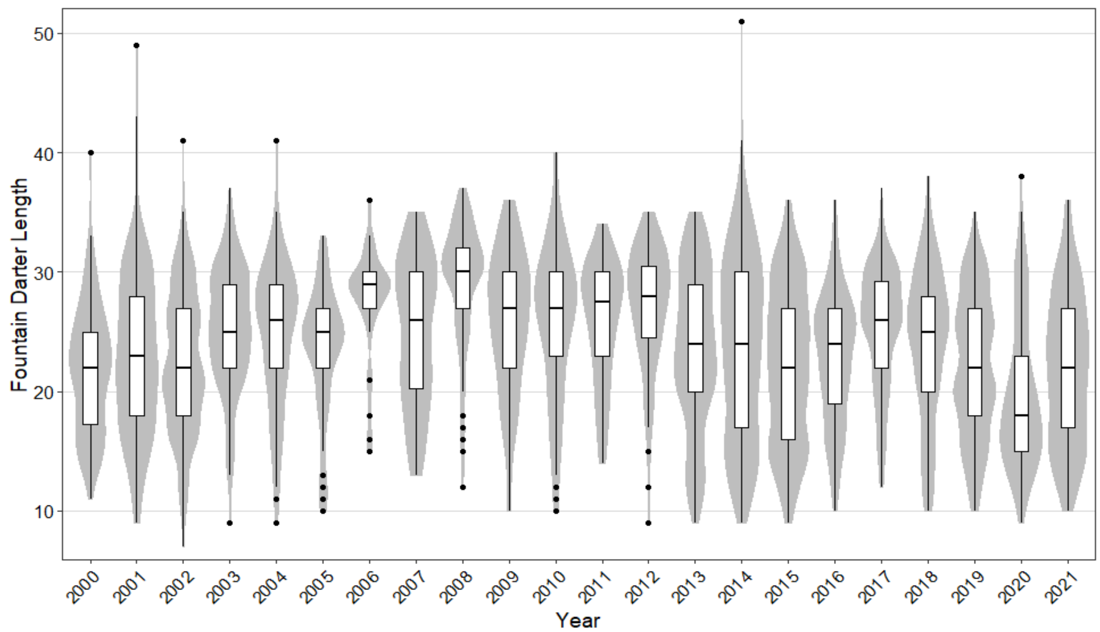
Aquatic vegetation communities in both systems are assessed by quantifying the areal coverage of taxa present. Mapping is conducted within each reach by collecting geospatial data for discrete patches of various taxa, which are visually delineated using kayak. Geospatial data are processed to construct polygons that represent discrete patches, and the total areal coverage of all vegetation taxa is calculated (EAA 2017a, 2017b). Data collected during each monitoring event are used to estimate spatiotemporal trends in vegetation assemblage structure, total areal coverage, and fountain darter habitat suitability.

We recommend linking system-level density and recruitment objectives to vegetation taxa that provide suitable habitat for fountain darters to fulfill life history requirements. As such, objectives for both systems were quantified according to areal coverage of SAV within two functional guilds. The first guild includes taxa that provide complex physical structure (hereafter referred to as *complex SAV*); data support optimal fountain darter habitats across ontogenetic stages. Multiple studies demonstrate that fountain darters associate with and have higher densities in complex SAV (Edwards and Bonner 2022; BIO-WEST n.d.:Figure 14). A taxa was considered complex if it has small branches or leaves that create a dense and ornate structure near the substrate. SAV restoration efforts in the Old Channel provide a model example of how increased coverage for multiple complex SAV taxa can enhance fountain darter populations. Figures 17 and 18 display the increased density and prevalence of recent recruits, respectively, since starting Old Channel restoration in 2013.



Notes: Error bars denote 95 percent confidence intervals, and the red dashed line is a fitted LOESS smooth function. SAV restoration efforts in this reach began in 2013.

Figure 17. Annual Trends in Mean Fountain Darter Density (darters/m²) at the Old Channel Reach of the Comal River from 2000 to 2021



Notes: The thick horizontal line in each box is the median, and the upper/lower bounds of each box represent the interquartile range. Whiskers represent minimum/maximum values up to 1.5 times the interquartile range; outliers beyond this are designated with solid black circles.

Figure 18. Annual Trends in Fountain Darter Size Structure (total length [millimeters]) at the Old Channel Reach of the Comal River from 2000 to 2021

The second guild includes taxa with a simpler physical structure (hereafter referred to as *simple SAV)*, which generally are considered suboptimal, but can provide suitable habitat when complex taxa are present (e.g., bryophyte in *Vallisneria* at Landa Lake). A taxa was considered simple if it lacks branches or has long leaves that extend toward the surface, reducing dense cover near the substrate. Despite providing suboptimal habitat, simple SAV dominate the vegetation assemblages in most reaches and very likely provide important dispersal corridors that facilitate connectivity among patches of complex SAV (Fagan 2002). Simple SAV more readily colonize areas, so separate SAV objectives for complex and simple guilds were developed to protect presence of complex SAV throughout the systems and prevent simple SAV from comprising the entire vegetation assemblage.

Taxa used for reach-level objectives for each guild are presented in Table 9. These taxa were chosen for analysis because they are prevalent within both systems. These taxa are also the most frequently sampled SAV during drop-netting and can therefore be linked to estimates of average fountain darter density per monitoring event. Several complex taxa not sampled during drop-netting were used to calculate the San Marcos complex SAV objective. Additional taxa included *Myriophyllum heterophyllum* because other studies observed its use as suitable habitat for darters (Edwards and Bonner 2022), *Heteranthera* because it is a taxa used to replace non-native vegetation during restoration efforts (EAA 2016), and bryophyte because it has shown to be highly suitable habitat in the Comal system (BIO-WEST n.d.). In addition to coverage objectives, we recommend that a minimum richness threshold of three SAV taxa including at least one complex SAV taxon per designated reach to ensure optimal fountain darter habitat is present within each reach.

The proposed SAVs for fountain darter habitat objectives in Table 9 include one species of non-native aquatic vegetation (*Hygrophila polysperma*) as an acceptable complex habitat in the Comal and San Marcos Rivers. Fountain darter densities are high for this non-native species (Figure 14), which qualifies it as complex habitat for the endangered fountain darter. As stated in Goal 6, the focus throughout each system will be on native vegetation restoration and protection. No planting or restoration of non-native *Hygrophila* is proposed in the Conservation Measures. However, if native SAV species are unable to establish as fountain darter habitat in select reaches of the rivers, removal efforts pertaining to non-native *Hygrophila* may need to be reduced to maintain habitat diversity of complex and simple taxa.

Table 9. List of Vegetation Taxa Used to Calculate Reach-Level Objectives for Complex and Simple SAV Coverage in Both Systems

Taxa by Category	Comal	San Marcos
Complex SAV		
Bryophyte	X	X
Cabomba	X	X
Heteranthera	—	X
Hydrocotyle	—	X
*Hygrophila**	X	X
Ludwigia	X	X
Myriophyllum	—	X
Simple SAV		
Potamogeton	X	X
Sagittaria	X	X
Vallisneria	X	—
Zizania	—	X

*Denotes non-native species

4.7.3.1 Long-Term Biological Goal Reaches

Calculations of submerged aquatic vegetation objectives for the Comal system LTBG reaches were based on data from 2001 to 2022, except for the Upper New Channel, which was first added to the EAHCP program in 2014. Simple SAV objectives were not calculated for the Old Channel, Upper New Channel, and Lower New Channel because simple taxa are not prevalent within these reaches. As such, minimum simple SAV taxa richness is also not included as an objective for these reaches.

Complex SAV objectives for the Spring Lake Dam and City Park LTBG reaches in the San Marcos system were calculated based on data from 2002 to 2022. Simple SAV objectives for these reaches were made using data from 2013 to 2022. Because Texas wild-rice restoration began in 2013, coverage for other simple SAV has decreased substantially. Therefore, data from 2013 to 2022, as opposed to the full monitoring record, were used to more accurately reflect variations in simple SAV coverage within a now Texas wild-rice-dominated community. Complex and simple vegetation objectives for the I-35 LTBG reach were calculated using data from 2014 to 2022 because this reach was expanded in 2014, making data collected during previous monitoring incompatible. For each system, complex and simple SAV objectives were first summed across taxa within each LTBG reach for each monitoring event per system. Average annual coverages of complex and simple SAV objectives were then computed per reach and used to calculate reach-level long-term means and standard deviations, which are presented in Tables 10 and 11.

Table 10. Sample Size (n), Mean (μ), and Standard Deviation (σ) Calculations of Complex SAV Coverages (m^2) among LTBG Reaches in Both Systems

Reach	*n*	Parameter		
		μ	**σ**	**μ – σ**
Comal				
Upper Spring Run	22	1,210	989	221
Landa Lake	22	2,850	1,112	1,738
Old Channel	22	1,142	558	584
Upper New Channel	9	1,055	414	641
Lower New Channel	22	2,036	981	1,055
San Marcos				
Spring Lake Dam	21	148	40	108
City Park	21	713	345	368
I-35	9	710	176	534

Table 11. Sample Size (n), Mean (μ), and Standard Deviation (σ) Calculations of Simple SAV Coverages (m^2) among LTBG Reaches in Both Systems

Reach	*n*	Parameter		
		μ	**σ**	**μ – σ**
Comal				
Upper Spring Run	22	774	366	408
Landa Lake	22	14,940	1,214	13,726
Old Channel	—	—	—	—
Upper New Channel	—	—	—	—
Lower New Channel	—	—	—	—
San Marcos				
Spring Lake Dam	10	1,198	338	860
City Park	10	2,036	815	1,221
I-35	9	915	363	552

4.7.3.2 Restoration Reaches

To support SAV objectives across longer stretches of each system, restoration reaches were evaluated for Biological Objectives. Figures 19 and 20 display the current LTBG study reaches along with the proposed restoration reaches in both systems, respectively. In the Comal River, the LTBG and proposed restoration reach footprint covers the majority of the upper system from Upper Spring Run to Lower Landa Lake and through the Old Channel Environmental Restoration and Protection Area. The recommended restoration reaches for the Comal system include: 1) Upper Landa Lake; 2) Lower Landa Lake; and 3) Upper Old Channel (Figure 19).

In the San Marcos system, the LTBG and proposed restoration reach footprint covers the majority of the upper San Marcos River from Spring Lake Dam to I-35. As shown in Figure 20, the recommended restoration reaches in the San Marcos River include: 1) Spring Lake Dam to City Park; and 2) City Park to Rio Vista Pool.

Figure 19. Proposed LTBG/Restoration Reach Delineation for the Comal River

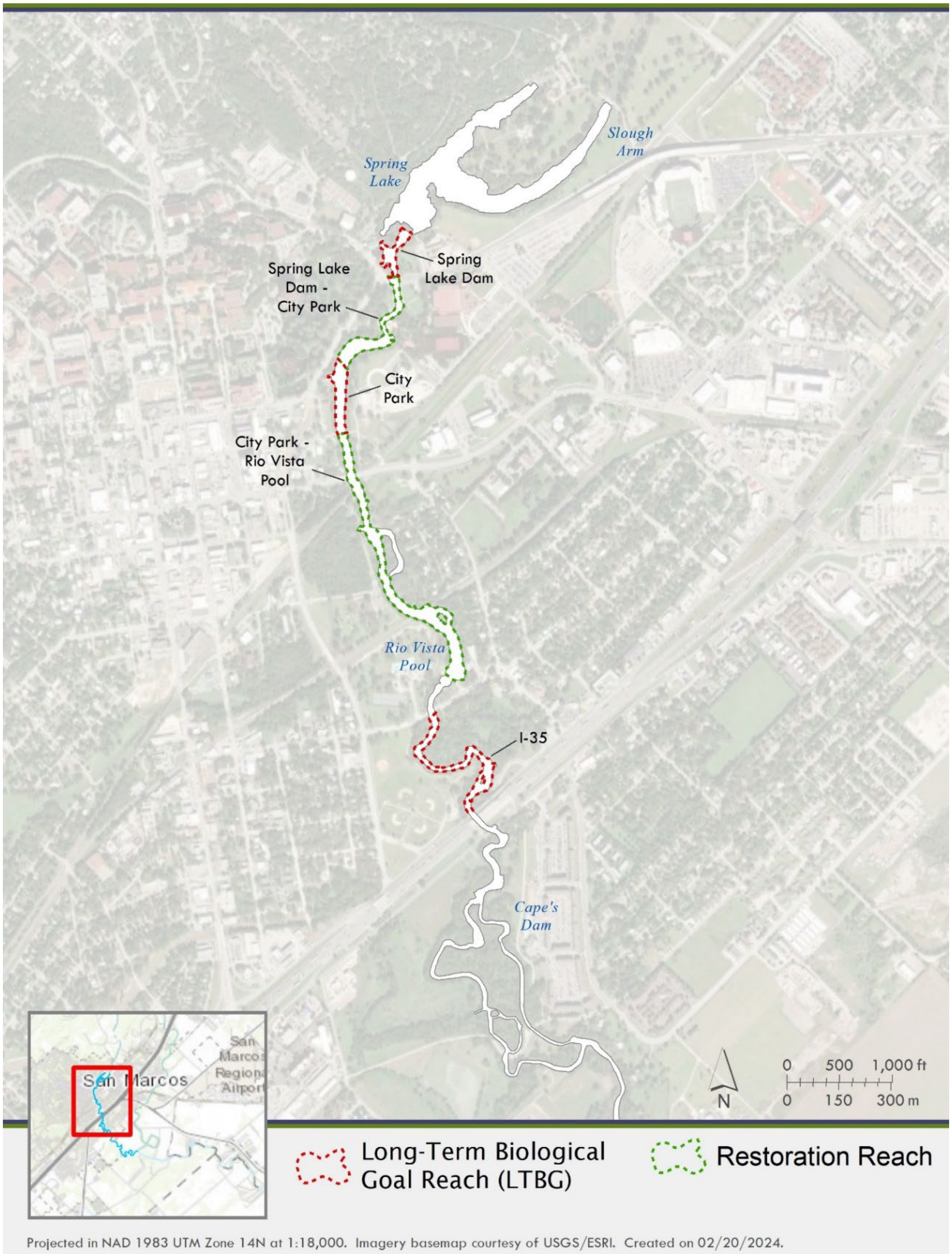


Figure 20. Proposed LTBG/Restoration Reach Delineation for the San Marcos River

Complex and simple SAV objectives for the proposed restoration reaches were established based on data from three full system mapping events in 2013, 2018, and 2023. SAV polygons per mapping event were clipped to the extent of each reach's defined boundaries using GIS software. Areas of each clipped polygon were then recalculated to estimate the areal coverage of each taxon per reach. SAV objectives were calculated using the same methodology and taxa list in Table 9. Long-term means and standard deviations for complex and simple SAV are presented for each restoration reach in Tables 12 and 13, respectively.

Table 12. Mean (μ) and Standard Deviation (σ) Calculations of Complex SAV Coverages (m^2) among Proposed Restoration Reaches in Both Systems. Sample size (n=3).

	Parameter		
Reach	μ	σ	μ – σ
Comal			
Upper Landa Lake	5,886	3,527	2,359
Lower Landa Lake	312	261	51
Upper Old Channel	2,110	952	1,158
San Marcos			
Spring Lake Dam - City Park	1,305	1,179	126
City Park - Rio Vista Pool	2,364	614	1,750

Table 13. Mean (μ) and Standard Deviation (σ) Calculations of Simple SAV Coverages (m^2) among Proposed Restoration Reaches in Both Systems. Sample size (n=3).

	Parameter		
Reach	μ	σ	μ – σ
Comal			
Upper Landa Lake	4,077	1,330	2,747
Lower Landa Lake	16,239	1,916	14,323
Upper Old Channel	1,946	518	1,428
San Marcos			
Spring Lake Dam - City Park	4,083	1,345	2,738
City Park - Rio Vista Pool	3,885	1,389	2,496

Based on the SAV observed in the LTBG and proposed restoration reaches during the EAHCP biological monitoring program, objectives aimed at conserving habitats and diverse native submerged aquatic vegetation assemblages (Goal 6) include:

Objective 6.5, Comal SAV Areal Coverage: *Maintain a minimum of three SAV taxa including at least one complex structured SAV taxon in each reach (Table 9). Maintain total areal coverages of complex and simple SAV above the following thresholds per reach:*

	Minimum Total Coverage (m^2)	
Reach	***Complex SAV***	***Simple SAV***
Upper Spring Run	*220*	*410*
*Upper Landa Lake**	*2,360*	*2,750*
Landa Lake	*1,740*	*13,730*
*Lower Landa Lake**	*50*	*14,320*

	Minimum Total Coverage (m²)	
Reach	***Complex SAV***	***Simple SAV***
*Upper Old Channel**	*1,160*	*1,430*
Old Channel	*580*	*—*
Upper New Channel	*640*	*—*
Lower New Channel	*1,060*	*—*
Total	*7,810*	*32,640*

**Denotes Proposed Restoration Reach*

Taxa richness and areal coverages should not fall below these thresholds within each reach for a minimum of three sampling events covering a 12-month period.

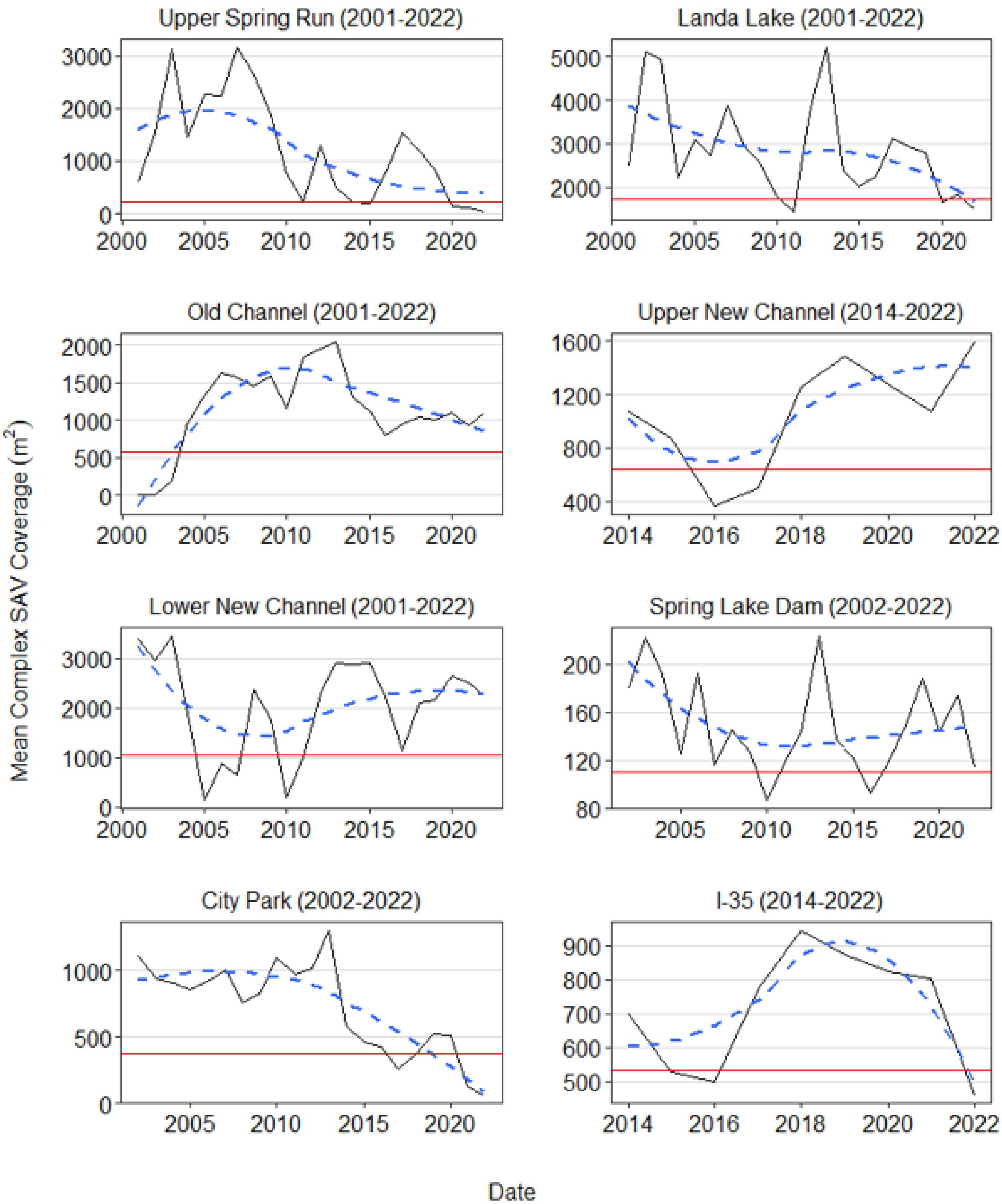
Objective 6.6, San Marcos SAV Areal Coverage: *Maintain a minimum of three SAV taxa including at least one complex structured SAV taxon in each reach (Table 9). Maintain total areal coverages of complex and simple SAV above the following thresholds per reach:*

	Minimum Total Coverage (m²)	
Reach	***Complex SAV***	***Simple SAV***
Spring Lake Dam	*110*	*860*
*Spring Lake Dam - City Park**	*130*	*2,740*
City Park	*370*	*1,220*
*City Park - Rio Vista Pool**	*1,750*	*2,500*
I-35	*530*	*550*
Total	*2,890*	*7,870*

**Denotes Proposed Restoration Reach*

Taxa richness and mean areal coverages should not fall below these thresholds within each reach for a minimum of three sampling events covering a 12-month period.

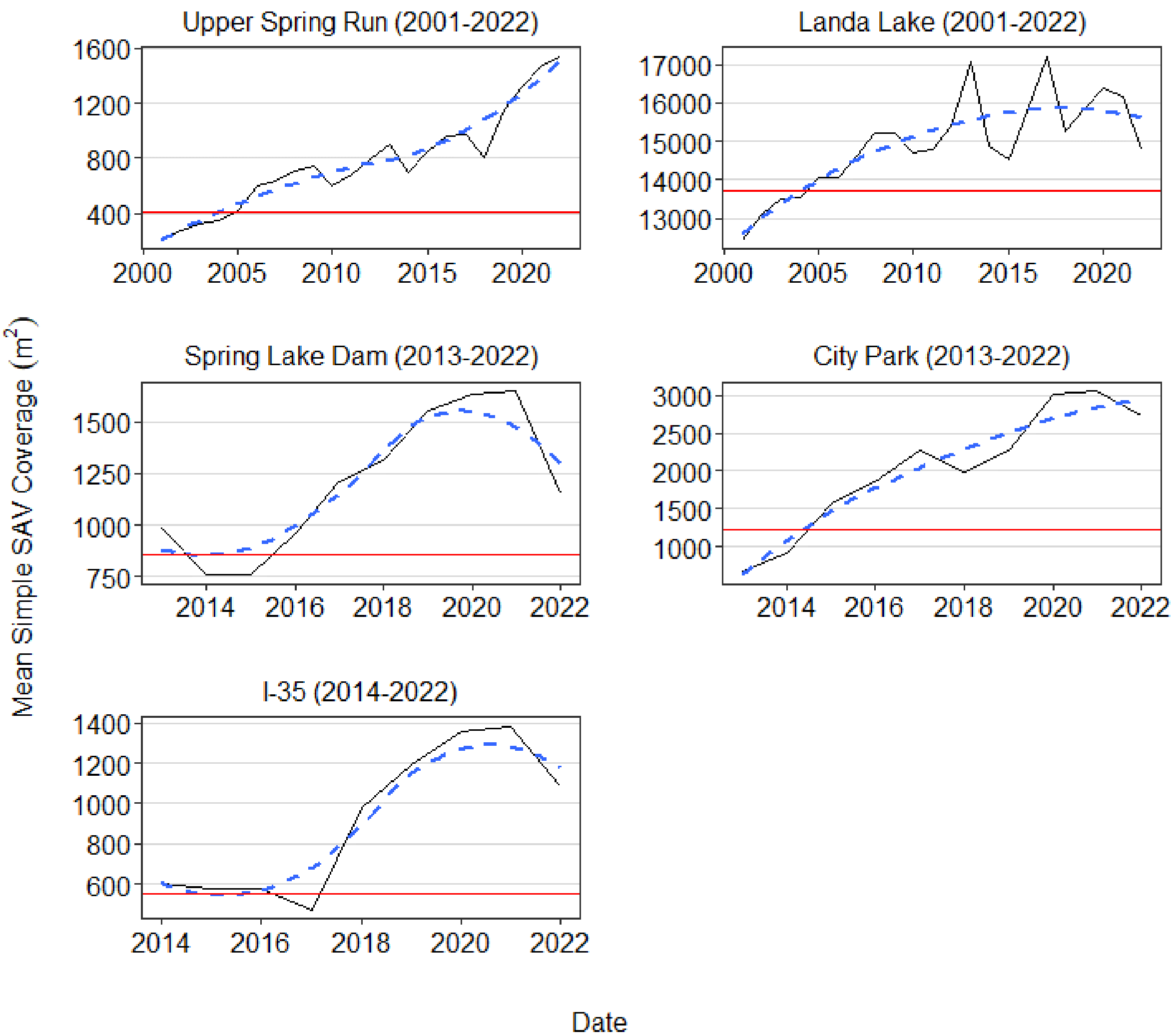
To illustrate how these objectives will be analyzed, Figure 21 shows annual trends in total coverage of complex SAV relative to each LTBG reach's respective objective thresholds in the Comal and San Marcos systems. Mean complex SAV was lower than the proposed threshold for 5 years (23%) in Upper Spring Run and Lower New Channel, 3 years (14%) in Old Channel and Landa Lake, and 2 years (22%) in Upper New Channel. Some years, when mean coverage substantially decreased below proposed thresholds (e.g., Lower New Channel and Spring Lake Dam in 2010), were a direct result of an extreme flood event. This warrants potentially modifying objectives calculations contingent upon whether high-flow pulses occurred (e.g., moving average), which would specifically help account for irrepressible stochastic events. Among the San Marcos River LTBG reaches, mean complex SAV was lower than the proposed threshold for 2 years (10%) in Spring Lake Dam, 3 years (14%) in City Park, and 1 year (5%) in I-35. It is evident that expansion success and the present dominance of Texas wild-rice in the study reaches has affected the amount of complex SAV coverage in each LTBG reach.



Notes: The dashed blue lines denote fitted LOESS smooth functions, and the solid red lines represent one standard deviation below the mean.

Figure 21. Long-Term Complex SAV Trends in the LTBG Reaches of the Comal (Upper Spring Run, Landa Lake, Old Channel, Upper and Lower New Channels) and San Marcos (Spring Lake Dam, City Park, and I-35) Systems

Figure 22 shows annual trends in total coverage for simple SAV relative to each LTBG reach's respective objective thresholds in the Comal and San Marcos systems. Although the simple SAV calculations for the LTBG reaches in the San Marcos system were made from post-EAHCP implementation data, the full monitoring record is presented in Figure 22 for historical context. Mean simple SAV was lower than the proposed threshold during 1 year in City Park (5%) and I-35 (13%). Similar to the complex SAV coverage in the LTBG reaches of the San Marcos River, the simple SAV guild has been affected by the dominance of Texas wild-rice in recent years.



Notes: The dashed blue lines denote fitted LOESS smooth functions, and the solid red lines represent one standard deviation below the mean.

Figure 22. Long-Term Simple SAV Trends in the LTBG Reaches of the Comal (Upper Spring Run and Landa Lake) and San Marcos (Spring Lake Dam, City Park, and I-35) Systems

As noted above, calculations for the proposed restoration reach objectives in the Comal and San Marcos systems (Tables 12 and 13) were determined using only three annual full system surveys. Therefore, there is no illustration to demonstrate the trends in total coverage of complex or simple SAV relative to each restoration reach's respective objective thresholds. However, the proposed restoration reach objectives are necessary to maintain system-wide flexibility in restoration efforts and are aimed at conserving habitats and diversity. By supporting diversity and habitat connectivity, the restoration reach objectives promote healthier SAV assemblages and conserve Covered Species habitat throughout a greater extent in the Comal and San Marcos systems.

5. Summary

Biological Goals and Objectives form the basis of the conservation strategy. This memorandum recommends Biological Goals and Objectives to replace those in the existing EAHCP and to include in the amended EAHCP as part of the permit renewal. The recommended Biological Goals and Objectives are based on biological monitoring data collected through the current EAHCP, input from the Biological Goals and Biological Objectives Subcommittees, and conformance with the structure of Biological Goals and Objectives described in the HCP Handbook. The list below summarizes the recommended Biological Goals and Objectives, with each objective nested under the goal it supports. Ultimately, the Biological Goals and Objectives will be used to guide development of Conservation Measures, the monitoring plan, adaptive management actions, and additional components of the EAHCP's conservation strategy, which will be completed in subsequent stages of the permit renewal process.

Goal 1: Conserve the quality and quantity of springflow and maintain suitable ecosystems within the Plan Area to provide for the persistence and resiliency of the Covered Species.

- **Comal Springflow**
  - **Objective 1.1, Minimum Comal Springflow Discharge:** *Maintain mean monthly spring discharge at Comal Springs (gage #08168710) greater than or equal to 45 cfs for at least 11 months per calendar year. Maintain daily average springflow greater than or equal to 30 cfs. This will be quantified by using mean daily springflow data to calculate average springflow for each month per year.*
  - **Objective 1.3, Long-Term Comal Springflow Discharge:**
    - *Maintain a 3-year moving-average annual Comal Springs discharge (gage #08168710) above 174 cfs.*
    - *Maintain a 30-year long-term average Comal Springs discharge above 225 cfs.*
- **San Marcos Springflow**
  - **Objective 1.2, Minimum San Marcos Springflow Discharge:** Maintain mean monthly discharge at San Marcos Springs (gage #08170000) greater than or equal to 60 cfs for at least 11 months per calendar year. Maintain daily average springflow greater than or equal to 45 cfs. This will be quantified by using mean daily springflow data to calculate average springflow for each month per year.
  - **Objective 1.4, Long-Term San Marcos Springflow Discharge:**
    - *Maintain a 3-year moving-average annual San Marcos Springs discharge (gage #08170000) above 136 cfs.*
    - *Maintain a 30-year long-term average San Marcos Springs discharge above 140 cfs.*
  - **Objective 1.5, Comal Springs and River Water Quality:** *Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C within Upper*

Spring Run, Spring Island, Spring Run 1–3, and Landa Lake. Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C for more than 50% of the days per year and less than or equal to 27°C within the Old Channel.

- **Objective 1.6, San Marcos Springs and River Water Quality:** *Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C within Spring Lake. Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C for more than 50% of the days per year and less than or equal to 27°C within the Headwaters, Upper River, Middle River, and Lower River.*

Goal 2: Conserve habitats to support resilient populations of Texas blind salamander, Comal Springs dryopid beetle, Peck's cave amphipod, and Edwards Aquifer diving beetle in the Plan Area.

- *See Objectives 1.1 through 1.6*

Goal 3: Conserve habitats to support resilient Comal Springs riffle beetle populations in the Plan Area.

- **Objective 3.1, Comal Springs Riffle Beetle Relative Abundance**: *Mean Comal Springs riffle beetle relative abundance should not fall below 2.4 counts/lure for a minimum of three sampling events covering a 12-month period, as measured at long-term biological monitoring areas (Landa Lake, Western Shoreline, Spring Island, Spring Run 3).*
- **Objective 3.2, Comal Springs Riffle Beetle Occurrence:** *Maintain Comal Springs riffle beetle likelihood of occurrence 0.52. Comal Springs riffle beetle likelihood of occurrence should not fall below 0.52 for a minimum of three sampling events covering a 12-month period.*

Goal 4: Conserve San Marcos Springs and River habitats and resilient San Marcos salamander populations in the Plan Area.

- **Objective 4.1*, San Marcos Salamander Habitat:** *Maintain total area of quality habitat above 23 m^2 at the Hotel site, above 30 m^2 at the Riverbed site, and above 14 m^2 at Spring Lake Dam. Areas of quality habitat should not fall below these values for a minimum of three sampling events covering a 12-month period.*

  * **Although habitat quality and protected area criteria are proposed, the San Marcos salamander biological monitoring program will be revised for the EAHCP permit renewal.**

Goal 5: Conserve and manage resilient Texas wild-rice populations in the San Marcos springs and river system.

- **Objective 5.1, Texas Wild-Rice System-Wide Areal Coverage:** *Maintain a minimum coverage of 8,000 m^2 across the upper San Marcos River system. Maintain two large, contiguous stands (each greater than 500 m^2) in the upper reaches of the San Marcos River system.*
- **Objective 5.2, Texas Wild-rice Reach-Specific Areal Coverage:** *Maintain minimum coverage per reach distributed longitudinally down the San Marcos River:*
  - *Spring Lake—40 m^2*
  - *Spring Lake Dam—360 m^2*
  - *Sewell Park to Hopkins—4,200 m^2*

- *Hopkins to I-35—3,200 m²*
- *Downstream of I-35—200 m²*

Goal 6: Conserve habitats, diverse native SAV assemblages, and resilient fountain darter populations in the Comal and San Marcos Springs and River system.

- **Objective 6.1, Comal Springs System Fountain Darter Density:** *Mean fountain darter density should not fall below 6.6 darters/m² for a minimum of three sampling events covering a 12-month period throughout the LTBG reaches.*
- **Objective 6.2, San Marcos Springs System Fountain Darter Density:** *Mean fountain darter density should not fall below 2.3 darters/m² for a minimum of three sampling events covering a 12-month period throughout the LTBG reaches.*
- **Objective 6.3, Comal Fountain Darter Recruitment Objective:** *Mean annual recruitment should not fall below 25%.*
- **Objective 6.4, San Marcos Fountain Darter Recruitment:** *Mean annual recruitment should not fall below 23%.*
- **Objective 6.5, Comal SAV Areal Coverage:** *Maintain a minimum of three SAV taxa including at least one complex structured SAV taxon in each reach (Table 9). Maintain total areal coverages of complex and simple SAV above the following thresholds per reach:*

	Minimum Total Coverage (m^2)	
Reach	***Complex SAV***	***Simple SAV***
Upper Spring Run	*220*	*410*
*Upper Landa Lake**	*2,360*	*2,750*
Landa Lake	*1,740*	*13,730*
*Lower Landa Lake**	*50*	*14,320*
*Upper Old Channel**	*1,160*	*1,430*
Old Channel	*580*	*—*
Upper New Channel	*640*	*—*
Lower New Channel	*1,060*	*—*
Total	*7,810*	*32,640*

** Denotes Proposed Restoration Reach*

Taxa richness and areal coverages should not fall below these thresholds within each reach for a minimum of three sampling events covering a 12-month period.

- **Objective 6.6, San Marcos SAV Areal Coverage:** *Maintain a minimum of three SAV taxa including at least one complex structured SAV taxon in each reach (Table 9). Maintain total areal coverages of complex and simple SAV above the following thresholds per reach:*

	Minimum Total Coverage (m^2)	
Reach	***Complex SAV***	***Simple SAV***
Spring Lake Dam	*110*	*860*
*Spring Lake Dam - City Park**	*130*	*2,740*
City Park	*370*	*1,220*
*City Park - Rio Vista Pool**	*1,750*	*2,500*
I-35	*530*	*550*
Total	*2,890*	*7,870*

** Denotes Proposed Restoration Reach*

Taxa richness and mean areal coverages should not fall below these thresholds within each reach for a minimum of three sampling events covering a 12-month period.

Goal 7: Promote community engagement and awareness of the EAHCP, support land and water conservation, and mitigate anthropogenic stressors and natural disturbances within the Plan Area that will benefit the Covered Species.

- *Given its broad scope and multi-faceted nature, objectives for Goal 7 have not yet been developed. We will consider the elements of Goal 7 when evaluating Conservation Measures to be recommended for inclusion in the renewed EAHCP.*

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Attachment 1

Edwards Aquifer Habitat Conservation Plan, Recommended Biological Goals and Objectives for the Permit Renewal Comment Response

[Note to reviewer: Attachment 1 provides responses to public comments received on the recommended EAHCP permit renewal Biological Goals and Objectives. It focuses on several key topics needing further clarification, based on the comments received. These key topics are 1) the EAHCP permit renewal process used to develop Biological Goals and Objectives; 2) clarification of language, analysis, or organization of the document; 3) springflow and river discharge objectives and how they compare to existing EAHCP objectives; 4) water quality objectives; and 5) species-specific objectives. Rather than address each comment individually, since many are repetitive, we reviewed all comments and grouped them into key topics, to which we provided responses in this attachment. All written comments received by EAA are included as an appendix to this attachment. A summary of each key topic noted above is provided below.]

1. EAHCP Permit Renewal Process

Commenters emphasized a need for the Science Committee to review and discuss the proposed goals and objectives as an entity rather than individually.

Response:

Following the guidance in the Edwards Aquifer Habitat Conservation Plan (EAHCP) Permit Renewal Work Plan, a draft of the Biological Goals and Objectives technical memorandum (BGO memo; November 15, 2023) was developed and reviewed by EAHCP staff, the U.S. Fish and Wildlife Service (USFWS), and members of the Implementing, Stakeholder, and Science Committees. The guidance recommends that once finalized and approved by the Implementing Committee, each memo will be incorporated into amended chapters of the EAHCP. The Work Plan process does not recommend the formation of additional subcommittees for every task or include approval of each memo by the Science Committee; however, two subcommittees were formed and their recommendations were considered in developing the memorandum. The Biological Goals Subcommittee and Biological Objectives Subcommittee were formed to provide guidance for the development of the Biological

Goals and Objectives (BGOs). The Biological Objectives Subcommittee included Science Committee members and species experts split into three different groups that focused on salamanders, macroinvertebrates, and fountain darter and Texas wild-rice. The Biological Goals Subcommittee provided a report (EAHCP Biological Goals Subcommittee 2023), while the Biological Objectives Subcommittee provided feedback and recommendations on their respective species, which informed the recommendations in the draft BGO memo. The draft BGO memo was shared with EAHCP Staff, USFWS, and EAHCP Implementing, Stakeholder, and Science Committee members; members from all the groups, including several Science Committee members, provided edits and comments (see appendix).

Per Implementing Committee preference in December 2023, a formal EAHCP Science Committee meeting and presentation of the recommended BGOs has been scheduled for March 7, 2024. The EAHCP Science Committee will then generate a response memorandum for the EAHCP Implementing Committee and EAHCP Program Manager. Comments on the BGO memo received from the EAHCP Science Committee memorandum will be taken into consideration prior to amending the EAHCP chapter on BGOs. Finally, it is important to clarify that the purpose of the BGO memo was to develop BGOs using the extensive EAHCP biomonitoring dataset to examine patterns in Covered Species population demographics and habitats. The memo did not consider pumping scenarios, management implications, or conservation strategies. Those will be addressed in subsequent tasks according to the Work Plan.

2. Clarification

Commenters requested clarification on a variety of points which included overall organization and formatting, explanation of analysis methodology, and requests for raw data.

The comments and suggestions to provide further clarification throughout the BGO memo are greatly appreciated. Several helpful comments pointed out areas of ambiguity that are addressed in the revised draft of the memo, and these areas will be subsequently considered as the memorandum is developed into the draft chapter of the HCP. The suggestion of restructuring the organization to present recommended objectives, and then to provide justification for the objectives has been noted for further consideration in the HCP chapter development. Additional or revised maps will be developed in the HCP to better clarify the geography and nomenclature of the reaches in each system. As the EAHCP renewal process considers impact analysis, Conservation Measures, and long-term monitoring, we will explore elaborating on the analysis methodology and expanding the explanation of some figures in the memorandum (e.g., Figures 14 and 16) in the draft HCP. Additionally, any direct requests for the raw data to the EAA Variable Flow Study reports (2000–2012) and the HCP Biological Monitoring Program reports (2013–2022) can be made to EAHCP staff. Raw data from 2000–2022 can also be found in the HCP Biological Monitoring Annual Reports on the Technical Reports Document Library webpage (Edwards Aquifer Authority › Science Document Library - Edwards Aquifer Authority).

3. Springflow

This section summarizes the original recommended objectives for springflow included in the November 15, 2023 version of the memo to provide contextual reference for the specific issues raised in comments.

3.1 Objectives for Springs and River Discharge

The recommended springs discharge springflow objectives include:

Objective 1.1, Comal Springs Discharge: *Maintain mean monthly spring discharge at Comal Springs (gage #08168710) greater than or equal to 45 cubic feet per second (cfs) for at least 11 months per calendar year. Maintain daily average springflow greater than or equal to 30 cfs. This will be quantified by using mean daily springflow data to calculate average springflow for each month per year.*

Objective 1.3, Long-Term Comal River Discharge: *Maintain a 3-year rolling-average annual Comal River discharge (gage #08169000) above 178 cfs.*

Objective 1.2, San Marcos Springs Discharge: *Maintain mean monthly discharge at San Marcos Springs (gage #08170000) greater than or equal to 60 cfs for at least 11 months per calendar year. Maintain daily average springflow greater than or equal to 45 cfs. This will be quantified by using mean daily springflow data to calculate average springflow for each month per year.*

Objective 1.4, Long-Term San Marcos River Discharge: *Maintain a 3-year rolling-average annual San Marcos River discharge (gage #08170500) above 138 cfs.*

Revisions are recommended to the flow-related objectives in the existing EAHCP (developed between 2009 and 2011) because additional data on flow-related responses of Covered Species populations are available through the biomonitoring program from 2000 to 2022. The recommended BGOs were developed independent of any pumping projections. This approach is consistent with the USFWS HCP Handbook (USFWS and National Marine Fisheries Service 2016). The primary focus was to use biomonitoring data to inform desired springflow and river discharge magnitudes that facilitate surface habitat redundancy.

Springflow objectives for Comal Springs were developed using models aimed at identifying a 30-day average springflow magnitude at which discharge was greater than 0 cfs at three key areas for the Comal Springs riffle beetle (Spring Run 3, Spring Island, and the western shoreline) and at which discharge conditions were greater than 30 cfs through the Old Channel Environmental Restoration and Protection Area (ERPA) specific to fountain darter. Springflow objectives for San Marcos Springs were developed using models aimed at identifying a 30-day average springflow magnitude at which water temperatures did not consistently exceed fountain darter reproductive thresholds and suitable physical habitat for the San Marcos salamander, fountain darter, and Texas wild-rice remained available in the system. Predictive models were developed based on existing biomonitoring data and regression coefficients were applied to unobserved data to determine the objectives. Thus, the springflow objectives were designed to represent the level of springflow necessary to maintain Covered Species resiliency and habitat redundancy based on observed data.

However, there is still a level of uncertainty in what conditions will be present throughout the systems at the predicted springflow outputs. For example, Spring Run 3 is predicted to remain flowing at the recommended objective of 30 cfs, but the standard error estimates include zero.

Commenters expressed concern that the recommended objectives do not provide the same level of protection to the species as the existing objectives and that additional justification is needed to demonstrate how the lower and more sustained recommended objectives are protective of the species. Related to this were concerns that a 3-year period was too short and the study period did not include the drought of record.

Response:

We provide an example using a 1- and 3-year timeframe to compare the existing flow-related objectives to the recommended springs and discharge objectives for the Comal Springs and River system. Assumptions include that Spring Run 3, Spring Island, and the western shoreline remain flowing (i.e., >0 cfs) under a mean monthly discharge of 45 cfs as predicted by the springflow models and that the necessary mechanisms are in place to meet the objectives as written. It is understood that the system likely cannot be managed to produce the springflow objectives as written. However, assuming that the system can be managed specifically to meet the objectives is necessary to compare the two scenarios. Therefore, hypothetical examples of implementation scenarios are provided below.

Flow-related objectives for the Comal System in the existing EAHCP (Edwards Aquifer Authority [EAA] 2012:Table 4-2, included below) are to achieve a modeled minimum daily average of 30 cfs lasting no longer than 6 months followed by a daily average of 80 cfs lasting at least 3 months and to maintain a long-term (50 years) daily average of 225 cfs. This modeled period includes the Drought of Record.

TABLE 4-2
LONG-TERM AVERAGE AND MINIMUM TOTAL COMAL DISCHARGE MANAGEMENT OBJECTIVES

Description	Total Comal Discharge (cfs)[a]	Time-step
Long-term average	225	Daily average
Minimum	30[b]	Daily average

[a]Assumes a minimum of a 50-year modeling period that includes the drought of record
[b]Not to exceed six months in duration followed by 80 cfs (daily average) flows for 3 months.

After 80 cfs for 3 months, the existing objective has no protections against flow decreasing below 80 cfs again. In fact, daily average flow could return to 30 cfs for another 6 months. This means that over the course of 1 year, daily average flow could be 30 cfs for a total of 9 months and 80 cfs for 3 months (Figure 1). In spring habitats for the Comal Springs riffle beetle, discharge at the western shoreline and Spring Island would occur for 9 months, while discharge at all three key areas would occur for only 3 months. With the EAHCP Old Channel flow-split management program in place, the

Old Channel ERPA would flow around 20 cfs (below the suitable range in terms of fountain darter habitat) for 9 months and around 45 cfs (within the suitable range) for only 3 months.

The recommended objectives are to maintain a monthly discharge of 45 cfs for at least 11 months per year, with daily average discharge never falling below 30 cfs. This prevents daily average flow of 30 cfs from extending more than 1 month in duration annually. Therefore, under the recommended objectives, daily average discharge could be 30 cfs for only 1 month and mean monthly discharge could be 45 cfs for 11 months (Figure 1). In terms of spring habitats for the Comal Springs riffle beetle, the western shoreline and Spring Island are predicted to remain flowing the entire time while all three key areas (including Spring Run 3) are predicted to flow for all but 1 month. With the EAHCP Old Channel flow-split management program in place, discharge through the Old Channel ERPA would be 20 cfs (below the suitable range) for only 1 month and 35 cfs (within the suitable range) for the other 11 months. Therefore, over a 1-year period, the recommended objectives would provide 11 of 12 months (>90%) in which all three key Comal Springs riffle beetle areas are predicted to flow and in which the Old Channel ERPA remains within the suitable flow range, whereas the existing objectives would provide only 3 of 12 months (25%) in which these conditions were met.

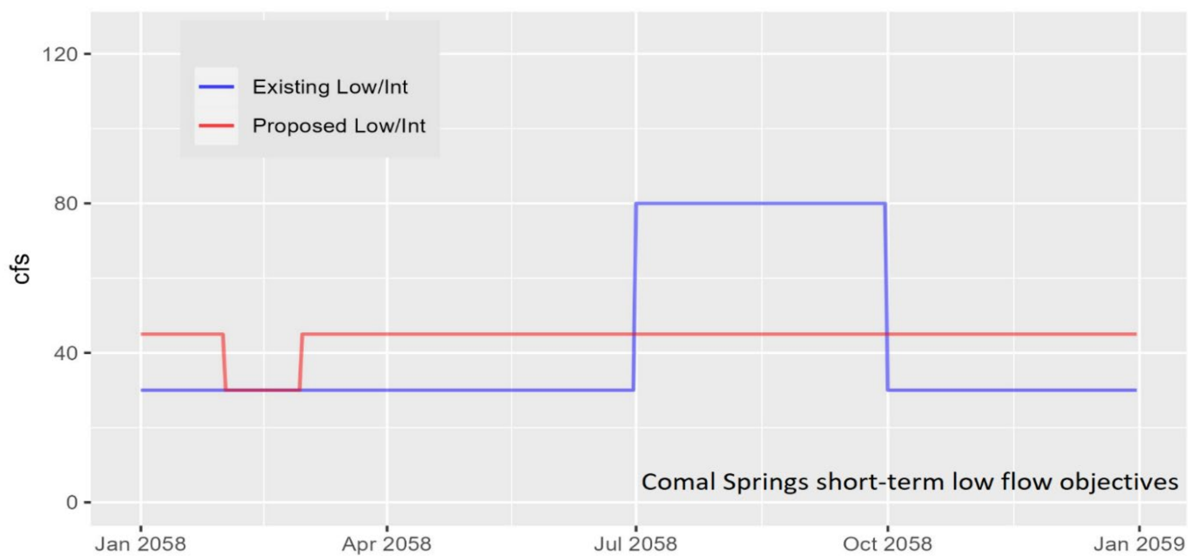

Figure 1. One-Year Comparison of the Existing and Proposed Springflow Objectives if Implemented to their Minimums

Due to the 3-year moving average proposed in the recommended objectives, additional protections are provided when applied over a hypothetical 3-year timeframe. Under the recommended objectives, only 1 year at the minimums would be allowable to adhere to the recommended 3-year moving average annual discharge of 178 cfs (Figure 2). This contrasts with the existing flow objectives (EAA 2012:Table 4-2) which only include a long-term average of 225 cfs to be maintained over the course of a 50-year modeled scenario. Under the existing objectives, the 30 cfs and 80 cfs minimum scenario could occur for greater than 10 consecutive years during a severe drought, if followed by 40 years of higher flow conditions, while still meeting the long-term average objective of 225 cfs.

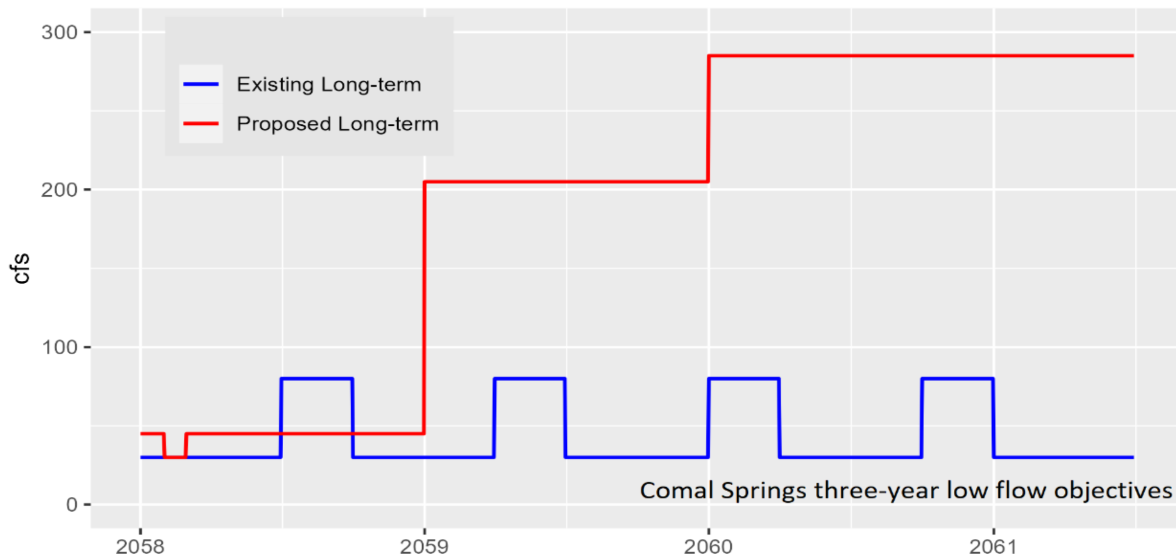

Figure 2. The Springflow Necessary to Maintain the Proposed Comal Springs Springflow Objectives in a 3-Year Period if Implemented to their Minimums

In this way, the recommended objectives attempt to guard against prolonged periods of low flow and offer intermittent periods to support recovery in between disturbance events. They also demonstrate the validity of using a shorter 3-year period compared to the existing 50-year period. The 3-year period enables managers to use observed gage data to assess whether the objectives are being exceeded on a regular basis, whereas a long-term period (e.g., 50 years) cannot be frequently evaluated.

Following the same rationale, a similar comparison can be made on a 1- and 3-year timeframe to compare the existing flow-related objectives to the recommended springs and discharge objectives for the San Marcos Springs and River System (Figures 3 and 4). The differences are that 1) the discharge values for both the existing discharge objectives (EAA 2012:Table 4-13, included below) and proposed (referenced above) are different in the San Marcos system than in the Comal system, and 2) the analysis in the San Marcos system focused on supporting suitable fountain darter, San Marcos salamander, and Texas wild-rice habitats during minimum flow conditions over the course of 1 year, while protecting for periods of extended drought by having a 3-year moving average of 138 cfs.

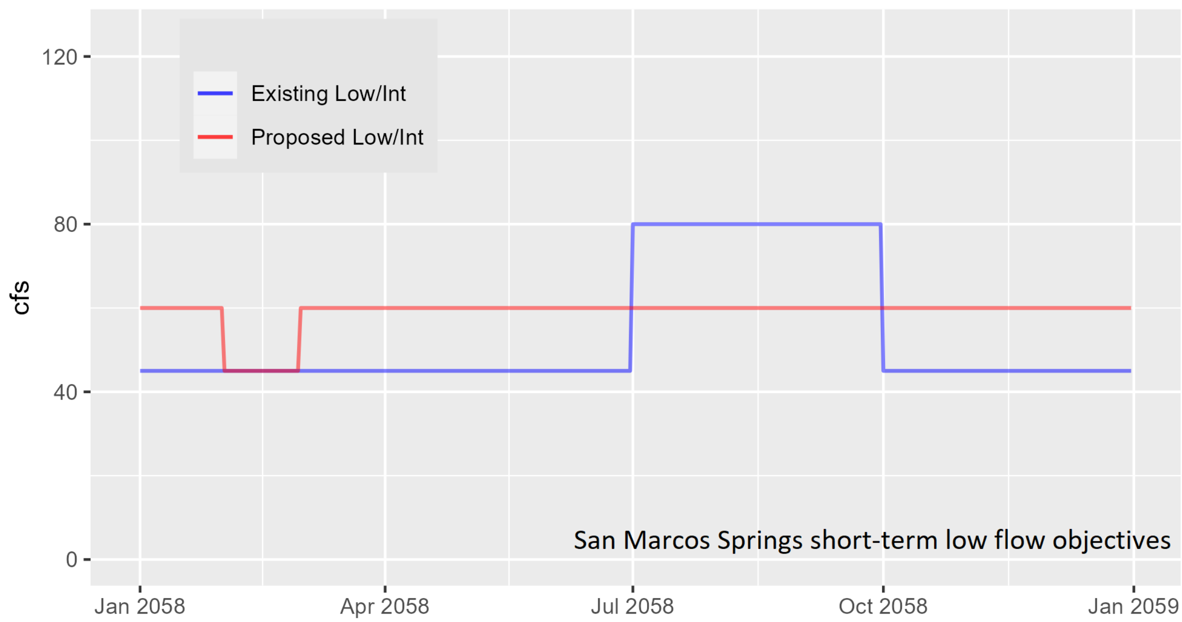

Figure 3. One-year Comparison of the Existing and Proposed San Marcos Springs Springflow Objectives if Implemented to their Minimums

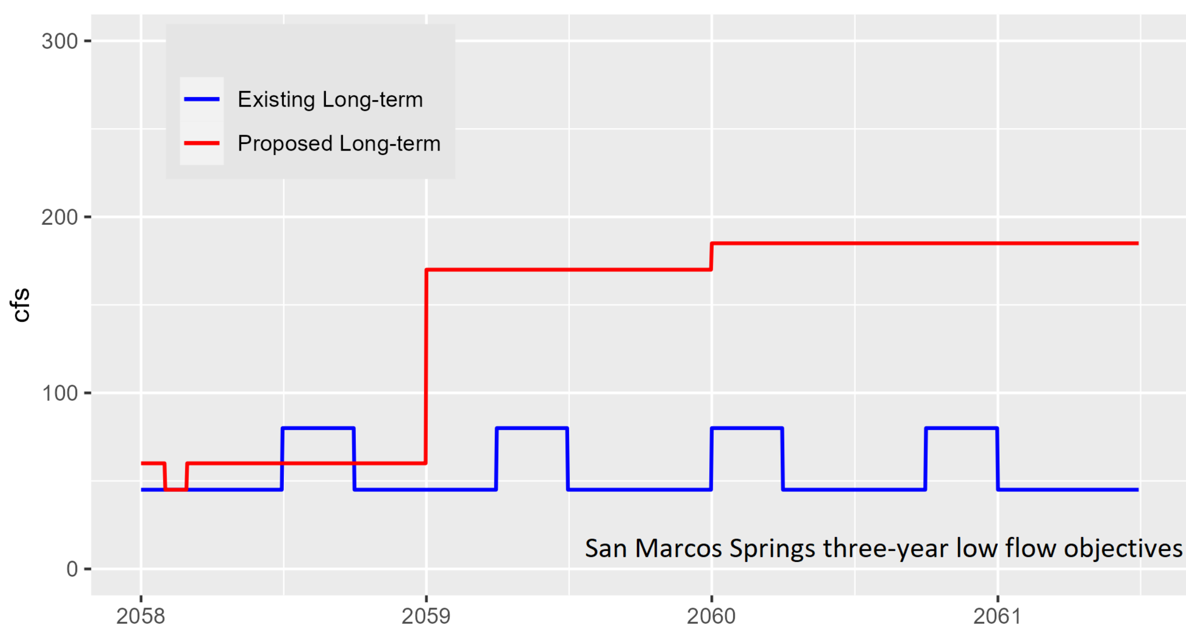

Figure 4. The springflow Necessary to Maintain the Proposed San Marcos Springs Springflow Objectives and River Discharge Objectives in a 3-year Period if Implemented to their Minimums

TABLE 4-13
LONG-TERM AVERAGE AND MINIMUM TOTAL SAN MARCOS DISCHARGE OBJECTIVES

Description	Total San Marcos Discharge (cfs)[a]	Time-step
Long-term average	140	Daily average
Minimum	45[b]	Daily average

[a] Assumes a minimum of a 50-year modeling period that includes the drought of record

[b] Not to exceed six months in duration followed by 80 cfs (daily average) flows for 3 months.

Finally, in response to multiple requests for a longer-term discharge requirement, the project team will add back in the existing criteria 225 cfs (Comal) and 140 cfs (San Marcos) over the proposed 30-year permit renewal period.

ACTION: The springflow objectives in the revised memorandum are revised to include:

Objectives 1.1 and 1.3, Comal Springs Discharge (gage #08168710)**:**

- *Maintain mean monthly spring discharge at Comal Springs greater than or equal to 45 cfs for at least 11 months per calendar year. Maintain daily average springflow greater than or equal to 30 cfs. This will be quantified by using mean daily springflow data to calculate average springflow for each month per year.*
- *Maintain a 3-year moving-average annual Comal Springs discharge above 174 cfs.*
- *Maintain a 30-year long-term average discharge above 225 cfs at Comal Springs.*

Objective 1.2 and 1.4, San Marcos Springs Discharge (gage #08170000)**:**

- *Maintain mean monthly discharge at San Marcos Springs greater than or equal to 60 cfs for at least 11 months per calendar year. Maintain daily average springflow greater than or equal to 45 cfs. This will be quantified by using mean daily springflow data to calculate average springflow for each month per year.*
- *Maintain a 3-year moving-average annual San Marcos River discharge above 136 cfs.*
- *Maintain a 30-year long-term average discharge above 140 cfs at San Marcos Springs.*

Commenters expressed concerns that the recommended flow-related objectives are not appropriate because there have been no instances of sustained low flows at those levels within the study period.

Response:

The 3-year moving average river discharge objectives have been observed during the biomonitoring study period. As shown in the BGO memo, the minimum 3-year moving average annual discharge was set based on the minimum observed over the study period in both systems during 2014. Covered Species demographic parameters (e.g., fountain darter density) initially declined with low flows in 2014 but increased within a year, indicating resiliency after this disturbance event.

For the most part, it is true that the minimum springflow objectives have not been observed during the biomonitoring study period. That said, discharge levels which approached the 45 cfs (Comal) and 60 cfs (San Marcos) objective levels have been observed in both systems in recent years. In August 2023, a minimum mean daily flow of 55 cfs was recorded at Comal Springs. Observations at 55 cfs support model predictions of wetted habitat for Comal Springs riffle beetle at 45 cfs. Most spring runs throughout the system were largely desiccated from July through September 2023, while Spring Island and Spring Run 3 remained 25–50% and 45–50% watered, respectively (BIO-WEST 2024a). Additionally, discharge through the Old Channel remained within the suitable range during the 2023 low flows.

Similarly, a minimum mean daily flow of 66 cfs was recorded in August 2023 in the San Marcos system. Based on observations at discharges consistently below 80 cfs in 2023, habitat degradation (e.g., siltation in Spring Lake, reduced submerged aquatic vegetation [SAV] coverage) occurred throughout the system and fountain darter reproductive temperature thresholds were exceeded throughout portions of the river. Despite the degraded habitat conditions in both systems, the Covered Species persisted during all low-flow sampling with multiple fountain darter population metrics that approximated or were higher than long-term averages (BIO-WEST 2024a, 2024b).

2023 conditions have not been observed for an extended period (11 months) and conditions would likely further degrade at 45 cfs in the Comal system and 60 cfs in the San Marcos system. This uncertainty was inherent in the original EAHCP discharge objectives (Tables 4-2 and 4-13, above) and remains with these proposed revisions. Hence, the proposed springflow objectives were developed to limit the occurrence and duration of minimum discharge conditions when compared to existing objectives. This reduction in duration combined with more intermittent periods between disturbance events provides opportunities for habitat conditions to recover throughout the systems, whereas increased duration of extreme low-flow events under the existing objectives limits opportunities for recovery.

ACTION: We will consider the implications of sustained low flows when developing Conservation Measures and long-term monitoring actions for the HCP.

Commenters noted that outdated data analyses (EAAESS/Hardy 2009; Saunders et al. 2001) used to predict wetted width in the San Marcos River and to validate the San Marcos River springflow objectives should be removed in place of more current data.

ACTION: The revised memorandum and HCP chapter will move away from the 2009 models to focus on habitat conditions observed and measured over the course of the EAHCP implementation period.

Commenters raised concerns about using river discharge data (U.S. Geological Survey [USGS] gages #08169000 and #08170500) instead of springflow and that high-flow pulses skew estimates of mean annual river discharge.

Response:

It is well supported in the literature that high-flow pulses have long-term positive effects on the function of riverine ecosystems (Poff et al. 1997; Humphries et al. 2014). During extended durations of low and stable flows, local production and inputs have the largest influence on river function.

High-pulse events transport resources from upstream sources and the surrounding watershed landscape and maintain geomorphic complexity of river channels (Humphries et al. 2014). It is also well documented over the course of the biomonitoring program that high-flow events can have acute negative impacts on fountain darter habitat availability in these systems by scouring out SAV in some reaches. Based on these complexities, it is important to recognize the potential effects of other flow regime characteristics (i.e., high flows) on ecosystem function. This makes mean annual river discharge a reasonable and useful index in addition to the separate springflow objectives, which do partition springflow from runoff events. That said, because differences between the springs and river discharge are not present during drought and are minimal during other periods, the team proposes to remove the river discharge gage calculation completely to avoid any confusion in the future.

ACTION: All discharge objectives will be developed and measured via springs discharge only at each respective USGS gage. The use of the springs discharge data instead of the river discharge data caused a decrease of the long-term 3-year rolling average in Comal from 178 cfs to 174 cfs and in San Marcos from 138 cfs to 136 cfs. See discussion of springflow objectives on pages 8 and 9.

3.2 Statistics for Comal Springs Objective

One commenter had several comments about the methods and results presented for the regression model used to predict station-level discharge, which were recommendations to revise descriptions of the modeling procedures for clarity and include additional analysis/results, as well as concerns about statements regarding model accuracy.

Response:

We appreciate the suggestions to help clarify the model structure and acknowledge that descriptions of our methods for model fitting can be improved.

The comments about centering and scaling are appreciated. Centering and scaling were conducted in tandem to standardize the predictor variable (i.e., 30-day springflow average) into z-score. 30-day springflow average data were centered by subtracting each data point by its mean and scaled by dividing the centered value by its standard deviation. The standardized predictor then has a mean of zero and standard deviation of one (i.e., standard normal distribution). Further, 30-day springflow average was standardized to help with model convergence and interpretation of model coefficients. For example, centering predictors make it easier to interpret the intercepts, representing the expected value of station-level discharge when 30-day springflow average is set to its mean, rather than it being at zero (i.e., marginal effect) (Gelman and Hill 2007; Hastie et al. 2009). These justifications for predictor standardization will be included in the revised memorandum.

We think including results on more rigorous multi-model inference is beyond the scope of this document because the main goal is modeling for prediction. That said, results from additional analyses are described and provided here. Performance of the fitted model was compared with two alternatively structured models using information criteria, root mean squared errors (RMSE), R^2, and stational-level contributions to R^2. Model 1 is a “null” model with a station-level random effect (varying intercept-only), Model 2 includes 30-day average springflow as a fixed effect and station-level random effect (varying intercept-only), and Model 3 is the model used for this objective described above (varying intercept and slope). Model 3 was the best supported for data inference, which had the lowest AIC_c score (1845) and RMSE (5.04), as well as the highest AIC_c weight (0.99) and R^2 (0.98).

Regarding the comment about RMSE for the fitted model, we agree that “highly accurate” may be an exaggeration, though we believe that “accurate” is a reasonable descriptor of performance. RMSE should be put into context with the distribution of the response variable and requirements of the problem being addressed. Given that discharge across stations ranged from 0 to 166 cfs and that variability of the middle 50% of observations (i.e., interquartile range) was ~35 cfs, we argue that an average prediction error of ~5 cfs is accurate. The range of discharge across stations can be added into the results to provide context for RMSE estimates.

To see how well the model generalizes to new data, 10-fold cross-validation repeated five times (50 total resampling iterations) was used to simulate new data based on the out-of-sample data (Hastie et al. 2009). Predictive performance was evaluated across all iterations by calculating RMSE and R^2. Cross-validation results showed mean RMSE (± standard error) and R^2 (± standard error) were very similar for both training (5.02 ± 0.02 and 0.97 ± 0.001, respectively) and test (5.24 ± 0.15 and 0.97 ± 0.001, respectively) datasets. Strong generalization performance demonstrates that the model is reliable for predicting station-level discharge. We can include these cross-validation results into the revised memorandum to further illustrate the reliability of the model for this objective.

ACTION: The revised memorandum includes descriptions of the methods for model fitting to make the procedures easier to understand for the reader and clarifications have been made to better explain the methods of centering and scaling.

4. Water Quality

Recommended water temperature objectives include:

Objective 1.5, Comal Springs and River Water Quality: *Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C within Upper Spring Run, Spring Island, Spring Run 1–3, and Landa Lake. Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C for more than 50% of the days per year and less than or equal to 27°C within the Old Channel.*

Objective 1.6, San Marcos Springs and River Water Quality: *Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C within Spring Lake. Maintain mean daily water temperature in surface habitats near the substrate less than or equal to 25°C for more than 50% of the days per year and less than or equal to 27°C within the Headwaters, Upper River, and Middle River.*

Commenters voiced concern that maintaining the water temperature objectives for 50% of days per year does not adequately protect the species. Commenters also suggested that, in

addition to water temperature, other water quality parameters should be included in the objective.

Response:

The suggestions regarding the water temperature objectives are appreciated. The proposed water temperature objectives are based on recovery criteria being considered by USFWS in its draft recovery plan for the Edwards Aquifer springs species.

In addition to input provided by USFWS, several studies demonstrate that the recommended temperature objectives are suitable for the Covered Species (Berkhouse and Fries 1995; McDonald et al. 2007; Nowlin et al. 2017). Spatial determination for the water temperature objectives was focused on the springs and thermally stable reaches of both systems as biomonitoring data indicates and some reaches downstream of Interstate (I-)35 and within fountain darter designated critical habitat are less thermally stable than the middle and upper reaches that are near the spring headwaters. It is expected that maintaining appropriate springflow is protective of suitable water temperatures in both systems as demonstrated by existing monitoring data (BGO memo Figures 5 and 6).

No objective was proposed for dissolved oxygen or other water quality attributes because these cannot be directly manipulated and managed. Adequate springflow is a driving variable for environmental parameters such as water temperature, dissolved oxygen, carbon dioxide, and turbidity. Due to the direct linkage between springflows and these water quality attributes, maintaining appropriate springflows (as met by the proposed objectives) is assumed protective of suitable water quality within both spring systems. Although there is no objective for other water quality parameters, monitoring for these constituents (e.g., contaminants, dissolved oxygen, conductivity, turbidity, pH) will remain in place and be conducted by the EAA Aquifer Sciences during monthly discrete sampling and opportunistically during disturbance events such as reduced flows.

ACTION: We will consider water quality indicators (contaminants, dissolved oxygen, conductivity, turbidity, pH) when developing Conservation Measures and long-term monitoring actions for the HCP.

5. Species

5.1 Statistics

Multiple comments by reviewers addressed concerns that one standard deviation from the mean is not the appropriate statistic for determining the fountain darter population metric and vegetation objectives, the Comal Springs riffle beetle population metric objective, and San Marcos salamander habitat objectives.

Response:

The standard deviation (σ), like the mean, is a statistical form of expectation. The standard deviation of a sample represents the level of dispersion from the mean (μ) that is expected on average.

Therefore, variables of interest would be expected to range from one standard deviation below the mean to one standard deviation above the mean from event to event (Rice 2007).

Establishing criteria based on one standard deviation below the mean was proposed by Dr. Chad Furl, P.E. (Chief Science Officer, EAA) during the Biological Objectives Subcommittee meetings in spring 2023. The criteria were suggested to balance between the HCP Handbook requirement of 'Achievable Objectives' while ensuring adequate protection of the species. Over the course of the 23-year biological monitoring program, consecutive routine biological surveys (spring and fall, approximately 6 months apart) have observed species counts less than one standard deviation below the mean. In 23 years, the condition has rarely been observed in three consecutive (i.e., spring, fall, spring) routine sampling periods, which essentially covers a 12-month period. Hence, the additional criteria of three consecutive routine monitoring events covering a 12-month period is proposed. The rationale is that two events have been observed several times with habitat and species rebounding quickly, but a third consecutive routine event is rare. Therefore, in our professional opinion, this is a good place to establish threshold criteria.

Developing objective criteria based on a sampling model framework and parameters associated with the normal distribution is justified because variation is a fundamental component to population dynamics since ecological processes are inherently stochastic. Statistical properties of the normal distribution provide a method to establish objective criteria that account for variability to better estimate whether changes in a given objective variable are ecologically meaningful. In a normally distributed dataset, more than ~16% of the data typically falls below one standard deviation below mean. The main utility of this sampling model framework is that these parameters provide simple descriptions of the processes that generated the data as well as numerical summaries of expectation that general practitioners can understand. Outcomes below the range of expected values (i.e., below one standard deviation) can therefore help define thresholds for indicating potential population/habitat pressures (i.e., stress or disturbance). Outcomes more than two standard deviations from the mean have been used as thresholds to represent catastrophic disturbance events that cause major shifts in population trajectories (Resh et al. 1988; Grossman and Sabo 2010). One standard deviation below the mean was chosen as an objective criterion to indicate stress (rather than a catastrophic disturbance) based on its common use in population and disturbance ecology (Battisti et al. 2016).

ACTION: This comment will be considered in developing long-term monitoring actions for the HCP.

5.2 Objectives for Fountain Darter

Commenters raised concerns that proposed objectives for fountain darter density are not protective of healthy, reproducing, and resilient populations. Several comments also questioned evaluating objectives on a calendar year basis.

Response:

The Biological Objectives for fountain darter density attempt to account for variation in density that would be expected during a given event. Densities lower than one standard deviation from the mean were characterized as potential population pressure and the objectives aim to limit extended durations of this type of population state. Although such events have occurred during the monitoring period, long-term monitoring data provide supporting evidence to suggest the density objectives are protective of resilient fountain darter populations. Following events where mean density was below the objective, the time for mean density to return to values within one standard deviation of the mean was less than 1 year for both systems. This demonstrates resiliency since the population recovered following declines. Populations would not be considered resilient if mean densities failed to return to the range of expected values following potential population pressure. These objectives were measured on a calendar year basis because existing monitoring data demonstrates fountain darter densities can recover to expected levels within 1 year. Annual analysis allows for acute deviations in a given event but attempts to capture patterns in population performance on a time scale relevant to overall population persistence given the life span of the fountain darter. In short, monitoring data supports that fountain darter populations should be resilient and persistent in the future if the parameters used to characterize their temporal variation from 2001 to 2022 (i.e., mean and standard deviation) remain at similar levels.

ACTION: No changes proposed to the density values. However, wording is clarified from "one calendar year" to "… a minimum of three sampling events covering a 12-month period". This comment will also be taken into consideration for development of long-term monitoring.

Commenters raised issues concerning the SAV objectives, which involved recommendations to include additional vegetation taxa, establishing system-level objectives, questions about why certain taxa were omitted, and concerns about including the non-native* Hygrophila*.

Response:

SAV taxa used to calculate each objective were selected because they represent the dominant vegetation types present in the system, were sampled during drop-net sampling as part of the EAHCP biomonitoring program, and have associated fountain darter density values. Texas wild-rice was not originally included in the simple SAV objective for the San Marcos River because this species has its own objective criteria independent of fountain darter habitat. Criteria were developed at the reach level rather than system level so that activities of any Conservation Measure (e.g., SAV restoration) could be explicitly linked to the objectives established for each reach. That said, system-level approach comments were common and adding additional reaches to provide better spatial representations of each system were further considered and agreed upon.

Consideration of non-native *Hygrophila* as suitable habitat for fountain darter was discussed during Texas wild-rice and fountain darter EAHCP Biological Objectives Subcommittee meetings. There was a general consensus that *Hygrophila* is recognized as suitable habitat, which is supported by drop-net data and previous studies (e.g., Edwards and Bonner 2022). Given this recognition, it was also suggested during these meetings that any *Hygrophila* removed during restoration efforts should be replaced by native taxa that also provide suitable habitat for fountain darter (e.g., *Ludwigia*). One reviewer's comment raised concerns about whether natives can persist after *Hygrophila* is removed. Data from past restoration in the Comal Springs and River support that natives can persist following *Hygrophila* removal in non-shaded areas with appropriate substrate conditions. Restoration efforts in the Comal River's Old Channel provide a model success story, demonstrating the persistence of exclusively native SAV assemblages (e.g., bryophyte, *Ludwigia*) from 2019 to the present following removal of *Hygrophila* and thinning of riparian coverage to allow ample sunlight (BIO-WEST 2023).

ACTION: Further discussion and analysis has been conducted and additional complex vegetation types (water stargrass [*Heteranthera dubia*], Eurasian watermilfoil [*Myriophyllum spicatum*] and bryophytes) have been added to the San Marcos system. Texas wild-rice is also now included in the simple vegetation category.

Additional reaches outside of the Long-Term Biological Goals study reaches were added in each system to provide better spatial representation of each system. These restoration reaches are as follows and are displayed in Figures 19 and 20 in the revised memorandum:

- Comal—Upper Landa Lake, Lower Landa Lake, and Upper Old Channel.
- San Marcos—Spring Lake Dam to City Park, City Park to Rio Vista.

5.3 Objectives for Texas Wild-rice

Commenters recommended adding an objective to maintain at least two large, contiguous Texas wild-rice stands for their viable seed production ability in the upper most portions of the San Marcos River.

Response:

There remains uncertainty regarding sexual reproduction, seed viability, and recruitment of Texas wild-rice in the San Marcos River. Although data on this topic is not available in the literature to offer guidance, it is agreed that maintaining a few large, contiguous stands for sexual reproduction would likely be a benefit.

ACTION: Maintenance of two large, contiguous Texas wild-rice stands specific to seed production in the upper most portions of the San Marcos River is included as a Texas wild-rice objective in the revised memorandum.

One commenter recommended increasing the Texas wild-rice coverage value below I-35.

Response:

The persistence of Texas wild-rice stands throughout the last 10 years of EAHCP implementation was used to guide objectives recommendations. Based on persistence analysis over this period, the higher levels of turbidity in this stretch, limited amounts of carbon dioxide in the water, and high risk for flood scour, the team does not agree with increasing the coverage above 200m^2 below I-35.

ACTION: We will consider Texas wild-rice coverage below I-35 in developing Conservation Measures and long-term monitoring and adaptive management for the HCP.

5.4 Objectives for Salamander

Commenters noted the objectives are centered on habitat only, and asked about the number of salamanders observed in these locations over the years and if additional sampling areas might be pertinent.

Response:

The National Academy of Sciences report and Biological Objectives Subcommittee both raised concerns over the sampling methodology to calculate San Marcos salamander population metrics. As such, the project team did not use this long-term count dataset to calculate population metrics. However, it is important to understand that all three existing and proposed monitoring areas have had persistent occupancy over the past 23 years. When examining just the total numbers during 15-minute timed counts in these areas, 5,154 total salamanders have been counted in the Hotel Reach with an average (±standard deviation) of 101.0 (±22.3) salamanders per 15-minute survey, 4,249 total salamanders counted in the Riverbed study area with an average of 83.3 (±23.4) salamanders per 15-minute survey, and 826 total salamanders counted in the proposed Spring Lake Dam study area with an average of 16.2 (±7.8) salamanders per 15-minute survey since the inception of the biological monitoring program. The reason for the consistently high numbers of salamanders throughout wide-ranging flow conditions over two decades is the quality of the habitat available. Differences in the numbers counted per standardized timed survey per event typically revolve around disturbances to the available habitat. The main disturbances are siltation or rooted vegetation encroachment in Spring Lake and recreation activity (foot traffic and rock removal or arrangement) below Spring Lake Dam. Therefore, only habitat quality and protected area criteria were proposed. This allows time for the new biological monitoring program for this species to be implemented during the permit renewal with the goal of developing population metrics once sufficient data is available.

Additionally, the addition of diversion springs as a fourth salamander monitoring area is supported by the number of San Marcos salamanders consistently observed in this location by USFWS San Marcos Aquatic Research Center biologists. The project team believes a protective approach is to establish additional habitat quality and area criteria for this fourth location and continue monitoring to document persistent occupancy, while developing population metrics into the future.

ACTION: The revised memorandum includes information on the number of salamanders observed over time in these study reaches to document to persistent occupancy of these spatially diverse habitat areas.

The revised document includes further definition and description of "quality habitat" specific to the persistent occupancy documented over the past 23 years.

To enhance protectiveness of this objective, language has been added to the revised memorandum regarding additional locations for Diversion Springs management to be continued in Spring Lake as part of the Conservation Measure for this species.

One reviewer stated, "Could there be a biological objective to maintain X area of recreation free salamander habitat in the Spring Lake Dam Reach? I'm trying to figure out a way to provide protection from recreation when the river is not in Condition M with SSA exclusions."

Response:

The project team concurs that recreation in the San Marcos River is a contributor to take of the Covered Species, which is even more detrimental at lower flows.

ACTION: We will consider the recreational impacts on salamander habitat in developing Conservation Measures and long-term monitoring and adaptive management for the HCP.

5.5 Objectives for Comal Springs Riffle Beetle

Commenters were concerned that including the standard deviation to set the objective at 2.4 counts/lure makes the objective criterion too low. It was also recommended that the San Marcos population in Spring Lake be included in the objective to facilitate redundancy and indicate overall species state.

Response:

The Comal Springs riffle beetle objective was developed using data from 2013 to 2022 and did not include data from 2004 to 2012. From 2004 to 2012, lures were set in areas with high-quality habitats that were known to have high beetle abundances. Some of this data was used to establish the existing reach-level density objectives (Spring Run 3: ≥20 beetles/lure; western shoreline: ≥15 beetles/lure; Spring Island Area: ≥15 beetles/lure). From 2013 to 2022, lure locations were fixed, more spatially varied, and were also set in areas known to harbor lower beetle abundances. Therefore, data from 2013 to 2022 likely better represent the range of available habitats within Comal Springs and thus better characterize the overall population. With this in mind, the recommended lower count objective at the system level is not directly comparable to the existing higher density objectives at the reach level and should not be assumed to be less protective of the species. Furthermore, including the standard deviation in the objective criteria accounts for variation in density that we would expect during any given event. It is acknowledged and was highlighted by the National Academy of Sciences report that the Comal Springs riffle beetle lure methodology has limitations. One could meet the proposed objective of 2.4 beetles per lure with all the beetles being collected on a single lure regardless the total amount of lures placed. As such, to enhance the protectiveness of the measure, further examination of the presence/absence percentage per total lure set will be added as a subcomponent to this objective.

ACTION: Based on comments, language has been added to the revised memorandum to incorporate monitoring of Comal Springs riffle beetle at the Hotel area of Spring Lake with the goal of developing population metrics.

Additionally, the project team has added language to the revised memorandum regarding the presence/absence per lure percentages in the Comal system to enhance the spatial protectiveness of this Biological Objective.

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Document: Recommended Biological Goals and Objectives for the Permit Renewal
12/27/2023

Reference Page Number	Line/Table/Figure Number	Reviewer Name	Reviewer Organization	Reviewer Comment
general		Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	Overall, we find the biological goals and objectives well-written and largely agreeable. We understand the complexity of renewing the ITP and updating the HCP. The City of New Braunfels looks forward to the permit renewal and updated HCP finalization over the next few years.
3	11 16	Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	The City of New Braunfels, and all other permitees and stakeholders, should be provided the same information to base comments as EAHCP staff was provided by USFWS. All permitees should have a voice in how the HCP is finalized with respect to comments and changes requested by USFWS. Footnotes with brief descriptions of current biological objectives that accompany the new proposed objectives would be helpful for comparison and to understand how and why changes have been made. We also think that it is critical that the EAHCP science committee be provided a chance to comment on documents such as this memo as a group and not just individually.
6	14 - 20	Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	Please explain why USGS gage #08169000 was selected to base the spring discharge calculations on instead of gage #08168710? If gage #08168710 data is not used, clarify how the data taken from gage #08169000 will be manipulated to represent the actual spring flow and not take additional stormwater runoff into account.
6	41-42	Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	Provide clarification on the flow objective threshold for Spring Run #3. The surface flow for the spring orifices in Spring Run #3 furthest from the Landa Lake confluence cease flow before most of the other orifices closer to the lake. Clarify the target objective regarding how much of Spring Run #3 should have surface flow during a low-flow scenario to preserve CSRB habitat. What is the justification for allowing most of this critical habitat to go dry at the surface?
7	22	Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	The City of New Braunfels would like to obtain additional information about how this spring flow objective would interact with two activities that occur on Landa Lake: Old Channel Flow Management and Vegetation Mat Management. The City has serious concerns that these conservation measures could not be appropriately executed during a prolonged low-flow scenario. The predicted minimum flow may allow the fountain darters to have adequate spring flow to survive, but would create conditions within the lake that would impair habitat. Have the changes in habitat composition created by these low flow scenarios (increased shade from vegetation mats, decreased dissolved oxygen) also been accounted for? What is the justification for selecting 11 months as the timeframe for the mean monthly spring discharge? How would this timeframe specifically benefit the species? The City recommends decreasing the duration at which flow would remain at 45 cfs, perhaps to only 4 - 6 months rather than 11, and/ or increasing minimums.
7	9 - 12	Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	From reading the memo, it is not apparent how or if short-term spring flow fluctuations and current conservation activities were taken into account when developing the spring flow objectives. How would these lower minimum flow rates allow for the management of increased floating vegetation mats on Landa Lake during low flow? Has there been a holistic evaluation regarding the changes in flow regimes to ensure the continued benefit of the endangered species while some conservation measures are prohibited by Condition M or are not physically possible during low flow scenarios?
11	Objective 1.3	Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	Please clarify how the current long-term average flow objective for Comal Springs (225 cfs) is assessed and how the proposed long-term average would be assessed. A comparison of current and proposed flow objectives in this memo or an associated document would be helpful.
11	Objective 1.3	Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	The proposed 3-yr rolling average for Comal, 178 cfs, is significantly different from the existing flow objective for long-term avg, 225 cfs. Provide justification for making such a significant change.
12	35 - 39	Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	Please provide justification for the substantial change of temperature objectives from the current plan to the proposed plan as a water quality objective and how this change benefits the species.
19	31-34, Objective 3.1	Phillip Quast/Amy Niles/Greg Malatek	CONB (IC-SH)	Provide explanation on Spring flow Objective 1.1. Is it adequate to support CSRB habitat in Spring Run #3 with reduced minimum spring flow and increased temperatures?
2,3	35 on page 2 to 10 on page 3	Tom Taggart	COSM (IC-SH)	The Stakeholders and IC members were assured that the spring flow numbers objectives would not change as part of the ITP renewal process. The process description indicates ICF recommended "increasing flexibility" in the BO for the fountain darter. Why did EAA and ICF change the BO in this draft versus prior assurance? How does this change "increase flexibility" and what does that equate to species needs. It certainly reduces flow targets vs. 2012 ITP.
3	Line 11-16	Tom Taggart	COSM (IC-SH)	This section should be revised to include review and approval of the BGO's by both Stakeholders and IC members (as well as any EAHCP Science Committee and independant reviews as assigned) and show the appropriate level of interface in the process. All the parties should have a view and voice on the proposed finalization process and not just EAA staff and ICF when USFWS concerns and comments/changes are addressed.
3	22-34	Tom Taggart	COSM (IC-SH)	The Goals are broad and appropriate. I can support these as shown. It would be nice to have Biological Objectives for Goal 7 completed earlier but I understand the constraints to that.
4	5,6	Tom Taggart	COSM (IC-SH)	It is recommended a report be prepared summarizing the biological objectives subcommittee work, recommendations and how their recommendations were incorporated into the draft BGO report, noting which recommendations were and weren't incorporated. Despite assertions of transparency, the content and methodology don't lend themselves to transparency.
Section 4	all	Tom Taggart	COSM (IC-SH)	The organization of this section makes it difficult to follow. Tables and figures should be in the sections they augment and not scattered into other areas. The Comal/San Marcos sections are one example of this. Explanations of choices and assumptions should be expanded. Clarity is important.
6	Line 41-42	Mark Enders	COSM (IC-SH)	Provide clarification on the flow objective threshold for Spring Run #3. Surface flow from individual springs in SR#3 will cease flowing from upgradient to downgradient as you near Landa Lake confluence. Clarify the target objective regarding how much of SR3 should and will remain flowing at 45cfs.
7	Line 6-7	Mark Enders	COSM (IC-SH)	At observed total Comal springflow of 60cfs, only approx. half of SR3 exhibits flow. Recommend increasing Comal minimim springflow objective to ensure flow through at least 75% of SR3 and/ or decrease duration at which a majority of SR3 would remain dry. Recommend including a statement in the memo clarifying that only a small portion of SR3 will exhibit flow at 40-45cfs (perhaps only 10-20% of the SR3 would exhibit flow at 40-45cfs).
6	21-42	Tom Taggart	COSM (IC-SH)	Further explanation of the modeling done and what criterion was chosen will help us understand this. When it states that SR3 is still flowing does that mean a surface flow? Subsurface? What extent will SR3 flow? Describe how the modeling takes any climate change effects into consideration when evaluating the historical use of data. Is the "objective criterion" future or retrospective as the model was used.
7	Objective 1.1	Tom Taggart	COSM (IC-SH)	Provide supporting documentation on the basis of how the 11 month average vs. a 12 month period was selected? Given the high degree of uncerctainty in these systems, why would we leave a month out? This is very different than our last effort and it is not clear how this benefits the species more than the original ITP values. Please explain how the proposed objectives for spring flow are more protective?

7	Line 9-12, Objective 1.1 (Comal Springs Discharge)	Mark Enders	COSM (IC-SH)	Provide more information on how the duration of 11 months at 45cfs was derived to be protective of species and habitat. Having worked in, closely observed and managed the Comal system for almost 10 yrs, I find it would it be diffcult to maintain sufficient suitable habitat in Landa Lake and Old Channel with sustained flow 45 cfs. In general, it is felt that the development of the springflow objectives don't adequately account for dynamic system processes and managment needs (i.e. expanded coverage and feasible mgmt of floating veg mats on Landa Lake, flood scouring, DO concentrations, ability to route flow into Old Channel, etc). Recommend decreasing the duration at which flow would remain at 45cfs or increase minimum flow objectives to align with feasibility of being able to "manage" the system and implement effective conservation measures and to be able to meet other Bio Objectives.
7,8	21page 7 through 33 Page9	Tom Taggart	COSM (IC-SH)	The section methodolgy doesn't provide the same level of protection as prior ITP (or that isn't presented clearly enough to ascertain). River morphology has changed since the 2009 study, which is based on 2001 channel geomteries, and no adjustment is shown. The 11 of 12 months approach is also used again and given the single monitoring guage the averages could differ wildly with surface flows also passing through the gauge. Low flow tolerance is not adequate with the "long term" 3 year period shown. **Why was 3 years vs a longer period chosen and what was the need to change the prior methodology the EARIP and EAHCP ITP 1 used?** The 2023 sampling of salamanders at low flow used to "confirm" conditions as suitable even though the report elsewhere is careful to point out that drought and other stressor effects may be delayed. We may not know all the effects of this drought condition yet. The assumptions have a high degree of uncertainty and seem more subjective than best available science. Recommend re-evaluation with Science Committee or independant review help.
9	21-31	Tom Taggart	COSM (IC-SH)	The declarative statement (Thus…) on 45 cfs beilng protective of the darter is not adequately supported and should be evaluated further.
9	Line 22-25, Objective 1.2 (San Marcos Springs Discharge)	Mark Enders	COSM (IC-SH)	The methodology used to arrive at the springflow objective for San Marcos relies on the Hardy 2009 model to estimate wetted area in the SM River at given flow rates. Assumptions listed on Page 9, Lines 4-20, may not hold true as channel geometries have likely changed since 2001. Hardy 2009 used 2001 channel geometries. May need to try to test/ validate Hardy model based on actual observed low flow in the San Marcos River over the past 5-10 yrs or perform new modeling exercise to verify wetted area at varying flows and at low-flow objectives.
9	Line 22-25, Objective 1.2 (San Marcos Springs Discharge)	Mark Enders	COSM (IC-SH)	Provide additional justification on how the duration of 11 months at 60cfs will be protective of species. In general, it is felt that the development of the springflow objectives don't adequately account for dynamic system processes and managment needs (i.e. ability to achieve proposed SAV coverage goals under sustained low-flow at 60cfs, magnified recreational impacts under sustainded low-flows, channelization, sedimentation/ algal & detritus accumulation in SM Salamader habitat, flood scouring). Recommend decreasing the duration at which flow would remain at 60cfs or increase minimum flow objectives to align with feasibility of being able to "manage" the system and implement effective conservation measures and to be able to meet other Bio Objectives. In general, it is felt that the duration of low-flow defined in the springflow objectives will not provide for resiliency of the species and align with the Bio Goals.
9	Line 15-18, Objective 1.2 (San Marcos Springs Discharge)	Mark Enders	COSM (IC-SH)	45-60 cfs for sustained periods may not be adequate to prevent significant siltation of SM Salamaner habitat. Significant siltation occurred in SM Salamander habitat at sustained flows of 70-90cfs as experienced 2022-23. Statement on Lines 18-20 is not necessarily supportive of the proposed flow objective as conditions during the Summer of 2023 (70-90cfs sustained for 3 month) is not predictive of 60cfs for 11 months. In addition, the presence of salamanders observed during low-flows of 2023 does not mean that lag effects as a result of low-flows and sub-optimal habitat conditions may not be realized in the future.
9	Line 7	Mark Enders	COSM (IC-SH)	Report states "At 60cfs, the majority of FD habitat is still conserved. Define "majority".
9	Line 13-15	Mark Enders	COSM (IC-SH)	Statement that springflow in Spring Lake keeps rocks utilized by SM Salamander silt free as long as water issues from springs is not necessarily true. Significant siltation of spring orifices occurs routinely even at higher flows. While it is assumed that maintenance of the spring opening areas will occur as a conservation measure, it is uncertain that maintenance efforts will be able to keep pace with needs to maintain suitable habitat at low-spring flow objective levels without causing negative impacts.
11	Objectives 1.3, 1.4	Tom Taggart	COSM (IC-SH)	Please show comparative analysis of the proposed flow objectives vs. those in the existing EAHCP. Provide a justification of how the proposed flow objectives are equal protective of the species.
11	Line 1-4, Objectives 1.3 and 1.4	Mark Enders	COSM (IC-SH)	Recommend using spring/ baseflow based on gages 08168710 and 08170000 for the 3yr rolling discharge average in lieu of 8169000 and 08170500 to avoid the 3yr rolling average being skewed by stormflows and watershed contributions. The proposed 3-yr rolling average for Comal, 178cfs, is significantly different from the existing flow objective for long-term avg, 225cfs. Provide more justification for making such a significant change.
11	Objectives 1.3 and 1.4	Mark Enders	COSM (IC-SH)	Provide information either in the memo or in other format to describe and compare existing flow objectives vs. those proposed in this memo. Provide clarification on how the current long-term average flow objective for Comal (225cfs) and SM (140 cfs) are currently assessed.
Misc	Flow Objectives 1.1, 1.2, 1.3, 1.4,	Mark Enders	COSM (IC-SH)	While observed springflow and river discharge from 2001-2022 does represent varied hydrological conditions within both the Comal and San Marcos River system, representing both low- and high-flow conditions, the amount of biological data available during extreme and prolonged low-flow periods is limited to draw conclusions about species health and resiliency through low-flow periods defined by the objectives. A primary concern is the species response to the proposed proposed flow objectives, which are significantly lower and more sustained than have been observed during the period of record for biological monitoring (2001-2022). While Comal and SM flows have come close to hitting the minimum flow values for very brief periods (+/- 1 month), there is no instance 2001-2022 of sustained low-flow at 60cfs and 40cfs.
12	Objective 1.5,1.6	Tom Taggart	COSM (IC-SH)	We should add other factors than just temperature and evaluate the effects of climate change etc. when establishing the flow objectives. Ambient air temperature is modelled to rise significantly even in the best case as presented on December 14, 2023. We should factor that in especially given we seek a longer ITP term.
12	Line 40-44, WQ Objective 1.6	Mark Enders	COSM (IC-SH)	To be more protective and to expand optimal habitat for the FD, recommend expanding this objective to Stokes Park or throughout the full extent of FD Critical Habitat. Also recommend high-end thermal threshold be 26c and not 27c (i.e. Maintain mean daily water temp <25c more than 50% of year and <26c from Headwaters to Stokes Park.) Flow objectives may need to be adjusted accordingly to achieve these temperature objectives. Climate change may also impact ability to achieve Temp Objectives during sustained low-flow periods at 60cfs (i.e. if number of days >100F increases, downstream T could be increased under prolonged low flow-conditions).
18	39	Tom Taggart	COSM (IC-SH)	Comments that the study and conclusions referenced in 4.1 as protective related to 4.2, 4.3, 4.4 etc. are subject to the same concerns listed previously. We are betting a lot on those assumptions. Recommend this also be referred for additional evaluation and modelling should include the drought of record for comparison with results of the 20 year data period. Analysis of the uncertainty of using a 20 year data set to forecast the 30 years going forward from 2028 should also be explored.
22	Objective 4.1	Mark Enders	COSM (IC-SH)	Consider increasing the objective for total area of maintained high-quality habitat for the SM Salamander. The additional area may include other potential spring openings or potential high quality habitat areas in Spring Lake. With limited habitat area within the SMR system, it makes sense to increase the area of high-quality habitat to allow for population resiliency and redundancy.
22	Objective 4.1	Mark Enders	COSM (IC-SH)	I understand that a monitoring section for the new EAHCP will be developed at a later date, but would like to recommend that SM Salamander monitoring, as well as genetics work, be included within the program to monitor changes in populations over time. I understand the issue with including a species-based population or density objective and am not necessarily recommending this but do want to ensure adequate, long-term monitoring of the SM Salamander.
24	obj 4.6	Tom Taggart	COSM (IC-SH)	TWR coverage objectives should be expanded further downstream and reach designations evaluated for changes given the bank hardening, fencing and other factors such as prolonged low-flow and recreation and the resulting effect on TWR in the upper reaches of the river. Also, add discussion of flood scouring effects and data that shows how the objective is conservative in those events, if it is. SAV objectives should be responsive to observed conditions and additional consideration of the observations of those doing the work in the habitat,

26	Line 14, TWR Objective 5.1	Mark Enders	COSM (IC-SH)	Proposed TWR coverage objective for the Hopkins to I-35 reach may need to be reconsidered and possibly decreased given the need to allow for other native SAV establishment and sub-optimal habitat suitability in some portions of this reach. Increase TWR coverage objective for Downstream of IH-35 reach to account for decrease in Hopkins to 35 reach. A potntial ecommendation would be to decrease the Hopkins to 35 TWR cover to 2,800m2 and increase Dwnstm of 3 to 600m2 or similar.
26	TWR Objective	Mark Enders	COSM (IC-SH)	Recommend adding an objective to maintain at least two large, contiguous TWR stands for their viable seed production ability. Per USFWS Chris Hathcock recommendation/ input that only large, contiguous stands have been found to produce viable seed which is important for maintainin long-term genetic diversity of TWR.
30	Objective 6.1 and 6.2	Mark Enders	COSM (IC-SH)	It is unclear how the proposed objectives for FD Density (long term mean minus the standard deviation), justify or are protective of healthy, reproducing, resilient FD populations, especially given the proposed changes in WQ (temp) and springflow objectives.
36-37	San Marcos SAV Objective 6.6	Mark Enders	COSM (IC-SH)	Based on observation and experience managing SAV in San Marcos River, it may prove difficult to maintain proposed coverage of SAV in the established reaches through sustained periods of low-flow at the proposed low-flow objective (45 & 60cfs). Over the past 10 years, it has been difficult to maintain this level of SAV coverages in these reaches due to various factors including recreation and low-flow. Two of these reaches, Spring Lake Dam and City Park have designated access points that focus recreation to these areas as part of an EAHCP strategy to manage recreational access (i.e. focus recreation to designated, harded access points and limit or restrict access to other areas). It is recommended that SAV objectives be applied to other reaches and/ or to assess SAV coverage on a more system-wide basis. I'd like to ensure that adequate FD habitat (i.e. SAV coverage) is established and maintained in areas outside of the current LTBG reaches which would also consider ensuring adequate FD habitat in Spring Lake given its buffer against negative impacts associated with recreation and low-flow. Perhaps we can shift the LTBG reaches or add new reaches that are more representative of the system as a whole and/ or are within areas demonstrated to support sustainable SAV coverage. Or perhaps develop FD SAV objectives for larger river segments similar to the TWR objectives. The spring flow objectives don't fully support or align with the SAV coverage objectives. It has been observed that low-flows have negative impacts on SAV coverage in the SM River, not due to recreation alone.
36-37	San Marcos SAV Objective 6.6	Mark Enders	COSM (IC-SH)	Recommend including Bryophyte as a complex SAV type, and Vallisneria & Stargrass (Heteranthera) as simple SAV type to be used to achieve SAV objective.
General comments		Tom Taggart	COSM (IC-SH)	Clearer information on the changes and additional review by Science Committee or other independent review will help us understand if these biological objectives are appropriate for the goals. Also, "independent" comments vs. group engagement in discussing them with EAA/ICF as the decision maker on the results is not compatible with or equivalent to the process we used to reach consensus. We should again perform to that standard in the renewal. There is an overemphasis on the minimum requirements vs. a recovery oriented conservation minded approach. That has not been characteristic of this effort previously.
Section 3 Recommended Biologic Goals		Charles Kreitler	SC	Biologic goals are fine and reflect the Goals Committee's thoughts
4.1 Objective .Springs and associated rivers		Charles Kreitler	SC	This section on quantity and quality requirements for Comal Springs, San Marcos Springs and associated river appear appropriate. They are well thought out and well presented.
Sections 4.2 and 4.3 . Aquifer species		Charles Kreitler	SC	Text is appropriate, but no mention of blind catfish. Should not this species be mentioned.
Section 4.4 Objectives for Comal Springs Riffle Beatle		Charles Kreitler	SC	No comment. No hydrology
Section 4.5. Objectives for San Marcos Salamander		Charles Kreitler	SC	Interesting decreases in habitat that may have resulted by man's perturbation of man's impact or from HCP imapct
Section 4.6 Objectives for wild rice		Charles Kreitler	SC	No comment. No hydrology? Habitat conservation does not appear to be related to spring discharge?
Section 4.7 1-2 Objectives for fountain darters		Charles Kreitler	SC	No comment. No hydrology? Habitat conservation does not appear to be related to spring discharge?
Section 4.7.3 Submerged Aquativ Vegetation		Charles Kreitler	SC	No comment. No hydrology? Habitat conservation does not appear to be related to spring discharge?
Section 5 Summary		Charles Kreitler	SC	Summary appears to capture the detail descriptions in the previous sections. Question? Should the habitats have minimum spring flow requirements or is this captured by establishing spring flow minimums for individual species?
2	8,9	Jason Martina	SC	maybe add an example of each of the 4 elements in parentheses
4	27	Jason Martina	SC	unsure of what "surface habitat" refers to. Is it in reference to the shore terrestrial habitat or the habitat directly above the water (e.g., emergent vegetation)?
6	26,27	Jason Martina	SC	but species aren't redundant (in the ecological sense) unless they are functionally redundant and there is definitely a difference among species in their funtion (submerged, floating, emergent, etc). However, I didn't really see this used in the report, so you can omit this comment
7	Table 1	Jason Martina	SC	confused about the way the table is structed. Why is intercept under coefficent, or is that the intercept only model?
9	22-25	Jason Martina	SC	How different are these target flow rates compared to the original biological goals?
11	1,2	Jason Martina	SC	It is unclear to me how you would manage for a 3-year average in discharge. Therefore, is this useful?

11	14-22	Jason Martina	SC	It might be useful to include in the text how these recommendations are different from the past BG recommendations. That seems to be the most transparent approach
12	33-44	Jason Martina	SC	How do you manage for water temp? What would be done if the water exceeds the upper limit? For all the other limits I can see a way to manage the system to reach the goal, but I don't see it for temp. Is it to just increase flow?
18	33	Jason Martina	SC	Does "wood" mean living or dead and is this just refering to detritus?
20	1 to 5	Jason Martina	SC	Does each location have to reach that minumum or is it the average of the three locations, the objective isn't clear. Three sampling events per location or three total?
22	Table 4	Jason Martina	SC	This focuses on habitat, but I was wondering what the sampling numbers look like. Number of salamanders found per m2 per sampling event or something like that. Is the number just too low to be useful?
26	Table 5	Jason Martina	SC	Might want to include the same type of analysis as before, finding the mean for a reach and then using one std dev to determine the minimum coverage. Is the worry that it would be too high?
29	2 to 4	Jason Martina	SC	why were these veg type omitted? Might be good to state why here. These are included in Figure 13 even though the text said they would be omitted
34	18 to 22	Jason Martina	SC	The problem is if the reason the natives aren't establishing is because of Hygrophila, then it seems to me that we still need to control and remove Hygrophila. Would need to determine if the natives can persist if the invasive is removed
35	Table 9	Jason Martina	SC	Coverage units? m2?
36	Table 10	Jason Martina	SC	Coverage Units?
20	17	Nathan Bendik	SC	I think this could include more areas of the river (at least), so may need to be more specific that this is areas near springs in the lake and just downstream of the dam. As written, this is somewhat simplistic. I think good quality habitat could also include smaller gravel and free interstitial spaces. For example Eliza Spring would not be considered high quality habitat under this definition but to my knowledge it has the highest documented densities of any central Texas Eurycea.
20	17	Nathan Bendik	SC	The fact that these statements are not supported at all by the primary literature significantly weakens them.
21	8	Nathan Bendik	SC	one st dev below the mean seems like an awfully low bar. Is there any scientific justification for this? How does one decide? Furthermore it is based on a poorly described method of measuring habitat. As we discussed in the subcommittee, we had serious reservations about these methods so I wouldn't base the biological objectives on how habitat was measured in the past. We need to get past the 70's paper and the 1993 unpublished thesis in what we use to base our knowledge on.
22	11	Nathan Bendik	SC	I think it would be more rigorous to take a step back and build an argument from first principles and primary literature rather than this haphazard sampling data. For example, it might read something like this: "Studies x, y, and z have shown densities of central Texas Eurycea salamanders from r to s; in habitats with characteristics a,b and c, these densities are highest (citations). Studies have estimated populations sizes for these species at these densities at the surface that range from j to k. Comparing our haphazard count data to these studies, we think we could achieve similar population sizes and densities if we maintain H amount of habitat.... Therefore, we strive to maintain this baseline of available quality habitat based on characteristics a, b, and c....etc."
22	2	Nathan Bendik	SC	a key component of having good habitat relates to flow to the springs, so you should conceptually combine those ideas here. Good flow, good habitat we should expect salamander occupancy to improve, so that could be part of the metric. So maintaining habitat is a good objective, but it should be bolstered by the other factors (maintaining flow and demonstrating that good quality habitat has salamanders in it). If flow goes down we may not expect "high quality habitat" either to be present or to matter (depending on how you define it). So establishing how flow, habitat and salamander occupancy/abundance are related is important. Building upon that, how management actions influence each of those things. Then you will have a more complete picture of how this system works, how your interventions are helping and how the species is responding.
22	11	Nathan Bendik	SC	I think the rock size and habitat structure could be better than what this document calls "high quality" habitat. The argument for it being high quality is not well supported. It may be high quality, but no one went through the effort to demonstrate in a scientific manner as to why.
23	1	Nathan Bendik	SC	I think what I would like to see is a commitment to understanding how management influences salamander occupancy or abundance. Thats how we will know if the objectives ultimately are worthwhile. You can then tie those actions to improving habitat. For example, see if salamander habitat can be expanded beyond your "core" areas via intervention. Demonstrate it is effective and keep doing it. Otherwise, you'll need to change it. So it would be tying the science to the management - via adaptive management. To do that well, we need to measure high quality habitat, we need to measure salamander's response to that, and we need to measure or track our management efforts.
21	2	Nathan Bendik	SC	Riffle beetle plot out of place in the middle of salamander section
4	Line 7-10	Virginia Parker	SMRF (SH)	SMRF would like to see more specificity around Goal #7. There needs to be a plan for land conservation over the recharge zone in order to protect quantity of recharge, as well as the riparian zone for water quality purposes. There also needs to be a plan for recreational disturbances during extremely low flows.
4	Line 19-20, 25-26	Virginia Parker	SMRF (SH)	We need to be able to decipher between the springflow contribution and stormwater runoff contribution at the San Marcos River gauge. How does gauge #08170500 do this? There needs to be a plan to separate the 2 sources.
4	Line 25-26	Virginia Parker	SMRF (SH)	A possible 3rd objective for springflow: Modeling to see what happens to cfs in a drought of record
7	Line 25-27	Virginia Parker	SMRF (SH)	The study describing wetted areas in the San Marcos River is dated back to 2009, and the area has changed over time. There needs to be new modeling done to determine any changes in the river channel and wetted areas, especially considering the risk of future drought, changes in vegetation, and recreational patterns, especially in low flow periods.
9	Line 22-25	Virginia Parker	SMRF (SH)	A mean monthly discharge of 60 cfs for at least 11 months of the calendar year is entirely too low. 60 cfs should be the low for no more than ONE month, as we have recently experienced, and a range of 80-120 cfs should be applied to 11 months, dependent upon circumstances. A large flood event could skew the mean severely, which begs the question of whether or not median numbers should also be referenced.
9	Line 22-25	Virginia Parker	SMRF (SH)	There needs to be mention of the impacts of high flows as well as low flows.
10	Line 20-22	Virginia Parker	SMRF (SH)	SMRF is very concerned with only looking at the 3 year rolling average. There needs to be a 10 year average goal as well. We should not only manage to the minimum, in order to have a long-term healthy system.
11	Line 19-22	Virginia Parker	SMRF (SH)	There needs to be more water quality monitoring other than just temperature, if for no other reason than to look for and understand increasing trends, and to be able to respond to any increasing trends appropriately.
12	Line 35-39	Virginia Parker	SMRF (SH)	Maintaining mean daily water temperature for more than 50% of the year for the Comal does not seem protective. This means that the entire summer could be significantly higher and still meet the objective.
12	Line 40-44	Virginia Parker	SMRF (SH)	Maintaining mean daily water temperature for more than 50% of the year for the San Marcos River does not seem protective. This means that the entire summer could be significantly higher and still meet the objective. In addition, the upper river and middle river need to be more clearly defined. There should also be an objective for temperature max for the lower river as well.
19	Line 17-23	Virginia Parker	SMRF (SH)	Including the standard deviation in the goal for the Riffle Beetle does not seem protective and should possibly be removed from the objective.
19	Line 5-6	Virginia Parker	SMRF (SH)	The Hotel area should be included as a sampling location.
26	Line 7-10	Virginia Parker	SMRF (SH)	In addition to persistent strands, there needs to be an objective for large contiguous emergent flowering strands, particularly 1) between Sewell and City Park and 2) Bicentennial Park
30	Line 3-8	Virginia Parker	SMRF (SH)	Include genetic monitoring of the species to set up an adaptive management plan for the future.
42	Line 15-17	Virginia Parker	SMRF (SH)	This needs to be much more specific through objectives. Lots of opportunity here. One objective needs to be included related to SMARC, continued data on the genetics of the different species, and set adaptive management plan based on the results.

40	Line 15-18	Virginia Parker	SMRF (SH)	30-45 cfs for the Comal Springs does not seem protective of the Riffle Beetle.
40	Line 19-23	Virginia Parker	SMRF (SH)	A mean monthly discharge of 60 cfs for at least 11 months of the calendar year is entirely too low. 60 cfs should be the low for no more than ONE month, as we have recently experienced, and a range of 80-120 cfs should be applied to 11 months, dependent upon circumstances. A large flood event could skew the mean severely, which begs the question of whether or not median numbers should also be referenced.
40	Line 24-27	Virginia Parker	SMRF (SH)	SMRF is concerned with only looking at the 3 year rolling average. There needs to be a 10 year average goal as well. We should not only manage to the minimum, in order to have a long-term healthy system.
40	Line 28-37	Virginia Parker	SMRF (SH)	There needs to be more water quality monitoring parameters other than just temperature, if for no other reason than to look for and understand increasing trends, and to be able to respond to any increasing trends appropriately.
40	Line 26-27	Virginia Parker	SMRF (SH)	A 3 year rolling average above 138cfs may be protective as long as springflow can be differentiated against urban stormwater runoff
40	Line 15-23	Virginia Parker	SMRF (SH)	Should median flow goals be assessed as well as mean? This may be more protective against extereme floods skewing the numbers
40	Line 28-37	Virginia Parker	SMRF (SH)	There needs to be an objective for protecting the watershed for water quality protection. (Also, could be included in Goal #7)
40	Line 28-32	Virginia Parker	SMRF (SH)	25 degrees C seems too high in the Comal for a protective target, especially if it is only the target for at least 50% of the year, which would allow the summer months to be much higher.
40	Line 33-37	Virginia Parker	SMRF (SH)	25 degrees C seems too high in the San Marcos River for a protective target, especially if it is only the target for at least 50% of the year, which would allow the summer months to be much higher.
41	Line 3-7	Virginia Parker	SMRF (SH)	2.4 seems too low. This is a significant difference from the current plan. There also needs to be a genetic data component added to the objective.
41	Line 10-13	Virginia Parker	SMRF (SH)	There needs to be a genetic component added to the objective.
41	Line 14-4	Virginia Parker	SMRF (SH)	There needs to be a 3rd objective added related to large contiguous strands in the river to ensure protection of seed production and protection.
6	Line 12-14	Virginia Parker	SMRF (SH)	The calculations do not include the drought of record. Should this be taken into account somehow?
10	Line -5	Virginia Parker	SMRF (SH)	The calculations do not include the drought of record. Should this be taken into account somehow?
39	Line 8-14	Virginia Parker	SMRF (SH)	There needs to be a clearly defined system-wide approach to SAV management for fountain darters.
11	Line 15-17	Virginia Parker	SMRF (SH)	Impervious cover very near the headwaters and river is also an important factor with regards to water quality. SMRF would like to see something stated that "X" amount of pervious cover will be conserved within "Y" buffer of the river and springs for both systems.
22	Line 7-10	Virginia Parker	SMRF (SH)	SMRF would like to see an objective added that some coverage of recreation-free habitat is maintained that is not dependent upon the Condition M criteria to protect the salamanders.
42	Line 12-14	Virginia Parker	SMRF (SH)	SMRF would like to see watershed protection include things like hazardous waste. One objective could be to hold 1-2 events per year in each springs community.
3	line 3	Kimberley Meitzen	TXST (IC-SH)	It would be good to include recognition of feedback/comments from the three committees (Implementing, Stakeholder, Science), public, etc., or any others that are providing feedback, and how those comments were addressed.
4	line 4	Kimberley Meitzen	TXST (IC-SH)	Would be very helpful to provide a map of the SM system with names used for the reaches referred to throughout the biological objectives. There were occasionally different names used for overlapping areas (Headwaters and Spring Lake Dam) and occasional inconsistent use of names for reaches (Upper vs. Middle, no mention of Lower?). A very clear map of polygons, or boundaries to reference the geographic locations mentioned in the document would be very helpful. Figure 8 used for water quality objective 1.6 demonstrates this and could be improved. in the text Headwaters, Upper, and Middle river are used, in other places all of this area is referred to as "Upper " river.
4	line 18-24	Kimberley Meitzen	TXST (IC-SH)	Suggest mentioning diff between San Marcos Spring gage and San Marcos River discharge gage and how each is used for the objectives.
6	line 1-2	Kimberley Meitzen	TXST (IC-SH)	Need more clarity on gages and objectives 1.2 and 1.4
7	line 21-23	Kimberley Meitzen	TXST (IC-SH)	Needs more clarity on the data used.
7	line 30	Kimberley Meitzen	TXST (IC-SH)	Modeled wetted area for SAV and salamander habitat was conducted almost 15 years ago. This has likely changed, and It would be valuable to have an updated wetted habitat mapping. This also needs to take into account what we now know about % area lost to recreation impacts during low flow conditions.
9	line 15-20	Kimberley Meitzen	TXST (IC-SH)	Was this observation before or after the modifications of the western spillway boards at Spring Lake to move more flow to the Eastern Spillway? Do salamanders have stress-induced lag effects from prolonged low flows? These observations seem too isolated to make an assessment low flow response.
9	line 22-25	Kimberley Meitzen	TXST (IC-SH)	Why 11 months? And why calendar months? Why not a sequential period of 11 mos., regardless of calendar year? With this you could have a consecutive period of up to 22 months at 60 cfs in back to back calendar years. 45 cfs per day average is too low. There is no evidence the system would be "healthy" and resilient under these low flow conditions.
9	line 26-27	Kimberley Meitzen	TXST (IC-SH)	Is this from the 2009 model? May not be accurate currently. Does not take into account habitat lost to recreation impacts.
9	line 14	Kimberley Meitzen	TXST (IC-SH)	Suggest word choice revision for water 'issues', although issues is a technically correct verb to use, it is not commonly used to describe spring flow, suggest replacing with flows, discharges, emerges, emanates...
11	line 3-4	Kimberley Meitzen	TXST (IC-SH)	Why not use the full available period of record? Or constrain both to the shortest of those i.e. 1996 - present. Why use calendar year and not hydrologic water year? Please justify use of 'average' instead of 'median' values. If means are used - are high, urban runoff flows teased out of the calculations? They can skew the average - hence preference for median values.
10	1	Kimberley Meitzen	TXST (IC-SH)	In addition to the three-year rolling average I suggest a longer term goal for both Comal and San Marcos - maybe 10 year rolling average? Something to align more with the longer permit and room for adaptive management with climate change realizations down the road. What would that look like?
11	line 13	Kimberley Meitzen	TXST (IC-SH)	I'm glad temperature is included, but I am wondering if there is away to include other water quality parameters that get at watershed condition and high-intensity recreation, like turbidity or e-coli ? Maybe that can be addressed in Goal 7.
19	line 1	Kimberley Meitzen	TXST (IC-SH)	Recommend adding an objective for CSRB in SM System/Spring Lake/Hotel Reach, even if just maintaining habitat and monitoring for presence.
19	1	Kimberley Meitzen	TXST (IC-SH)	Recommend language to enable testing new sampling/surveying techniques and flexibility in evaluating population numbers during such a process to determine best techniques and methods to be using.
22	line 11-14	Kimberley Meitzen	TXST (IC-SH)	Recommendation to include more sites in addition to Diversion Springs, and make this a stated objective.
22	line 8	Kimberley Meitzen	TXST (IC-SH)	Provide more clarity on the 14m2 area at Spring Lake Dam, all one big patch, or total area of a few small patches? Just in the reach downstream of Eastern Spillway?
23	line 31-33	Kimberley Meitzen	TXST (IC-SH)	Could there be a biological objective to maintain X area of recreation free salamander habitat in the Spring Lake Dam Reach? I'm trying to figure out a way to provide protection from recreation when the river is not in Condition M with SSA exclusions.
26	line 7-8	Kimberley Meitzen	TXST (IC-SH)	Clarify geography of 'upper' San Marcos to be consistent with use throughout the document.
26	line 9-15	Kimberley Meitzen	TXST (IC-SH)	Recommend adding language in Objective 5.2 or as a new Objective 5.3 that focuses on maintaining at least 2-3 large*, contiguous Texas wild-rice stands with emergent, flowering capability to support seed production, with one of those locations including a stand between Sewell and City Park. *May need to quantify large in terms of square meters.
27	line 115	Kimberley Meitzen	TXST (IC-SH)	What does the long term data reveal for coverage below I-35 compared the recent restoration work conducted through SARP? Very little TWR restoration work has been conducted here compared to other areas maintained through the HCP and I think the potential for more coverage is there. I would suggest increasing this lower river TWR coverage value and then increasing the overall system value, even if just by 500 m2 .
26	Table 5	Kimberley Meitzen	TXST (IC-SH)	Can you create a table or figure showing the percent coverage of TWR for each of these reaches over the 2013-2022 time frame and if possible incorporate the 2023 spatial data?

36	line 10, Figure 18	Kimberley Meitzen	TXST (IC-SH)	I think it is good to maintain the consistency of using the LTBG reaches, but given the 30 year permit- it may be a good idea to provide an objective to add new reaches, or be more flexible with the spatial area of the LTBG reach - for example adding an upstream or downstream buffer based on different system stressors, for example recreation in the City Park reach can have a big effect on the upstream portion of that reach and as shown in Figure 18 and 19 this reduces the complex and simple SAV coverage.
34	Table 8	Kimberley Meitzen	TXST (IC-SH)	Add bryophyte to San Marcos list, include Heteranthera for San Marcos list (not sure if it should be complex or simple), provide a place holder for another regionally native veg type that may be added to the system in the future.
36-37	line 10 (Page 36) - line 3 (page 37)	Kimberley Meitzen	TXST (IC-SH)	It may be beneficial to approach this from more of a system-wide approach instead of by the LTBG reaches. Would it be possible to quantify areal coverage for longer river segments similar to the TWR objectives?
42	lines 12-17	Kimberley Meitzen	TXST (IC-SH)	Would appreciate more clarity on when and how these will be incorporated. These objectives may be an opportunity to include objectives for species genetic studies, refugia being maintained at SMARC, ensuring watershed water quality mitigation parameters are considered like an objective for one annual household hazards waste events (e.g., Objective for one household hazardous waste collection event per year (or every other year) that includes EAHCP community outreach). etc...
Overall	general concerns/comments	Kimberley Meitzen	TXST (IC-SH)	Concerned there is not enough justification for using one standard deviation below the mean for the species population targets, and a general concern there are a lot of objectives focused toward minimums.
Overall	general concerns/comments	Kimberley Meitzen	TXST (IC-SH)	Should there be any objectives for species genetics?
Overall	general concerns/comments	Kimberley Meitzen	TXST (IC-SH)	Should there be objectives for maintaining recreation-free habitat other than SSA areas protected by Condition M?
Overall	general concerns/comments	Kimberley Meitzen	TXST (IC-SH)	I think it would be beneficial to have more system wide objectives - for example instead of just focusing the fountain darter biomonitoring to the LTBG reaches - can there be an inter-annual objective to sample the full longitudinal extent of the river from Spring Lake to Blanco confluence? I also recommend system-wide objectives for SAV instead of just LTBG reaches.
Overall	general concerns/comments	Kimberley Meitzen	TXST (IC-SH)	Would like to see some form of science committee review of the objectives.
Overall	general concerns/comments	Kimberley Meitzen	TXST (IC-SH)	Would like to see all the raw data used in the formulation of the objectives available for use.
26	Table 5; Lines 11-15	Chris Hathcock	USFWS (TWR)	Segments A and B are arguably the most important segments for resiliency of the species since they contain the most important flowering stands and make up 75% of the total population. Based on the annual rice survey data over the past 10 years, minimum goals of 360 sq. meters for Segment A and 4,200 sq. meters for Segment B correspond to each segment's coverage before 2011 and before 2014, respectively (i.e., before restoration of these segments through the original HCP). For persistence of the species, I recommend that future goals build upon and/or at least preserve areas of wild-rice achieved through successful efforts of the 2013 HCP. Additionally, based on 2017-2021 annual Texas wild-rice surveys, there are currently at least 2,400 sq. m and 8,500 sq. m of potential Texas wild-rice habitat in Segments A and B, respectively. Given changing river conditions in future years, but also recognizing the priority that should be given to these segments compared to those farther downstream, I recommend minimum areal coverages of at least 1,200 sq. m for Segment A and 7,000 sq. m for Segment B. In my opinion, these minimum coverages would allow for 1) successful production and dispersal of seed to downstream segments to achieve self-sustainability and resiliency in the natural population, and 2) maintenance of an ex situ seed bank by USFWS. The species' seeds are viable in refrigerated storage for only 4-6 months, so must be collected on a regular seasonal basis at least 3-4 times each year. There are currently no other river segments from which viable seed of the species can be reliably collected.
24	lines 37-40	Chris Hathcock	USFWS (TWR)	There have been no catastrophic events on the river since 2016 to test whether the population would be self-sustainable over the long term. The current drought may be considered a catastrophic event but its effects are currently on-going. Although low water levels allow expansion of rice into mid-stream channels previously too deep to support wild-rice, and although wild-rice is capable of dispersing to shallow-water areas more successfully than other submerged aquatic vegetation, extended drought will probably result in a net-decrease of wild-rice long-term. In fact, BioWest recently reported current areal cover of wild-rice to be around 8,000 sq. meters (i.e., about half that than reported earlier in year). This highlights the extreme variability in wild-rice coverage within a given time period. In fact, overall aquatic plant community cover/sp. diversity/sp. distribution within any stream system is highly dynamic. Therefore, degree of self-sustainability and minimum coverage requirements cannot be understood based on short-term (i.e., over 1 to a few years) observations.
24	34-37	Chris Hathcock	USFWS (TWR)	It seems that the objective of 8,000 sq. m was determined first, and then segment numbers were devised to add up to this total. As I stated above, Spring Lake Dam and Sewell Park to Hopkins are the most important segments in preventing species extinction and can support nearly 11,000 sq. m of wild-rice combined. The minimum coverages denoted in Table 5 for these segments, however, do not reflect this nor protect any of the gains in wild-rice coverage achieved in the current HCP. The proposed minimum coverages also do not take advantage of the greater conservation value of certain areas and segments over others. Instead, I think it is important to recognize total available habitat in each segment and the importance of each segment to long-term resiliency, self-sustainability, redundancy, etc. As previously stated, Segments A (Spring Lake Dam) and B (Sewell Park to Hopkins) contribute most to prevention of extinction because they are in the most ideal habitat, support the largest contiguous stand (i.e., stands most capable of pollination since more plants are in close proximity and in different stages of flowering), and are most capable of promoting self-sustainability because their seeds disperse to the greatest area of potential germination sites downstream. Additionally, available habitat for the species, based on annual rice surveys by both USFWS and Biowest, has been consistently over at least 14,650 sq. m over the past 10 years. Starting with total available habitat per segment seems like a reasonable springboard for devising a minimum coverage goal per segment. I think a total system coverage of at least 11,600 sq. m is appropriate given species needs and total available habitat. Making the most of this available habitat would involve prioritizing certain large stands (e.g., currently those in Segments A and B) as "Species Resiliency/Seed-Bank Stands" and others (e.g., Downstream of I-35) as "Redundancy Stands". Resiliency/Seed-Bank Stands would require more active protection from recreation, floating vegetation mats, etc.; however, Redundancy Stands are largely vegetative (non-emergent and non-flowering) and more protected naturally because they are submerged in deeper water away from recreational and other impacts. In my opinion, separating and prioritizing in this way would allow the most efficient use of resources to achieve species preservation over the next 30 years.
7	9-12	Nathan Pence	GBRA (IC-SH)	While the minimum springflow of 30 cfs remains unchanged from the current EAHCP, the 45 cfs goal for 11 months is not fully vetted. The current EAHCP allows for the 30 cfs so long as it does not exceed 6 months in duration and calls for that to be followed by a minimum of 80 cfs for 3 months. It is important to note that the 80 cfs pulse represented an opportunity to allow for Fountain Darter reproduction during a repeat of the Drought of Record in the Comal system and was also intended to ensure Spring Run 3 connectivity to the system is not lost for greater than 6 months. This timeframe is about equivalent to the life span of a riffle beetle, so the flow objective and timeframe was intended to ensure no generations of riffle beetles would be lost. Without this pulse, what is the plan to allow for Fountain Darter reproduction and riffle beetle connectivity and reproduction during a repeat of the Drought of Record?

9	22-25	Nathan Pence	GBRA (IC-SH)	While the minimum springflow of 45 cfs remains unchanged from the current EAHCP, the 60 cfs goal for 11 months is not fully vetted. The current EAHCP allows for the 45 cfs so long as it does not exceed 6 months in duration and calls for that to be followed by a minimum of 80 cfs for 3 months. There is insufficient information provided to understand how this metric would impact actual pumpage, CPM curtailment, and springflows through a repeat of the drought of record, as compared to the current EAHCP.
10	3	Nathan Pence	GBRA (IC-SH)	The 2001-2022 monitoring period does not include the drought of record, and contains a single severe drought period (that wasn't of such duration as the drought of record). The lack of a significant drought doesn't reflect conditions present during a repeat of the drought of record. There is insufficient information provided to understand how this metric compares to the current EAHCP.
10	3	Nathan Pence	GBRA (IC-SH)	Springflows during this 2001-2022 period were managed during certain periods, partially by pre-HCP EAA Critical Period Management rules and then later in the period with the current EAHCP mitigation strategies and conservation measures in place. Such springflow management doesn't allow for a true representation of flow/species analysis. There is insufficient information provided to understand how this metric compares to the current EAHCP.
11	1-2	Nathan Pence	GBRA (IC-SH)	The lowering of the long-term average from 225 cfs to 187 cfs will undoubtedly have impacts on springflow through drought periods, and presumably would drive springflows to minimums more often and for longer periods. This is a concern on many fronts, including water quality and species survival. Additionally, the use of USGS gage #08169000 includes local runoff. In a drought period there may be small local events that contribute to this gaged flow, thus skewing the springflow calculation under this objective. There is insufficient information provided to understand how this metric would impact actual pumpage, CPM curtailment, and springflows through a repeat of the drought of record, as compared to the current EAHCP.
11	3-4	Nathan Pence	GBRA (IC-SH)	The lowering of the long-term average from 140 cfs to 138 cfs may have impacts on springflow through drought periods, and presumably would drive springflows to minimums more often and for longer periods. This is a concern on many fronts, including water quality and species survival. Additionally, the use of USGS gage #08170500 includes local runoff. In a drought period there may be small local events that contribute to this gaged flow, thus skewing the springflow calculation under this objective. There is insufficient information provided to understand how this metric would impact actual pumpage, CPM curtailment, and springflows through a repeat of the drought of record, as compared to the current EAHCP.
12	35-44	Nathan Pence	GBRA (IC-SH)	The thermal requirement (EAHCP objective) of 25 and 27 degrees in the Comal system for 50 percent of the time are a significant deviation from previous thermal objectives that were minimums. The purpose of these thermal requirements were not only related to survivability of species, but also to protect reproduction. Allowing water temps to fall below previously defined thresholds 50 percent of the time without any justification or discussion on the subject is contrary to the processes that made the EAHCP a success.
12	35-44	Nathan Pence	GBRA (IC-SH)	While these objectives are questionable biologically, it is also unclear how these practically get implemented in the management of pumpage during drought periods. As such, these objectives present as goals without any mechanism to control aquifer management to meet such goals.
19	17-23	Nathan Pence	GBRA (IC-SH)	The abundance-based objectives for CSRB derived from mean minus the standard deviation are questionable. There is no indication or justification that this level of abundance is adequate to indicate a healthy reproducing, resilient population of CSRB, especially under the newly proposed thermal and springflow objectives, which would conceivably allow the springs to flow at lower levels for longer periods of time and attain temperatures higher than those previously identified as protective under the current HCP.
22	7-11	Nathan Pence	GBRA (IC-SH)	The biological objectives proposed are not consistent with those proposed by the Salamander Biological Objectives subcommittee and they should include some sort of numeric criteria based on sound surveying protocols. Historic presence/absence data is used to justify using only maintenance of high quality habitat, but the methods behind this abundance data is not discussed. By only requiring the maintenance of "high quality habitat", significant observation of salamander presence/absence is lost.
30	3-8	Nathan Pence	GBRA (IC-SH)	The abundance-based objectives for Fountain Darter derived from mean minus the standard deviation are questionable. There is no indication or justification that this level of abundance is adequate to indicate a healthy reproducing, resilient population of Fountain Darter, especially under the newly proposed thermal and springflow objectives, which would conceivably allow the springs to flow at lower levels for longer periods of time and attain temperatures higher than those previously identified as protective under the current HCP.
40-44	N/A	Nathan Pence	GBRA (IC-SH)	This contains the summary of the TM, reiterating the objectives commented upon above. Similar comments apply here as well.
Overall	N/A	Nathan Pence	GBRA (IC-SH)	The modeling performed during the development of the current EAHCP included assumptions regarding full pumping of permits (subject to Critical Period Management) for the entire ~572k AF/yr of permits. The analyses performed here do not reflect a condition in which the resulting springflow that would reflect a full permitted pumpage scenario. In fact, it is likely that year-to-year pumpage for the 2001-2022 period evaluated varied significantly. Shouldn't such analysis be adjusted to account for the potential under-pumpage experienced in the aquifer during this period as compared to a full permitted pumpage scenario?
Overall		Donelle Robinson	USFWS	**Biological Goals**-We liked the biological goals and think that they consider the species needs well. We have a few minor comments with regard to wording-Goals 4-6 specify the locations to conserve. It would be helpful if Goals 2 and 3 can also be worded this way (e.g., subsurface habitat, spring habitat).
Overall		Donelle Robinson	USFWS	**Biological Objectives General**-Overall, it is difficult for us to tease apart the Biological Objectives from the rest of the HCP because the effects are occurring in the same areas as the Biological Objectives and Conservation Measures, but we do not have that other information yet to fully understand the effects to the species. When reading Biological Objectives for specific areas, we had a hard time understanding what would occur in other areas. As mentioned at the meeting, we believe that management and monitoring should be a systemwide approach, and it would make more sense to have systemwide objectives. For example, we don't fully understand the status of fountain darters outside of representative reaches, San Marcos salamanders outside of proposed management areas, Comal Springs riffle beetles in the San Marcos system, and Texas blind salamanders in caves and wells managed by the Permittees. We believe that this HCP should be geared toward a robust adaptive management program based on the monitoring and results.
Overall		Donelle Robinson	USFWS	**Biological Objectives Organization**-We would recommend starting with each Biological Objective then following it with the rationale. Currently the objectives have information before and after them and the organization was difficult for reading them. Using additional subsection headers may also help organize the information.
		Donelle Robinson	USFWS	**SMART Objectives and Issuance Criteria**-We appreciate the effort involved in ensuring that the objectives are measurable and achievable. However, we need more information that the objectives are based on biological needs for permit issuance criteria (discussed in 9.2.1 under Achievable in the HCP handbook, and the Issuance Criteria (14.3.2 and 16.1.3 HCP handbook and ESA section 10(a)(2)(B); 50 CFR 17.22(b)(2), 17.32(b)(2), and 50 CFR 222.307(c)(2)]). This includes considering whether the conservation is adequate to avoid precluding recovery of the species and to avoid adversely modifying critical habitat. We need additional information for this with regards to the springflow and habitat objectives.

		Donelle Robinson	USFWS	**Springflow Objectives and Effects**-To fully understand the springflow objectives, we will need to be able to tease apart how the pumping effects the springflows. The figures below (from the Barton Springs Edwards Aquifer Conservation District HCP) are good examples of how to show this {***see reference photos in Sheet 2*** } . We also will need the climate change analyses to understand how the frequency of different flow rates may change. Please note that consideration of springflows for species needs should also consider habitat conditions that are interrelated with springflows, such as lower DO, increased sedimentation, and increased effects of recreation, unless there are other ways to mitigate for the interrelated effects.
		Donelle Robinson	USFWS	**Water Quality Objectives**-We agree with the temperature objective. Based on our discussion, we understand that DO monitoring will continue but will not have an associated objective because springflows are the primary factor that can be controlled for DO. Please explain why it's not an objective in the HCP.
		Donelle Robinson	USFWS	**Habitat Objectives**- As discussed when we met, we do not think that the objectives for normal conditions should be based on the worst-case scenarios. We suggest considering extreme conditions such as drought of record and scouring floods separately.
		Donelle Robinson	USFWS	**Using Counts or Densities as Objectives**-We are not sure that it makes sense to use specific numbers as biological objectives since it is not entirely in the control of the HCP. The habitat, springflow, and water quality that can be controlled make more sense to focus on and ensuring that the habitat is suitable enough that the species continue to persist throughout it.
		Donelle Robinson	USFWS	**Other Comments**- Please note that we will likely have additional comments after the major comments from above are addressed, but we do not think it makes sense to address items at this time that may change.
		Donelle Robinson	USFWS	**Other Species**-We understand that other species are still under evaluation for coverage, and these species would need Biological Goals and Objectives if it is determined that these species need to be covered by the HCP because take will occur as a result of the Covered Activities.
		Donelle Robinson	USFWS	**Other Factors**-Based on our discussion, we understand that recreation, captive refugia, and parasite or disease control will be covered in the conservation measures. We believe that these are important to address but do not necessarily need to be their own Biological Objectives.
		Donelle Robinson	USFWS	**Monitoring**-Based on our discussion, we understand that monitoring will be addressed in a separate section. We should set up another meeting on the monitoring approach and the data needed for compliance monitoring. We would also like to have a discussion to better understand the methodology for the fountain darters for this evaluation and suggest having a meeting for that. We want to emphasize that monitoring needs for the Biological Objectives may not cover all of the compliance monitoring needed to evaluate take for the HCP, and a systemwide approach will be needed for this. We are also concerned that current monitoring does not adequately capture the total population or total habitat for the animal species, which is important for understanding take. Both monitoring for take and for the biological objectives will need to be included in the HCP. For example, recreational take of fountain darter habitat has occurred in areas outside of the representative reaches but is not directly monitored, so it is difficult to assess what take, if any, occurred. Similarly, San Marcos salamander habitat is not fully monitored, but all of the habitat may be directly affected by sedimentation due to low flow conditions in Spring Lake. We also would like to encourage an approach that fulfills monitoring requirements but would allow for flexibility in the 30-year permit term in case monitoring needs change. An example of this flexibility is in the language below from the Barton Springs Pool HCP: *6.1.7.1 The City will monitor salamander populations and habitat. Salamander population surveys will be conducted at perennial Parthenia, Eliza, and Old Mill springs and at intermittent Upper Barton Spring when flowing at least bimonthly throughout the year or other interval sufficient to determine the status of the species and population dynamics as deemed appropriate by a City salamander biologist and approved by the Service. The City will develop and maintain a written monitoring plan. The City will ensure that all people surveying for salamanders are properly trained. Surveys can include methods to elucidate life history characteristics of both species. Methods will* *be evaluated by the Service and conducted under the terms and conditions of a valid federal Endangered Species Act 10(a)(1)(A) scientific permit issued to the City.* *6.5.4 Wild Population Monitoring* *The overall goal of population monitoring is to collect data from which the status of the species can be inferred. Measurement of salamander abundance in each spring site is one method for inferring population size and long-term trends in population growth. The Plan proposes to conduct bi-monthly census surveys of salamander populations and use time-series statistical methods to evaluate trends in population size and factors that covary with salamander abundance. Additional data collected on salamander size and age category are used to test for recruitment using common parametric and non-parametric statistical methods. Additional research that contributes to an understanding of factors influencing survival, reproduction, and recruitment in wild populations of E. sosorum and E. waterlooensis would be positive contributions to predicting the fate of populations. A better understanding of genetic variation in protected species and mean evolutionary fitness of populations as well as of individuals, phenotypes, and genotypes would provide baselines upon which to assess probabilities of species persistence. Assessments of population response to natural and artificial selection would provide a basis for evaluating the long-term fate of protected species in the wild. All of these research avenues may require experimental designs other than the bi-monthly abundance estimates proposed. Therefore, the proposed survey frequency should be modified based on monitoring plans approved by the Service.*
2	35-40	Robert Mace	TXST (IC-SH)	Who was on the Biologic Objectives Subcommittee, and where are their recommendations? The web page for this effort does not include membership or the recommendations. Consider amending the web page and/or including the recommendations as an attachment to this memo. Should also include information on membership of the three species groups. How was governance handled on these committees? Did all members sign off on the recommendations? Do the subcommittees fully endorse this memo?
3	12-13	Robert Mace	TXST (IC-SH)	No feedback with subcomittees and comittees on USFWS comments? Suggest adding a feedback loop with the subcommittees and committee on this.
4	25-26	Robert Mace	TXST (IC-SH)	"We" is used here, which suggests the authors of the memo. Are these recommendations from the authors of the memo or the subcommittee?
6	9-10	Robert Mace	TXST (IC-SH)	Suggest clarifying here that the low-flow objective is daily.
7, 9	Objectives 1.1 and 1.2	Robert Mace	TXST (IC-SH)	These objectives are not protective of the species or the systems. As written, they are solely focused on minimum flows whcih is not enough to support a healthy ecosystem. Accordingly, the recommendations act as an objective function through which groundwater production can (or will?) be optmized to producng an outcome of the lowest flows mentioned.
7, 9	Objectives 1.1 and 1.2	Robert Mace	TXST (IC-SH)	These objectives are substantial changes from the current numbers. As the chair of the Science Committee for the current HCP, there was a great deal of heated discussion and negotiation to arrive at the numbers the committee recommended. Changes in these numbers should be accompanied by a rigorous discussion of evidence supporting the changes including a review by the Science Committee.
11	Objectives 1.3 and 1.4	Robert Mace	TXST (IC-SH)	Odd that the low flows are based on system flows and not spring flows. This is a change from the current standard with no discussion of the reason for the change. Uncomfortable with this change since compliance could be achieved with no benefit to springflows.
11	Figure 4	Robert Mace	TXST (IC-SH)	Unclear what the LOESS smooth functions are here for (not discussed in text)--they added confusion. If they are kept, then the caption needs to describe what the black lines are.

		Patrick Shriver	SAWS (IC-SH)	Comment for 4.1.1 - Springs >Though this is a complicated section to quantitatively understand these relate to the species of coverage and represent the modeled targets for springflow protection generally in our current approved ITP and Plan. The 11 month threshold for higher CFS of 45 is beyond current and any contemplated measures (other than mother nature). *Without these specificities the National Academies of Science (NAS) found “flow protection measures will be effective in meeting flow components” of the plan at minimum continuous flows of 30 CFS. However as noted in overarching issues there are catastrophic scenarios (spills, floods, etc.) that have additional considerations. (It is not that I or even SAWS don’t recognize this as a good thing, but it is both a stretch based on the covered species, cost effective/justifiable conservation methods, permit duration as it relates to climate assumptions or models and again those maybe 25th percentile flow benchmarks for rivers feel out of scope). I think ok to benchmark ourselves but surely SAWS has shown through diversification and permit management that we are committed.
		Patrick Shriver	SAWS (IC-SH)	Comment for 4.1.2 - Riverine >There are no specific conservation measures that cost effectively can guarantee 3- year rolling averages inserted as the current objectives for Comal River and or San Marcos River. I would suggest either lowering the threshold by half (90 CFS and 70 CFS respectively) or greatly expanding out the time-period of the rolling average (min. 10 years). Or it ought to be difficult to conscribe to this as an objective. An offer of adaptive management if specific science within the scope of the habitats and species of the plan indicates something other this may be changes in variables outside of permitted water management activity. {Recharge?}
Pp. 3 - 4	P.3 line 17 -- p. 4, line 3	Myron Hess	SH Chair	The Biological Goals generally appear to reflect the Goals Subcommittee recommendations and seem to be appropriate.
P.4	Lines 9-10	Myron Hess	SH Chair	It would be helpful to have some elaboration of the anticipated process for establishing the elements of Goal 7. Will specific objectives be developed? If so, what process and timing is anticipated for that development? If not, how will that goal be considered and what process is anticipated for implementing the goal and providing for stakeholder input ?
P. 6	Lines 24-28	Myron Hess	SH Chair	The concept of redundancy, although critically important, has more limited utility in these systems than is often true for other species because all units of the system are dependent on a single aquifer. Because it is not possible to ensure habitat redundancy for these species in the absence of adequate springflow, it is doubly important to develop protective springflow targets.
P. 7	Table 1	Myron Hess	SH Chair	The accuracy of the referenced modeling is critical to evaluation of the proposed springflow discharge objective. It would be helpful to have access to additional explanation of the model and modeling effort.
P. 7	Lines 9-12	Myron Hess	SH Chair	The ordering of the sentences in this objective introduces unnecessary ambiguity. The last sentence appears to be intended only to apply to the first sentence and determination of mean monthly discharge, as it should. However, in its current placement it could be mistakenly interpreted as applying, in some way, to both prior sentences, which would undermine the critical role of the 30 cfs daily minimum criterion. The third sentence should follow immediately after the first sentence to make its limited applicability more clear.
P. 9	Lines 5-7	Myron Hess	SH Chair	Protection of aquatic vegetation, including TWR, is a function of, at minimum, flow protection and recreation management. This statement, and those surrounding it, seem to suggest that flow protection alone would be sufficient to protect the vegetation, which does not seem to be borne out by the history of management under the EAHCP. Based on what has been learned about the impacts of recreation, the failure to acknowledge, in any objective, the importance of recreation management, which must be balanced with reasonable access, appears to be a critical shortcoming that should be addressed. Modeling of aquatic vegetation and flow also is dependent on channel morphology which can change dramatically over time, and has changed since the referenced modeling was undertaken. Given a 30-year permit period, additional dramatic changes are virtually uncertain. Accordingly, a robust adaptive management component that provides for periodic reassessment of key aspects and appropriate adjustments will be needed.
P. 9	Lines 13-15	Myron Hess	SH Chair	This statement seems to be contrary to the frequent acknowledgement in reports and presentations of the importance of mechanical approaches for maintaining high quality salamander habitat, including this document at p. 22, lines 23-25. I had understood, perhaps incorrectly, that vegetation management and fanning of the substrate were relied upon to help reduce sedimentation. In 2023, reduced flow levels, although not sustained at levels as low as 60 cfs, did result in visually obvious reductions in flow velocity. Do we have adequate information to support a conclusion that a sustained flow of 60 cfs, or 45 cfs, is adequate to prevent siltation?
P. 9	Lines 15-20	Myron Hess	SH Chair	This statement may be overbroad. My understanding is that during low flow periods in 2023, flow conditions at Spring Lake Dam, even with flow above 60 cfs, became questionable for maintenance of salamander habitat and that adjustments were made to help redirect a portion of the flow at the dam. It seems that consideration of ongoing assessments and adjustments should be acknowledged and potentially included going forward.
P. 9	Lines 22-25	Myron Hess	SH Chair	The ordering of the sentences in this objective introduces unnecessary ambiguity. The last sentence appears to be intended only to apply to the first sentence and determination of mean monthly discharge, as it should. However, in its current placement it could be mistakenly interpreted as applying, in some way, to both prior sentences, which would undermine the critical role of the 45 cfs daily minimum criterion. The third sentence should follow immediately after the first sentence to make its limited applicability more clear.
P. 9	Lines 31-33	Myron Hess	SH Chair	See comment above (p. 9, lines 5-7) regarding changes in channel morphology.
P. 10	Lines 20-22	Myron Hess	SH Chair	I certainly agree that using a 3-year rolling average is superior to relying only on minimum flow levels. However, using a 3-year rolling average based on a flow level that is 1 standard deviation below the mean dramatically limits the role of that criterion in limiting long-term environmental degradation. Higher flow levels play a critical role in maintaining the health of these spring ecosystems on which the entire wild populations of these species depend. Accordingly, a longer-term flow criterion, such as a 10-year rolling average flow, also should be considered, as should the appropriateness of using 1 standard deviation below the mean as the criterion. I had hoped to review such flow data, but a limitation of time and my technical ability precluded doing that type of review in order to inform these comments. This is not a typical HCP, dealing with only a portion of the habitat for a species, and, consistent with the current HCP, the role of higher flows in maintaining long-term ecosystem health needs more consideration.
P. 11	Lines 1-2	Myron Hess	SH Chair	See comment above (p. 10, lines 20-22) regarding long-term flow criteria.
P. 11	lines 3-4	Myron Hess	SH Chair	See comment above (p. 10, lines 20-22) regarding long-term flow criteria.
P. 12	line 5	Myron Hess	SH Chair	The ≥ (greater than) symbols in this line should be replaced with ≤ (less than) symbols to accurately reflect temperature requirements for the species.
P. 12	lines 35-39	Myron Hess	SH Chair	Strongly support inclusion of temperature objective for Comal System. It is a known critical factor affecting fountain darters and is a criterion for which compliance can be controlled through a combination of flow protection, including flow split management, and riparian vegetation management. The portion of the objective referring to Upper Spring Run, Spring Island, Spring Run 1-3, and Landa Lake is straight-forward but should it be limited solely to habitats near the substrate for Landa Lake? Is the near substrate qualification appropriate for use throughout Landa Lake? Second sentence is both less clear and excessively qualified. It appears likely that the entire sentence is intended to apply only to the Old Channel and, accordingly, it should be clarified accordingly: e.g., by moving "Within the Old Channel" to the beginning of the sentence. Allowing exceedance of 25° C for up to 49.9% of the days in any year, which also means that level of exceedance would be acceptable every year, and in any area not covered by the first sentence, does not appear to be protective and deviates significantly from the current objectives. That approach would effectively eliminate the 25° C criterion for these areas during the hottest six months of every year, when a temperature criterion is most important and when it is likely to be relevant to conditions in the aquatic system. It appears from Figure 6, that such exceedances have been infrequent. That approach would leave only a maximum of 27° C as the temperature criterion for the hottest months in all years in the Old Channel, which is not adequately protective.

P. 12	lines 40-44	Myron Hess	SH Chair	Strongly support inclusion of temperature objective for San Marcos System. It is a known critical factor affecting fountain darters and is a criterion for which compliance can be controlled through a combination of flow protection and riparian vegetation management. The portion of the objective referring to Spring Lake is clear and based on Figure 7 appears very achievable. Is the near substrate qualification appropriate for use at the Spring Lake Dam location? Temperature farther up in the water column at that location will determine temperatures at locations just downstream of the dam. Second sentence is both less clear and excessively qualified. The differentiation would be clearer if the second sentence began with "Within the Headwaters, Upper River, and Middle River, maintain ...." Allowing exceedance of 25° C for up to 49.9% of the days in any year, which also means that level of exceedance would be acceptable every year, and in any area not covered by the first sentence, does not appear to be protective and deviates significantly from the objectives in the current HCP. That approach would effectively eliminate the 25° C criterion for these areas during the hottest six months of every year, when a temperature criterion is most important and when it is likely to be relevant to conditions in the aquatic system. It appears from Figure 7, that such exceedances have been extremely rare. That approach would leave only a maximum of 27° C as the temperature criterion for the hottest months in all years in those reaches, which is not adequately protective.
p. 18	lines 1-8	Myron Hess	SH Chair	Suggest adding an objective to acknowledge the importance of water quality parameters beyond just temperature. Again, that is included in the current HCP. Although it may not be appropriate, at least at this time, to establish specific numerical criteria for additional pollutants, it would be appropriate, particularly with a proposed 30-year permit term, to incorporate an objective providing for the continued monitoring of a suite of such pollutants in order to be able to detect a potentially problematic trend in water quality. The response to such a detection could be to initiate efforts to identify potential sources/causes and potential solutions. It likely would not be realistic to propose, at this time, specific responses beyond such investigation but identification of trends and the investigation of potential causes and solutions has the potential to produce valuable information that could be used outside of the EAHCP or in future iterations of the EAHCP to address an identified threat. Such an objective could be included under this Goal or under Goal 7. Why is there no consideration of retaining a dissolved oxygen criterion?
p. 20	lines 1-5	Myron Hess	SH Chair	The rationale for focusing on three consecutive occurrences <u>within a calendar year</u> is unclear. If three consecutive occurrences is the appropriate criterion, why would it be less concerning if those three occurrences were spread over two calendar years? Unless there is a specific supporting rationale for the calendar year approach, suggest rephrasing to refer to three consecutive occurrences within any 12 month period. It is unclear why 1 standard deviation below the mean is an appropriate criterion. Why is it not appropriate to include a longer-term criterion that is focused on maintaining overall healthy population trends instead of focusing solely on minimum numbers? As suggested above, in relation to flow objectives, strongly encourage adding an objective that considers longer-term population health, which would be more consistent with approach in current HCP. Given the acknowledged importance of redundancy elsewhere in the document, why is the continued presence of CSRB at the hotel area springs in Spring Lake not an important indicator of species well-being that should be included in an objective? Even if existing data are insufficient to support a quantitative criterion, maintaining a population at that location seems appropriate as an objective.
P. 22	lines 7-10	Myron Hess	SH Chair	Again, the rationale for focusing on consecutive sampling events within a calendar year is unclear. Would it not be problematic to have three consecutive sampling events below the criterion if two were in one year and the third in the following year? Does this criterion apply separately for each of the three sites or would it be violated only if all three sites fell below the areal values? Strongly suggest that some criterion for presence of salamanders be added. I recognize that there was concern expressed about count methodology during the subcommittee process, but this species only occurs in this system so the focus should be on more than maintaining habitat.
P. 22	lines 11-15	Myron Hess	SH Chair	The addition of the Diversion Spring area seems appropriate based on the discussion during the subcommittee meetings. In the absence of quantitative data, it is understandable that an specific numerical objective is not proposed. However, a relatively specific plan for adding that area to the objective should be incorporated into the actual language in the objective rather than simply generally referring to its anticipated addition.
P.26	lines 7-15	Myron Hess	SH Chair	Although all are important, not all TWR stands are equally valuable. In particular, it seems important to incorporate into these objectives a focus on maintaining, within key areas, stands that are capable of sexual reproduction in order to help maintain genetic diversity. Many other proposed objectives incorporate a monitoring frequency. Would that be appropriate here?
P. 28	lines 28-30	Myron Hess	SH Chair	Although this is a straight-forward statement of the specifics of the objective, there is no discussion or explanation of why that is an appropriate or adequate objective. The objective would be achieved as long as fountain darter density rose just slightly above that very low level for at least one sampling event in three. At minimum, the addition of a more protective longer-term density level seems appropriate. Again, as mentioned elsewhere, it is unclear why a calendar year is more appropriate for use than a 12-month period. Given rapid advancements in genetics work, consideration also should be given to developing data to allow for incorporation of genetic criteria.
p. 30	lines 1-2	Myron Hess	SH Chair	This introductory language, unlike for many other objectives, does not expressly incorporate the various flow objectives. That likely is an oversight, but, regardless, those flow objectives should be incorporated for Objectives 6.1 and 6.2.
P. 30	lines 3-5	Myron Hess	SH Chair	As noted above, the rationale for use of a calendar year for the criterion is unclear. At least in theory it would allow for 4 consecutive sampling events below the criterion at the end of one year and the beginning of another. The addition of a longer-term density criterion more reflective of healthy populations, than just identifying a minimum, would appear to be appropriate and consistent with the basic approach of the EAHCP. Given rapid advancements in genetics work, consideration also should be given to developing data to allow for incorporation of genetic criteria.
P. 30	lines 6-8	Myron Hess	SH Chair	The comment immediately above is incorporated here by reference.
P. 30	lines 10-12	Myron Hess	SH Chair	Data from 2001--prior to when habitat management efforts commenced--may not be representative of what should be expected with ongoing management of the flow split and vegetation. Figure 16, if I'm reading it correctly, shows increasing densities corresponding with EAHCP implementation. Some acknowledgement of the differences would seem appropriate.
P. 30	lines 12-13	Myron Hess	SH Chair	Although I find Figure 14 difficult to interpret with any precision in terms of number of sampling events, it appears that most occurrences below the proposed criterion occurred prior to implementation of the EAHCP and thus prior to efforts aimed at management of vegetation and recreation. That is true for the three consecutive events occurring in 2001. Figure 16 also appears to be consistent with that interpretation. Accordingly, it is unclear how to interpret those data and some elaboration would be helpful, including clarification of whether data in the table are limited to LTBG reaches.
P. 31	lines 3-4	Myron Hess	SH Chair	It is unclear to me why the number of sampling events shown here is greater for each of the systems than the numbers shown on p. 29 at lines 5-6. Are these separate sampling efforts from those referenced in the intensity discussion?
P. 31	lines 13-14	Myron Hess	SH Chair	This introductory language, unlike for many other objectives, does not expressly incorporate the various flow objectives. That may simply be an oversight, but, unless there is a specific basis for not doing so, those flow objectives should be incorporated for Objectives 6.3 and 6.4.
P. 31	lines 15-16	Myron Hess	SH Chair	Am I correct in interpreting this as indicating that mean annual recruitment in any year should not fall below 25 percent?
P. 31	lines 17-18	Myron Hess	SH Chair	Am I correct in interpreting this as indicating that mean annual recruitment in any year should not fall below 23 percent?
Pp. 36-37	P. 36, line 10 thru p. 37, line 2	Myron Hess	SH Chair	As discussed previously for other objectives, particularly given the large standard deviations, the addition of a longer term average value as a management goal is needed to provide a target for long-term ecosystem health. The reference in line 1 to "within each reach" introduces ambiguity. Would the objective be violated only if the values in <u>each</u> reach were below the applicable minimum total coverage or if the value in <u>any</u> reach were below the minimum total coverage? Presumably, the latter interpretation is intended, but clarification is needed because of the dramatic difference in resulting protection levels.
P. 37	lines 12-16	Myron Hess	SH Chair	It is unclear what specific approach is being suggested, but this concept seems logical. Can you provide further discussion of what is anticipated and how an approach will be developed?
General Comments		Myron Hess	SH Chair	The process of developing goals and objectives is a critical step. Although the BGO memo provides extremely helpful information, the opportunity for group discussion and for posing specific questions has been very limited. As discussed during the December Implementing Committee meeting, a presentation to the Science Committee with the opportunity for that Committee to further discuss these issues and provide input could be valuable and could offer an opportunity for interested stakeholders to gain a better understanding of the rationale for the proposed objectives and of potential options that might improve upon them.

6	12 to 28	Conrad Lamon	SC	Explanation of the data used needs work. On line15 "Data from gage #08168710 are a calculated springs discharge". If they are calculated values, they are not data in a statistical sense, but predictions, or estimates. If they are estimates, we should be able to determine the formula used to calculate them without regression.
6	19	Conrad Lamon	SC	A better explanation of "each monitoring event at each station". It is unclear what is being measured and what is being used from the gage. Is the "30 day rolling average" centered on the "monitoring events"? Describe and summarize the data used in text, table and graphical form. For use in a predictive model (later comments), you would want a 30 day period prior to "monitoring event" because you can't predict using a 30 day average centered on today, as only half of the data have been observed. A better explanation is needed to justify the use of a the "rolling average" in lieu of instantaneous measurements.
6	29 to 30	Conrad Lamon	SC	This is quite a mouthful, but not very informative. It leaves many questions unanswered. Show model form (formula), define units for station discharge (and describe the sampling involved in previous paragraph), provide sample sizes by location and most will be answered. Was the Old Channel station taken as a reference station? Model Formula would let us know.
6	32 to 33	Conrad Lamon	SC	Centering and scaling of the predictor is not to approximate a normal distribution. "better". No distributional assumptions are enforced on the predictor variable in regression. A description of the process used to center and scale the predictor variable would be useful. The order is likely reversed, in that if you rescale, it should be done before centering. Show graphs depicting scaled and unscaled data. Show plot of data to illustrate the effects of rescaling.
6	34 to 35	Conrad Lamon	SC	I am wondering what the performance of the null model would be. Why not provide an anova table (or better yet a graph) so we can see the contributions of each model component? "High accuracy" might be an exaggeration with a 5.04 RMSE, assuming that is in units CFS and not rescaled
6	39	Conrad Lamon	SC	Extrapolation is to be avoided with regression models. This is the reason we should always summarize the data used to fit the models, to avoid their use outside of this range. Use of the historical record could serve to increase the sample size and include observations in the range of interest. the range needed.
7	Table 1	Conrad Lamon	SC	Need to have ability to perform a t test with table 1, so include SE of the estimates. Sample sizes could be included.
8	Figure 2	Conrad Lamon	SC	With each subplots vertical axis rescaled, the slopes all look the same. Use same scale in each panel.
8	Figure 2	Conrad Lamon	SC	Include data on plots of predictions so we see the fit.
8	Figure 2	Conrad Lamon	SC	I was under the impression that the predictor variables were centered, but the appear untransformed in these plots.
8	Figure 2	Conrad Lamon	SC	I am not confident that these are predictions, but maybe just plots of the regression lines with 1 SE error. Prediction intervals are not commonly 1SE. Again, include data and my question is answered.
8	Figure 2	Conrad Lamon	SC	shows only (partial) uncertainty in slope, and therefore it's a CI about the slope, not fitted values. Fitted predictions (or residuals), if they were shown, would also include prediction intervals, which account not only for the uncertainty in slope, but also of observations about that uncertain slope (see, for instance, Fig 2.7, Lawrence C Hamilton, Regression with Graphics, Duxbury, Belmont California, 1992.). So, the 1-alpha CI will be slope estimate +/- t (alpha, df) * (SE). So instead of slope +/- SE it's actually a 50% CI with df=1. Unusual choice.
9	Table 2	Conrad Lamon	SC	Need prediction intervals here, not just +/- SE, Are we afraid they will include zero? We should be, and the probability implied by these models of doing so should be quantified and stated. That makes for better risk assessment.
10	6	Conrad Lamon	SC	should be annual average not average annual. Both in text and on figure 3 caption
10	11 and 12	Conrad Lamon	SC	"both typical and atypical" flows are not evident from the graph. Any dataset will leave the +/- 1SE band, likely about 50% of the time. see comments regarding slope CI. Above, 1SE is only 50% of the distribution.
10	Figure 3	Conrad Lamon	SC	we're losing the important variability, that can dry it out for months, and has twice, none of which shows in Figure 3. It is unclear what is meant to be shown by this figure. By smoothing the annual averages with a three year window (if that is what was done, I'm not sure), we are effectively smoothing twice. show the variability in each of the annual means, or just plot the data...and technically, it's called a moving average, not a rolling average.
11	Figure 4	Conrad Lamon	SC	This and all figures with line graphs need to have points added, to help count years, which is difficult now.
15 and 16	Figure 6 and Fig 7	Conrad Lamon	SC	again we are smoothing a mean (i.e., smoothed) daily water temp. Should we use daily max, if that is the reason we are concerned with temperature?
19	22-23	Conrad Lamon	SC	the explanation for the threshold choice is unclear.
20	26 and 27plus Tables 3,4 6,7,9 and their referring text	Conrad Lamon	SC	This approach is only conservative if the Statistical distribution of Salamanders in Spring Lake is normal (or at least symmetrical) AND stationary. One major point of long term monitoring is determining stationarity. While we may think we see it now, we can't depend on it in future monitoring. In fact. this distribution can be thought of as a statistical distribution, a convolution of many separate distributions describing the number of salamanders found at each location and at at each time of the sampling in Spring Lake (and each substrate and veg cover as well), The best way to keep track of all these factors is a model, to explain the "biases" introduced by including multiple sites, times, etc. A similar exercise to the one outlined here may be taken, using model residuals to determine whether the process is trending based on movement measured by the residual mean (hopefully near zero) and the residual or unexplained variability (smaller than that for the whole sample) providing a more sensitive "alarm", able to detect smaller changes faster. This comment is offered for all species' objectives so treated (CSRB, Fountain darter density and recruitment) as well as complex/simple SAV coverage and San Marcos Salamander habitat coverage objectives, in that it applies to the methodological approach..
various	Figures 4, 9, 10, 14, 15, 16 17,18 19	Conrad Lamon	SC	All these figures claim to show trends, but trend assessment was not performed in any formal way. These figures do not show trends, but fitted LOESS smooth functions of the data. As such, they will invite a good deal of "bump hunting" from the reader, a purpose for which they are not well suited, due to lack of a "universal" error estimate. For this reason it is a good idea to include the "pointwise" uncertainty estimates associated with the loess estimates on the plots, so the reader does not "see" bumps that are highly uncertain. Edge effects are also a know feature of smoothers, and loess is no exception. Inclusion of uncertainty bounds would show this added uncertainty near the edges, which is often the portion of the graph that holds the most interest to managers. Are these Loess curves with default settings for the window width (span in loess terminology)? The span or window width is the most important feature of non parametric smoothers, and indeed it's adjustment leads to a family of smoothes. Need to justify the choice of span.
33	Fig 16	Conrad Lamon	SC	"Annual trends in mean fountain darter density" should be " Annual mean fountain darter density".
33	Fig 17	Conrad Lamon	SC	Caption should read Annual boxplots and violin plots displaying fountain darter total length [millimeters] at the ...
21	6 to 8 and Tables 3,4 6,7,9 and their referring text	Conrad Lamon	SC	These are not parameters from a normal distribution. The mean and Sd are sample quantities. The distribution of CSRB abundance is not nearly normal. Mu and sigma are population parameters and are therefore unknown (unknowable by frequentist rules), use our estimates of the true parameters.
29	Table 6	Conrad Lamon	SC	Is this the mean for all stations aggregated together? What if our future samples are in different substrates, vegetation types? Won't the mean be biased?
30	Figure 14	Conrad Lamon	SC	Are these average densities for all Comal sites, substrates, and veg types , averaged by sampling event? See bias comment above.
7	10	Melani Howard	Recreation (SH)	Why was the springflow approach changed from the original HCP and why was it minimized? Sustained low flows are not conducive to healthy habitat. Does this approach help protect the dynamic of springflow? How was the "11 months" derived?
9	5	Melani Howard	Recreation (SH)	Was any model besides Thom Hardy's used? His model is based on 2009 bathymetry data and the river has changed since that date.
11	19-21	Melani Howard	Recreation (SH)	Is this limiting monitoring WQ to just one variable (temperature)? Recommend continuing to monitor the WQ variables that are now monitored. The statement that adequate springflow "should" maintain healthy habitat suggests that it might be important to continue to be aware of a more holistic picture of water quality over time.
12	44	Melani Howard	Recreation (SH)	define the geographic range of Headwater, Upper river, Midddle River - or reference the geographic range
19	4	Melani Howard	Recreation (SH)	Add monitoring of the Hotel reach of the SMR. At least a presence/absence to monitor their existence
22	16	Melani Howard	Recreation (SH)	Add a literature citation for "high quality habitat"
22	29-31	Melani Howard	Recreation (SH)	Is the objective written in such a manner that Conservation Measures can be built to address recreation and sedimentation that are impacting the salamander pop?
26	7-8	Melani Howard	Recreation (SH)	add specific protection for the seed- bearing TWR stands in upper & lower Sewell and Bicentennial

34	12-14	Melani Howard	Recreation (SH)	Remove the addition of Hygrophila as acceptable for the SMR . By 2025, it will be eliminated from reaches above IH35 and continued maintenance of this effort needs to be authorized in the next HCP
36	10-12	Melani Howard	Recreation (SH)	Is this limiting the establishment of SAV to only the LTBG reaches? This was a problem in the old HCP and it was amended to include the Restoration Reaches. We need a sysyem-wide approach. What about establishing Recreation Reaches (low expectations of SAV/TWR) and Restoration Reaches (higher effort to establish SAV)
Overall	Overall	Melani Howard	Recreation (SH)	How will climate change be rolled into the objectives?
Overall	Overall	Melani Howard	Recreation (SH)	Developing watershed land conservation and mgt of recreation during low flows Conservation Measures will need to be based on a Biological Objective. Need to evaluate if the WQ BO is adequate to support these CMs.
Overall	Overall	Melani Howard	Recreation (SH)	The BOs are managing to the minimum. A sustained minimum threshold would not be beneficial to listed species.
Overall	Overall	Melani Howard	Recreation (SH)	Add an objective to continue improving our knowledge of the HCP species. Strive to continuously improve protections for listed species.

Appendix F8 | **Climate Report 1: Customized Statistically Downscaled CMIP 5 and CMIP 6 Projections**

AGU ADVANCING EARTH AND SPACE SCIENCES

Earth's Future

RESEARCH ARTICLE
10.1029/2024EF004716

Key Points:

- This study presents a flexible approach to the challenge of selecting climate projections for decision-making
- We find projected temperature and precipitation changes will stress groundwater resources in the Edwards Aquifer using this approach

Supporting Information:

Supporting Information may be found in the online version of this article.

Correspondence to:
A. M. Wootten,
amwootte@ou.edu

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Customized Statistically Downscaled CMIP5 and CMIP6 Projections: Application in the Edwards Aquifer Region in South-Central Texas

A. M. Wootten[1], H. Başağaoğlu[2], F. P. Bertetti[2], D. Chakraborty[3], C. Sharma[3], M. Samimi[2], and A. Mirchi[4]

[1]South Central Climate Adaptation Science Center, University of Oklahoma, Norman, OK, USA, [2]Edwards Aquifer Authority, San Antonio, TX, USA, [3]School of Civil and Environmental Engineering, and Construction Management, University of Texas at San Antonio, San Antonio, TX, USA, [4]Department of Biosystems and Agricultural Engineering, Oklahoma State University, Stillwater, OK, USA

Abstract Climate projections are being used for decision-making related to climate mitigation and adaptation and as inputs for impacts modeling related to climate change. The plethora of available projections presents end users with the challenge of how to select climate projections, known as the "practitioner's dilemma." In addition, if an end-user determines that existing projections cannot be used, then they face the additional challenge of producing climate projections for their region that are useful for their needs. We present a methodology with novel features to address the "practitioner's dilemma" for generating downscaled climate projections for specific applications. We use the Edwards Aquifer region (EAR) in south-central Texas to demonstrate a process to select a subset of global climate models from both the CMIP5 and CMIP6 ensembles, followed by downscaling and verification of the accuracy of downscaled data against historical data. The results show that average precipitation changes range from a decrease of 10.4 mm to an increase of 25.6 mm, average temperature increases from 2.0°C to 4.3°C, and the number of days exceeding 37.8°C (100°F) increase by 35–70 days annually by the end of century. The findings enhance our understanding of the potential impacts of climate change on the EAR, essential for developing effective regional management strategies. Additionally, the results provide valuable scenario-based projected data to be used for groundwater and spring flow modeling and present a clearly documented example addressing the "practitioner's dilemma" in the EAR.

Plain Language Summary Groundwater, constituting over one-third of global water resources, is crucial for sustaining ecosystems, agriculture, and drinking water supplies. In the face of climate change, rising temperatures and shifting precipitation patterns are anticipated to diminish the availability of groundwater for both societal and ecological requirements. Regional managers, in preparing for these changes, need localized climate projections for effective planning. However, the abundance of available climate projections poses a significant challenge for decision-makers in climate adaptation, known as the "practitioner's dilemma." This dilemma, though widely acknowledged, lacks a standardized solution. Our paper introduces a methodology to navigate this challenge, specifically tailored to the needs of the Edwards Aquifer Authority. This authority is actively engaged in implementing protection and habitat conservation plans to alleviate stress on groundwater and major springs in the Edwards Aquifer Region, located in south-central Texas. Our projections indicate that rising temperatures are likely to increase evapotranspiration, thereby exacerbating the strain on groundwater resources in this region as climate conditions evolve. Furthermore, our approach offers a customizable approach to "the practitioner's dilemma," potentially serving as a model for other decision-makers in the United States to effectively utilize climate projections in their strategic planning.

1. Introduction

More than one-third of global water supplies emanate from groundwater (Famiglietti, 2014), which is indispensable for human health, ecosystems, and energy and food security (Giordano, 2009). Groundwater plays a critical role in meeting consumptive water use needs and sustaining ecology, especially when surface water resources are scarce. Nearly 70% of groundwater withdrawals have been allocated to sustain agricultural production worldwide (Margat & Gun, 2013; Rosegrant et al., 2009). In the United States, groundwater provides about 40% of water for agriculture and domestic supplies (Lall et al., 2018; Russo & Lall, 2017). The intensive use of groundwater, particularly for irrigation, has caused groundwater overdraft in some regions when withdrawal

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rates exceeded recharge rates (Ferguson & Gleeson, 2012; Loáiciga, 2009; McCabe & Wolock, 2016; Siebert et al., 2010). Additional stressors may include higher pumping rates driven by population growth and socio-economic developments that could exacerbate groundwater depletion (Costantini et al., 2023; Shaabani et al., 2023; Wu et al., 2020). Elevated temperatures and shifts in precipitation patterns resulting from climate change could increase evapotranspiration and affect availability of recharge, leading to greater depletion of groundwater in some groundwater basins (Condon et al., 2020). Conversely, these changes could result in increased flooding and added recharge in other groundwater basins (Costantini et al., 2023). Thus, region-specific climate change assessments are needed to effectively manage future groundwater sustainability.

At global and continental scales, most climate projections use output from global climate models (GCMs). However, regional and local climates are not well represented by GCMs due to their coarse resolution (≥100 km, Rummukainen, 2010). Statistical downscaling techniques can translate the climate response simulated by GCMs to smaller spatial scales, reducing biases and adding information for decision makers (Rummukainen, 2016; Tabari et al., 2016). In addition, the use of statistical downscaling has allowed for GCM projections to be incorporated in impact assessment analyses. These assessments include studies that examined impacts to groundwater and aquifers (e.g., Gordu & Nachabe, 2023; Scibek & Allen, 2006), streamflow (e.g., Neves et al., 2020; Wootten et al., 2023), aquatic ecosystems and species (e.g., Keller et al., 2022), and water resources, quality, and security (Bhatt et al., 2023; Fu et al., 2022; Jaramillo & Nazemi, 2018). In a recent study, Chakraborty et al. (2021) assessed the impacts of potential future climates on groundwater levels in the Edwards Aquifer using MACA downscaled projected climatic data from CMIP5. However, MACA-downscaled data sets were developed for much larger areas of the United States at coarser spatial resolution, which presents a challenge in accurately representing regional climatic characteristics (Lall et al., 2018).

The "practitioner's dilemma" is not the lack of available data and projections, but the challenge of choosing and using projections wisely in regional decision making (Barsugli et al., 2013) and each of the aforementioned studies grappled with this challenge. While the "practitioner's dilemma" is a well-recognized challenge to using downscaled climate projections, there are no standard practices defined to handle that challenge, though there are studies building toward that standardization (e.g., Jagannathan et al., 2020, 2021, 2023; Maraun, 2023). The "practitioner's dilemma" traditionally focuses on selecting from pre-existing data sets but not on the case when new projections are needed, and pre-existing projections do not meet those needs. This study contributes to addressing the "practitioner's dilemma" through a presented approach to selecting GCMs and downscaling them for the Edwards Aquifer Region (EAR).

The Edwards Aquifer in south central Texas is a karst aquifer that is the primary drinking water source for more than 2 million people and provides important environmental flows, sustaining habitats for several threatened/endangered species at two major spring systems. The sustainability of the Edwards Aquifer depends on a delicate balance between recharge, withdrawals, spring flow, and runoff, all of which can be affected by climate change. Several studies have examined historical and projected future climate effects on the sustainability of water resources in south central Texas. Using earlier generations of GCMs, Loáiciga et al. (2000) noted that without considering variations in aquifer recharge and the implementation of sound pumping strategies, the water resources of the Edwards Aquifer could be severely impacted under future warmer climates. Based on projected temperature increases and projected decreases in spring flow for the region, Devitt et al. (2019) concluded that groundwater-bound species in the Edwards Aquifer system are at a high risk of extinction within the next century. Using projected climate data sets for the Edwards Aquifer region, statistically downscaled from CMIP5 models using the Multivariate Adaptive Constructed Analogs (MACA, Abatzoglou & Brown, 2012), Chakraborty et al. (2021) concluded that the combined effects of increased evapotranspiration, decreased soil moisture, and reduced diffuse recharge due to projected higher future temperatures could intensify hydrological droughts and reduce groundwater levels, exacerbating groundwater sustainability challenges. The Edwards Aquifer Authority (EAA) has been implementing several aquifer protection programs to support established habitat conservation plans and to mitigate stress on the groundwater and major springs that provide habitat for threatened and endangered species (Committee to Review the Edwards Aquifer Habitat Conservation Plan, Phase 3 et al., 2018). Accurate assessment of the effectiveness of these protection programs under future climate conditions and regional socioeconomic developments depends on the careful selection and creation of climate projections, which reflects the EAA's own "practitioner's dilemma".

Typically, the "practitioner's dilemma" pertains to selecting from existing downscaled climate projections. However, an added layer of the "practitioner's dilemma" arises when existing projections do not meet user needs. In such cases, developing new projections becomes necessary, as exemplified by the requirements of the EAA. However, this secondary challenge is often overlooked in the literature and was not addressed by Barsugli et al. (2013). We note the reasons for creating fine resolution (~1 km) projections in this study rather than relying on other data sets such as the CMIP6-LOCA2 (Pierce et al., 2023) or the CMIP6-STAR (Hayhoe et al., 2023), contributing to the literature regarding the choice between utilizing existing data versus creating new data sets. The groundwater flow models developed and used by the EAA to simulate and forecast groundwater levels and spring flow under current and projected climate conditions rely on gridded data at a spatial resolution of 0.4 km. Such fine resolution is critical for accurately capturing spatiotemporal variations in mean and extreme climate events and their combined effects with spatial variations in hydrogeologic and topographic features (Figure S1a in Supporting Information S1) on aquifer recharge and regional groundwater flow patterns. Specifically, the fine-resolution representation of areas with heavy storms and extreme precipitation events along ephemeral and perennial streams is crucial because extreme precipitation-driven focused recharge along discrete features (e.g., sinkholes) and dissolution along faults and fractures within stream channels are more significant for aquifer recharge than gravity-driven dispersed recharge over inter-stream areas in the EAR (Sun et al., 2020). Raw GCM data are unable to capture these features (Figure S1b in Supporting Information S1). Other downscaled projections, including CMIP6-LOCA2 and CMIP6-STAR in the literature, have a resolution from 4 to 6 km, which also does not capture these critical features (Figure S1c in Supporting Information S1). Therefore, custom downscaling to 1 km was deemed necessary for this project and successfully captured the topographic effects in the EAR (Figure S1d in Supporting Information S1). The decision to create custom 1 km projections aligns with previous literature suggesting that a spatial resolution finer than 4 km is required to accurately assess climate impacts on vegetation dynamics in complex topography (e.g., Franklin et al., 2013).

This study presents an approach to addressing the "practitioner's dilemma" for the EAA as our contribution to the larger discussion regarding the development and use of decision-relevant climate projections. In addition, this study generates customized downscaled climate projections for the Edwards Aquifer Region (hereafter EAR) of south-central Texas to facilitate the assessment of the potential impacts of climate change on groundwater levels and spring flows. The fine resolution (~1 km) downscaled projections are specifically designed to capture the historical climate of the region and account for multiple known sources of uncertainty in the climate projections (Crosbie et al., 2011; Lafferty & Sriver, 2023; Wootten et al., 2017). The following sections describe the approach to GCM selection and downscaling and the insights for future impacts modeling efforts, essential for evaluating the long-term sustainability of the EAR amid a changing climate.

2. Region, Data, and Methods

2.1. Study Region

The Edwards Aquifer is characterized by faulted and fractured carbonate rocks, heterogeneous hydrogeological properties and flow pathways, conduit flow, presence of sinkholes, sinking streams, caves, ecologically rich springs, and highly productive water wells. The San Antonio segment of the Edwards Aquifer system covers an area of approximately 14,200 km^2 (5,490 mi^2) and is divided into three distinct hydrogeological zones from north to south, including the contributing zone, recharge zone, and the artesian zone, as shown in Figure 1 (Lindgren et al., 2004; Schindel, 2019). Spring flow and runoff in the contributing zone feed streams that cross the outcrop of the Edwards Limestone in the recharge zone. Faulting (Balcones Faut Zone), fractures, and karst features facilitate vertical downward percolation of surface water, recharging the aquifer. The artesian zone of the aquifer, where most of the large production wells are located, is confined and fully saturated. The Edwards Aquifer is the primary water source for much of the area, including the City of San Antonio and surrounding communities. The aquifer also provides habitat for several threatened and endangered groundwater-bound endemic species such as the Texas blind salamander and Fountain darter (Committee to Review the Edwards Aquifer Habitat Conservation Plan, Phase 3, 2018) at the major springs in the region, including Comal Springs and San Marcos Springs. The EAR is in the southern tip of the Southern Great Plains (SGP) region of the United States and has a distinct precipitation gradient from east to west (Figure 1). The domain for the downscaling covers the EAR from 28.75°N to 30.50°N and 100.75°W to 97.75°W. The entire SGP region is used for the evaluation and ensemble subset selection of the GCMs, as GCMs are more capable of representing physical processes on the scale of the SGP region and the continental United States than in the relatively smaller domain of the EAR.

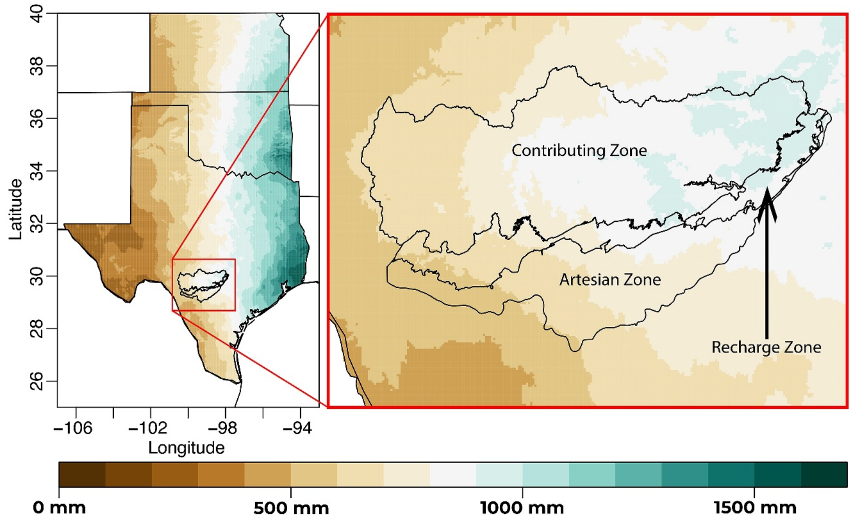

Figure 1. 1980–2014 climatology of average annual precipitation (P) across the Southern Great Plain region (left) and in the downscaling region (the Edwards Aquifer Region, right).

2.2. Observation and Global Climate Model Data

The observation data used in this study is the Daymet version 4 (Thornton et al., 2022, hereafter Daymet) which provides gridded observations of daily Tmax, daily Tmin, and daily total P at ∼1 km spatial resolution, starting 1 January 1980, across North America. The Daymet data were reprojected from their native map projection to a geographic projection using the functions available in the raster package (v 3.3–13) in R. Climate data is derived using 33 GCMs from the Coupled Model Intercomparison Project (CMIP) Phase 5 (CMIP5, Andrews et al., 2012) and 23 GCMs from Phase 6 (CMIP6, Eyring et al., 2016). The number of models used for downscaling was initially reduced to five each from CMIP5 and CMIP6 via the ensemble subset selection approach discussed in the next section. The list of models initially considered is provided in Table S1 of Supporting Information S1.

2.3. Ensemble Subset Selection Approach

The ensemble subset selection approach used in this study is based in part on the work of McSweeney et al. (2015) and Parding et al. (2020). The subset selection approach is described here with regards to its use to select a subset of models for statistical downscaling of daily high temperature (Tmax), daily low temperature (Tmin), and daily total precipitation (P) for the EAR.

2.3.1. Data Preparation

Several data preparation steps are implemented prior to starting the ensemble subset selection. First, for each GCM, the climatology of annual total P, annual average Tmax, and annual average Tmin are calculated for the respective historical periods of each ensemble (1980–2005 for CMIP5 and 1980–2014 for CMIP6). Second, the climatology of all three variables from all models is interpolated using bilinear interpolation to the Daymet grid and cropped to the SGP region. Third, the first two steps are repeated to create the climatology of all three variables for a future period (2070–2099) under the RCP 8.5 for the CMIP5 ensemble and the SSP 5–8.5 for the CMIP6 ensemble. The choice to use the end-century and high emission scenarios for subset selection is based on maximizing the change signal and potential spread of the ensemble. Fourth, the projected change of each variable from each GCM in the SGP region is calculated using historical and future climatology. The historical climatology and projected change are used with the ensemble subset selection approach to identify a subset of five GCMs from both the CMIP5 and CMIP6 ensembles that represent a range of future uncertainty while accurately representing the seasonality and magnitude of historical data for a region. Selection of a subset of models that meet specific performance criteria can reduce the computational burden needed to assess a multitude of models, especially given the often wide range of uncertainty across the full ensemble of model results, which can hinder effective decision making in assessing likelihood of future conditions. Recent literature suggests that some "hot-models" (those GCMs with a high equilibrium climate sensitivity [ECS]) should be removed from use

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(Hausfather et al., 2022). However, a GCM with a high ECS values does not automatically make it an outlier for regional projected changes, particularly when incorporated into an impact assessment (Rahimpour Asenjan et al., 2023). As such, we retained all GCMs for this subset selection, regardless of their ECS value.

2.3.2. Historical Error Calculation

The first component of the ensemble subset selection approach is to determine the error of the historical climatology of all possible combinations of five model ensemble subsets. For this first component, the approach determines which ensemble subset minimizes the historical error. For each possible ensemble subset and a given variable, the historical climatology for the five GCMs are averaged together to produce a subset mean climatology. For each possible subset, the historical error is the normalized root mean square error (NRMSE) of the subset mean climatology compared to the Daymet observations:

$$NRMSE_s = \frac{\sqrt{\sum_{i=1}^{N} (M_i \quad O_i)^2}}{\sqrt{N}\sigma_O} \tag{1}$$

where M is the subset mean climatology, and O is the historical climatology from Daymet. The *RMSE* of ensemble subset s is determined as the square root of the mean squared errors from each of the ith grid cells, where N is the total number of grid cells. The *NRMSE* of subset s is calculated as the *RMSE* of subset s divided by the standard deviation (σ) of the historical observations. The resulting *NRMSE* reflects the skill of the ensemble subset for a given variable across the SGP, which is in line with scale of information provided by GCMs.

2.3.3. Future Spread Calculation

The second component of the ensemble subset selection approach is to determine how much of the future spread in the ensemble is captured by the subset. This is accomplished using the fractional range coverage (*FRC*) calculated similarly to that described by McSweeney et al. (2015) and Parding et al. (2020). At each grid cell in the SGP region, the *FRC* is calculated by

(2)

where s is the ensemble subset, i is the grid cell, and *max* and *min* are the maximum and minimum projected change, respectively. The numerator of Equation 2 is the range of projected change from a given subset s for grid cell i. The denominator of Equation 2 is the range projected change for grid cell i from the full ensemble. The *FRC* across all grid cells are averaged together to create a single *FRC* value for ensemble subset s via

$$FRC_s = \frac{\sum_{i=1}^{N} FRC_{s,i}}{N} \tag{3}$$

The *NRMSE* and *FRC* reflect the skill and spread, respectively, of each individual ensemble subset. Like the *NRMSE* calculation, the FRC is aggregated to one value for the SGP to reflect the ability of the subset to capture the spread of ensemble changes across the larger region, which is more in line with the scale of information provided by GCMs.

2.3.4. Multivariate Combination and Ensemble Subset Selection

The final component of the ensemble subset selection approach focuses on determining which ensemble subset minimizes the *NRMSE* and maximizes the *FRC*. Ideally, the minimum *NRMSE* is zero, representing a subset that perfectly captures the historical climatology, and the maximum *FRC* is one, representing a subset that has the same future spread as the full ensemble. Therefore, the subset selection approach calculates the Euclidean distance (D) of each subset from the ideal situation using the *NRMSE* and *FRC* values from each subset using

(4)

In this study, we implemented the multivariate subset selection approach. The value of D is calculated for each subset s and variable v. Following a similar approach to Sanderson et al. (2017), the values of D for a given subset s over multiple variables can be combined using linear combination by

$$\Delta_s = \sum_{v=1}^{V} \frac{D_{s,v}}{V} \tag{5}$$

where Δ_s is the multivariate distance for subset s, v is the climate variable, V is the total number of climate variables, and D is the Euclidean distance for a given variable v and subset s. In the multivariate selection approach, the subset with the minimum multivariate distance is used. We applied the approach detailed in this section separately for the CMIP5 and CMIP6 ensembles, resulting in two separate five member ensembles that are then statistically downscaled for the EAR. This final step represents a departure from the approach of Parding et al. (2020), which used skill scores and user-defined weights to rank individual GCMs, where this study uses a multivariate distance (Equation 5) to select a GCM subset to capture skill and spread for the SGP region. This larger region is the focus of subset selection to minimize the error of GCM representation of larger scale patterns that affect the EAR while capturing the spread of changes from the GCM ensemble. A subset of five GCMs from each ensemble was chosen in consultation with the EAA to limit computational demands for the subsequent use of the projections in groundwater and spring flow modeling.

2.4. Downscaling Technique

2.4.1. Equidistant Quantile Mapping (EDQM) and Equi-Ratio Quantile Mapping (ERQM)

The downscaling techniques used for statistical downscaling of climatic features from GCMs for the EAR are equidistant quantile mapping (EDQM) and its variant known as equi-ratio quantile mapping (ERQM). We implemented these techniques for the EAR following the same procedures described by Wootten et al. (2020). The EDQM was used to produce downscaled projections of daily Tmax and Tmin. The ERQM was used to produce downscaled projections of daily total P. In addition, while the two techniques are subtlety different, they share the same basic procedure. As such, we refer to the downscaling and results from the downscaling procedure as EDQM in the results and discussion sections.

2.4.1.1. Equidistant Quantile Mapping (EDQM)

The EDQM approach, used for downscaling daily Tmax and Tmin, has been similarly applied in several other studies (Cannon et al., 2015; Lanzante et al., 2019; Li et al., 2010). For the downscaling in this study, we followed the procedure used in Dixon et al. (2020). The EDQM approach for downscaling daily Tmax and Tmin is mathematically equivalent to the quantile delta mapping (QDM, Cannon et al., 2015). The downscaling in this study makes uses of the implementation of EDQM available in the MBC R Package (GitHub—cran/MBC), which reflects the EDQM method created by Li et al. (2010). The calculation is summarized below with specific notes for its application in this study.

The EDQM has four major steps. First, the cumulative distribution function (CDF) of the GCM-projected climatic feature values is determined for a given climatic variable, and then the corresponding quantile levels are computed by

(6)

The second step is to calculate the change factor (Δ) between the simulated projected climatic feature values and the simulated historical climatic feature values from the GCMs at quantile levels by

(7)

Third, the downscaled projected climatic feature values are determined by first estimating historical climatic feature values from the GCM-projected climatic feature values using the inverse CDF of the observed historical climatic feature values. Finally, the change factor, determined in Equation 7, is added to the estimated historical climatic feature values, as described below.

(9)

where m is the GCM-modeled value of the climate variable, p is the GCM-projected value of the climate variable,

o is the observed historical value of the climate variable, h is the GCM-modeled historical value of the climate variable, τ is the quantile level, $F_{m,p}$ is the CDF of the GCM-modeled future variable, $F_{o,h}$ is the CDF of the observed historical value of the variable, Δ_m is the change factor, and $\hat{x}_{o,p}$ is the downscaled value of the target variable.

In line with the previous work by Dixon et al. (2020), we applied the EDQM using a monthly time window with a 2-week overlap. For example, the values of Δ_m for July were calculated using the month of July, the final 2 weeks of June, and the first 2 weeks of August. The use of a monthly time window enables a more accurate representation of seasonal variability in the downscaled climatic features in the region.

2.4.1.2. Equi-Ratio Quantile Mapping (ERQM)

The ERQM is a variation of the EDQM that uses a multiplicative rather than an additive approach to determine and apply the change factors. The implementation used here is the same as in Dixon et al. (2020), Wootten et al. (2020), and Lanzante et al. (2021). The ERQM procedure is similar to the EDQM procedure except that Equations 7 and 9 are replaced by

(10)

(11)

The ERQM variation of EDQM is applied for downscaling daily P because the multiplicative change factor prevents the downscaled P from having negative values. We also applied the ERQM with seasonal time window, following the work of Wootten et al. (2020), in order to provide enough non-zero P days to construct a robust CDF. Prior to the execution of ERQM, a trace adjustment similar to Pierce et al. (2015) was applied to correct the wet-day fraction of the modeled precipitation data to match that of the Daymet observations. In addition, prior to implementing ERQM a cube root transformation was applied to precipitation to yield a more Gaussian distribution. The ERQM was performed on the transformed P data, and the reverse transformation was applied to the results of ERQM.

2.4.2. Training Period and Output Resolution

The training period for the statistical downscaling is different for the CMIP5 and CMIP6 ensemble subsets. The Daymet data, available from 1980 onward, limits the training period for both ensembles. The respective GCM ensembles have different historical simulation periods. The historical simulation period for the CMIP5 and CMIP6 ensembles end in 2005 and 2014, respectively. Thus, for the CMIP5 ensemble, the training period is 1980–2005, while the training period for the CMIP6 ensemble is 1980–2014. The output resolution of the projections matches the resolution of the Daymet data used in training (∼1 km).

2.4.3. Future Pathways and Period

Due to the slightly different training periods and the variations in emissions scenarios between CMIP5 and CMIP6, the future period between two ensembles differs. The future period of available downscaled projections using CMIP5 and CMIP6 GCMs is 2006–2099 and 2015–2099, respectively. In this study, we used CMIP5 GCM output created using representative concentration pathways (RCPs) 4.5 and 8.5 (Riahi et al., 2007; van Vuuren et al., 2011) and CMIP6 GCM output created using shared socioeconomic pathways (SSPs) 2–4.5 and 5–8.5 (O'Neill et al., 2016). The RCP 4.5 and SSP 2–4.5 scenarios assume that the current energy production and use, and mitigation and adaptation strategies remain the same or similar in the future. Conversely, the RCP 8.5 and SSP 5–8.5 scenarios depict a worst-case situation, wherein future energy production heavily relies on fossil fuels, with minimal attention given to mitigation and adaptation measures. Consequently, the RCP 4.5 and SSP 2–4.5 represent intermediate emission scenarios, while RCP 8.5 and SSP 5–8.5 represent high emission scenarios.

3. Results

3.1. Ensemble Subset Selection

The ensemble subset selection approach detailed in Section 2.3 was applied to the CMIP5 and CMIP6 ensembles to select five models from each ensemble for use in the statistical downscaling. The five GCMs chosen to form the ensemble subsets have a mean absolute error similar to, or less than, that of the full ensemble for all three variables to be downscaled for the EAR (Table 1). The spatial pattern and direction of the error of the ensemble subsets is similar to the full ensemble for total annual P (Figure S2 in Supporting Information S1), annual average of daily Tmax (Figure S3 in Supporting Information S1), and annual average of daily Tmin (Figure S4 in Supporting Information S1). The ensemble subset selection approach is designed to select GCMs that minimize historical error while maximizing the spread of projected changes for all three climate variables for the SGP region. The latter portion of the approach aims to capture as much of the uncertainty of climate projections associated with the GCMs as possible. The results from the ensemble subset selection for the SGP show that the ensemble subset captured most, if not all, the spread of the full ensemble for all three variables (Figure 2).

3.2. Downscaling for the Edwards Aquifer Region

Next, we analyze the representativeness of the historical downscaled climate data (Tmax and P) for the EAR. In Figure 3, we compare the seasonal cycles of Tmax and P over the historical period from downscaled CMIP5 and CMIP6 models with the seasonal cycles from the Daymet historical data. While the downscaled Tmax from CanESM2 and CanESM5 are comparable to the observations from Daymet, the downscaled P from CanESM2 and CanESM5 do not reasonably represent the seasonality of P in the EAR.

Prior research indicates that ERQM and similar statistical downscaling techniques produce output that is time synchronous with the driving GCM (Wootten et al., 2020). This is different from a delta method for statistical downscaling where the output is time synchronous with the observations used for training. In other words, ERQM and similar methods incorporate dynamic changes in weather sequences from a GCM into the downscaled output. However, this also implies that incorrect seasonal cycles in a GCM can be translated into downscaled output. As a result of this effect, CanESM2 and CanESM5 were excluded from subsequent analyses.

To compensate for the exclusion of the two GCMs, we included two additional GCMs from CMIP6 models (INM-CM-8 and INM-CM-5.0) that exhibit similar magnitudes and seasonality for P as the other CMIP6 models. Consequently, we used four GCMs from the CMIP5 ensemble subset and six GCMs from the CMIP6 ensemble subset in the subsequent analyses and for use by the EAA. The historical and projected annual mean daily Tmax and daily total P from the CMIP5 and CMIP6 ensemble subsets under the intermediate and high emission scenarios along with the uncertainty bands for the San Antonio International airport (SAT) are shown in Figure S5 of Supporting Information S1, as an example.

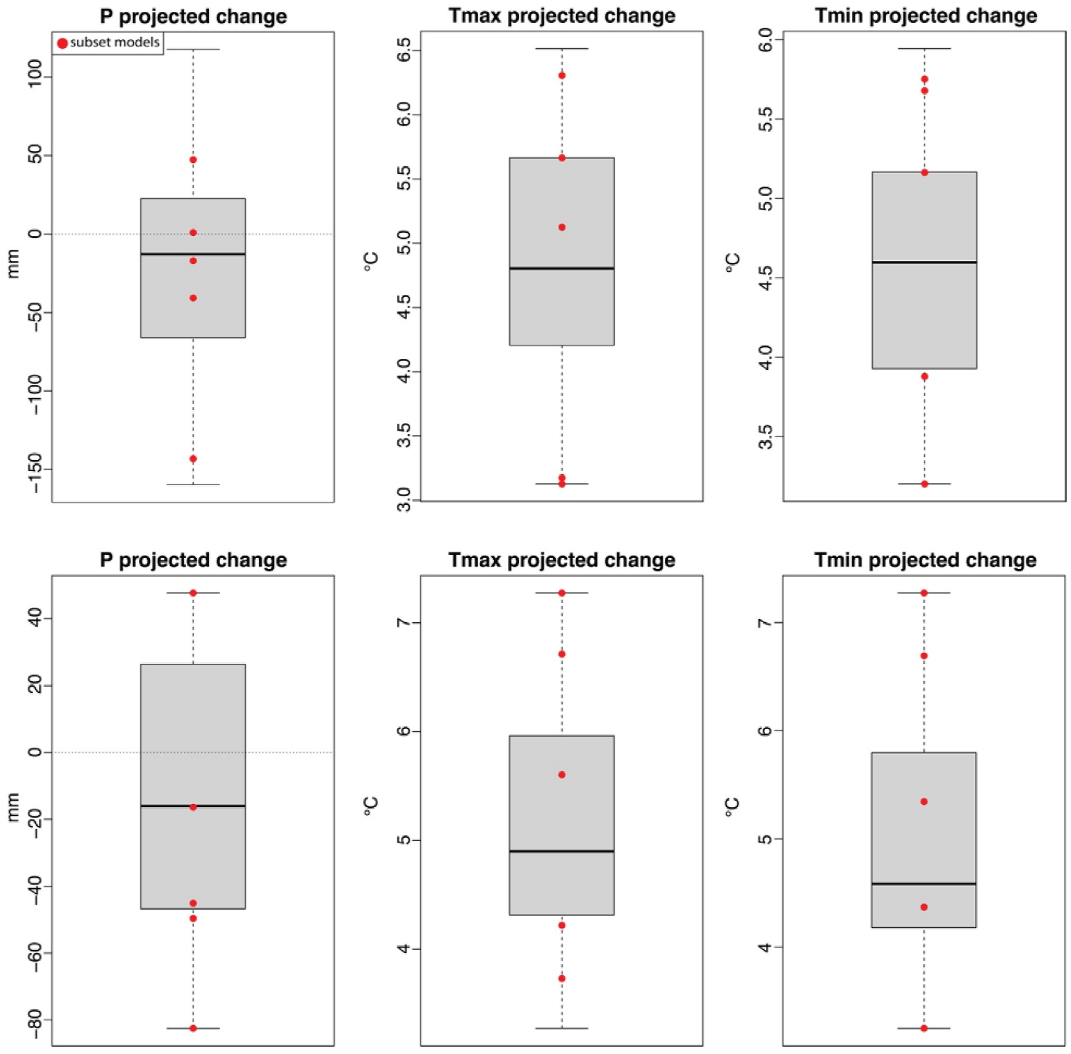

Figure 2. Spread of projected changes by the end of the century (2070–2099) for the CMIP5 (top row) and CMIP6 (bottom row) ensembles and subsets for the Southern Great Plains National Climate assessment (NCA) region. Boxplots represent the full ensemble of models available, while the red dots are the models selected for downscaling.

3.2.1. Historical Error

A fundamental purpose of statistical downscaling is to reduce the biases of the GCM output for a particular region, typically referred to as bias-correction. For both P and Tmax, the spatial RMSE of the ensemble subsets downscaled by EDQM is much less than the spatial RMSE of the raw ensemble subset (RMSE is 76%–99% smaller for the CMIP5 ensemble and 54%–99% smaller for the CMIP6 ensemble). The mean error and root mean square error (RMSE) of P in each individual model were also reduced by the implementation of EDQM (Table 2). The error of Tmax and Tmin was also reduced by the EDQM both for the mean subset and for the individual models in each subset (Tables 3 and 4). There is also improvement in the spatial distribution of error of the raw GCM ensemble subsets. The raw CMIP5 and CMIP6 ensemble subsets exhibit a tendency to overestimate P in the western and southern portions of the domain, underestimate P in the central and northeastern portions, and underestimate Tmax (Figure S6 in Supporting Information S1). The raw ensemble subsets also tended to overestimate Tmin (Figure S7 in Supporting Information S1) in the EAR.

3.2.2. Projected Changes

The downscaled ensemble subsets provide EAR-specific guidance on potential climatic changes. The available projections cover the period of 2006–2099 for CMIP5 and 2015–2099 for CMIP6. In this section, we focus on

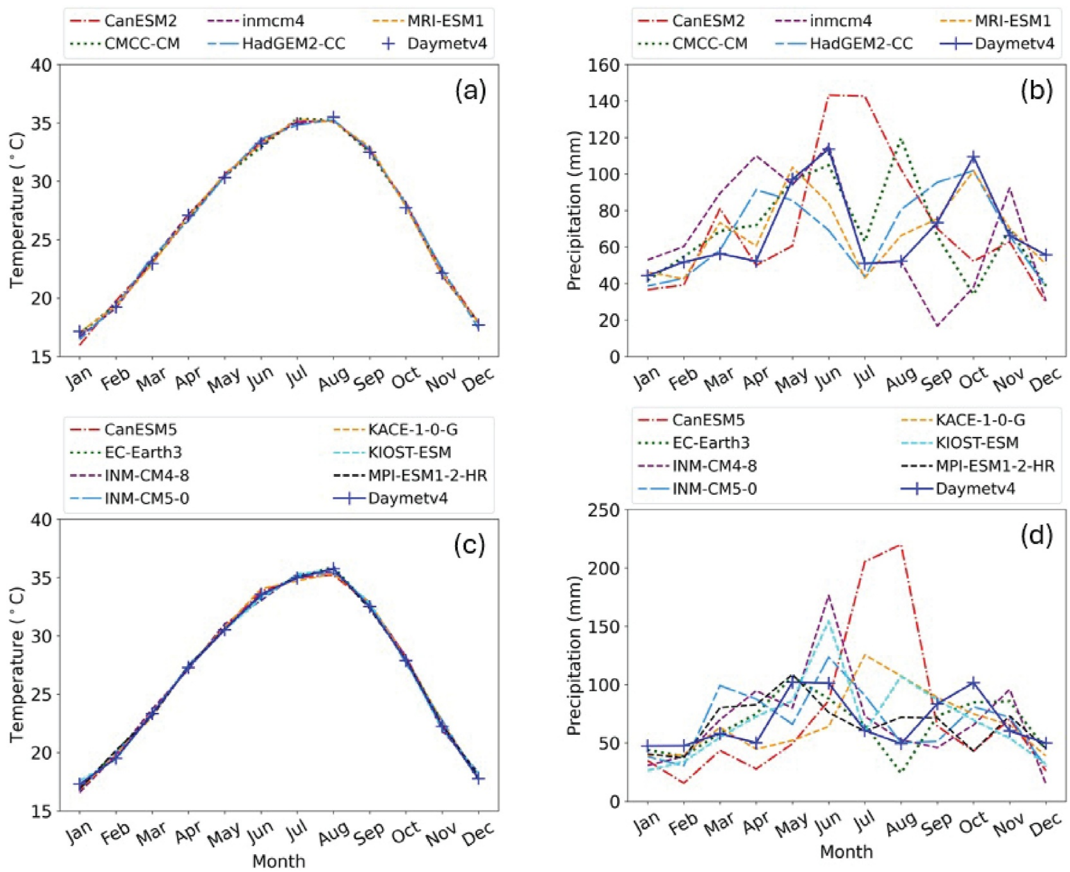

Figure 3. Comparison of monthly variations in historical Tmax and P from the downscaled CMIP5 ensemble subset (a–b) and the downscaled CMIP6 ensemble subset (c–d) to Daymet data at the San Antonio International Airport (SAT) location.

the projected changes during the mid-century (2036–2065) and end-century (2070–2099). These two periods are commonly used for calculating projected changes in the National Climate Assessment (NCA). Because the MRI-ESM1 was not run using the RCP 4.5 as an input, projected changes from the CMIP5 subset with RCP 4.5 consists of three models, while the CMIP5 subset with RCP 8.5 includes four models.

Table 2
Mean Error and Root Mean Square Error for All Subset Models for the EAR Annual Precipitation (P, mm) Pre-Downscaling (Pre-DS) and Post-Downscaling (Post-DS)

3.2.2.1. Projected Temperature Changes

The ensemble-mean projected changes in Tmax are notably larger in the CMIP6 subset than in the CMIP5 subset (Figure 4). Despite a slight temperature change gradient from west to east in the EAR, the projected increases are similar across the region. For mid-century under intermediate emissions (RCP 4.5 and SSP 2–4.5), the mean projected changes in Tmax range from 1.68°C to 2.18°C. By end-century under the same emissions, the projected changes in Tmax increase to 2.2°C and 2.64°C. For mid-century under high emissions (RCP 8.5 and SSP 5–8.5), the mean projected changes in Tmax range from 2.08°C to 2.66°C. For end-century under high-emission scenarios, the mean projected changes in Tmax further increase to 4.25°C–4.3°C.

Projected increases in temperature extremes follow similar patterns to the projected increases in Tmax. The average annual number of days with high temperatures over 100°F (37.78°C, Tmax100) is projected to increase in the EAR, with the greatest increases in the southern portion of the region and the smallest increases in the higher elevation regions in the western and northern

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Table 3
Mean Error and Root Mean Square Error for All Subset Models for the EAR Annual Average High Temperature (Tmax, °C) Pre and Post Downscaling

portions of the region (Figure S8 in Supporting Information S1). For reference, Tmax100 is calculated for each grid cell and averaged to the EAR mean. The mean projected changes in Tmax100 during mid-century under intermediate emission scenarios are in the range of 18.76–43.15 days. The mean projected changes in Tmax100 by end-century under the same emission scenarios range from 26.63 to 42.45 days. The mean projected increase in Tmax100 during mid-century under high emission scenarios ranges from 30.27 to 51.07 days and 68.21–71.69 days by end-century. These results indicate a higher risk of experiencing more frequent and prolonged dry spells, potentially triggering the onset of droughts within the EAR under future climates, especially under high emission scenarios. The individual GCMs all suggest an increase in both Tmax and Tmax100 across the region but with varying magnitudes (Table 5, Figures S9–S12 in Supporting Information S1). The results for Tmin are similar to Tmax in both magnitude and spatial patterns across the EAR (Figures S13–S15 in Supporting Information S1).

3.2.2.2. Projected Precipitation Changes

The mean projected changes in P within the EAR are more variable under different emission scenarios. In general, the CMIP5 subset projects higher P, while the CMIP6 subset projects less P. Under the intermediate emission scenarios, the CMIP5 subset projects the most substantial increase in P in end-century, while the CMIP6 subset projects the most significant decrease in P in mid-century. In particular, the CMIP6 subset projects less P, especially on the eastern side of the region, under both intermediate and high emission scenarios (Figure 5). The mean projected increases in P during mid-century under low emissions exhibit a broader variation, ranging from an increase of 27.23 mm (CMIP5) to a decrease of 40.85 mm (CMIP6). Under the same emission scenario, the mean P is projected to increase in the range of 1.28 mm (CMIP6) to 49.87 mm (CMIP5) during end-century. Under the high emission scenarios during mid-century, the mean projected range from a decrease of 14.55 mm (CMIP6) to an increase of 16.78 mm (CMIP5). However, under high emission scenarios during end-century, the mean P is projected to decrease in the range of 0.99 mm (CMIP6) and 19.88 mm (CMIP5).

The ensemble subsets indicate a negligible to small increase in 1-day maximum precipitation (rx1day) with no clear spatial pattern (Figure S16 in Supporting Information S1). Under intermediate emissions in mid-century, the mean projected changes in rx1day are in the range of 8.26 mm (CMIP6) and 12.01 mm (CMIP5). In the end of the century under the same emissions scenario, the mean changes in rx1day range from 8.88 mm (CMIP6) to 9.81 mm (CMIP5). Under high emissions during mid-century, the mean changes in rx1day are projected to be in the range of 6.06 mm (CMIP5) and 12.06 mm (CMIP6). Under the same emission scenarios, the mean projected changes in rx1day by the end of the century range from 10.30 mm (CMIP6) to 17.42 mm (CMIP5). Thus, unlike P, the mean projected changes in rx1day show little variation regardless of the emissions scenarios. The projected changes in P have a wide range reflecting the potential for both a drier or wetter future across the EAR, while the rx1day is projected to increase (Table 6, Figures S17–S20 in Supporting Information S1). The anomalies in regional average projected climatic features acquired from the CMIP5 and CMIP6 subsets under intermediate and high emission scenarios are summarized in Table 7.

Table 4
Mean Error and Root Mean Square Error for All Subset Models for the EAR Annual Average Low Temperature (Tmin, °C) Pre-Downscaling (Pre-DS) and Post-Downscaling (Post-DS)

4. Discussion

The approach to creating customized downscaled projections for the EAR includes selecting a subset of GCMs, downscaling those chosen GCMs, determining historical error, and determining projected changes. In this case, the ensemble subset selection approach initially identified five GCMs from CMIP5 and five GCMs from CMIP6, collectively yielding comparable results to their respective full ensembles. These subsets were changed in consultation with EAA to remove those with unreasonable seasonal cycles of P. The

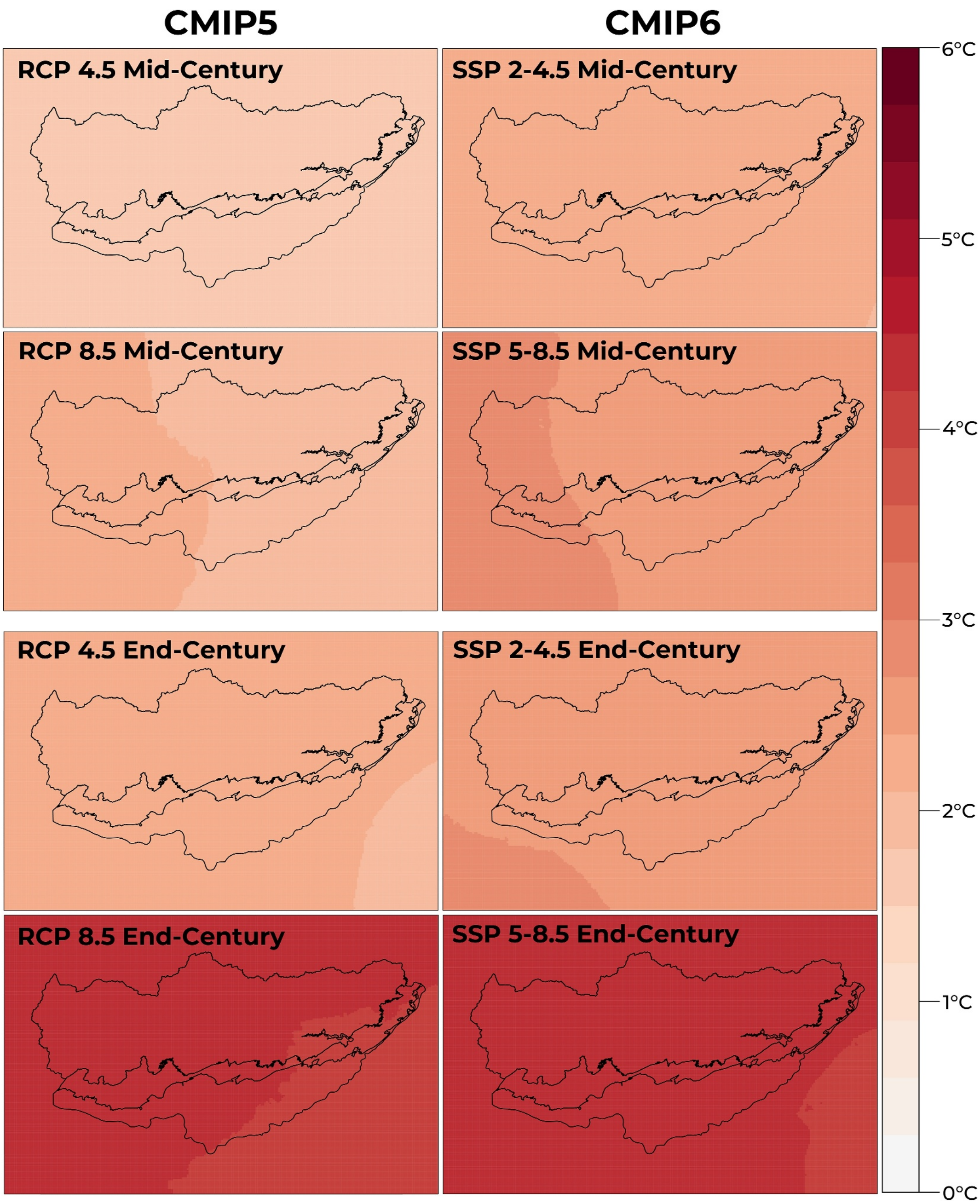

Figure 4. Mean projected changes in annual average high temperature (Tmax) for the mid-century (2036–2065) and end-century (2070–2099) from the downscaled CMIP5 (left) and CMIP6 (right) ensembles. CMIP5 ensemble includes the RCP 4.5 and RCP 8.5 scenarios. CMIP6 ensemble includes the SSP 2–4.5 and SSP 5–8.5 scenarios.

statistical downscaling reduced the error for the selected GCMs for all three variables. According to the ensembles of downscaled projections (Table 7), the average daily Tmax is projected to increase by 1.93°C–2.37°C on average by mid-century and 2.42°C–4.27°C on average by end-century. These changes are similar for Tmin. The projected changes in P exhibited greater variations between the CMIP5 and CMIP6 ensembles. According to the CMIP5 downscaled ensembles, average total P in the EAR is projected to increase by 16.78–27.23 mm on average by mid-century. The CMIP5 ensembles also project P to increase by 49.87 mm on average (intermediate scenarios) and decrease by 19.88 mm on average (high scenarios) by end-century. According to the CMIP6 downscaled ensembles, P is projected to decrease by 14.55–40.85 mm on average by mid-century. The CMIP6 ensembles project little change in P (decrease by 0.99 mm to increase of 1.28 mm) by end-century. Thus, during

Table 5
Projected Changes in Annual Average High Temperature (Tmax, °C) and Annual Average Number of Days Tmax ≥100°F (Tmax100, Days) for All Models Across the EAR

		Intermediate emission scenario (RCP 4.5 and SSP 2–4.5)				High emission scenario (RCP 8.5 and SSP 5–8.5)			
		Tmax		Tmax100		Tmax		Tmax100	
Group	Model	Mid-century	End-century	Mid-century	End-century	Mid-century	End-century	Mid-century	End-century
CMIP5	CMCC-CM	1.85	2.8	24.84	38.68	2.33	5.58	37.9	104.76
	HadGEM2-CC	2.67	3.23	28.85	37.32	3.23	5.3	41.67	86.11
	inmcm4	0.51	0.57	2.58	3.9	1.11	2.8	13.62	29.9
	MRI-ESM1	NA	NA	NA	NA	1.66	3.3	27.89	52.07
CMIP6	EC-Earth3	2.77	3.72	57.23	64.79	3.64	5.9	78.92	106.3
	INM-CM4-8	1.85	1.9	31.9	28.86	2.41	3.95	38.15	55.83
	INM-CM5-0	1.7	1.92	25.9	35.13	2.16	3.24	32.47	45.46
	KACE1-0-G	2.72	3.3	43.11	35.06	3.15	4.9	51.87	76.53
	KIOST-ESM	2.55	2.78	73.34	63.84	2.74	4.03	74.2	87.61
	MPI-ESM1-2-HR	1.49	2.19	27.44	27.02	1.88	3.79	30.8	58.38

the projected warmer temperatures in the EAR, while CMIP5 ensemble projects increased precipitation, CMIP6 ensemble project reduced precipitation by mid-century under both intermediate and high emission scenarios. However, under persistently warming temperatures by end-century, while CMIP5 and CMIP6 ensembles project increased precipitation under the intermediate emission scenario, they project reduced precipitation under the high emission scenario. Increasing temperatures will likely lead to a net increase in evapotranspiration though this was not formally evaluated in this study.

Our findings align with earlier studies that used previous generations of GCMs and noted projected increases in Tmax and decreases in P (e.g., Loáiciga, 2009; Loáiciga et al., 2000), and projections from two National Climate Assessments (Kloesel et al., 2018; Marvel et al., 2023). *A key finding is that the temperatures will likely increase in the EAR with a corresponding increase in the frequency of very hot days, which will increase evapotranspiration. These factors are poised to intensify the frequency and severity of drought conditions in the EAR under the changing climate*. More frequent drought conditions could lead to decreased groundwater availability, reduced spring flow, and elevated surface water temperatures. Such shifts pose challenges for aquifer management, especially with population growth and required sustainable environmental flow for karstic spring ecosystems. Our findings are consistent with those of Loáiciga et al. (2000); Loáiciga (2009), which suggest that the Edwards Aquifer's groundwater resources could be at risk in a changing climate, particularly without rigorous mitigation efforts. This study builds upon and refines the approach taken by Loáiciga et al. (2000); Loáiciga (2009) in integrating climate projections for the EAR. Their research employed a change factor (or delta method), applying uniform change factors to historical temperature and precipitation data, remains time-synchronous with the historical observations. However, it does not capture the dynamic variability in weather patterns provided by GCMs, thereby artificially limiting variability in rain events and maintaining the original distribution shape. In contrast, the EDQM downscaling in our approach to addressing the needs of the EAA allows for a nuanced representation of changes, including alterations in the tails of the distribution indicated by the GCM (Wootten et al., 2020), which is crucial for accurate hydrological modeling of the Edwards Aquifer. The downscaled climate projections also indicate an increase in 1-day maximum P but fewer rainy days on average. These changes may weaken diffuse recharge while enhancing the role and impact of focused recharge. Moreover, as precipitation events become more intense and less frequent, the likelihood of flooding increases due to larger amounts of runoff and reduced soil absorption. In addition, the projections produced in this study provided added confidence to existing projections for the region and the necessary resolution for future assessments of projected changes in groundwater levels and springs flow in the EAR. The climate projections generated in this work will be integral to future groundwater and spring flow modeling efforts in the Edwards Aquifer and will be presented as part of our follow-up research.

A noteworthy aspect of this study is the comparison between the CMIP6 and CMIP5 model ensembles with a larger projected temperature increase in the CMIP6 ensemble. This difference suggests a discussion of the "hot

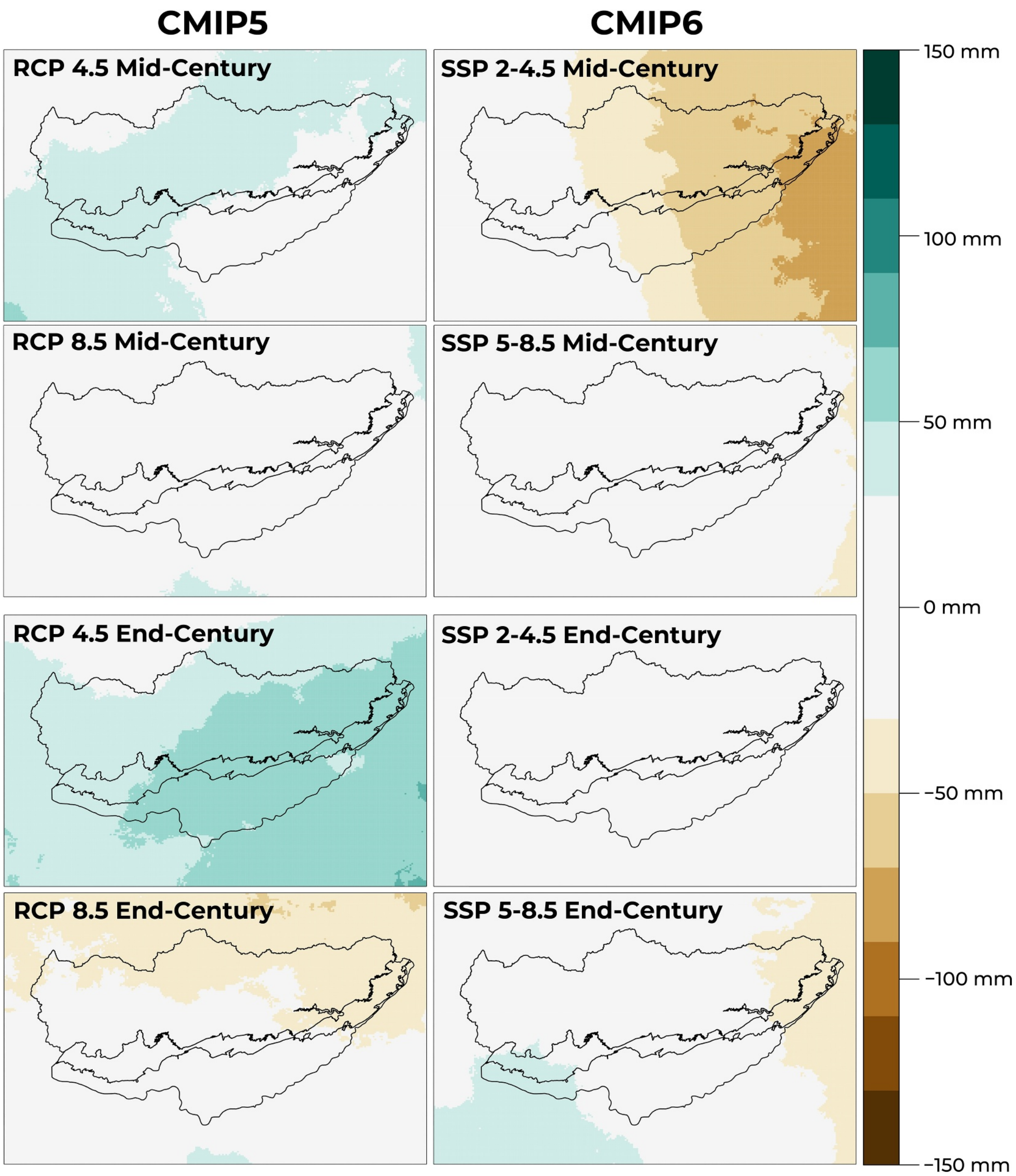

Figure 5. Mean projected changes in average annual total precipitation (P) for the mid-century (2036–2065) and end-century (2070–2099) from the downscaled CMIP5 (left) and CMIP6 (right) ensembles. CMIP5 ensemble includes the RCP 4.5 and RCP 8.5 scenarios. CMIP6 ensemble includes the SSP 2–4.5 and SSP 5–8.5 scenarios.

model" issue is warranted. Some CMIP6 models, termed "hot models," exhibit an ECS that exceeds the range deemed "very likely" (between 2°C and 5°C) by the Intergovernmental Panel on Climate Change's Sixth Assessment Report (AR6, Hausfather et al., 2022). Hausfather et al. (2022) recommend excluding models that fall outside this "very likely" ECS range, as they may overestimate the sensitivity to emissions scenario-induced forcing changes. This aspect highlights the importance of model selection and interpretation in climate studies with regards to the "practitioner's dilemma".

The ensemble subset selection approach focused on how effectively each potential subset captured the historical climatology of three variables across the Southern Great Plains (SGP) and the range of projections in the full ensemble. Except for CanESM5, selected GCMs fall within the "very likely" ECS range suggested by AR6 report (Table S2 in Supporting Information S1). ECS is a global metric that quantifies the global average temperature increase expected after the climate system stabilizes following a doubling of atmospheric carbon dioxide levels.

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Table 6
Projected Changes in Annual Precipitation (P) and 1-Day Maximum Precipitation (rx1day) (mm) for all Models Across the EAR

The ability of a GCM to accurately represent this global sensitivity metric does not necessarily correlate with ability to capture regional physical processes or impacts of large-scale climatic changes, particularly for precipitation projections. For example, the EC-Earth3 and KACE1-0-G have a similar ECS value, but the downscaled EC-Earth projects a precipitation decrease in the EAR while the downscaled KACE1-0-G projects an increase in the EAR (Table S2 in Supporting Information S1). *This finding highlights a critical aspect*: *the ECS values of the subset models may not necessarily have a strong relationship with regional precipitation projections post-downscaling*. *This underscores the importance of considering regional-specific dynamics and responses when selecting or creating decision-relevant climate projections*. Aligned with this critical observation, CanESM2 and CanESM5 were omitted from further analyses at the EAR-scale in this study, but their exclusion was not due to their ECS values, but because of their poor representation of the seasonality of historical regional precipitation within the EAR (see Figure S5 in Supporting Information S1), and this was deemed unacceptable with respect to the EAA's needs for climate projections.

Hydrological models are known for their complex and non-linear responses to temperature and precipitation changes (Chen et al., 2016; Ross & Najjar, 2019). Recent studies, including Rahimpour Asenjan et al. (2023), have explored the effects of excluding "hot models" from streamflow projections with mixed results. Omitting "hot models" sometimes reduced the uncertainty in streamflow projections, in other instances, it either had no impact or even increased the uncertainty. This variability in outcomes underscores a second point for the challenge of the "practitioner's dilemma": *GCMs outside the "very likely" ECS range may still*, *following downscaling and hydrology modeling*, *produce plausible projections of climate impacts for a specific application or decision-context*. This is likely because a GCM that is an outlier in terms of ECS may well not be an outlier for regional scale changes as is shown in our results (Table S2 in Supporting Information S1). Future research should delve into understanding the potential impacts of "hot models" on various climate-related aspects, such as aquifer recharge, particularly as the sample size in this study was small compared to other studies such as Rahimpour Asenjan et al. (2023). The current selection of projections discussed in this study represents a diverse range of projections that will be integral to our ongoing efforts in groundwater and spring flow modeling within the Edwards Aquifer. This approach ensures a comprehensive and nuanced understanding of climate impacts on the EAR, considering a wide range of model sensitivities and scenarios.

Downscaled climate projections are subject to various sources of uncertainty, including uncertainties related to the GCMs, emissions scenarios, and the

Table 7
Regional Average of Projected Changes in Climate Variables From CMIP5 and CMIP6 Subset Ensembles During Mid-Century and End-Century Under Intermediate Emission (RCP 4.5 and SSP 2–4.5) and High Emission (RCP 8.5 and SSP 5–8.5 Scenarios)

		CMIP5	CMIP6
Time period			
Mid-Century	Tmax		
End-Century	Tmax		

downscaling process itself (Hawkins & Sutton, 2009, 2011; Wootten et al., 2017). Additionally, the training data used in statistical downscaling introduces another layer of uncertainty (Pourmokhtarian & Driscoll, 2016; Wootten et al., 2020). It is generally observed that the uncertainty in downscaling is less significant than that in GCMs and scenarios, particularly concerning temperature projections. In addition, other studies have noted that the uncertainties of the hydrology models or other impacts models are themselves significant sources of uncertainty in climate impacts assessments (e.g., Chen et al., 2011; Giuntoli et al., 2018; Krysanova et al., 2018; Piotrowski et al., 2021; Trudel et al., 2017). While our downscaled projections do not incorporate a variety of downscaling techniques or multiple sets of gridded observations for training, the ensemble subset selection approach we employed effectively captures the GCM uncertainty within our CMIP5 and CMIP6 subset ensemble. Moreover, by utilizing multiple emissions scenarios, our projections also address scenario uncertainty. Thus, the projections generated in this study adequately encompass the key sources of uncertainty pertinent to future analyses. However, future research could benefit from considering multiple downscaling techniques or incorporating additional training data, particularly for the EAR or additional comparisons to pre-existing downscaled projections. This consideration is especially relevant for precipitation projections, where the uncertainty associated with the downscaling technique and training data tends to be more pronounced (e.g., Wootten et al., 2020). Such an expansion in methodologies and data sources would enhance the robustness and reliability of future climate impact assessments.

Overall, this study presents a complete approach to selecting and/or creating new projections in the decision-relevant context of the EAA. This approach allows for selecting a subset of GCMs to either downscale or work with from a pre-downscaled data set. In addition, this approach is flexible enough to allow for analytic selection and evaluation and for incorporating other insights or needs identified by an end-user for a given application. The approach described in this study is offered as an approach to addressing the “practitioner's dilemma” that could be easily applied to other contexts and regions and offers the opportunity to address when new projections are needed alongside of selections from pre-existing projections. However, this approach is one of many, and it is beyond the scope of this project to compare approaches to determine best practices and standardized evaluation and selection protocols to address the larger challenge of the “practitioner's dilemma.” This comparison remains a gap in the literature that is a critical need for the future use and development of decision-relevant climate projections. In addition, this method and other subset selection methods may also be sensitive to the resolution of the data used. This aspect in particular is the subject of future research by the authors.

Management of the Edwards Aquifer relies on several mitigation and conservation strategies designed to maintain adequate spring flow to ensure the viability of threatened and endangered species at two major spring systems. Specific spring flow rates (e.g., long-term average flows and minimum short-term flows) were established as part of the Edwards Aquifer Habitat Conservation Plan (RECON Environmental Inc. et al., 2012) and its associated Incidental Take Permit (ITP) (U.S. Fish and Wildlife Service, 2015). For example, the target 10-day average minimum spring flows at Comal and San Marcos springs are 0.85 m^3/s (30 ft^3/s) and 1.27 m^3/s (45 ft^3/s), respectively. The magnitude and sequence for implementing spring flow protection measures are based on sustaining minimum spring flows through conditions equivalent to the regional drought of record, which occurred in the 1950s. The current ITP expires in 2028, and its renewal will require explicit consideration of the potential effects of future climate on the groundwater system and spring flows. Thus, a particular concern is whether current mitigation measures will be adequate to ensure adequate spring flows under future droughts.

While the climate projections described here provide insight into future changes in the magnitude and frequency of stressors on the aquifer (e.g., increased temperatures and fewer days with precipitation), the projections must be used to produce estimates of aquifer recharge, which are then input to a groundwater flow model that incorporates pumping demand and implementation of mitigation strategies. Accurate estimation of recharge, particularly in the spatially complex karstic aquifer system, is enhanced through our downscaling process with finer discretization. The groundwater flow model will simulate water levels and spring flows over the proposed ITP renewal period for all 19 sets of projections. These results will be crucial for evaluating the adequacy of the current regulatory framework or identifying needs for changes in aquifer management. Recharge and groundwater flow modeling is currently in progress and results will be reported upon completion of these studies.

5. Conclusions

This study details an approach to addressing the "practitioner's dilemma" in the decision-context of the Edwards Aquifer Authority, resulting in the production of downscaled climate projections of daily high temperature, daily low temperature, and daily total precipitation for the Edwards Aquifer Region. The unique needs of the Edwards Aquifer Region required producing new downscaled projections rather than relying on pre-exisiting data sets. This is different from traditional studies in regards to the "practitioner's dilemma." The process encompasses the selection of appropriate GCMs for downscaling and the downscaling process itself that can be flexibly applied to other regions and account for other insights. We utilized subset ensembles from the CMIP5 and CMIP6 GCMs with statistical downscaling correcting the errors in the chosen GCMs. Our newly developed data set projects significant climatic changes for the Edwards Aquifer Region. By the end of the century, the ensemble means of regional average temperatures are projected to rise by 2.0°C–4.3°C while annual precipitation is projected to vary from a decrease of 10.4 mm to an increase of 25.6 mm. A decrease in rainy days by up to 6 and an increase in the number of days with temperatures exceeding 37.8°C (100°F) of 35–70 days annually on average are also projected. Projected climatic stress in the region could have been worse if the downscaled climatic data from "hot models" were included in the regional climate analyses. They were omitted as they did not accurately represent the magnitude and seasonality of historical precipitation in the region. The projected climatic shifts are likely to increase heatwaves, dry spells, and evapotranspiration rates, thereby exacerbating the potential for development of drought conditions. This could lead to a reduction in the availability of groundwater within the Edwards Aquifer. The set of downscaled projections generated in this study will be pivotal in future groundwater and spring flow modeling. They will provide a robust and comprehensive understanding of the potential impacts of climate change on the Edwards Aquifer, aiding in the development of effective strategies to manage and mitigate these impacts. Moreover, this study presents an approach to addressing the "practitioner's dilemma," advancing the discussion on the production of decision-relevant climate projections.

Data Availability Statement

GCM data from CMIP5 and CMIP6 were accessed from the Earth System Grid Federation (ESGF) repositories, which are publicly accessible with registration (ESGF User Support Working Team, 2019). The Daymet version 4 data is publicly available from NASA EarthData and Oak Ridge National Laboratory (Thornton et al., 2022). R code for subsequent analyses is available via Zenodo (Wootten, 2024a). R Code for Ensemble Subset Selection Algorithm v 1.0 is also available via Zenodo (Wootten, 2024b). The downscaling makes use of the same code in the MBC R package (GitHub—cran/MBC, Cannon et al., 2015). The EAA is committed to providing the downscaled projections to interested users. However, the EAA has chosen not to provide a direct link or access to their data repository owing to security concerns. The EAA has granted permission to the South Central CASC to provide the EAR downscaled climate projections via the USGS ScienceBase (Wootten et al., 2024).

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Appendix F9 | **Climate Report 2: Temperature and Precipitation Projections in the Edwards Aquifer Region**

Temperature and Precipitation Projections in the Edwards Aquifer Region

Prepared for:

Edwards Aquifer Authority
900 E. Quincy
San Antonio, TX 78215
Contact: Chad Furl
210-222-2204 ext 149

Prepared by:

ICF
15102 Jones Maltsberger Road
Suite 101B
San Antonio, TX 78247
Contact: Lucas Bare
505-310-3427

July 2024

EAHCP PERMIT RENEWAL

ICF

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Contents

Tables and Figures

Acronyms and Abbreviations

Abbreviation	Definition
CMIP	Coupled Model Intercomparison Project
EAA	Edwards Aquifer Authority
EAHCP	Edwards Aquifer Habitat Conservation Plan
GCMs	Global Climate Models
IPCC	Intergovernmental Panel on Climate Change
ITP	Incidental Take Permit
RCPs	Representative Concentration Pathways
South Central-CASC	South-Central Climate Adaptation Center
SSPs	Shared Socioeconomic Pathways
WCRP	World Climate Research Programme

Chapter 1
Introduction

To inform the planning process for the Edwards Aquifer Habitat Conservation Plan (EAHCP) Incidental Take Permit (ITP) Renewal, the Edwards Aquifer Authority (EAA) contracted with ICF to analyze historical and projected temperature and precipitation values across the Edwards Aquifer region. The report objectives are as follows:

1. Describe mean temperature and precipitation projections across the Edwards Aquifer region during the 2030–2059 time period.
2. Compare mean spatial and temporal characteristics of the 2030–2059 temperature and precipitation projections with historical values occurring from 1991–2020.
3. Compare minimum precipitation projections during 2021–2060 to measured minimum precipitation values during prolonged periods of historic precipitation drought across the Edwards Aquifer region (1981–2020) and at the San Antonio International Airport weather station (1947–present), which includes the drought of record[i].

Analyzing historical and projected temperature and precipitation values will help EAA understand future surface water and groundwater conditions and assess how spring flow may change under a range of potential climate futures based on multiple climate models (i.e., using a climate ensemble) and greenhouse gas trajectories (i.e., emissions scenarios). Understanding how spring flow may change is necessary for considering how future climate conditions may affect the Covered Species habitat throughout the proposed 30-year permit term.

EAA provided future model and emissions scenario projections of temperature and precipitation for the Edwards Aquifer region. ICF used the climate projections to identify and evaluate the seasonality, timing, and geography of future changes in climate, including projected precipitation changes during noteworthy historical drought lengths. This is an important early step in the modeling workflow of the project. The temperature and precipitation projections will ultimately inform modeled future recharge for the Edwards Aquifer, which will then be used to model projected spring flow. Projected spring flow will eventually be used to evaluate potential impacts on Covered Species as part of the ITP Renewal process.

This report is organized as follows:

- Chapter 2, *Data and Methods*, identifies the Edwards Aquifer region, historical weather data, and future model projections used in the analysis.
- Chapter 3, *Temperature and Precipitation*, discusses historical and projected temperature and precipitation levels.
- Chapter 4, *Drought*, includes discussion of future drought projections.
- Chapter 5, *Discussion*, summarizes findings from the analysis.

2.1 Edwards Aquifer Region

The Edwards Aquifer region consists of nine surface water basins that drain portions of the Texas Hill Country and provide recharge to the aquifer (Figure 1). The basins include portions of the EAA-delineated Recharge Zone, Contributing Zone, and/or Artesian Zone.

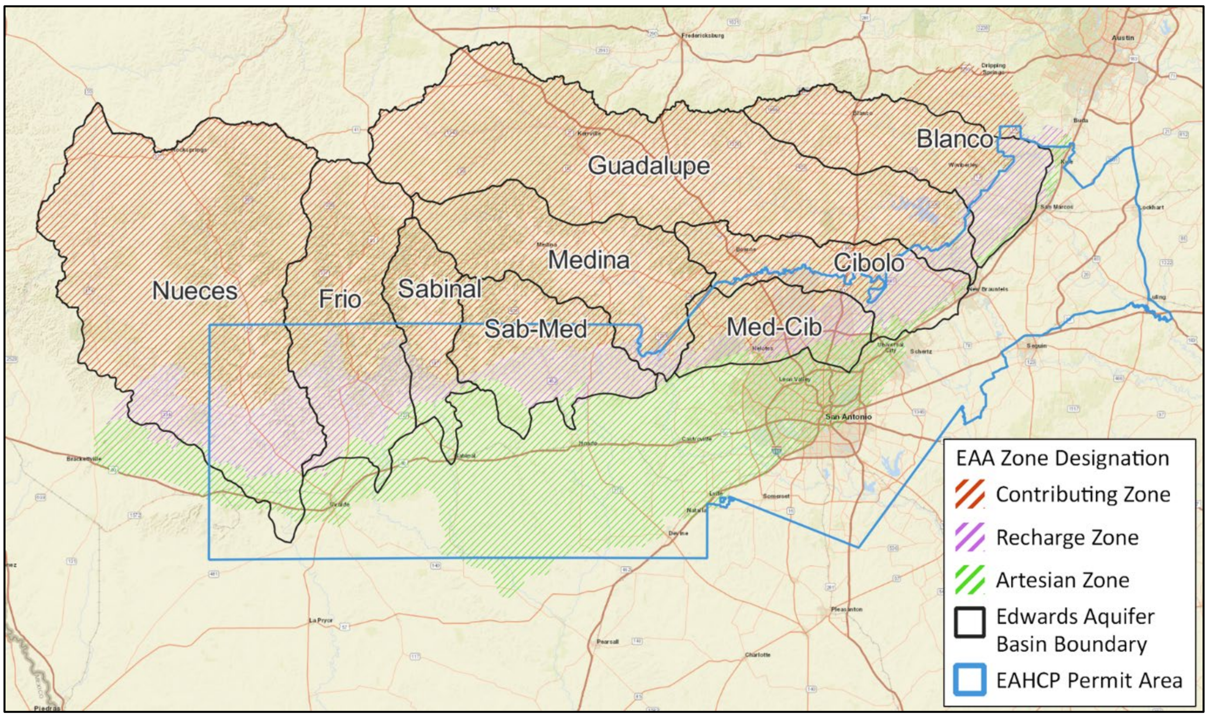

Figure 1. The Edwards Aquifer Region

2.2 Methods

The purpose of this report is to describe near-term projections of future temperature and precipitation and compare with historical climate data to better understand future climate conditions in the Edwards Aquifer region. The analysis considers both average future conditions along with drought conditions.

2.2.1 Description and Comparison of Mean Future Climate

Mean future climate projections from 2030 to 2059 were described and compared to historical weather averages from 1991 to 2020 to evaluate changes in temperature and precipitation that may occur during the proposed permit term (2028–2058). The analysis identifies and evaluates the seasonality, timing, and geography of mean future changes in climate by directly comparing future monthly and annual projected changes in precipitation and temperature relative to historical weather observations.

For this analysis, 30-year time horizons are used to analyze and describe the mean temperature and precipitation scenarios to minimize the influence of inter-annual climate variance (e.g., the impact of an El Niño event on temperature anomalies) and capture near-future climate change during the proposed permit term. When evaluating climate projections, a common approach is to compare historical and future periods of similar lengths. To that end, the historical time horizon uses the 30 years in the near past (1991–2020) and the future time horizon is evaluated over 30 years in the near future overlapping with the proposed permit term (2030–2059). These time horizons are used to compare composite precipitation and temperature averages during the future and historical time horizons.

Table 1 presents the time horizons used for historical and future mean temperature and precipitation.

2.2.2 Comparison of Historical Droughts to Future Predicted Drought

Drought projections represent worst-case precipitation drought conditions across the Edwards Aquifer region. In contrast to the mean future temperature and precipitation analysis in Section 2.2.1, the purpose of this analysis is to demonstrate how the lowest (or minimum) precipitation values compare during noteworthy drought lengths for the proposed permit term relative to the historical period. Drought projections use the same future Coupled Model Intercomparison Project (CMIP) Global Climate Model (GCM) data but focus over a longer timeframe (2021–2060) to capture more tail-end extremes from a longer sampling of years.

Two analyses of precipitation drought projections are completed using historical gridded Daymet data and historical point-based weather station data at the San Antonio International Airport. Historical Daymet weather data are evaluated over 1981–2020, and historical San Antonio International Airport weather station data are evaluated over 1947–present. Historical San Antonio International Airport weather station data are evaluated for a longer time period relative to the gridded Daymet data to include the drought of record in the 1950s.

For each precipitation drought analysis, the minimum precipitation totals are calculated for consecutive timeframes of 1, 2, 3, 4, and 7.5 years. The precipitation drought lengths correspond approximately with the length of noteworthy historic precipitation droughts in the region, including the drought of record, and were selected based on the methods described in Başağaoğlu et al. (2023). For the gridded Daymet analysis, the minimum precipitation totals are averaged across the Edwards Aquifer region for each historical and future period. For the point-based San Antonio International Airport analysis, the minimum precipitation totals are calculated at the 1 km x 1 km grid cell location overlapping with the airport weather station location. The ensemble mean and full range of model projections for the future timeframe are compared to historical data for each drought length bin.

Table 1 presents the time horizons used for historical and future minimum precipitation during droughts.

Table 1. Scenario Analysis Time Horizons

Analysis	Label	Interval
Mean Future Temperature and Precipitation	Historical	1991–2020
	Future	2030–2059
Gridded Future Minimum Precipitation Droughts	Historical	1981-2020
	Future	2021–2060
Point-Based Future Minimum Precipitation Droughts	Historical	1947–present
	Future	2021–2060

2.2.3 Historical Weather Data

The historical weather data used in this report were primarily drawn from the publicly available, gridded Daymet dataset (ORNL DAAC 2020; Thornton et al. 2020), which provides long-term, continuous, gridded estimates of daily weather and climatology variables by interpolating and extrapolating ground-based weather station observations through statistical modeling techniques (ORNL DAAC 2020). These datasets are provided on 1 km x 1 km spatial grid and are available from 1980 to present day (Thornton et al. 2020). The relevant weather variables drawn from the Daymet version 4 repository include daily precipitation depth, daily maximum temperature, and daily minimum temperature.

The point-based precipitation drought analysis uses ground-based Daily Global Historical Climatology Network (Menne et al. 2012) precipitation depth from the San Antonio International Airport weather station (Station USW00012921). This point-based precipitation dataset is available from 1947 to present day and accessed through the United States National Climatic Data Center Climate Data Online portal.

2.2.4 Future Climate Projections

The World Climate Research Programme (WCRP) coordinates and facilitates climate research across the world. WCRP's CMIP seeks a better understanding of past, present, and future climate changes arising from natural variability and from changes in radiative forcing. One of the main CMIP goals is to make multi-model output (i.e., ensemble simulation results) available in a standardized format (World Climate Research Programme 2020). CMIP future climate projections are released in phases. The Fifth Phase of the CMIP (CMIP5) was released during 2012–2013. The Sixth Phase of the CMIP (CMIP6) was released during 2019–2022.

The EAA, in collaboration with the South-Central Climate Adaptation Center (South Central-CASC), developed and implemented a customized downscaling model to produce statistically downscaled, projected future daily minimum air temperature, daily maximum air temperature, and daily precipitation depth from CMIP5 and CMIP6 GCMs (Wootten et al. 2023). These projections are downscaled to the 1 km x 1 km spatial resolution of the Daymet dataset.

Given that climate change is a result of changes in global greenhouse gas emissions, different climate projections can be formulated using different greenhouse gas emissions scenarios. To understand potential future climate projections, scientists have developed different emissions scenarios derived from global socioeconomic and greenhouse gas emissions pathways. Representative Concentration Pathways (RCPs) were originally developed for use by the Intergovernmental Panel on Climate Change (IPCC) for use in CMIP5. Different RCP scenarios depict alternative options for how global greenhouse gas emissions could evolve over the course of this century. The RCP scenarios make assumptions about fossil fuel use, technological evolution, population growth, and other driving factors. Shared Socioeconomic Pathways (SSPs) were developed specifically for use in CMIP6. Like RCPs, SSPs represent a range of future climate change scenarios and development pathways that encompass various trajectories of global greenhouse gas emissions. Unlike RCPs, SSPs were also coupled with assumptions about the level of ambition for mitigating climate change. RCP 4.5 and SSP2-4.5 represent a moderately warmer future and assume significant mitigation of greenhouse gas emissions by mid-century. RCP 8.5 and SSP5-8.5 represent a hotter future where emissions continue largely unabated through the end of the century.

Future climate projections used in the CMIP multi-model outputs utilize RCPs and SSPs as potential future climate trajectories. These efforts also support the IPCC assessment reports that offer comprehensive information on the scientific, technical, and socio-economic knowledge on climate change, future impacts and risks, and different mitigation and adaptation options. The fifth assessment report (AR5) was published in 2014 and the sixth assessment report (AR6) was published in 2021.

As part of this analysis, six CMIP6 GCMs and two emissions scenarios (SSP2-4.5 and SSP5-8.5) were selected as the primary basis for the temperature and precipitation scenarios. Four CMIP5 GCMs and two emissions scenarios (RCP 4.5 and RCP 8.5) were also selected as a secondary, or supplementary, basis for temperature and precipitation projections. The EAA provided the future model and emissions scenario outputs on the Daymet 1 km x 1 km spatial grid for the Edwards Aquifer region. Model-based probabilistic projections are evaluated using the model ensemble averages and individual models, including model percentiles, to characterize a full range of potential climate change outcomes. Table 2 lists the CMIP6 models and emissions scenarios, and Table 3 lists the CMIP5 models and emissions trajectories. Annual time series for the full time period (1991–2059) are provided in Section 3.2.2 to illustrate interannual variability in temperature and precipitation across the Edwards Aquifer region.

Table 2. Future CMIP6 Models and Emissions Trajectories

Model Name	Emissions Trajectories
EC-Earth3	SSP2-4.5, SSP5-8.5
INM-CM4-8	SSP2-4.5, SSP5-8.5
INM-CM5-0	SSP2-4.5, SSP5-8.5
KACE-1-0-G	SSP2-4.5, SSP5-8.5
KIOST-ESM	SSP2-4.5, SSP5-8.5
MPI-ESM1-2-HR	SSP2-4.5, SSP5-8.5

Table 3. Future CMIP5 Models and Emissions Trajectories

Model Name	Emissions Trajectories
CMCC-CM	RCP 4.5, RCP 8.5
HadGEM2-CC	RCP 4.5, RCP 8.5
inmcm4	RCP 4.5, RCP 8.5
MRI-ESM1	RCP 8.5

Chapter 3
Temperature and Precipitation

Future mean temperature and rainfall projections, introduced in Section 2.2.4, are described and analyzed in this section relative to historical conditions. Historical climate data are described in Section 3.1, and Section 3.2 describes and analyzes future temperature and rainfall projections relative to the historical data.

The time series are divided into the time horizons shown in

Table 1. Historical weather data are used for 1991–2020. Future CMIP GCM simulations provided by EAA are used for 2030–2059.

3.1 Historical Climate

3.1.1 Key Takeaways

- Precipitation varies across the Edwards Aquifer region by both geography and season. Historically, the eastern portion of the region has experienced more precipitation than the western portion of the region. There are strong seasonal trends in precipitation as well, with relative peaks in late spring (May) and early fall (September) on average.
- Temperature tends to be greatest in the southern portion of the Edwards Aquifer region and lowest in the northwestern portion. Seasonally, temperatures peak in August.
- Maps of historical precipitation and temperature in the region capture local topography, with higher elevations of the Texas Hill Country experiencing higher precipitation totals and cooler temperatures relative to surrounding valleys.

3.1.2 Results

The 1991–2020 time horizon was used to aggregate daily weather parameters to a historical climate description for the Edwards Aquifer region.

Figure 2 shows mean historical annual precipitation values between 1991 and 2020. As the figure illustrates, the eastern portion of the Edwards Aquifer region experiences more precipitation than the western portion. This leads to a west-to-east, dry-to-wet gradient across the region. This precipitation is most concentrated in the Blanco, Cibolo, Med-Cib, and eastern Guadalupe basins. Nueces, the farthest west basin, is historically dry relative to the other basins in the Edwards Aquifer region. Given the high spatial resolution of the historical values, this map also captures topography across the region, illustrating that higher elevations experience higher precipitation totals that runoff into the lower-elevation rivers and streams in each basin. Lower precipitation totals highlight the locations of valleys surrounded by hills and mountains within each basin.

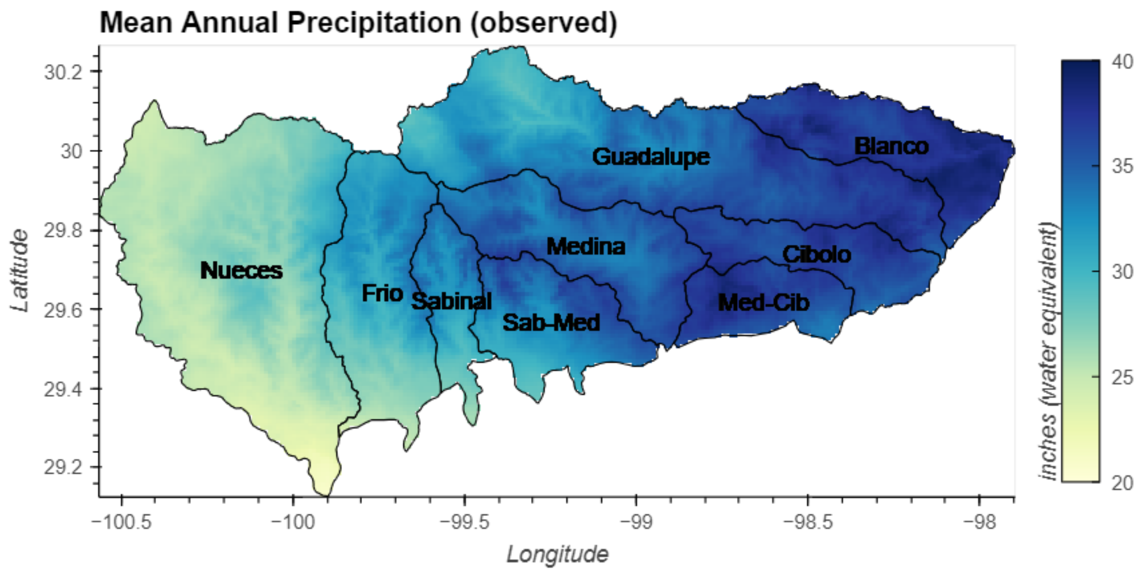

Figure 2. Mean Annual Total Precipitation over the Edwards Aquifer Region (1991–2020) based on Daymet Version 4 Reanalysis

Figure 3 shows mean annual temperature values across the basin between 1991 and 2020. As the figure illustrates, average annual temperatures are generally higher in the southern portion of the Edwards Aquifer region, peaking at 74–75 ˚F in the southern tip of the Nueces basin. The northwestern part of the Guadalupe basin has the lowest average annual temperatures (63–64 ˚F). The historical average annual temperature map also captures topography across the region, with higher elevations experiencing cooler temperatures relative to the lower-elevation valleys in each basin.

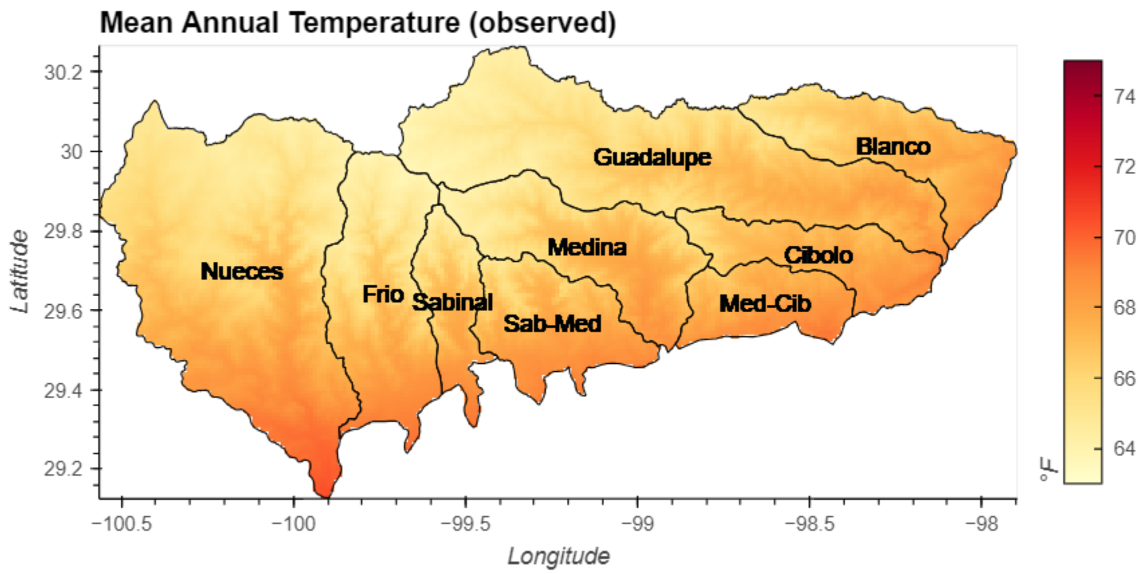

Figure 3. Mean Annual Temperature over the Edwards Aquifer Region (1991–2020) based on Daymet Version 4 Reanalysis

Figure 4 shows monthly mean daily minimum and maximum temperatures averaged across the Edwards Aquifer region between 1991 and 2020. The figure illustrates seasonal variation in temperatures, with temperatures reaching their peak for the year in August and their low for the year in December and January. Daily minimum and maximum temperatures follow similar seasonal trajectories in magnitude throughout the year.

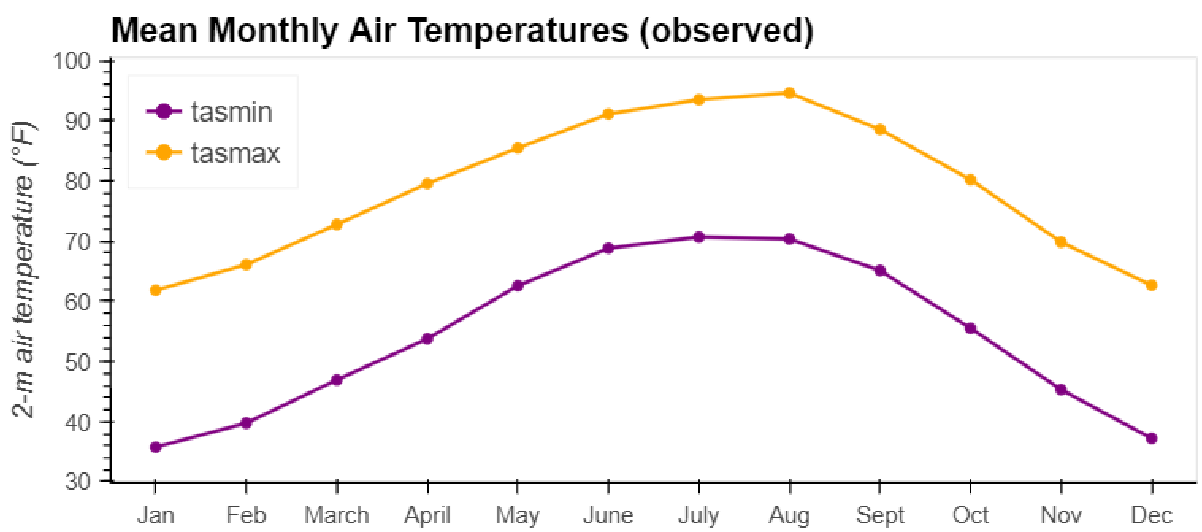

Figure 4. Historical Monthly Mean Daily Minimum/Maximum Temperature (1991–2020) averaged over the Edwards Aquifer Region based on Daymet Version 4 Reanalysis

Figure 5 shows historical monthly precipitation over the Edwards Aquifer region averaged across 1991–2020. May has the highest total precipitation (4.4 inches) while February has the lowest total precipitation (1.6 inches). There is strong seasonal variation in precipitation patterns, with peaks in precipitation in both the spring (May) and the fall (September). This bimodal precipitation distribution is ubiquitous in central Texas, peaking in May and October separated by a trough with low points in July and August. The historical lower precipitation totals in July and August are important because July and August are also the warmest months with the largest average temperature.

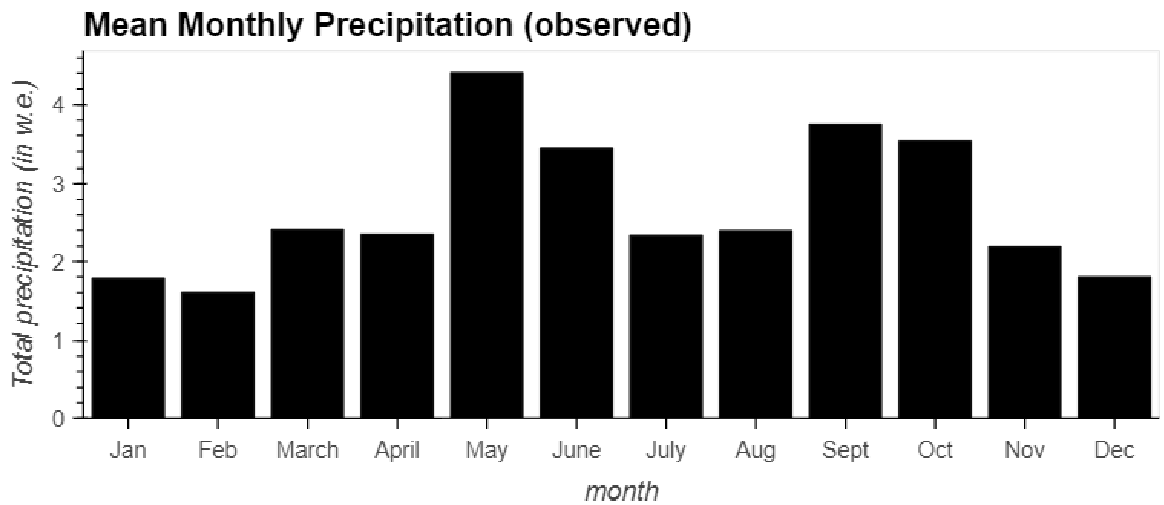

Figure 5. Historical Monthly Precipitation (1991–2020) averaged over the Edwards Aquifer Region based on Daymet Version 4 Reanalysis

3.2 Future Projections

3.2.1 Key Takeaways

- Ensemble mean climate projections indicate minimal change in annual total precipitation depth relative to historical values and changes in seasonal precipitation such that summers are projected to be wetter while there is an attenuation of the springtime peak in precipitation. The greatest rates of precipitation decrease are projected in the western portion of the Edwards Aquifer region.
- There is high model variability in future precipitation projections which indicates a high degree of uncertainty in future precipitation trends across the region.
- Temperatures are projected to increase across the Edwards Aquifer region through 2059. The magnitude and extent of projected change is greater under the higher emissions scenarios, with the greatest rates of warming projected in the western portion of the region.

3.2.2 Results

One future time horizon, 2030–2059, was used to aggregate daily weather parameters to a projected future climate description for the Edwards Aquifer region.

Figure 6 presents projected model-averaged total annual precipitation over the Edwards Aquifer region from 2030 to 2059 under both CMIP5 and CMIP6 model ensembles as well as for two different climate emissions pathways for each ensemble. Under both model ensembles, precipitation is projected to continue to be greater in the eastern half of the Edwards Aquifer region with the Blanco, western Guadalupe, Cibolo, and Med-Cib basins receiving the most precipitation. Compared to the rest of the basins, the western-most basin, Nueces, will experience lower precipitation totals. In CMIP5 model ensembles, the higher emissions scenario (RCP 8.5) is projected to bring slightly more precipitation as illustrated most clearly in the western-most basin projection. In CMIP6 model ensembles, the higher emissions scenario appears to result in a slightly drier western-most basin.

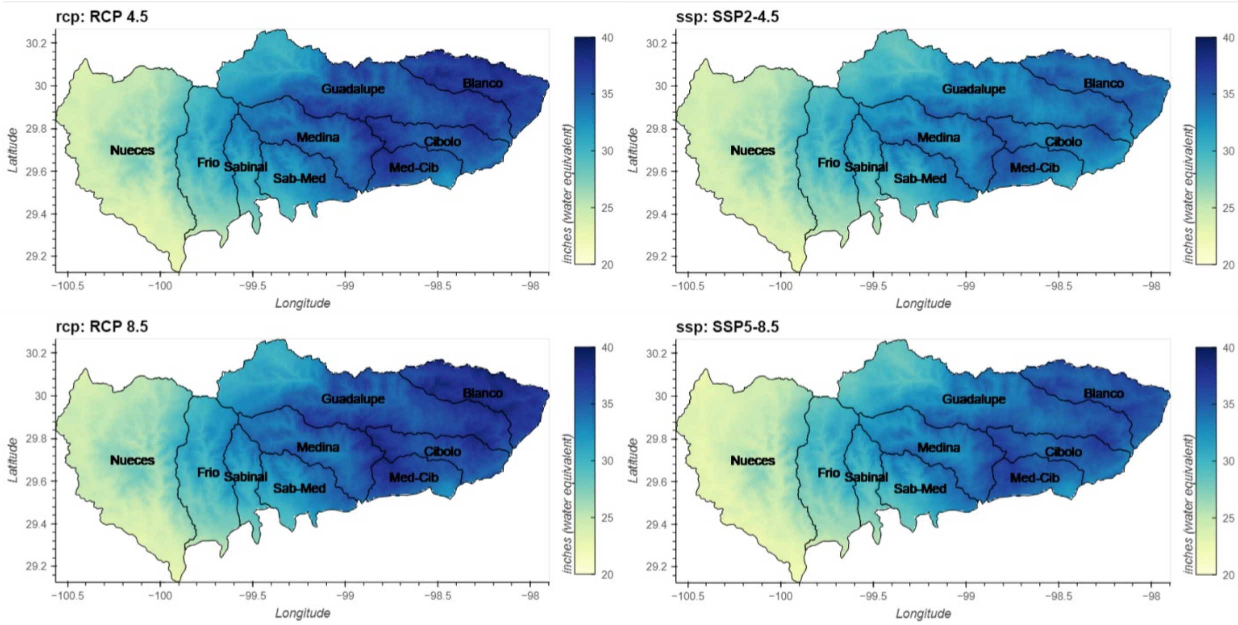

Figure 6. Projected Model-Averaged Total Annual Precipitation over the Edwards Aquifer Region (2030–2059)

The CMIP5 model ensemble is shown on the left and the CMIP6 model ensemble is shown on the right. Two corresponding emissions pathways are presented for each ensemble (top/bottom). Figure represents the ensemble mean for each emissions scenario (RCP/ SSP).

Figure 7 presents the percent change in projected model-averaged total annual precipitation over the Edwards Aquifer region for the period 2030–2059 relative to 1991–2020. Under CMIP5 RCP 4.5 projections, most of the Edwards Aquifer region will experience a decrease in precipitation (i.e., a drying trend), with the greatest drying occurring in the Nueces basin in the western side of the region. However, the southern-most tip of the Nueces basin and the central portion of the Guadalupe basin are projected to experience a slight increase in precipitation. Under CMIP5 RCP 8.5 projections, a less intense drying trend is expected relative to CMIP5 RCP 4.5 projections and more of the region is expected to experience a slight increase in precipitation. Under CMIP6 SSP2-4.5 projections, most of the basin is projected to experience a drying trend except for the southernmost tip of the Nueces basin and the southern border of the Frio basin, both of which may experience slight increases in precipitation. Drying is projected to be most pronounced in the eastern portion of the Edwards Aquifer region. Under CMIP6 SSP5-8.5 projections, the drying trend is projected to be more pronounced in the western portion of the region than under the lower emissions pathway, while projected drying in the eastern portion of the Edwards Aquifer region is less pronounced relative to the SSP2-4.5 emissions scenario.

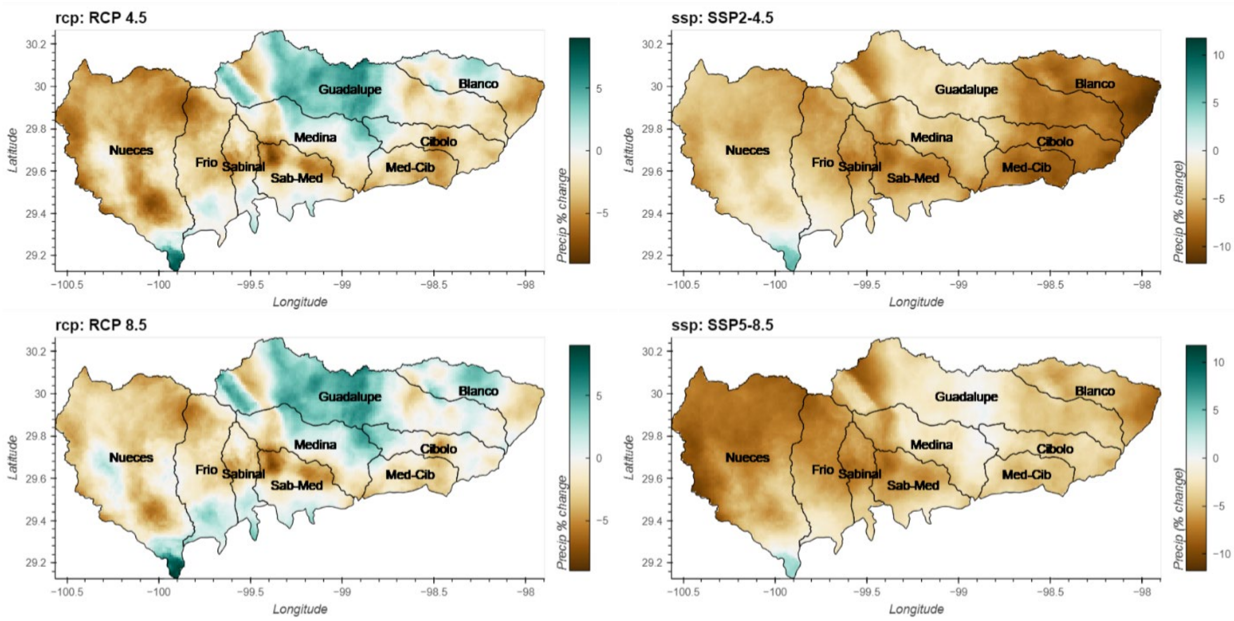

Figure 7. Percent Change in Projected Model-Averaged Total Annual Precipitation (2030–2059) over the Edwards Aquifer Region Relative to the Historical Period (1991–2020)

CMIP5 model ensemble mean results are on the left and CMIP6 ensemble mean results are on the right, with corresponding emissions pathways on the top/bottom. Panels represent the ensemble means for each emissions scenario (RCP/SSP).

Figure 8 shows projected mean annual temperatures over the Edwards Aquifer region between 2030 and 2059 under both CMIP5 and CMIP6 model ensembles and for two different emissions pathways. Under all model ensembles and emissions trajectories, the southern half of the region is projected to experience warmer temperatures.

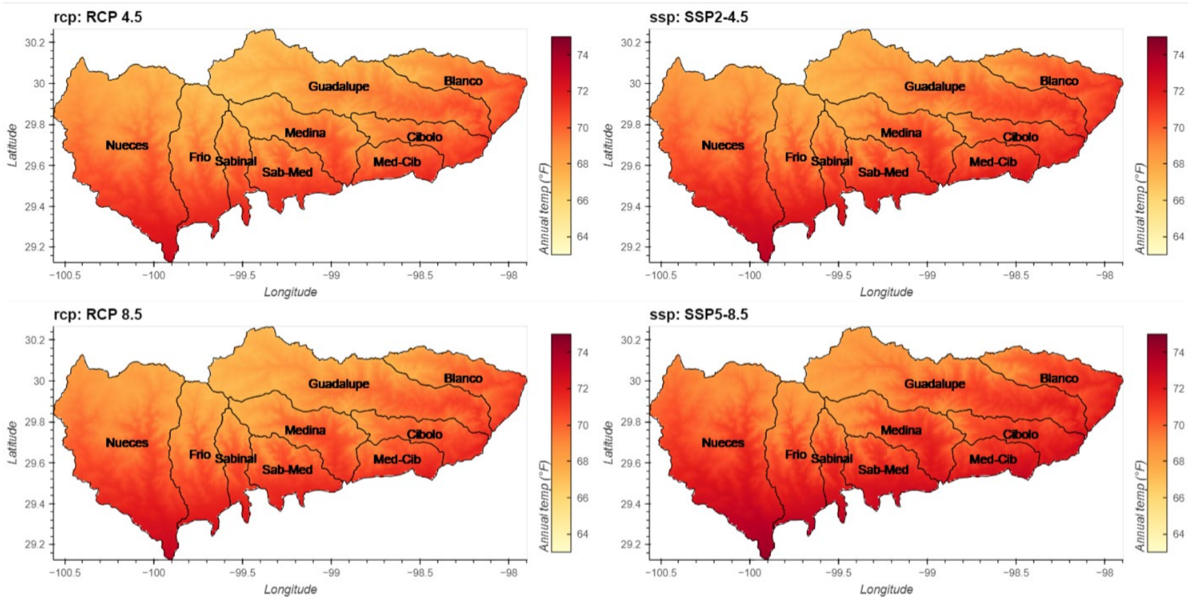

Figure 8. Projected Mean Annual Temperature over the Edwards Aquifer Region (2030–2059)

The CMIP5 model ensemble is on the left and the CMIP6 model ensemble is on the right. Two corresponding emissions pathways are presented for each ensemble (top/bottom). Panels represent the ensemble means for each emissions scenario (RCP/SSP).

Figure 9 illustrates the difference in projected mean annual temperature for the period 2030–2059 relative to 1991–2020 across the Edwards Aquifer region. In the CMIP5 model under RCP 4.5, the difference is most pronounced in the northwestern parts of the region, with the northern part of the Nueces and Frio basins and the western parts of the Medina and Guadalupe basins showing the greatest difference in mean annual temperatures relative to the historical period. Under RCP 8.5, the difference in mean annual temperature is greater across the region with the same trends as historical under RCP 4.5. The CMIP6 projections show greater differences in projected mean temperature across the region relative to the CMIP5 model ensembles. The differences are most pronounced in the northwestern basins and are greater under the high emissions scenario (SSP5-8.5) than the low emission scenario (SSP2-4.5).

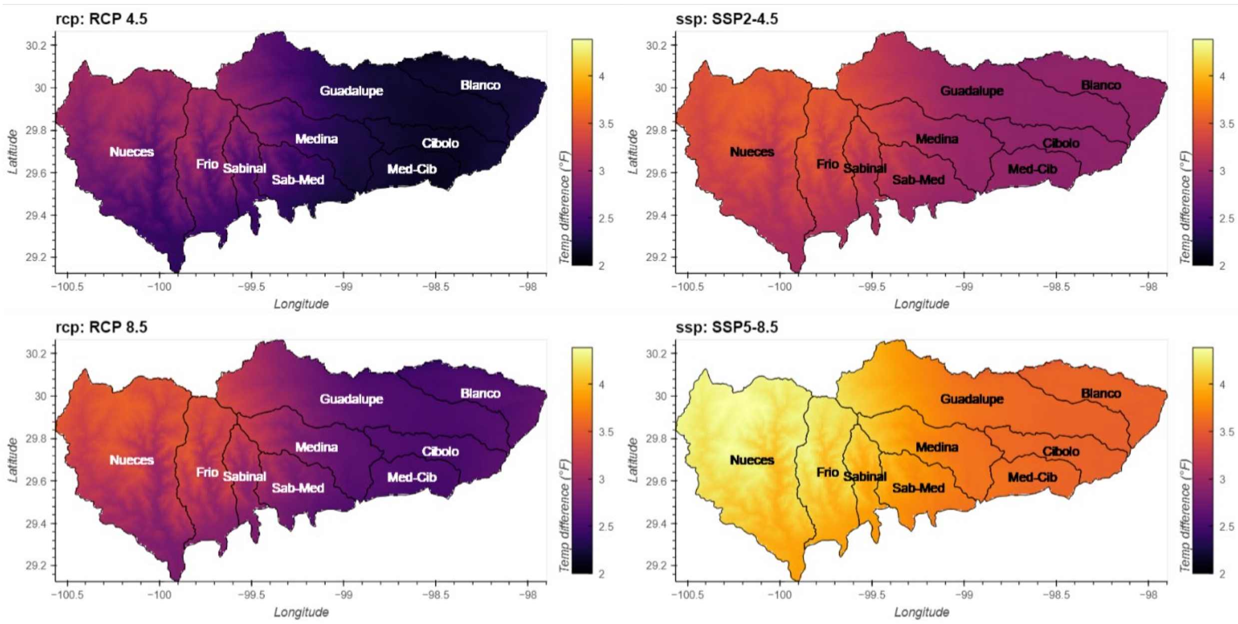

Figure 9. Difference in Projected Mean Annual Temperature (2030–2059) over the Edwards Aquifer Region Relative to the Historical Period (1991–2020)

CMIP5 model ensemble results are on the left, and CMIP6 ensemble results are on the right, with corresponding emissions pathways on the top/bottom. Panels represent the ensemble means for each emissions scenario (RCP/SSP).

As Figure 10 illustrates, temperatures are projected to increase through 2059 relative to historical temperatures. Trends vary across models, with some models projecting greater warming than others. All models, however, do suggest some degree of warming, and there is little difference between the model ensemble means for each emissions trajectory until after 2050 at which point warming is projected to be greater under a higher emissions scenario (RCP 8.5 or SSP2-4.5).

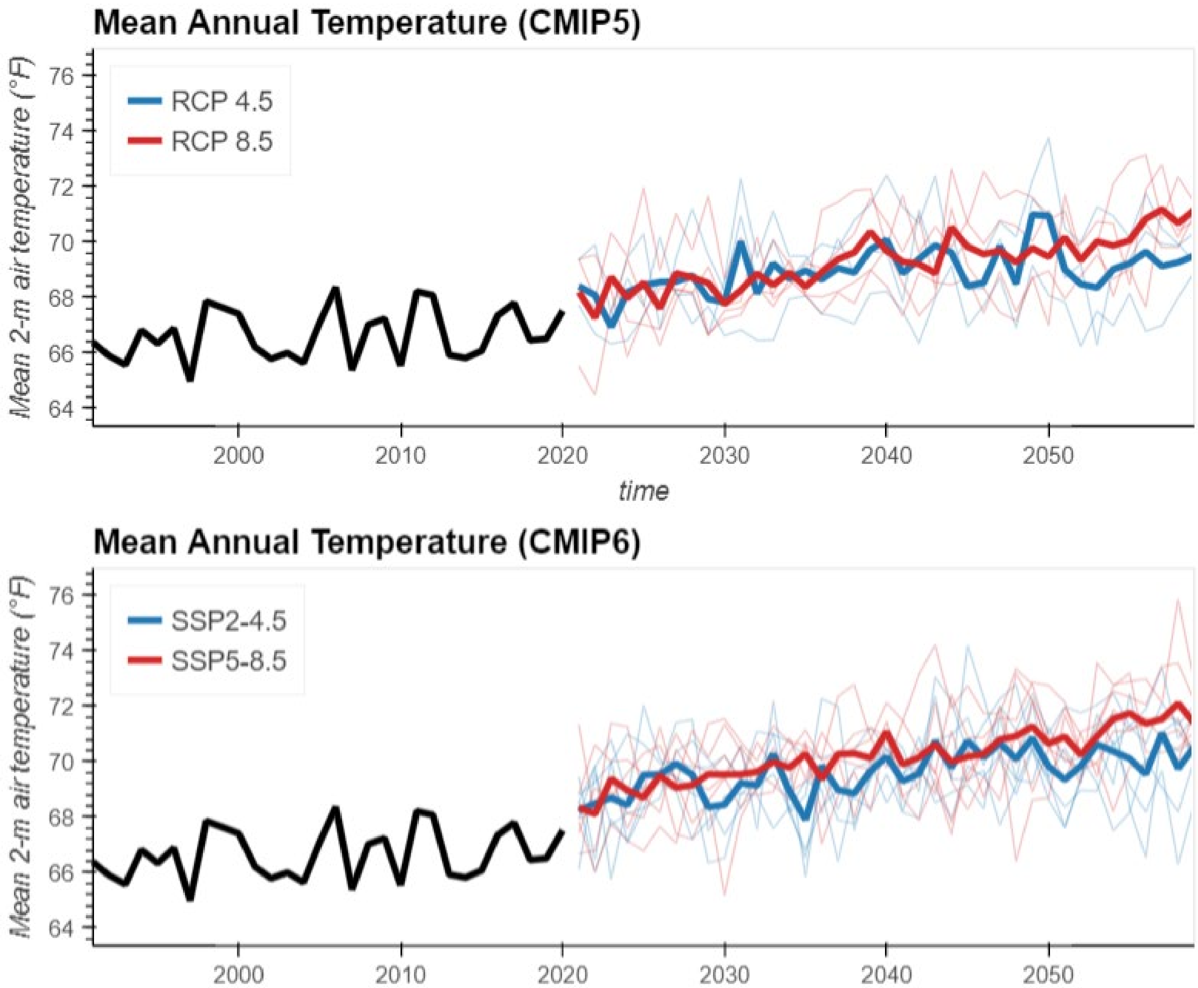

Figure 10. Historical and Projected Annual Average Temperatures

The CMIP5 model ensemble is on the top, and the CMIP6 model ensemble is on the bottom. Two corresponding emissions pathways are included for each model ensemble (blue and red lines). Bold lines denote model ensemble means, while thin lines denote individual model realizations within the ensemble.

As Figure 11 illustrates, models vary in projecting future precipitation through 2060. The high degree of variability between model projections leads to a static, or limited, ensemble mean trend in precipitation projections through 2059. In addition, there is high interannual variability in precipitation which drives anomalously high and low precipitation years in some models.

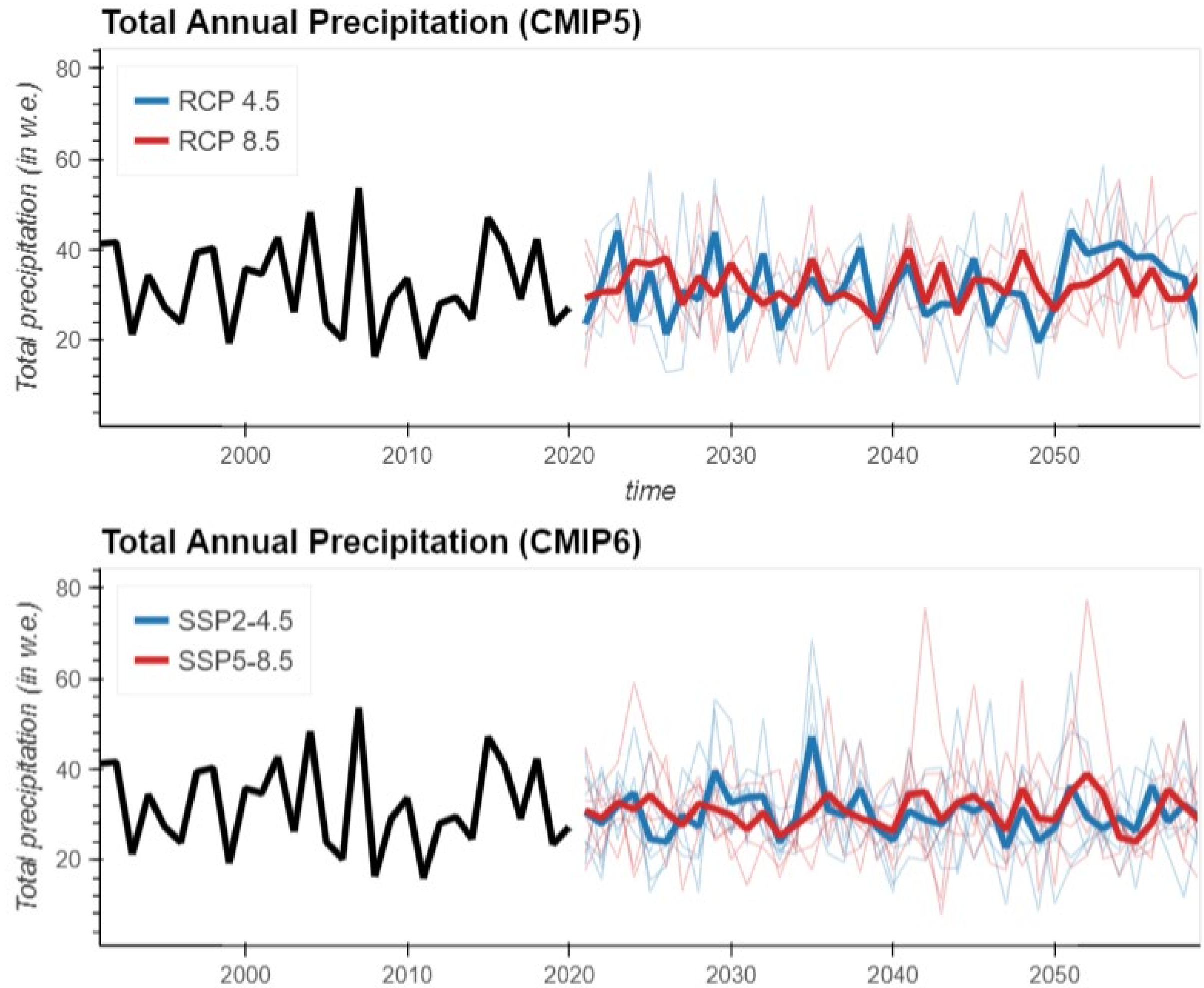

Figure 11. Historical and Projected Total Annual Precipitation

The CMIP5 model ensemble is on the top, and the CMIP6 model ensemble is on the bottom. Two corresponding emissions pathways are included for each model ensemble (blue and red lines). Bold lines denote model ensemble means, while thin lines denote individual model realizations within the ensemble.

Figure 12 illustrates seasonal and monthly variation in projections of temperatures for 2030–2059 for CMIP5 and CMIP6 model ensembles using violin plots. Across models, temperatures peak in June, July, and August and reach their yearly lows in December and January. Temperatures are projected to be higher between 2030 and 2059 relative to historical temperature for both CMIP5 and CMIP6 model ensembles and for both emissions pathways. Projections under the low emissions scenario suggest slightly smaller increases in temperature relative to the higher emissions scenario although the differences are minimal given the near-term and mid-century timeframe. Greater differences between emissions trajectories would be expected later in the century. Equivalent monthly temperature plots for the nine basins within the Edwards Aquifer region are provided in Appendix A.

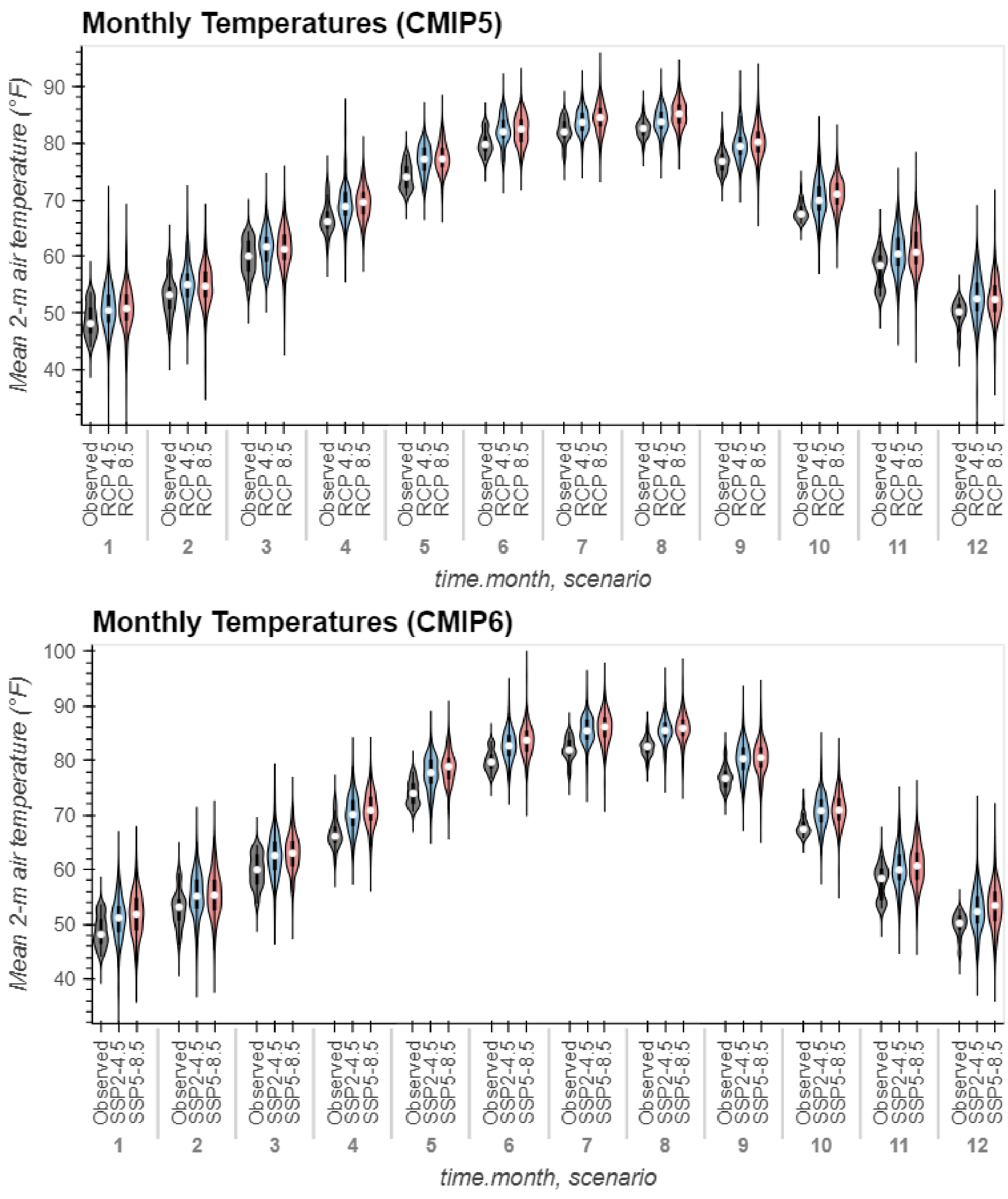

Figure 12. Violin Plot Distributions of Average Basin-Wide Monthly Temperatures (2030–2059)

CMIP5 model ensemble is on the top, and CMIP6 model ensemble is shown on the bottom, with two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).

Figure 13 illustrates projected model-averaged monthly total precipitation across the Edwards Aquifer region during 2030–2059 and 1991–2020. Historically, precipitation has been variable throughout the year, and it is projected to stay variable in the future. While there appears to be a slight trend toward drier conditions relative to historical conditions, there is high variability in future precipitation trends. Some months show increased precipitation while other months show decreased precipitation relative to historical values. Generally, there appears to be a trend toward wetter summers and an attenuation of the spring (May) peak in precipitation under future projections. Equivalent monthly precipitation plots for the nine basins within the Edwards Aquifer region are provided in Appendix A.

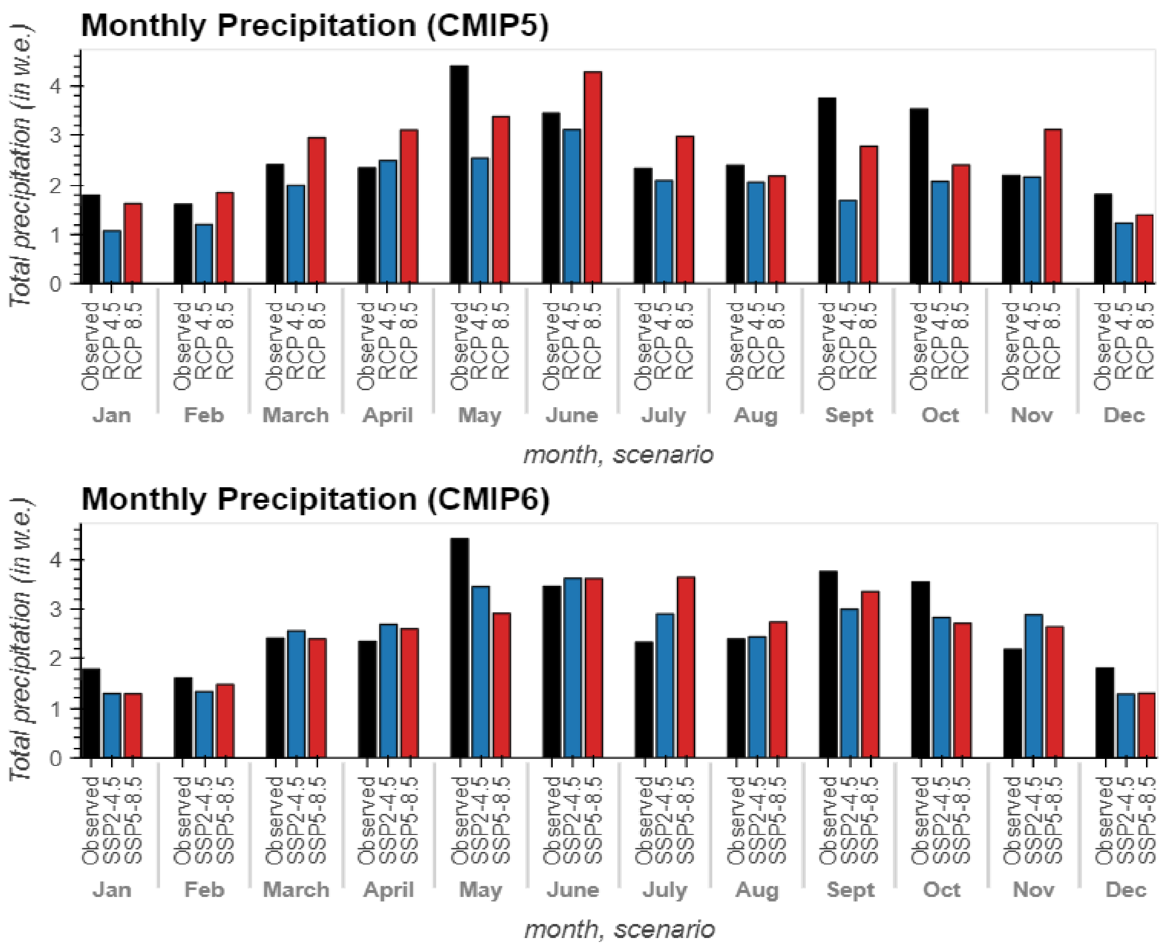

Figure 13. Model-Averaged Monthly Total Precipitation (2030–2059) averaged over the Edwards Aquifer Region

CMIP5 model ensemble means are shown on the top, and CMIP6 model ensemble means are shown on the bottom, with two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures.

Chapter 4
Drought

Future drought projections, introduced in Section **Error! Reference source not found.**, are described and analyzed in this section relative to historical conditions. Section 4.1 presents an analysis of the future temperature and precipitation projections relative to the historical data during noteworthy historic droughts. Historical weather data from the Daymet dataset are used for 1981–2020 to estimate precipitation totals across the Edwards Aquifer Region in Section 4.1.2.1. Historical weather data from the San Antonio International Airport weather station are used for 1947–present to estimate precipitation totals and average temperatures in Section 4.1.2.2. Future CMIP GCM simulations provided by EAA are used for 2021–2060 in both analyses.

4.1 Historical Drought and Drought Projections

4.1.1 Key Takeaways

- To understand how future precipitation could change during periods of drought, gridded and point-based minimum precipitation projections were also developed for drought conditions.
- For the gridded analysis across the Edwards Aquifer region, most models project similar to slightly lower minimum precipitation relative to historical minimum precipitation levels for all drought durations except for the 1- and 7.5-year droughts, which increased for most models.
- For the point-based analysis at the San Antonio International Airport weather station, which includes the 1950s drought of record, nearly all models project increased minimum precipitation relative to historical minimum precipitation levels for all precipitation drought durations.
- Precipitation drought projections tend to be higher under higher emissions scenarios (RCP 8.5, SSP5-8.5) than moderate emissions scenarios (RCP 4.5, SSP2-4.5).
- Within each model drought ensemble, there is a wide range of projected minimum precipitation totals suggesting a high degree of uncertainty in future precipitation.

4.1.2 Results

4.1.2.1 Gridded Edwards Aquifer Region Drought

Table 4 illustrates different historical and model precipitation drought projections averaged across the Edwards Aquifer region. Overall, longer-duration precipitation droughts are projected to experience slight drying through the end of the permit term relative to the past 40 years in the historical record. The ensemble mean projections generally suggest lower precipitation totals for most drought durations, except for 1- and 7.5-year duration precipitation droughts that project an increase in lowest precipitation totals under the model ensemble mean. While most models project drier precipitation totals during the most severe droughts, there is a wide range of projected precipitation totals within each model ensemble, and some models suggest increasing precipitation totals for all drought durations. This underscores that any changes in future precipitation during the most severe precipitation droughts come with a high degree of uncertainty. It is important to note that as drought duration increases, the range of modeled precipitation decreases, therefore the confidence in decreasing precipitation totals increases. This is likely an artifact of both (1) the loss of year-to-year variability as precipitation is summed over longer-duration events and (2) a reduction in the number of droughts sampled (e.g., more 1-year periods relative to 7.5-year periods during a fixed 2021–2060 future timeframe).

Table 4. Lowest Precipitation Totals under Modeled and Historical Drought Projections averaged across the Edwards Aquifer Authority Region

Drought projections are presented as the lowest precipitation totals (in inches) during consecutive 1-, 2-, 3-, 4-, and 7.5-year periods within each time horizon (1981–2020 for historical, 2021–2060 for future modeled). To demonstrate the full range of potential climate futures, the model ensemble for each emissions scenario and model (CMIP5: RCP 4.5, RCP 8.5; CMIP6: SSP2-4.5, SSP5-8.5) is presented as an ensemble minimum, mean, and maximum.

Drought Scenarios: Precipitation							
Drought Duration	Historical Precipitation (inches)	Historical Drought Dates	Version	Emissions Scenario	Model Ensemble Minimum	Model Ensemble Median	Model Ensemble Maximum
1-year	8.4	2010-09-26 to 2011-09-26	CMIP5	RCP 4.5	7.2	8.1	11.7
				RCP 8.5	7.1	11	16
			CMIP6	SSP2-4.5	6.5	9.0	14
				SSP5-5.8	5.4	9.3	12
2-year	32	2007-09-05 to 2009-09-04	CMIP5	RCP 4.5	24	27	35
				RCP 8.5	22	34	44
			CMIP6	SSP2-4.5	25	29	37
				SSP5-5.8	29	33	36
3-year	65	2010-09-08 to 2013-09-07	CMIP5	RCP 4.5	46	56	70
				RCP 8.5	37	56	72
			CMIP6	SSP2-4.5	50	56	63
				SSP5-5.8	56	58	71
4-year	87	2007-09-14 to 2011-09-14	CMIP5	RCP 4.5	67	86	88
				RCP 8.5	78	85	104
			CMIP6	SSP2-4.5	73	75	89
				SSP5-5.8	77	89	98
7.5-year	184	2007-09-05 to 2015-03-06	CMIP5	RCP 4.5	147	193	202
				RCP 8.5	186	201	222
			CMIP6	SSP2-4.5	162	181	190
				SSP5-5.8	170	189	207

Figure 14 illustrates 2021–2060 modeled precipitation drought projections relative to 1981–2020 observations graphically. Higher emission trajectories (RCP 8.5, SSP5-8.5), shown in red, tend to project higher precipitation totals than moderate emissions trajectories (RCP 4.5, SSP2-4.5), shown in blue. This is likely at least partially due to the projected intensification of the water cycle with warming temperatures.

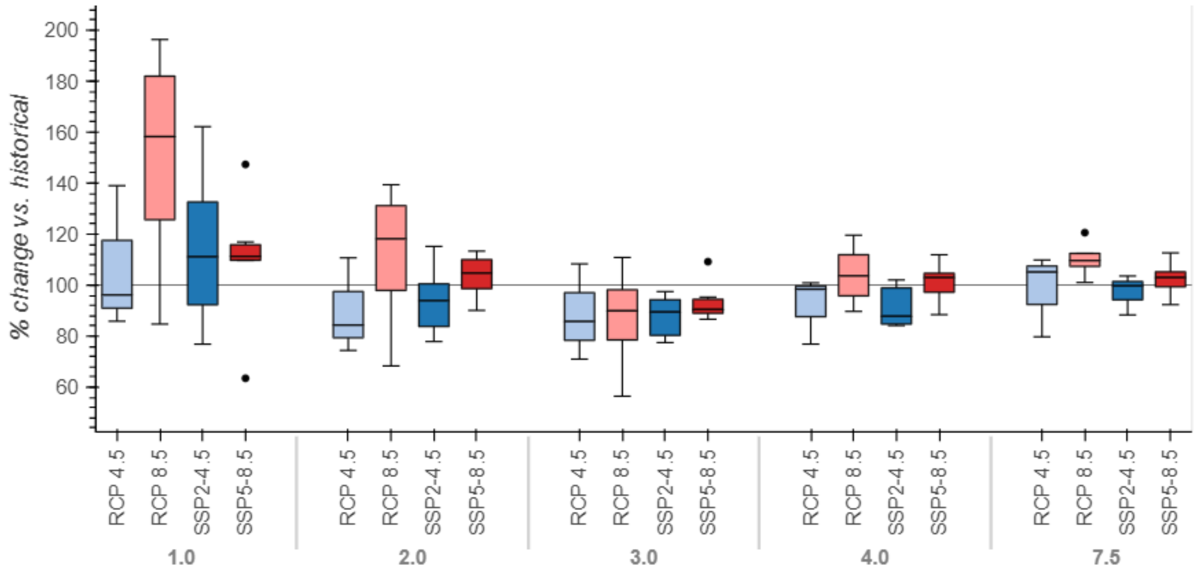

Figure 14. 2021–2060 Modeled Precipitation Drought Projections Relative to 1981–2020 Observations

Drought projections are presented as the lowest precipitation totals during consecutive 1-, 2-, 3-, 4-, and 7.5-year periods relative to the historical values (Historical: 100%). Boxplots display the ensemble minimum, 25th percentile, 50th percentile (median), 75th percentile, and maximum for each emissions scenario.

4.1.2.2 Point-Based San Antonio International Airport Drought

Table 5 and Figure 15 illustrate different historical and modeled precipitation droughts at the San Antonio International Airport. Overall, minimum precipitation is projected to increase during all drought lengths, including the 7.5-year length associated with the drought of record. For example, under the CMIP6 SSP5-8.5 emissions scenario, the 7.5-year drought precipitation total is projected to increase by roughly 29% (from 146 inches under historical conditions to 188 inches under future conditions). This suggests that that the region may not experience a future 7.5-year period with precipitation as low as the drought of record during the proposed permit term.

The precipitation drought projections presented here are designed to represent worst- or near-worst-case droughts (i.e., minimum precipitation values) and may not represent the exact conditions as those observed during notable historical droughts. Specifically, these precipitation drought scenarios do not use idealized projections for each individual drought in response to emissions trajectories (i.e., perfect representation of the same drought under future conditions), but rather provide representations of precipitation droughts of similar length as notable historical droughts.

Table 5. Lowest Precipitation Totals under Historical and Modeled Drought Projections at the San Antonio International Airport

Drought projections are presented as the lowest precipitation totals (in inches) during consecutive 1-, 2-, 3-, 4-, and 7.5-year periods within each time horizon (1947–present for historical, 2021–2060 for future modeled). To demonstrate the full range of potential climate futures, the model ensemble for each emissions scenario and model (CMIP5: RCP 4.5, RCP 8.5; CMIP6: SSP2-4.5, SSP5-8.5) is presented as an ensemble minimum, mean, and maximum.

San Antonio International Airport Drought Projections—Precipitation							
Drought Duration	Historical Precipitation (inches)	Historical Drought Dates	Version	Emissions Scenario	Model Ensemble Minimum	Model Ensemble Median	Model Ensemble Maximum
1-year	8.9	2010-09-08 to 2011-09-08	CMIP5	RCP 4.5	5.4	11	16
				RCP 8.5	9.3	13	18
			CMIP6	SSP2-4.5	7.3	8.6	14
				SSP5-8.5	7.3	9.9	13
2-year	24	2007-09-04 to 2009-09-03	CMIP5	RCP 4.5	28	28	35
				RCP 8.5	24	36	47
			CMIP6	SSP2-4.5	26	29	39
				SSP5-8.5	30	31	35
3-year	45	1953-12-18 to 1956-12-17	CMIP5	RCP 4.5	52	57	71
				RCP 8.5	41	58	80
			CMIP6	SSP2-4.5	53	56	69
				SSP5-8.5	55	60	72
4-year	64	1953-01-16 to 1957-01-16	CMIP5	RCP 4.5	74	90	94
				RCP 8.5	88	89	106
			CMIP6	SSP2-4.5	74	77	97
				SSP5-8.5	81	90	98
7.5-year	146	1949-08-07 to 1957-02-05	CMIP5	RCP 4.5	156	205	206
				RCP 8.5	188	204	229
			CMIP6	SSP2-4.5	159	179	196
				SSP5-8.5	179	188	231

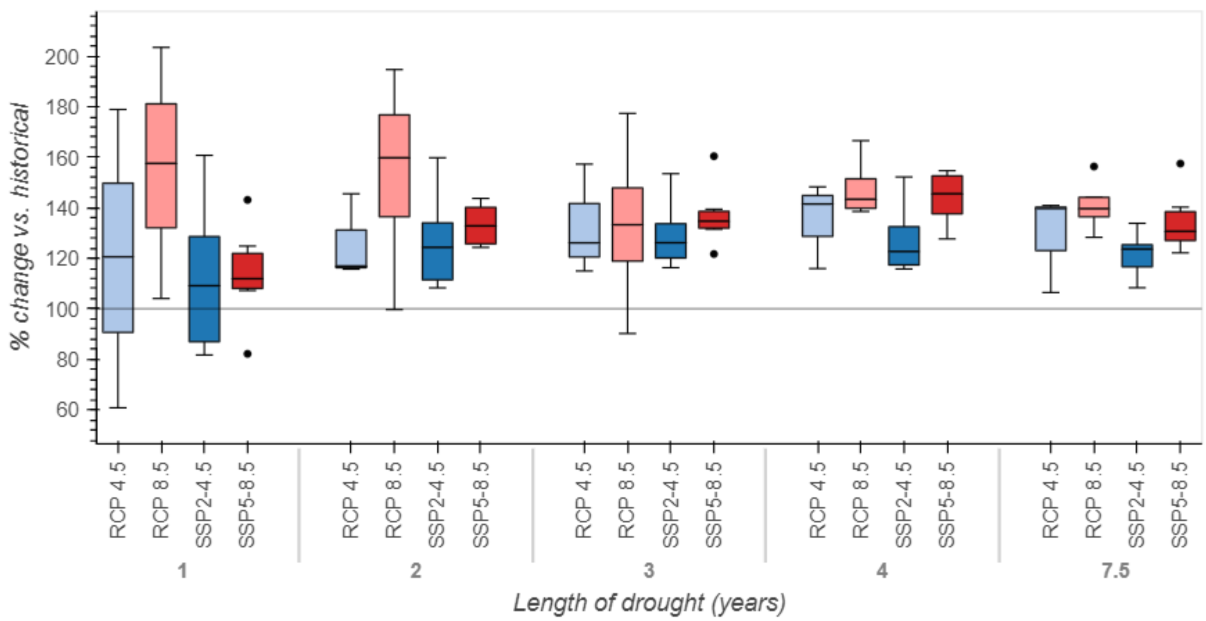

Figure 15. 2021–2060 Modeled Precipitation Drought Projections Relative to 1947-Present Observations

Drought projections are presented as the lowest precipitation totals during consecutive 1-, 2-, 3-, 4-, and 7.5-year periods relative to the historical values (Historical: 100%). Boxplots display the ensemble minimum, 25th percentile, 50th percentile (median), 75th percentile, and maximum for each emissions scenario.

Chapter 5
Discussion

On average, historically the Edwards Aquifer region has experienced drier conditions in the west over the Nueces basin and wetter conditions in the east over portions of the Blanco, Guadalupe, Cibolo, and Med-Cib basins. This has led to a west-to-east, dry-to-wet gradient in annual total precipitation. Historically, temperatures have been warmest in the southern portions of the Edwards Aquifer region. Across the region, while temperatures follow a unimodal seasonal cycle, peaking in late summer, precipitation has historically followed a bimodal seasonal cycle, peaking in late spring and early fall. This renders the region more susceptible to drought conditions during July and August during the warmest months, especially during unusually dry summers.

To inform future modeling efforts and evaluate changes during the proposed permit term, GCM projections of future model-averaged temperature and precipitation were evaluated relative to historical observations. Changes in future GCM-simulated temperature and precipitation may lead to enhanced drought risk across the region in the future, particularly as temperatures warm during anomalously dry periods. Temperatures are projected to increase across all months through 2060, leading to enhanced evapotranspiration rates especially during the warmest summer months.

The region will likely be most susceptible to drought conditions during the warmer late spring to early fall months (May–October). Models project that precipitation will decrease across both emissions trajectories in May, September, and October, while temperature is projected to increase during these months. While precipitation is projected to increase in July and August, it is important to note that these months are projected to experience the largest interannual variability (i.e., year-to-year shifts from high-to-low) in precipitation totals. Unusually dry July and August precipitation totals could lead to enhanced drought conditions by midcentury as temperatures warm.

The largest rates of drying and warming are projected in the western portion of the Edwards Aquifer region in the Nueces basin, which is historically the driest basin in the region. This basin will likely experience the greatest increases in drought risk during the proposed permit term due to decreasing precipitation input and increasing temperatures in a historically dry region.

Last, precipitation drought projections, or worst-case multi-year precipitation deficits (i.e., future minimum precipitation values), were evaluated to understand how noteworthy precipitation droughts may intensify during the permit renewal term. Overall, the region may not experience a future 7.5-year period with precipitation as low as the drought of record during the proposed permit term. Precipitation totals increase for most drought durations in the future relative to the historical period for the 7.5-year drought duration. Analysis of historical and modeled future precipitation at the San Antonio International Airport weather station, in particular, indicates that future minimum precipitation is projected to increase across nearly all model simulations, although precipitation projections come with a high degree of uncertainty.

Chapter 6
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EAHCP PERMIT RENEWAL

Appendix A
Future Temperature and Precipitation Plots by Basin

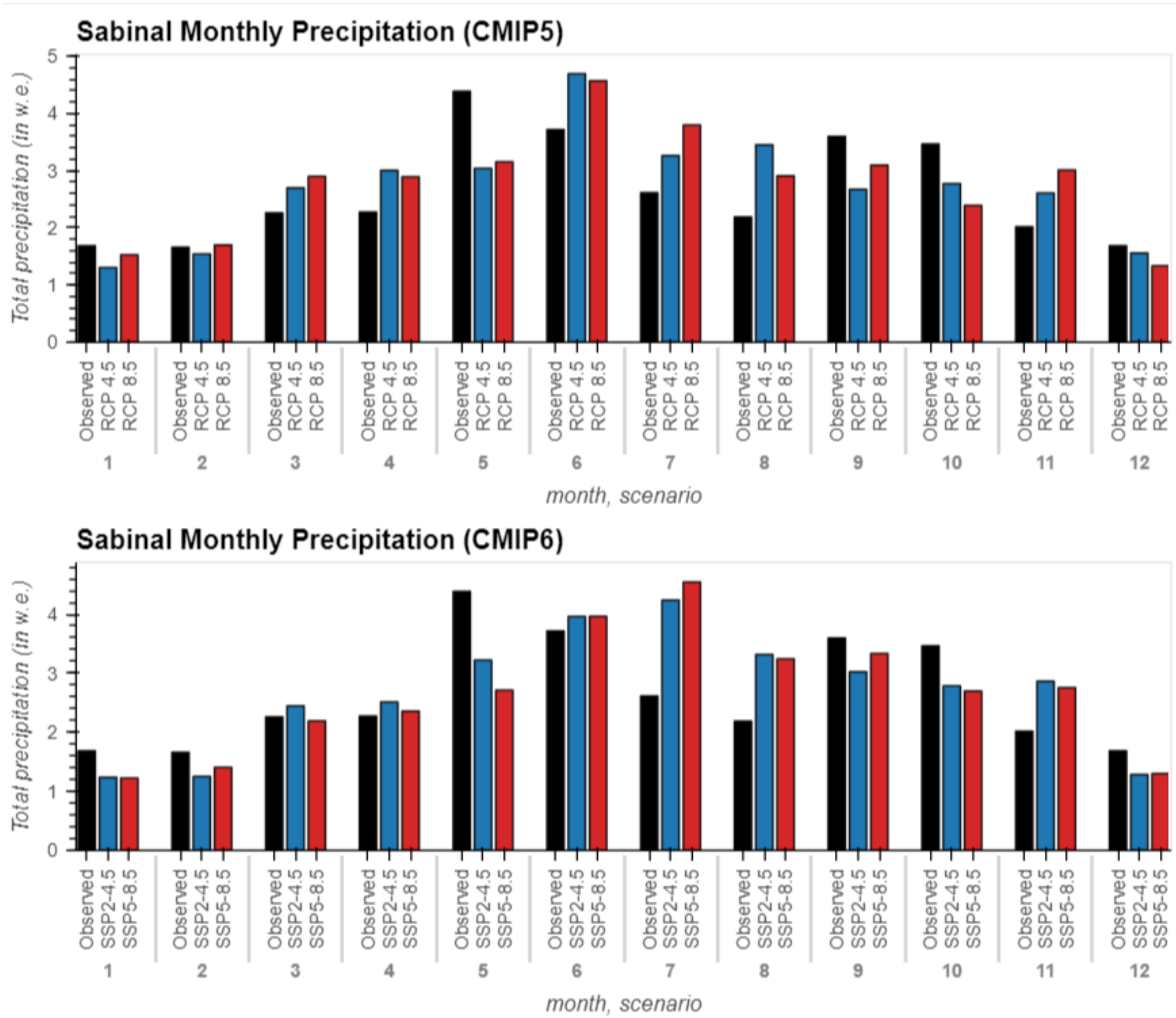


Figure A-1. Mean Monthly Total Precipitation (2030–2059) averaged over the Sabinal Basin

Shown are model ensemble means for CMIP5 (top) and CMIP6 (bottom) and two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures.

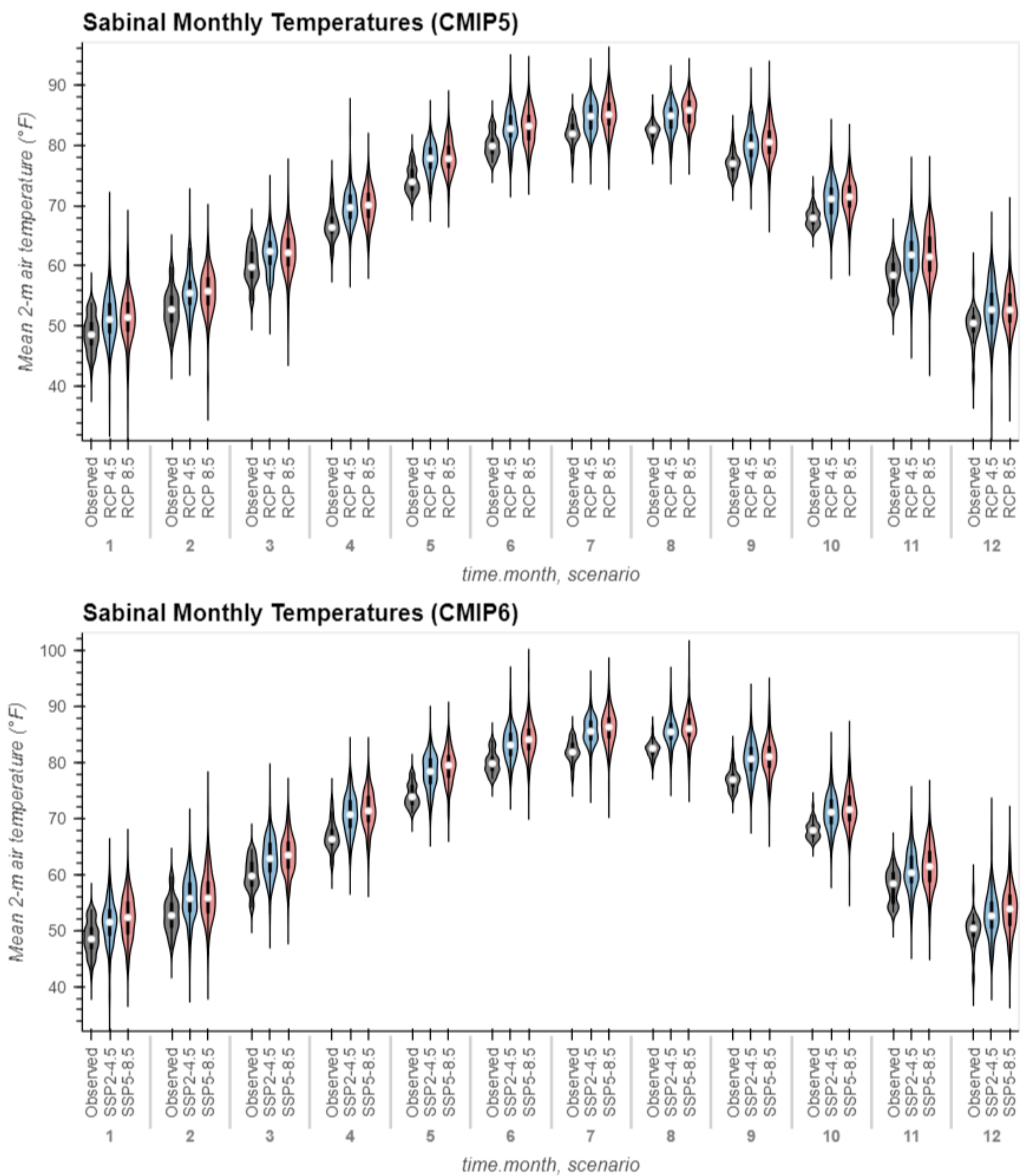


Figure A-2. Violin Plot Distributions of Average Sabinal Basin-Wide Monthly Temperatures (2030–2059)

Shown are CMIP5 (top) and CMIP6 (bottom) model ensembles and two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).

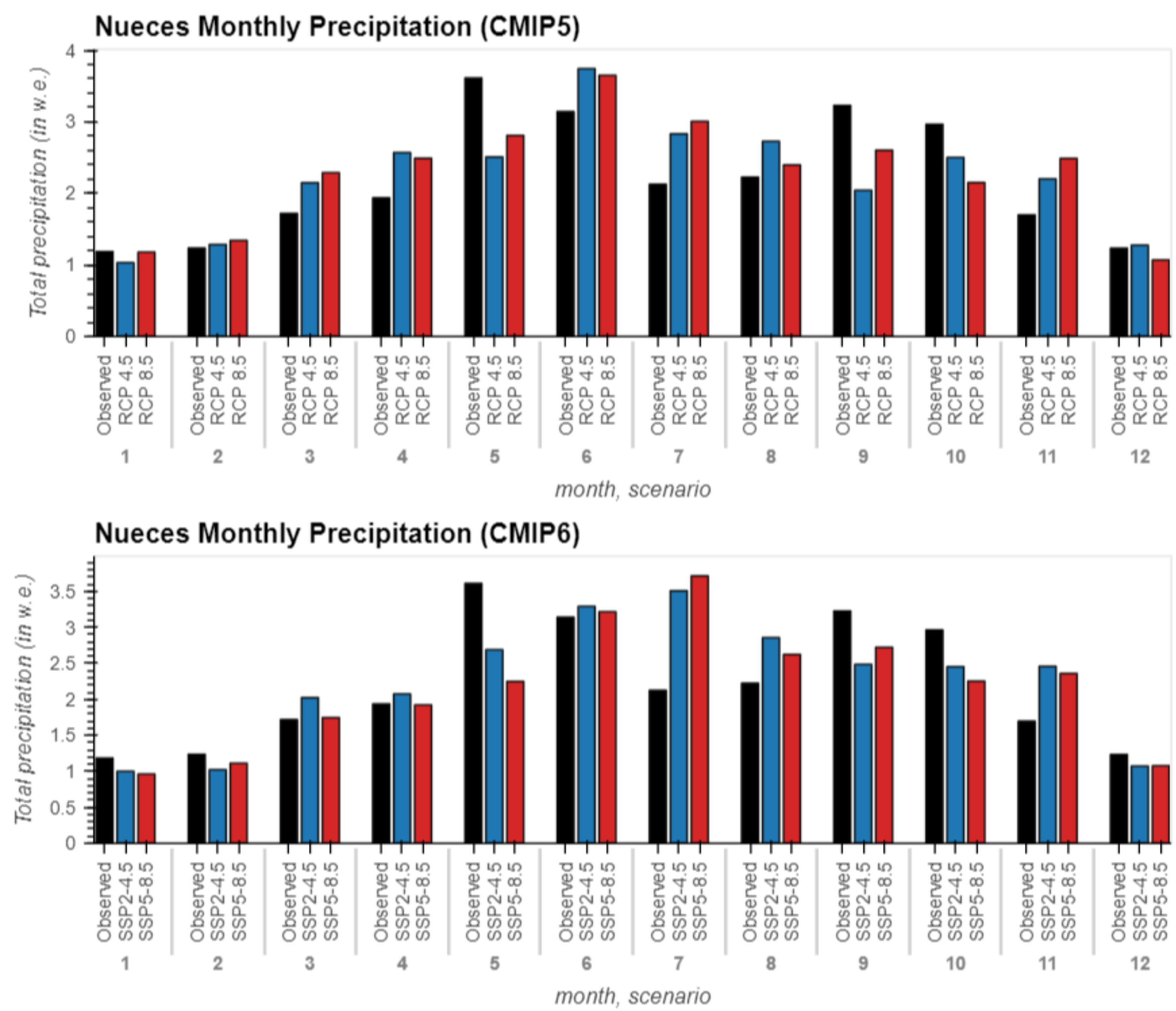


Figure A-3. Mean Monthly Total Precipitation (2030–2059) averaged over the Nueces Basin

Shown are model ensemble means for CMIP5 (top) and CMIP6 (bottom) and two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures**.**

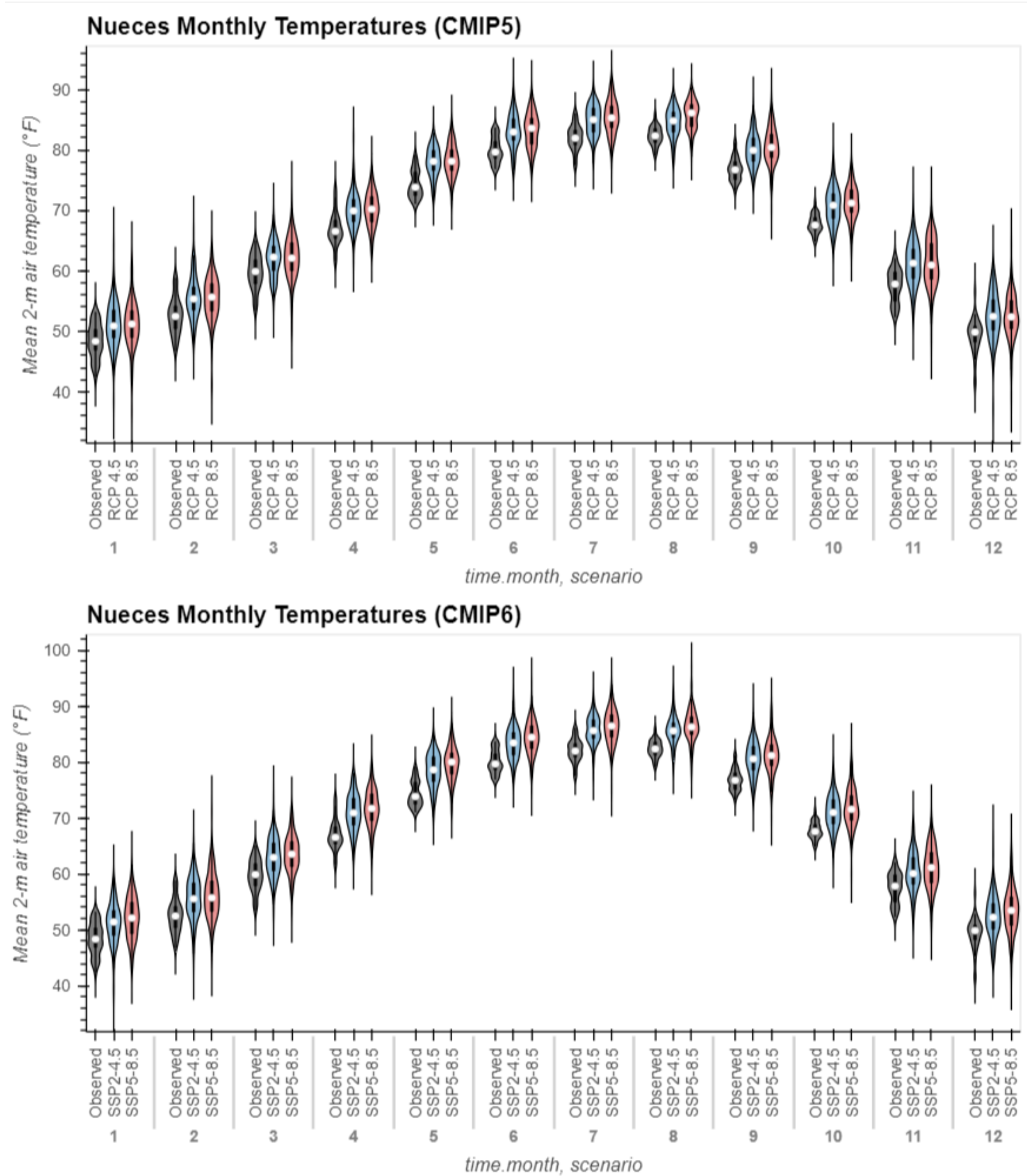


Figure A-4. Violin Plot Distributions of average Nueces Basin-Wide Monthly Temperatures (2030–2059)

Shown are CMIP5 (top) and CMIP6 (bottom) model ensembles and two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).

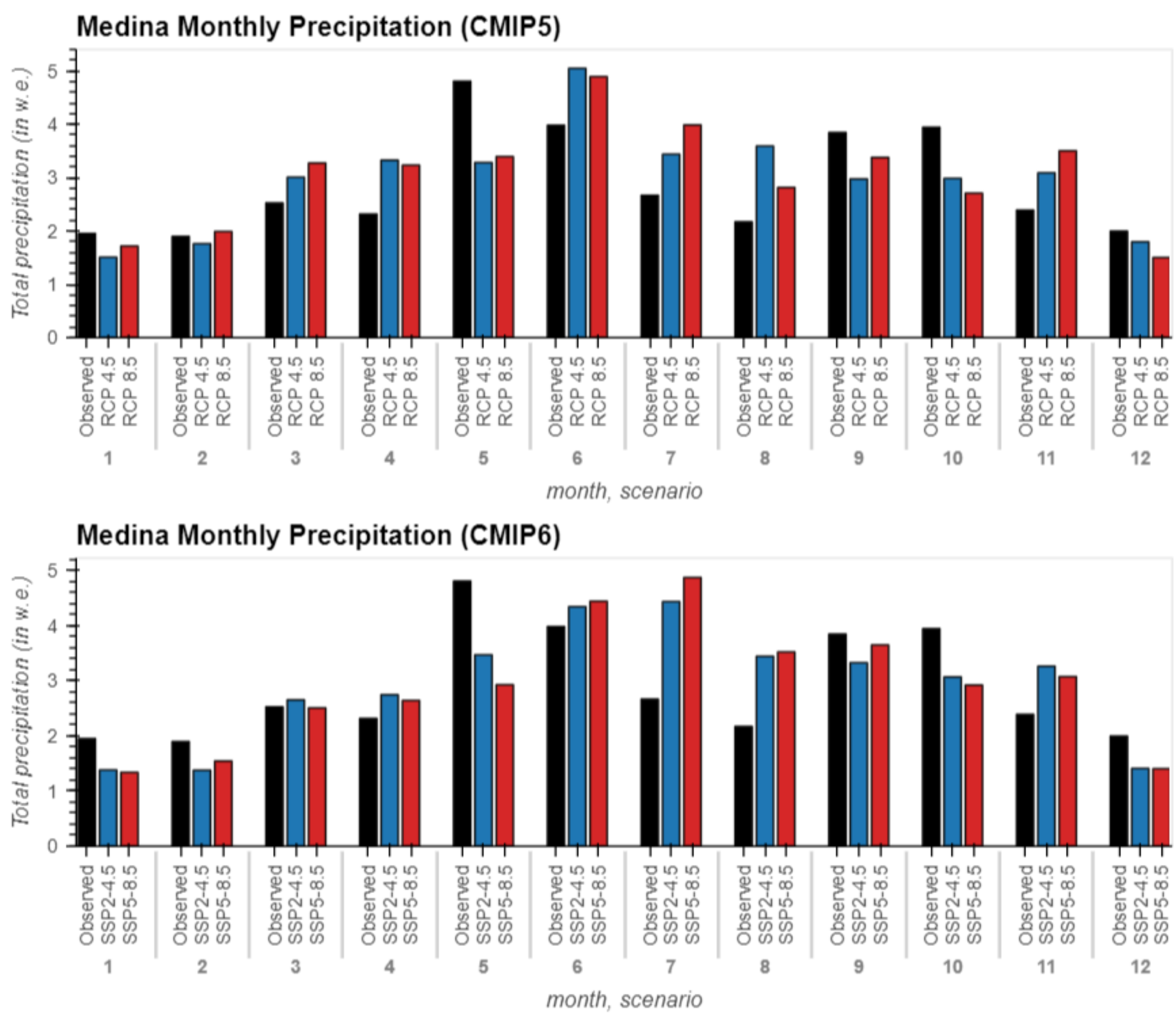


Figure A-5. Mean Monthly Total Precipitation (2030–2059) averaged over the Medina Basin

Shown are model ensemble means for CMIP5 (top) and CMIP6 (bottom) and two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures.

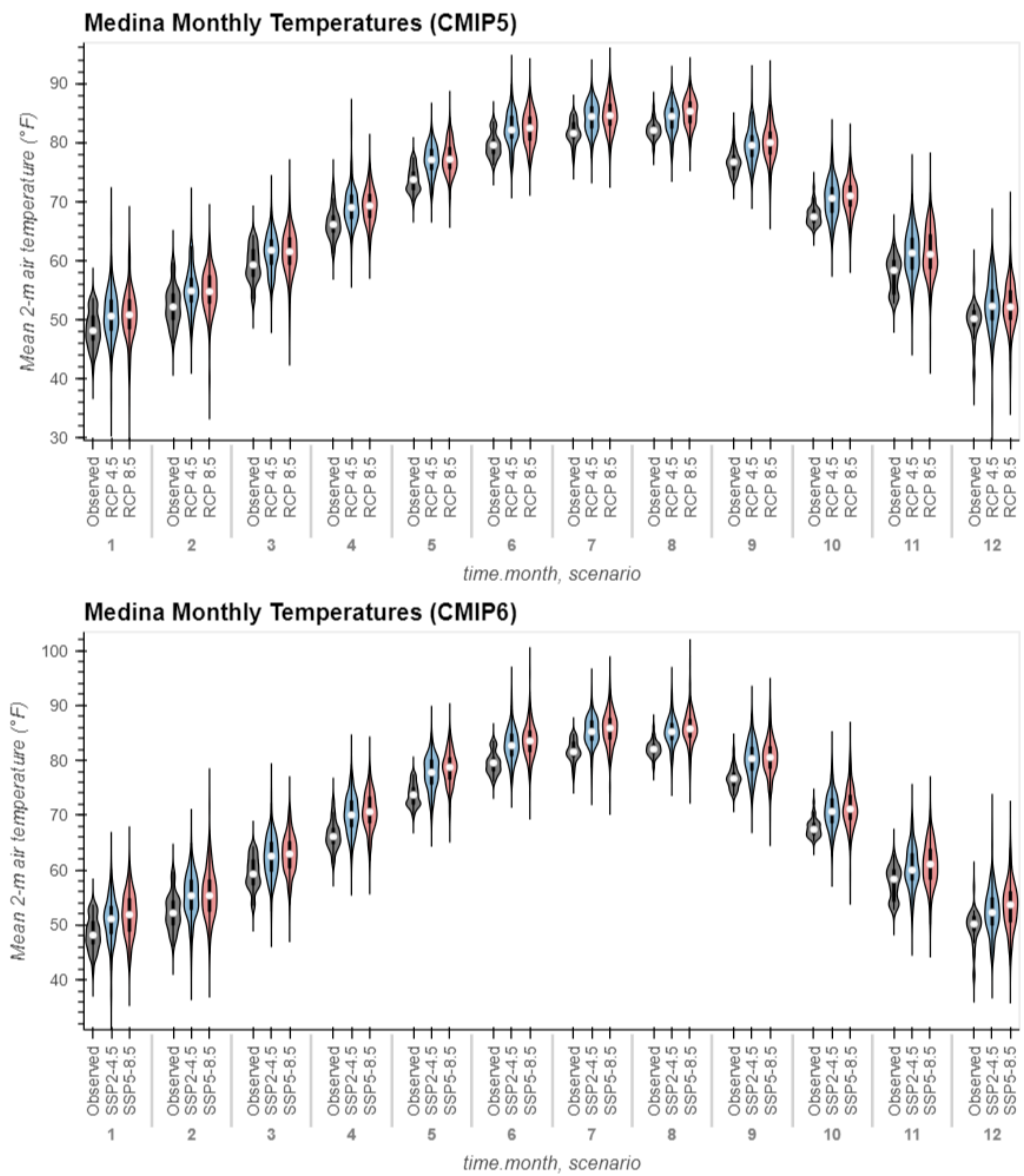


Figure A-6. Violin Plot Distributions of Average Medina Basin-Wide Monthly Temperatures (2030–2059)

Shown are CMIP5 (top) and CMIP6 (bottom) model ensembles and two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).

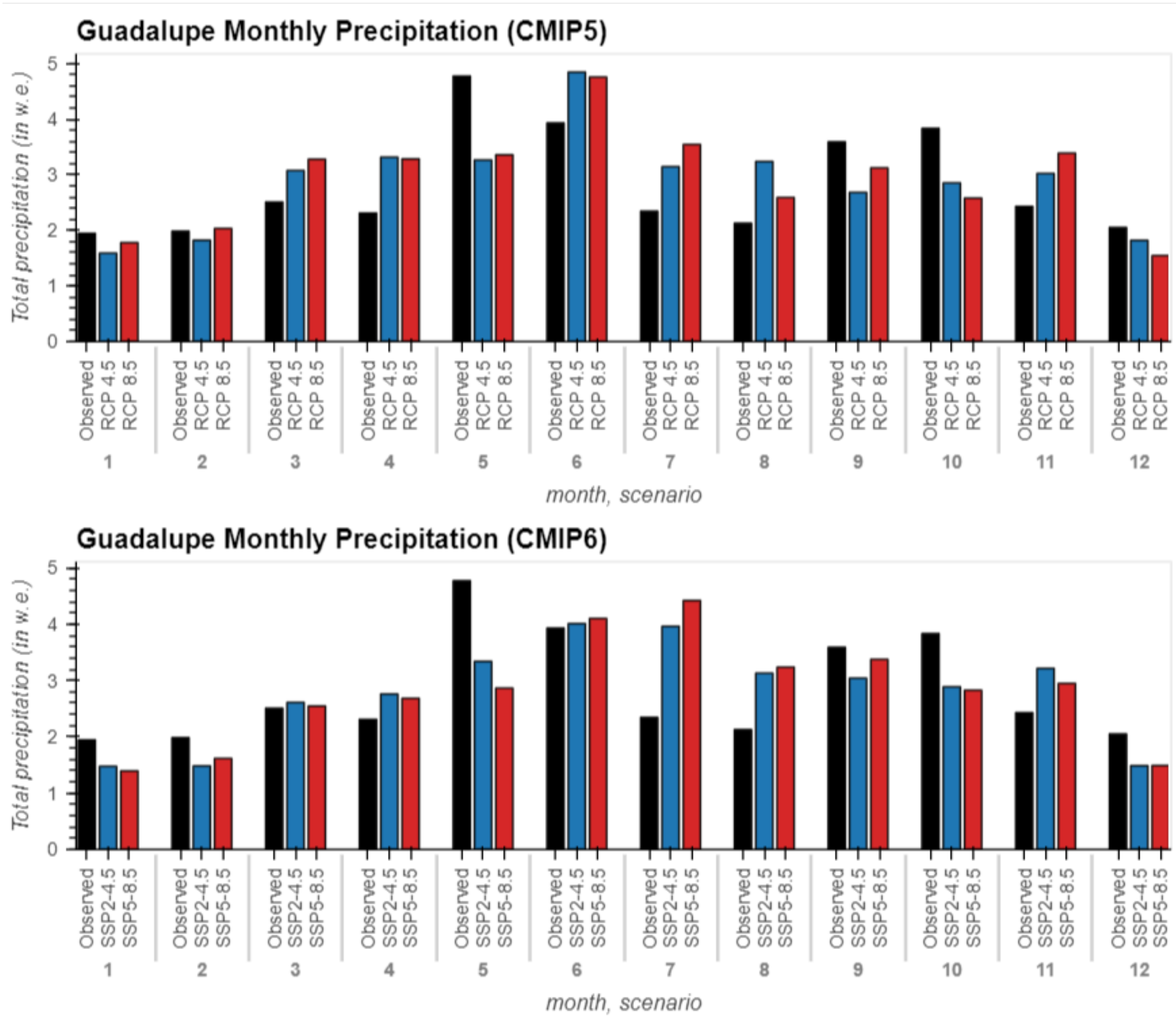


Figure A-7. Mean Monthly Total Precipitation (2030–2059) averaged over the Guadalupe Basin

Shown are model ensemble means for CMIP5 (top) and CMIP6 (bottom) and two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures.

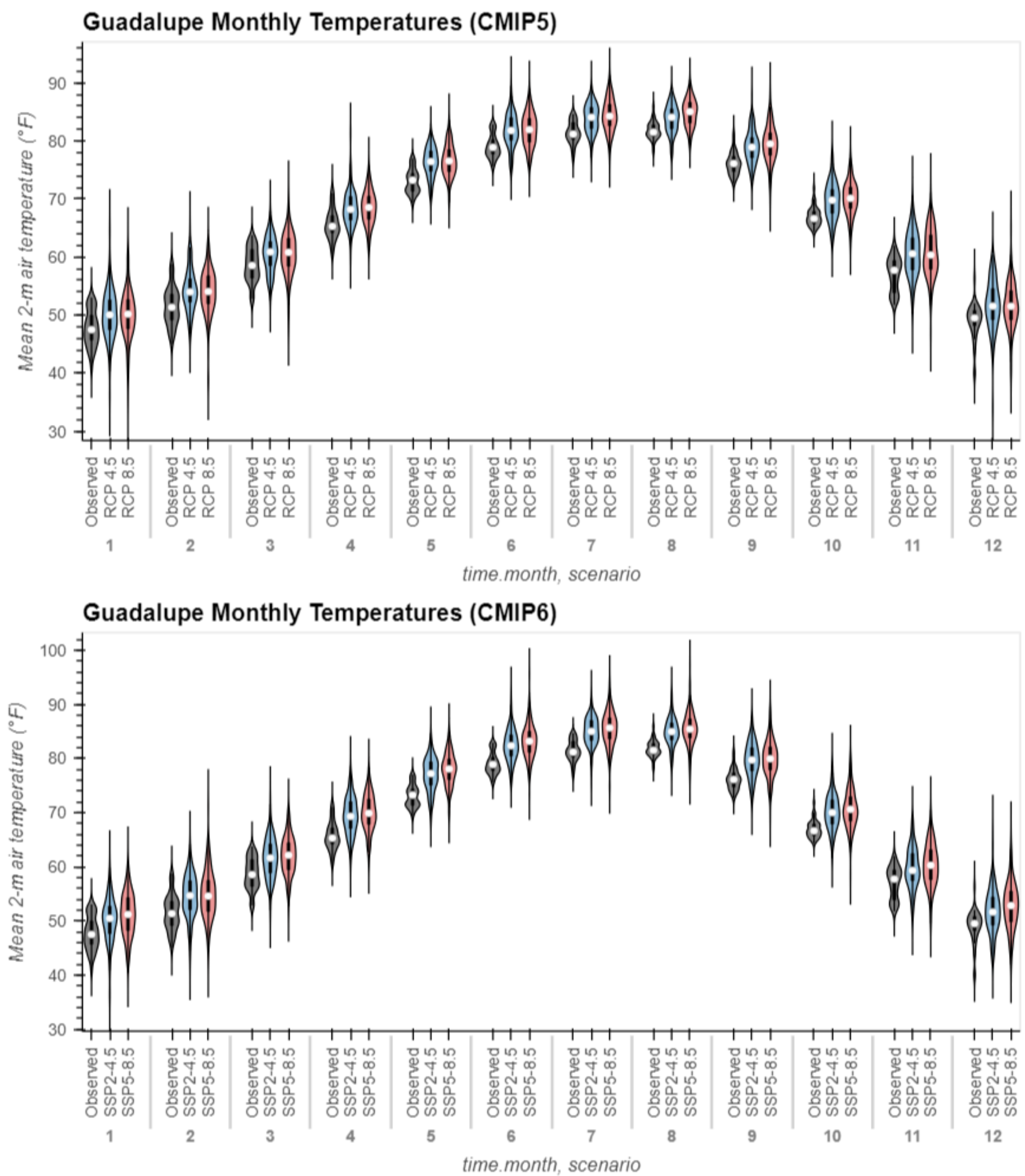


Figure A-8. Violin Plot Distributions of Average Guadalupe Basin-Wide Monthly Temperatures (2030–2059)

Shown are CMIP5 (top) and CMIP6 (bottom) model ensembles and two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).

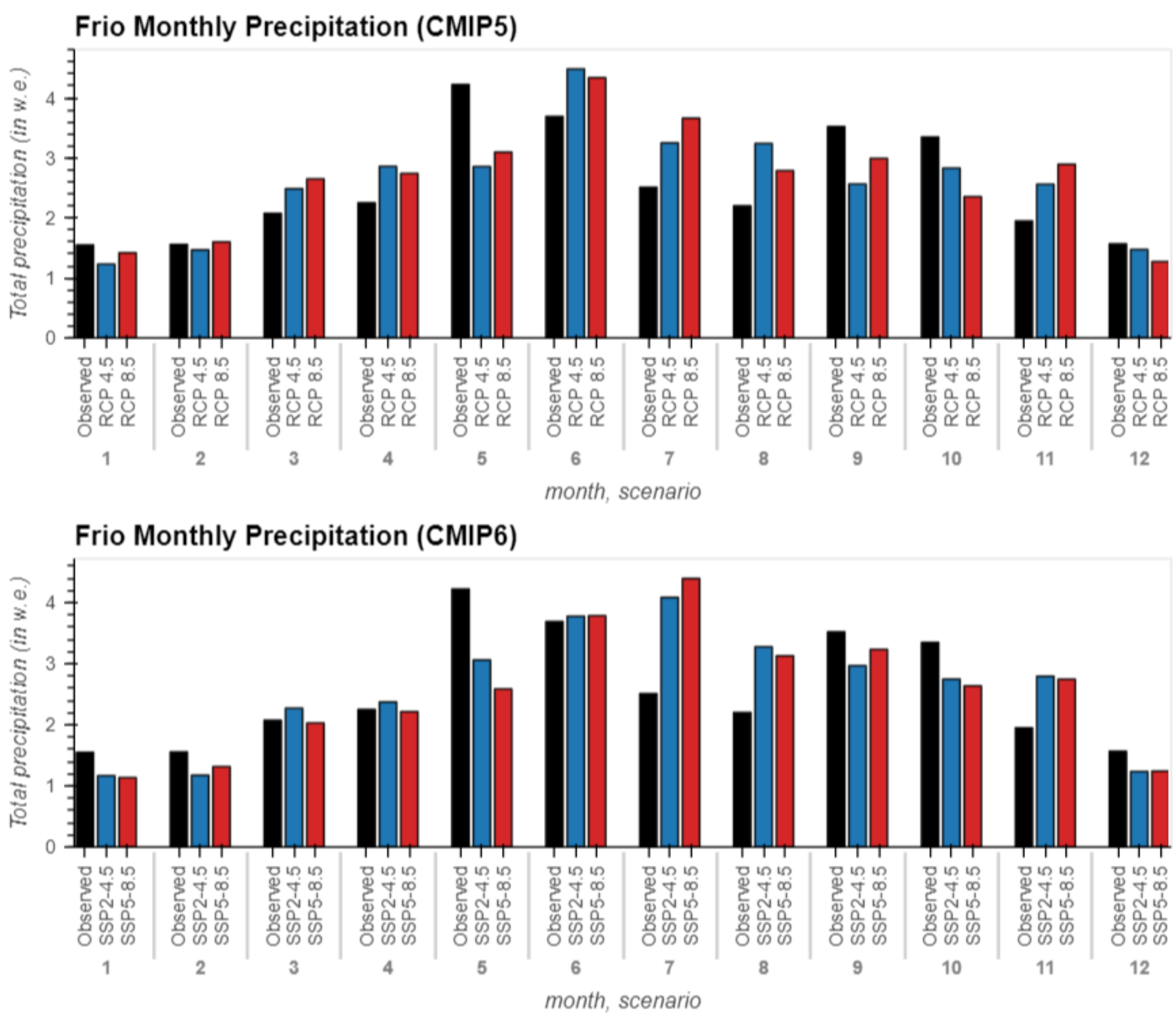


Figure A-9. Mean Monthly Total Precipitation (2030–2059) averaged over the Frio Basin

Shown are model ensemble means for CMIP5 (top) and CMIP6 (bottom) and two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures.

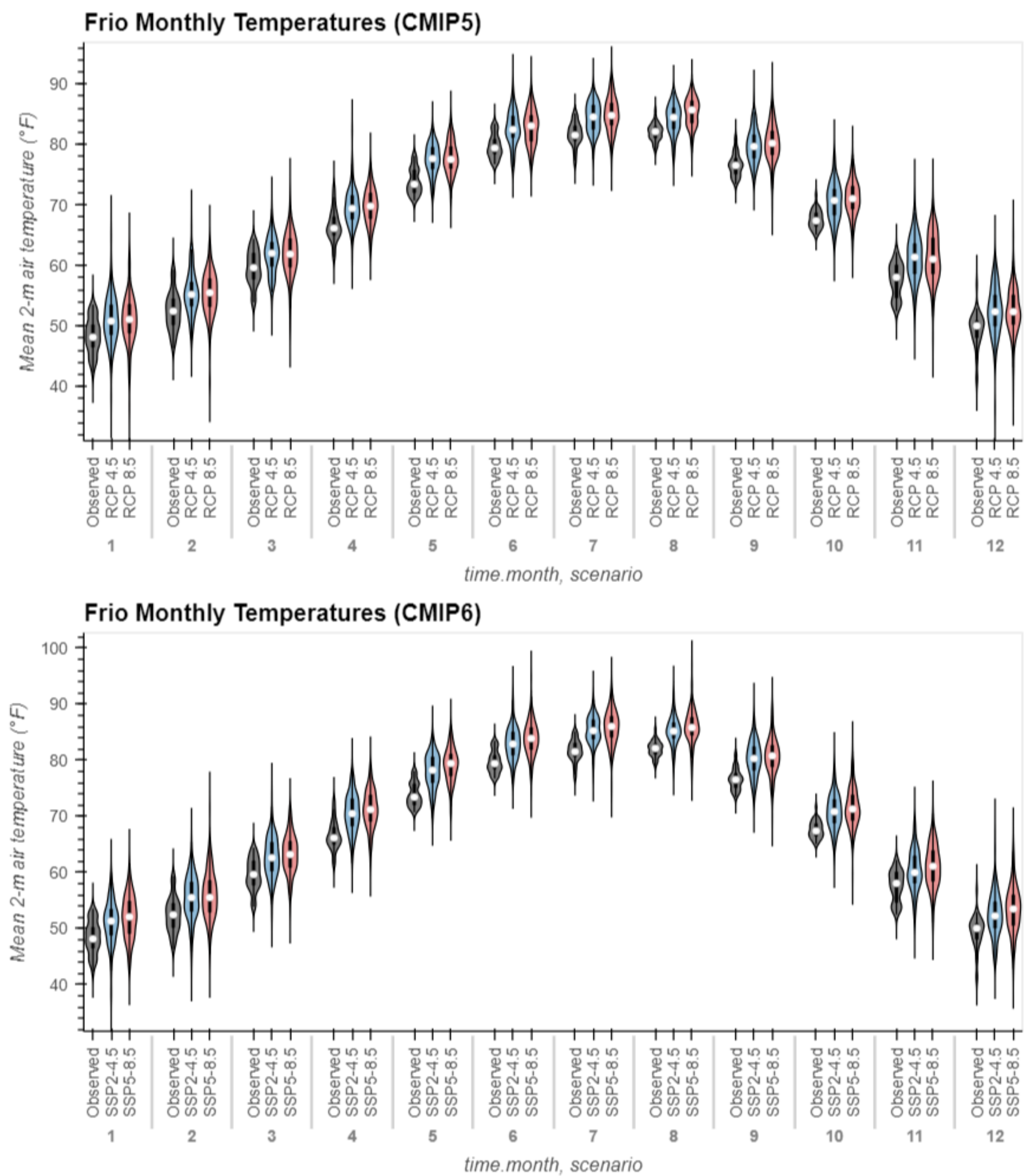


Figure A-10. Violin Plot Distributions of Average Frio Basin-Wide Monthly Temperatures (2030–2059)

Shown are CMIP5 (top) and CMIP6 (bottom) model ensembles and two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).

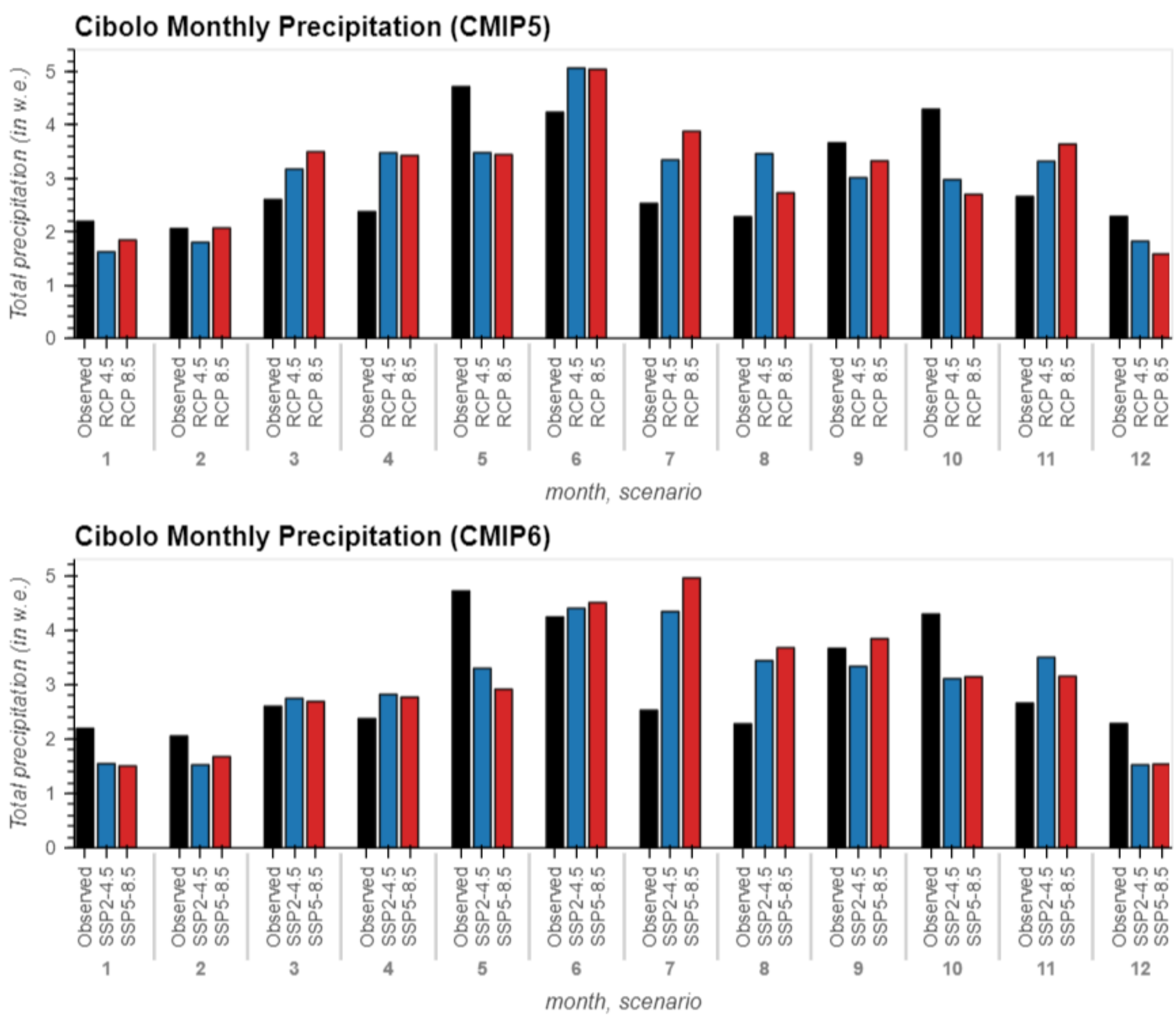


Figure A-11. Mean Monthly Total Precipitation (2030–2059) averaged over the Cibolo Basin

Shown are model ensemble means for CMIP5 (top) and CMIP6 (bottom) and two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures**.**

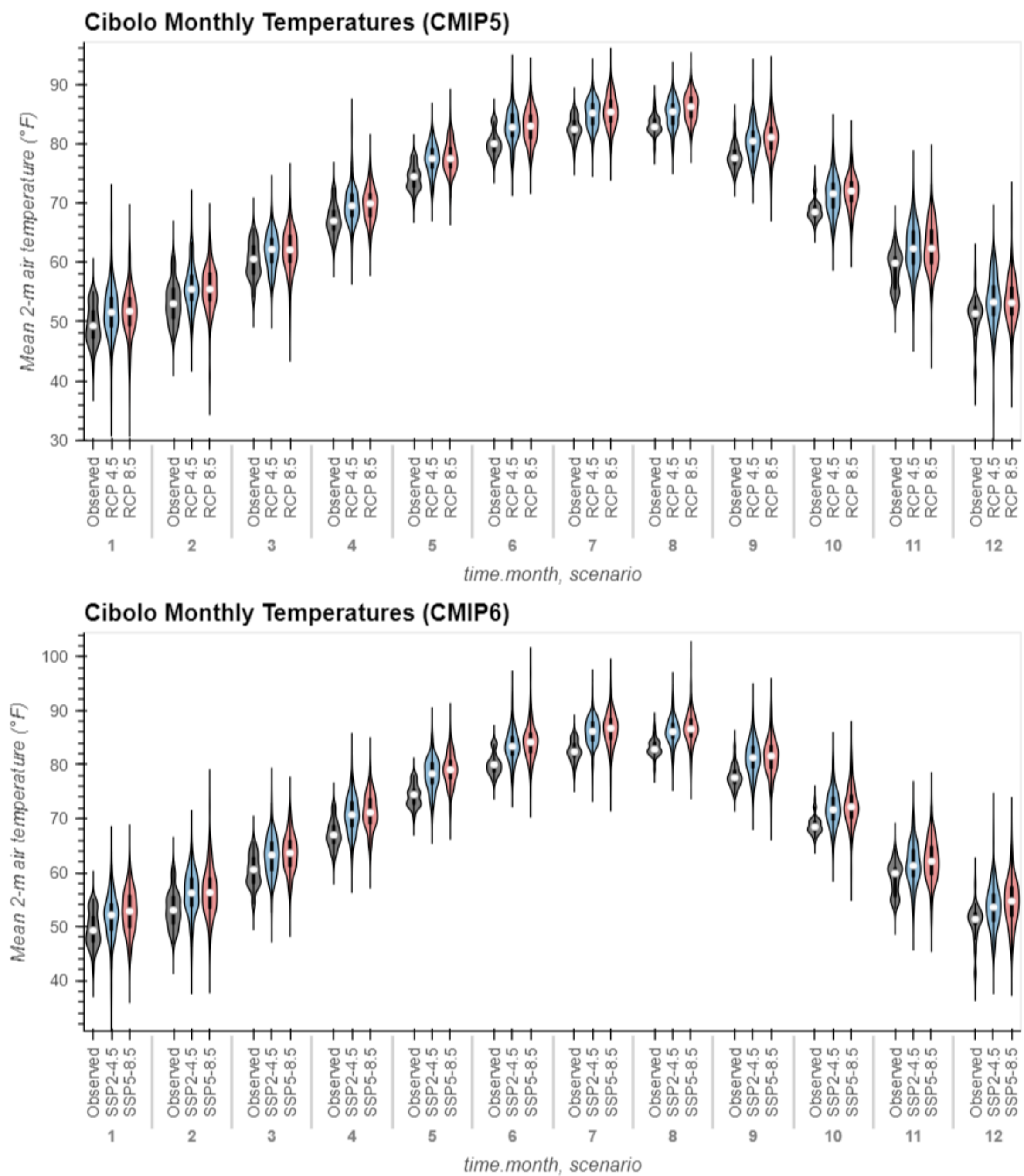
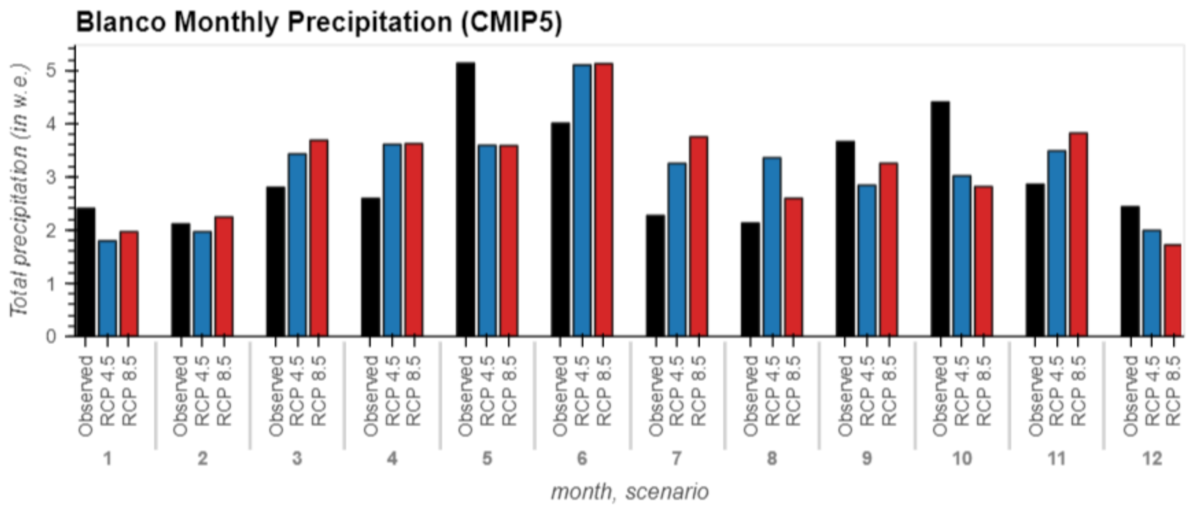


Figure A-12. Violin Plot Distributions of Average Cibolo Basin-Wide Monthly Temperatures (2030–2059)

Shown are CMIP5 (top) and CMIP6 (bottom) model ensembles and two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).



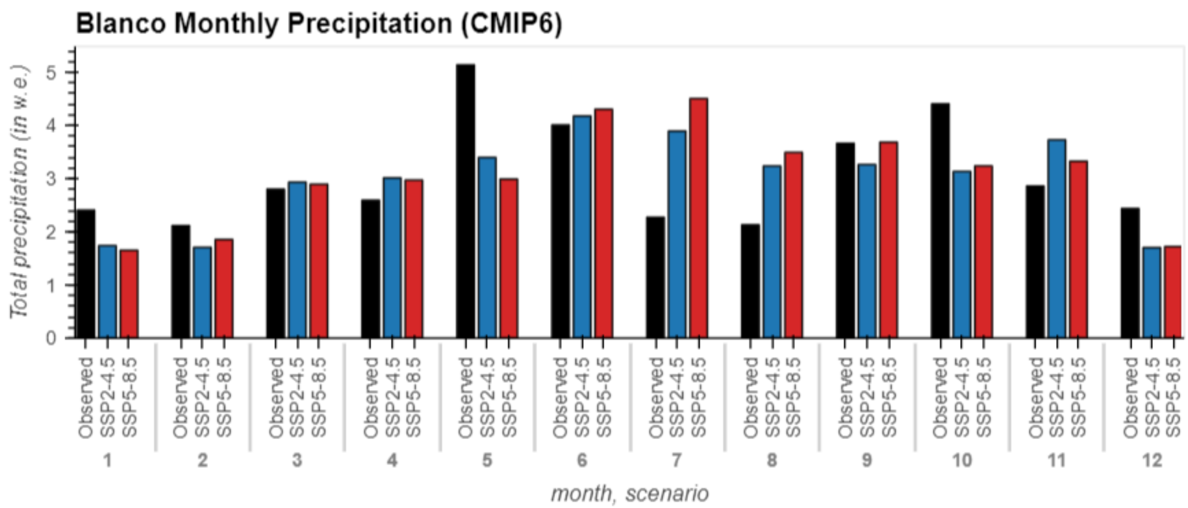
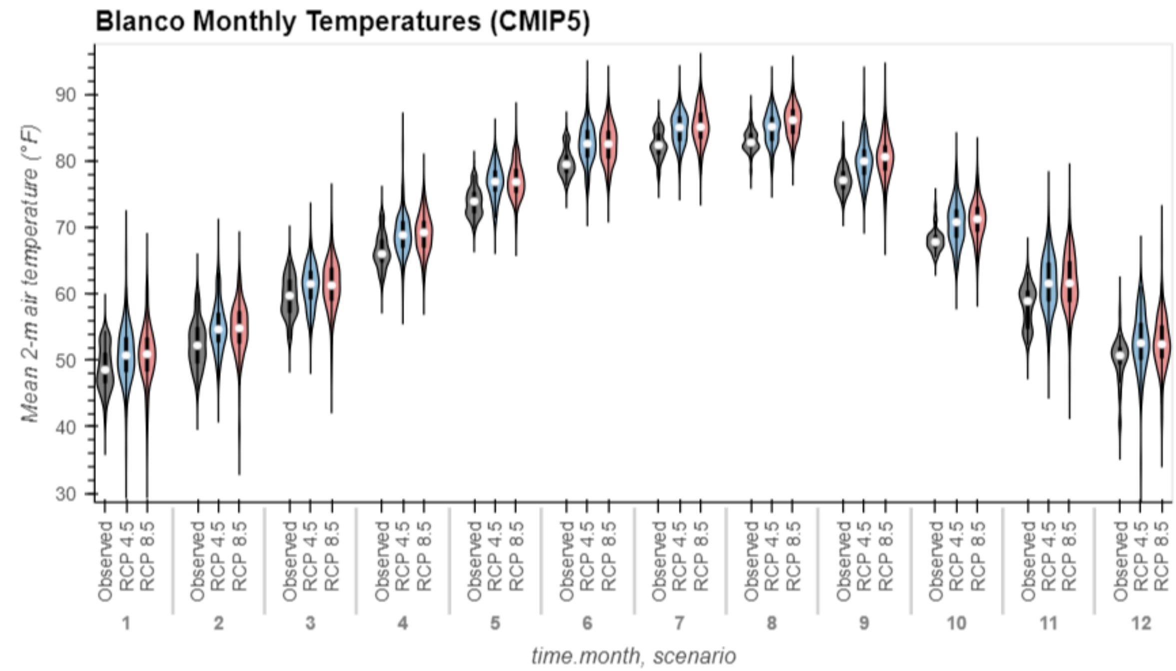


Figure A-13. Mean Monthly Total Precipitation (2030–2059) averaged over the Blanco Basin

Shown are model ensemble means for CMIP5 (top) and CMIP6 (bottom) and two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures**.**



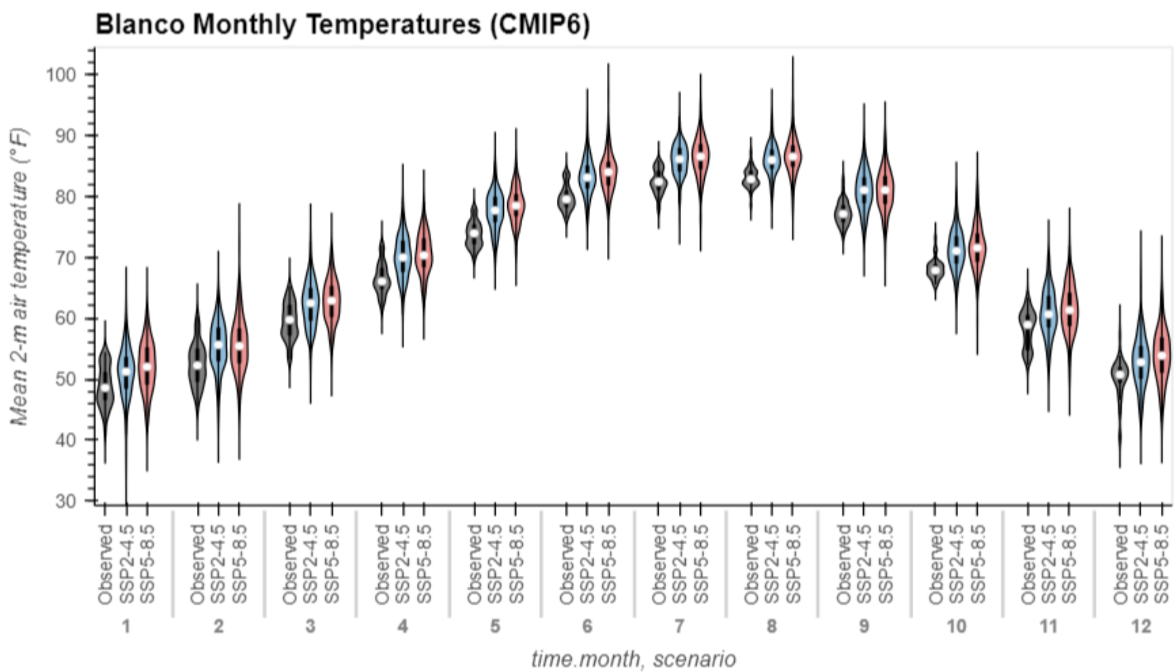


Figure A-14. Violin Plot Distributions of Average Blanco Basin-Wide Monthly Temperatures (2030–2059)

Shown are CMIP5 (top) and CMIP6 (bottom) model ensembles and two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).

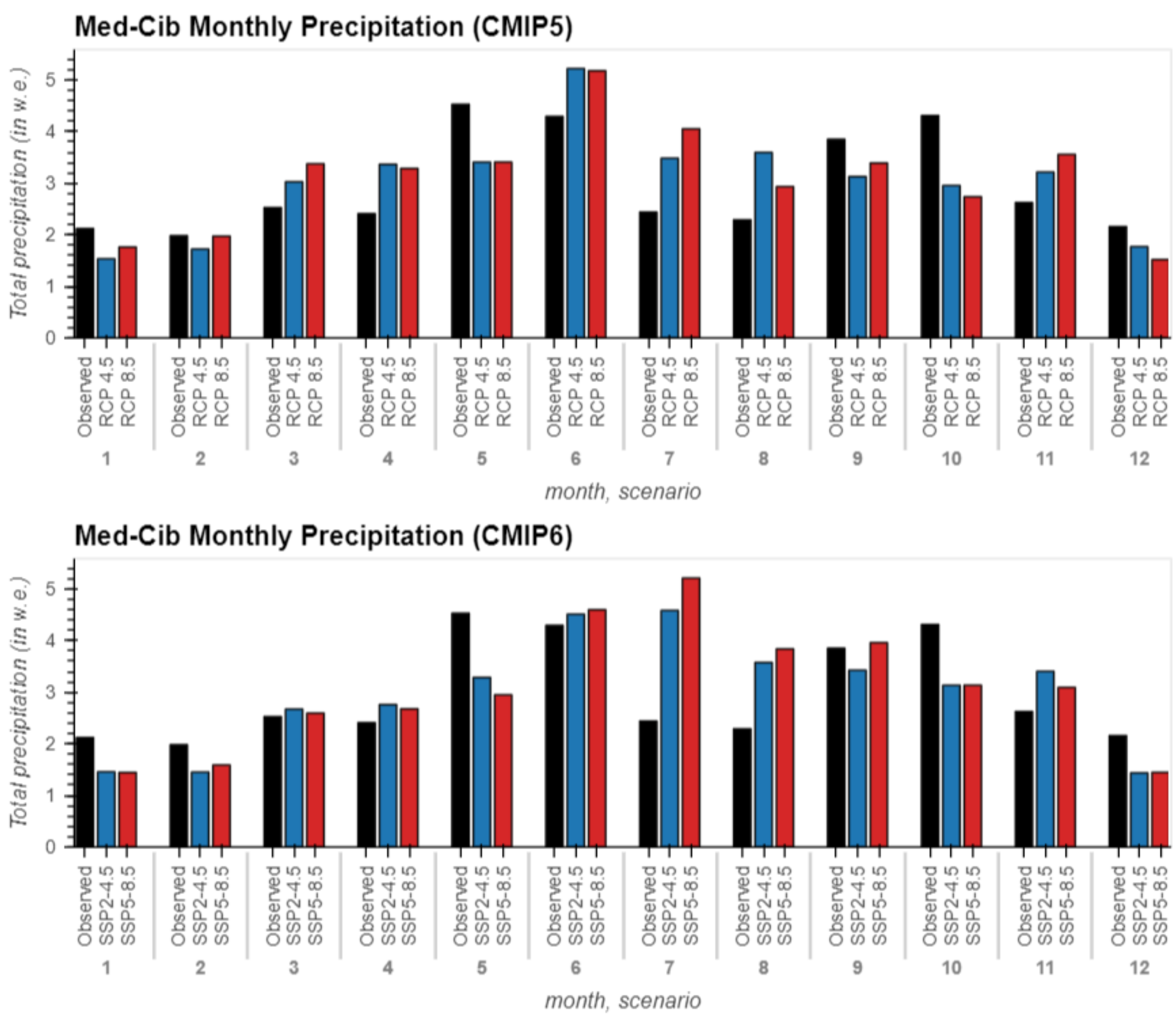


Figure A-15. Mean Monthly Total Precipitation (2030–2059) averaged over the Med-Cib Basin

Shown are model ensemble means for CMIP5 (top) and CMIP6 (bottom) and two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures**.**

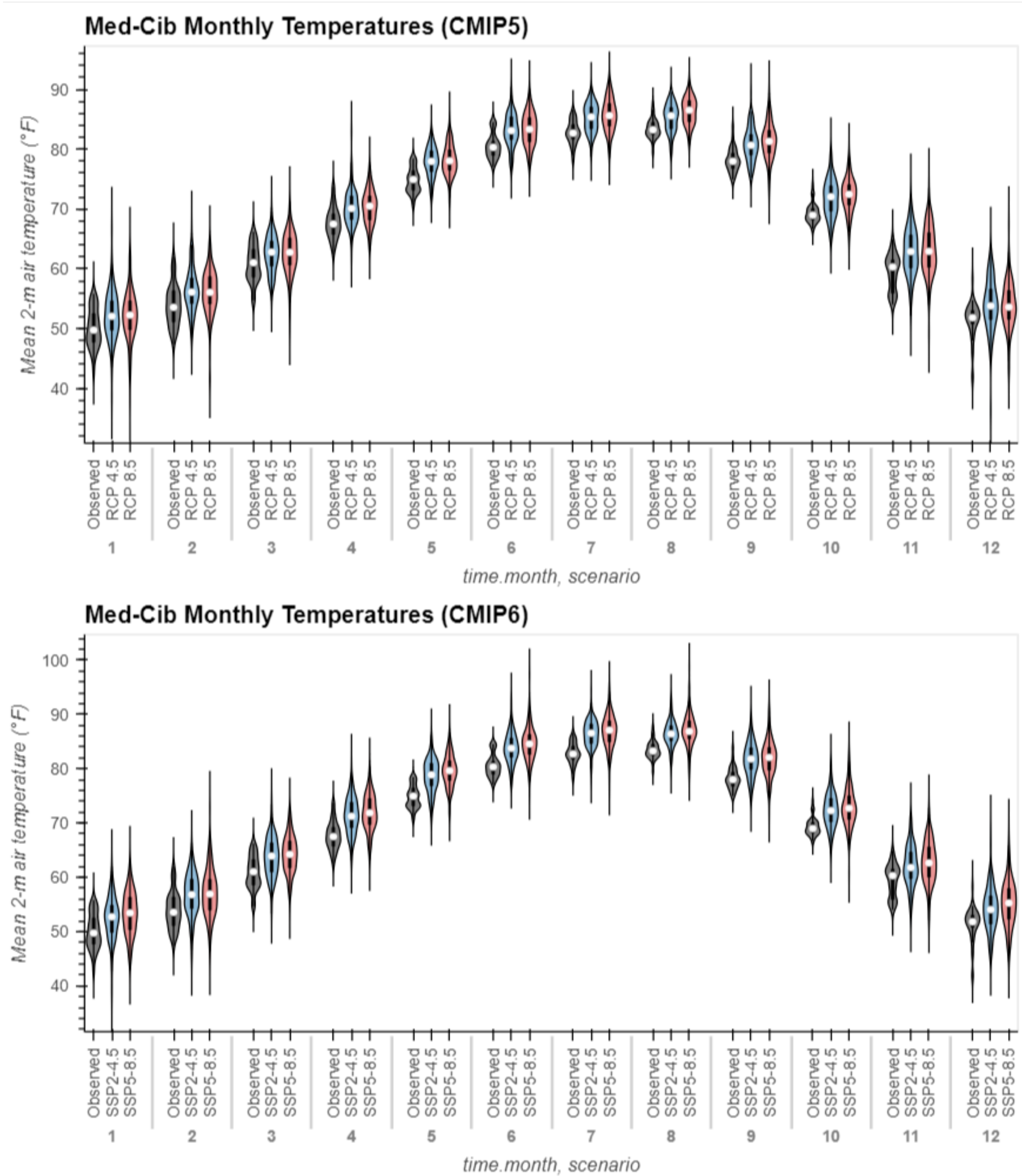


Figure A-16. Violin plot distributions of average Med-Cib basin-wide monthly temperatures (2030–2059)

Shown are CMIP5 (top) and CMIP6 (bottom) model ensembles and two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).

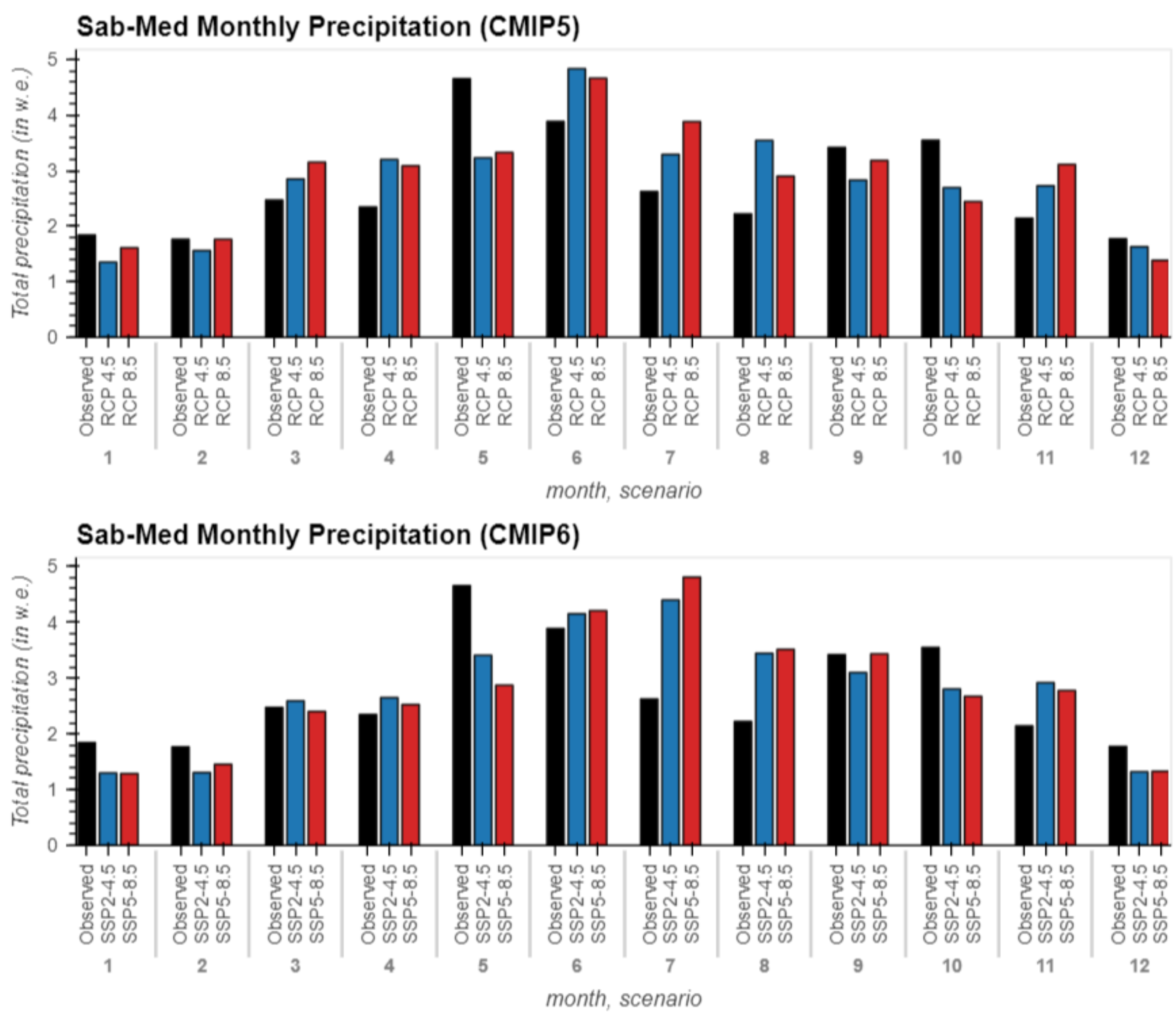


Figure A-17. Mean Monthly Total Precipitation (2030–2059) averaged over the Sab-Med Basin

Shown are model ensemble means for CMIP5 (top) and CMIP6 (bottom) and two corresponding emissions trajectories. The historical monthly precipitation totals are denoted in black in both subfigures**.**

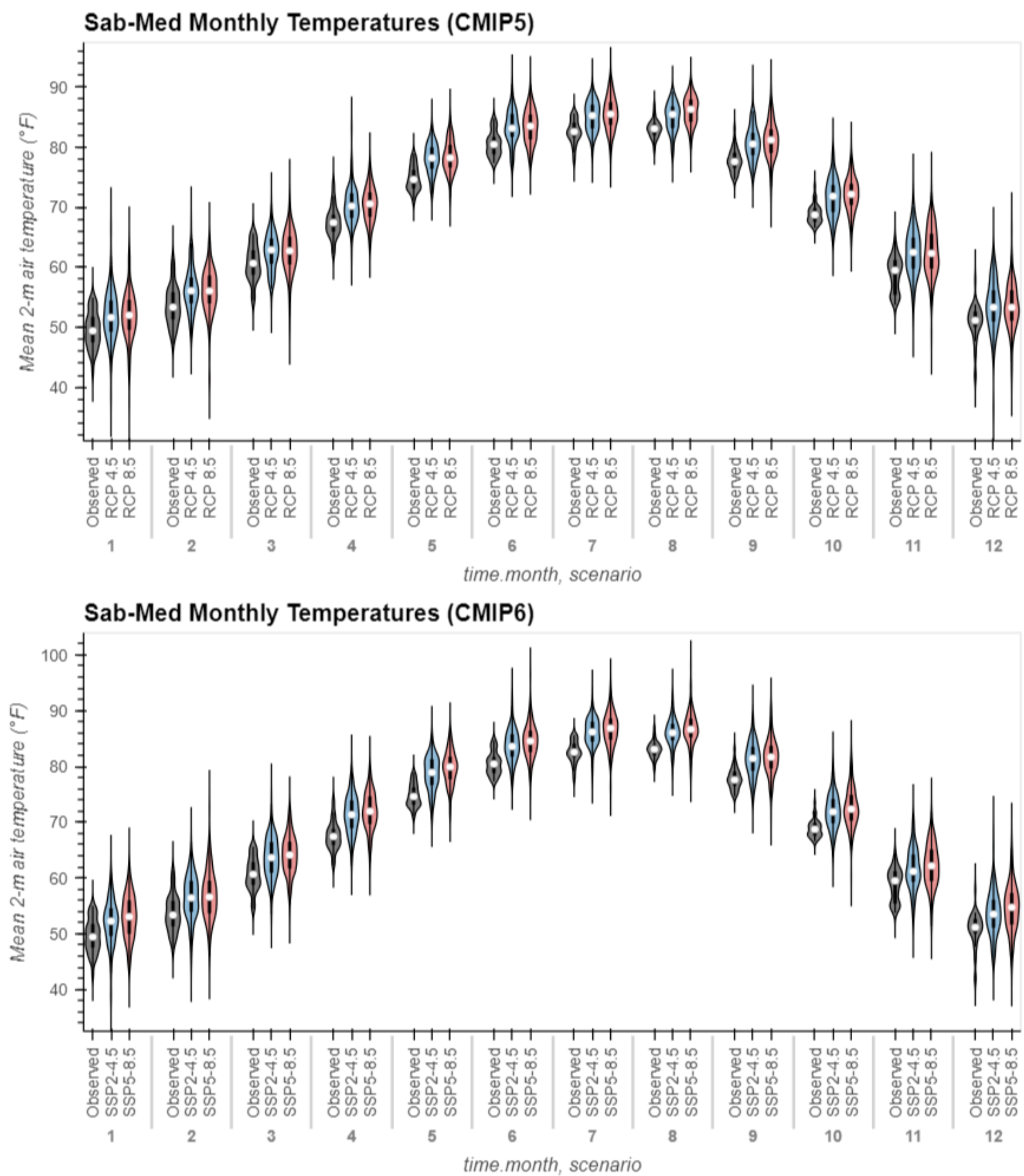


Figure A-18. Violin Plot Distributions of Average Sabinal Basin-Wide Monthly Temperatures (2030–2059)

Shown are CMIP5 (top) and CMIP6 (bottom) model ensembles and two corresponding emissions trajectories. The historical distributions in monthly temperatures (1991–2020) are denoted in black in both subfigures. White dots denote ensemble mean values while black bars represent the 25th–75th interquartile range. Horizontal widths of violin plots represent the density of values (wider = more models with monthly values).

[i] The drought of record occurred from 1951 through 1956 and is characterized by an average recharge for any 7-year period of equal to 168,700 acre-feet as derived for the period 1950–1956.

Appendix F10 | **Climate Report 3: Estimated Edwards Aquifer Recharge and Springflows under Future Climate Conditions**

ESTIMATED EDWARDS AQUIFER RECHARGE AND SPRING FLOWS UNDER FUTURE CLIMATE CONDITIONS

CHAPTER 1, FUTURE ESTIMATES OF EDWARDS AQUIFER RECHARGE USING CLIMATE DATA

Authors: H. Başağaoğlu and L. Schmidt

CHAPTER 2, PROJECTED SPRING FLOWS UNDER FUTURE CLIMATE CONDITIONS: MODFLOW MODELING ANALYSIS

Authors: C. Yang and L. Schmidt

Edwards Aquifer Authority
900 E Quincy Street
San Antonio, TX 78215

September 2024

EAHCP
PERMIT RENEWAL

Edwards Aquifer Authority. 2024. *Estimated Edwards Aquifer Recharge and Spring Flows Under Future Climate Conditions*. September. San Antonio, TX. Prepared with assistance from ICF, Austin TX.

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List of Acronyms and Abbreviations

°F	degrees Fahrenheit
ac-ft	acre-feet
AI	artificial intelligence
amsl	above mean sea level
ASR	Aquifer Storage and Recovery
cfs	cubic feet per second
CPM	critical period management
EAA	Edwards Aquifer Authority
EAHCP	Edwards Aquifer Habitat Conservation Plan
EAR	Edwards Aquifer region
ERT	Extremely Randomized Trees
ft	feet
GCM	global climate model
HGBoost	Histogram-based Gradient Boosting
HSPF	Hydrologic Simulation Program-Fortran
in	inches
ITP	Incidental Take Permit
ML	machine learning
MODFLOW	modular finite-difference groundwater flow
NAS	National Academy of Sciences
PET	potential evapotranspiration
RWCP	Regional Water Conservation Program
SAMP	Strategic Adaptive Management Program
SAT	San Antonio International Airport
SAWS	San Antonio Water System
SHAP	Shapley Additive Explanation
TRB	targeted recharge basin
TWDB	Texas Water Development Board
USGS	U.S. Geological Survey
VISPO	Voluntary Irrigation Suspension Program Option
XAI	explainable Artificial Intelligence
XGBoost	Extreme Gradient Boosting

Executive Summary

The Edwards Aquifer Habitat Conservation Plan (EAHCP) Incidental Take Permit (ITP) renewal process is evaluating the potential effects of climate change on covered species to support the information needed to apply for a proposed permit duration of 30 years. The goal of this report is to assess the potential effects of climate change on the Edwards Aquifer by characterizing changes in future recharge and estimating the effects of those changes on aquifer water levels and the spring flows that support covered species habitat. The Edwards Aquifer Authority (EAA) has previously utilized the U.S. Geological Survey's (USGS) modular finite-difference groundwater flow (MODFLOW) modeling program tailored for use for the Edwards Aquifer to simulate future spring flows; however, the method for estimating inputs (i.e., recharge) was based on streamflow data, and did not incorporate climate change indicators such as temperature and precipitation. Therefore, it was necessary to develop a method to evaluate the effect of future projected temperature and precipitation on aquifer recharge to model spring flows under potential future climate conditions.

This analysis describes the development of predictive models that generate future estimates of Edwards Aquifer recharge using downscaled temperature and precipitation projections from global climate models (GCMs). The report presents the results of modeled recharge from 2023 to 2065, which covers the proposed permit term (2028–2058). The recharge projections are then used within the EAA MODFLOW program to model future aquifer levels and spring flows.

Chapter 1, *Future Estimates of Edwards Aquifer Recharge Using Climate Data*, details the development of a recharge model at the basin scale to estimate future recharge in the Edwards Aquifer region based on temperature and precipitation projections derived from 19 GCMs. After evaluating several approaches to modeling recharge, an artificial intelligence (AI)/machine learning (ML) model based on extremely randomized trees (ERT) was selected. The AI/ML model was coupled with the Shapley Additive Explanation (SHAP) (Shapley 1953; Lundberg et al. 2020) to generate explainable Artificial Intelligence (XAI) models, which were used to identify the most influential hydroclimatic features in predicting recharge. The analysis identified previous month recharge as the most critical feature in determining monthly recharge, followed by precipitation in the target basin, precipitation in neighboring basins, and the previous month's precipitation in neighboring and target basins. Current and lagged precipitation were identified as more critical to the model than temperature.

Using this AI/ML model, the team predicted historical recharge and projected future recharge by month and year through 2065 across eight basins. USGS recharge data served as the ground truth for the predictive recharge analysis, and long-term climate data, including daily precipitation and temperature, were used to train the AI/ML models and test their predictive accuracy in forecasting aquifer recharge.

When compared to observed recharge, some models tended to overpredict recharge, which was most impactful during drought conditions. After post-training and post-adjustments, the resulting models are reasonably and statistically similar to USGS historical data and behave similarly to the USGS approach, the Puente (1978) method, making the estimated cumulative recharge consistent with the assessments of the effectiveness of various spring flow protection measures enumerated in the EAHCP. The results project recharge from most GCMs after 2030 to be lower than the recharge observed in the recent past, irrespective of various modeled emission scenarios. The ranges and magnitudes of the projections, however, are similar to those in the recent past, suggesting that the associated groundwater modeling results are likely to vary in a manner similar to historical observations.

Chapter 2, *Projected Spring Flows Under Future Climate Conditions: MODFLOW Modeling Analysis*, utilizes the recharge outputs from the AI/ML model to simulate future spring flows using the MODFLOW modeling program as tailored for the Edwards Aquifer (Lindgren et al. 2004; Liu et al. 2017). This model was nearly identical to that used for previous EAHCP analyses, with only minor modifications to improve efficiency.

The simulation period spans from 2023 through 2065, totaling 43 years with 516 stress periods (months). The calculations occur at monthly time steps consistent with pumping and recharge data availability. The model includes the spring flow protection measures that exist in the current EAHCP. The model follows five steps in the simulation of spring flows via a Jupyter notebook (Kluyver et al. 2016). In Step 1, the monthly recharge generated from the climate models is converted and reformatted for use. In Step 2, the 10-year moving annual average of total recharge is calculated to determine any periods in which the 10-year moving average falls below 500,000 acre-feet, which is a trigger value for San Antonio Water System (SAWS) Aquifer Storage and Recovery (ASR)-related forbearance requirements. In Step 3, the model is run and the reduction of total pumping via the Regional Water Conservation Program (RWCP) is implemented; reductions in pumping are implemented from EAA forbearance of SAWS ASR leases in years following those years where the 10-year average is below the trigger level; the full range of critical period management (CPM) pumping reductions based on water levels and spring flow values is applied; and protective measures of RWCP, EAA forbearance, and CPM Stages 1–5 pumping reductions are implemented. In Step 4, the annual water level at the J17 index well for each year in the simulated period is checked; if the water level is below 635 feet above mean sea level, reductions in pumping covered by Voluntary Irrigation Suspension Program Option (VISPO) leases are applied in the year after VISPO is triggered. Step 4 includes another full model run and implements the protective measures in Step 3 and VISPO-related reductions if triggered. Step 5 is a full run of the model and applies pumping reductions related to SAWS ASR forbearance. Spring flow protection measures implemented in Steps 3 and 4 are also included in Step 5.

The Jupyter notebook and corresponding model were assessed by comparing its output for the historical drought of record and by using a range of realistic recharge inputs. The current model successfully reproduced the outcomes from previous drought modeling in the EAHCP and generated reasonable and anticipated results across three distinct recharge input tests. Quality assurance and control evaluations of the model provide confidence in its ability to project water levels and spring flows based on future recharge scenarios.

Separate model runs were then conducted for each of the projected recharge sequences associated with the 19 downscaled GCMs to project water levels and spring flows from 2023 to 2065. The model projects water levels for the J17 index well and spring flows for Comal and San Marcos Springs. The median modeled flow rates for Comal and San Marcos Springs were consistent with historical data, and the model effectively captured low flow conditions below 100 cubic feet per second without bias. The analysis confirmed that protective measures were triggered as expected and aligned with groundwater management criteria. The modeling results produced three drought sequences similar to the 1950s drought of record and more than 19 sequences similar to the 2011–2015 drought.

The 19 projections were categorized into three groups: Neutral, Stressed, and Low Flow. Neutral projections showed spring flows similar to the past 40 years, while Stressed scenarios had lower flows that remained above daily average minimum targets. The Low Flow scenarios, however, included two climate projections with one or more stress periods where flows dropped below the proposed minimum daily average spring flow discharge objectives.

For both spring systems, increases in spring flow rates correspond to the peaks of monthly recharge to the aquifer, while decreases reflect less recharge and greater applied pumping, particularly during the summer season. The exaggerated intra-annual sawtooth shape of the spring flow rates is likely due to the application of maximum allowed monthly groundwater pumping in the model; however, the modeled declines are consistent with seasonal pumping. The analysis also revealed that some protective measures, like ASR forbearance, were not triggered during Low Flow scenarios resulting in very low flows; however, under no scenario do spring flows cease.

This analysis successfully incorporated projected future temperature and precipitation data to estimate future recharge and produce future spring flow projections under varying climate scenarios. Several future spring flow projections produce drought sequences similar to those experienced in recent history but none that appear more severe than the drought of record. The majority of future spring flow projections indicate that existing spring flow protection measures would maintain spring flows above minimum average daily spring flow discharge objectives for the Comal and San Marcos Springs, but 2 of the 19 projections produce flow rate sequences over the course of 1 to 4 months that are below these objectives. No future spring flow projections result in zero flows in Comal or San Marcos Springs.

Chapter 1

Future Estimates of Edwards Aquifer Recharge Using Climate Data

Evaluation of future environmental effects, including climate change, is a necessary component of the application process for renewal of the Edwards Aquifer Habitat Conservation Plan (EAHCP) Incidental Take Permit (ITP). A thorough assessment of the potential effects of future climates on the Edwards Aquifer requires more than a review of future climate model projections and includes characterizing changes in future recharge and estimating effects of those changes on aquifer water levels and spring flows. The Edwards Aquifer Authority (EAA) has an available groundwater flow model that can simulate water levels and spring flows using recharge as input (Liu et al. 2017), but a method to estimate future recharge has not previously been developed.

The following sections describe the methodology used to generate predictive models of recharge for the Edwards Aquifer system using meteorological parameters output by global climate models (GCMs) and present the results of modeling recharge from 2023 to 2065, encompassing the proposed permit renewal period of 30 years (2028–2058).

1.1 Current Recharge Estimates for the Edwards Aquifer

Estimates of annual recharge to the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer are provided by the U.S. Geological Survey (USGS) using a methodology described in Puente (1978). Although there is some acknowledged additional uncertainty, the USGS also provides estimates of monthly recharge (Puente 1978; USGS 2023). Calculations have been made to quantify recharge from 1934 to the present, and the Puente method is specified in the EAHCP (RECON et al. 2012; U.S. Fish and Wildlife Service 2015) as the means for calculating recharge in the aquifer system.

The USGS method for estimating recharge is based on streamflow data (Puente 1978). Estimates for recharge are made monthly for eight individual river basins in the contributing zone (Figure 1-1). The basic approach is a water balance, in which recharge in a basin is the difference in streamflow measured at gaging sites upstream and downstream of the recharge zone, plus the estimated runoff generated in the recharge zone. This balance is applied directly in five of the nine basins that have stream gages located upstream and downstream of major contributing rivers. The other four basins either have gaging stations only downstream of the recharge zone or have no gaging sites at all. Recharge in these partially or ungaged basins is estimated based on assumptions relating the runoff characteristics from gaged areas to ungaged areas. Recharge in the Medina River basin also includes seepage losses from Medina Lake and Diversion Reservoir. One of the gaged basins, the Guadalupe River Basin, is not considered to contribute significant recharge. Total recharge to the system is the sum of the other eight basin recharge estimates.

The basins, from west to east, are:

- Nueces-West Nueces River Basin (Nueces)
- Frio-Dry Frio Basin and adjacent areas (Frio-Dry Frio)

- Sabinal River Basin and adjacent areas (Sabinal)
- Area between Sabinal River Basin and Medina River Basin (Seco-Hondo)
- Medina River Basin (Medina)
- Area between the Medina River Basin and Cibolo Creek Basin (Bexar)
- Cibolo Creek and Dry Comal Creek Basins (Cibolo Dry Comal)
- Blanco River Basin and adjacent areas (Blanco)

In general, we use the abbreviated names (in parentheses above) for each of these basins in this report. To perform the analyses, we used reported recharge data through 2022.

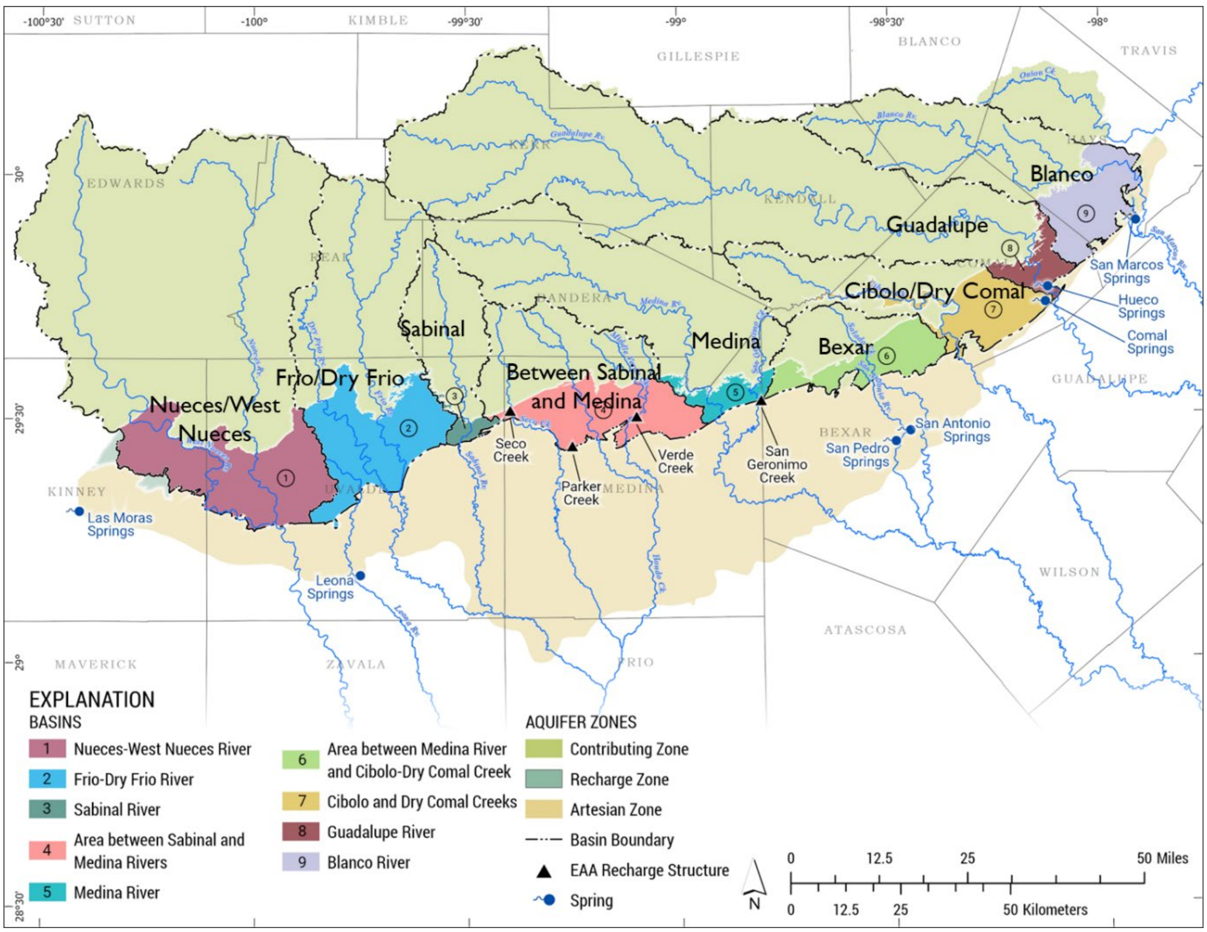


Figure 1-1. Map of the Edwards Aquifer region including the recharge basins described in Puente (1978). Basins are colored where they cross the recharge zone of the aquifer.

One major limitation of the current method for determining recharge is that it relies upon measured stream flows at gages above and below the recharge zone. Besides using precipitation data to calculate upstream and downstream rainfall ratios in basin segments to aid in the separation of baseflow, the Puente method does not incorporate temperature, precipitation, or other environmental factors in its calculation of recharge. As a result, the method is not suitable for calculating future recharge based solely on climate model data.

A surface water–based mechanistic model using Hydrologic Simulation Program-Fortran (HSPF) was developed by the EAA in the 2010s (e.g., Clear Creek Solutions 2012, 2013). HSPF explicitly incorporates precipitation and evapotranspiration data, but discrepancies between the HSPF model recharge estimates and the USGS estimates, especially at high and low flow extremes, resulted in shelving of the HSPF approach.

Thus, one of the major difficulties in assessing future climate-related impacts on spring flows and other aquifer components is the inability to directly estimate recharge from climate data. Further, it is important that methodologies to estimate future recharge be consistent with past measurements of recharge. That is, we would strongly prefer to have a recharge model for future projections that behaves similarly to the Puente method, which has been used extensively in assessments of the effectiveness of various spring flow protection measures enumerated in the EAHCP.

1.2 Artificial Intelligence/Machine Learning–Based Aquifer Recharge Models

After evaluating several approaches to modeling recharge, we used artificial intelligence (AI)/machine learning (ML) models based on ensemble decision tree algorithms encompassing monthly total precipitation, and monthly average minimum and maximum temperatures to develop recharge models for all eight recharge basins that predict historical recharge and project future recharge by month through the year 2065.

In our analyses, we examined four AI/ML models based on boosting and bagging algorithms that exhibited high predictive performance across diverse domains in our recent research (Chakraborty et al. 2021, 2024; Başağaoğlu et al. 2023; Nicolae et al. 2023). These AI/ML models are Extremely Randomized Trees (ERT) (Geurts et al. 2006), Random Forest (RF) (Breiman 2001), Extreme Gradient Boosting (XGBoost) (Chen and Guestrin 2016), and Histogram-based Gradient Boosting (HGBoost) (Guryanov 2019). Boosting algorithms reduce bias and sequentially train models that focus on errors of previous models, making them particularly effective for models with high bias. Complementary to this, bagging algorithms reduce variance and perform average predictions from models trained on different subsets of data, making them effective for models with high variance.

Compared to statistical models, the ensemble decision tree–based AI/ML models used in this study are non-parametric; thus, the model structure does not need to be specified *a priori*. The models can unfold nonlinear relationships and patterns between multidimensional predictors and predictands. Unlike statistical models, they do not rely on prespecified assumptions about the distribution of residuals and the functional form of the equation or non-collinearity among the predictors. Additionally, the tree-based AI/ML models are interpretable and offer better predictive accuracy than traditional statistical models (Chang et al. 2016; Dumitrescu et al. 2021).

The tree-based ensemble AI/ML models chosen for this study are also conducive to integration with explanatory methods, improving the explainability of AI/ML-based decisions (Başağaoğlu et al. 2022). Among the explanatory methods, we coupled the AI/ML models with the Shapley Additive Explanation (SHAP) (Shapley 1953; Lundberg et al. 2020) to generate explainable Artificial Intelligence (XAI) models. These XAI models were used in this study to identify the most influential hydroclimatic features in predicting the aquifer recharge for each basin.

We first assessed the predictive performance of the AI/ML models in generating basin-wide time-series of monthly precipitation totals and average minimum and maximum temperatures for the region. These results were used to supplement the temperature record from 1946 to 1980. Subsequently, we used AI/ML models to predict monthly aquifer recharge for each recharge basin as well as aggregated recharge across the Edwards Aquifer region (EAR) from 1946 to 2023. We then projected aquifer recharge from 2023 through 2065, considering potential future climatic conditions obtained from downscaled GCMs under intermediate- and high-emission scenarios.

1.3 Available Recharge Data

USGS monthly recharge estimates from 1934 to 2022 are complete for all basins with no missing values. These estimates represent the sole historical recharge data available for the EAR. However, due to inherent challenges in direct field measurements of aquifer recharge, these estimates entail uncertainties. As acknowledged in his report, Puente's method is susceptible to greater uncertainties during periods of exceptionally low or high stream flow because gage readings under these extreme conditions may lack precision. Given the absence of direct recharge measurements or alternative recharge estimates in the region, USGS recharge data is regarded as ground-truth data for the AI/ML-based predictive recharge analysis in this study. For the development of the AI/ML recharge model, we selected a subset of the USGS recharge data to focus on the period from November 1946 to December 2022. This period is purposely limited to better correspond with available historical climate data (discussed in the following sections). Moreover, the recharge dataset is split into two parts. One set, from November 1946 to December 2003, is used to train the AI/ML models, while the remainder, from January 2004 to December 2022, is used for validation testing of the models.

Aquifer recharge from the basins within the San Antonio pool, including Seco-Hondo, Bexar, and Cibolo Dry Comal exhibits statistically weaker correlations with recharge from the basins within the Uvalde pool, including Sabinal, Frio-Dry Frio, and Nueces (Figure 1-2), due to different geographical setting of the two pools. Additionally, the Uvalde pool experiences warmer and drier conditions compared to the San Antonio pool. Figure 1-2 further illustrates that recharge from the Medina Basin shows no statistically significant correlation with recharge from other basins within the EAR.

Historically larger recharge peaks, with at least one peak exceeding 100,000 acre-feet (ac-ft)/month, have been estimated for Frio-Dry Frio, Seco-Hondo, Cibolo Dry Comal, and Nueces basins. Lower recharge, with all recharge values falling below 50,000 ac-ft/month, have been estimated for Sabinal, Medina, and Blanco. Notably, aquifer recharge in the Guadalupe River Basin is reportedly considered negligible and is therefore not included in the list of recharge basins in the calculations.

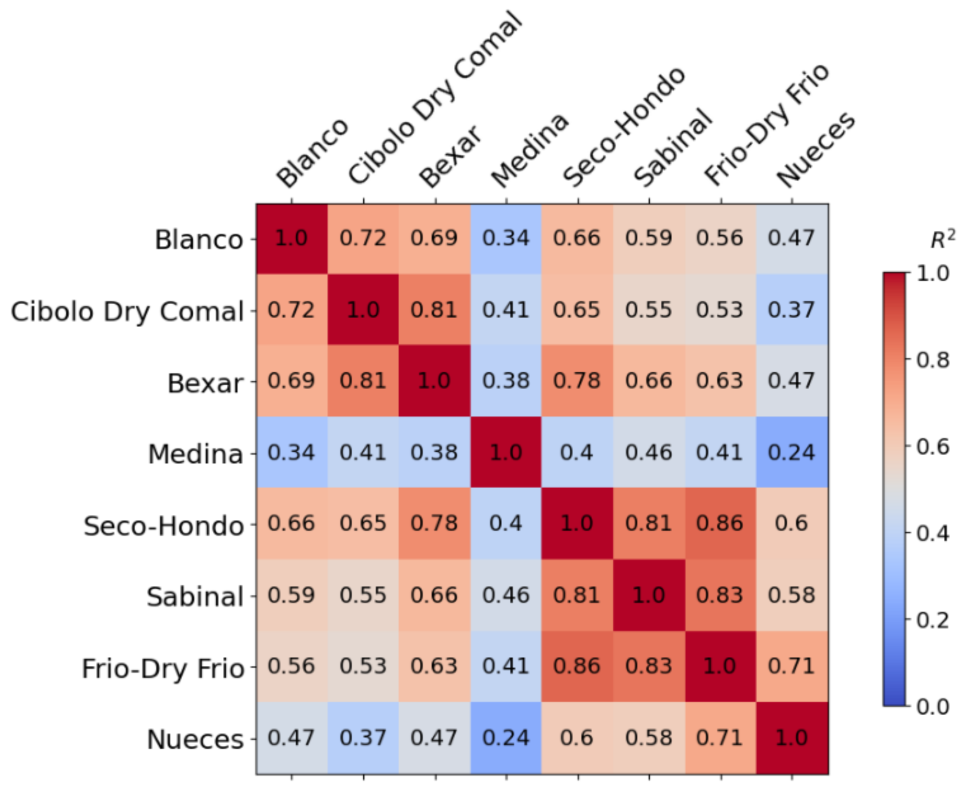


Figure 1-2. Statistical correlation of monthly aquifer recharge from recharge basins within the EAR, using USGS estimated monthly recharge data from January 1934 to December 2022

Temporal variations in recharge estimates within each basin are highly irregular, characterized by multiple isolated large recharge peaks surrounded by lower recharge events, which present challenges for recharge prediction using statistical or AI/ML-based models. These large peaks coincide with major storm events and show close correlations with monthly fluctuations in groundwater levels at the J17 and J27 index wells (Figure 1-3 and Figure 1-4). Large recharge peaks are typically associated with heavy storms and the resulting focused recharge within the EAR. For instance, the 1950s drought of record, which is marked by the longest and most intense meteorological and hydrological droughts in the past century, was ended by back-to-back heavy storm events in 1957 and 1958. This is exemplified by the groundwater response at the J17 well, where groundwater levels rose from 625.2 feet (ft) above mean sea level (amsl) in December 1956 to 650.1 ft amsl in December 1957 and further to 678.0 ft amsl in December 1958, marking an increase of approximately 53 ft over 2 years in response to heavy storm events (Figure 1-3). The rapid recovery of groundwater levels to high-recharge peaks following consecutive heavy storm events is consistently observed in the historical data for the Bexar Basin as well as in other recharge basins within the EAR.

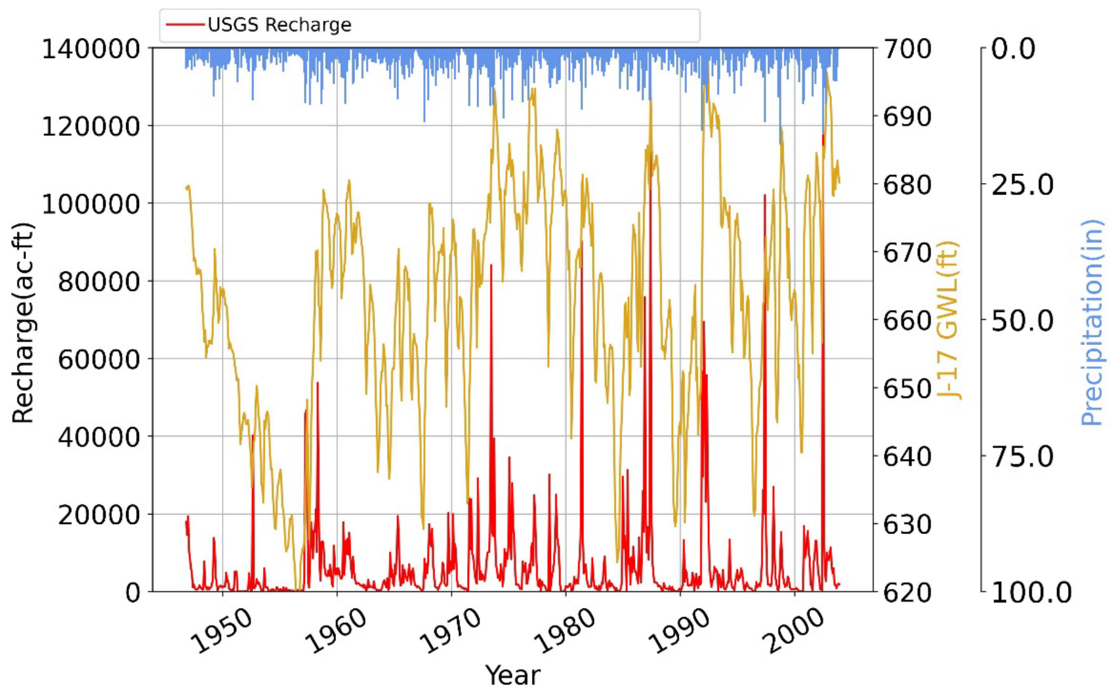


Figure 1-3. Comparison of monthly variations in aquifer recharge estimated by the USGS for the Bexar basin for the period of November 1946 to December 2003 to groundwater levels recorded at the J17 index well and monthly precipitation totals recorded at the SAT

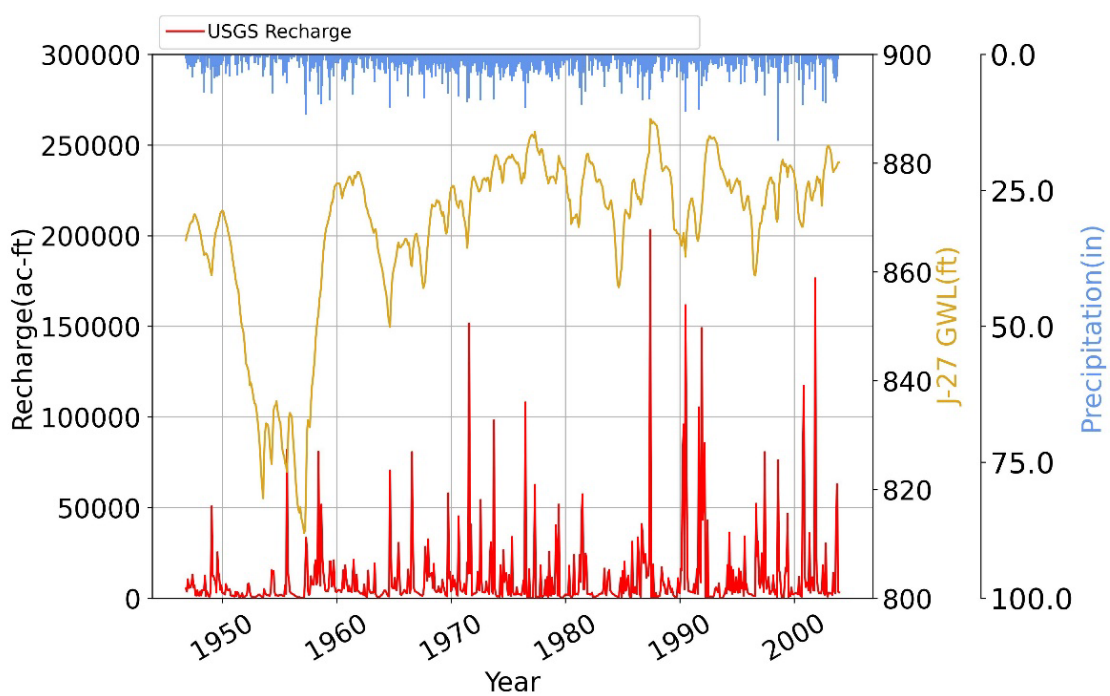


Figure 1-4. Comparison of monthly variations in aquifer recharge estimated by the USGS for the Nueces basin for the period of November 1946 to December 2003 to groundwater levels recorded at the J27 index well and monthly precipitation totals recorded at the SAT

While increases in groundwater levels at the J27 index well correlate with increases in aquifer recharge in the Nueces Basin, the impact of larger recharge peaks on groundwater levels after the year 1960 is less pronounced compared to 1950 through 1956 (Figure 1-4). Groundwater levels at the J27 well did not exhibit extreme declines, comparable to those observed during the drought of record between 1960 and 2003. Interestingly, estimated large recharge peaks in the late 1980s, early 1990s, and early 2000s within the Nueces Basin were associated with considerably smaller recovery in groundwater levels, in comparison to relatively smaller recharge peaks and resulting significantly higher recovery in groundwater levels in the late 1950s.

1.4 Historical Climate Data for the Edwards Aquifer Region

In our predictive and projective recharge analyses, we relate aquifer recharge to climatic forcings, including monthly minimum and maximum average temperatures, and monthly total precipitation, as the same set of climatic variables are available from GCMs. Therefore, it is essential to acquire or generate long-term climate data in each recharge basin for aquifer recharge predictions and projections.

The only comprehensive observed long-term daily climate dataset in the EAR including daily precipitation totals and daily minimum and maximum temperatures is available for the San Antonio International Airport (SAT) location. Climate data for the SAT location have been available since September 1, 1946, and thus cover the period of the drought of record. In addition, gridded daily precipitation totals, daily minimum and maximum temperature at a spatial resolution of 1 kilometer ×1 kilometer are available across the EAR from Daymet version 4 (hereafter Daymet) (Thornton et al. 2022) back to January 1, 1980. The Daymet dataset is the same as was used in our GCM downscaling effort (Wootten et al. 2024).

Also available are monthly precipitation totals at a relatively coarser spatial-scale (1°×1°) beginning in January 1940 from the Texas Water Development Board (TWDB) website (https://waterdatafortexas.org/lake-evaporation-rainfall). In our analyses, monthly precipitation data for Quadrant ID 807 was used for the Nueces Basin, Quadrant ID 808 was used for the Frio-Dry Frio, Sabinal, Seco-Hondo, and Medina Basins, and Quadrant ID 809 was used for the Bexar, Cibolo Dry Comal, and Blanco Basins. Figure 1-5a illustrates that monthly precipitation recorded at the SAT is statistically correlated with monthly precipitation from TWDB Quadrant ID 809, which covers the SAT. The correlation measures, based on the coefficient of determination, R^2=0.76, and root-mean square error of RMSE=1.11 in, reveal a decent correlation, considering the point measurement nature of precipitation data at the SAT compared to precipitation data from the TWDB at its 1°×1° spatial resolution and the spatial variability of precipitation. Figure 1-5b demonstrates that annual precipitation trends recorded at the SAT and those obtained from the TWDB are well aligned. The annual precipitation plot is preferred for enhanced clarity over the monthly precipitation plot.

The availability of such long-term climate data is imperative for effectively training AI/ML models to learn about the relationship between climate forcings and aquifer recharge and to test the predictive accuracy of the AI/ML models in forecasting aquifer recharge before using them for recharge projections. To maintain consistency with the temporal resolution of the historical recharge data, we converted the daily climate data at the SAT to monthly data. Because none of the basins in the EAR have extensive local or regional climate data measurements, the initial step involves constructing basin-averaged long-term climate data for each recharge basin with the help of external data available for the region. Although precipitation measurements display significant spatial variability, the temperature data at the SAT is indicative of temperatures in the San Antonio pool of the EAR. This region is relatively cooler and wetter than the area represented by the Uvalde pool of the EAR.

Because the climate data at the SAT is representative for the San Antonio pool of the EAR, a good statistical correlation between the recorded precipitation at the SAT and precipitation data from the TWDB (Figure 1-5) justifies the use of precipitation data from the TWDB quadrants as analogs for the recharge basins within the EAR. This extends the available historical data beyond the start date of the Daymet data (January 1980). Consequently, the TWDB database furnishes long-term precipitation data prior to 1980 and dating back to 1946 for all recharge basins.

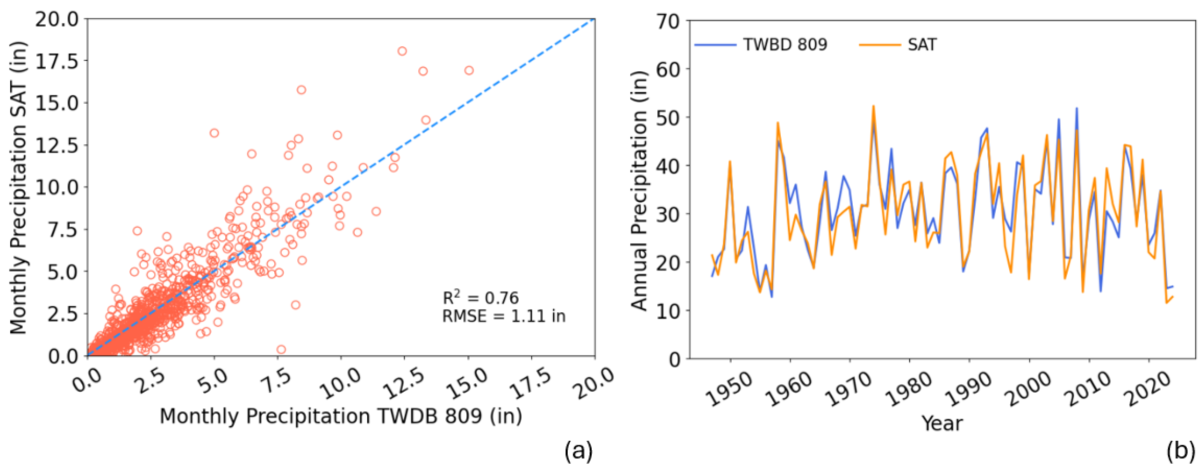


Figure 1-5. Comparison of (a) monthly precipitation data recorded at the SAT to monthly precipitation data from TWDB's Quadrant ID 809, encompassing the SAT, and (b) annual precipitation totals at the SAT and from the TWDB's Quadrant ID 809

The next step involves generating long-term temperature data for all recharge basins. The gridded Daymet temperature data are only available from January 1, 1980, while long-term temperature data that goes back to the 1940s are available only at the SAT. Therefore, we characterized the relationship between basin-specific daily climate data from Daymet and daily climate data from SAT from January 1, 1980, to present (2022) for all basins. In this analysis, we constructed basin-averaged gridded monthly precipitation totals in addition to basin-averaged minimum and maximum temperatures (as described in the following paragraph). Local daily climate data at the SAT were upscaled to monthly data. Figure 1-6 illustrates that the local climate data is statistically well-correlated with the basin-average Daymet climate data using the Bexar basin as an example.

To develop the basin averaged data, three-dimensional—two spatial and one temporal dimension—daily gridded weather datasets were processed to obtain one-dimensional, spatially averaged, monthly time series for input to recharge models. Two gridded weather products were used: Daymet for model training and downscaled GCM outputs for recharge projections. Three variables from each gridded weather product were used for model input: precipitation, minimum temperature, and maximum temperature. The gridded datasets for each variable were spatially averaged to the eight individual river basins associated with USGS recharge estimates (Figure 1-7). To compute the spatial averages, the gridded datasets were masked to the river basins, delineated by vector polygons, using the *mask_3D_geopandas()* method in the *regionmask* Python (https://pypi.org/project/regionmask/) package, and the spatial average of the masked data was computed using the *xarray* Python package. The resulting one-dimensional, daily timeseries was then resampled to a monthly timestep to match the frequency of USGS recharge estimates. The monthly sum was taken for precipitation and the monthly mean was taken for minimum and maximum temperature. Prior to spatial averaging, all gridded datasets with non-standard calendars were converted to standard calendars using the *convert_calendar()* method in *xarray*. Precipitation units were converted to inches (in) and temperature units were converted to degrees Fahrenheit (°F).

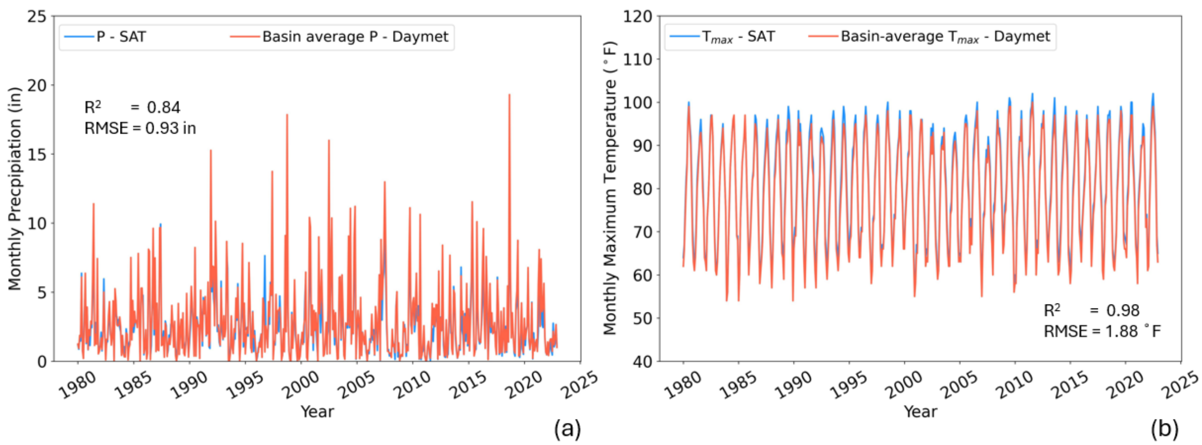


Figure 1-6. Comparison of monthly precipitation (a) and maximum temperature data (b) recorded at the SAT (local) to monthly precipitation data from Daymet for the Bexar basin

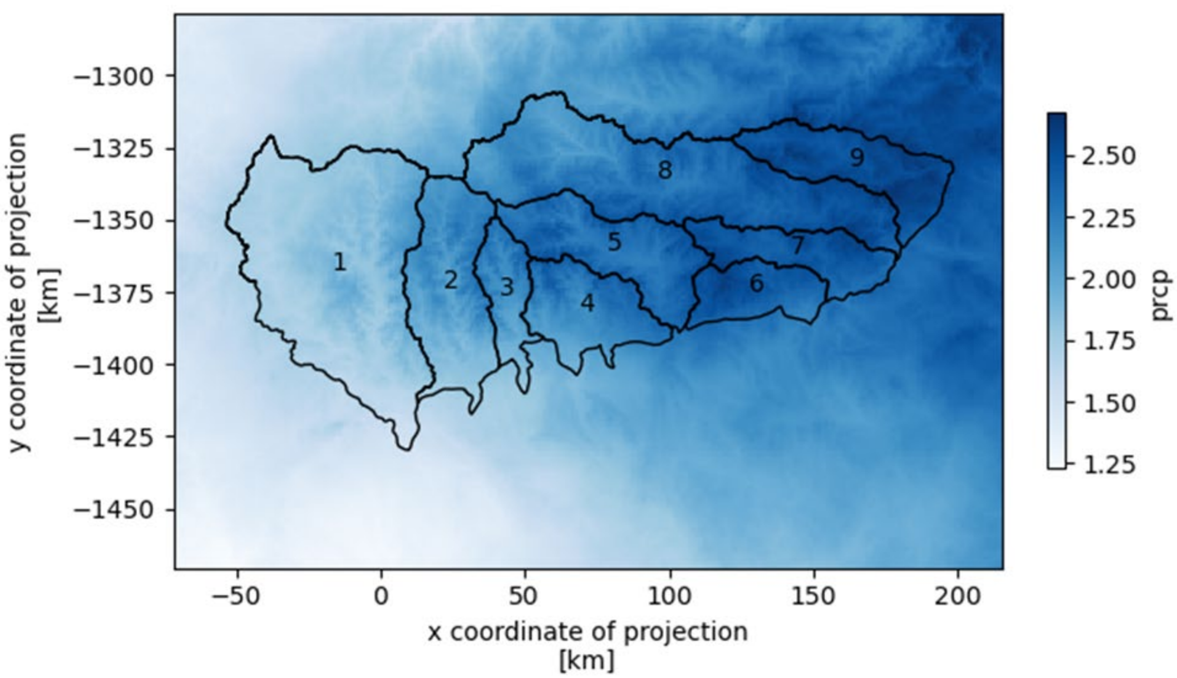


Figure 1-7. Polygons (black lines) delineating the nine major river basins comprising the contributing zone used to spatially average gridded weather datasets, superimposed over the mean daily precipitation (cm) from 1980 to 2022 from Daymet

The relationship between the Daymet climate data and local climate data at the SAT was established next using the AI/ML modeling framework. In this framework, Daymet climate variables are treated as target variables, while local climate variables at the SAT are treated as predictors. We randomly allocated 80% of the data, including the predictors and target variables in a tabular form, for training the AI/ML models and used the remaining 20% of the data, unseen by the AI/ML models during the training phase, to assess their predictive performance. All the models displayed high prediction accuracy relative to the test data. For example, R^2 and RMSE between the local data at the SAT and basin-averaged precipitation data for the Bexar Basin varied in the range of 0.88 to 0.92 and 0.99 to 1.02 in, respectively; for monthly maximum temperature the R^2 and RMSE were 0.994 to 0.995 and 0.97 to 1.42°F, respectively; and for monthly minimum temperature, 0.994 and 0.93 to 0.95°F, respectively.

A comparison of testing data, which encompasses randomly shuffled monthly precipitation totals and monthly maximum temperatures from the Daymet database and the AI/ML-based (using the ERT model) prediction of Daymet data from the SAT is shown in Figure 1-8. The data in the training and testing sets were randomly shuffled to ensure that data from extreme and non-extreme events are included in the training and testing of the AI/ML models in an unbiased fashion. In the end, all the AI/ML models exhibited high prediction accuracy. The ERT model closely matched the timing and magnitude of the peak precipitation values (Figure 1-8). Therefore, it is used in subsequent AI/ML-based analysis as the primary model.

We implemented the same procedure for all the recharge basins, generating an ERT model for each basin using basin-specific climatic data. The trained and tested model for each basin was then used to extrapolate basin-averaged Daymet climate data from 1980 back to 1946, using climate data from SAT as the predictors. In the end, we generated basin-averaged climate data for each basin from September 1946 to December 1979 to supplement the Daymet data. Monthly basin-scale precipitation totals were drawn from the TWDB database, and monthly basin-average minimum and maximum temperatures were extrapolated from basin-average Daymet data using the ERT model. AI/ML-modeled temperatures and TWDB precipitation data from September 1946 to December 1979 were combined with the basin-scale Daymet temperature data and precipitation data from January 1980 through December 2022 to generate climate data for each basin from September 1946 through December 2022.

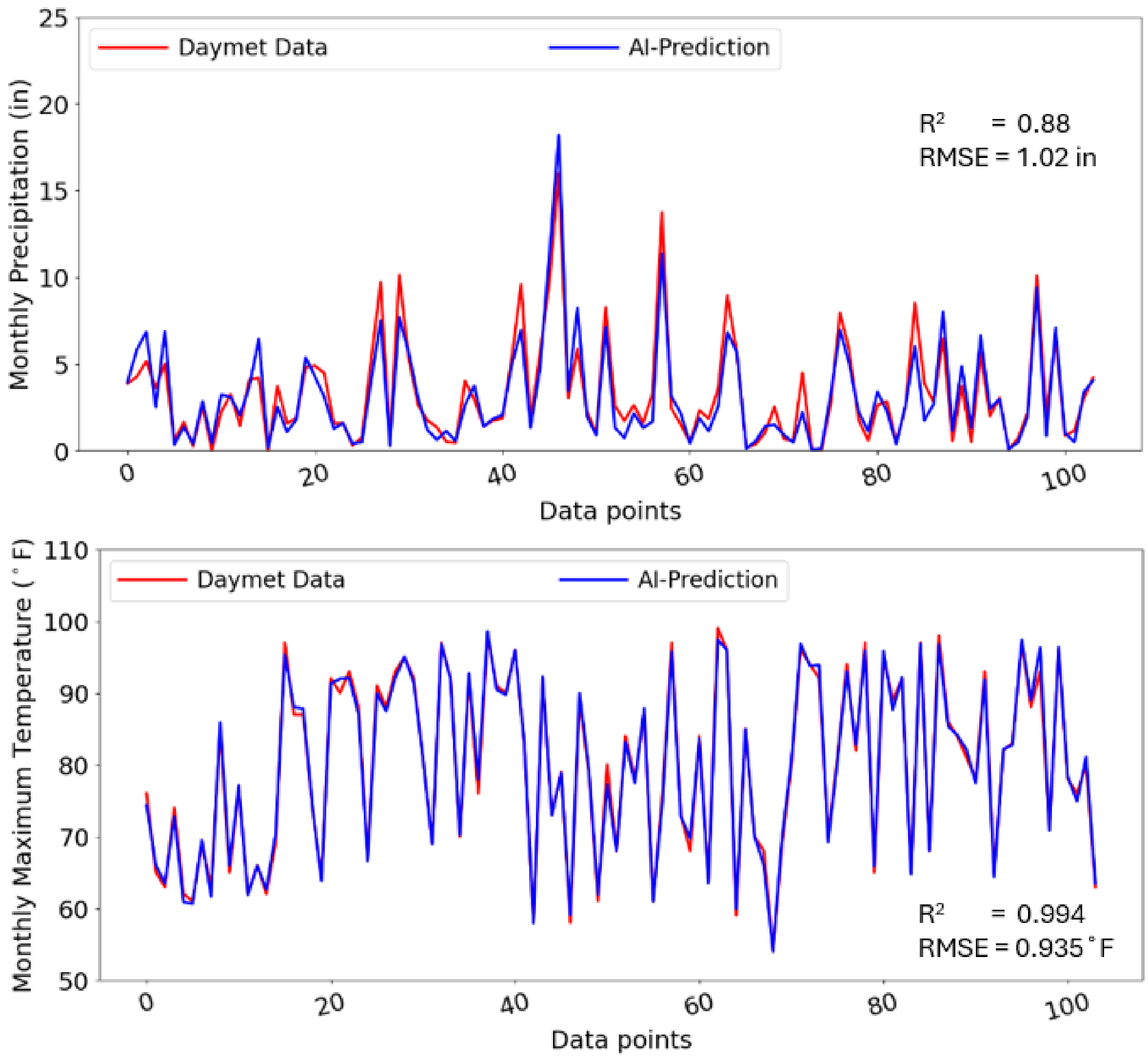


Figure 1-8. Comparison of testing data comprising randomly shuffled monthly basin-average precipitation (top) and maximum temperature (bottom) data for the Bexar basin and their predictions by the ERT model

1.5 AI/ML-Based Aquifer Recharge Predictions

Following the climate data assembly, we next constructed AI/ML models to predict aquifer recharge for a particular basin (i.e., targeted basin) using hydroclimatic variables and their lagged values from the targeted basin, along with those from the neighboring basin to the west and neighboring basin to the east. The AI/ML models in this analysis differ from those used in generating long-term climate data for each basin. Due to lagged variables in the AI/ML-based recharge predictions, the data for the training and testing data sets cannot be randomly shuffled. Recharge predictions must be executed sequentially because the recharge estimate for the current month would be influenced by the estimates for the climatic variables and aquifer recharge for the preceding month. Our analyses indicated that lags exceeding 1 month had insignificant impacts on recharge predictions; therefore, we used only 1-month lag in hydroclimatic variables in the models.

We used hydroclimatic features for the AI/ML model, including monthly precipitation totals, monthly minimum and maximum temperatures, along with their 1-month lags for the targeted basin (e.g., Bexar Basin). Additionally, we included the same climatic features from the adjacent basin to the west (e.g., the Medina Basin for the Bexar Basin) and the adjacent basin to the east (e.g., Cibolo Dry Comal for the Bexar Basin), as well as the recharge value in the targeted basin from the previous month in addition to month as the engineered feature in the AI/ML models. We used the hydroclimatic data from November 1946 to December 2003 to train the AI/ML models and the data from January 2004 through December 2022 to assess the predictive performance of the AI/ML models. In this set-up, 75% of the data was allocated to the training dataset and the remaining 25% was allocated to the testing dataset.

1.5.1 Recharge Model Testing

Using the Bexar recharge basin as an example, the AI/ML model closely captured the time-series of the aquifer recharge and overall trend (Figure 1-9). Similar results were obtained for other basins. Despite highly irregular patterns in the USGS recharge data, the AI/ML-based predictions reproduce the data quite closely. However, there were instances where the USGS model predicted zero recharge during dry periods, whereas the AI/ML models predicted non-zero recharges. For example, during the period of August, September, and October in 2006, while the USGS model predicted zero recharge, the ERT model predicted 204 ac-ft, 507 ac-ft, and 1,886 ac-ft during these 3 months, respectively (Figure 1-9).

The ERT model predictions are in close agreement with the timing and magnitude of monthly aquifer recharge peaks. While the AI/ML models accurately represented temporal fluctuations in aquifer recharge until 2016, they did not entirely reproduce the significant recharge peak in November 2004 (Figure 1-9). For instance, the USGS recharge estimate was 71,171 ac-ft, while the ERT model predicted 31,498 ac-ft and XGBoost model predicted 53,573 ac-ft, which was the closest to the USGS estimate. Two non-zero peaks consistently predicted by the AI/ML models for October 2009 and September 2018 were not captured by the USGS model. In the following section, we delve into these differences in reference to temporal monthly fluctuations at the J17 well and recharge predictions using additional HSPF simulations.

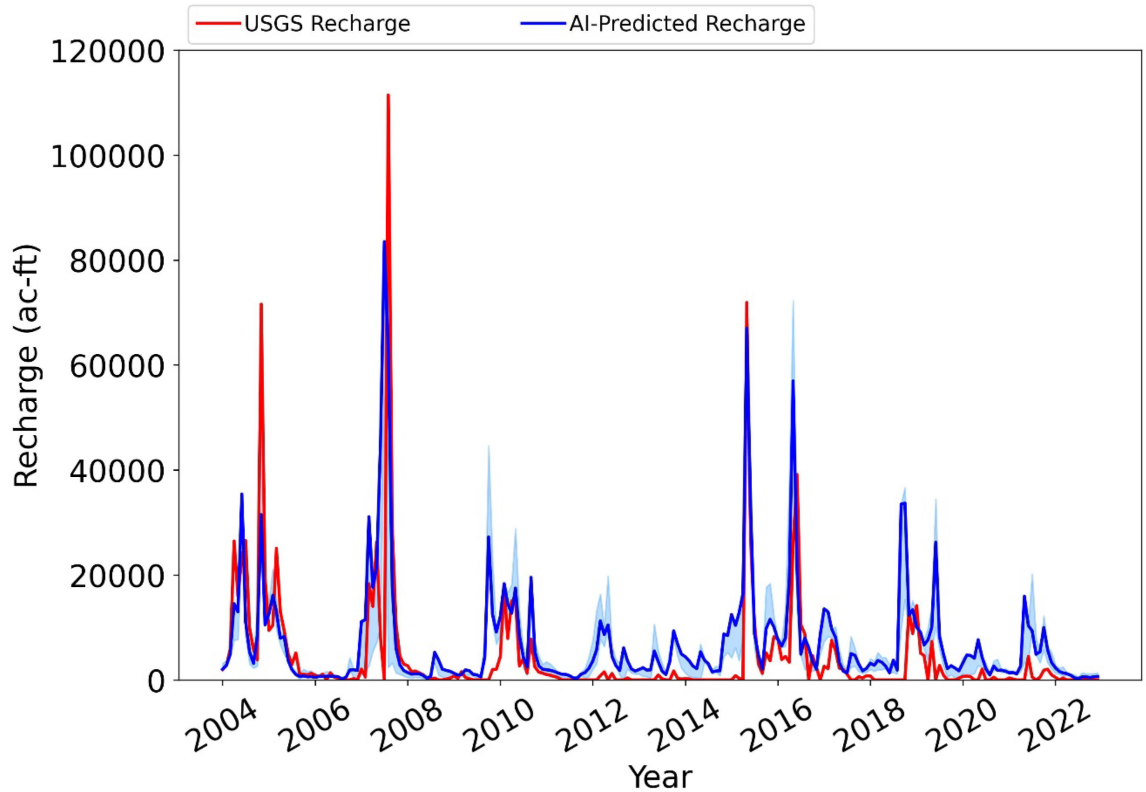


Figure 1-9. AI-based monthly recharge estimates for the Bexar basin. Recharge predictions by the ERT model are shown by the solid blue line, while the light blue shadow represents the uncertainty band formed by the recharge predictions by the ERT, RF, XGBoost, and HGBoost models

We also compare AI/ML-based recharge estimates to USGS recharge estimates for the Nueces Basin in Figure 1-10. Like the Bexar Basin, the significant recharge peaks estimated by the USGS model are well captured by the AI/ML models. Although the magnitudes of the most significant recharge peaks differ (e.g., May 2015), the timing of the recharge peaks is consistent between the two models. In the following section, we delve into these differences in reference to temporal monthly fluctuations in groundwater levels at the J27 well and recharge predictions by HSPF simulations.

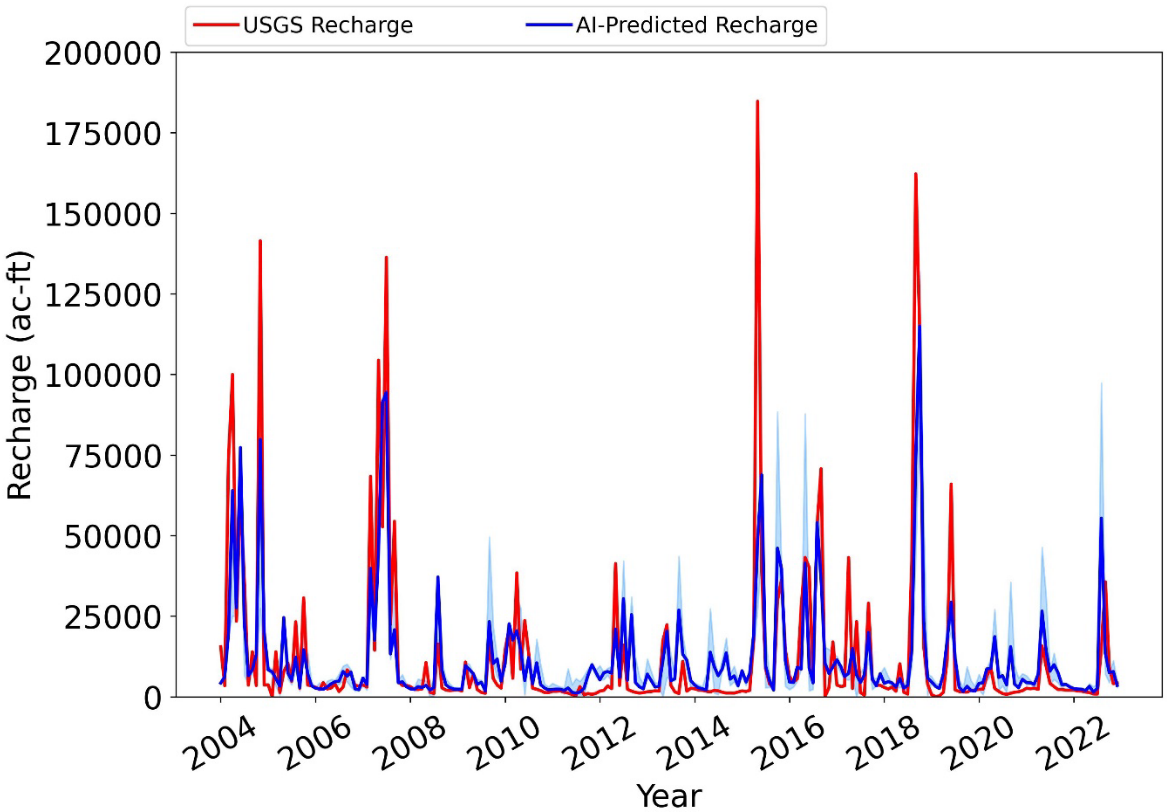


Figure 1-10. AI-based monthly recharge estimates for the Nueces basin. Recharge predictions by the ERT model are shown by the solid blue line, while the light blue shadow represents the uncertainty band formed by the recharge predictions by the ERT, RF, XGBoost, and HGBoost models

1.5.2 Importance of Features in Predicting Aquifer Recharge

The ERT model was coupled with the SHAP method to create an XAI model. The Shapley value represents the average marginal contribution of each predictor value across all possible combinations of predictors. The global explanation from SHAP, as depicted by the beeswarm plot in Figure 1-11, identifies the most influential features, ranked by importance, for accurately predicting aquifer recharge. Predictors with large absolute Shapley values are deemed most important. In Figure 1-11, the importance of the predictors is presented in descending order, with the most influential predictors listed at the top. Hot-colored (red) and cold-colored (blue) dots correspond to the high and low predictor values. Positive and negative of SHAP values on the x-axis correspond to increased or reduced recharge, respectively. For example, increases in precipitation in the targeted recharge basin (TRB), depicted by red dots, are associated with enhanced recharge, as represented by positive SHAP values on the x-axis. Conversely, higher maximum temperatures, denoted by red dots, are associated with reduced recharge, as indicated by negative SHAP values on the x-axis.

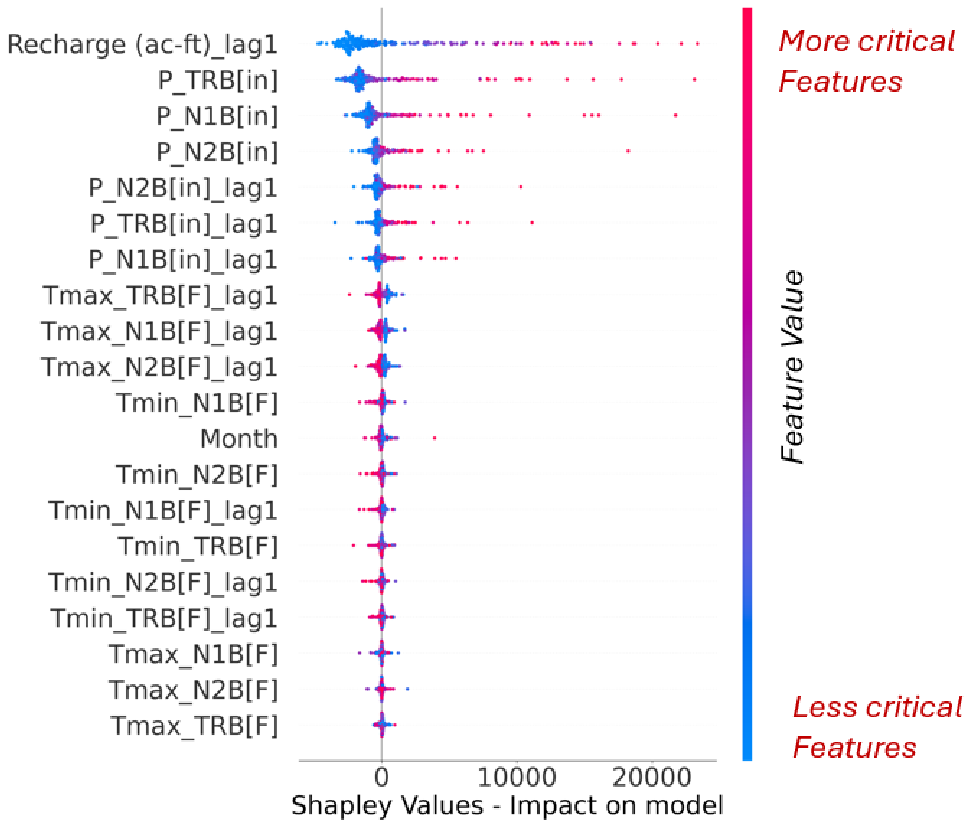


Figure 1-11. The global explanation from ERT-SHAP for aquifer recharge on the testing data. P and T represent monthly precipitation totals and monthly temperatures, respectively. TRB, N1B, and N2B stand for the target recharge basin, neighboring recharge basin west, and neighboring recharge basin east, respectively

The information gained in Figure 1-11 underscores the significance of recharge from the previous month, potentially reflecting antecedent soil moisture conditions, in forecasting recharge in the current month. Moreover, current and lagged values of monthly precipitation totals are more critical than monthly temperatures in predicting aquifer recharge. These findings are applicable to all basins in the EAR.

1.5.3 AI/ML-Based Aquifer Recharge Predictions with Respect to Groundwater Levels at the Index Wells

We examined the disparities in the magnitude and timing of the peak aquifer recharge as estimated by the ERT model and the USGS model. To support this analysis, we used previously developed HSPF models to simulate streamflow and recharge for the Edwards Aquifer system (Clear Creek Solutions 2012, 2013). There are 12 HSPF models comprising nine recharge basins. Groundwater recharge calculated for the Guadalupe River Basin is excluded from the HSPF results to be consistent with the manner in which the Guadalupe River Basin is handled in the Puente (1978) method. Time-series of precipitation and potential evapotranspiration (PET) data are required inputs for the HSPF models. Precipitation and temperature data for the period 2001 through 2022 were extracted from the DayMet V4 dataset (https://daymet.ornl.gov/overview) for use in the HSPF recharge calculations.

Calculation of PET is simplified in the HSPF simulations because of limited data availability. PET is obtained from the reference evapotranspiration (ET_o) using a crop coefficient of 0.85 uniformly distributed across the region. ET_o was calculated with the Hargreaves-Samani method. HSPF estimated recharge for each basin was then used as a check for the AI/ML models.

Using the Bexar Basin as an example (Figure 1-12), the most notable distinctions include: zero aquifer recharge estimated by the USGS for April 2006 is not predicted by the AI/ML models, the non-zero recharge peak predicted by the AI/ML models for October 2009 is not accounted for in the USGS recharge estimation, and the non-zero recharge peak predicted by the AI/ML models for September 2018 is not included in the USGS recharge estimation.

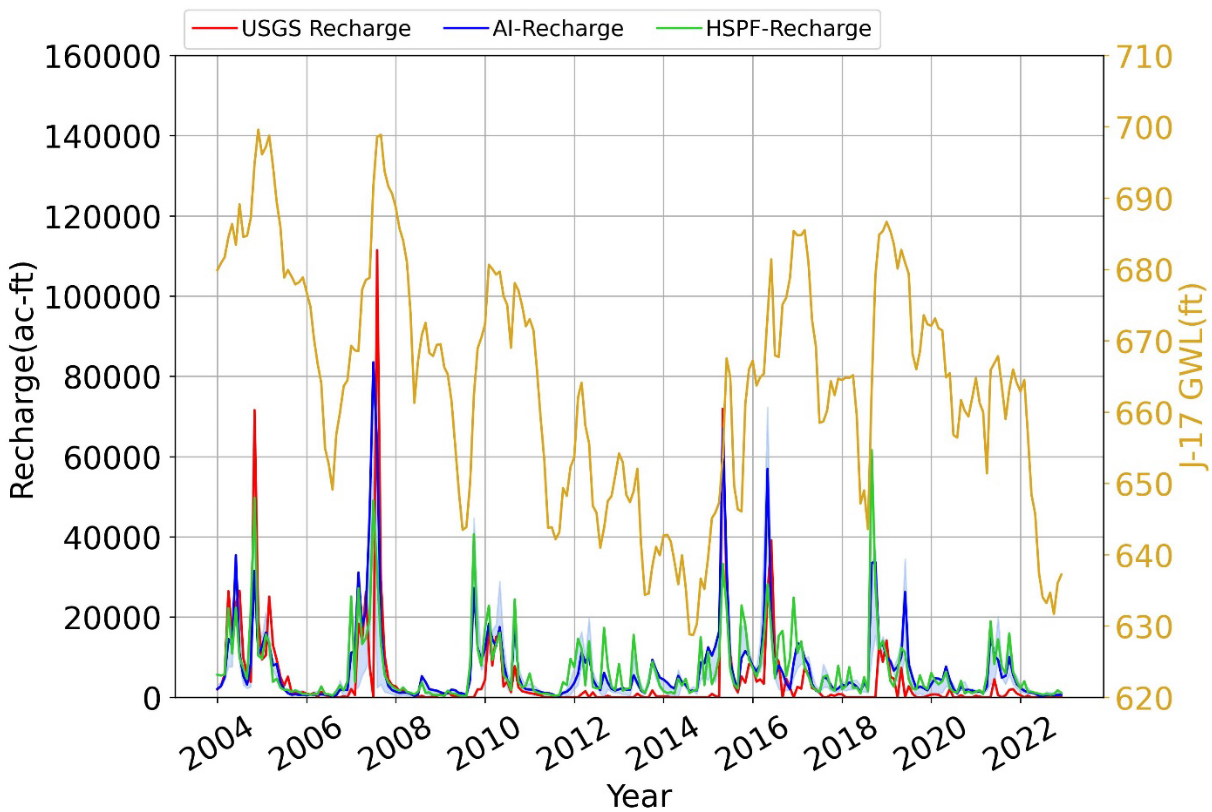


Figure 1-12. AI/ML-based monthly recharge estimates for the Bexar Basin, in comparison to monthly recharge estimates by the USGS model and HSPF model. Recharge predictions by the ERT model are shown by the solid blue line, while the light blue shadow represents the uncertainty band formed by the recharge predictions by the ERT, RF, XGBoost, and HGBoost models. Temporal variations in groundwater levels at the J17 index well are shown as a reference

We explore these discrepancies by incorporating simulation results from the HSPF model, alongside estimates from the data-driven AI/ML models and USGS model in Figure 1-12. Additionally, we incorporate temporal fluctuations in groundwater levels at the J17 well, which is representative of the groundwater system in the San Antonio pool to provide further insight. The AI/ML models do not use groundwater levels at the index wells as a modeling feature, and hence, they are unaware of groundwater conditions at these wells during the prediction process.

As seen in Figure 1-12, during April 2006, groundwater levels at the J17 well rise following a period of decline earlier in the year. This relative change is not consistent with zero recharge recorded for the Bexar Basin in that month. Our in-house HSPF simulations also indicate non-zero recharge in April 2006, consistent with the estimates from the AI/ML models. Similarly, in October 2009, a sharp rise in groundwater levels coincide seamlessly with non-zero recharge predicted by both the AI/ML and HSPF models. Similarly, the larger recharge event in September 2018 identified by the AI/ML and HSPF models correlates well with the significant rise in groundwater levels at the J17 well, but is not consistent with estimates from the USGS model. A confounding factor is that precipitation, while often regionally correlated, can be significantly variable spatially. Thus, the response at J17 may also be influenced by recharge contributions from other basins. However, while not zero, there is low recharge recorded in the other seven basins during these periods—at levels that appear to be insufficient to fully account for the level changes at J17.

These discrepancies between groundwater levels at the index well and recharge predictions by the USGS model for recent years for the Bexar Basin could lead to disparities in annual and cumulative recharge estimates from each of the recharge models. Zero recharge predicted by the USGS model, contrasted with small non-zero recharge responses to small precipitation events during relatively dry periods as predicted by the AI/ML and HSPF models, may also contribute to disparities.

As shown in Figure 1-13, increases in groundwater levels at the J27 index well, representative of groundwater conditions in the Uvalde pool of the Edwards Aquifer, exhibit strong correlation with aquifer recharge events estimated for the Nueces Basin by the USGS, AI/ML, and HSPF models. Although the timing of the significant recharge events is well aligned from all models, aquifer recharge peaks predicted by the USGS are, in general, larger than the estimates by the AI/ML and HSPF models. However, the relative magnitudes of recharge peaks within each model remain consistent in relation to changes in groundwater levels at J27. In essence, greater Nueces Basin recharge in the USGS model is required to produce increases in groundwater levels at the J27 well when compared to AI/ML and HSPF modeled recharge. In contrast to the Bexar Basin, fewer instances of zero recharge events are predicted for the Nueces Basin by the USGS model, which better aligns with predictions of the AI/ML and HSPF models—as might be expected, there are reduced uncertainties under a perennial flow regime compared to the ephemeral streams in the Bexar Basin. Consequently, the AI/ML models trained on historical data at the Nueces Basin predict recharge more consistently, and the predictions are well aligned with the fluctuations in groundwater levels at the J27 index well.

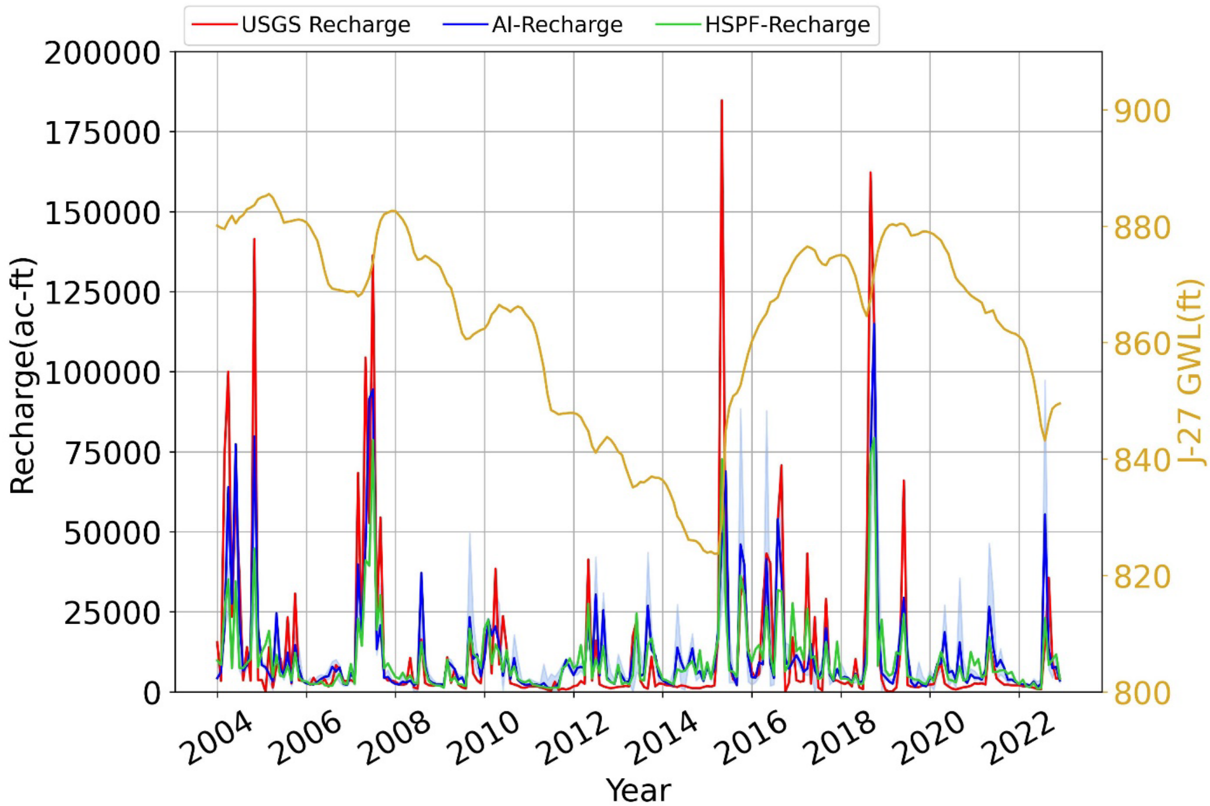


Figure 1-13. AI/ML-based monthly recharge estimates for the Nueces Basin, in comparison to monthly recharge estimates by the USGS model and HSPF model. Recharge predictions by the ERT model are shown by the solid blue line, while the light blue shadow represents the uncertainty band formed by the recharge predictions by the ERT, RF, XGBoost, and HGBoost models. Temporal variations in groundwater levels at the J17 index well are shown as a reference

1.5.4 AI/ML-Based Aquifer Recharge Predictions and Adjustments

As discussed in the previous sections, the USGS model often attributes zero recharge during dry periods, whereas the AI/ML and HSPF models often predict non-zero recharge values during these same periods, partly in response to small precipitation events within a basin. Consequently, cumulative recharge values diverge as the AI/ML and HSPF models aggregate non-zero recharge values. This is evident in Figure 1-14.

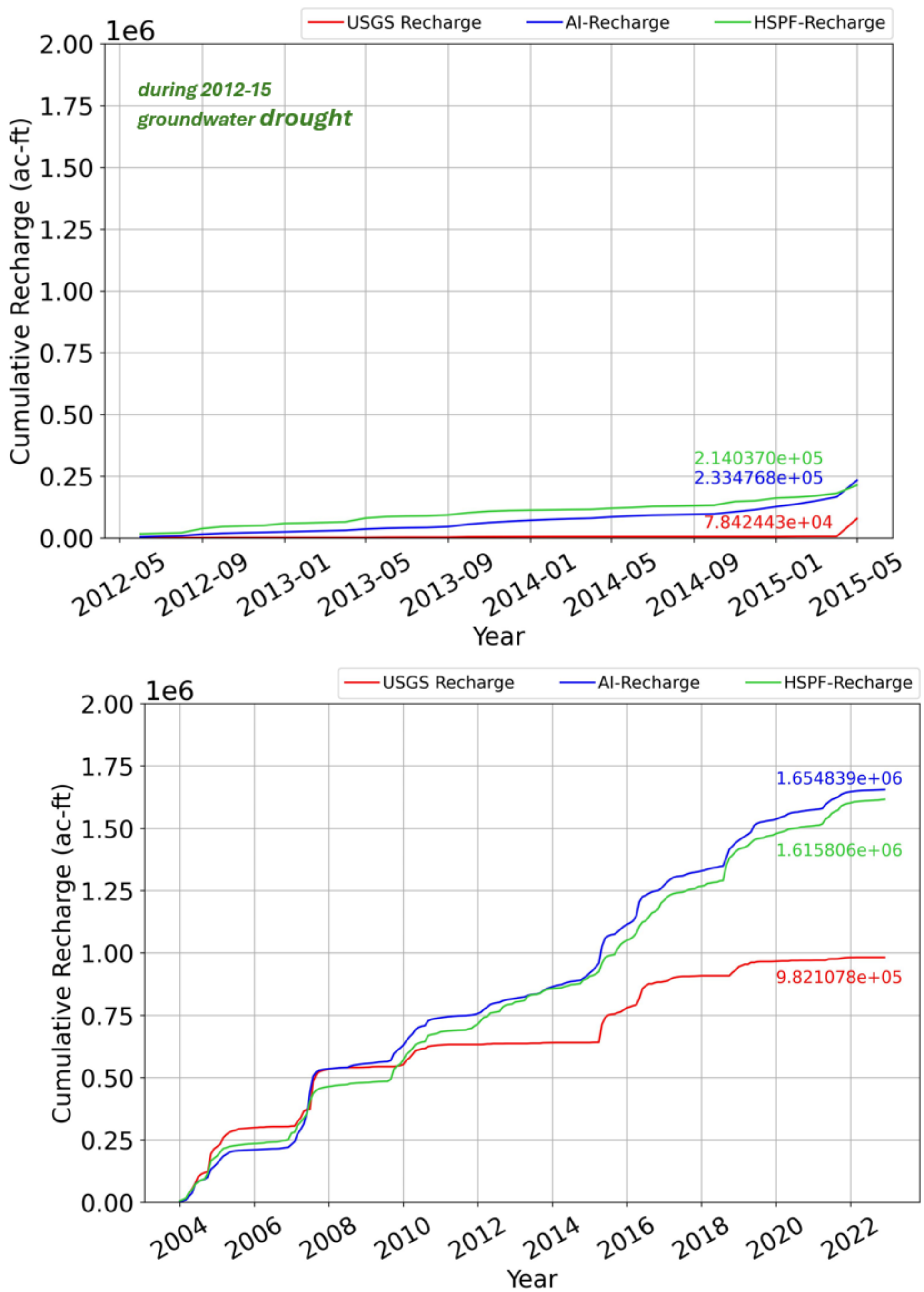


Figure 1-14. Cumulative aquifer recharge in the Bexar Basin during the 2012–2015 drought period (top panel) and for the entire testing period (2004–2022) (bottom panel) as estimated by the USGS (red), AI/ML (blue), and HSPF (green) models

Figure 1-14 (top panel) presents calculated recharge estimates for the Bexar basin as estimated by the USGS, AI/ML, and HSPF models. Both the AI/ML and HSPF models predict greater cumulative recharge relative to the USGS model during the 2012 through 2015 drought period. These differences occur for many basins during short-term drought events and contribute to divergence between USGS and AI/ML model recharge predictions. If we introduce a threshold for the AI/ML-based predictions, below which aquifer recharge during drought periods is set to zero to mimic the USGS model estimates, we obtain results like those shown in Figure 1-15 in which the AI/ML model correlation with the USGS model is much improved.

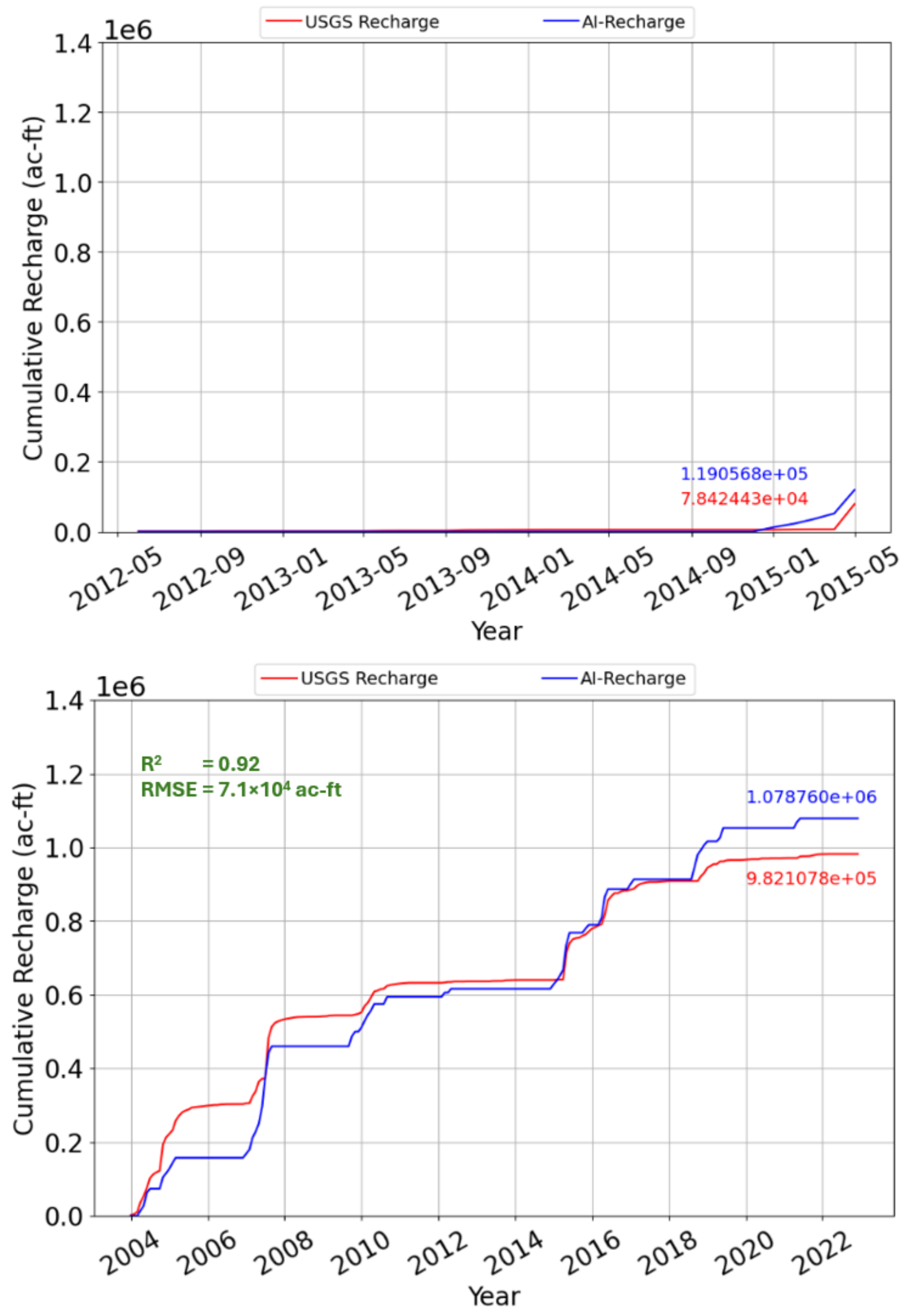


Figure 1-15. Cumulative aquifer recharge in the Bexar Basin during the 2012–2015 drought period (top panel) and for the period 2004–2022 (bottom panel) as predicted by the USGS (red) and AI/ML (blue) models. A recharge threshold of 10,000 ac-ft is used to set monthly recharge values below 10,000 ac-ft in the Bexar Basin to zero

We determined recharge threshold values for AI/ML-based recharge predictions for each basin, below which aquifer recharge is presumed to be zero, to mirror the outcomes from the USGS model. The values were selected by maximizing the R^2 values of the model relative to the USGS estimates. Threshold recharge values range from 0 (for the Nueces Basin) to 20,000 ac-ft (for the Seco-Hondo Basin). By implementing these threshold values, the USGS estimated aquifer recharge and AI/ML-predicted aquifer recharge in each basin displayed improved correlations with R^2= 0.88–0.98 and RMSE= 3.7×10^4 –1.92×10^5 ac-ft for the period of 2004 through 2022. Figure 1-16 and Figure 1-17 present the final recharge model results after implementation of the threshold values.

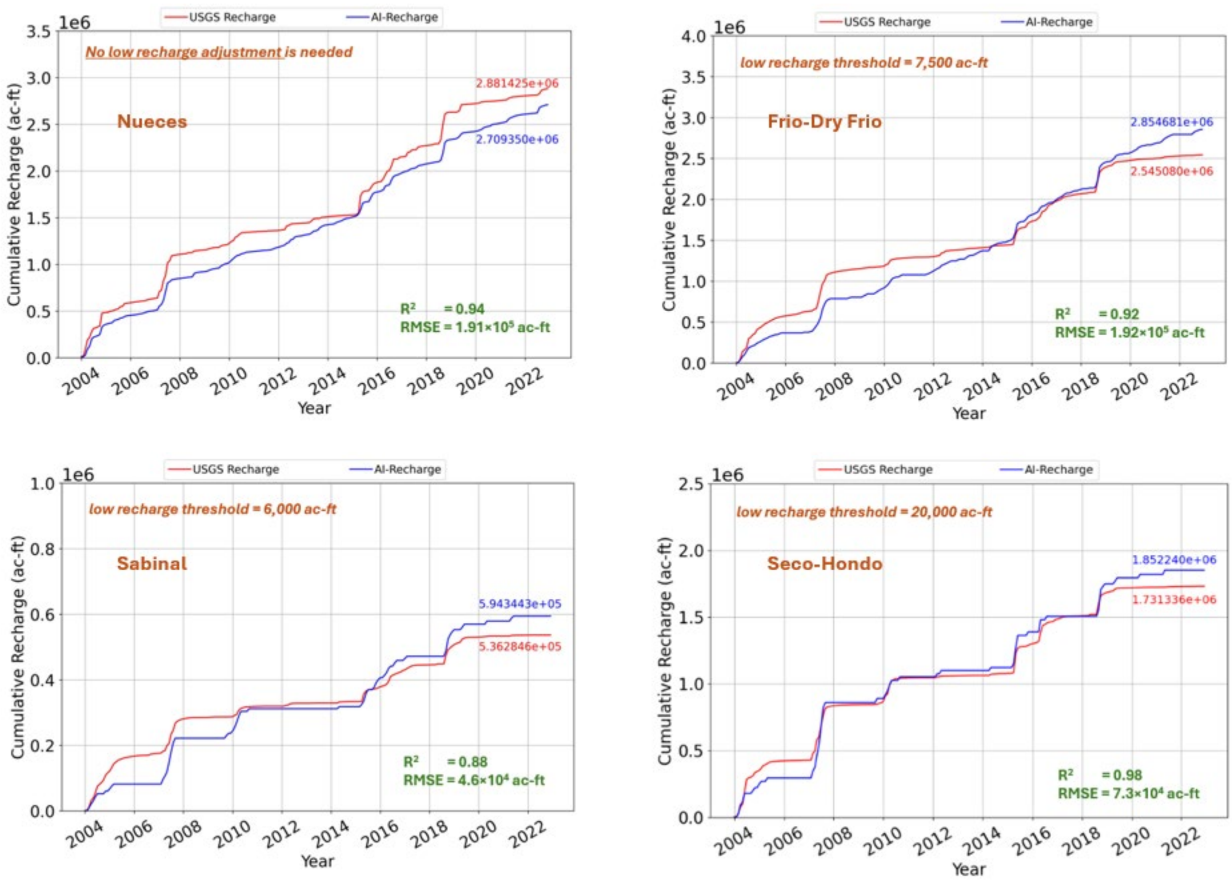


Figure 1-16. Comparison of cumulative aquifer recharge for the Nueces, Frio-Dry Frio, Sabinal, and Seco-Hondo Basins for the period from 2004–2022, after application of threshold values to reduce AI/ML modeled recharge during drought periods

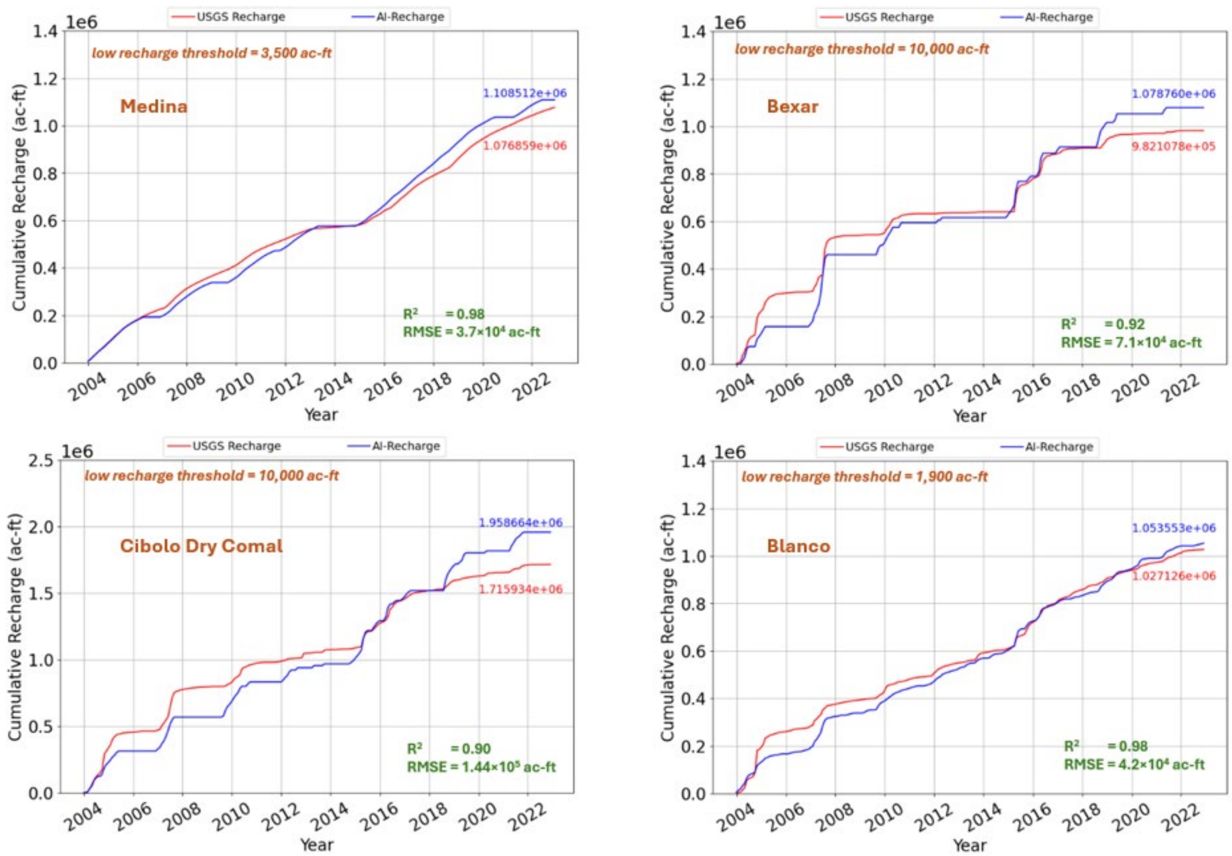


Figure 1-17. Comparison of cumulative aquifer recharge for the Medina, Bexar, Cibolo Dry Comal, and Blanco Basins for the period from 2004–2022, after application of threshold values to reduce AI/ML modeled recharge during drought periods

Total cumulative recharge predicted by the ERT model across the EAR, after implementing basin-specific recharge thresholds, is presented in comparison to USGS recharge estimates in Figure 1-18. The AI/ML model estimate, for which the 2004 through 2022 USGS recharge was not used to train the model, reproduces the USGS values quite well. The total difference in cumulative recharge between the two models for the entire EAR over the 18-year test period is about 6%.

As confirmed by comparison to values during the test period from 2004 through 2022, the AI/ML models for each recharge basin reasonably reproduce the timing and magnitude of recharge consistent with the Puente (1978) approach. Figure 1-19 shows a comparison of USGS estimated annual recharge and the ERT model predicted annual recharge for each basin. Median values of recharge and the range of recharge values for each basin during the test period (2004–2022) compare favorably.

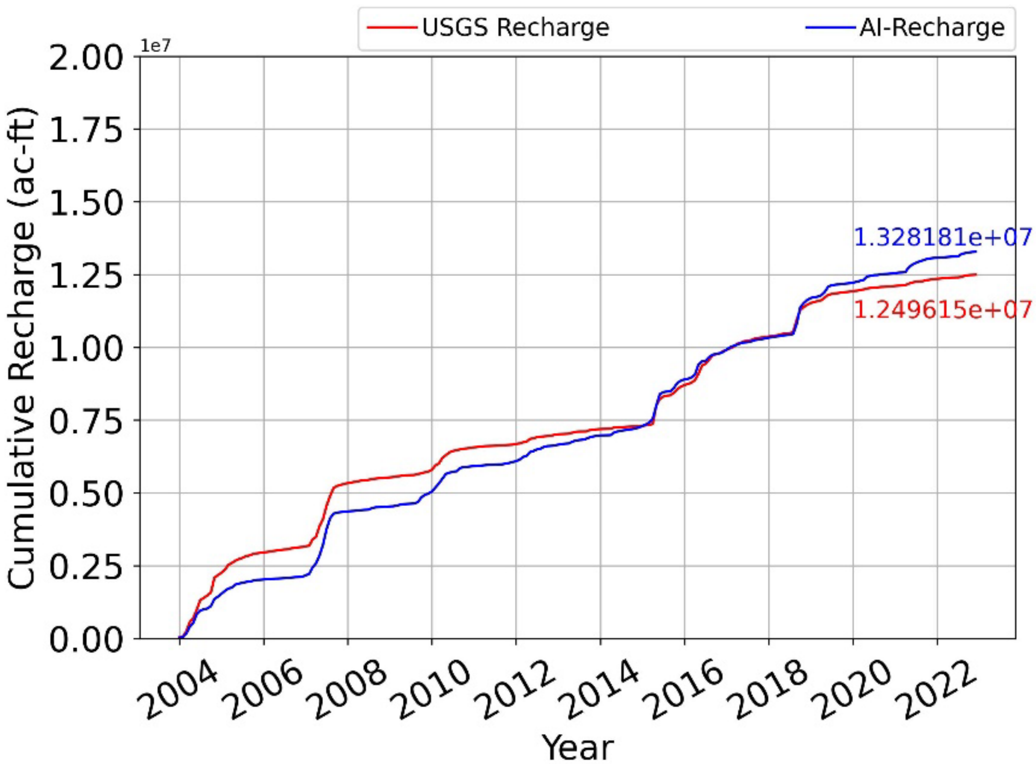


Figure 1-18. Comparison of cumulative aquifer recharge for the entire EAR for the period from 2004 through 2022, when a threshold recharge, below which AI-predicted aquifer recharge is presumed to be zero to replicate the outcomes from the USGS recharge model

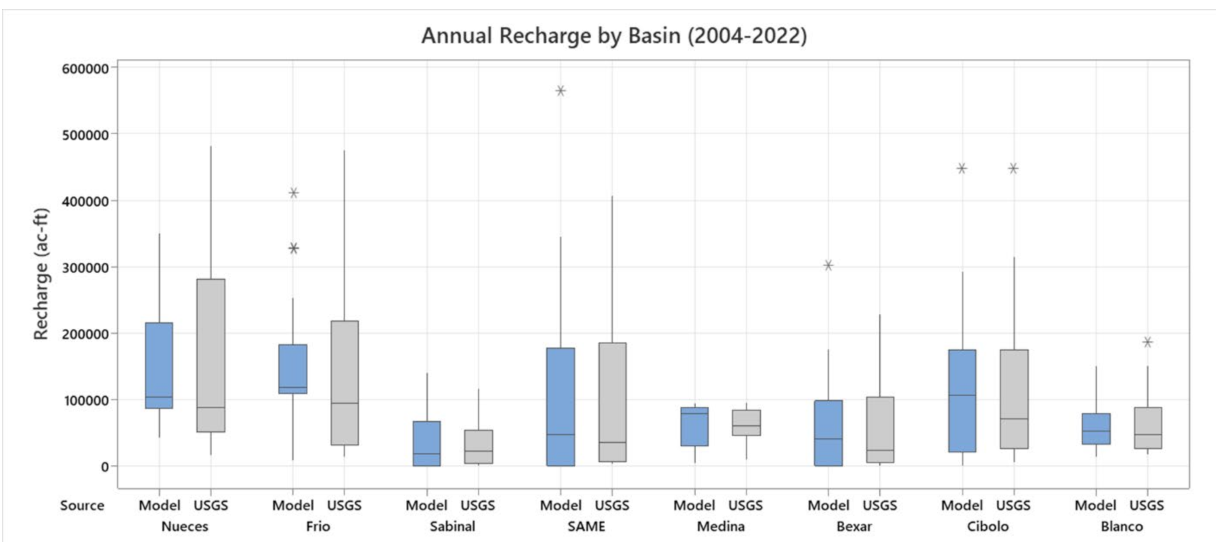


Figure 1-19. Box plot of annual recharge for each basin for the period 2004–2022. AI/ML model predictions are in gray and USGS calculated values are in blue

1.6 Recharge Projections Under Future Climate Conditions

Scenario-based future climatic conditions were derived from GCMs, using a statistical downscaling method focused on the EAR (Wootten et al. 2024). Time-series data for temperature and precipitation from each of the 19 GCMs assessed in our downscaling effort were used in combination with the AI/ML recharge models to produce projections of recharge for the Edwards Aquifer for the period 2023 through 2065. Recharge projections were generated by month for each basin and organized for input to subsequent groundwater flow modeling.

An example of projected aquifer recharge generated from two GCMs under differing emissions scenarios (i.e., four of the 19 GCMs) for the Bexar recharge basin is shown in Figure 1-20. The variability in projected recharge rates based on different GCM models and the emission scenarios is evident in the figure. For example, while aquifer recharge projections for the Bexar Basin are high when using the data from HadGEM2-CC under the intermediate emissions scenario, projections derived from the KIOST-ESM under the intermediate emission scenario are lower. Notably, these lower projections from the KIOST-ESM are comparable to projected recharge from the HadGEM2-CC under the high-emission scenario. Among the four projections in Figure 1-20, the most concerning recharge conditions, potentially posing a higher risk to groundwater sustainability, are observed in the future recharge projection using data from KIOST-ESM under the high-emission scenario. However, while basin-scale recharge estimates are informative, the actual effects on groundwater levels and spring flows requires evaluation in a flow model.

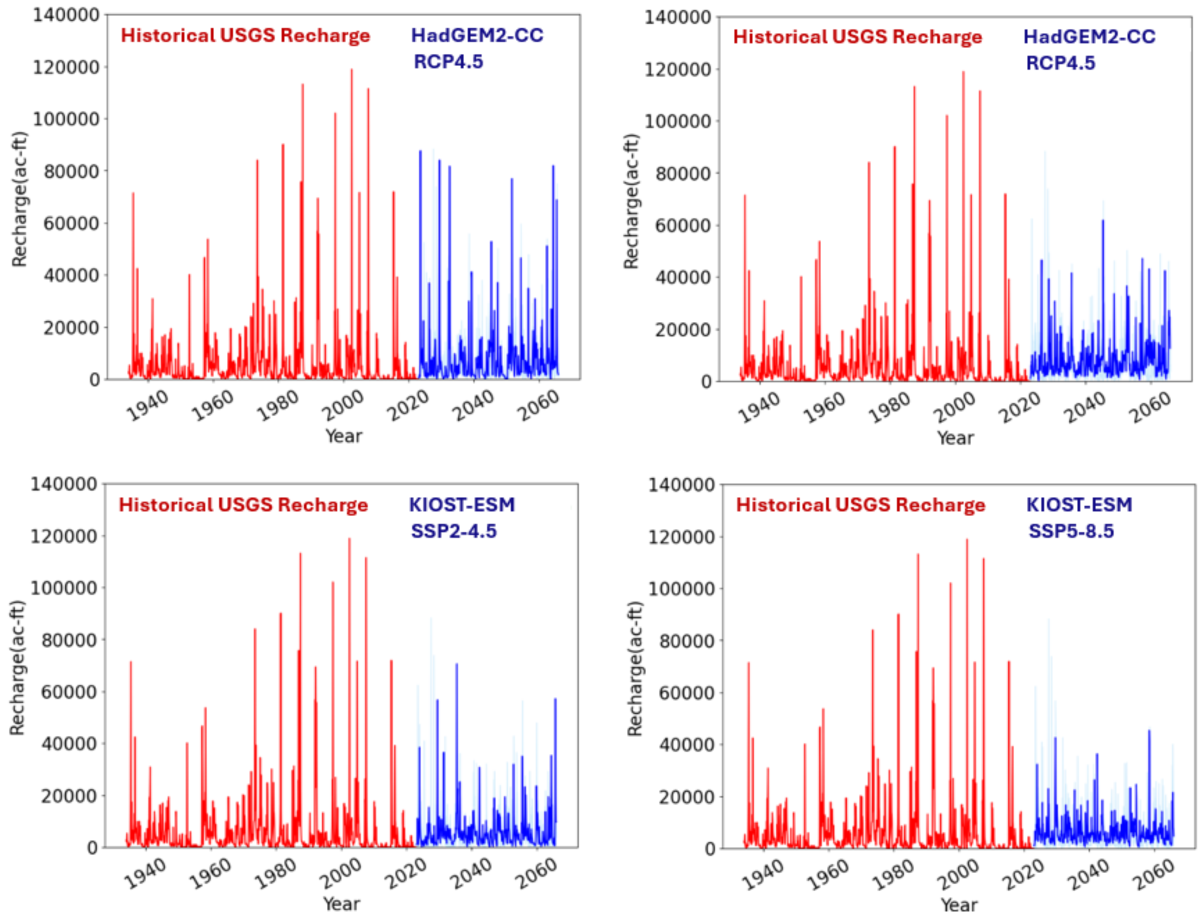


Figure 1-20. Projected aquifer recharge for the Bexar recharge basin using downscaled climate data from 2023 through 2065, sourced from two GCMs, including a CMIP5 (HadGEM2-CC) and CMIP6 (KIOST-ESM) models under intermediate- and high-emission scenarios. These are the AI-based recharge predictions, not incorporating recharge thresholds. Recharge predictions by the ERT model are shown by the solid blue line, while the light blue shadow represents the uncertainty band formed by the recharge predictions by the ERT, RF, XGBoost, and HGBoost models

The cumulative total projected monthly recharge across all basins from 2023 through 2065 are shown in Figure 1-21. Also shown is the cumulative historical total monthly recharge for the period 1980 through 2022. Projected recharge from most GCMs is less than the recharge observed in the recent past, irrespective of the modeled emission scenario (Figure 1-21).

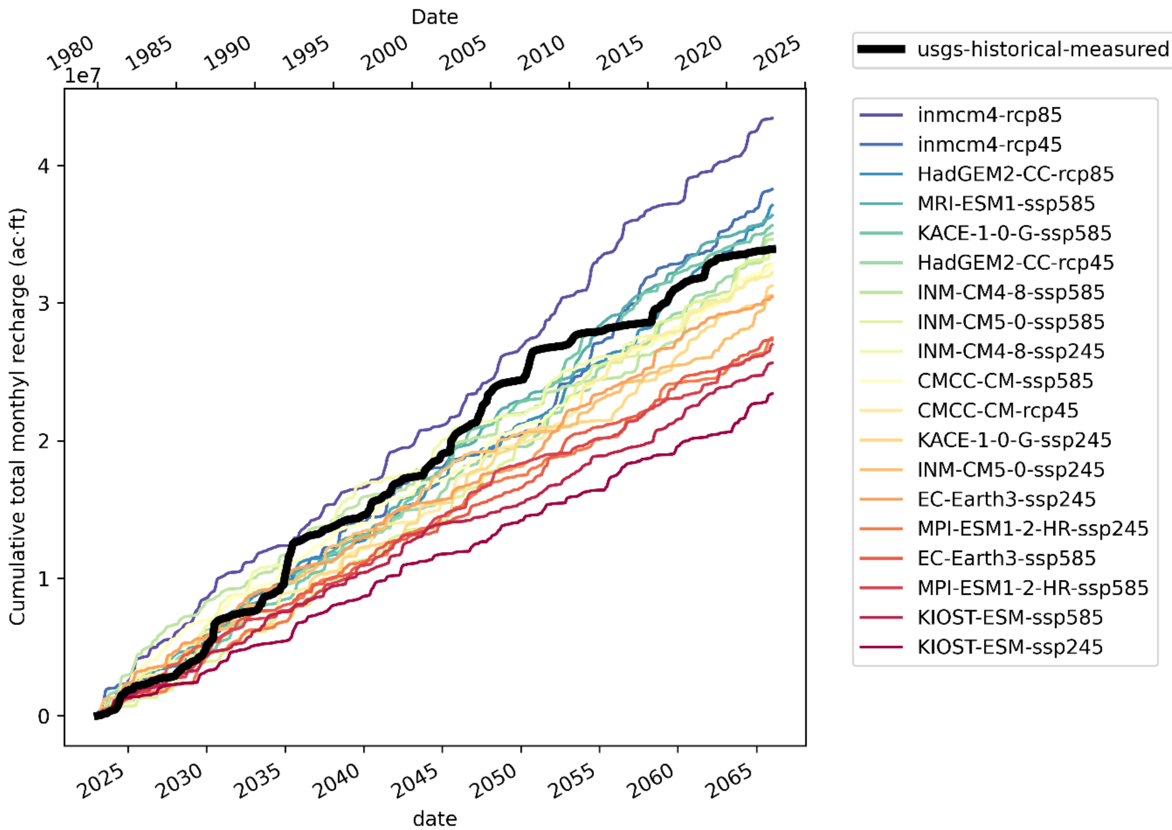


Figure 1-21. Projected cumulative monthly total recharge from each GCM (colored lines) for the period 2023–2065. Cumulative monthly historical recharge for the period 1980–2022 is shown by the heavy black line

A box plot summary of the projected (2023–2065) total monthly recharge for each GCM is shown in Figure 1-22. Also shown is a box plot of total monthly historical recharge for the period 1934 through 2022. Projected values of recharge bracket historical recharge for the Edwards Aquifer. The ranges and magnitudes of the projections are not dissimilar to the range of recharge experienced in the past, which suggests that the associated groundwater modeling results are likely to vary in range and magnitude that are similar to historical observations.

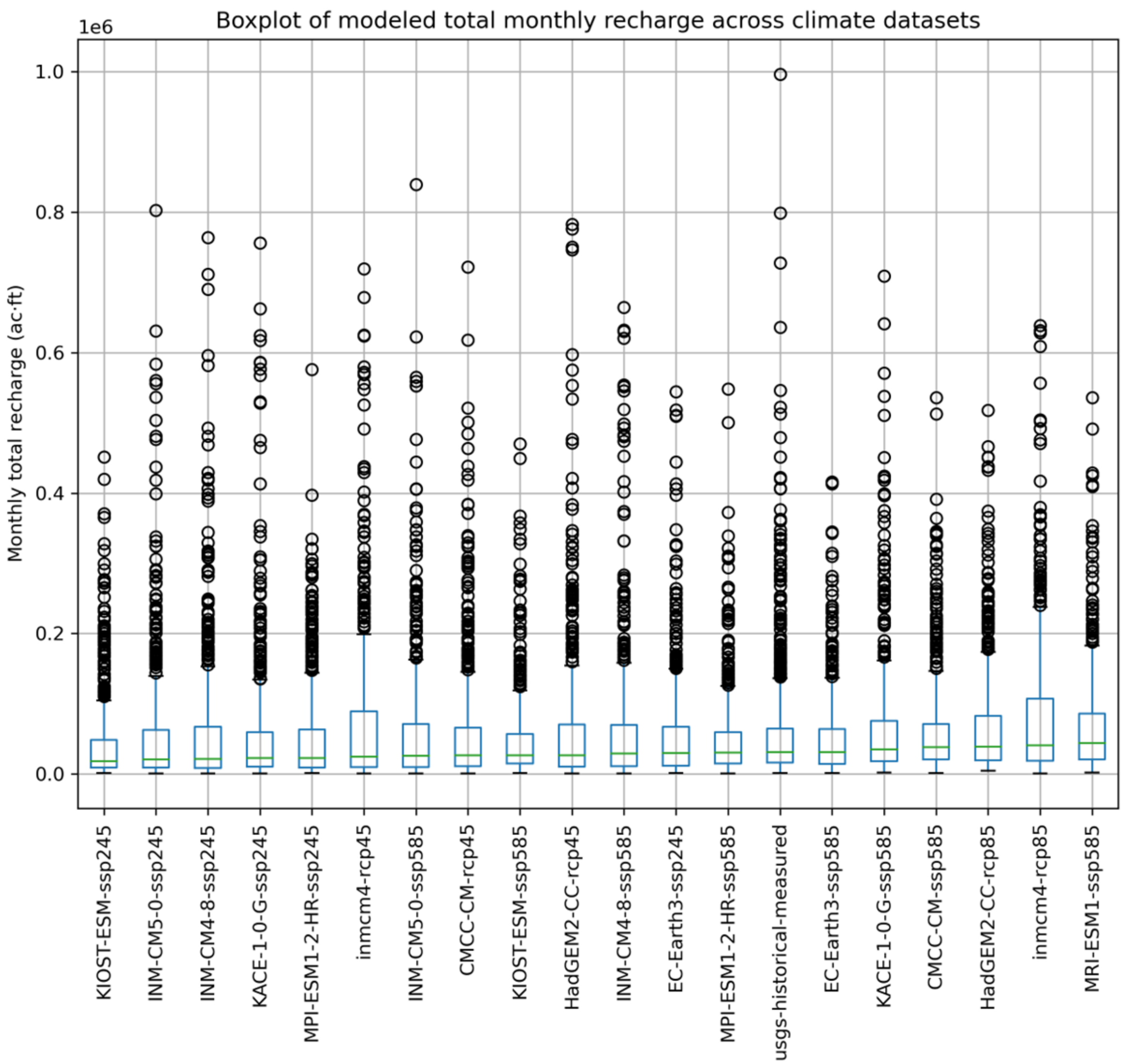


Figure 1-22. Box plots of projected total monthly recharge for the Edwards Aquifer from each GCM for the period 2023–2065. Measured historical recharge for the period 1934–2022 is also shown for comparison. Note the projections and historical recharge box plots are ordered by their median recharge values

Chapter 2

Projected Spring Flows Under Future Climate Conditions: MODFLOW Modeling Analysis

The USGS modular finite-difference groundwater flow (MODFLOW) modeling program was used to estimate groundwater levels and spring flow under varying recharge and discharge conditions for the Edwards Aquifer (Lindgren et al. 2004). This hydrogeologic numerical simulation model has served as the basis for subsequent evaluations of critical period management (CPM) measures and options for spring flow protection during development of the EAHCP (RECON et al. 2012; HDR 2011). The HDR (2011) version of the model is informally referred to as the "Bottom-Up package" or "Bottom-Up model." The Lindgren et al. (2004) model was updated in 2017 to add conceptual features and improve model calibration using more recent pumping and recharge data (Liu et al. 2017). The updated model of Liu et al. was then used in conjunction with the management modules created for the earlier EAHCP analyses (HDR 2011) to run the EAHCP Phase II model simulations. Model construction, modifications, simulations, and the associated results are thoroughly documented in the model reports (Lindgren et al. 2004; Liu et al. 2017) and technical memoranda associated with the EAHCP Phase II analyses (Appendix C; Furl 2019) including the review by the EAA-appointed Groundwater Model Advisory Panel (Liu et al. 2017:Appendix), the National Academy of Sciences (NAS) Reports 1–3 covering the EAHCP (NAS 2015, 2017, 2018), and technical presentations delivered to the NAS panel and EAHCP Science Committee (www.eachp.org).

The information provided in the following sections summarizes work to update and verify model files used in this analysis and to incorporate recharge projections developed from the climate model data that are described in Chapter 1. We also provide a brief outline of model results to highlight various trends in projected spring flows.

2.1 Model Preparation

The EAHCP Phase II version of the MODFLOW model used in these simulations was not substantively changed from the previous calibrated version developed by Liu et al. (2017). Some modifications to input files and the execution of the model were required to incorporate a longer period of analysis, reduce potential errors in generating input files, and to simplify and make the running of each simulation more efficient.

The EAHCP Phase II model is configured for a 12-year numerical simulation that includes the drought of record period (1947–1958) with a total of 144 stress periods (months). To accommodate a proposed ITP renewal period of 30 years (i.e., 2028–2058), and to be consistent with the mid-century timeframe commonly used in future climate modeling, a simulation period spanning from 2023 through 2065, totaling 43 years with 516 stress periods (months), was established for this modeling effort. The period from 2023 through 2027 is included to minimize the impacts of the initial aquifer conditions on the simulated spring flows. However, sensitivity analysis suggests that the initial aquifer conditions exhibit minor impacts on simulated spring flows only within the first 3 to 7 stress periods (months) of any model run.

Several MODFLOW-specific packages were revised to simulate the additional stress periods. These packages include the DIS package for spatial and temporal discretization, the DRN package for the parameters of the spring drainage features, the OC package for controlling model output, the MPW package for implementing well pumping management, the RCH package for distributing recharge, and the WEL package for the well pumping. No modifications are made to the other MODFLOW packages, including the BAS package that specifies the locations of active and inactive cells and the initial heads in all cells, the LPF package for the aquifer parameters, and the HFB package for horizontal barriers.

Updates to the DIS package are made solely for the time discretization section, which includes a total of 516 stress periods. No modifications are made to the spatial discretization section defined in the DIS package, such as the top and bottom elevations of the Edwards Aquifer. Updates to the DRN package are made to repeat the parameters of the springs over the 516 stress periods because the spring conductivity parameters, as established in the EAHCP Phase II model analysis, do not vary over time. The OC package is also updated to output the results of the 516 stress periods. The initial water heads, defined in the BAS package for the EAHCP Phase II model analysis, are used in the current modeling simulation under climate projections. The initial aquifer condition (heads) has only minor impacts on the modeling results, and the values are similar to long-term average water levels for the aquifer.

The configuration of groundwater pumping has been previously discussed in the HDR (2011)report and the two technical memos (Appendix C; Furl 2019). In the current modeling analysis, the configuration of groundwater pumping that was used in the EAHCP Phase II model analysis is not modified. The WEL package is used to represent groundwater pumping of both the permitted and exempt wells, implement the reduction of protective measures such as the Voluntary Irrigation Suspension Program Option (VISPO), the Regional Water Conservation Program (RWCP), and the EAA Forbearance of San Antonio Water System (SAWS) Aquifer Storage and Recovery (ASR) Leases. Two other packages are related to the implementation of CPM Stages 1–5. Details of the procedure to implement spring flow protective measures through pumping reduction are discussed in the next section. CPM is implemented in the TRF package (implementation of the CPM rules) and the MPW package, which contains information on the pool (i.e., San Antonio or Uvalde pool) and use of each managed pumping well in the aquifer (HydroGeoLogic, Inc. 2004, 2005). The TRF package is irrelevant to stress periods; therefore, no modifications are made. Modifications are made for the MPW package and data of the pool and use of each managed pumping well in the aquifer is repeated at each of the 516 stress periods.

Groundwater recharge is implemented in the RCH package. The EAHCP Phase II model is calibrated and validated with the input of USGS recharge estimates with adjustments (Lindgren et al. 2004; Liu et al. 2017). USGS monthly groundwater recharge estimates provided at each of the eight recharge basins are distributed to recharge zones defined in the model (Lindgren et al. 2004; Liu et al. 2017). The current modeling analysis follows the same procedure used for calibration and validation of the EAHCP Phase II model (Liu et al. 2017) to distribute monthly recharge estimated with the AI/ML models. The procedure of distribution of monthly USGS groundwater recharge in basins to the recharge zones was previously implemented via an Excel worksheet. After carefully reviewing the worksheet, the EAA modeling team found two minor errors: 1) the recharge from the Cibolo Dry Comal Basin was overreduced relative to the methods used in Lindgren et al. (2004), and 2) the cap of the USGS recharge from the Blanco Basin was not enabled. These errors did not affect the previous drought of record analyses conducted as part of the EAHCP Phase II work because the accepted historical recharge values for that period were included directly in the model (i.e., no intervening spreadsheet calculation was required). The minor errors could have affected the quality of the 2017 model calibration, but subsequent uncertainty analyses of model performance did not identify a more suitable set of calibration parameters (White et al. 2020). After correcting the minor errors, the EAA modeling team decided to implement the procedure to distribute monthly recharge via a Python-based script (https://www.python.org/) to avoid manual mistakes, improve efficiency of numerical simulations, and more easily integrate recharge input into an automatic procedure for running the modeling analysis.

2.2 Modeling Procedure

Figure 2-1 summarizes the main steps of the procedure used to run the EAA model with projected recharge (Winterle pers. comm. 2023). In Step 1, the monthly recharge generated from the climate models is converted and reformatted for use in the RCH package. In Step 2, the 10-year moving annual average of total recharge is calculated to determine any periods in which the 10-year moving average falls below 500,000 ac-ft, which is a trigger value for ASR-related forbearance requirements. Because the monthly recharge estimates from the AI/ML models are provided for the period of 2023–2065, USGS reported annual total recharge values for the period of 2014–2022 are used to calculate the 10-year moving average annual average through 2031.

Step 3 consists of several parts and includes the first full run of the model. Reduction of total pumping via the RWCP is implemented in Step 3. Step 3 also implements reductions in pumping from EAA forbearance of SAWS ASR leases in years following those years where the 10-year average is below the trigger level calculated in Step 2. Step 3 also applies the full range of CPM pumping reductions based on water levels and spring flow values. Step 3 implements protective measures of RWCP, EAA forbearance, and CPM Stages 1–5 pumping reductions “on the fly” through the Groundwater Management Module (HDR 2011; HydroGeoLogic, Inc. 2004, 2005).

The calculated water level at the J17 index well on October 1 of each year in the simulated period is checked in Step 4. If the water level in the J17 index well is below 635 ft amsl on that date, then reductions in pumping covered by VISPO leases are applied in the year after VISPO is triggered. Step 4 includes another full model run and implements the protective measures in Step 3 and VISPO-related reductions if triggered.

Step 5 is a full run of the model and applies pumping reductions related to SAWS ASR forbearance, which is triggered based on two conditions: 1) the 10-year moving annual average recharge is below 500,000 ac-ft, and 2) the water level in J17 index well is below 630 ft amsl (based on results from of Step 4). A Python script is implemented to check the two conditions for all stress periods. In a month when the two conditions are met, reduction in groundwater pumping following the scheme listed in Table 4 in the report by Furl (2019) is applied. Implementation of the SAWS ASR forbearance is accomplished via the RCH package (HDR 2011; Liu et al. 2017; Winterle 2019). Spring flow protection measures implemented in Steps 3 and 4 are also included in Step 5.

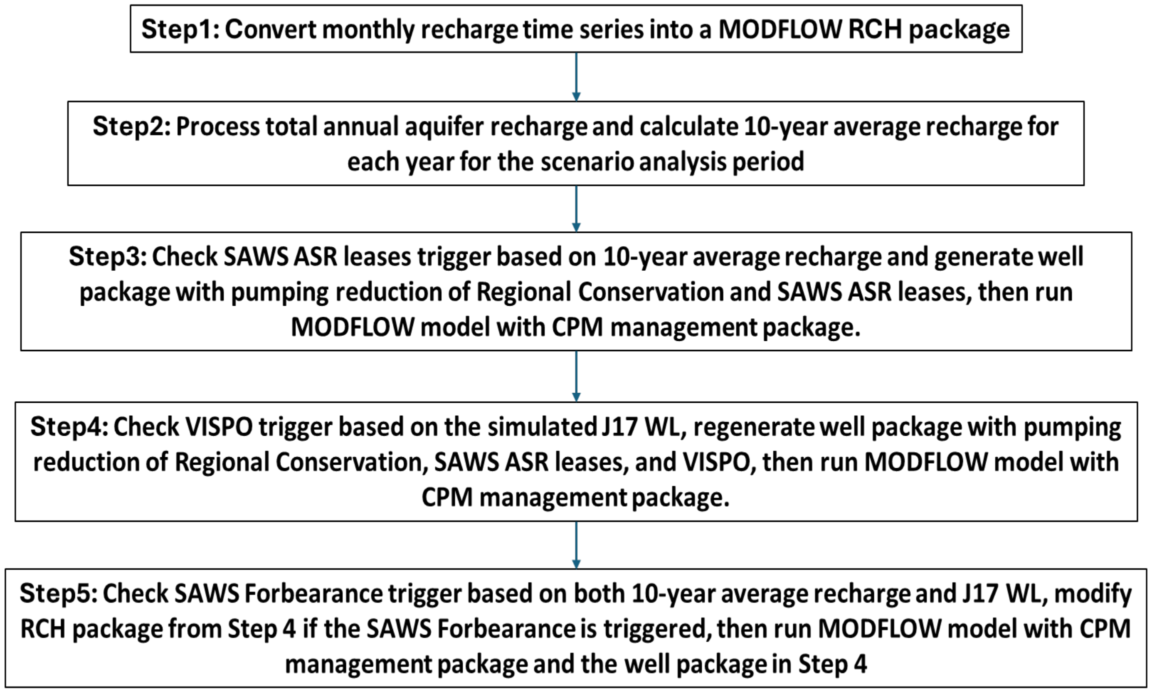


Figure 2-1. Modeling Procedure with Projected Recharge to Simulate Spring Flows in the Edwards Aquifer

The five steps of the modeling procedure depicted in Figure 2-1 are implemented via a Jupyter notebook (https://jupyter.org) (Kluyver et al. 2016) that includes several Python programming language modules. While the EAHCP Phase II model was also previously run in part using a Jupyter notebook interface, the new and revised Python modules and scripts in the updated Jupyter notebook constitute the main changes to the modeling process in this analysis. Most of the changes were made to reduce the potential for data entry errors and to streamline the running of the model. Scripts were developed to: 1) properly distribute the monthly recharge per basin output from the recharge model into the RCH package, 2) automate identification and implementation of VISPO reductions, 3) automate the identification and implementation of SAWS ASR forbearance in the RCH package, and 4) create visualizations and user-friendly output files for post-processing and inspection of results. Appendix A provides an example of the Jupyter notebook for the modeling analysis with example input of recharge from the KIOST-ESM ssp245 GCM.

The modeling procedure in the Jupyter notebook has several advantages. First, modeling efficiency is significantly increased. The time required to complete a model run for each climate model input was reduced from 3–7 days using the manual procedure to 8–14 hours with the newly automated procedure. This reduced the time required to complete the full range of models by several weeks. Second, the scripting helps to avoid potential data entry and other transcription errors that can occur when updating recharge and well packages manually. Only the projected basin-scale recharge values are needed to initiate a complete model run. Finally, post-processing and quality checks are improved because of added control of output file types and locations. Intermediate results and final results are saved and available for inspection without additional file type conversion or the need for proprietary software.

2.3 Model Validation

2.3.1 Comparisons to the Archived EAHCP Phase II Model Runs

The EAA model was previously run as part of the EAHCP Strategic Adaptive Management Program (SAMP). Model runs were conducted for the drought of record period from 1947 to 1958 with a total of 144 stress periods (months). One of the archived EAHCP SAMP model runs was repeated with the new automatic modeling procedure in the Jupyter notebook to test the new modeling procedure. For this test run, no updates are made in the SAMP model. The recharge package in the SMAP model was used without modification, and no changes were applied to the SAWS ASR forbearance scheme implemented in the SAMP model.

Figure 2-2 and Figure 2-3 show results from the archived SAMP model and the current model as run with the automated procedure. Water levels in the J17 index well and spring flow rates for both Comal Springs and San Marcos Spring produced by the two models are nearly indistinguishable. The results indicate the current model and the associated Jupyter notebook procedure are equivalent to previous models used to assess spring flow protection measures for the EAHCP Phase II.

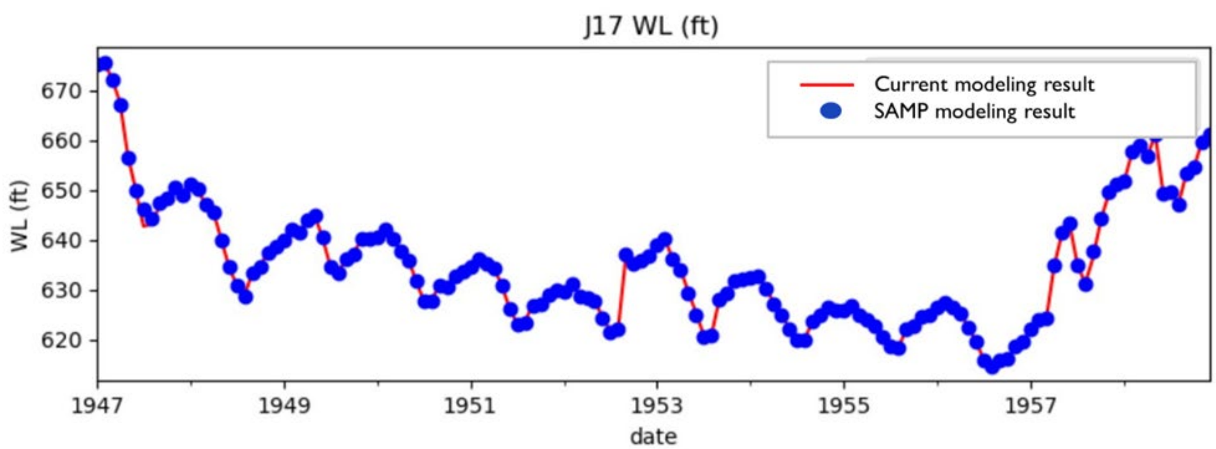


Figure 2-2. Comparison of J17 water levels (WL) simulated with the modeling procedure described in the previous section compared to the SAMP modeling result

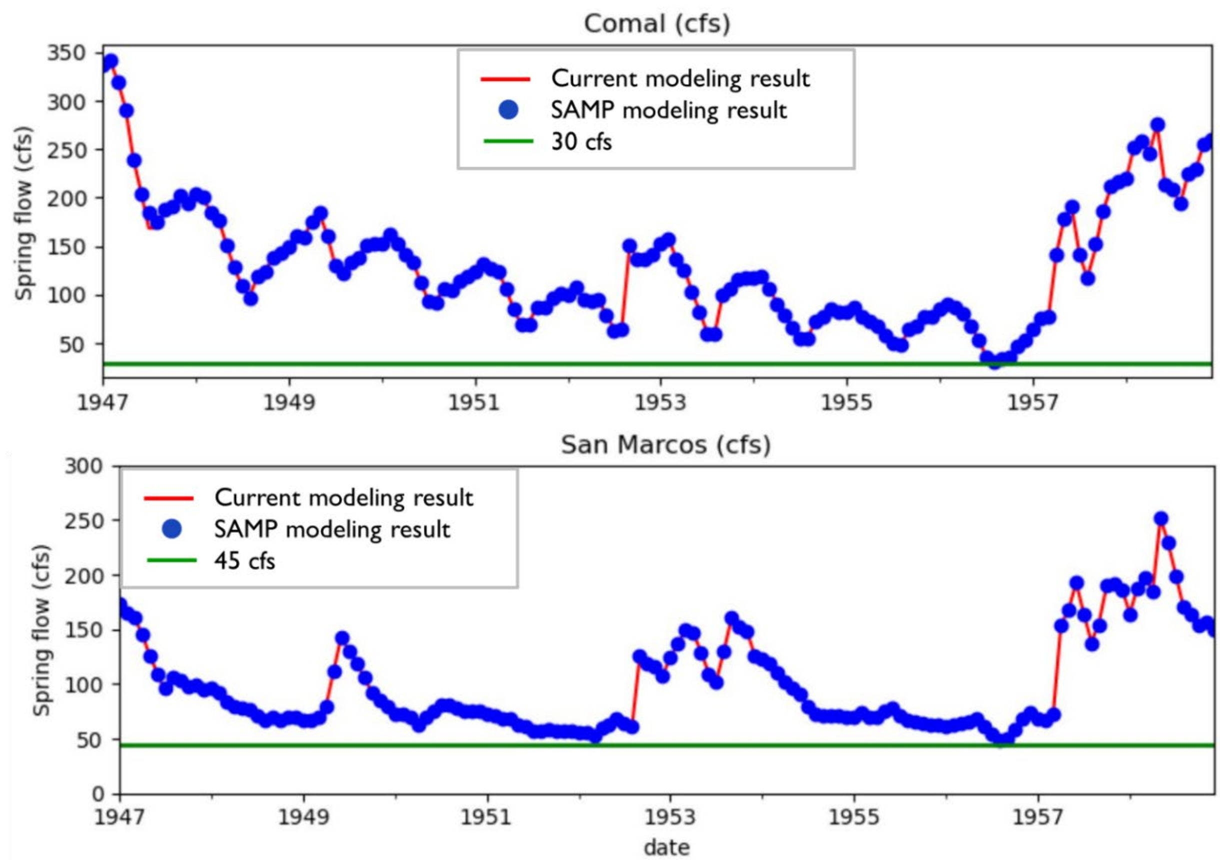


Figure 2-3. Comparison of spring flow rates of Comal Springs (top) and San Marcos Springs (bottom) simulated with the current modeling procedure compared to the SAMP modeling result

2.3.2 Modeling Analysis Using USGS, HSPF, and AI/ML Modeled Recharge for Historical Period 2001–2022

As discussed in previous sections, the MODFLOW model used to produce the projected water levels and spring flows is the same as has been used in earlier HCP-related analyses. The Lindgren et al. (2004) and the updated Liu et al. (2017) models were calibrated using best available aquifer data and the results are provided in the respective reports. Because the focus of the current modeling effort is to assess performance of spring flow protection measures, maximum permitted pumping is always applied. This limits our ability to directly compare model outputs to actual historical water levels and spring flows. One way of testing the model is to conduct a set of analyses with known recharge inputs and compare model output(s) for appropriate magnitude and scale of water levels and spring flow. Three modeling analyses were performed using reported USGS recharge, recharge calculated using an existing HSPF model (described in Section 1.5.3), and the AI/ML recharge model for the historical period of 2001–2022. These model runs provide a means to compare model output using reasonable, but differing recharge input variables.

Because the validation period is 22 years (2001–2022) with a total of 264 stress periods (months), the model's MODFLOW packages described previously were updated accordingly to accommodate

264 stress periods. In addition, the initial aquifer conditions for the EAA model calibration of Liu et al. (2017) were applied by updating the BAS package. The Liu et al. (2017) model calibration was conducted for 2001–2011, so the initial heads used in that simulation are appropriate.

The AI/ML recharge from the GCMs is provided for the period 2004–2022 (19 years). Details of the AI/ML modeling are found in Chapter 1. As a result, data from USGS reported recharge in 2001–2003 was appended to the AI/ML recharge input so that these three model evaluation runs had the same number of stress periods.

The three modeling runs were conducted using the Jupyter notebook with the automatic modeling procedure. The modeling results are shown in Figure 2-4 and Figure 2-5. The results for this set of tests may not correlate well with actual water levels and spring flows observed from 2001–2022 because of the continuous application of maximum permitted pumping in the model. Nonetheless, we can use information from the three recharge estimations (e.g., Chapter 1, Figure 1-13) to assess the results. Simulated water levels in the J17 index well are generally higher with the HSPF recharge than with the USGS and the AI/ML recharge (Figure 2-4). This result is consistent with the relatively greater recharge estimated by the HSPF models, especially during dry periods. Simulated flow rates for Comal Springs and San Marcos Springs are consistent with variations in water levels at J17 for each recharge model (Figure 2-5). The HSPF recharge generally produces higher flow rates of both springs than the USGS recharge and the AL/ML recharge, particularly during the low flow periods (Figure 2-5).

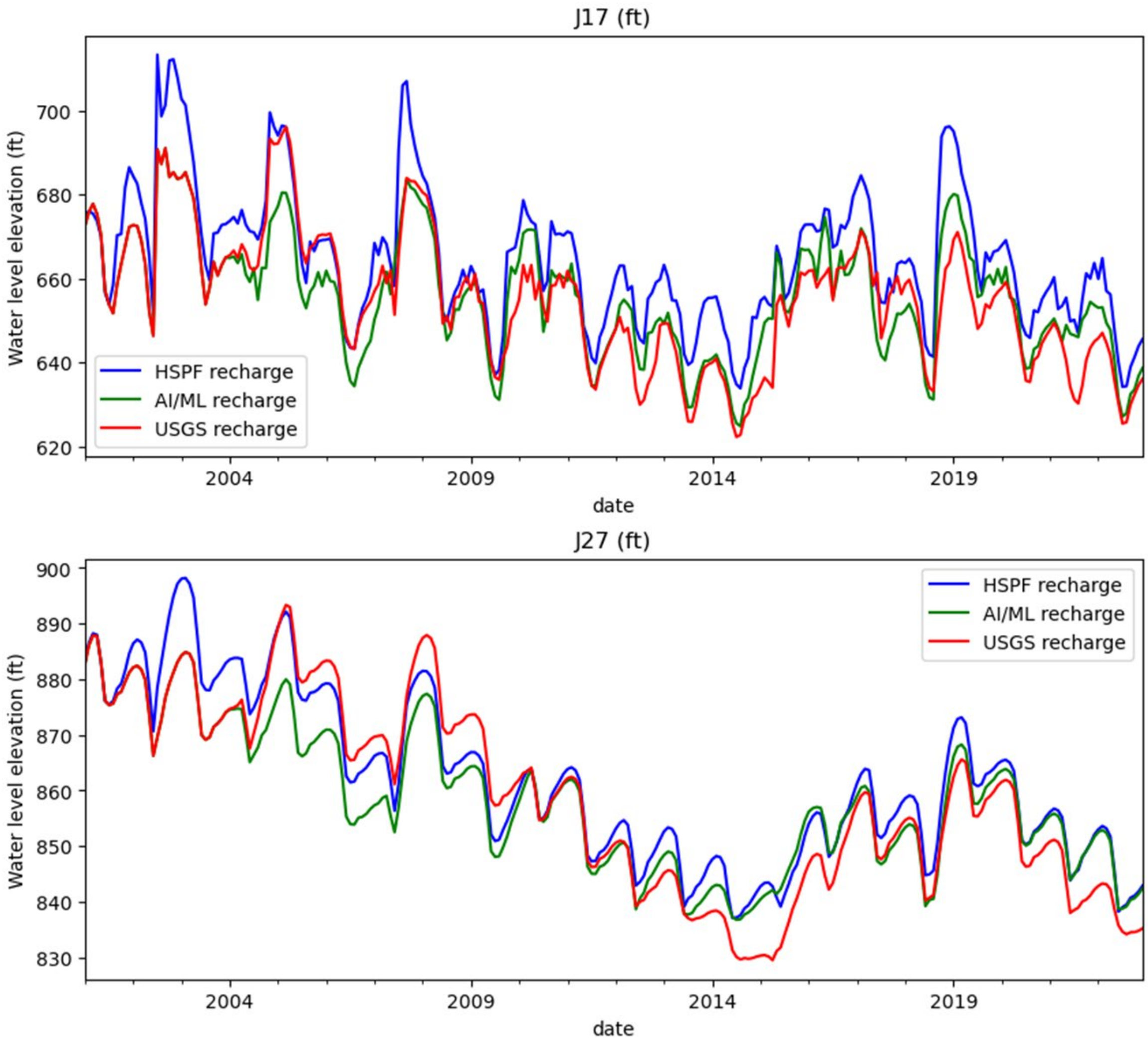


Figure 2-4. Comparison of J17 water levels (top) and J27 water levels (bottom) simulated using the groundwater flow model with the USGS recharge, HSPF recharge, and AI/ML recharge models

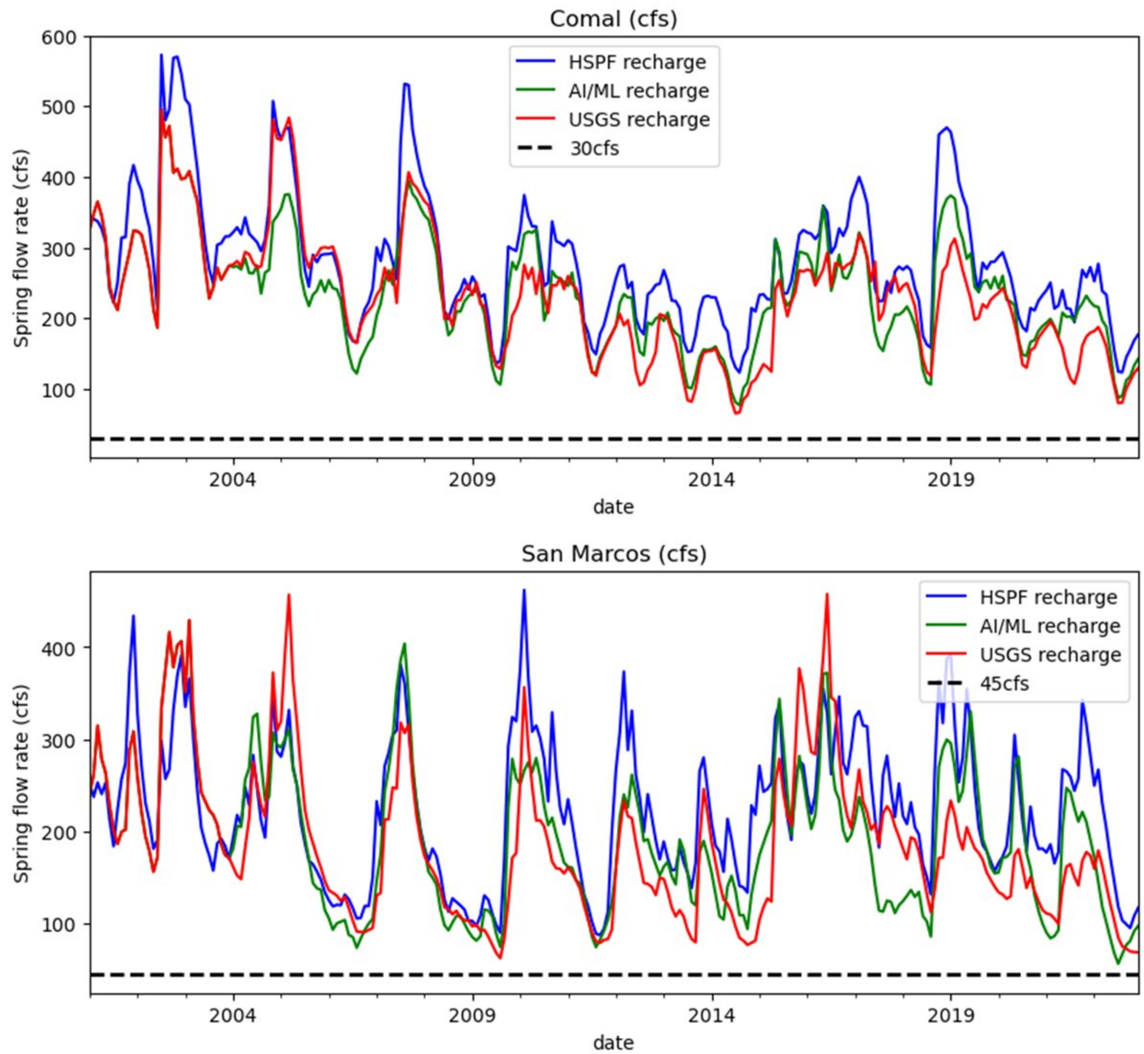
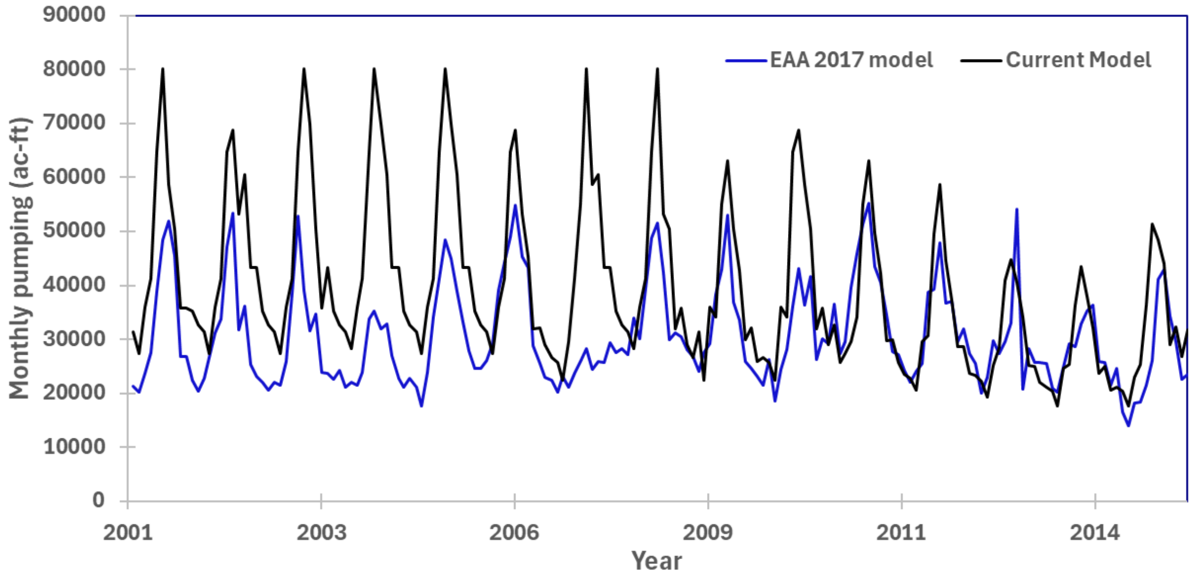


Figure 2-5. Comparison of spring flow rates for Comal Springs (top) and San Marcos Springs (bottom) simulated using the groundwater flow model and the USGS recharge, HSPF recharge, and AI/ML recharge models

Simulated water levels in the J27 index well show more agreement between the HSPF and the AI/ML recharge estimates (Figure 2-4). One reason for this that the Uvalde pool recharge is dominated by inputs from the Nueces and West Nueces rivers (a single basin recharge calculation) so there is less variation in the estimates of the two models relative to other outputs, which represent inputs from multiple basins.

An important observation can be made regarding the variation or sensitivity in model output relative to the recharge model used. Minimum spring flows produced by the USGS recharge estimates and the associated AI/ML recharge model are quite similar (Figure 2-4). In some cases, the AI/ML recharge model produces lower flows, and in other cases, the USGS recharge produces lower flows. With the exception of a few instances (e.g., 2018 at San Marcos and 2022 at Comal), the pattern displayed by the AI/ML recharge model is a reasonable facsimile of the results produced by historical recharge data. This provides added confidence that the AI/ML recharge model is a good representation of recharge for the aquifer system and can be used in the projections of future water levels and spring flows. The differences also make clear the relative changes in model output that result from differences in recharge input.

As mentioned previously, direct comparison of model output and observed historical water levels and spring flows is not particularly relevant because of the strict way in which maximum permitted pumping and other mitigation measures are applied in the model. Groundwater pumping in the model simulations is generally higher than the actual pumping from the Edwards Aquifer. Figure 2-6 compares the estimated monthly total pumping in the Edwards Aquifer used in the Liu et al. (2017) model and the monthly pumping input in the current model analysis for the period 2001–2015. Clearly groundwater pumping in the current model is greater than the actual estimated monthly pumping (top plot of Figure 2-6). However, as might be expected during severe drought conditions, estimated pumping from January 2014 to January 2015 is very similar in both models (bottom plot of Figure 2-6). We can use this period to conduct a spot check on model performance. We evaluated the output of the model using the USGS estimated recharge as input for September 2014 when aquifer levels at J17 and spring flows at Comal Springs were at their lowest. The minimum water level at J17 as calculated by the bottom-up model is 623 ft amsl while the actual level was 627 ft amsl. Similarly, the minimum spring flow at Comal Springs in September 2014 is calculated by the model to be 65 cubic feet per second (cfs) while the actual measured low spring flow at Comal Springs for that period was also 65 cfs. Results are different for San Marcos Springs. Low flows in San Marcos did not fall below 100 cfs in September 2014, but the bottom-up model estimates flows of about 80 cfs. Thus, for a specific timeframe in which we can compare withdrawals and conditions between observed data and conditions used in the model, the model performs reasonably well and is consistent with its performance during the EAHCP Phase II drought of record analysis (Furl 2019).



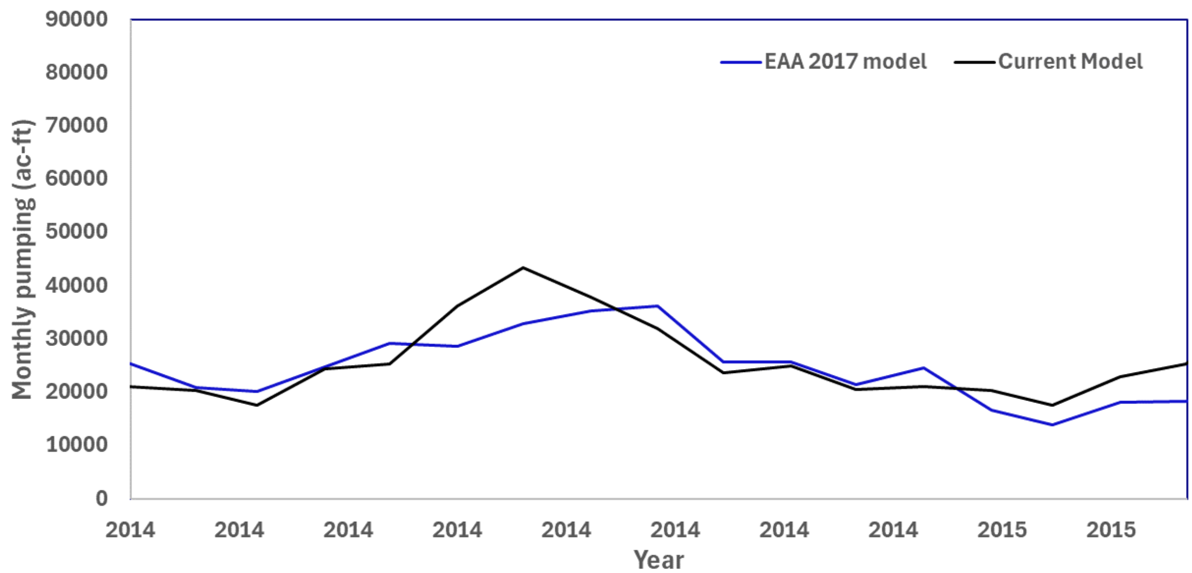


Figure 2-6. Comparison of monthly pumping from the output of the EAA 2017 model and the EAHCP Phase II model simulation using USGS recharge with protective measures. The bottom plot is focused on the period January 2014 to May 2015. Pumping extracted from the output of the EAA 2017 model represents estimated actual pumping from the aquifer

2.4 Results and Discussion

Separate model runs were conducted for each of the projected recharge sequences associated with the 19 downscaled GCMs (Wootten et al. 2024). Simulating a single climate projection with the Jupyter notebook and the automatic modeling procedure typically required about 8–14 hours. Three of the 19 simulations faced numerical convergence issues, but by adjusting the convergence criteria specified for solving nonlinear groundwater flow equations, these issues were effectively resolved.

2.4.1 Modeled Projected Water Levels for the J17 Index Well

Figure 2-7 displays modeled water levels in the J17 index well for all 19 climate projections spanning from 2023 to 2065. Modeled water levels in J17 exhibit a range from 614 ft amsl to 698 ft amsl. Figure 2-7 (bottom) illustrates the modeled water levels in the J17 index well specifically during the first 12 stress periods (months). The influence of the initial aquifer conditions on modeling results is primarily confined to the first three to seven stress periods.

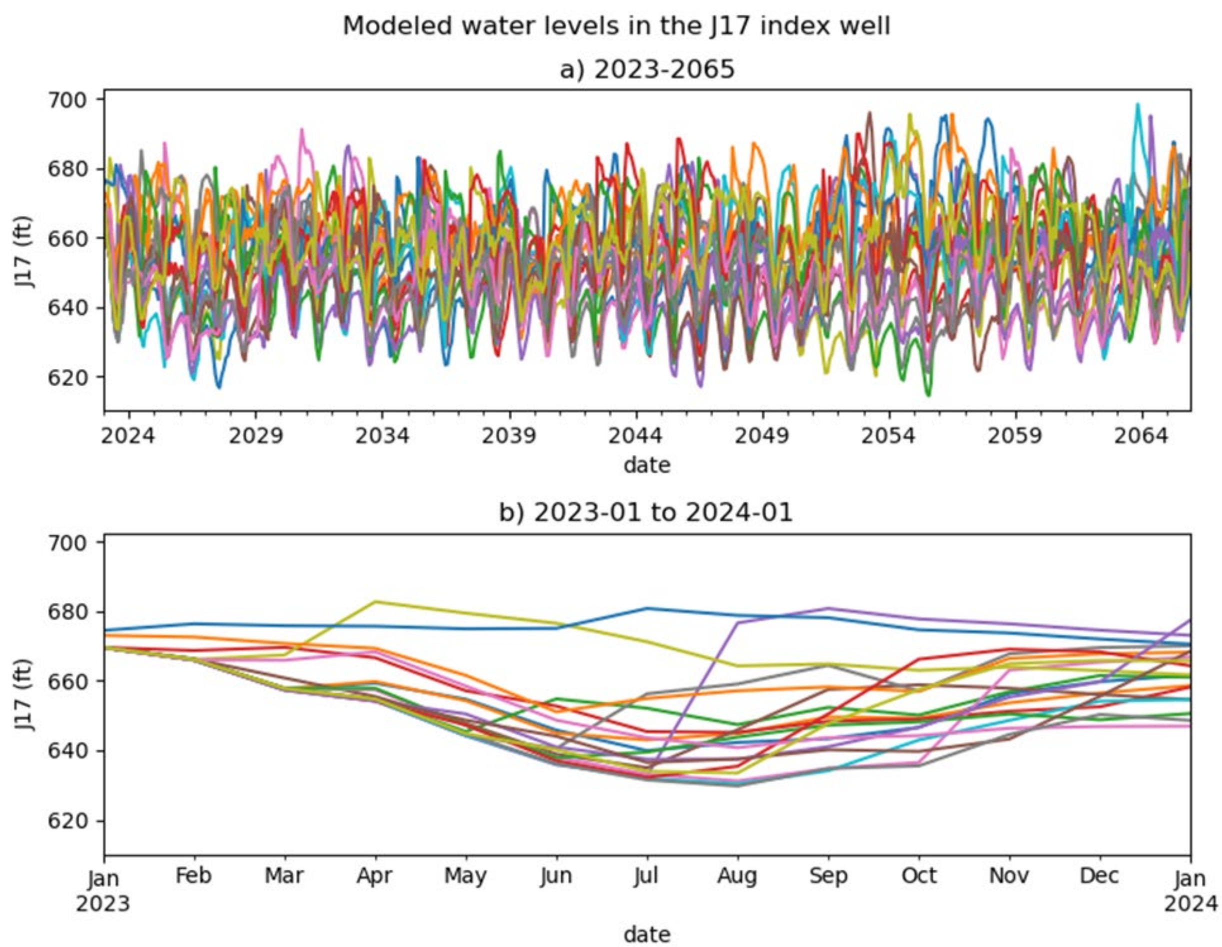


Figure 2-7. Modeled water levels for the J17 index well for the 19 GCM projections spanning (a) from 2023 to 2065 and (b) during the first 12 stress periods of the model runs

2.4.2 Modeled Projected Spring Flows

Modeled spring flow rates for Comal Springs and San Marcos Springs for all 19 climate projections are presented in Figure 2-8 and Figure 2-9. Across all models, simulated flow rates range from 24 cfs to 516 cfs for Comal Springs and from 27.6 cfs to 498.7 cfs for San Marcos Springs. The model is known to be sensitive to large values of recharge, especially for San Marcos Springs, and was purposely calibrated to perform better at low flow conditions, so the higher modeled spring flows have the greatest uncertainty.

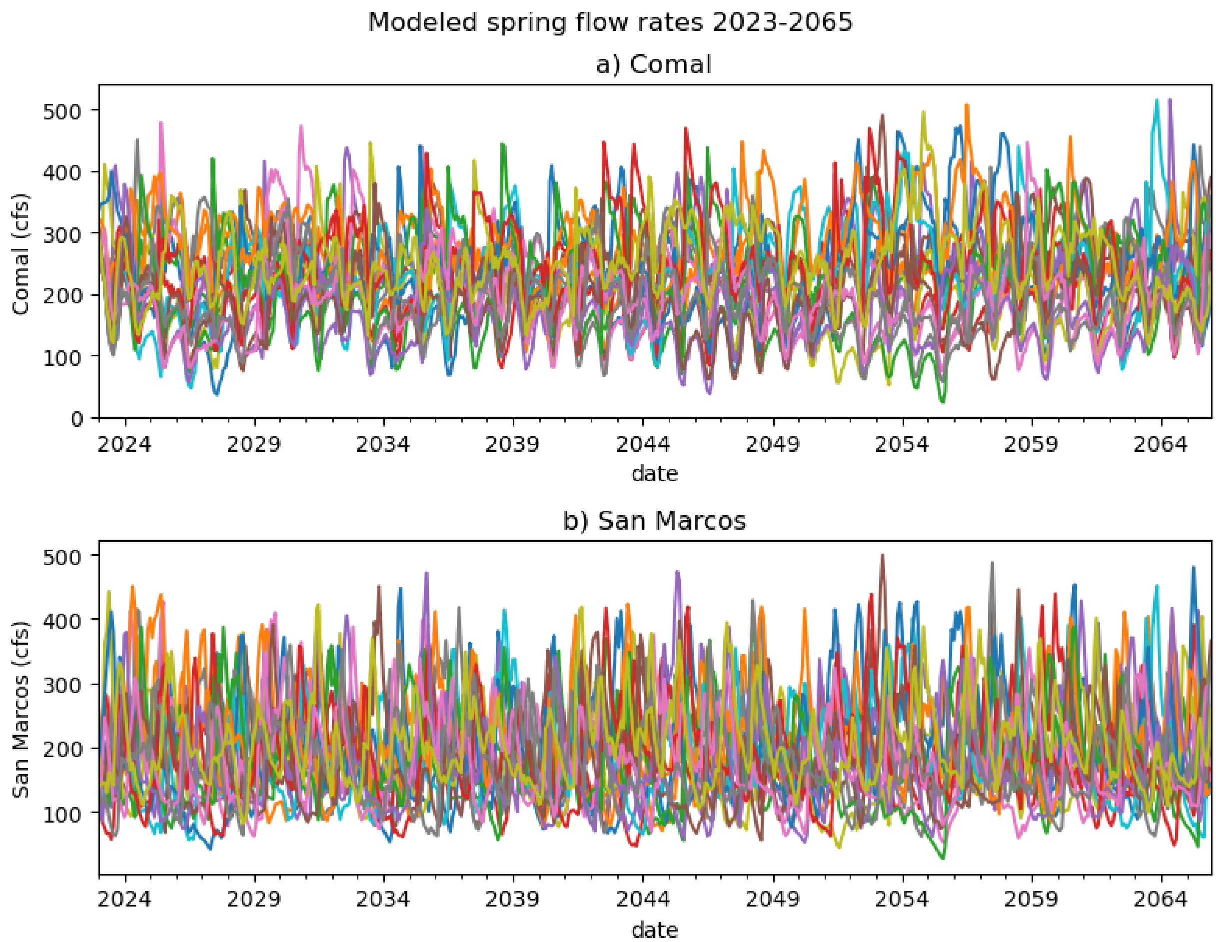


Figure 2-8. Modeled spring flow rates for a) Comal Springs and b) San Marcos Springs from 19 GCM projections spanning from 2023 to 2065

Figure 2-9 recasts the model results to depict the range of spring flow values (maximum to minimum) for all models combined. Also shown are the median values of the modeled spring flow rates over the simulation period. While informative, it is difficult to assess long-term flow conditions because of the applied maximum allowed pumping regime used in the model; however, the projections indicate long-term median flow values of about 210 cfs and 180 cfs for Comal and San Marcos springs, respectively.

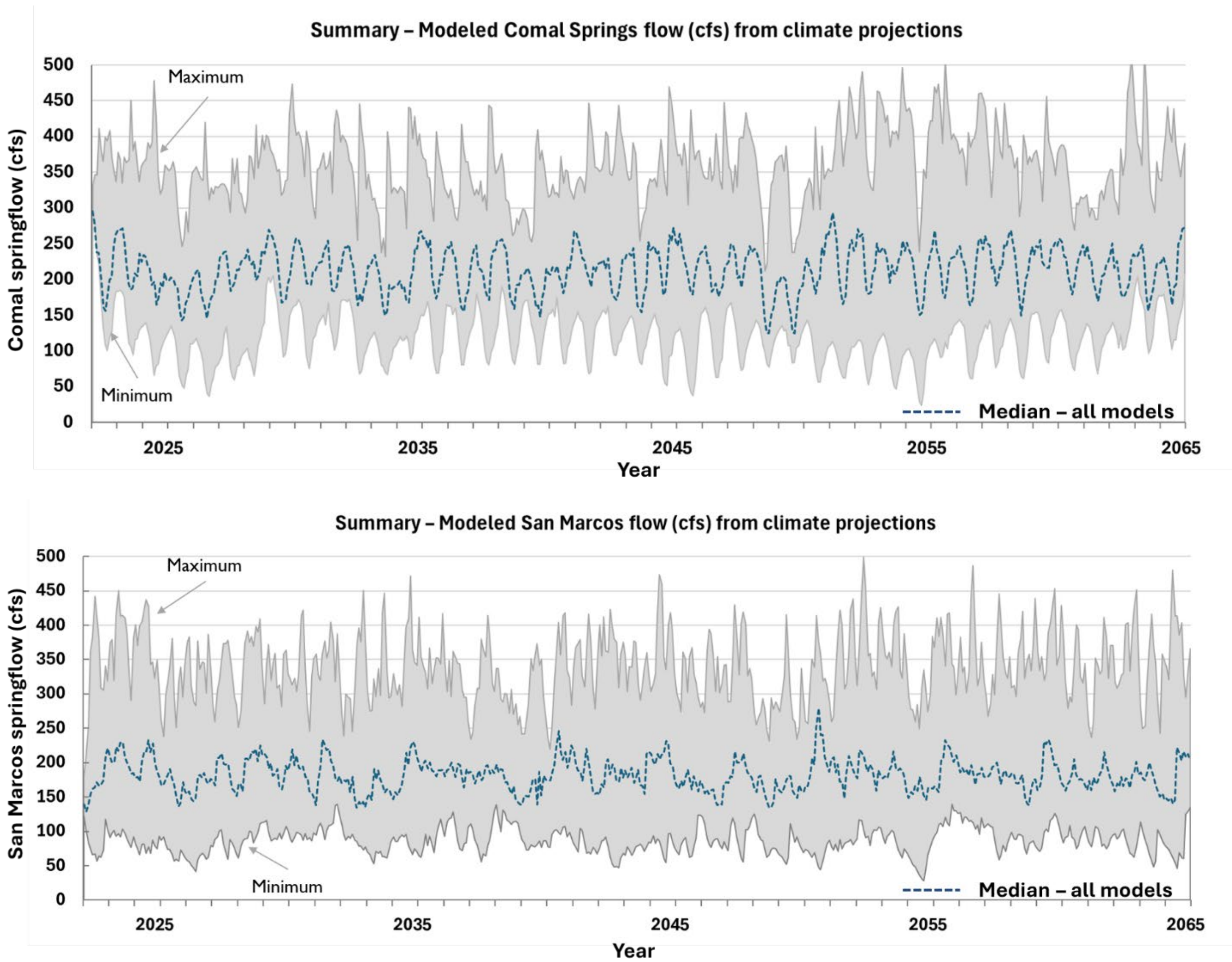


Figure 2-9. Summary of modeled spring flows for Comal Springs (top) and San Marcos Springs (bottom) using GCM projections spanning from 2023 to 2065. The dashed line is the median value of all models, and the shaded area is the range of the modeled spring flows

The cumulative probability distributions of all 19 model projections of flow at Comal Springs from 2023 to 2065 are shown in Figure 2-10. Also shown in Figure 2-10 is the cumulative probability distribution of historical Comal Springs flow rates from 1980 to 2023. The modeled spring flow rates are generally lower than the historical spring flow rates and are influenced by: 1) generally lower projected cumulative recharge relative to historical recharge (Figure 1-21), and 2) the effects of high pumping stress. A detailed look at lower spring flow rates (Figure 2-10b) indicates the cumulative probability distribution of historical spring flow rates below 100 cfs is effectively bracketed by the cumulative probability distributions of the modeled spring flow rates. This suggests that the projected recharge values and current spring flow protection measures in the model result in low flow distributions that are similar to historical observations.

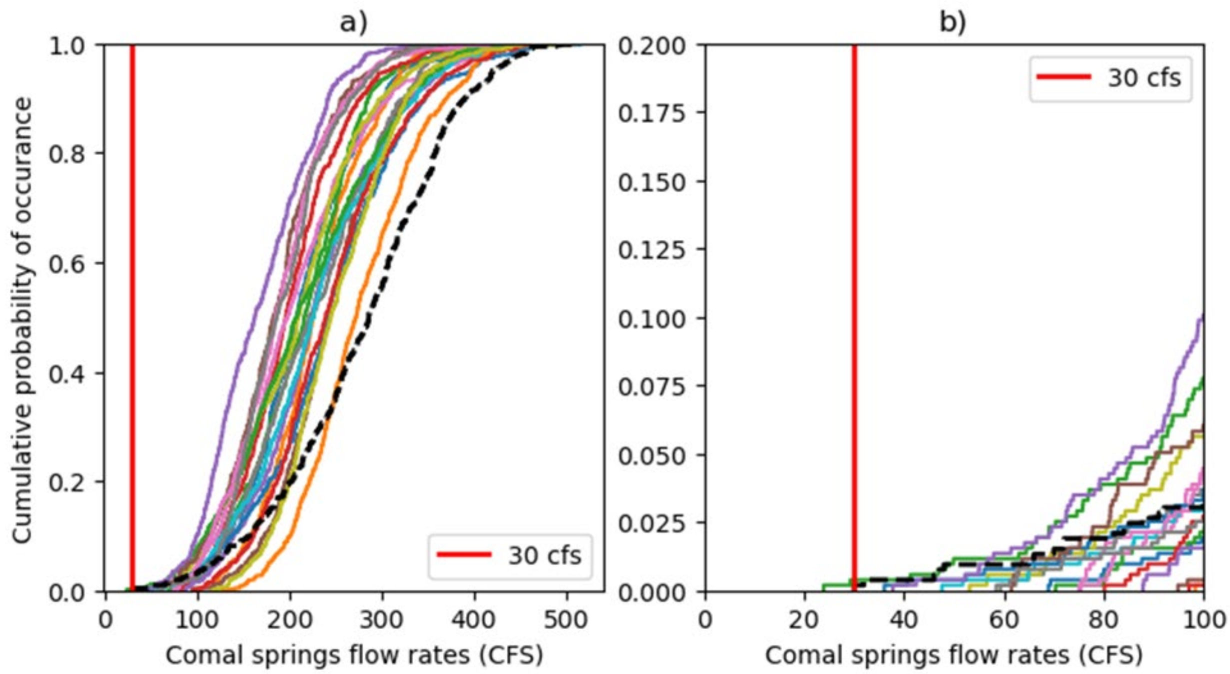


Figure 2-10. Cumulative probability of (a) modeled future Comal Springs flows from GCMs spanning from 2023 to 2065. The dashed dark line represents historical spring flows for the period 1980–2023, and (b) a zoomed-in version of the plot focusing on flows of 100 cfs and below

2.4.3 Protective Measures Triggered for Climate Projections

Table 2-1 summarizes the occurrences of three protective measures: VISPO, ASR lease forbearance, and SAWS ASR forbearance for each of the 19 climate projections. Information in Table 2-2 is presented graphically in Figure 2-11, which shows the frequency of these protective measures triggered across the 19 climate projections. Key findings include: 1) VISPO is triggered at least once in 14 out of 19 climate projections, and the frequency of VISPO implementation varies from 5 to 19 years among those 14 climate projections; 2) both the SAWS ASR forbearance and the ASR lease forbearance are triggered in 9 of the 19 climate projections; and 3) one projection, KIOST-ESM ssp245, dominates the number of times these protection measures are implemented.

Table 2-2 lists the occurrence frequency of the CPM stages for each of the 19 climate projections. Figure **2-12** shows stacked bar plots illustrating CPM frequency in the San Antonio pool for each of the 19 climate model projections. Key findings include: 1) 12 of the 19 model projections trigger CPM Stage 5 in the San Antonio Pool at least once; 2) projections KACE-1-0-G ssp245 and KIOST-ESM ssp245 have the most occurrences of CPM Stages of 4 and 5 both in the San Antonio and Uvalde pools; and 3) in contrast, the inmcm4 rcp85 scenario has about 90% of its modeled periods in normal (no restrictions) or Stage 1 for the San Antonio pool.

Table 2-1. Summary of VISPO and ASR related protective measures

Climate projection	VISPO		ASR Lease Forbearance		SAWS ASR Forbearance	
	Year Applied	Number of Years	Year Applied	Number of Years	Period Applied (year-month)	Number of periods
CMCC-CM_rcp45	2034, 2037, 2043, 2045, 2060	5				
CMCC-CM_ssp585						
EC-Earth3_ssp245	2038, 2045, 2049, 2050, 2051, 2064, 2065	7				
EC-Earth3_ssp585	2035, 2039, 2043, 2044, 2048, 2049, 2050, 2056, 2057, 2063	10				
HadGEM2-CC_rcp45	2032, 2041, 2044, 2050, 2051	5				
HadGEM2-CC_rcp85						
INM-CM4-8_ssp245	2024, 2043, 2044, 2048, 2049, 2050, 2056, 2059, 2060	9				
INM-CM4-8_ssp585	2042, 2043, 2048, 2055, 2056, 2057	6	2056, 2057, 2059	3	2056-04, 2056-05, 2056-06, 2056-08	4
INM-CM5-0_ssp245	2027, 2028, 2041, 2051, 2052, 2053, 2060, 2061, 2062	9	2056, 2060	2	2060-06, 2060-07, 2060-08	3
INM-CM5-0_ssp585	2024, 2025, 2027, 2028, 2031, 2034, 2044, 2045, 2063	9	2027, 2028, 2029, 2030, 2031	5	2027-07, 2027-08, 2030-07, 2030-08	4
inmcm4_rcp45	2027, 2028, 2047, 2048, 2051	5	2028	1	2028-01, 2028-02	2
inmcm4_rcp85						
KACE-1-0-G_ssp245	2027, 2035, 2042, 2053, 2054, 2055, 2056	7	2027, 2029, 2030	3	2027-06, 2027-07	2
KACE-1-0-G_ssp585			2029	1		
KIOST-ESM_ssp245	2026, 2027, 2028, 2029, 2034, 2035, 2039, 2040, 2046, 2047, 2048, 2050, 2051, 2053, 2055, 2059, 2060, 2062, 2063	19	2027, 2028, 2029, 2030, 2031, 2032, 2034, 2035, 2048, 2051, 2053, 2054, 2055, 2062, 2063	15	2027-07, 2027-08, 2028-06, 2028-07, 2028-08, 2028-09, 2028-10, 2028-11, 2028-12, 2029-01, 2029-03, 2029-04, 2029-05, 2029-06, 2030-07, 2032-07, 2034-06, 2034-07, 2034-08, 2034-09, 2034-10, 2053-08, 2054-07, 2054-08, 2054-09, 2054-10, 2055-04, 2062-06, 2062-07, 2062-08	30
KIOST-ESM_ssp585	2027, 2029, 2046, 2047, 2048, 2050, 2056, 2058	8	2029, 2030, 2053, 2054, 2055	5	2029-05, 2029-06, 2055-07, 2055-08	4
MPI-ESM1-2-HR_ssp245	2026, 2027, 2029, 2034, 2041, 2053, 2056, 2062	8	2027, 2028, 2029, 2030	4	2027-04, 2027-05, 2028-06, 2028-07, 2028-08, 2028-09, 2028-10	7
MPI-ESM1-2-HR_ssp585	2024, 2029, 2034, 2036, 2053, 2054, 2056, 2061	8	2027, 2028, 2029, 2059, 2060, 2061	6	2028-06, 2028-07, 2028-08, 2060-08	4
MPI-ESM1-ssp585						

Table 2-2. Summary of CPM stage occurrences in the models. Vaues indicate the number of time steps (total of 516) in each condition.

	San Antonio Pool Stage						Uvalde Pool Stage				
Climate projection	**Normal**	**1**	**2**	**3**	**4**	**5**	**Normal**	**2**	**3**	**4**	**5**
CMCC-CM_rcp45	125	149	162	69	9	2	188	47	28	19	234
CMCC-CM_ssp585	145	195	129	46	1		347	85	46	19	19
EC-Earth3_SSP585	73	157	176	93	17		58	71	60	51	276
EC-Earth3_ssp245	130	165	128	78	14	1	170	89	60	41	156
HadGEM2-CC_rcp45	173	152	124	59	8		233	31	41	33	178
HadGEM2-CC_rcp85	215	171	103	25	2		362	57	31	20	46
INM-CM4-8_ssp245	125	125	141	99	21	5	269	91	69	28	59
INM-CM4-8_ssp585	187	113	128	69	11	8	357	80	33	14	32
INM-CM5-0_ssp245	126	152	116	92	21	9	161	88	59	46	162
INM-CM5-0_ssp585	174	153	106	66	10	7	267	44	19	25	161
KACE-1-0-G_ssp245	168	104	122	81	22	19	143	58	39	7	269
KACE-1-0-G_ssp585	217	136	122	39	2		366	25	20	13	92
KIOST-ESM_ssp245	29	109	149	174	36	19	4	13	10	4	485
KIOST-ESM_ssp585	48	119	195	115	28	11	37	54	34	33	358
MPI-ESM1-2-HR_ssp245	58	137	172	123	23	3	54	69	50	38	305
MPI-ESM1-2-HR_ssp585	65	137	177	122	9	6	126	109	72	34	175
MRI-ESM1_SSP585	222	177	98	19			347	52	38	21	58
inmcm4_rcp45	221	151	76	47	13	8	250	55	37	36	138
inmcm4_rcp85	323	136	52	5			484	23	8	1	

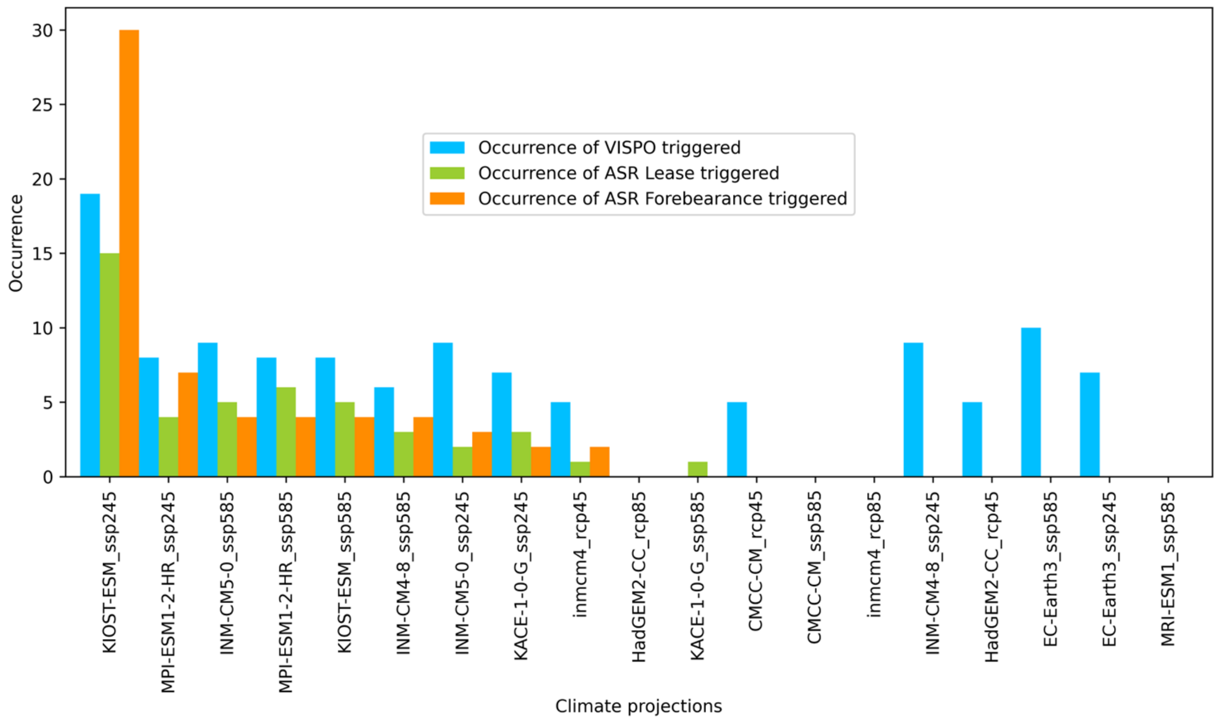


Figure 2-11. Bar plots of the projected occurrences of VISPO, ASR Lease forbearances, and SAWS ASR forbearance triggered under the 19 climate projections

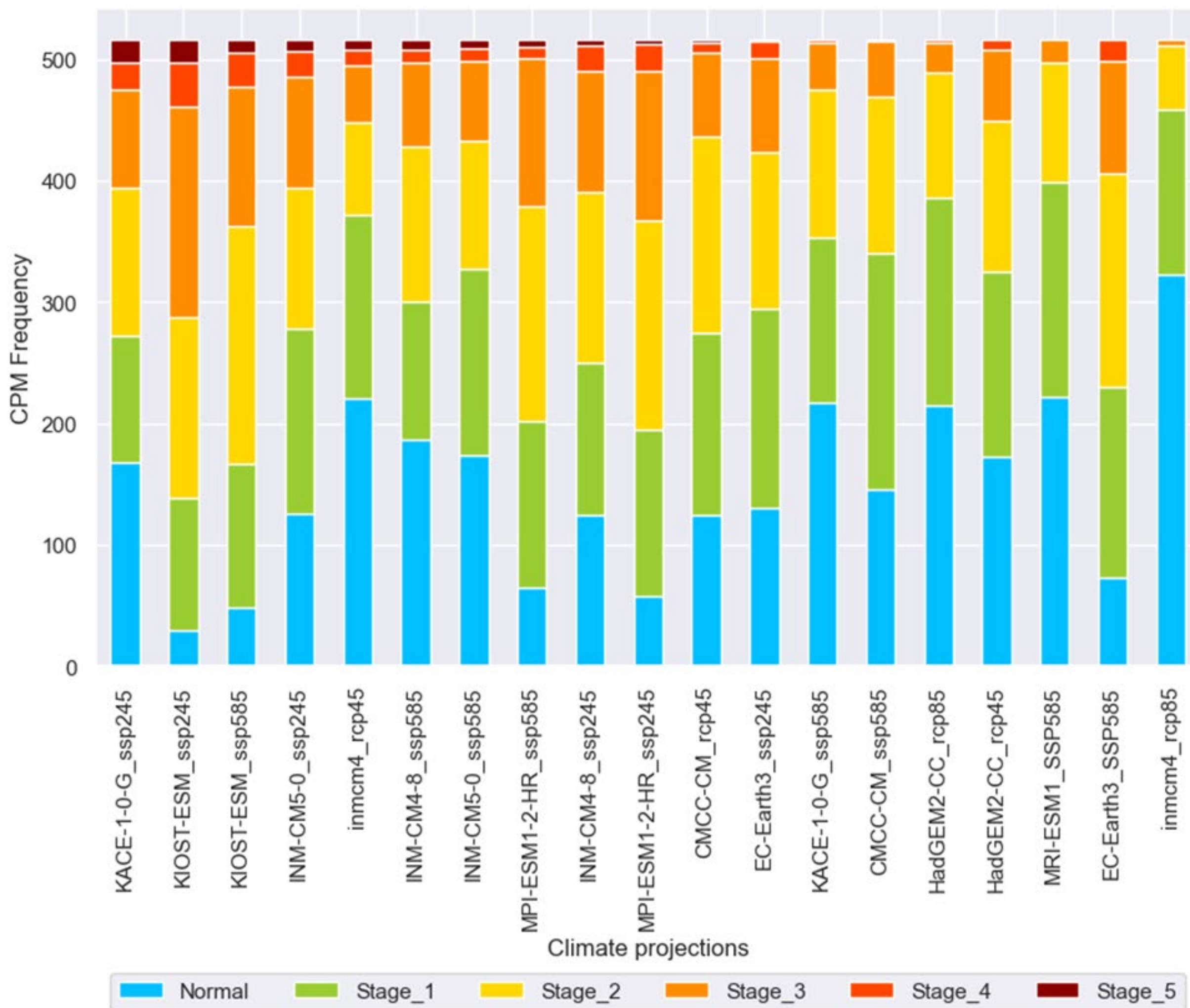


Figure 2-12**. Stacked bar plots of frequency of CPM for the modeled climate projections. GCMs are sorted with decreasing frequency of Stage 5 from left to right**

2.4.4 Potential Hydrological Droughts Under Future Climates

The 1950s drought of record for the EAR stands out as the most severe in the past century. The EAHCP Phase II and Bottom-Up modeling focused on the period from 1947 to 1958 to assess spring flow protection measures (Appendix C; HDR 2011; Furl 2019). Comal Springs flows reached historically low levels during this time. The 2010–2015 drought is the most recent severe drought in the Edwards Aquifer region, and until very recently (2022–2024) it was the only severe drought when at least some of the spring flow protection measures were enabled.

We inspected the results for projected Comal Springs flows from the 19 models to identify sequences that may be similar or worse than the drought of record and to identify sequences that may be equivalent to the drought of 2011–2015. Figure 2-13 shows modeled Comal Springs flow rates from 2046 to 2057 for the KACE-1-0-G ssp245 model projection compared to the observed Comal Springs flow rates during 1947–1958. The plot suggests the modeled spring flow rates from 2046 to 2057 are quite similar to what was observed during the drought of record. Importantly, projected springs flows do not cease during this projected severe drought sequence. Although one or two other modeled flow sequences for Comal Springs are also similar to the drought of record, we found no examples of sequences that were more severe (e.g., lower flow for longer periods) than the drought of record in any of the 19 model runs.

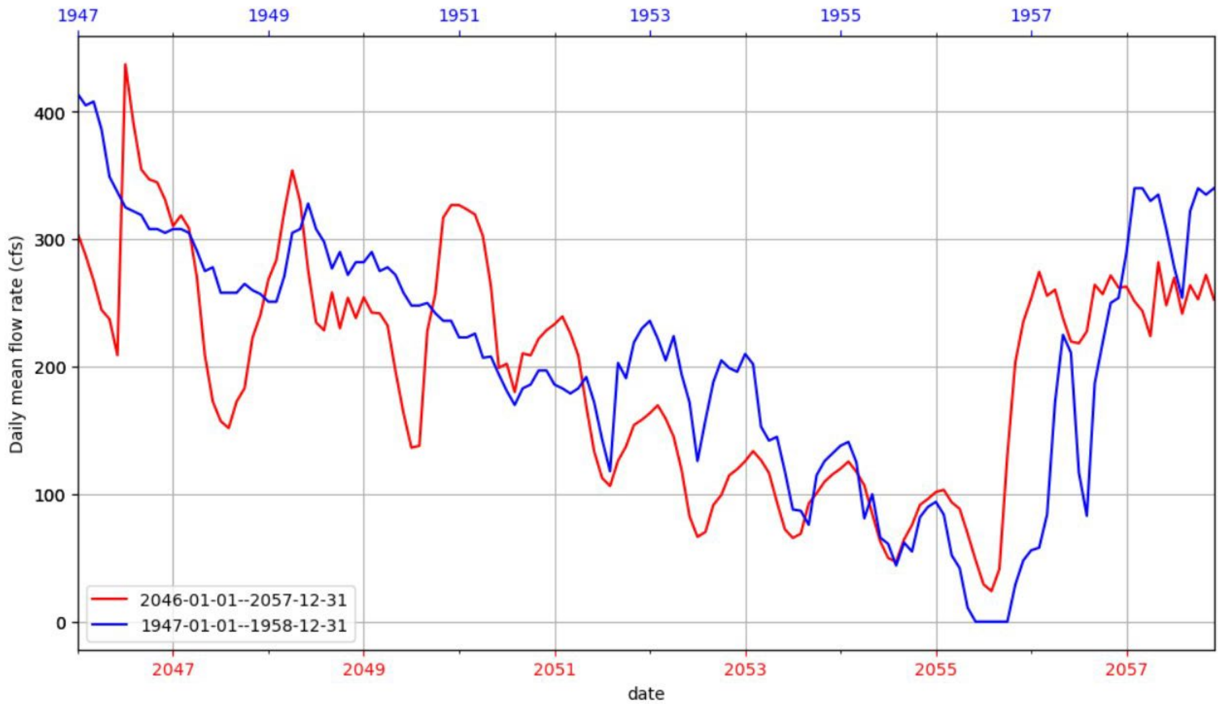


Figure 2-13. Comparison of the modeled projected Comal Springs flow rates (red) from the KACE-10-G ssp245 GCM during 2046–2057 to historical spring flow rate measurements (blue) during 1947–1958.

Figure 2-14 displays the modeled Comal Springs flow rates from the CMCC-CM rcp45 climate projection for the period 2039–2046 as compared to observed Comal Springs flows during 2009–2016. Clearly, the modeled spring flow rate sequence shows a similar pattern to the 2011–2015 drought. There are more than 19 instances of spring flow rate sequences from the various climate projections that display a similar pattern to the 2011–2015 drought. However, in each of those instances Comal Springs flows do not fall below goals set in the EAHCP. This pattern suggests droughts like the one experienced in 2011–2015 will not be uncommon in the future but are likely to be manageable using the current spring flow protection measures.

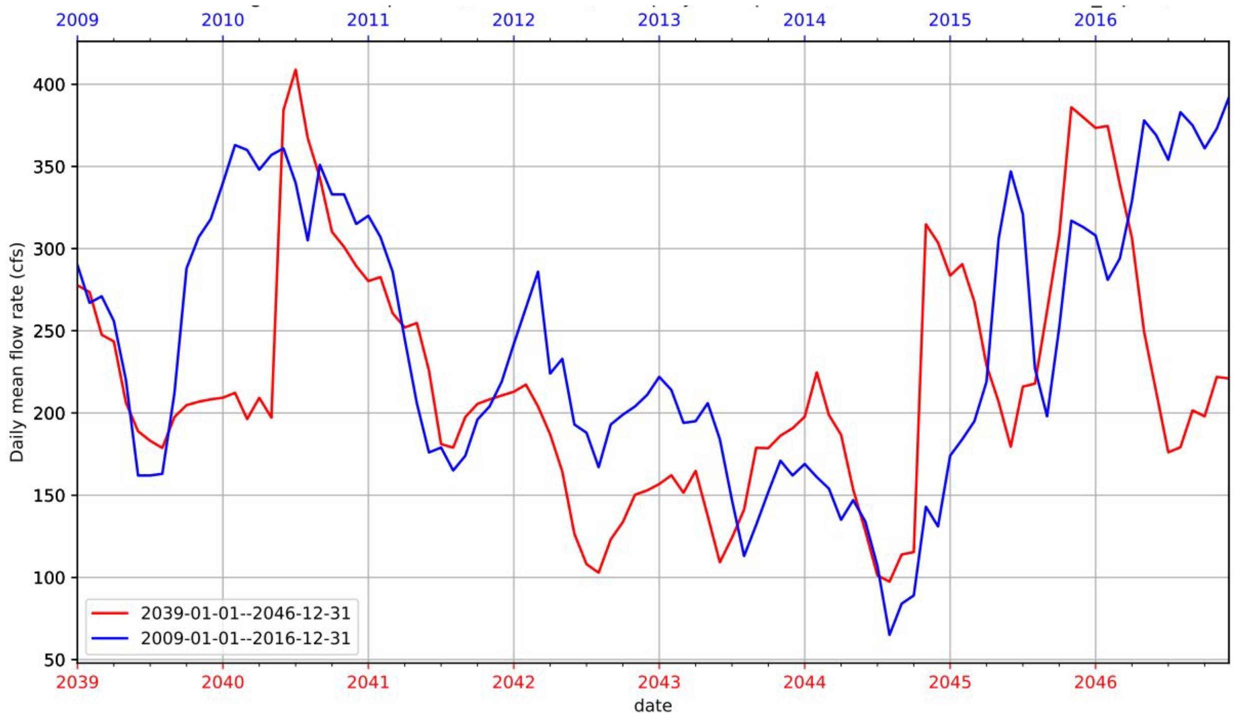


Figure 2-14. Comparison of the modeled projected Comal Springs flow rates (red) from the CMCC-CM rcp45 GCM during 2039–2047 to historical spring flow rate measurements (blue) during 2009–2017

2.4.5 Selected Individual Model Results

The ensemble characteristics of modeled spring flow rates for both Comal Springs and San Marcos Springs, as depicted in Figure 2-9, indicate the range of flows and minimum flows in nearly all model projections are similar to conditions experienced in the past few decades. This strongly suggests that for the 19 climate projections assessed, the established spring flows protection measures for the aquifer system are suitable for the proposed renewal period of 2028 to 2058. However, it is important to assess modeled spring flow rates under each individual climate projection to evaluate when flow minima occur and what factors may contribute to the model projection results.

Graphical results for projected Comal and San Marcos springs flows for all 19 models are provided in Appendix B. Comparing statistics of water levels and the modeled spring flow rates with historical measurements, we can qualitatively group the 19 climate projections into three broad categories. We label these categories as Neutral, Stressed, and Low Flow. Neutral model results have projected water level and spring flow values that are similar to recent historical trends in the aquifer. For example, Neutral model results have projected J17 water levels below CPM Stage 3 in less than 18% of the 516 stress periods (months) of the modeled period. Approximately 10 of the models fit into this category. Stressed model results have projected J17 water levels that are in CPM Stage 3 more than 18% of the time and generally have sustained lower than median flows at the springs. Nine of the models fit into the category. Low flow models exhibit the lowest flows at either Comal Springs or San Marcos Springs during the period 2028–2058. These flows are below minimum daily average spring flow discharge objectives, 30 cfs for Comal and 45 cfs for San Marcos, as proposed in the technical memorandum, *Recommended Biological Goals and Objectives for the Permit Renewal*

(Kunkel et al. 2024). Two models fit into this category—one is in the Neutral group and the other is in the Stressed group.

A set of example results from a Neutral model, INM-CM4-8 ssp585, is shown in Figure 2-15 for both Comal and San Marcos springs. The projected spring flows include high and low flow periods with average flows near the median for the 19 models. The lowest projected flows during drought sequences are also well above the minimum daily average spring flow discharge objective for either spring.

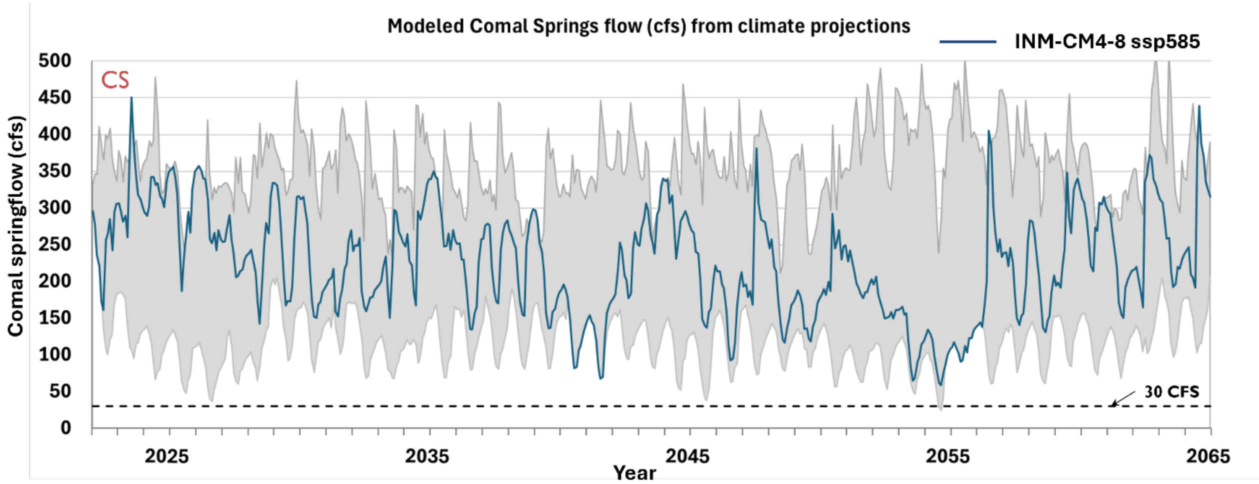
Figure 2-16 depicts an example of results that represent a Stressed model, KIOST-ESM ssp245. At Comal Springs, results from this model dominate the lowest flows (of all model runs) for many years. The KIOST-ESM ssp245 results represent projected conditions that would suggest CPM Stage 3 conditions or more in the San Antonio pool nearly 35% of the time between 2028 and 2058. As seen in Figure 2-11, this climate projection model also has the highest frequency of VISPO- and ASR-related triggers.

An example of a Low Flow model, KACE-1-0-G ssp245, is shown in Figure 2-17. When inspecting projected flows at San Marcos Springs, this model would generally fit into the Neutral category, but there is one drought sequence in the early 2050s in which the minimum projected flow is less than 45 cfs. Similarly, flow at Comal Springs in the same time period is projected to decrease below 30 cfs. All modeled stress periods (months) between 2028 and 2058 with low flows are listed in Table 2-3.

Table 2-3 lists the timing and periods when the modeled spring flow rates are below minimum daily average spring flow objectives at Comal or San Marcos springs. It should be noted that among the 19 climate projections, only two produce very low spring flow rate sequences and these are limited to one to four stress periods (months) with no sequences that produce zero flows. For several models, the period from the mid-2040s to mid-2050s appears to be associated with lower recharge and lower spring flows.

Table 2-3. Summary of Lowest Spring Flow Events in the Low Flow Models

Low Flow Condition	Model	When	Periods	Cause?
Comal Springs below 30 cfs	KACE-1-0-G ssp245	Jul–Aug 2055	2	Not all measures applied (no ASR trigger)
San Marcos Springs below 45 cfs	KACE-1-0-G ssp245	May–Aug 2055	4	Not all measures applied (no ASR trigger)
San Marcos Springs below 45 cfs	INM-CM5-0 ssp245	Aug 2051	1	Not all measures applied (no ASR trigger)



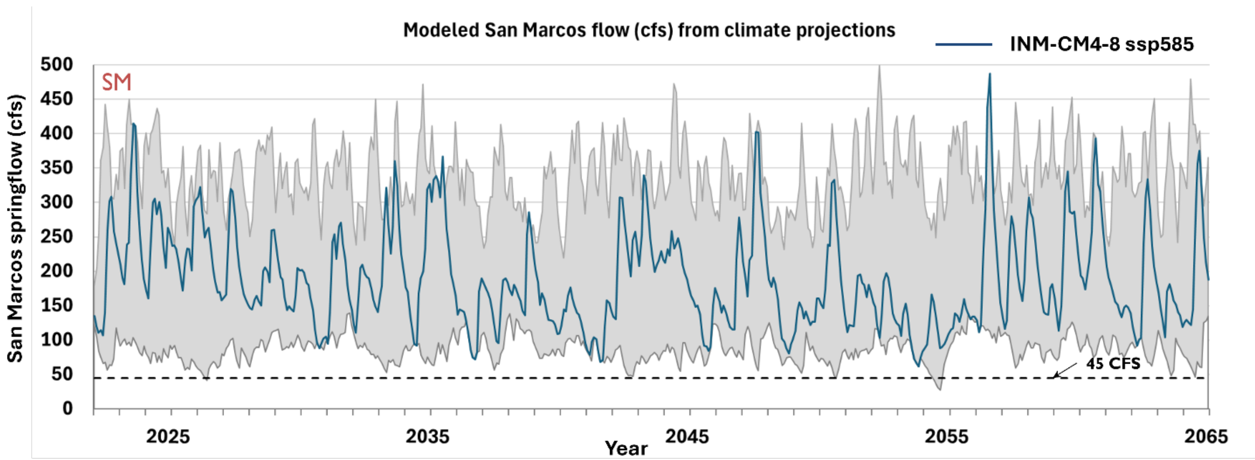
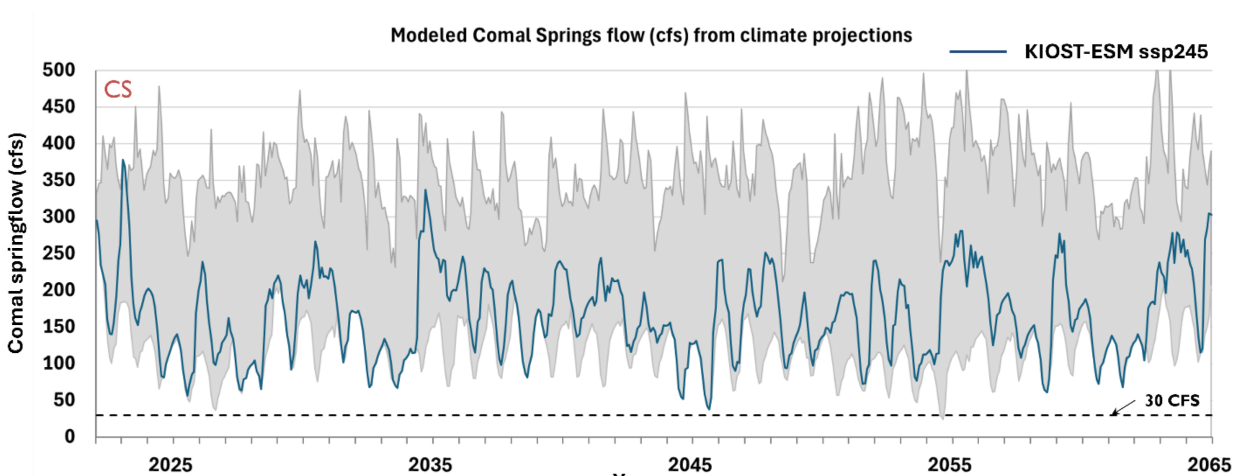


Figure 2-15. Modeled Comal Springs (top) and San Marcos Springs (bottom) flows from the INM-CM4-9 ssp585 GCM for the period 2023–2065. This model is an example of a Neutral group model. The shaded area depicts the range of modeled spring flow rates for all 19 climate model projections.



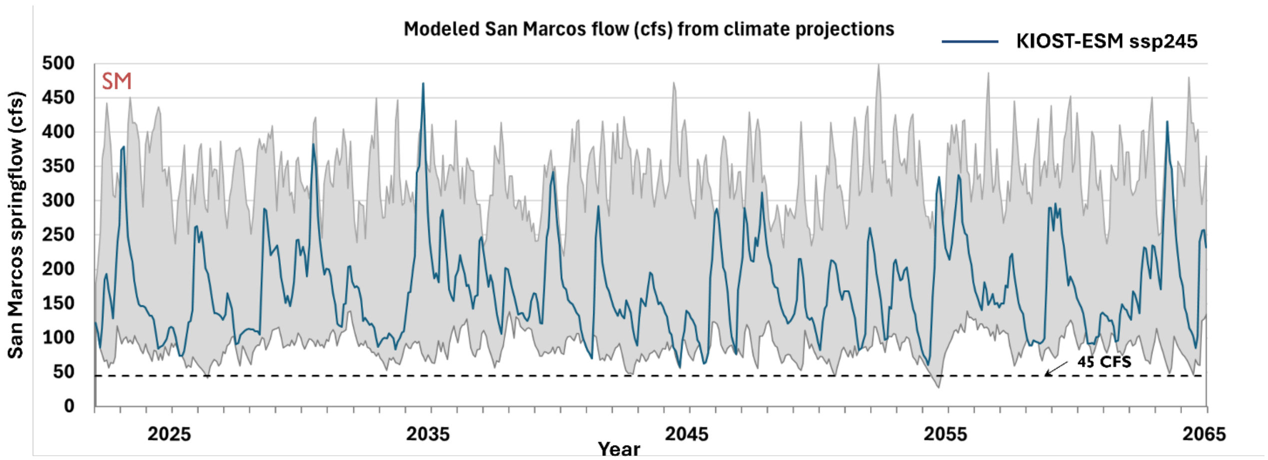


Figure 2-16. Modeled Comal Springs (top) and San Marcos Springs (bottom) flows from the KIOST-ESM ssp245 GCM for the period 2023–2065. This model is an example of the Stressed group models. The shaded area depicts the range of modeled spring flow rates for all 19 climate model projections.

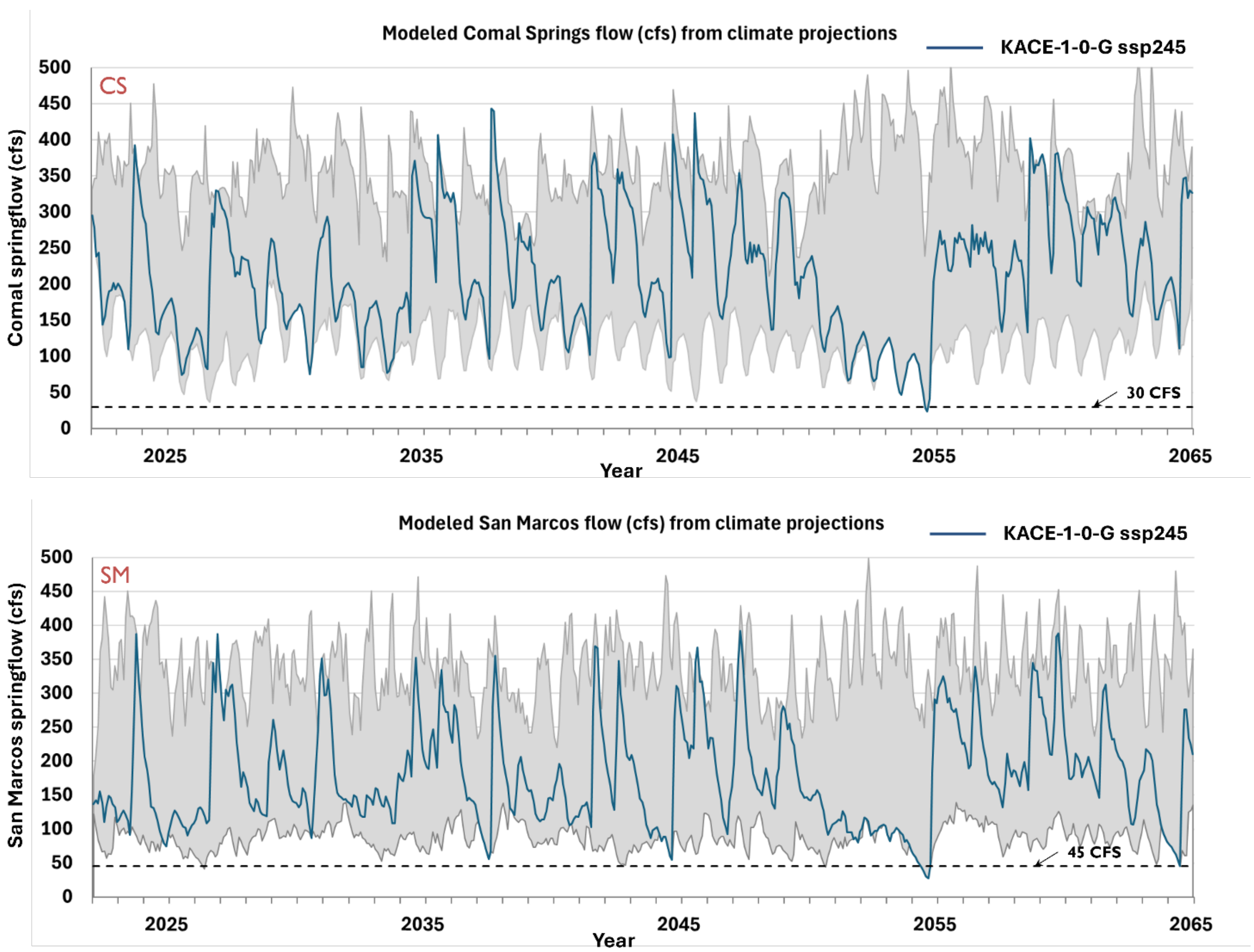


Figure 2-17. Modeled Comal Springs (top) and San Marcos Springs (bottom) flows from the KACE-1-0-G ssp245 GCM for the period 2023–2065. This model is an example of a Low Flow model. The shaded area depicts the range of modeled spring flow rates for all 19 climate model projections.

Water levels and spring flow rates are generally affected by complex interactions between groundwater recharge and groundwater pumping in the Edwards Aquifer. Numerical models of the aquifer system explicitly incorporate these interactions, and the model's response to system inputs and withdrawals is also sensitive to the application of spring flow protection measures. Figure 2-18 illustrates the range of factors that contribute to projected model flow rates at Comal Springs and San Marcos Springs from the climate model INM-CM4-8 ssp245 (a Neutral group model). The figures are complex but reveal some of the components controlling the magnitude of flow at either spring system. Shown in the figures are: 1) monthly applied pumping, adjusted for CPM conditions and VISPO and ASR triggers, 2) monthly and annual applied recharge, the dark green line and green bars, respectively, 3) the 10-year moving average of annual recharge as indicated by the light green line, 4) the 500,000 ac-ft ASR-related trigger value for 10-year average annual recharge, and 5) the resulting projected spring flow rate in dark blue.

For both spring systems, increases in spring flow rates correspond to the peaks of monthly recharge to the aquifer (Figure 2-18), while decreases are a reflection of less recharge and greater applied pumping, especially during each summer. The exaggerated intra-annual sawtooth shape of the spring flow rates is likely caused by application of maximum allowed monthly groundwater pumping in the model, but the periodicity of declines is consistent with seasonal pumping. The short-term trend (within a couple of years) of the spring flow rates follows projected annual recharge, while the longer-term trend correlates with the 10-year moving average annual recharge. Variations in groundwater pumping are easily correlated with CPM restrictions during lower flow periods and application of VISPO- and ASR-related measures. For example, reduced pumping in the 2054–2058 timeframe (Figure 2-18) is associated with application of CPM restrictions and ASR forbearance.

Figure 2-19 shows an example of modeled spring flow rates of San Marcos Springs from the KIOST-ESM ssp245 model (a Stressed group member). For this model projection, 10-year moving average annual recharge falls below 500,000 ac-ft in several periods. When combined with CPM restrictions, there is a noticeable difference in maximum permitted pumping across the range of the simulation period.

Figure 2-20 depicts an example of projected spring flows for Comal Springs from a Low Flow model, KACE-I-0-G ssp245. During the significant drought period that occurs from 2051–2055, there is exceptionally low annual recharge, and pumping is reduced in accordance with applied CPM restrictions. However, the timing of this drought sequence is such that the 10-year moving average of annual recharge does not fall below 500,000 ac-ft during the drought. Thus, ASR-related forbearance is not triggered. The net result is that as flows at Comal Springs and San Marcos Springs reach their lowest, not all spring flow protection measures are implemented. Both Low Flow models are affected in the same manner—intense short-term droughts do not trigger all available spring flow protection measures, which results in very low flows.

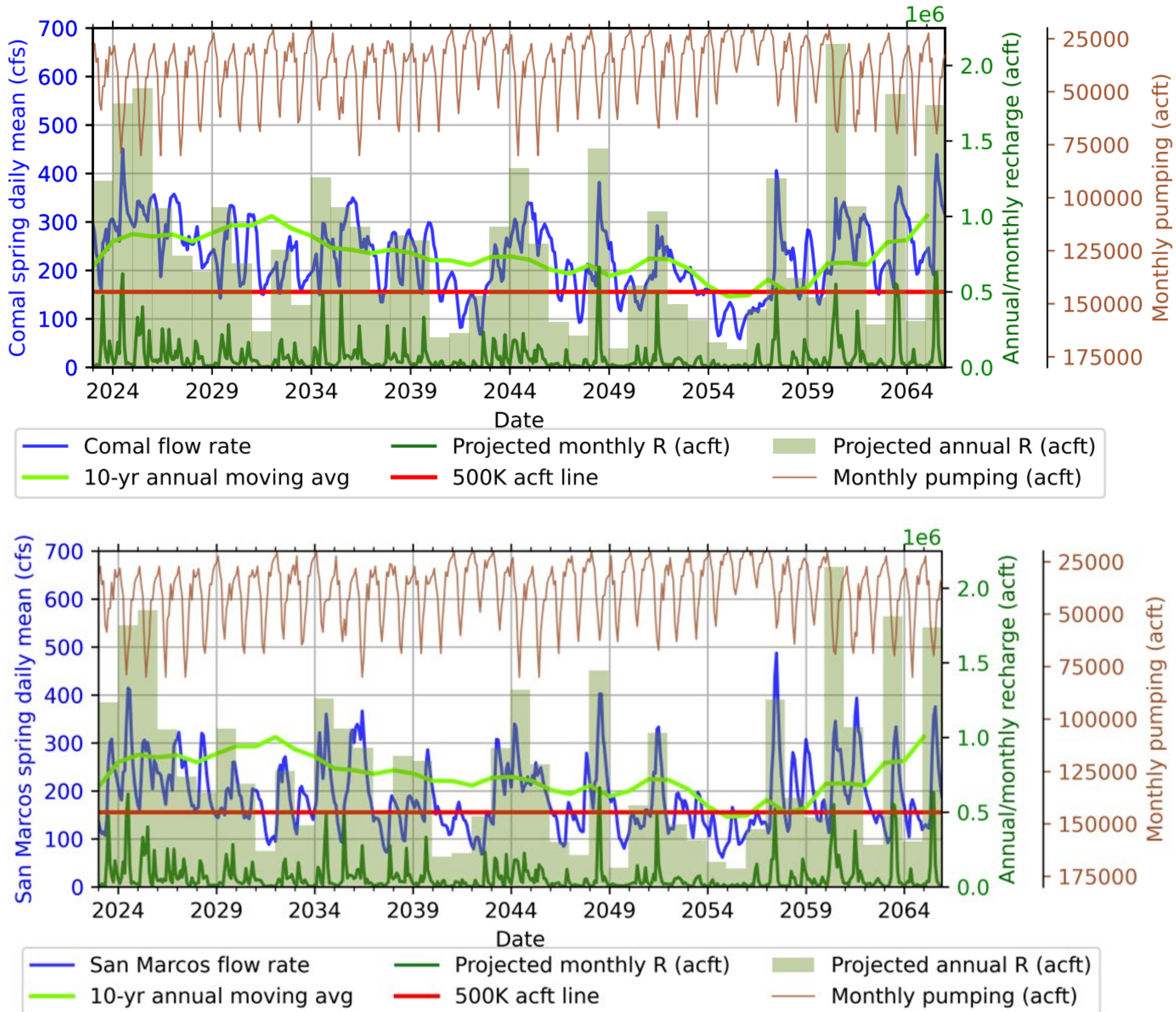


Figure 2-18. Projected Comal (top, blue) and San Marcos springs flows (bottom, blue) from the INM-CM4-8 ssp585 GCM (a Neutral group model) spanning from 2023 to 2065. Applied monthly pumping (brown), total monthly recharge (dark green line), annual recharge (green bar), and the 10-year moving annual average recharge (light green line) are shown.

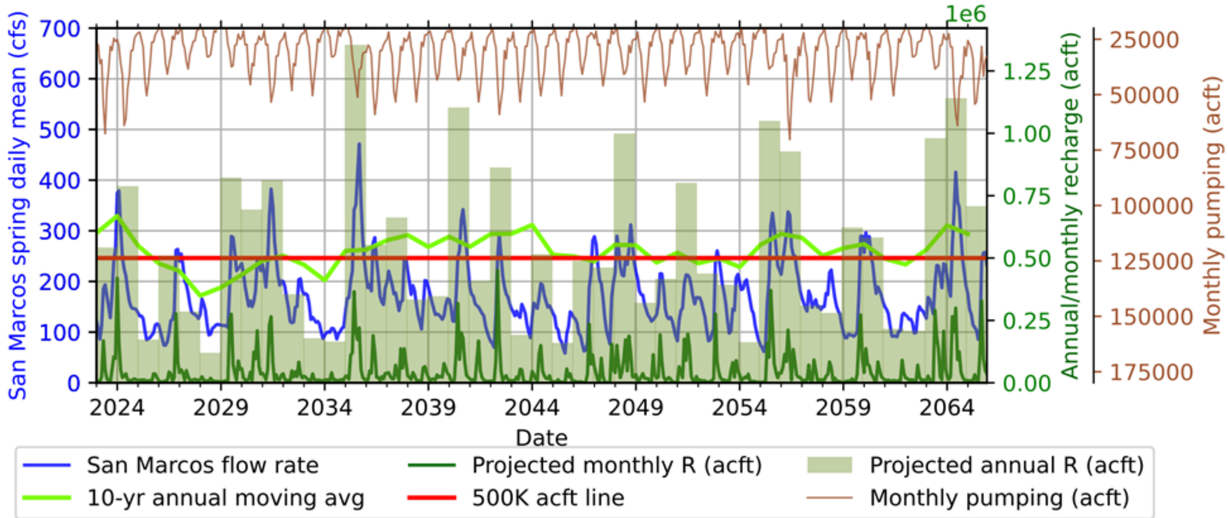


Figure 2-19. Projected San Marcos Springs flows (blue) from the KIOST-ESM ssp245 GCM (a Stressed group model) spanning from 2023 to 2065. Applied monthly pumping (brown), total monthly recharge (dark green line), annual recharge (green bar), and the 10-year moving annual average recharge (light green line) are shown.

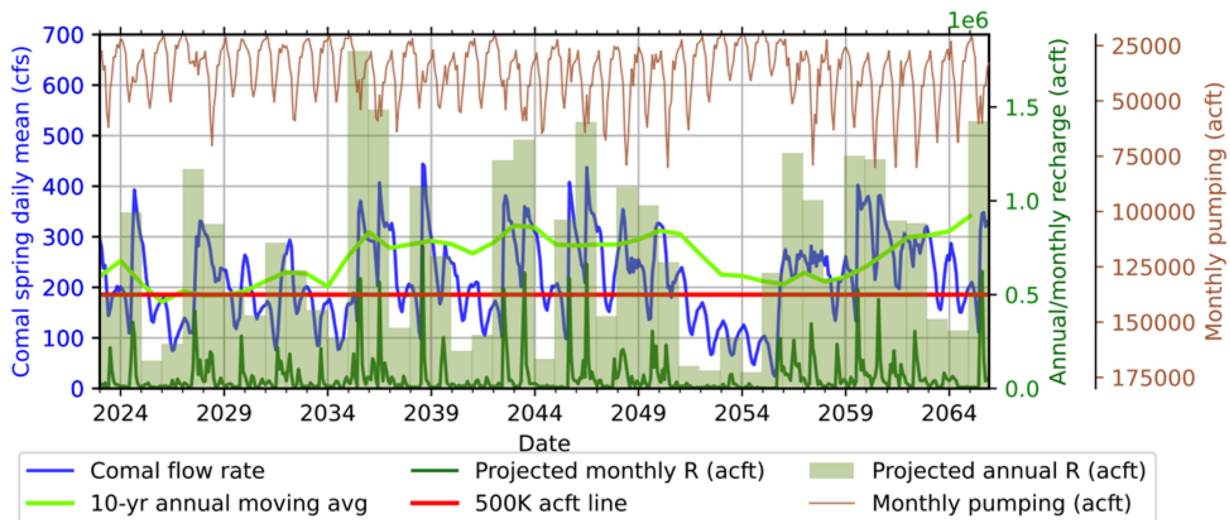


Figure 2-20. Projected Comal Springs flows (blue) from the KACE-1-0-G ssp245 GCM (a Low Flow group model) spanning from 2023 to 2065. Applied monthly pumping (brown), total monthly recharge (dark green line), annual recharge (green bar), and the 10-year moving annual average recharge (light green line) are shown.

2.5 Summary

Projections of future recharge, developed from downscaled GCMs, were used with an existing numerical groundwater model for the Edwards Aquifer to produce projections of future water levels and spring flows for the period 2023–2065. The MODFLOW model used in the simulations is the same as used in previous EAHCP Phase II simulations but was updated to include: 1) a capability to model 516 stress periods instead of the originally modeled 144 stress periods, 2) modifications to the Jupyter notebook and Python-based scripting package to automate running of the model, and 3) addition of features to produce more user-friendly output files. Pumping and spring flow protection measures in the model were the same as in the EAHCP Phase II analyses.

The Jupyter notebook and associated model were evaluated by comparing model output for the drought of record and by comparing model output using a range of realistic recharge inputs. The current model replicated results from previous modeling of drought of record, and the model successfully produced reasonable and expected output from the three separate recharge input tests. Results of the quality assurance and quality control checks of the model provide confidence in the model's performance for projecting of water levels and spring flows given projections of future recharge.

MODFLOW modeling analysis of spring flow rates was performed using a total of 19 GCM climate projections. Median values of the combined modeled spring flow rates for 2023–2065 are in the range of those historically observed for both the Comal Springs and San Marcos Springs. The cumulative distributions of the Comal Springs flows suggests that historical flow rates below 100 cfs are enveloped by the spring flow rates simulated from the climate projections; thus, the model outputs appear to be unbiased relative to low flow conditions. Analysis of the modeling results confirms that the protective measures are triggered appropriately and correspond to the groundwater management criteria. By comparing sequence patterns of the modeled Comal Spring flows to those of the historical drought periods, we found the modeling results produce a few (~3) sequences similar to the pattern of the 1950s drought of record and more than 19 sequences similar to the recent 2011–2015 drought.

Results of the 19 model projections can be qualitatively classified into three groups: Neutral, Stressed, and Low Flow. Neutral model results have water levels and spring flows that are reasonably similar to aquifer conditions over the past 4 decades. Stressed model results have generally lower spring flows and water levels but do not have minimum flows below proposed minimum average daily spring flow discharge objectives. The Low Flow includes two climate projections with one or more stress periods producing modeled spring flow rates that are lower than the proposed minimum average daily spring flow objectives.

Analysis of the impacts on modeled spring flow rates indicate that the exaggerated intra-annual sawtooth pattern is due to application of maximum permitted monthly pumping. As expected, the peaks of the modeled spring flow rates are associated with monthly recharge. Short-term and long-term trends in water levels and spring flows follow the trends in annual recharge and 10-year moving average of annual recharge, respectively. Further analysis of the lowest modeled spring flow rates indicate that some protective measures (ASR forbearance measures) are not triggered during those periods.

Some observations from the modeling analysis of projected groundwater levels and spring flows: 1) the EAHCP Phase II MODFLOW model successfully incorporated projected future recharge to produce estimates of future spring flows under varying climate scenarios; 2) several model projections produce drought sequences similar to those experienced in recent history but none that appear more severe than the drought of record; 3) the majority of GCM projections indicate that existing spring flow protection measures would maintain spring flows above minimum average daily spring flow discharge objectives for the Comal and San Marcos springs, but 2 of the 19 projections produce flow rate sequences over the course of one to four months that are below these objectives; and 4) no projections result in zero flows in Comal or San Marcos springs.

3.1 Executive Summary

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Appendix A
MODFLOW Jupyter Notebook Example

Introduction

- This jupyter notebook should work together with the following subfolders
    - baseModel
    - GenerateWellPackage
    - postprocessingLogFiles
    - recharge
    - updateRCH_SAWSasrForbearance
    - documentation folder includes documents related to this type of simulations.
- Copy all files in those folders with this Jupyter notebook together. Do not change the names of the subfolders
- The projected recharge should be copied to the subfolder of recharge, .\recharge\rechargeprocessing

User Interface

- projectedR_filename: the file name for the projected recharge
- scenario: a string to combine GCM and rcp which is used for saving the WL of J17 and J27 and Q

In [ ]:
```
projectedR_filename ='formatted_ProjRech_KIOST-ESM_ssp245_adjusted.csv'
scenario = 'KIOST-ESM_ssp245'
```

No need to change after this cell

In [ ]:
```

```

In [ ]:
```

```

In [ ]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```

In [ ]:
```
import os
from pathlib import Path
```

In [ ]:
```
import shutil
import subprocess
```

Step 1, Convert monthly recharge time series into a Modflow.RCH file

- Estimates based on the Puente method will require adjustment prior to input into the Modflow model (Lindgren et al, 2004; Liu et al., 2017).
- EAA previously developed a spreadsheet to load in the Puente method numbers and apply the necessary corrections. A python script was also developed by Logan to convert the corrected recharge numbers from the spreadsheet into a .RCH file.
- Use these tools to create the .RCH file with the appropriate number of stress periods for the desired scenario.

In [ ]:
```
## Load the python module to generate the RCH pacakge from the proected recharge
## the allocatingRCH requires two imput parameters:
##     The folder for the data (including the input and output)
##     The name of the projected recharge
##     the projected recharge should be placed within the folder of the data.
## The output of the module is the RCH package with added "Allocated_" to the name of

from recharge.AllocateRecharge import allocatingRCH
```

In [ ]:
```
help(allocatingRCH)
```

```
Help on function allocatingRCH in module recharge.AllocateRecharge:

allocatingRCH(data_directory, recharge_filename)
```

In [ ]:
```
cwd = os.getcwd()
```

In [ ]:
```
iRCH = True ## for processing recharge
```

In [ ]:
```
recharge_folder = os.path.join(cwd,'recharge','rechargeprocessing')
if iRCH == True:
    allocatingRCH(recharge_folder, projectedR_filename)
```

In [ ]:
```

```

Step 2, Process Future Recharge Scenario to get total annual aquifer recharge and then calculate 10-year average recharge for each year of the scenario analysis period

- The 10-year average recharge numbers should be based on the raw Puente method numbers, not the corrected numbers used for the model input. Make note of all the years when the 10-year average recharge is below 500,000 acre-feet.
- Note that the USGS recharge before 2023 was used together with the projected recharge (2023-2065) to calculate 10-year average annul recharge

In [ ]:

```

```

In [ ]:

```
usgsRechFile = os.path.join( cwd, 'recharge','rechargeprocessing','USGSmonthlyRecharge
rchUSGS = pd.read_csv(usgsRechFile,parse_dates=True,index_col='date')
```

In [ ]:

```

```

In [ ]:

```
projRechFile = os.path.join( cwd, 'recharge','rechargeprocessing',projectedR_filename)
rchProj = pd.read_csv(projRechFile,parse_dates=True,index_col='date')
rchProj.head()
```

Out[ ]:

	Nueces	Frio	Sabinal	SAME	Medina	MECI	Cibolo	
date								
2023-01-31	2798.968647	0.000000	0.00000	0.000000	0.00	0.000000	0.000000	
2023-02-28	5005.608405	0.000000	0.00000	0.000000	0.00	0.000000	0.000000	
2023-03-31	3795.695989	0.000000	0.00000	0.000000	0.00	0.000000	0.000000	
2023-04-30	10280.794869	9174.712058	0.00000	0.000000	0.00	0.000000	0.000000	
2023-05-31	33475.853824	38231.247307	17352.01556	41347.264558	4394.32	11112.642139	11124.194112	1

In [ ]:

```
# rchProj.resample('Y').sum().to_csv('IPSL-CM5A-MR-RCP85-projectedHSPFrechargeScaledWi
```

In [ ]:

```

```

In [ ]:

```
totalRchUSGS = rchUSGS.resample('Y').sum().sum(axis=1)
totalRchProj = rchProj.resample('Y').sum().sum(axis=1)
```

In [ ]:

```
totalR = pd.concat([totalRchUSGS,totalRchProj],axis=0)
totalR.head()
```

Out[ ]:
```
date
1934-12-31     179601.0
1935-12-31    1258139.0
1936-12-31     909578.0
1937-12-31     400588.0
1938-12-31     432702.0
Freq: A-DEC, dtype: float64
```

In [ ]:
```
totalR.tail()
```

Out[ ]:
```
date
2061-12-31    2.148216e+05
2062-12-31    2.081732e+05
2063-12-31    9.801406e+05
2064-12-31    1.138691e+06
2065-12-31    7.062272e+05
Freq: A-DEC, dtype: float64
```

In [ ]:
```
totalR_10yr_movingAvg = totalR.rolling(10).mean()
```

In [ ]:
```
totalR_10yr_movingAvg = pd.DataFrame(totalR_10yr_movingAvg)
totalR_10yr_movingAvg.columns=['totalR']
```

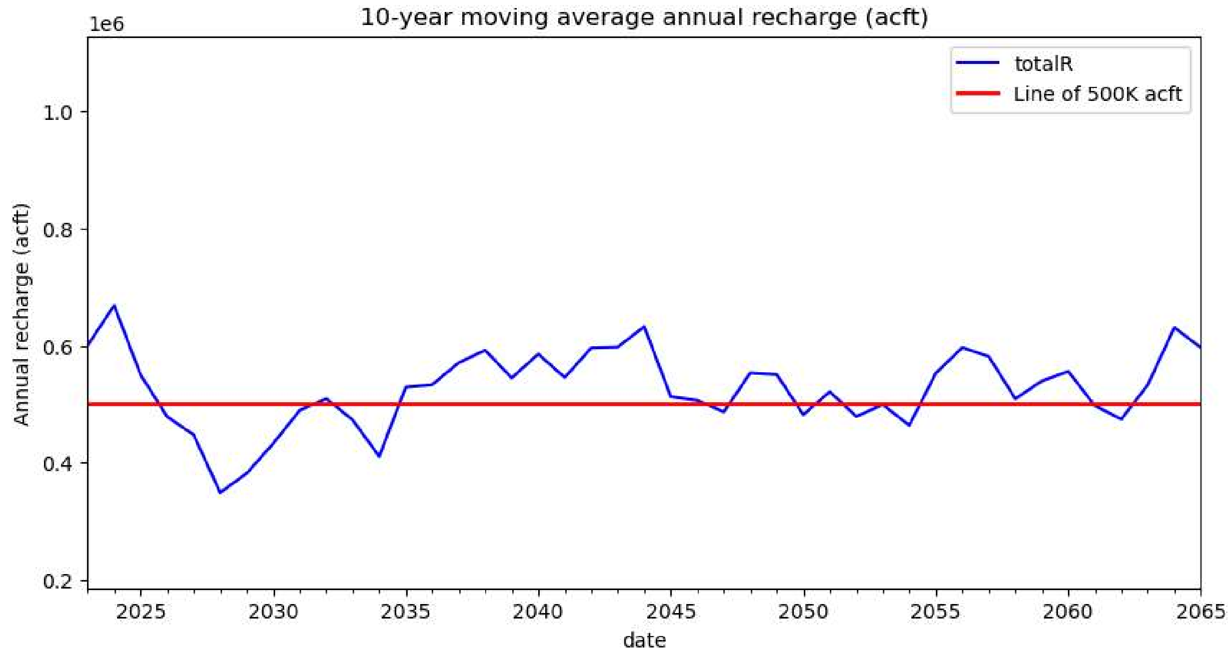
In [ ]:
```

```

In [ ]:
```
cond = (totalR_10yr_movingAvg.index.year>2022) & (totalR_10yr_movingAvg['totalR']<5000
years_totalR_below500K = totalR_10yr_movingAvg.loc[cond,:].index.year.tolist()
years_totalR_below500K
```

Out[ ]:
```
[2026,
 2027,
 2028,
 2029,
 2030,
 2031,
 2033,
 2034,
 2047,
 2050,
 2052,
 2053,
 2054,
 2061,
 2062]
```

In [ ]:
```
fig,ax =plt.subplots(figsize=(10,5))
totalR_10yr_movingAvg.plot(ax=ax,style='b-',label = '10-year moving average (acft)')
R_belwo500K = pd.DataFrame({'date':[totalRchProj.index[0],totalRchProj.index[-1]],'Lin
R_belwo500K  = R_belwo500K .set_index('date')
#J17WL635.plot(ax=ax[0,1])
R_belwo500K .plot(ax=ax,style='r-',lw=2)
ax.set_ylabel('Annual recharge (acft)')
ax.set_xlim('2023-01-01','2065-12-31')
ax.set_title('10-year moving average annual recharge (acft)')
```

Out[ ]:
```
Text(0.5, 1.0, '10-year moving average annual recharge (acft)')
```




```
In [ ]:
```

Step 3, Create the first run

- Use the Jupyter script “GenerateWellFiles.py” to create the .WEL files. This script uses a .csv file called “Pumping Regime Types” to determine the conservation measures that are triggered for each year of the scenario analysis. Because it is not yet known which conservation measures will be triggered during the analysis, we first need to run it with only the conservation measures that are known.
- Regional Conservation. This conservation measure assumes that a reduction of 10,000 af out of the 578,000 af of total permitted pumping will not be pumped. The 10k af reduction is implemented for any year where CON is specified in column C of the Pumping Regime Types .csv file. For most scenario analysis, this should be specified for every year
- SAWS ASR Leases. The SAWS ASR program actually includes two parts. The first part is 50,000 af of permits that fall under lease options. In most years, when the 10-yr average recharge is above 500,000 af, this water will be pumped as normal. These years are known in advance based on the analysis of recharge estimates done in Step 2 above. For these years with 10-yr average recharge greater than 500,000 af, the number 1 should be specified in column D of the Pumping Regime Types file. For those years when the 10-yr average recharge falls below 500,000 af, enter the number 3 in column D. (Note: the number 2 in column D should not be used, as it is part of an obsolete program and no longer used.
- VISPO Leases. The VISPO program includes 41,795 af of leased water that is pumped in most years, but is not pumped in years when, on October 1 of the previous year, the 10-day average water level in Index Well J-17 was below 635 ft. For future scenario analyses, these years are not yet known. Therefore, the model has to be run without VISPO forbearance and the results analyzed to see which years meet the VISPO trigger. Therefore, for this first

run through the analysis, the word NORMAL should be entered in column B of the Pumping Regime Types file.

In [ ]:

Step 3.1 Make a new folder for conducting Step 3 analysis

In [ ]:

In [ ]:
```
## Create a folder with a name of Step3
folderStep3 = os.path.join(cwd,'step3')
if not os.path.exists(folderStep3):
    os.makedirs(folderStep3)
```

In [ ]:
```
## Create a subfolder for conducting model simualtions
folderStep3Simulation = os.path.join(folderStep3,'simulation')
if not os.path.exists(folderStep3Simulation):
    os.makedirs(folderStep3Simulation)
```

In [ ]:
```
## Need to copy the model files from the basemodel folder into the simualtion folder
baseModelFolder = os.path.join(cwd,'baseModel')
files = os.listdir(baseModelFolder)
for file in files:
    file =os.path.join(baseModelFolder,file)
    shutil.copy2(file,folderStep3Simulation)
```

In [ ]:
```
## Copy the rch Pacakge to the simulation folder
fileRCH = os.path.join(recharge_folder,'allocated_'+projectedR_filename[:-3]+'rch')
shutil.copy2(fileRCH,folderStep3Simulation)
```

Out[ ]:
```
'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step3\\simulation\\a
llocated_formatted_ProjRech_KIOST-ESM_ssp245_adjusted.rch'
```

In [ ]:

Step 3.2 create well package

In [ ]:
```
## Create a subfolder of genWellPacakge with the folder of Step 3:

folderStep3Well = os.path.join(folderStep3,'genWellPack')
if not os.path.exists(folderStep3Well):
    os.makedirs(folderStep3Well)
```

In [ ]:
```
## Copy the pumping type file to the folderStep3Well
PRTfile = os.path.join(cwd,'GenerateWellPackage','Pumping Regime Types.csv')
shutil.copy2(PRTfile,folderStep3Well)
```

Out[ ]:
```
'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step3\\genWellPack
\\Pumping Regime Types.csv'
```

In [ ]:
```
# Now we need to update the PRT file based on the recharge
PRTfile = os.path.join(folderStep3Well,'Pumping Regime Types.csv')
pumping_regime=pd.read_csv(PRTfile)
pumping_regime
```

In [ ]:
```
years_totalR_below500K
```
Out[ ]:
```
[2026,
 2027,
 2028,
 2029,
 2030,
 2031,
 2033,
 2034,
 2047,
 2050,
 2052,
 2053,
 2054,
 2061,
 2062]
```
In [ ]:
```
## Set inital value for VISPO column to be Normal
pumping_regime['VISPO'] = 'NORMAL'
```
In [ ]:
```
pumping_regime['SAWS'] = ['3' if pumping_regime.loc[i,'Year']-1 in years_totalR_below5
```
In [ ]:
```
pumping_regime
```
In [ ]:
```

```
In [ ]:
```
_,pumpRegimeFile = os.path.split(PRTfile)
PRTfile_updatedStep3 = os.path.join(folderStep3Well,pumpRegimeFile[:-4]+'_step3.csv' )
pumping_regime.to_csv(PRTfile_updatedStep3,index=False)
```
In [ ]:
```
PRTfile_updatedStep3
```
Out[ ]:
```
'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step3\\genWellPack
\\Pumping Regime Types_step3.csv'
```
In [ ]:
```
## Copy the L1normal_2023_2065.wel to the folder of genwellpackage
```
In [ ]:
```
## Copy the L1normal_2023_2065.wel from the folder of genwellpackage to the folderStep
fileL1norm = os.path.join(cwd,'GenerateWellPackage','L1normal_2023_2065.wel')
shutil.copy2(fileL1norm,folderStep3Well)
```
Out[ ]:
```
'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step3\\genWellPack
\\L1normal_2023_2065.wel'
```
In [ ]:
```
## Load the python module to generate the Well
from GenerateWellPackage.GenerateWellFiles import updateWellPackage
```
In [ ]:
```
help(updateWellPackage)
```
```
Help on function updateWellPackage in module GenerateWellPackage.GenerateWellFiles:

updateWellPackage(pathWell, pumpingRegimeFile, startingDate, endingDate, oriWellFile,
iRunSplitWell=True, iCheckNewWel=True)
```

- After editing the Pumping Regime Types file, the Generate_Pumping_Files Jupyter script is ready to run. The script will generate a .WEL file called L3ASR3.wel.
- This is the .WEL file that should be run through the Groundwater Management Module for the first run.

In [ ]:

```

```

In [ ]:

```
iWell = True
_,pumpingRegimeFile = os.path.split(PRTfile_updatedStep3)
startingDate ='2023-01-01'
endingDate = '2065-12-31'
oriWellFile = 'L1normal_2023_2065.wel'
if iWell == True:
    targetWellFile = updateWellPackage(folderStep3Well, pumpingRegimeFile, startingDat
```

In [ ]:

```
## Copy the generated file to the simulation folder
shutil.copy2(targetWellFile,folderStep3Simulation)
```

Out[ ]:

```
'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step3\\simulation\\L
3ASR3.wel'
```

Step 3.3 Prepare input files for model simulations

In [ ]:

```
### Need to update the RCH and well pacakge names in the MODFLOW nam  file
namFile = os.path.join(folderStep3Simulation,'itprenewal2023.nam')
with open(namFile,'r') as namF:
    namLines= namF.readlines()
    namF.close()

newLines =[]
_, welPackName = os.path.split(targetWellFile)
_, rchpackName = os.path.split(fileRCH)
for line in namLines:
    newline = line
    if 'WEL 12' in line:
        print(line)
        newline= line[:7] +'   ' + welPackName +'\n'
        print(newline)
    if 'RCH 18 ' in line:
        newline= line[:7] +' ' + rchpackName +'\n'
    newLines.append(newline)

with open(namFile,'w') as namF:
    for line in newLines:
        namF.write(line)
    namF.close()
```

```
WEL 12 L4STG5_new-41795vspo.wel

WEL 12   L3ASR3.wel
```

Step 3.4 Run the simulation of Step 3

In [ ]:
```
## Change the current dir to the folder of simulation
os.chdir(folderStep3Simulation)
exec_cmd = ['mfnr12_525.exe', 'itprenewal2023.nam']
proc = subprocess.Popen(exec_cmd, stdout=subprocess.PIPE, stderr=subprocess.STDOUT)

while proc.poll() is None:
    txt = proc.stdout.readline()
    txt = txt.decode('utf-8')
    if len(txt.strip())>0:
        print(txt)

if proc.returncode == 0:
    print("Simulation executed successfully")
else:
    print("Simulation encountered an error")
    print("Error:", proc.returncode)

## make sure chabge the current dir to main folder with this Jupyter notebook
os.chdir(cwd)
```

In [ ]:

In [ ]:

Step 3.5 Postprocess the results of Step 3 simulation

- After running the Groundwater Management Modul batch file from Step 3, evaluate the output water levels for J-17.

In [ ]:
```
from postProcessingLogFiles.logstat6 import extractingSimulationResults
```

In [ ]:

In [ ]:
```
## Postprocessing the results
logFile = os.path.join(folderStep3Simulation,'itprenewal2023.log')
step3OutputF = os.path.join(folderStep3Simulation,'Step3_log.csv')
extractingSimulationResults(logFile,step3OutputF)
```

Step 3.6 Check the results

In [ ]:
```
dates = pd.date_range('2023-01-01','2065-12-31',freq='M')
```

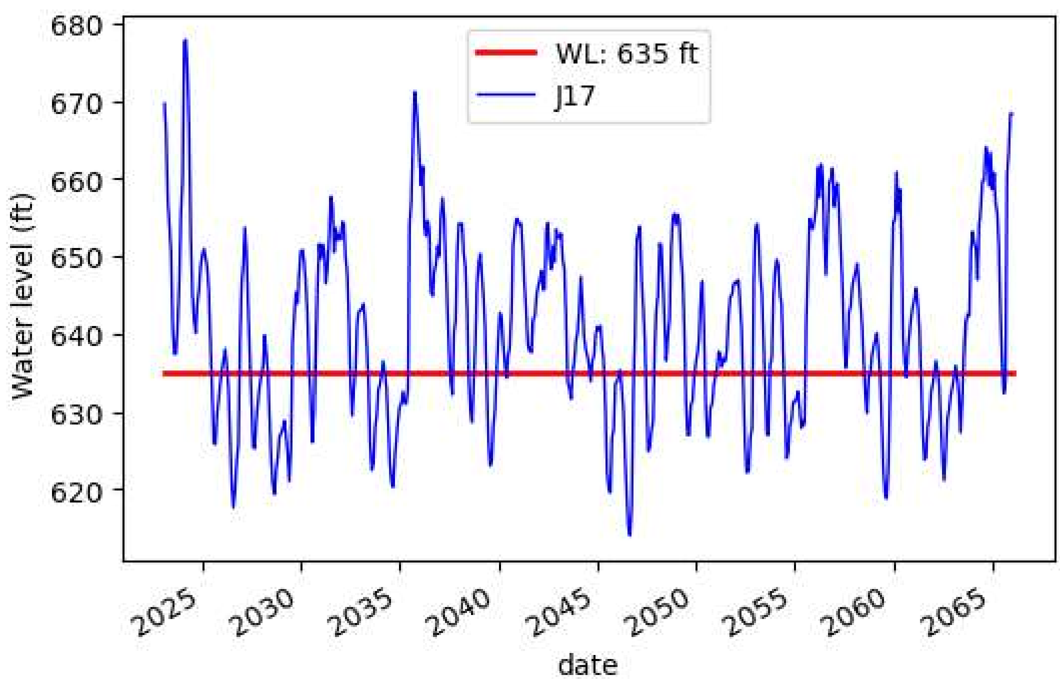
In [ ]:
```
len(dates)
```

Out[ ]:
```
516
```

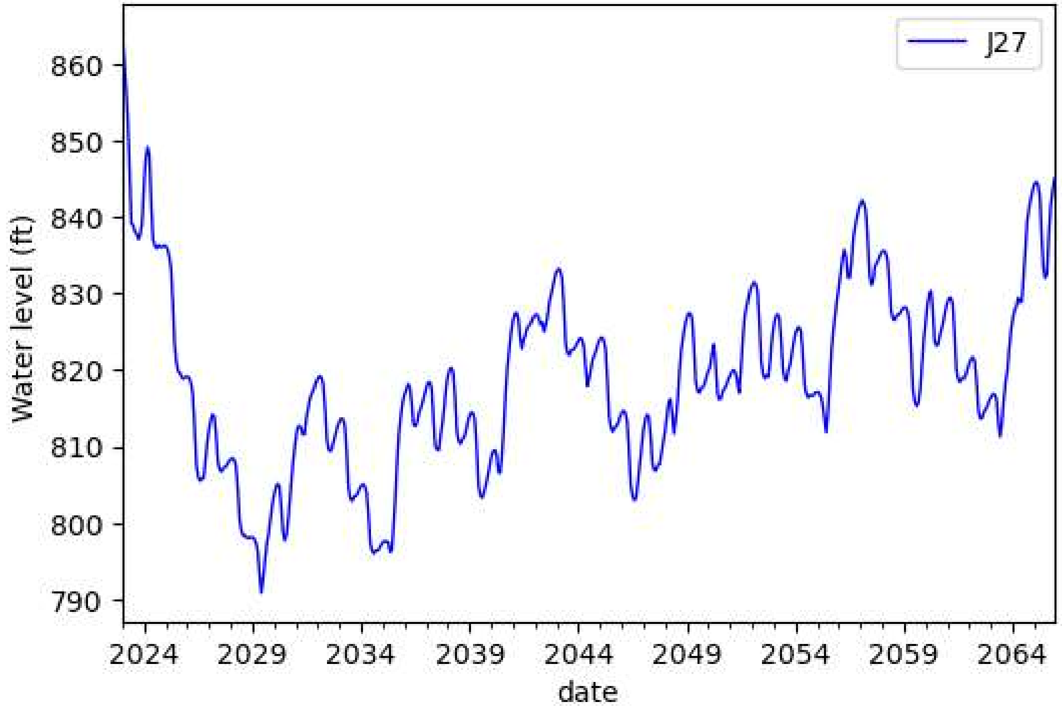
In [ ]:
```
logStep3 = pd.read_csv(step3OutputF)
```

In [ ]:
```
logStep3
```

In [ ]:
```
logStep3['date'] = dates
logStep3 = logStep3.set_index('date')
```

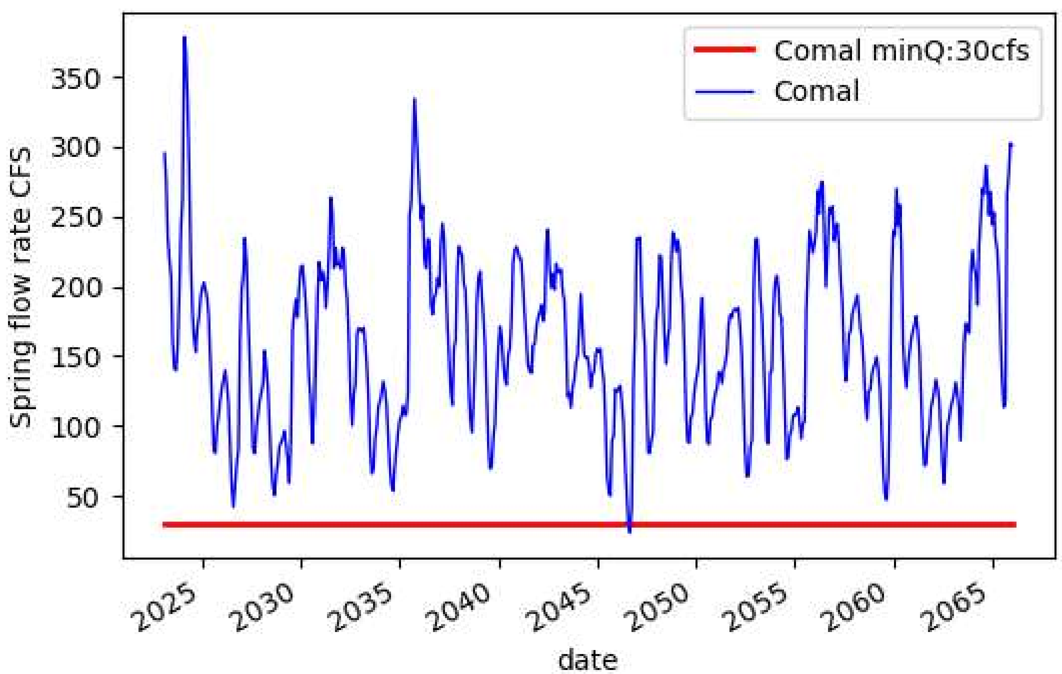
In [ ]:
```
logStep3.columns
```
Out[ ]:
```
Index(['SP', 'days', 'Comal', 'San Marcos', 'J17', 'J27'], dtype='object')
```
In [ ]:
```
fig,ax =plt.subplots(figsize=(6,4))

J17WL635 = pd.DataFrame({'date':[logStep3.index[0],logStep3.index[-1]],'WL: 635 ft':[6
J17WL635 = J17WL635.set_index('date')
#J17WL635.plot(ax=ax[0,1])
J17WL635.plot(ax=ax,style='r-',lw=2)
logStep3[['J17']].plot(ax=ax,style='b-',lw=1)
ax.set_ylabel('Water level (ft) ')
```
Out[ ]:
```
Text(0, 0.5, 'Water level (ft) ')
```


In [ ]:
```
fig,ax =plt.subplots(figsize=(6,4))

logStep3[['J27']].plot(ax=ax,style='b-',lw=1)
ax.set_ylabel('Water level (ft) ')
```
Out[ ]:
```
Text(0, 0.5, 'Water level (ft) ')
```



In [ ]:
```
fig,ax =plt.subplots(figsize=(6,4))
minColmal = pd.DataFrame({'date':[logStep3.index[0],logStep3.index[-1]],'Comal minQ:30
minColmal = minColmal.set_index('date')
minColmal.plot(ax=ax,style='r-',lw=2)
logStep3[['Comal']].plot(ax=ax,style='b-',lw=1)
ax.set_ylabel('Spring flow rate CFS')
```

Out[ ]:
```
Text(0, 0.5, 'Spring flow rate CFS')
```

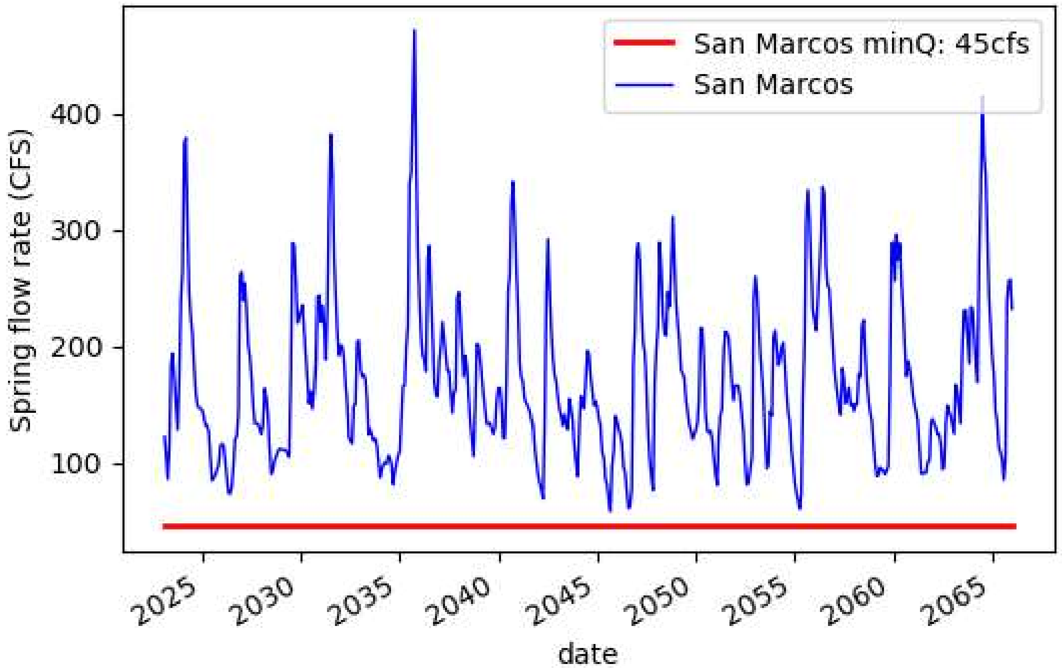


In [ ]:
```
fig,ax =plt.subplots(figsize=(6,4))
minSM = pd.DataFrame({'date':[logStep3.index[0],logStep3.index[-1]],'San Marcos minQ:
minSM = minSM.set_index('date')
minSM.plot(ax=ax,style='r-',lw=2)
```

```
logStep3[['San Marcos']].plot(ax=ax,style='b-',lw=1)
ax.set_ylabel('Spring flow rate (CFS)')
```

Out[ ]:

```
Text(0, 0.5, 'Spring flow rate (CFS)')
```



In [ ]:

```
## Output the WL of J17 and J27 and Q of two springs to a folder of outputWLQ

outputLogStep3 = logStep3.loc[:,['Comal', 'San Marcos', 'J17', 'J27']]
outputLogStep3.columns = ['Comal (cfs)', 'San Marcos (cfs)', 'J17 (ft)', 'J27 (ft)']
outputPath = os.path.join(os.getcwd(),'outputWLQ')
if not os.path.exists(outputPath):
    os.makedirs(outputPath)
outputLogStep3.to_csv(os.path.join(outputPath,scenario+'_Step3_results.csv'))
```

In [ ]:

Step 4, Create the second run and update .WEL file

- After running the Groundwater Management Modul batch file from Step 3, evaluate the output water levels for J-17.
- Identify all the instances when the level is below 635 acre feet on October 1 (end of 9th Stress Period in each year).
- Whenever this occurs, Column B of the Pumping Regime Types file should be edited to change from Normal to Dry in the next year .
- This change will specify the VISPO forbearance is implemented for that year.
- Run the Generate_Pumping_Files Jupyter script again using this modified input.
- Then run the resulting L3ASR3.wel file through the Groundwater Management Module.
- By Jim Winterle

Step 4.1, Create a folder and copy the files for Step4 simulation

In [ ]:
```
## Create a folder with a name of Step4
folderStep4 = os.path.join(cwd,'step4')
if not os.path.exists(folderStep4):
    os.makedirs(folderStep4)
```

In [ ]:
```
## Create a subfolder for conducting model simualtions
folderStep4Simulation = os.path.join(folderStep4,'simulation')
if not os.path.exists(folderStep4Simulation):
    os.makedirs(folderStep4Simulation)
```

In [ ]:
```
## Need to copy the model files from the basemodel folder into the simualtion folder
baseModelFolder = os.path.join(cwd,'baseModel')
files = os.listdir(baseModelFolder)
for file in files:
    file =os.path.join(baseModelFolder,file)
    shutil.copy2(file,folderStep4Simulation)
```

In [ ]:
```
## Copy the rch Pacakge to the simulation folder
fileRCH = os.path.join(recharge_folder,'allocated_'+projectedR_filename[:-3]+'rch')
shutil.copy2(fileRCH,folderStep4Simulation)
```

Out[ ]:
```
'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step4\\simulation\\a
llocated_formatted_ProjRech_KIOST-ESM_ssp245_adjusted.rch'
```

In [ ]:

Step 4.2, Update well package

In [ ]:
```
## Create a subfolder of genWellPacakge with the folder of Step 3:

folderStep4Well = os.path.join(folderStep4,'genWellPack')
if not os.path.exists(folderStep4Well):
    os.makedirs(folderStep4Well)
```

- Identify all the instances when the level is below 635 acre feet on October 1 (end of 9th Stress Period in each year).

In [ ]:
```
cond = (logStep3.index.month == 9) & (logStep3['J17']<635)
logStep3.loc[cond,'J17']
```

In [ ]:
```
vispoYears = list(logStep3.loc[cond,'J17'].index.year+1)
vispoYears
```

Out[ ]:
```
[2026,
 2027,
 2028,
 2029,
 2034,
 2035,
 2039,
 2040,
 2046,
 2047,
 2048,
 2050,
 2051,
 2053,
 2055,
 2059,
 2060,
 2062,
 2063]
```

In [ ]:
```
PRTfile_updatedStep3
```

Out[ ]:
```
'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step3\\genWellPack
\\Pumping Regime Types_step3.csv'
```

In [ ]:
```
## Load the pumping regime types file generated previously
pumping_regime=pd.read_csv(PRTfile_updatedStep3)
pumping_regime.head(2)
```

Out[ ]:

	Year	VISPO	CON	SAWS	Layer 1 ID	Layer 2 ID	Layer 3 ID
0	2023	NORMAL	CON	1	NaN	NaN	NaN
1	2024	NORMAL	CON	1	NaN	NaN	NaN

In [ ]:
```
pumping_regime['VISPO'] = ['DRY' if pumping_regime.loc[i,'Year'] in vispoYears else 'N
pumping_regime.head()
```

Out[ ]:

	Year	VISPO	CON	SAWS	Layer 1 ID	Layer 2 ID	Layer 3 ID
0	2023	NORMAL	CON	1	NaN	NaN	NaN
1	2024	NORMAL	CON	1	NaN	NaN	NaN
2	2025	NORMAL	CON	1	NaN	NaN	NaN
3	2026	DRY	CON	1	NaN	NaN	NaN
4	2027	DRY	CON	3	NaN	NaN	NaN

In [ ]:
```
## Save the updated pumping regime types to a new file for step 4
_, rgtFile4 = os.path.split(PRTfile_updatedStep3)
rgtFile4 = rgtFile4.replace('step3','step4')
rgtFile4path = os.path.join(folderStep4Well,rgtFile4)
pumping_regime.to_csv(rgtFile4path,index=False)
```

In [ ]:
```
rgtFile4path
```

Out[ ]: 'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step4\\genWellPack\\Pumping Regime Types_step4.csv'

In [ ]:

In [ ]:
```
## Copy the pumping type file to the folderStep3Well
fileL1norm = os.path.join(cwd,'GenerateWellPackage','L1normal_2023_2065.wel')
shutil.copy2(fileL1norm,folderStep4Well)
```

Out[ ]: 'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step4\\genWellPack\\L1normal_2023_2065.wel'

In [ ]:

In [ ]:
```
iWell = True
_,pumpingRegimeFile = os.path.split(rgtFile4path)
startingDate ='2023-01-01'
endingDate = '2065-12-31'
oriWellFile = 'L1normal_2023_2065.wel'
if iWell == True:
    targetWellFile = updateWellPackage(folderStep4Well, pumpingRegimeFile, startingDat
```

In [ ]:
```
## Copy the generated file to the simulation folder
shutil.copy2(targetWellFile,folderStep4Simulation)
```

Out[ ]: 'C:\\Users\\cyang\\Desktop\\BottomUp Analysis\\KIOST-ESM_ssp245\\step4\\simulation\\L3ASR3.wel'

In [ ]:

Step 4.3, Prepare model simulation

In [ ]:
```
### Need to update the RCH and well pacakge names in the MODFLOW nam  file
namFile = os.path.join(folderStep4Simulation,'itprenewal2023.nam')
with open(namFile,'r') as namF:
    namLines= namF.readlines()
    namF.close()

newLines =[]
_, welPackName = os.path.split(targetWellFile)
_, rchpackName = os.path.split(fileRCH)
for line in namLines:
    newline = line
    if 'WEL 12' in line:
        print(line)
        newline= line[:7] +'   ' + welPackName +'\n'
        print(newline)
    if 'RCH 18 ' in line:
        newline= line[:7] +' ' + rchpackName +'\n'
    newLines.append(newline)

with open(namFile,'w') as namF:
    for line in newLines:
        namF.write(line)
    namF.close()
```

WEL 12 L4STG5_new-41795vspo.wel

WEL 12   L3ASR3.wel

Step 4.4, Run the simulation of Step 4

In [ ]:
```
## Run the model
## Change the current dir to the folder of simulation
os.chdir(folderStep4Simulation)
exec_cmd = ['mfnr12_525.exe', 'itprenewal2023.nam']
proc = subprocess.Popen(exec_cmd, stdout=subprocess.PIPE, stderr=subprocess.STDOUT)

while proc.poll() is None:
    txt = proc.stdout.readline()
    txt = txt.decode('utf-8')
    if len(txt.strip())>0:
        print(txt)

if proc.returncode == 0:
    print("Simulation executed successfully")
else:
    print("Simulation encountered an error")
    print("Error:", proc.returncode)
## make sure chabge the current dir to main folder with this Jupyter notebook
os.chdir(cwd)
```

Step 4.5 PostProcess results of the Step 4 Simulation

In [ ]:
```
## Postprocess LOG file
logFile = os.path.join(folderStep4Simulation,'itprenewal2023.log')
step4OutputF = os.path.join(folderStep4Simulation,'Step4_log.csv')
extractingSimulationResults(logFile,step4OutputF)
```

In [ ]:

Step 4.6 Check the results of Step 4

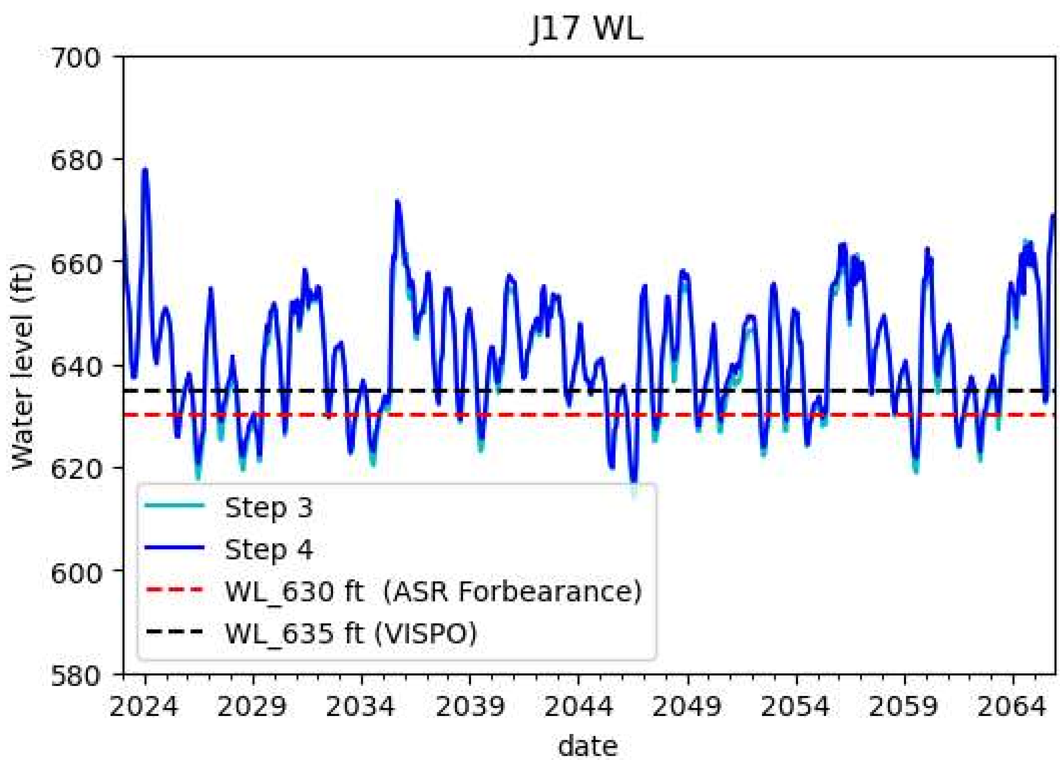
In [ ]:

In [ ]:
```
logStep4 = pd.read_csv(step4OutputF)
logStep4['date'] = dates
logStep4 = logStep4.set_index('date')
```

In [ ]:
```
fig,ax =plt.subplots(figsize=(6,4))
logStep3['J17'].plot(ax=ax,style=['c-'],label='Step 3')
logStep4['J17'].plot(ax=ax,style=['b-'],label='Step 4')
#logStep5['J17'].plot(ax=ax,style=['go'],label='Step 5',markersize = 3)
#logStat6_Jim['J17'].plot(ax=ax,style=['g-'],label='Jim Archive')

df1 = pd.DataFrame({'date':logStep4.index,'WL_630':[630]*len(logStep4.index)})
df1 =df1.set_index('date')
df1['WL_635'] = [635]*len(logStep4.index)

df1['WL_630'].plot(ax=ax,style='r--',label='WL_630 ft  (ASR Forbearance)')
```

```
df1['WL_635'].plot(ax=ax,style='k--',label='WL_635 ft (VISPO)')
ax.set_ylim(580,700)
ax.set_ylabel('Water level (ft)')
ax.set_title('J17 WL')
ax.legend(loc='best')
```

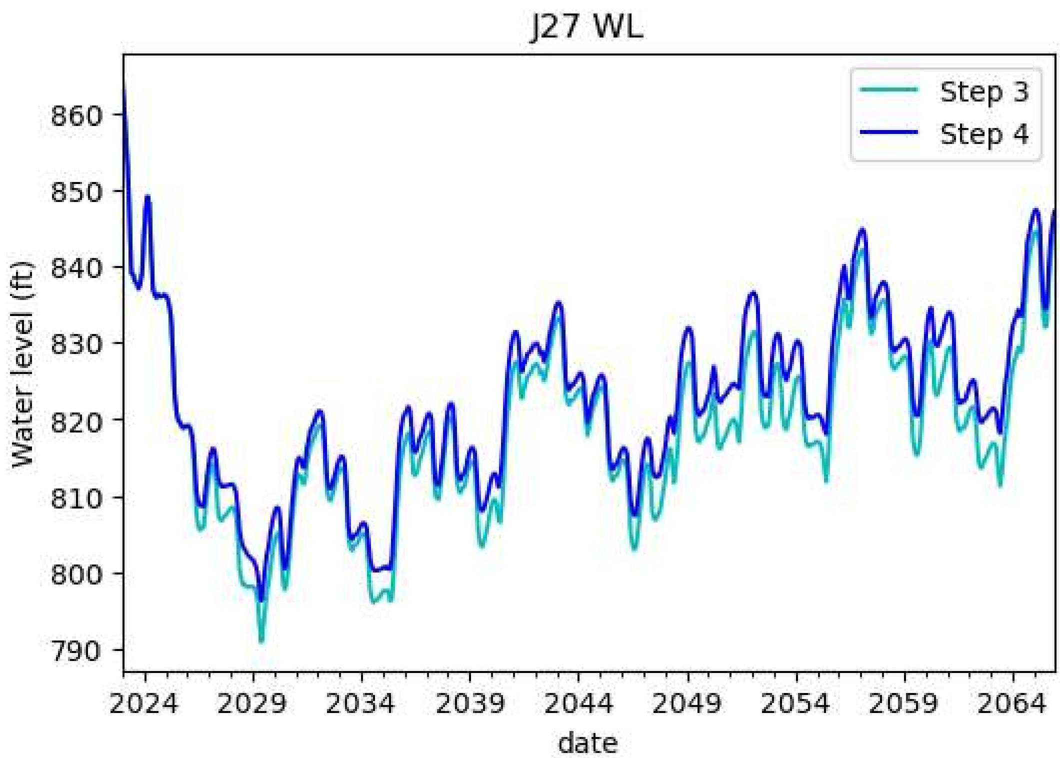
Out[ ]: <matplotlib.legend.Legend at 0x1c75afaf610>



In [ ]:

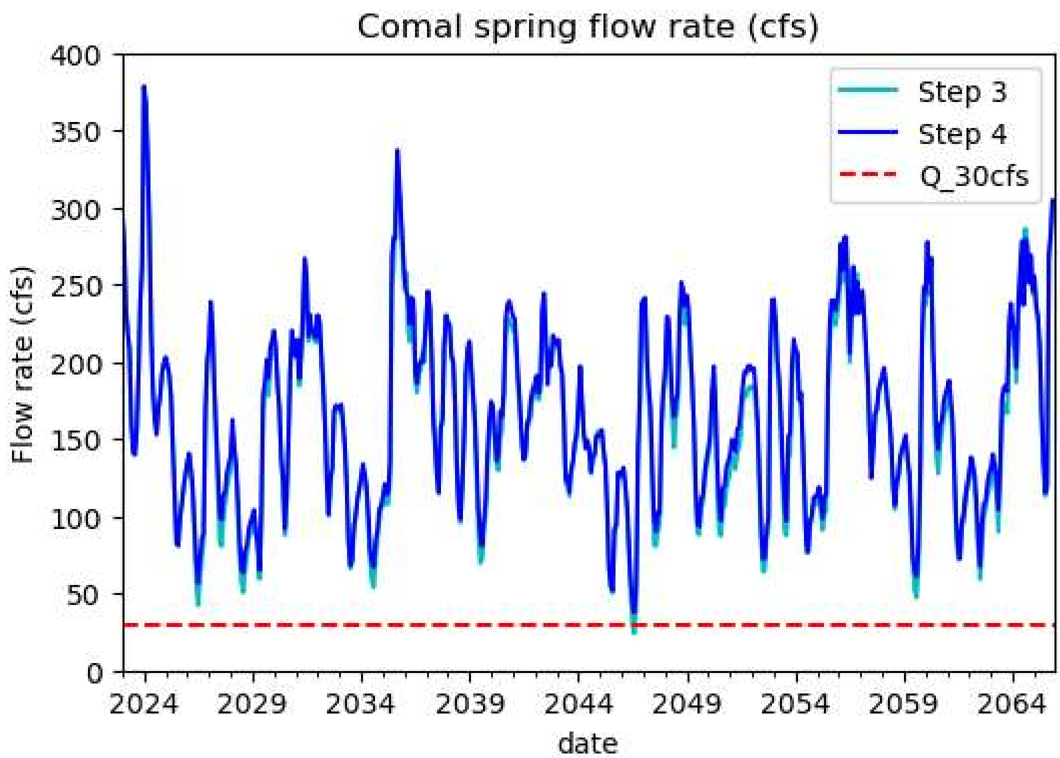
```
fig,ax =plt.subplots(figsize=(6,4))
logStep3['J27'].plot(ax=ax,style=['c-'],label='Step 3')
logStep4['J27'].plot(ax=ax,style=['b-'],label='Step 4')
#logStep5['J27'].plot(ax=ax,style=['go'],label='Step 5',markersize = 3)
#logStat6_Jim['J27'].plot(ax=ax,style=['g-'],label='Jim Archive')
df1 = pd.DataFrame({'date':logStep4.index,'WL_630':[630]*len(logStep4.index)})
df1 =df1.set_index('date')
#df1['WL_635'] = [635]*len(logStep4.index)
#df1['WL_630'].plot(ax=ax,style='r--',label='WL_630')
#df1['WL_635'].plot(ax=ax,style='k--',label='WL_635')
#ax.set_ylim(580,700)
ax.set_ylabel('Water level (ft)')
ax.set_title('J27 WL')
ax.legend(loc='best')
```

Out[ ]: <matplotlib.legend.Legend at 0x1c74d6a1b90>



In [ ]:
```
fig,ax =plt.subplots(figsize=(6,4))
logStep3['Comal'].plot(ax=ax,style=['c-'],label='Step 3')
logStep4['Comal'].plot(ax=ax,style=['b-'],label='Step 4')
#logStep5['Comal'].plot(ax=ax,style=['go'],label='Step 5',markersize=3)
#logStat6_Jim['Comal'].plot(ax=ax,style=['g-'],label='Jim Archive')

df1 = pd.DataFrame({'date':logStep4.index,'Q_30cfs':[30]*len(logStep4.index)})
df1 =df1.set_index('date')
#df1['Q_30cfs'] = [30]*len(logStep4.index)

df1['Q_30cfs'].plot(ax=ax,style='r--',label='Q_30cfs')
ax.set_ylim(0,400)
ax.set_ylabel('Flow rate (cfs)')
ax.set_title('Comal spring flow rate (cfs)')
#df1['Q_30cfs'].plot(ax=ax,style='k--',label='WL_635')
ax.legend(loc='best')
```

Out[ ]:
```
<matplotlib.legend.Legend at 0x1c75aac5090>
```

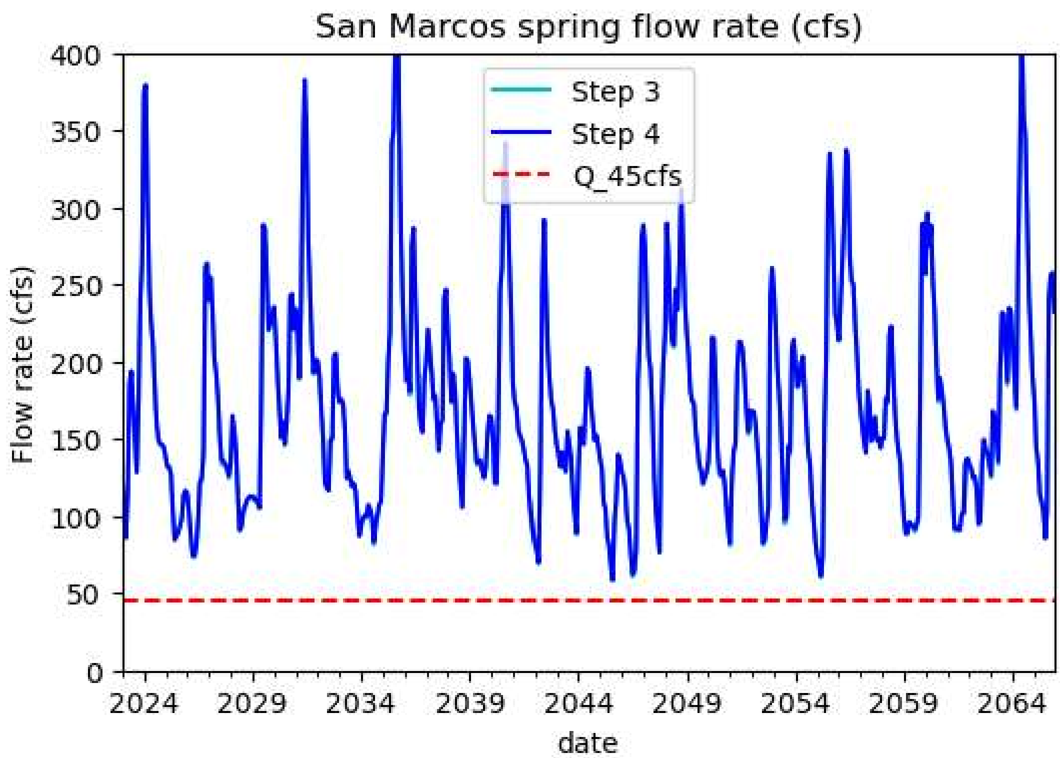


In [ ]:

```
fig,ax =plt.subplots(figsize=(6,4))
logStep3['San Marcos'].plot(ax=ax,style=['c-'],label='Step 3')
logStep4['San Marcos'].plot(ax=ax,style=['b-'],label='Step 4')

df1 = pd.DataFrame({'date':logStep4.index,'Q_45cfs':[45]*len(logStep4.index)})
df1 =df1.set_index('date')
#df1['Q_30cfs'] = [30]*len(logStep4.index)

df1['Q_45cfs'].plot(ax=ax,style='r--',label='Q_45cfs')
ax.set_ylim(0,400)
ax.set_ylabel('Flow rate (cfs)')
ax.set_title('San Marcos spring flow rate (cfs)')
#df1['Q_30cfs'].plot(ax=ax,style='k--',label='WL_635')
ax.legend(loc='best')
```

Out[ ]:

```
<matplotlib.legend.Legend at 0x1c75adb98d0>
```



In [ ]:
```
## Output the WL of J17 and J27 and Q of two springs to a folder of outputWLQ

outputLogStep4 = logStep4.loc[:,['Comal', 'San Marcos', 'J17', 'J27']]
outputLogStep4.columns = ['Comal (cfs)', 'San Marcos (cfs)', 'J17 (ft)', 'J27 (ft)']
outputPath = os.path.join(os.getcwd(),'outputWLQ')
if not os.path.exists(outputPath):
    os.makedirs(outputPath)
outputLogStep4.to_csv(os.path.join(outputPath,scenario+'_Step4_results.csv'))
```

In [ ]:
```

```

Step 5: Modify the .RCH file for a third run, if needed

Step 5.1, Create a folder and copy the files for Step5 simulation

In [ ]:
```
## Create a folder with a name of Step5
folderStep5 = os.path.join(cwd,'step5')
if not os.path.exists(folderStep5):
    os.makedirs(folderStep5)
```

In [ ]:
```
## Create a subfolder for conducting model simualtions
folderStep5Simulation = os.path.join(folderStep5,'simulation')
if not os.path.exists(folderStep5Simulation):
    os.makedirs(folderStep5Simulation)
```

In [ ]:
```
## Copy files from the folder of simulation at Step 4 to Simulation of Step 5
fileLst = os.listdir(folderStep4Simulation)

for fl in fileLst:
    ext = fl[-3:]
    if 'rch' in fl:
```

```
        rchFileNameStep5= fl
    if ext not in ['csv','cbb','cbd','cbw','crc','glo','hds','lg2','log','lst']:
        file =os.path.join(folderStep4Simulation,fl)
        shutil.copy2(file,folderStep5Simulation)
```

In [ ]:

```
rchFileNameStep5
```

Out[ ]:

```
'allocated_formatted_ProjRech_KIOST-ESM_ssp245_adjusted.rch'
```

Table 4. SAWS ASR forbearance representation in MODFLOW Drought of Record simulations.

Month In 1956	HDR (2011) (ac·ft)	Nonroutine AMP Runs (ac·ft)
January	1700	3200
February	1400	3500
March	1100	4500
April	2200	4500
May	3800	5600
June	5600	5600
July	5600	5600
August	5600	5600
September	5600	3000
October	5200	2000
November	4700	1700
December	3800	1500

Step 5.2, Calculate injection rate at four cells with Nonroutine AMP (Table above)

(1) the 10-yr average recharge is below 500,000 af, and (2) the 10-day average water level at J-17 is below 630 ft

In [ ]:

```
def calc_inj_rate(x,years_below500K):
## acft-month
    ASRInj_month = [3200,3500,4500,4500,5600,5600,5600,5600,3000,2000,1700,1500]
    month = [i+1 for i in range(12)]
    SAWS_ASR_month =dict(zip(month,ASRInj_month))
    acre_sqft=43559.9  ## acre to square ft
    area_grid = 1320*1320  # sqare ft
    #print(x.name)
    rate = 0.0
    # check if 10-year average of annual recharge in the the previous year fall in the
    if (x.name.year-1 in years_below500K) and (x['J17']<630.0):
        rate = SAWS_ASR_month[x.name.month]  # acft
        rate = rate/x.name.daysinmonth*acre_sqft    # convert ft3/day
```

```
        rate = rate/(4*area_grid)     # convert ft/day at 4 grids
        #print(rate)
    else:
        rate = 0.0
    return rate
```

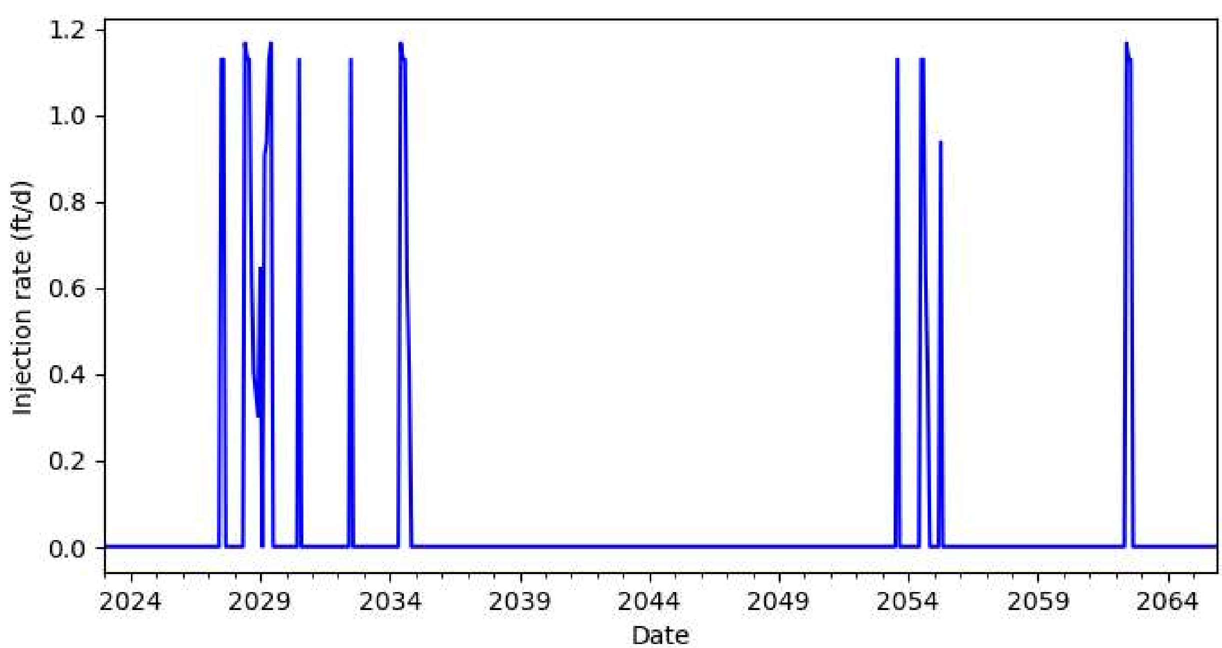
In [ ]:
```
years_totalR_below500K
```

Out[ ]:
```
[2026,
 2027,
 2028,
 2029,
 2030,
 2031,
 2033,
 2034,
 2047,
 2050,
 2052,
 2053,
 2054,
 2061,
 2062]
```

In [ ]:
```
updateSawsASR = logStep4[['J17']]
updateSawsASR['RCH_inj'] = updateSawsASR.apply(lambda x: calc_inj_rate(x,years_totalR_

updateSawsASR
```

In [ ]:
```
fig, ax = plt.subplots(figsize=(8,4))
updateSawsASR['RCH_inj'].plot(ax=ax,linestyle='-',color='b')
ax.set_ylabel('Injection rate (ft/d)')
ax.set_xlabel('Date')
```

Out[ ]:
```
Text(0.5, 0, 'Date')
```



In [ ]:
```
updateSawsASR.to_csv(os.path.join(folderStep5,'injected_ASR_forbearance.csv'))
```

In [ ]:

Step 5.3, Update the recharge package at the four cells with the injection rate (ft/day) previously calculated

In [ ]:
```
from updateRCH_SAWSasrForbearance.readingWritingRch import updatingRCH
```

In [ ]:
```
rchFileNameStep5
```

Out[ ]:
```
'allocated_formatted_ProjRech_KIOST-ESM_ssp245_adjusted.rch'
```

In [ ]:
```
rchFileOri = os.path.join(folderStep5Simulation,rchFileNameStep5)
## the new file name to be saved after the updating
outRchFile = rchFileOri.replace('allocated_','step5_')
### the recharge of each stress period at a cell

newR = updateSawsASR['RCH_inj'].values
### If true the RCH file will be updated with the the newR, otherwise, no update and s
iUpdated = True
# Four injection cells
cells = [(269, 469), (270, 461), (279, 457), (267, 435)]  # Base 0
oriDataDict = updatingRCH(rchFileOri, outRchFile, newR,cells,iUpdated)
```

Step 5.4, Prepare the files for model simulation of Step 5

In [ ]:
```
### Need to update the RCH and well pacakge names in the MODFLOW nam  file
namFile = os.path.join(folderStep5Simulation,'itprenewal2023.nam')
with open(namFile,'r') as namF:
    namLines= namF.readlines()
    namF.close()

newLines =[]
_, rchpackName = os.path.split(outRchFile)
for line in namLines:
    newline = line
    if 'RCH 18 ' in line:
        newline= line[:7] +' ' + rchpackName +'\n'
    newLines.append(newline)

with open(namFile,'w') as namF:
    for line in newLines:
        namF.write(line)
    namF.close()
```

In [ ]:

Step 5.5, Run the simulation of Step 5

In [ ]:
```
## Run the model
## Change the current dir to the folder of simulation
os.chdir(folderStep5Simulation)
exec_cmd = ['mfnr12_525.exe', 'itprenewal2023.nam']
proc = subprocess.Popen(exec_cmd, stdout=subprocess.PIPE, stderr=subprocess.STDOUT)
```

```
while proc.poll() is None:
    txt = proc.stdout.readline()
    txt = txt.decode('utf-8')
    if len(txt.strip())>0:
        print(txt)

if proc.returncode == 0:
    print("Simulation executed successfully")
else:
    print("Simulation encountered an error")
    print("Error:", proc.returncode)

## make sure chabge the current dir to main folder with this Jupyter notebook
os.chdir(cwd)
```

In [ ]:

```
```

Step 5.6 Postprocess the modeling results

folderStep5Simulation =r'E:\projects\EAA_All_modflows\Rerun_RCP85_IPSL-CM5A-MR_20240116\step5\simulation' logFile = os.path.join(folderStep5Simulation,'itprenewal2023.log') step5OutputF = os.path.join(folderStep5Simulation,'Step5_log.csv') extractingSimulationResults(logFile,step5OutputF)

In [ ]:

```
## Postprocess LOG file
logFile = os.path.join(folderStep5Simulation,'itprenewal2023.log')
step5OutputF = os.path.join(folderStep5Simulation,'Step5_log.csv')
extractingSimulationResults(logFile,step5OutputF)
```

In [ ]:

```
```

In [ ]:

```
```

Step 5.6 Check the modeling results of the Step 5 simulation

In [ ]:

```
logStep5 = pd.read_csv(step5OutputF)
if len(logStep5) != len(dates):
    print(" Step 5 simulation has a convergence issue! Please check the run!")
else:

    logStep5['date'] = dates
    logStep5 = logStep5.set_index('date')
```

In [ ]:

```
```

In [ ]:

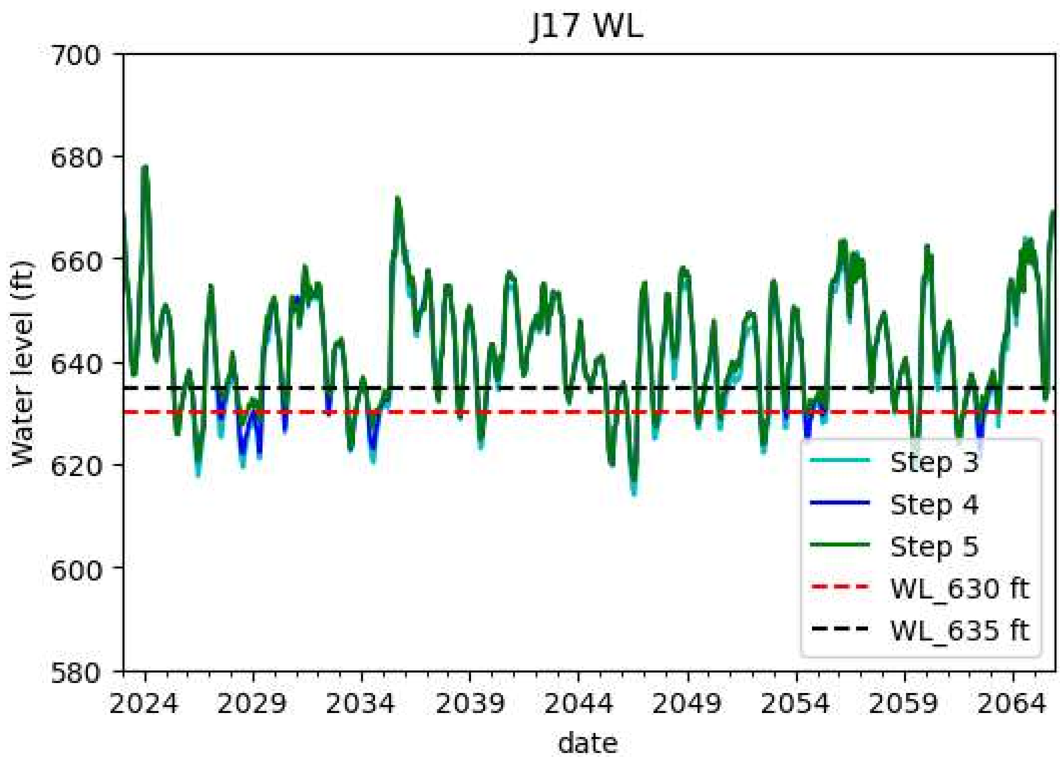
```
```

In [ ]:

```
fig,ax =plt.subplots(figsize=(6,4))
logStep3['J17'].plot(ax=ax,style=['c-'],label='Step 3')
logStep4['J17'].plot(ax=ax,style=['b-'],label='Step 4')
logStep5['J17'].plot(ax=ax,style=['g-'],label='Step 5',markersize = 3)
#logStat6_Jim['J17'].plot(ax=ax,style=['g-'],label='Jim Archive')

df1 = pd.DataFrame({'date':logStep4.index,'WL_630':[630]*len(logStep4.index)})
df1 =df1.set_index('date')
```

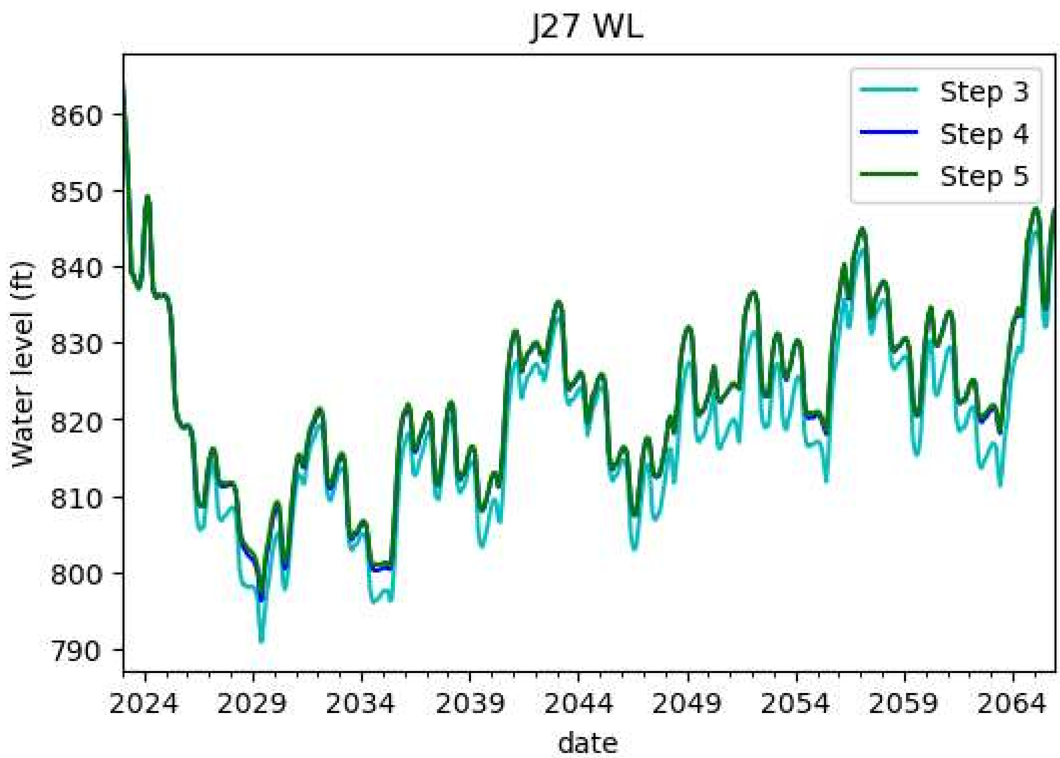
```
df1['WL_635'] = [635]*len(logStep4.index)

df1['WL_630'].plot(ax=ax,style='r--',label='WL_630 ft')
df1['WL_635'].plot(ax=ax,style='k--',label='WL_635 ft')
ax.set_ylim(580,700)
ax.set_ylabel('Water level (ft)')
ax.set_title('J17 WL')
ax.legend(loc='best')
```

Out[ ]: <matplotlib.legend.Legend at 0x1c75acc0cd0>



In [ ]:
```
fig,ax =plt.subplots(figsize=(6,4))
logStep3['J27'].plot(ax=ax,style=['c-'],label='Step 3')
logStep4['J27'].plot(ax=ax,style=['b-'],label='Step 4')
logStep5['J27'].plot(ax=ax,style=['g-'],label='Step 5',markersize = 3)
#logStat6_Jim['J27'].plot(ax=ax,style=['g-'],label='Jim Archive')
df1 = pd.DataFrame({'date':logStep4.index,'WL_630':[630]*len(logStep4.index)})
df1 =df1.set_index('date')
#df1['WL_635'] = [635]*len(logStep4.index)
#df1['WL_630'].plot(ax=ax,style='r--',label='WL_630')
#df1['WL_635'].plot(ax=ax,style='k--',label='WL_635')
#ax.set_ylim(580,700)
ax.set_ylabel('Water level (ft)')
ax.set_title('J27 WL')
ax.legend(loc='best')
```

Out[ ]: <matplotlib.legend.Legend at 0x1c75ab22550>

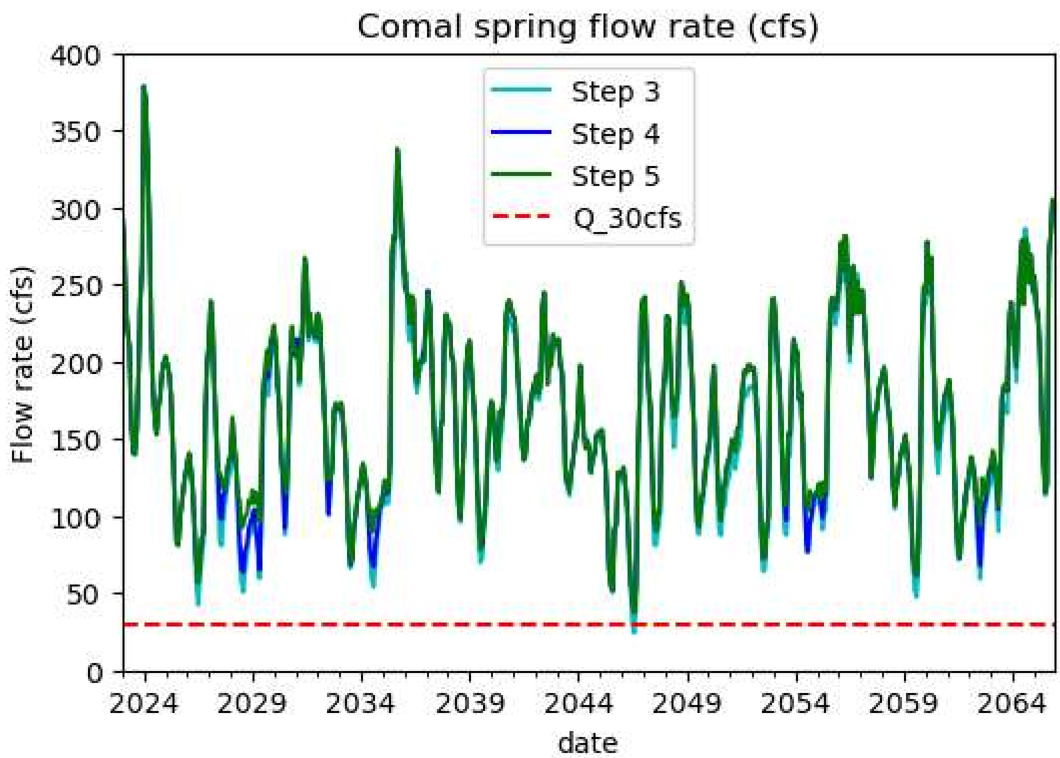


In [ ]:

```
fig,ax =plt.subplots(figsize=(6,4))
logStep3['Comal'].plot(ax=ax,style=['c-'],label='Step 3')
logStep4['Comal'].plot(ax=ax,style=['b-'],label='Step 4')
logStep5['Comal'].plot(ax=ax,style=['g-'],label='Step 5',markersize=3)
#logStat6_Jim['Comal'].plot(ax=ax,style=['g-'],label='Jim Archive')

df1 = pd.DataFrame({'date':logStep4.index,'Q_30cfs':[30]*len(logStep4.index)})
df1 =df1.set_index('date')
#df1['Q_30cfs'] = [30]*len(logStep4.index)

df1['Q_30cfs'].plot(ax=ax,style='r--',label='Q_30cfs')
ax.set_ylim(0,400)
ax.set_ylabel('Flow rate (cfs)')
ax.set_title('Comal spring flow rate (cfs)')
#df1['Q_30cfs'].plot(ax=ax,style='k--',label='WL_635')
ax.legend(loc='best')
```

Out[ ]:

```
<matplotlib.legend.Legend at 0x1c7b5088590>
```



In [ ]:

```
logStep5[logStep5['Comal']<30]
```

Out[ ]:

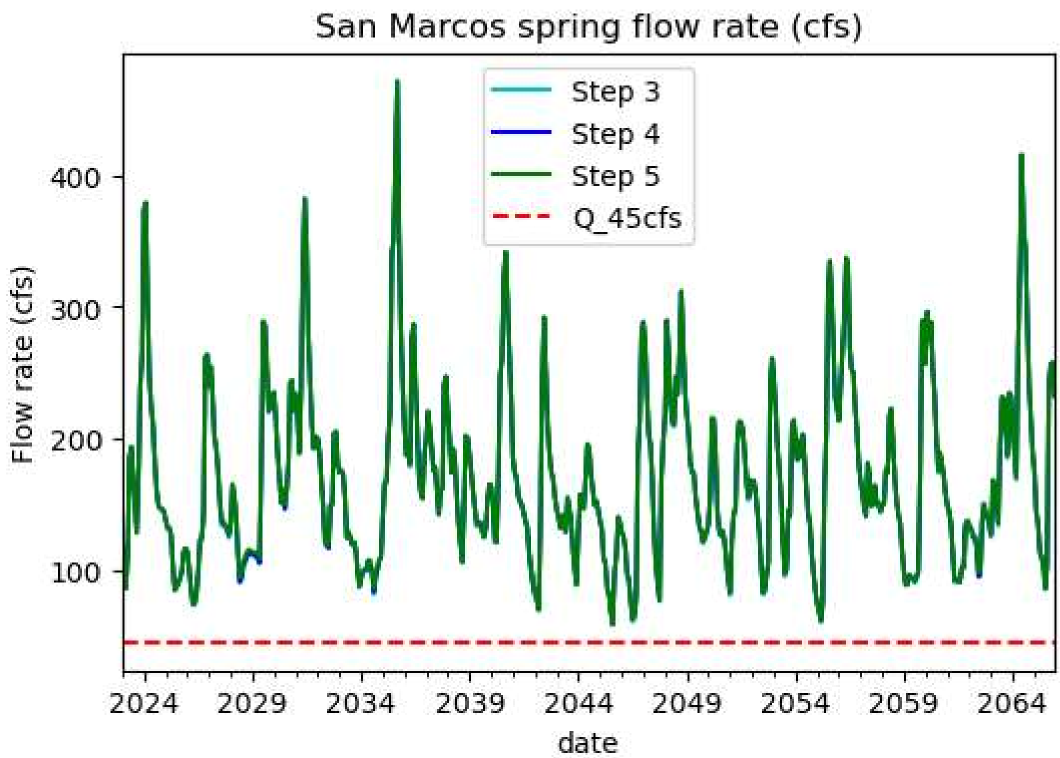
	SP	days	Comal	San Marcos	J17	J27
date						

In [ ]:

```
fig,ax =plt.subplots(figsize=(6,4))
logStep3['San Marcos'].plot(ax=ax,style=['c-'],label='Step 3')
logStep4['San Marcos'].plot(ax=ax,style=['b-'],label='Step 4')
logStep5['San Marcos'].plot(ax=ax,style=['g-'],label='Step 5',markersize=3)
#logStat6_Jim['San Marcos'].plot(ax=ax,style=['g-'],label='Jim Archive')

df1 = pd.DataFrame({'date':logStep4.index,'Q_45cfs':[45]*len(logStep4.index)})
df1 =df1.set_index('date')
#df1['Q_30cfs'] = [30]*len(logStep4.index)

df1['Q_45cfs'].plot(ax=ax,style='r--',label='Q_45cfs')
#ax.set_ylim(0,600)
ax.set_ylabel('Flow rate (cfs)')
ax.set_title('San Marcos spring flow rate (cfs)')
#df1['Q_30cfs'].plot(ax=ax,style='k--',label='WL_635')
ax.legend(loc='best')
```

Out[ ]:

```
<matplotlib.legend.Legend at 0x1c7b49b5090>
```



In [ ]:
```
logStep5.loc[logStep5['San Marcos']<45,'San Marcos']
```

Out[ ]:
```
Series([], Name: San Marcos, dtype: float64)
```

In [ ]:
```
## Output the WL of J17 and J27 and Q of two springs to a folder of outputWLQ

outputLogStep5 = logStep5.loc[:,['Comal', 'San Marcos', 'J17', 'J27']]
outputLogStep5.columns = ['Comal (cfs)', 'San Marcos (cfs)', 'J17 (ft)', 'J27 (ft)']
outputPath = os.path.join(os.getcwd(),'outputWLQ')
if not os.path.exists(outputPath):
    os.makedirs(outputPath)
outputLogStep5.to_csv(os.path.join(outputPath,scenario+'_Step5_results.csv'))
```

In [ ]:

The end

In [ ]:

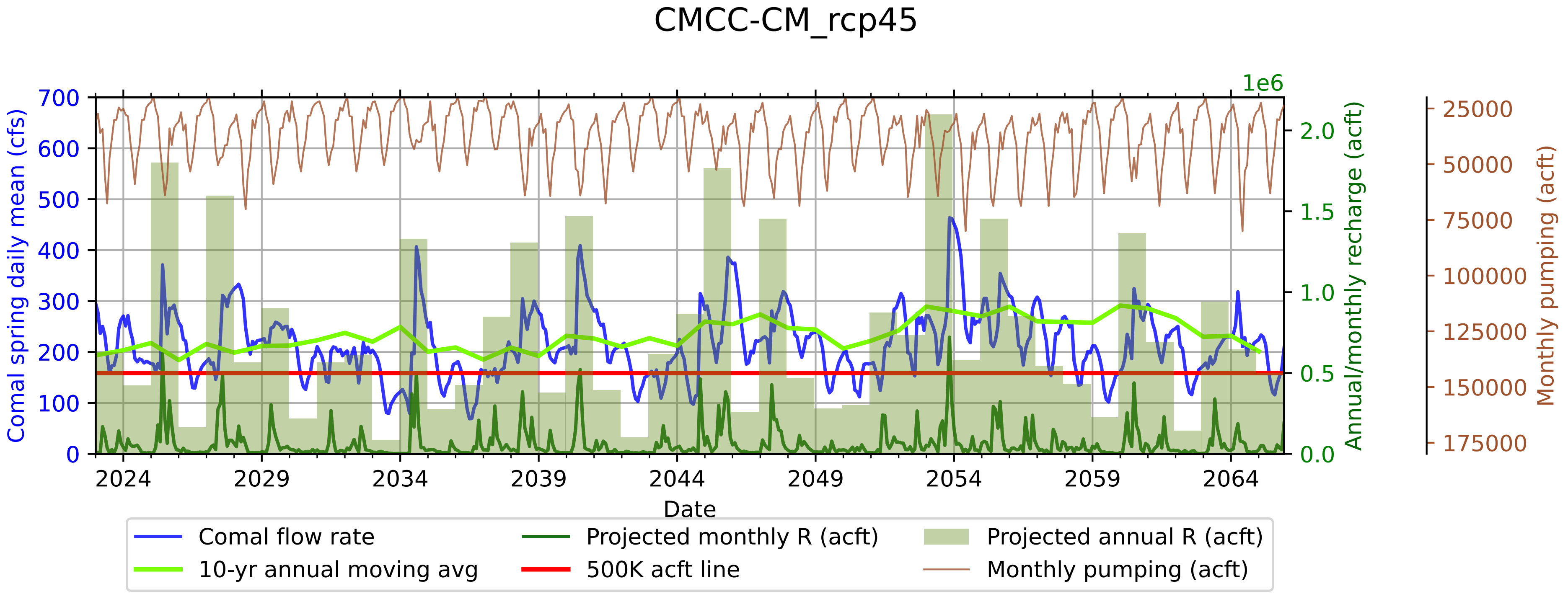
In [ ]:

In [ ]:

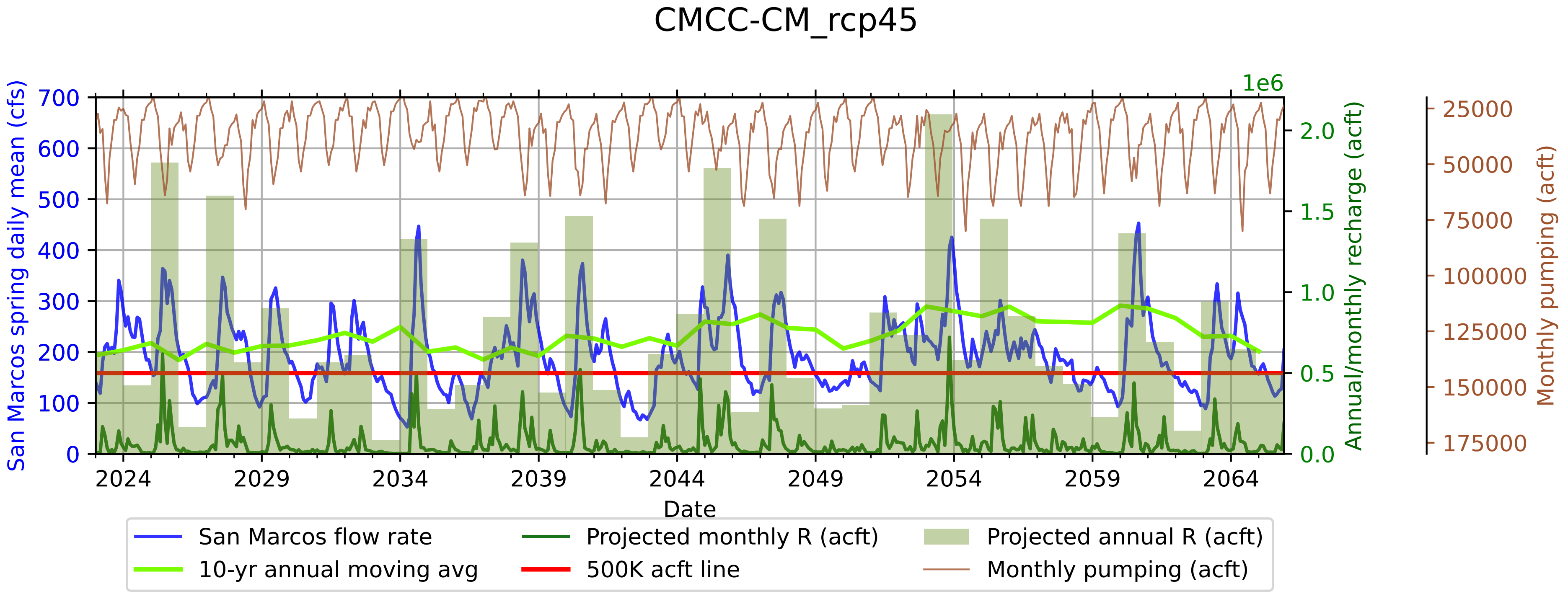
In [ ]:

Appendix B

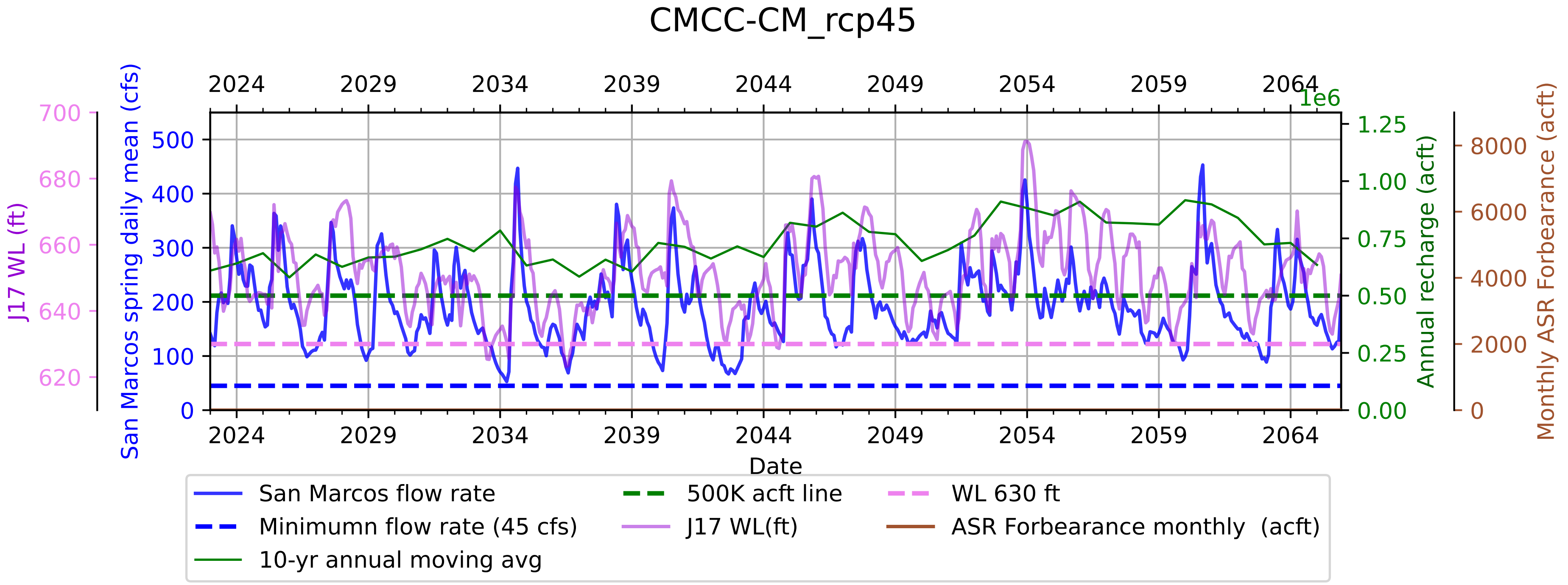
Summary of Individual Model Results

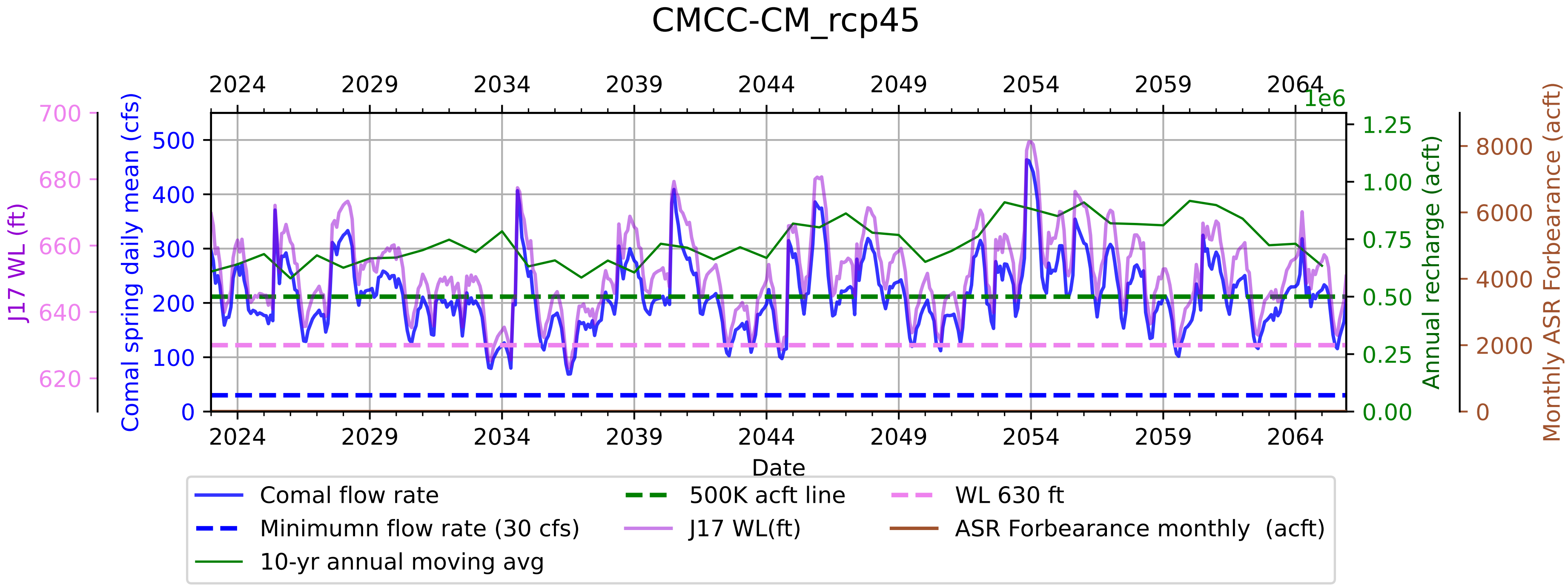


CMCC-CM_rcp45
Comal spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
Date
700
600
500
400
300
200
100
0
2.0
1.5
1.0
0.5
0.0
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

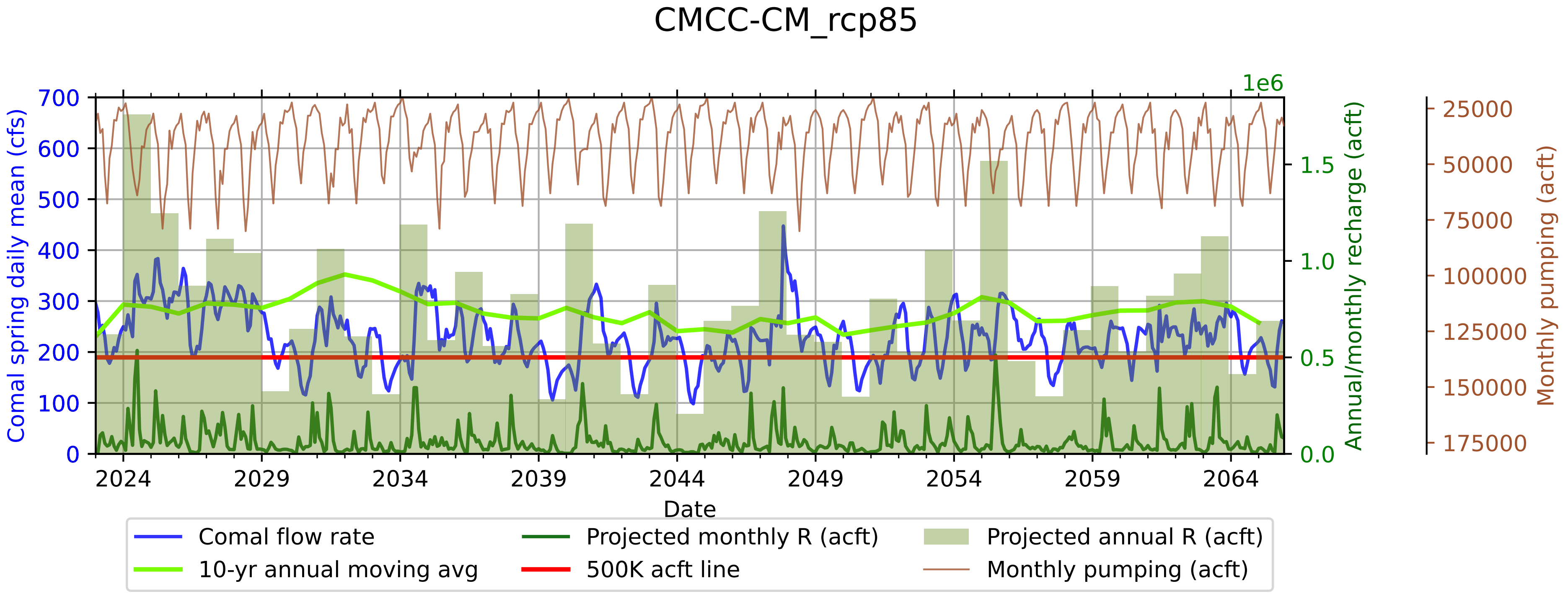


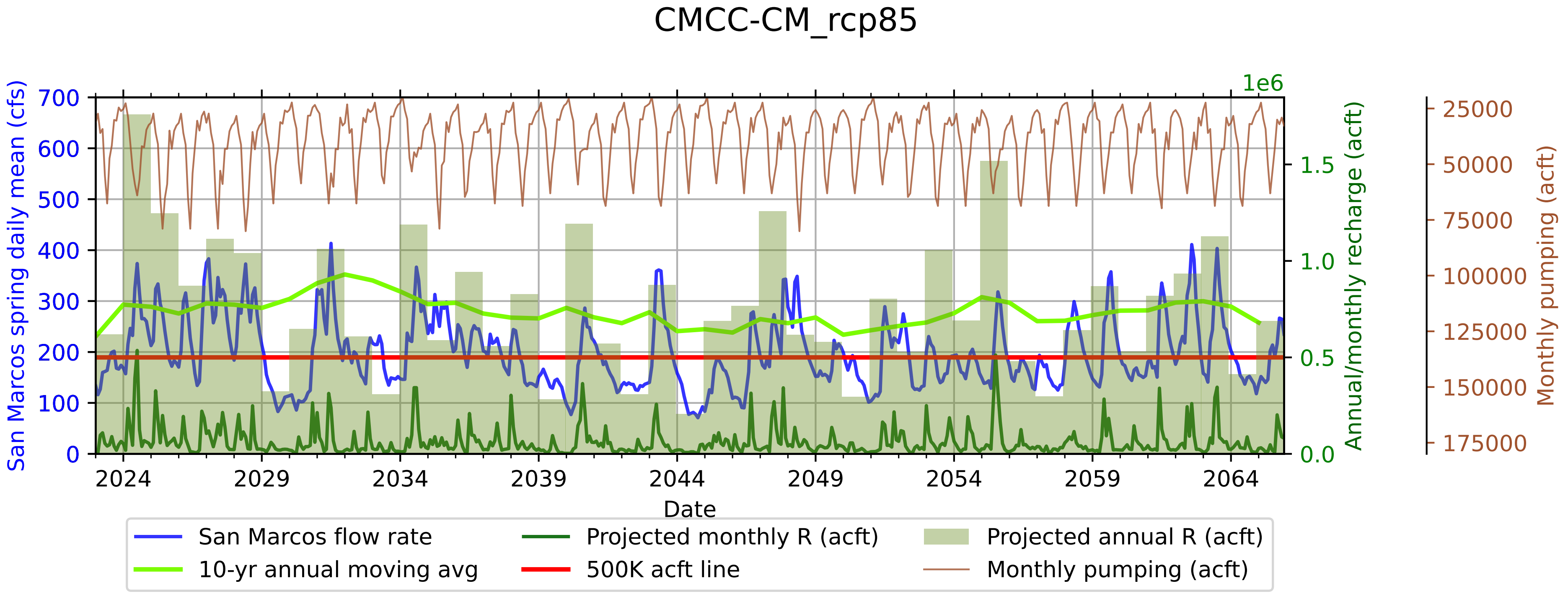
CMCC-CM_rcp45
San Marcos spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
Annual/monthly recharge (acft)
0.0
0.5
1.0
1.5
2.0
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)


CMCC-CM_rcp45
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
700
680
660
640
620
J17 WL (ft)
500
400
300
200
100
0
San Marcos spring daily mean (cfs)
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
8000
6000
4000
2000
0
Monthly ASR Forbearance (acft)
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

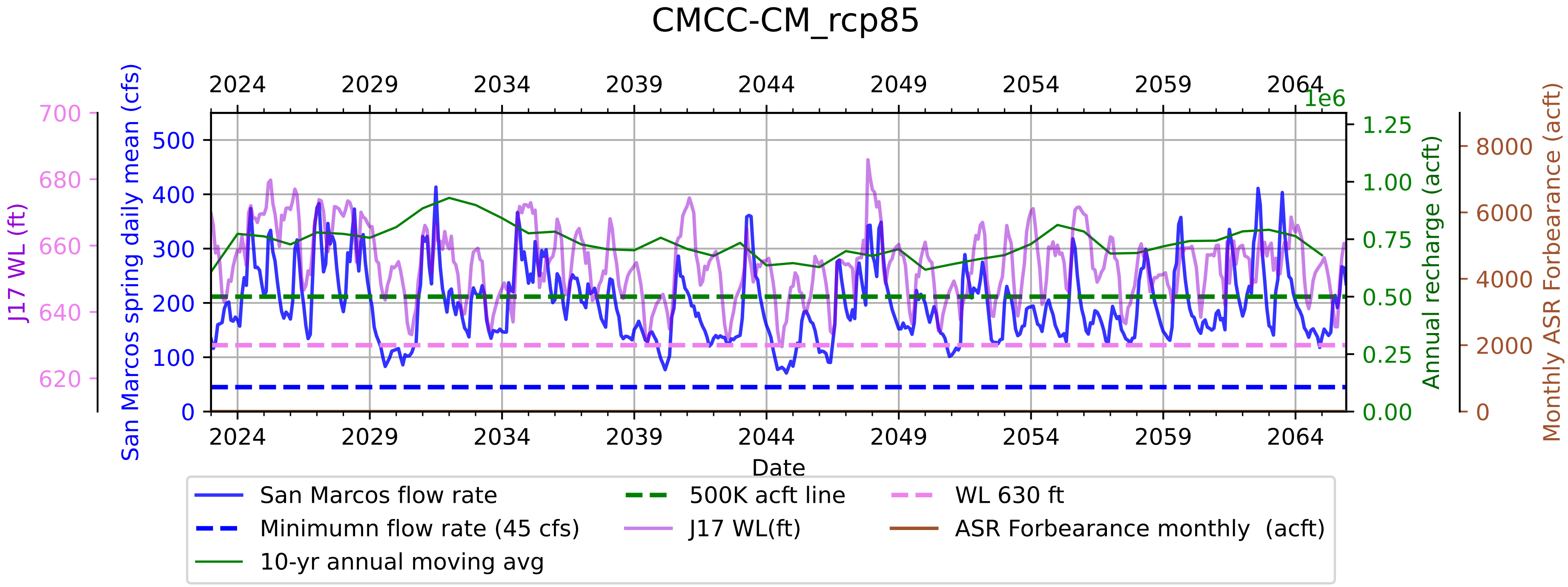


CMCC-CM_rcp45
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

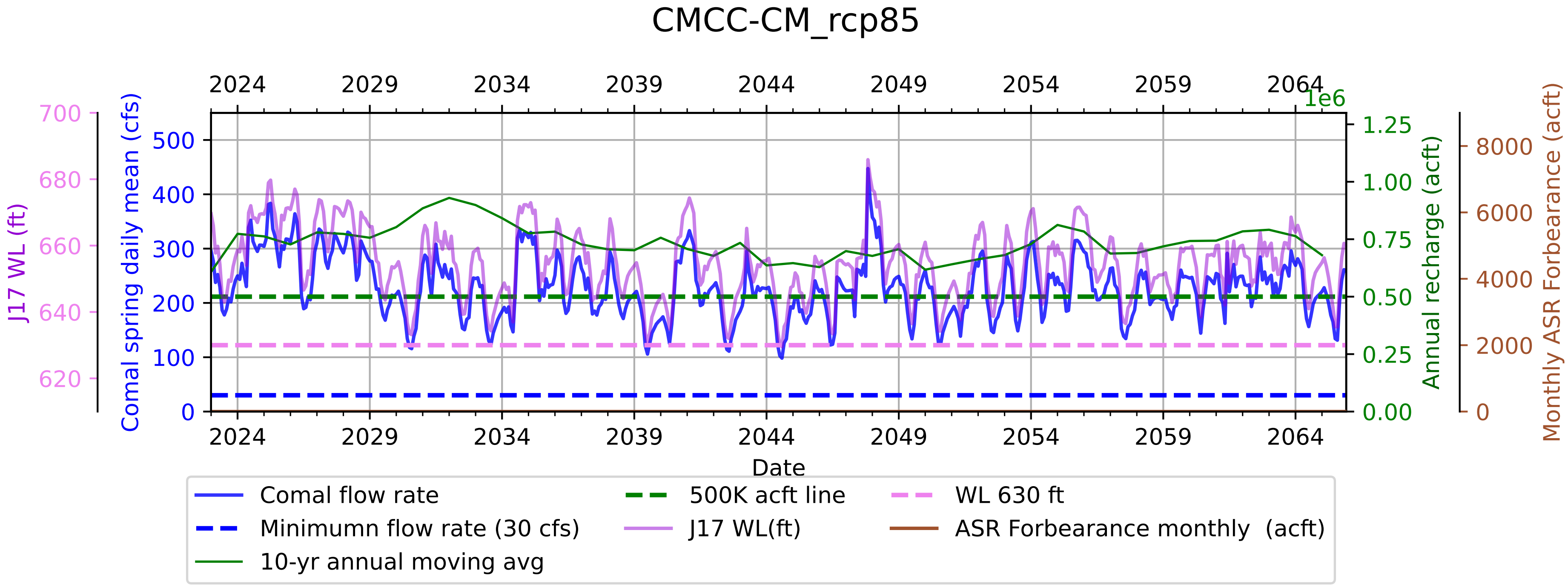

CMCC-CM_rcp85
Comal spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
0
100
200
300
400
500
600
700
0.0
0.5
1.0
1.5
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



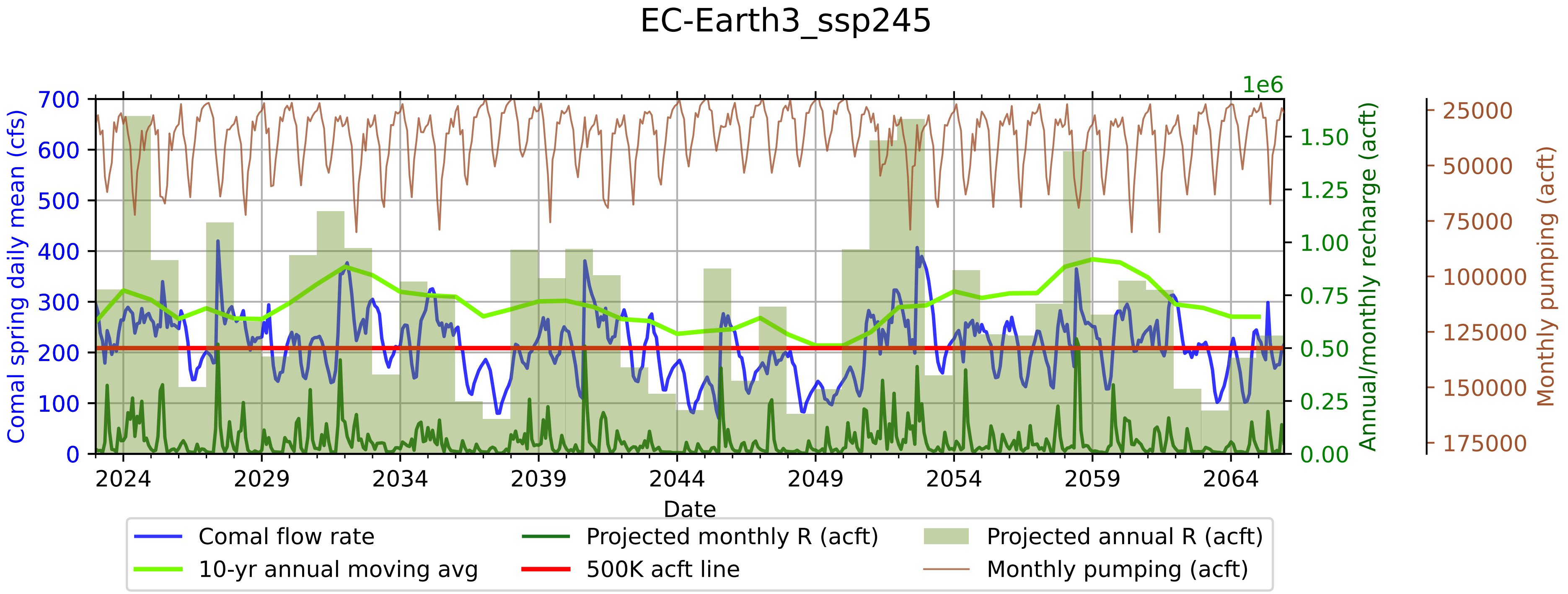
CMCC-CM_rcp85
San Marcos spring daily mean (cfs)
Annual/monthly recharge (acft)
1e6
Monthly pumping (acft)
Date
0
100
200
300
400
500
600
700
0.0
0.5
1.0
1.5
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



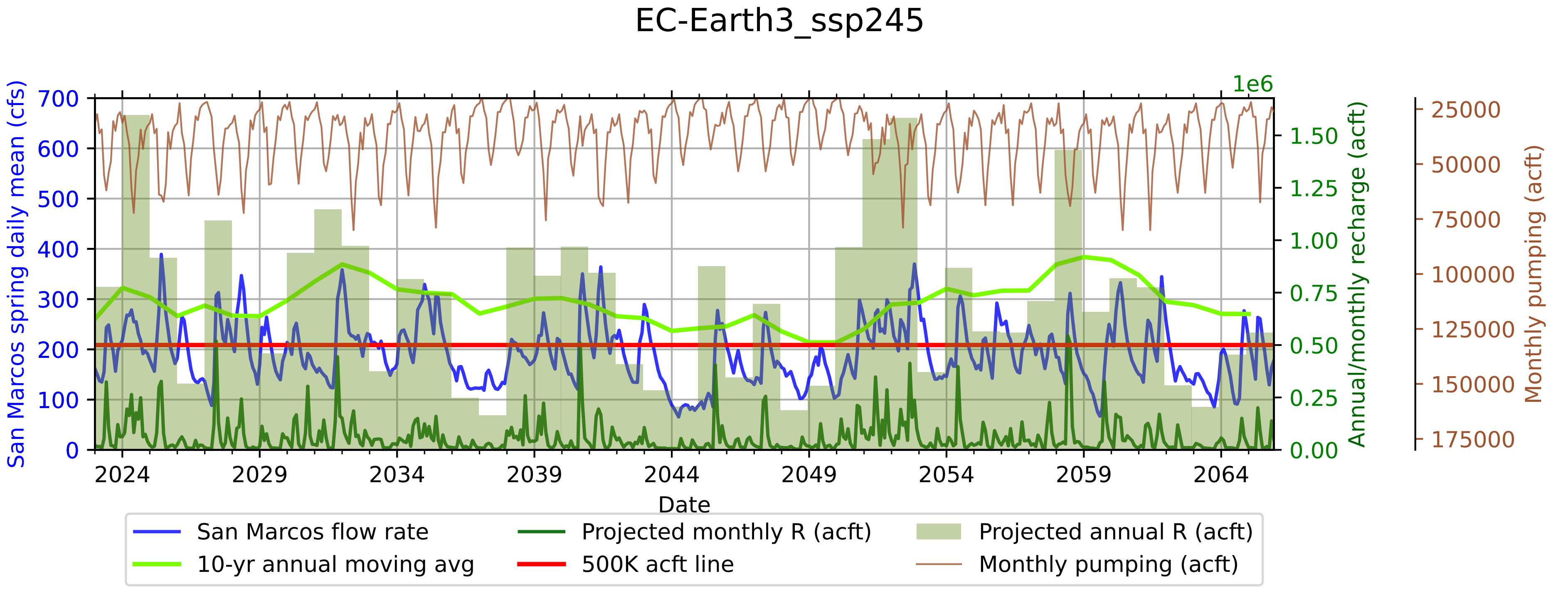
CMCC-CM_rcp85
J17 WL (ft)
700
680
660
640
620
San Marcos spring daily mean (cfs)
500
400
300
200
100
0
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
1e6
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
Monthly ASR Forbearance (acft)
8000
6000
4000
2000
0
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

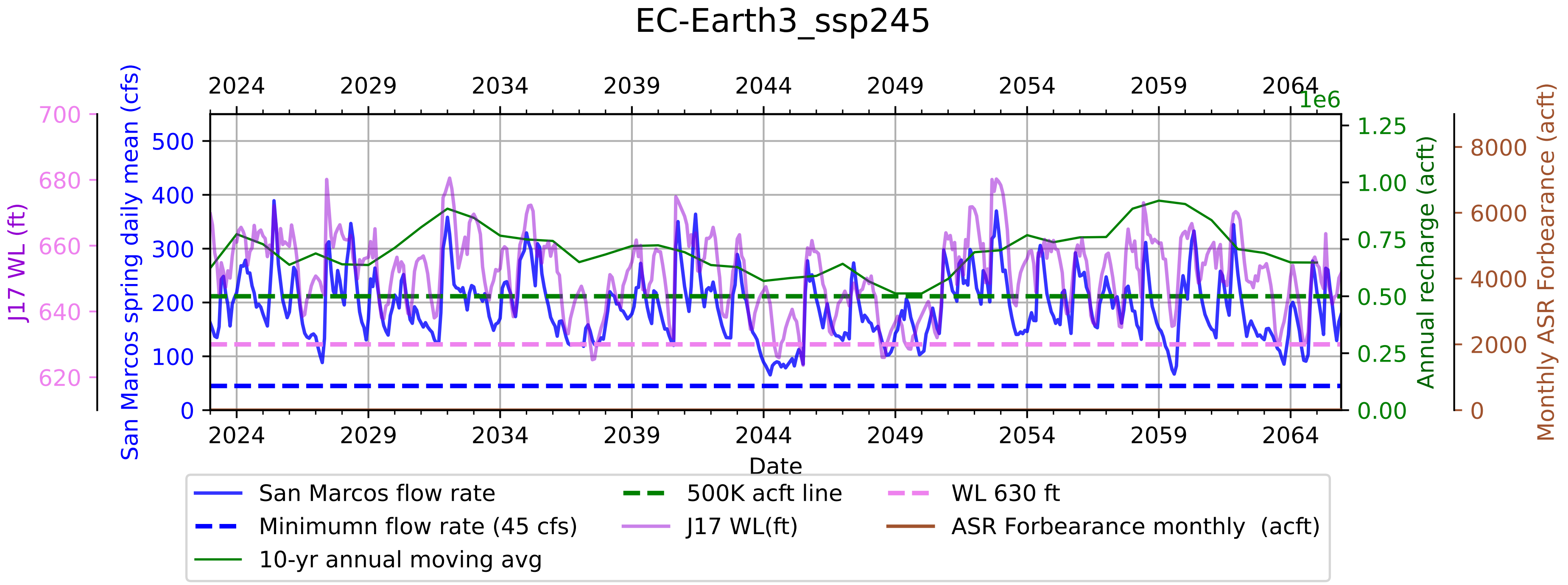


CMCC-CM_rcp85
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
2024
2029
2034
2039
2044
2049
2054
2059
2064
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

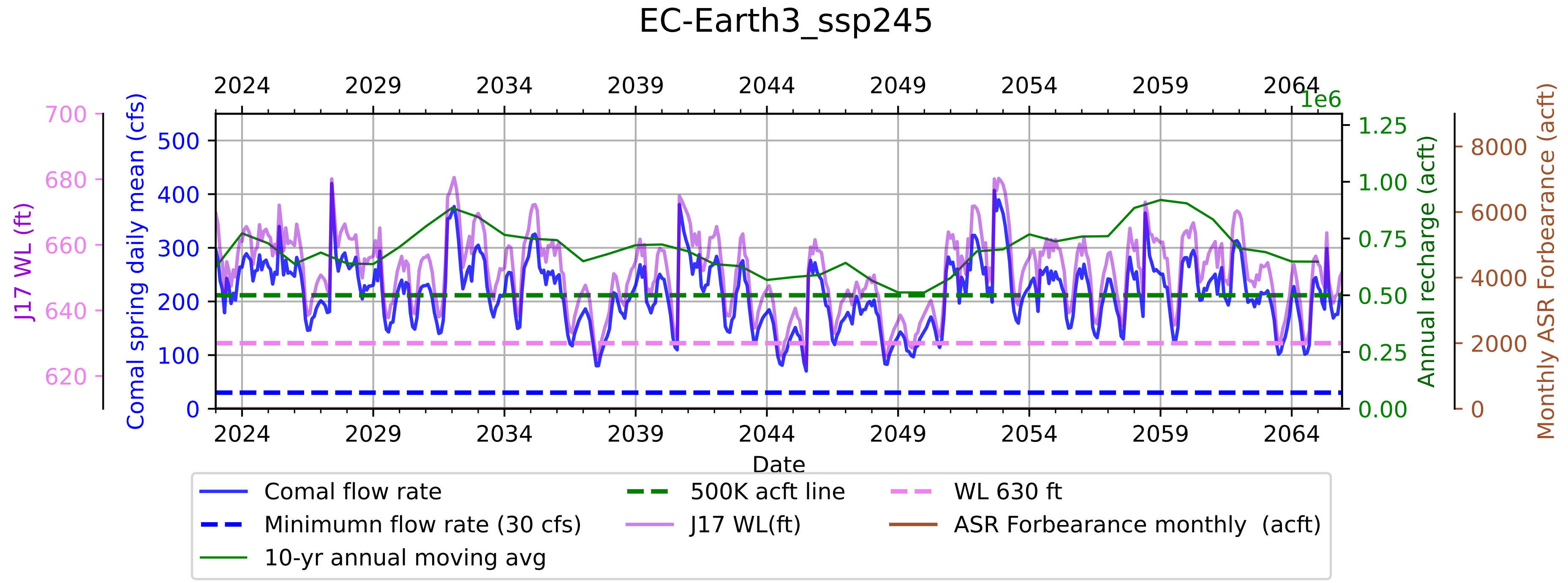


EC-Earth3_ssp245
1e6
Comal spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
700
600
500
400
300
200
100
0
1.50
1.25
1.00
0.75
0.50
0.25
0.00
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

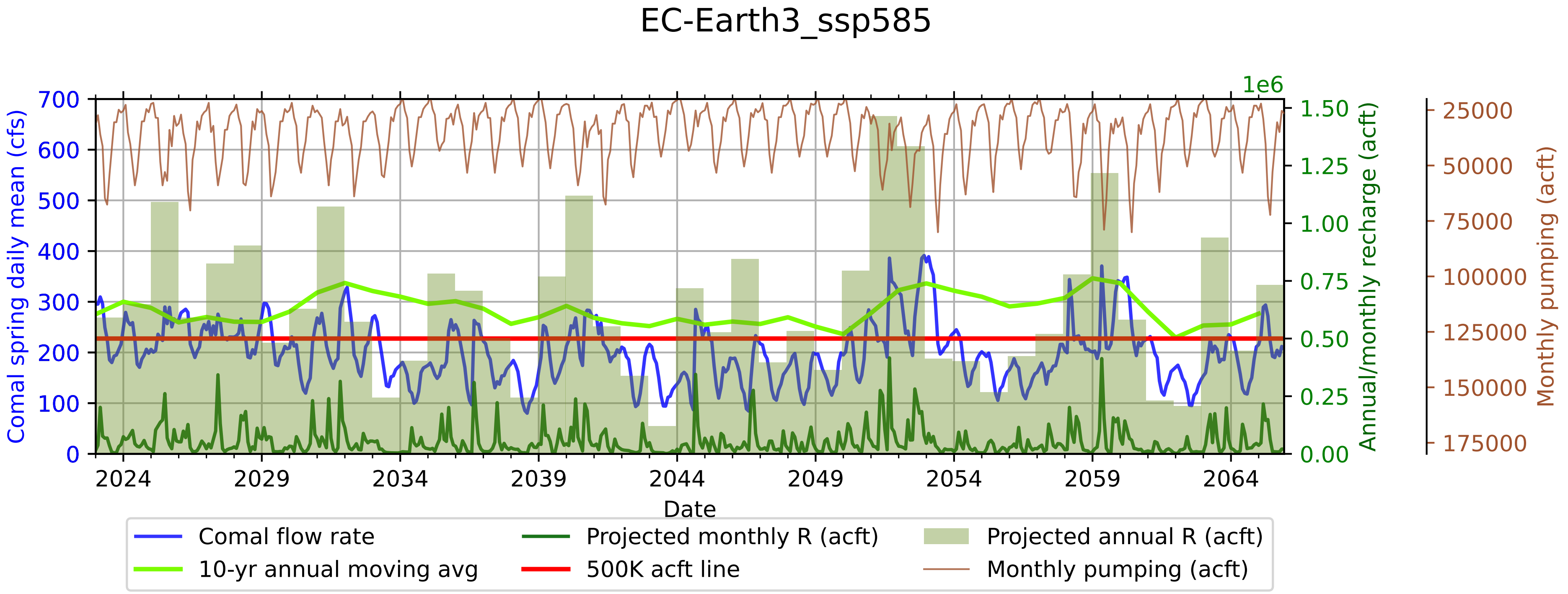

EC-Earth3_ssp245
San Marcos spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
700
600
500
400
300
200
100
0
1.50
1.25
1.00
0.75
0.50
0.25
0.00
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

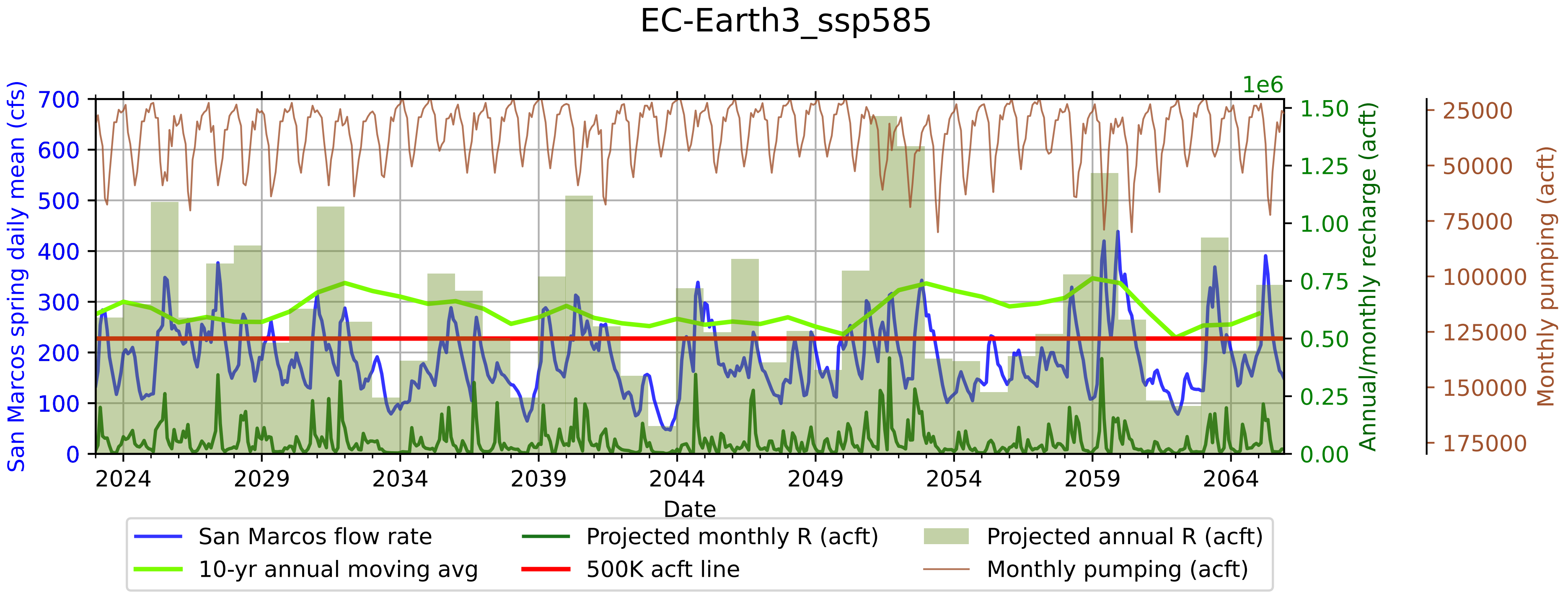


EC-Earth3_ssp245
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

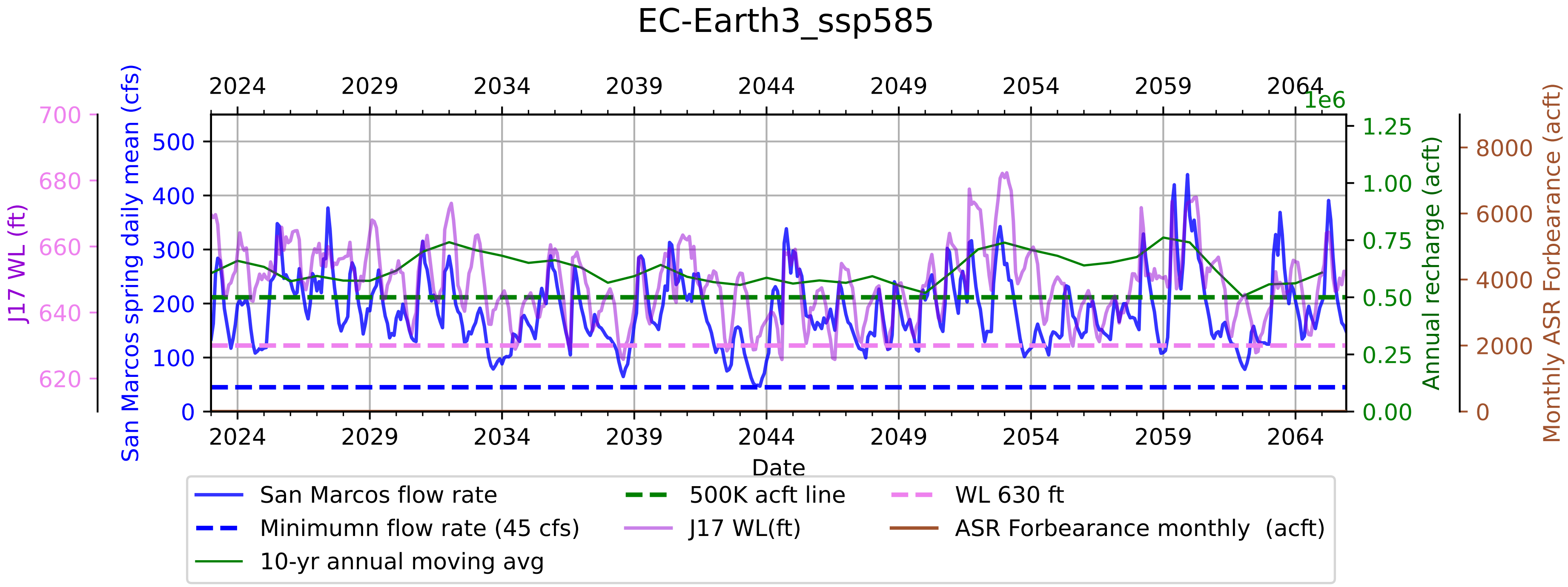


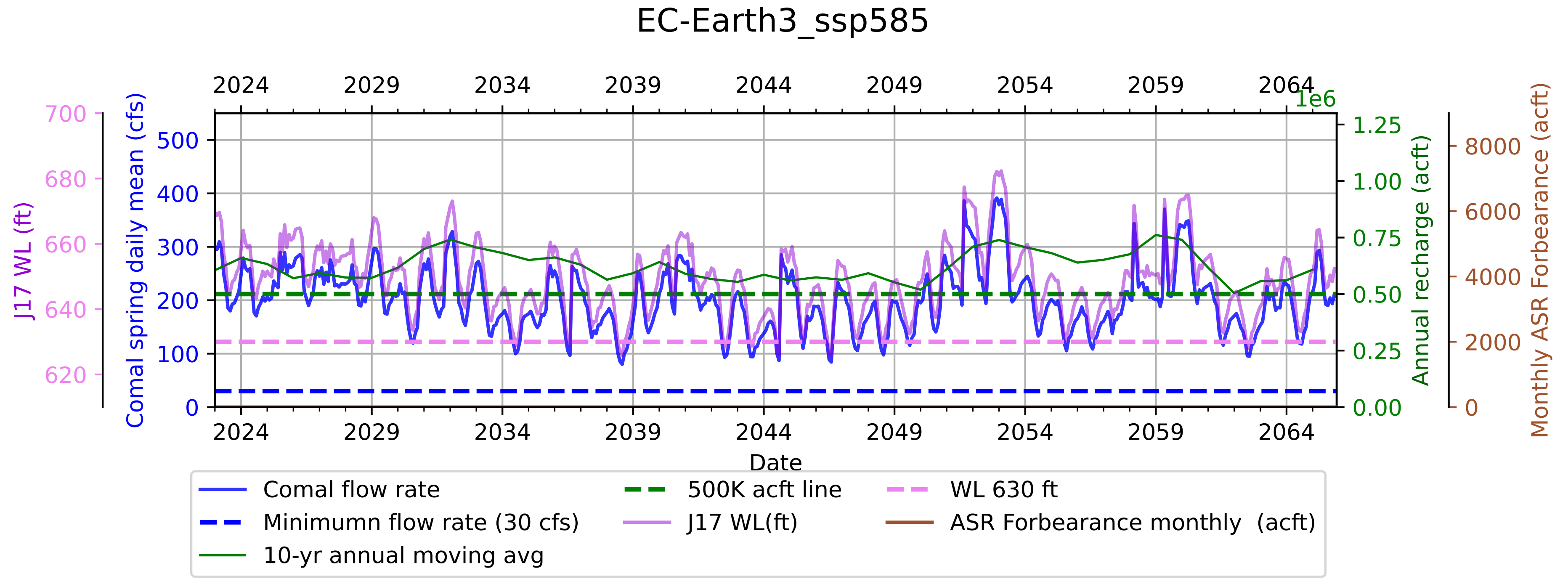
EC-Earth3_ssp245
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

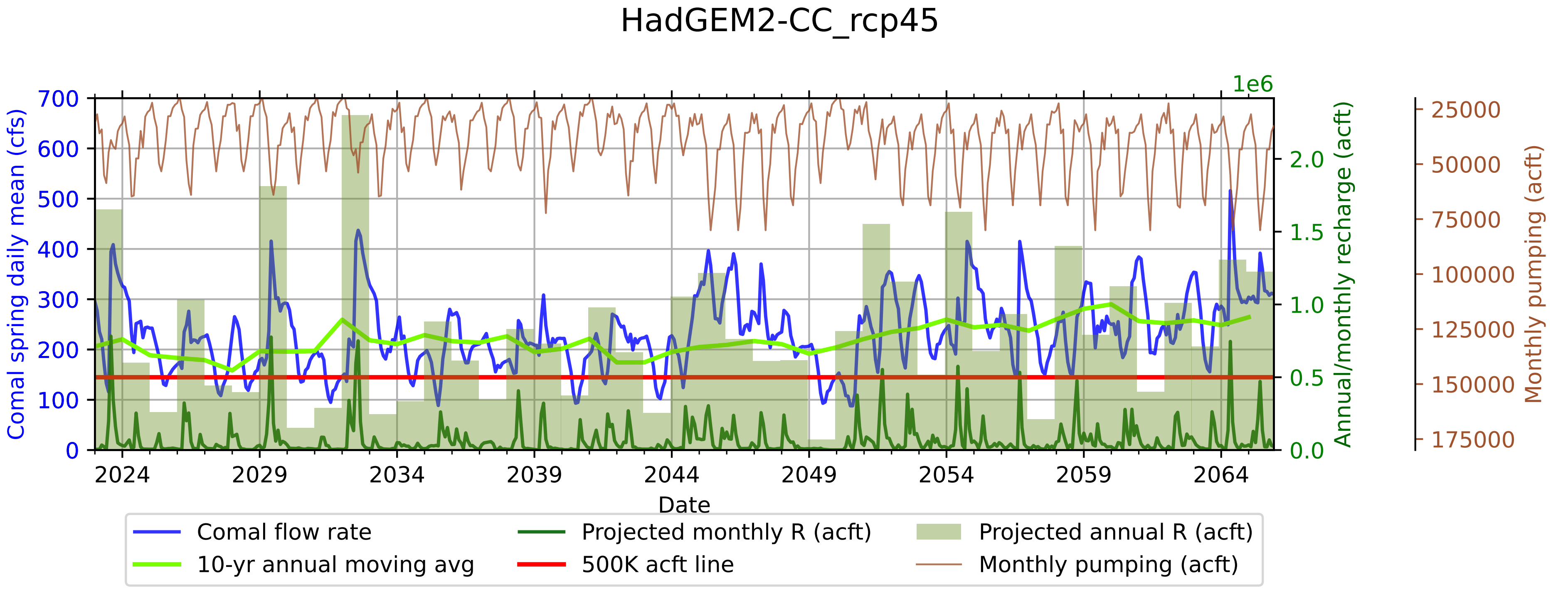

EC-Earth3_ssp585
Comal spring daily mean (cfs)
0
100
200
300
400
500
600
700
Annual/monthly recharge (acft)
1e6
0.00
0.25
0.50
0.75
1.00
1.25
1.50
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



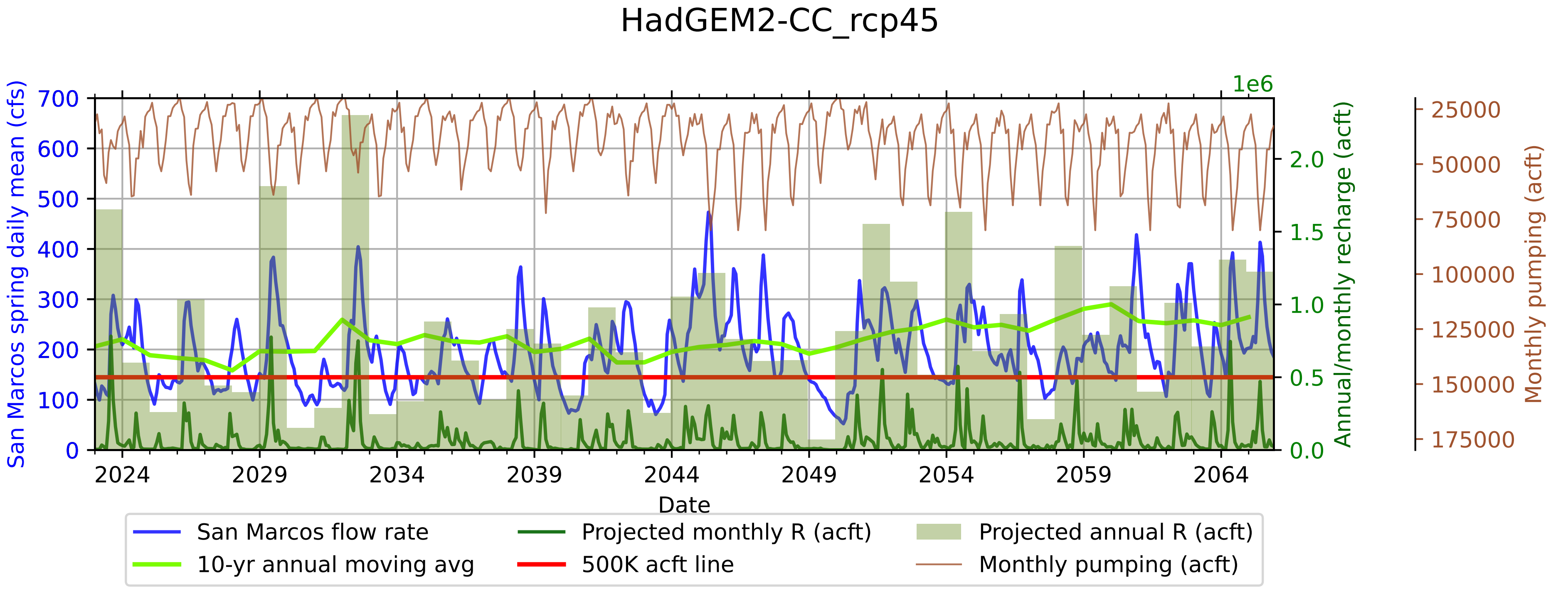
EC-Earth3_ssp585
San Marcos spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)


EC-Earth3_ssp585
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
700
680
660
640
620
J17 WL (ft)
500
400
300
200
100
0
San Marcos spring daily mean (cfs)
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
8000
6000
4000
2000
0
Monthly ASR Forbearance (acft)
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

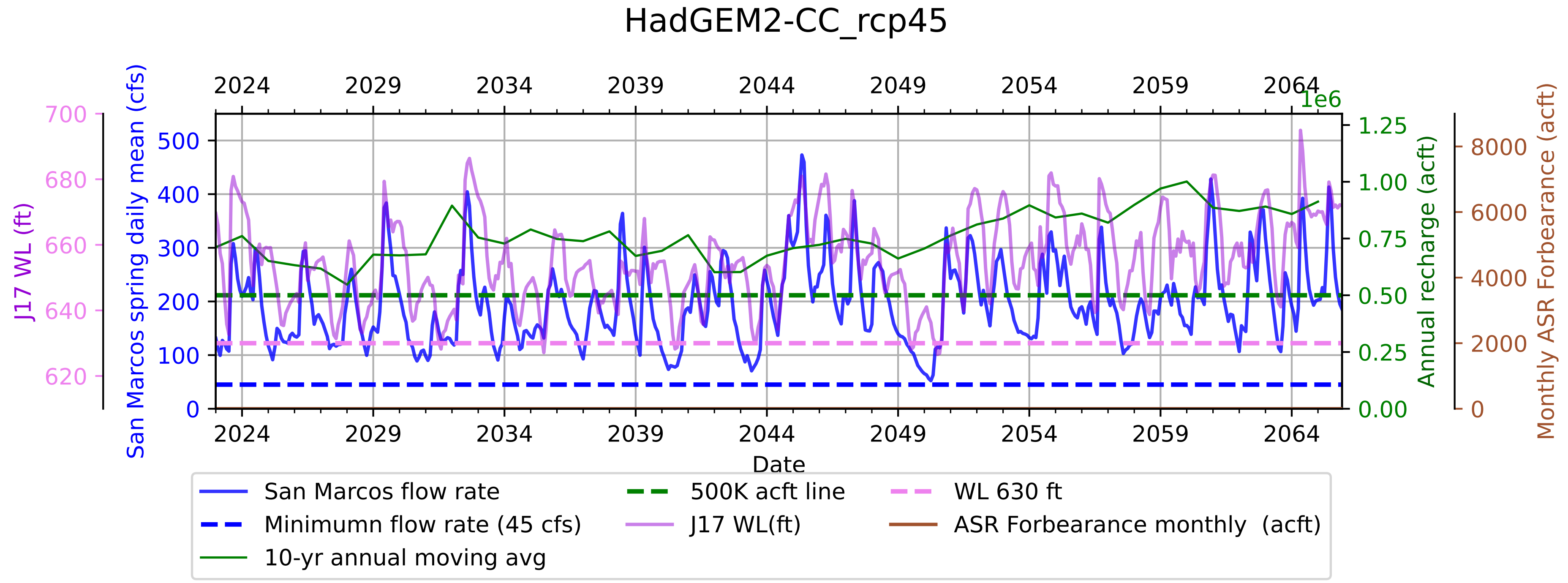

EC-Earth3_ssp585
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
1e6
Monthly ASR Forbearance (acft)
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

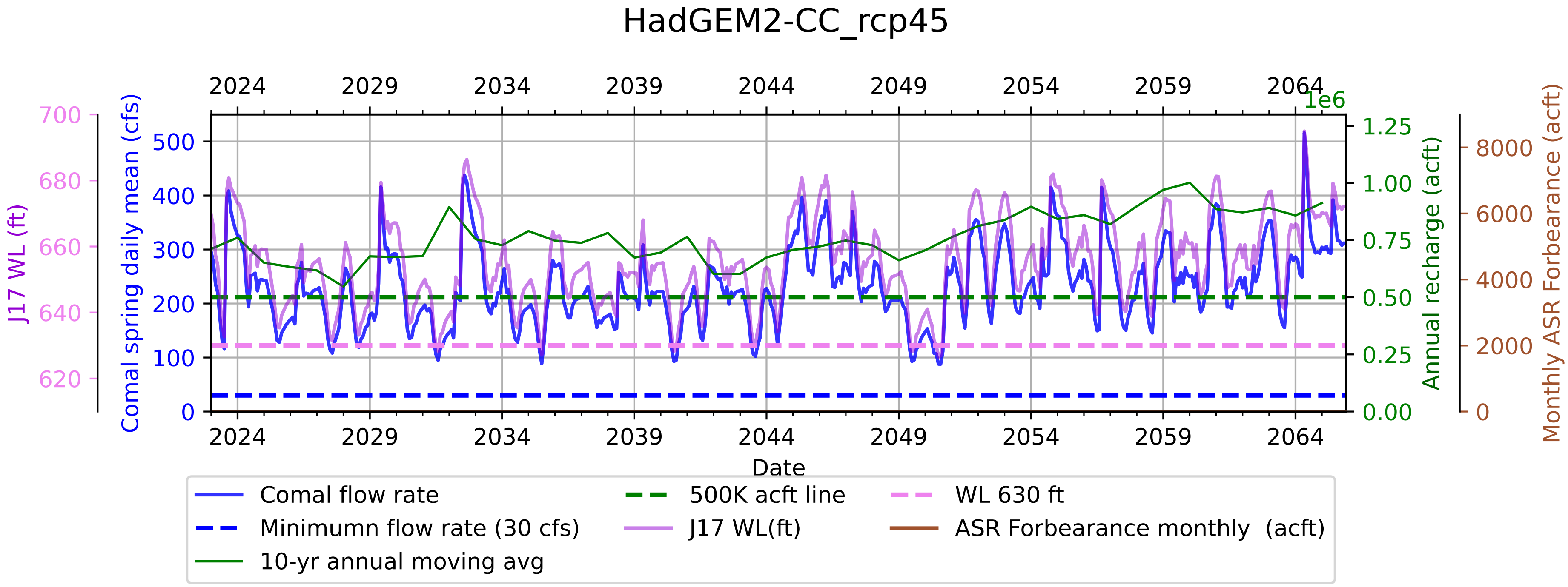


HadGEM2-CC_rcp45
Comal spring daily mean (cfs)
Annual/monthly recharge (acft)
1e6
Monthly pumping (acft)
Date
0
100
200
300
400
500
600
700
0.0
0.5
1.0
1.5
2.0
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

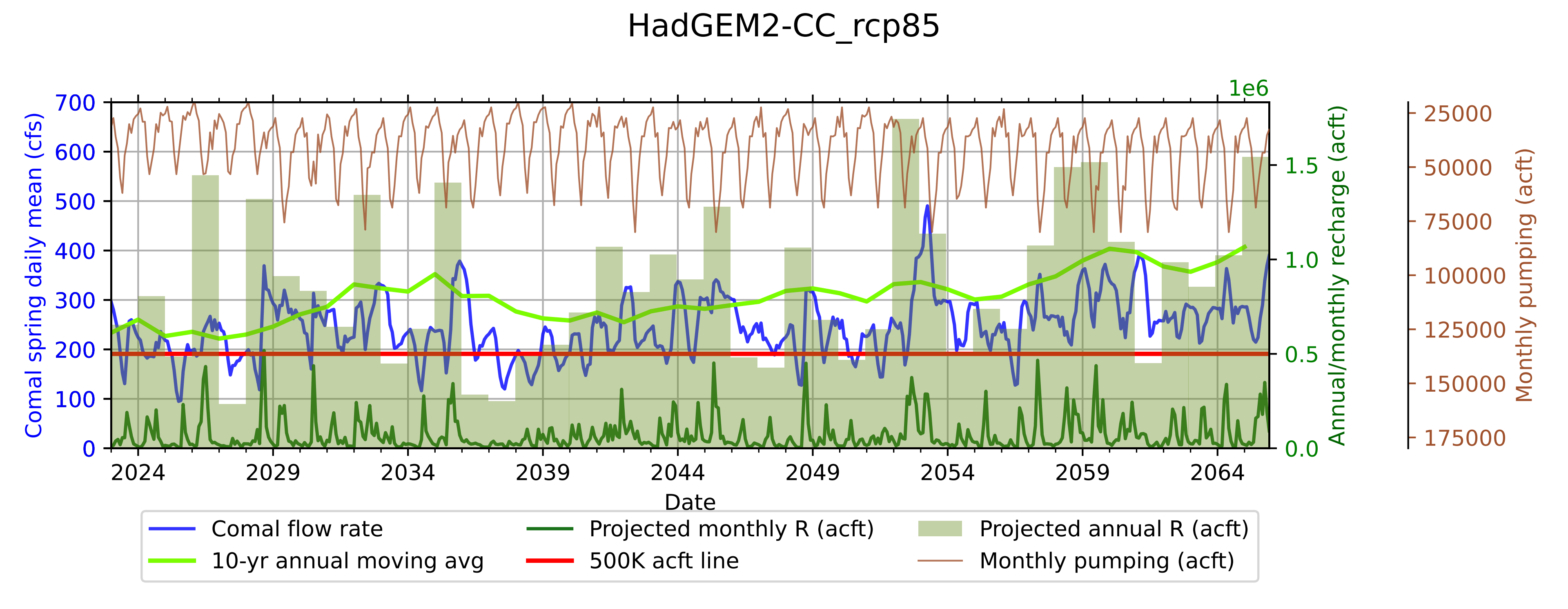


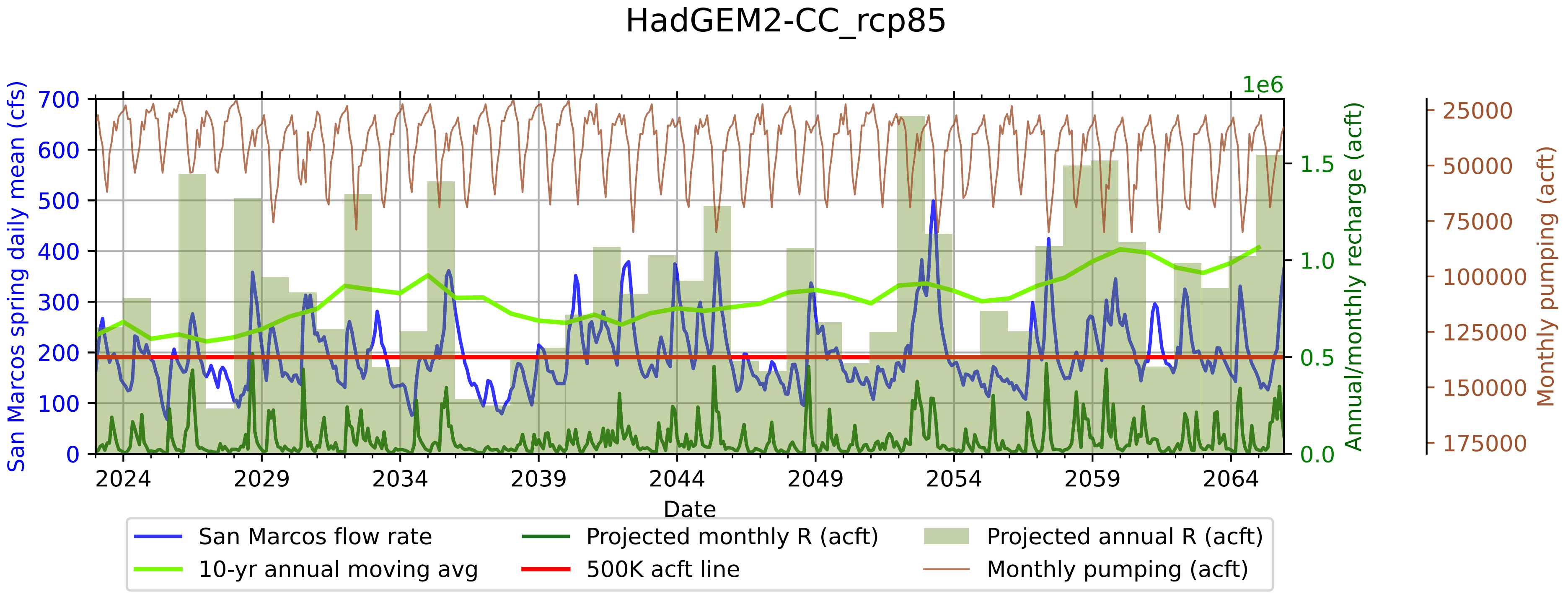
HadGEM2-CC_rcp45
San Marcos spring daily mean (cfs)
Annual/monthly recharge (acft)
1e6
Monthly pumping (acft)
Date
0
100
200
300
400
500
600
700
0.0
0.5
1.0
1.5
2.0
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)


HadGEM2-CC_rcp45
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
2024
2029
2034
2039
2044
2049
2054
2059
2064
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

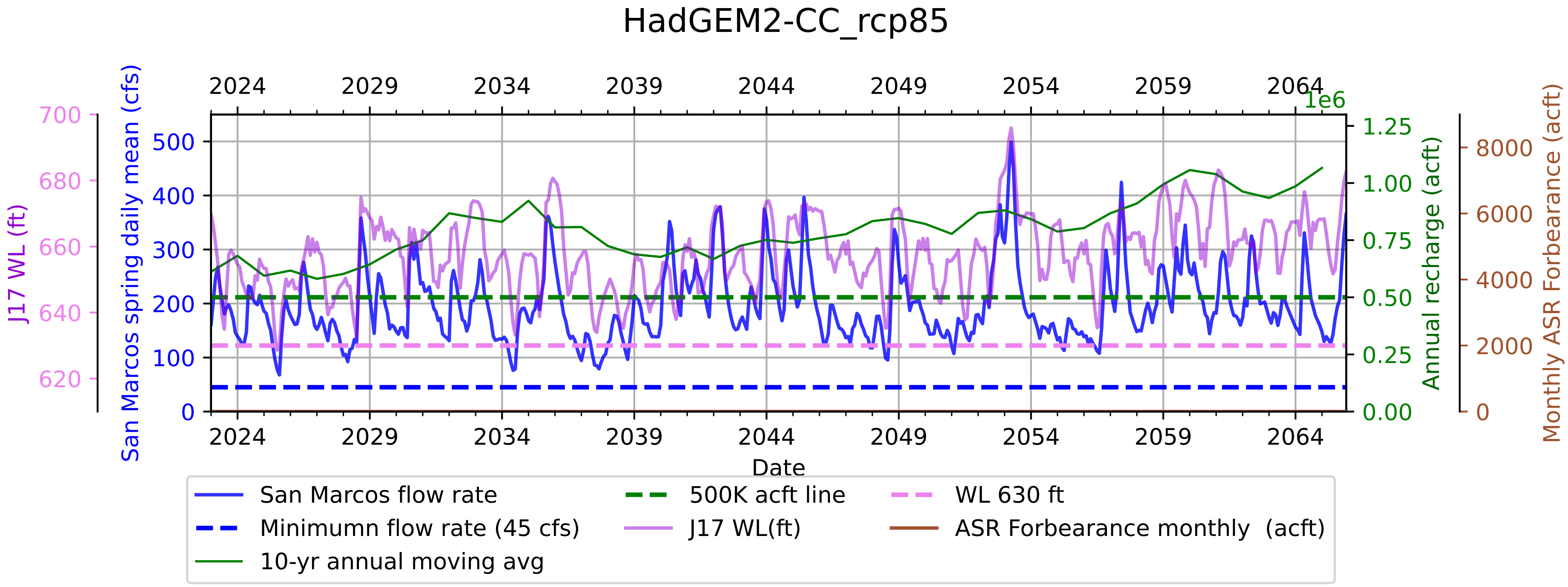


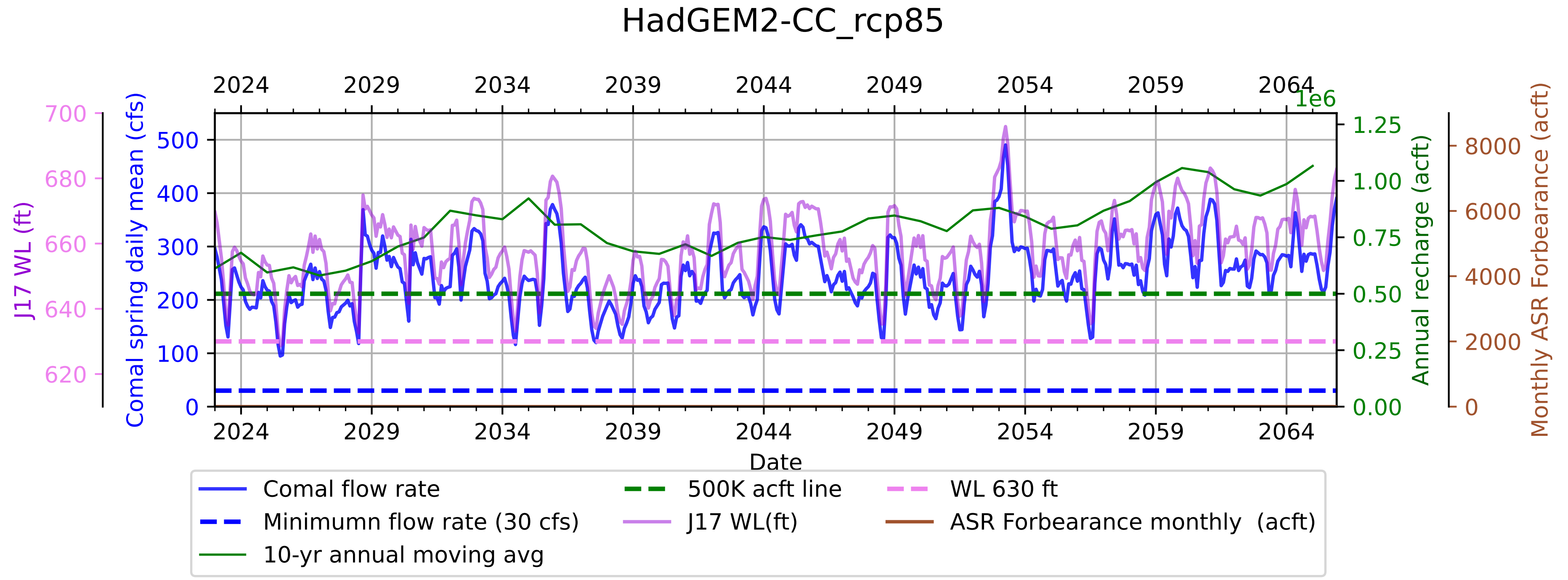
HadGEM2-CC_rcp45
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
700
680
660
640
620
J17 WL (ft)
500
400
300
200
100
0
Comal spring daily mean (cfs)
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
8000
6000
4000
2000
0
Monthly ASR Forbearance (acft)
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)


HadGEM2-CC_rcp85
Comal spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

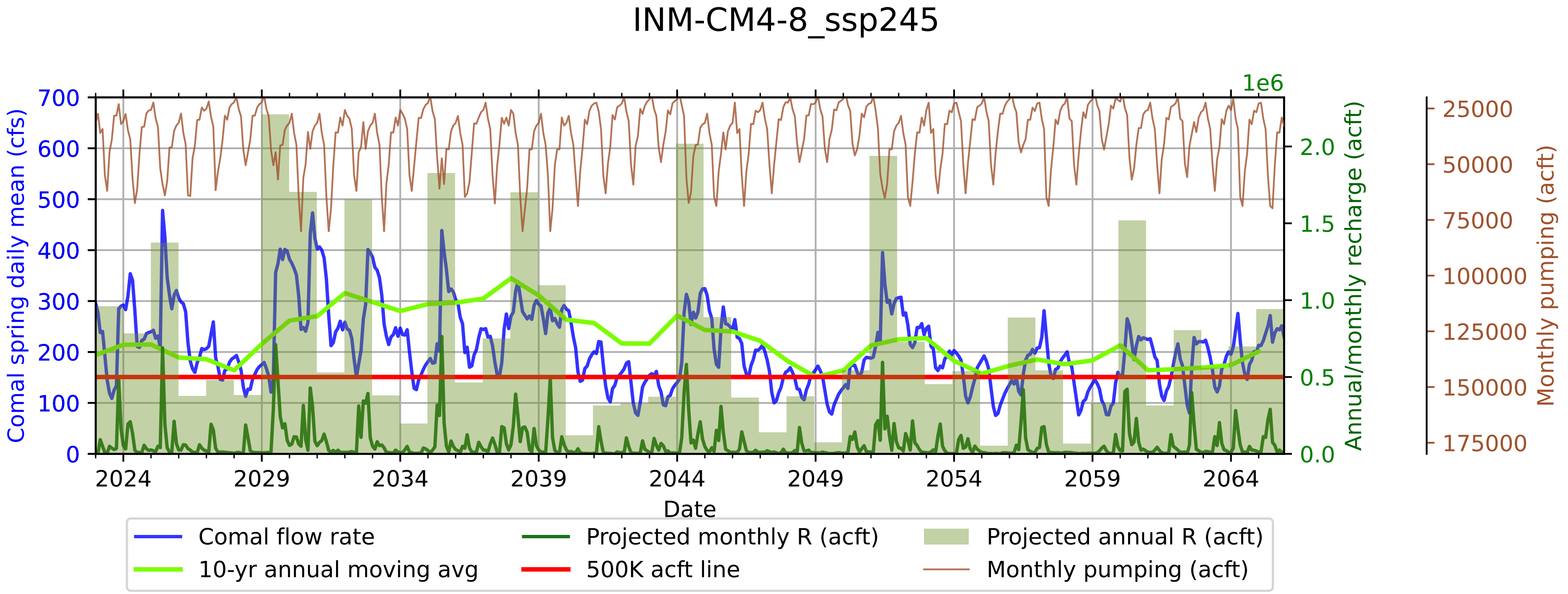


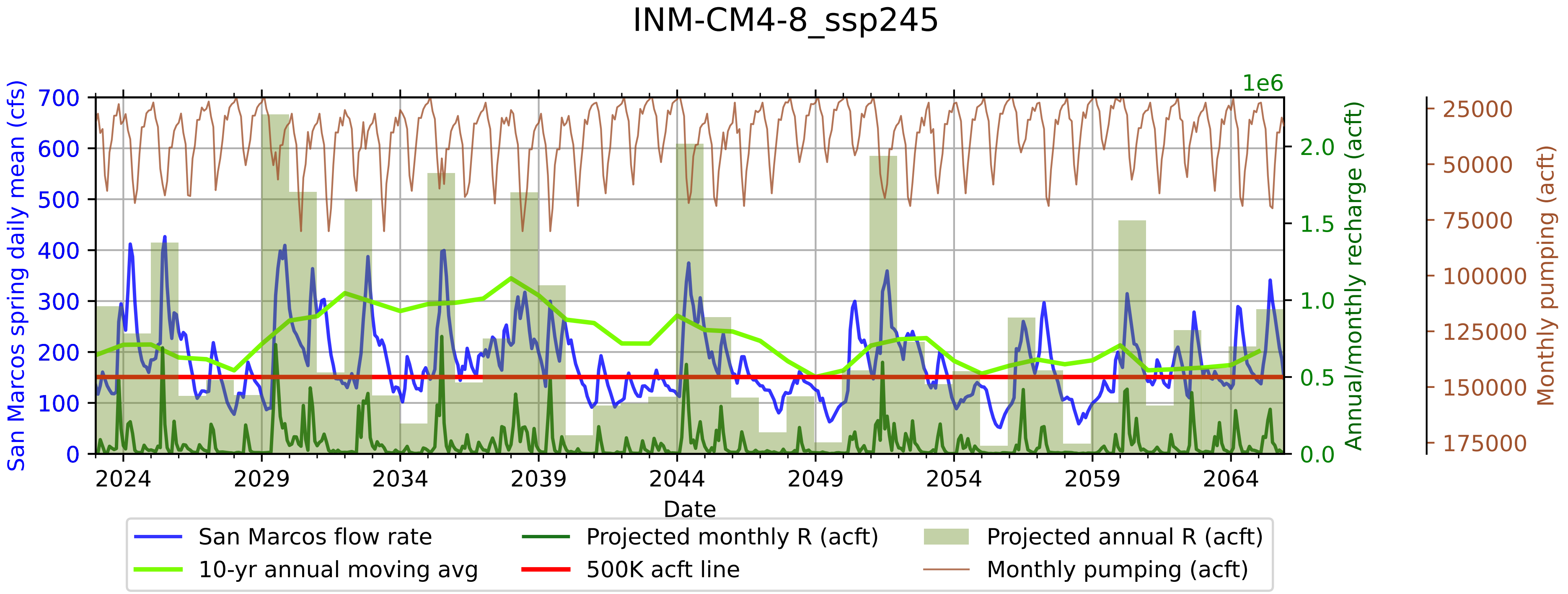
HadGEM2-CC_rcp85
San Marcos spring daily mean (cfs)
700
600
500
400
300
200
100
0
1e6
1.5
1.0
0.5
0.0
Annual/monthly recharge (acft)
25000
50000
75000
100000
125000
150000
175000
Monthly pumping (acft)
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

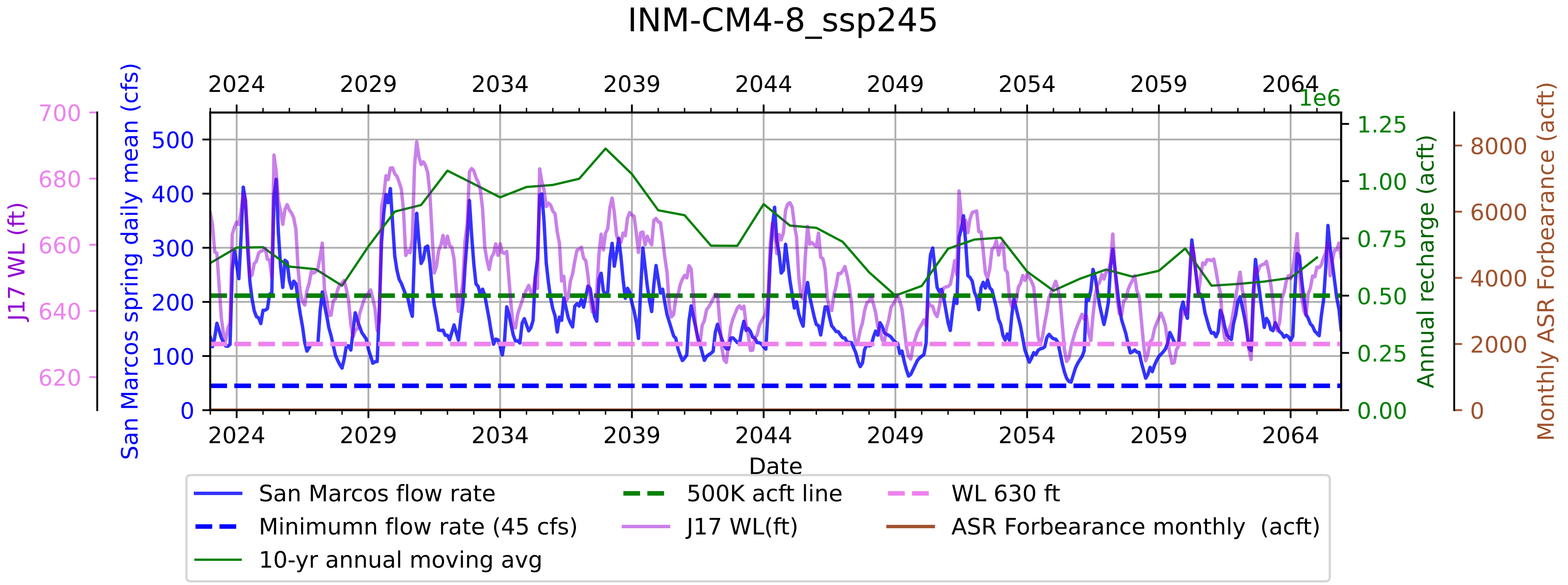

HadGEM2-CC_rcp85
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
2024
2029
2034
2039
2044
2049
2054
2059
2064
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)



HadGEM2-CC_rcp85
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
700
680
660
640
620
J17 WL (ft)
500
400
300
200
100
0
Comal spring daily mean (cfs)
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
8000
6000
4000
2000
0
Monthly ASR Forbearance (acft)
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

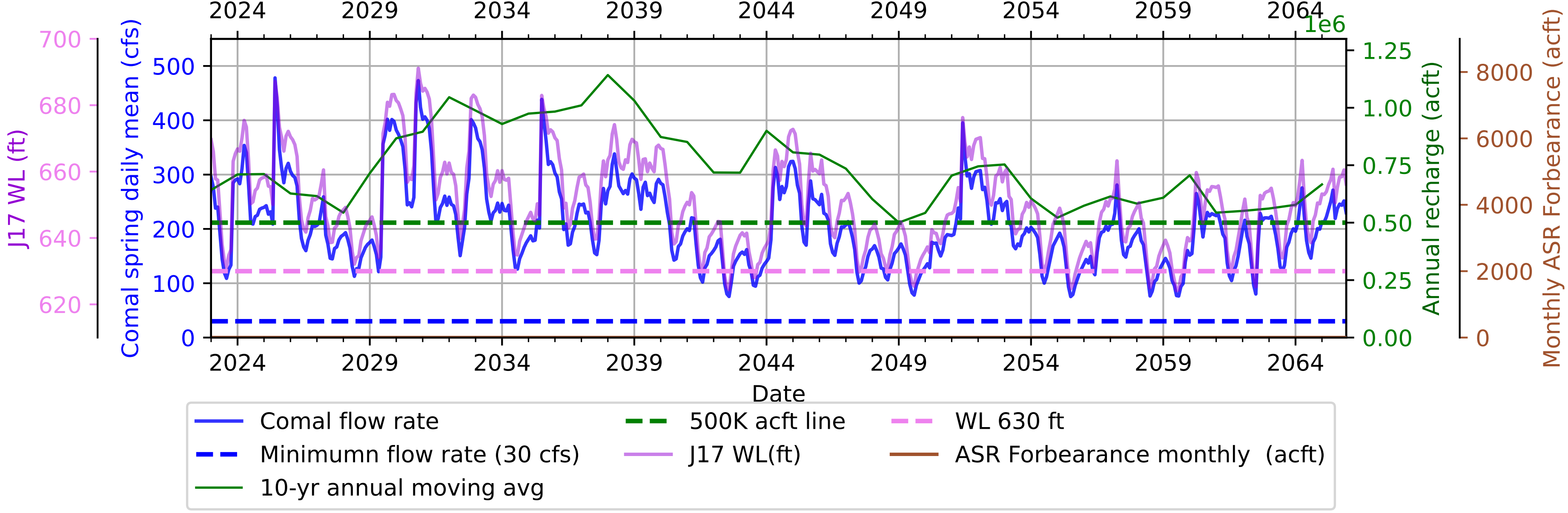

INM-CM4-8_ssp245
Comal spring daily mean (cfs)
Annual/monthly recharge (acft)
1e6
Monthly pumping (acft)
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

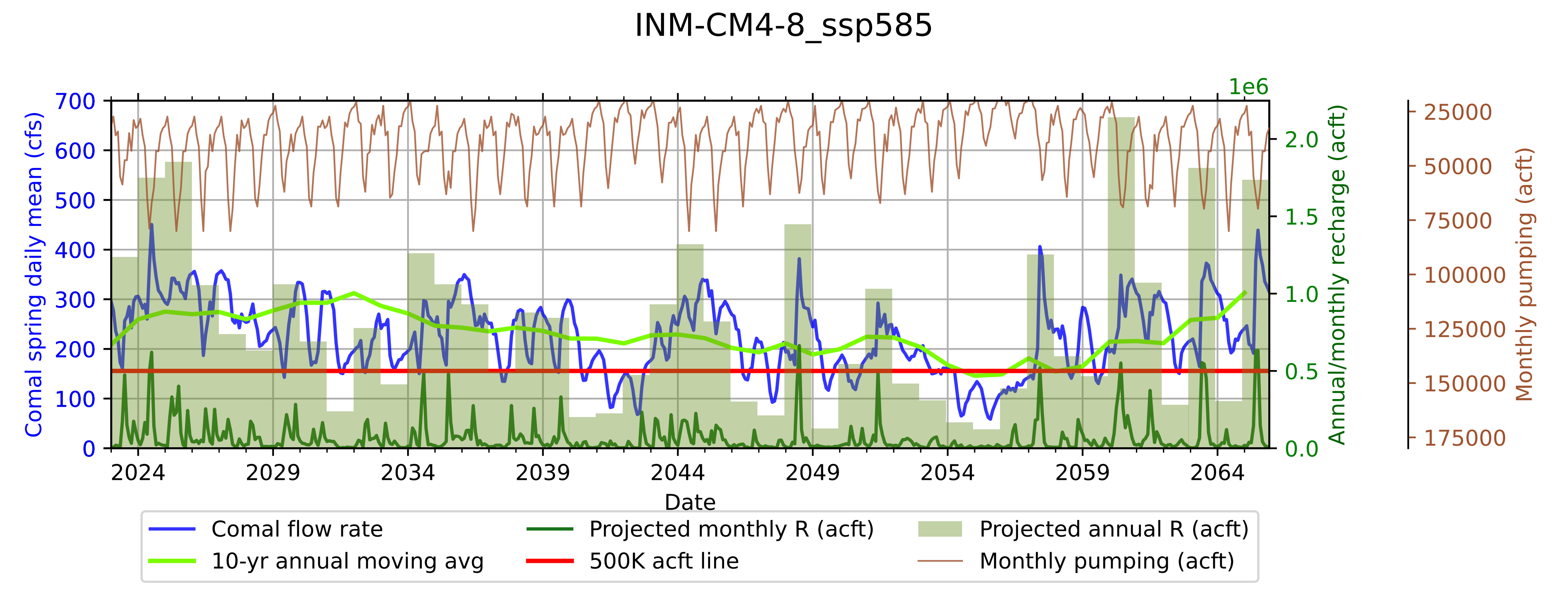

INM-CM4-8_ssp245
San Marcos spring daily mean (cfs)
700
600
500
400
300
200
100
0
1e6
2.0
1.5
1.0
0.5
0.0
Annual/monthly recharge (acft)
25000
50000
75000
100000
125000
150000
175000
Monthly pumping (acft)
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



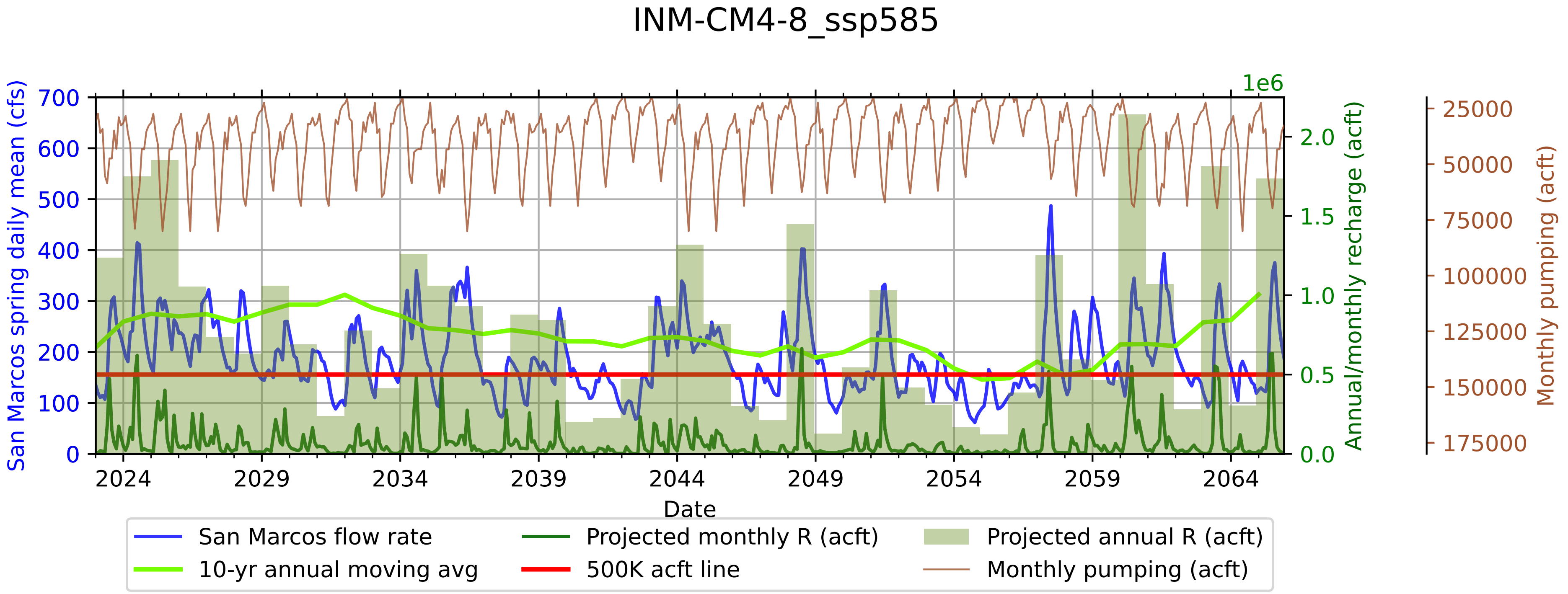
INM-CM4-8_ssp245
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
J17 WL (ft)
700
680
660
640
620
San Marcos spring daily mean (cfs)
500
400
300
200
100
0
Annual recharge (acft)
1.25
1.00
0.75
0.50
0.25
0.00
Monthly ASR Forbearance (acft)
8000
6000
4000
2000
0
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

INM-CM4-8_ssp245

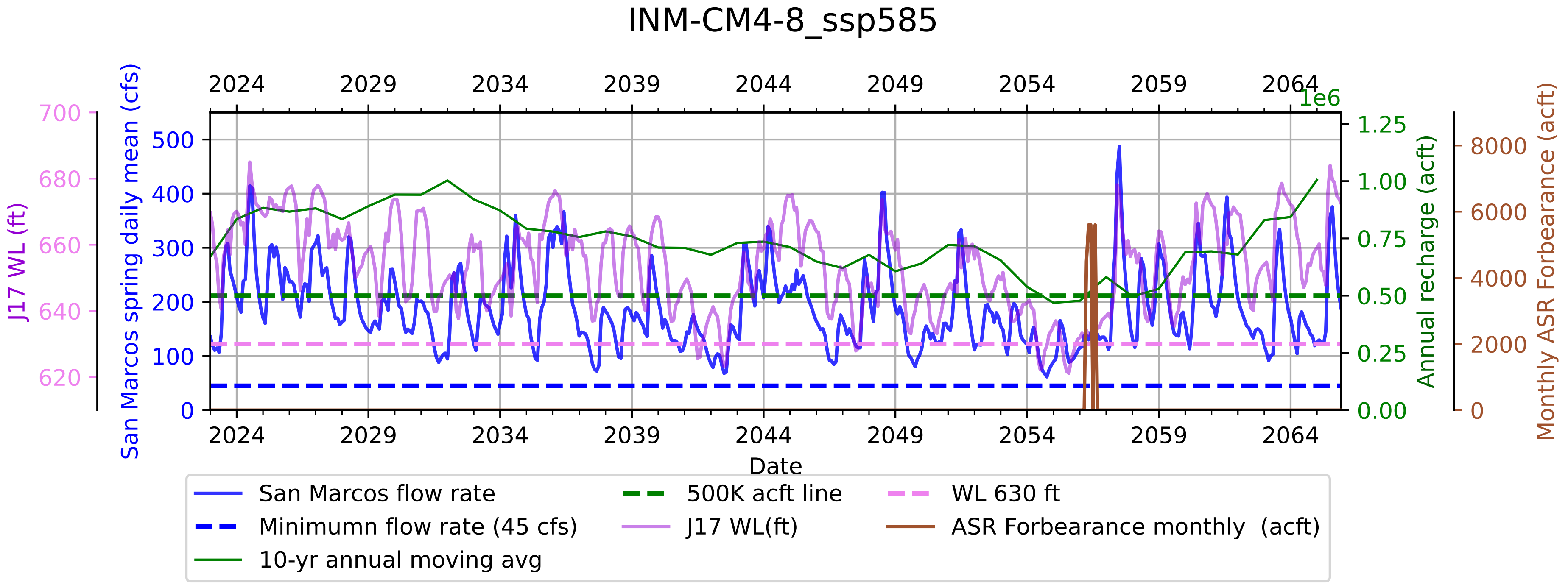




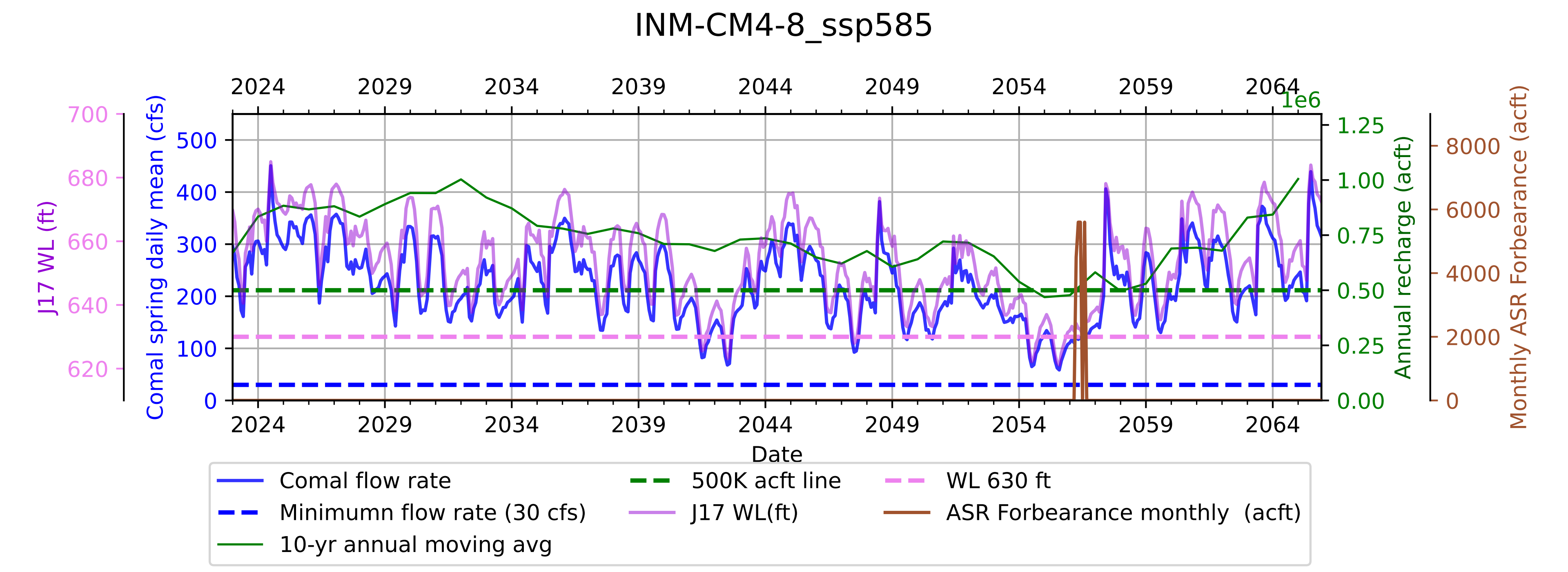
INM-CM4-8_ssp585
Comal spring daily mean (cfs)
700
600
500
400
300
200
100
0
1e6
Annual/monthly recharge (acft)
2.0
1.5
1.0
0.5
0.0
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



INM-CM4-8_ssp585
San Marcos spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
Annual/monthly recharge (acft)
0.0
0.5
1.0
1.5
2.0
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

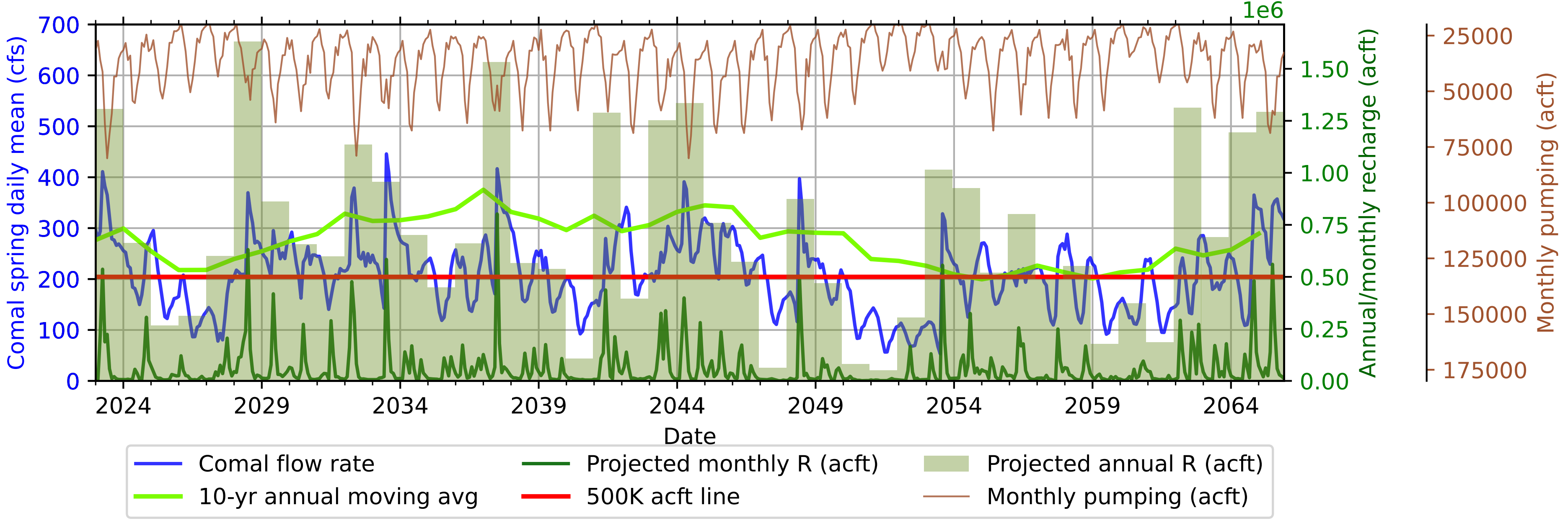


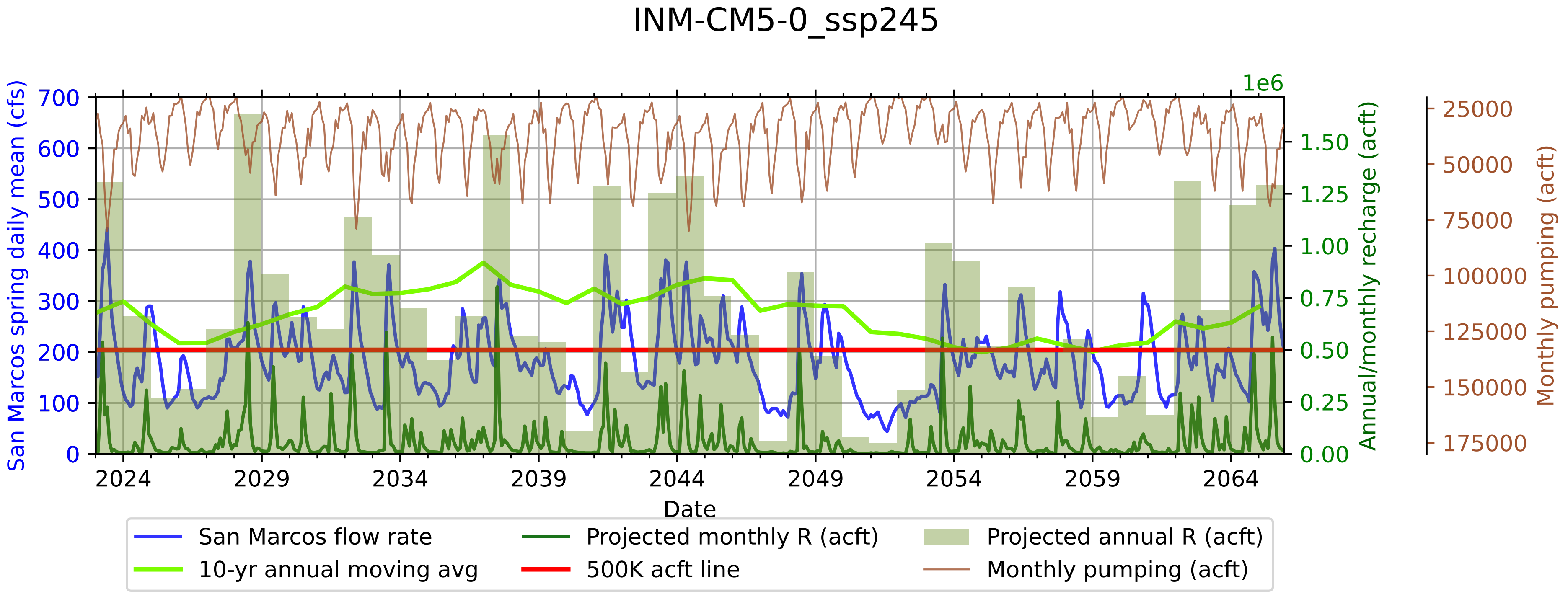
INM-CM4-8_ssp585
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
J17 WL (ft)
700
680
660
640
620
San Marcos spring daily mean (cfs)
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
8000
6000
4000
2000
0
Monthly ASR Forbearance (acft)
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)



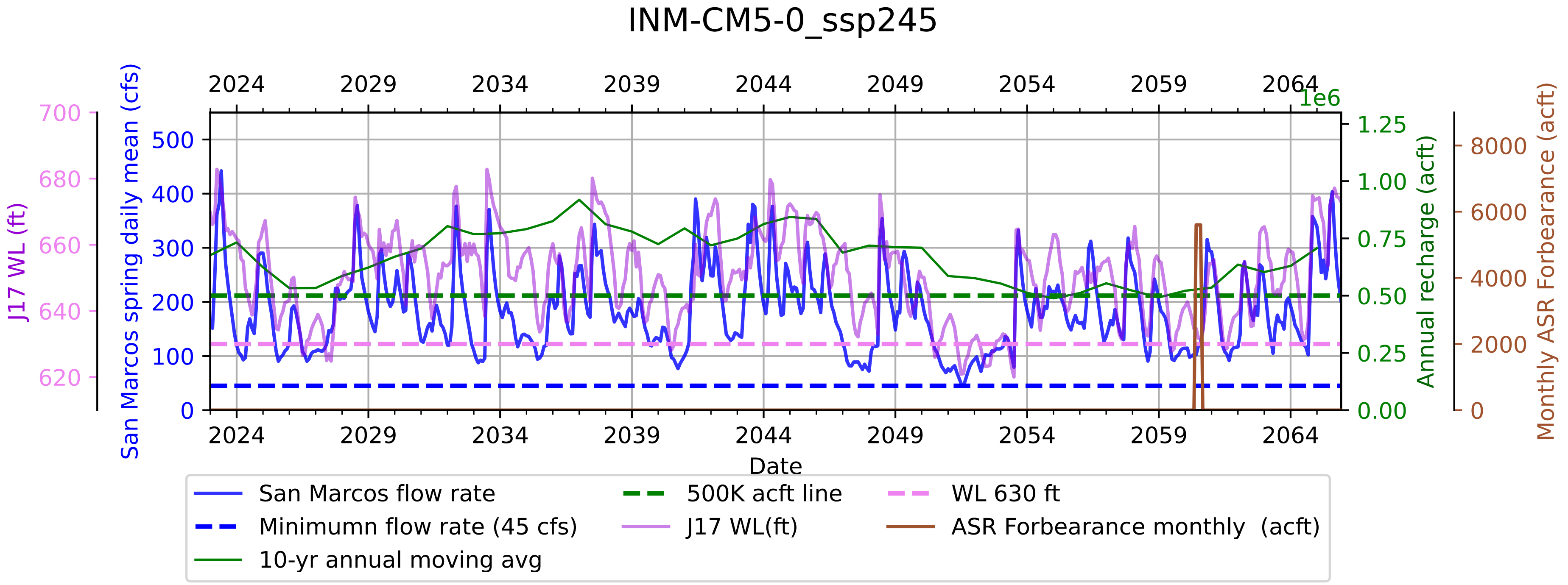
INM-CM4-8_ssp585
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
1e6
Monthly ASR Forbearance (acft)
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

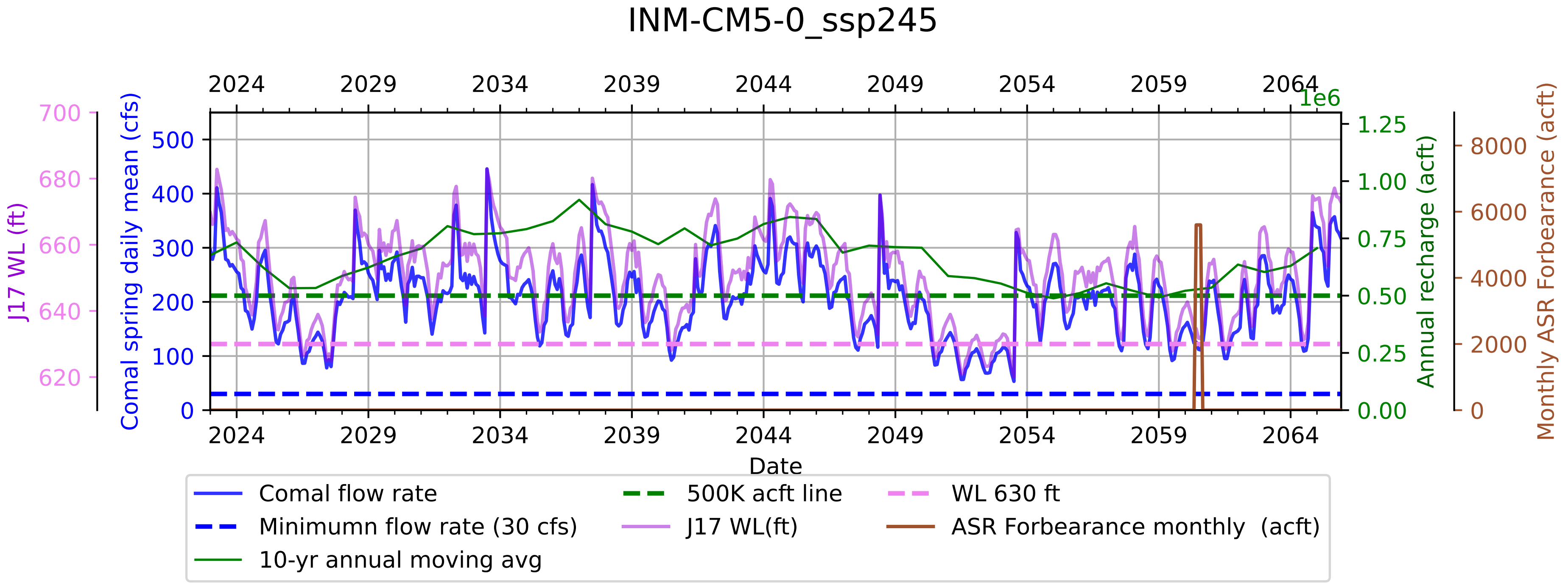
INM-CM5-0_ssp245

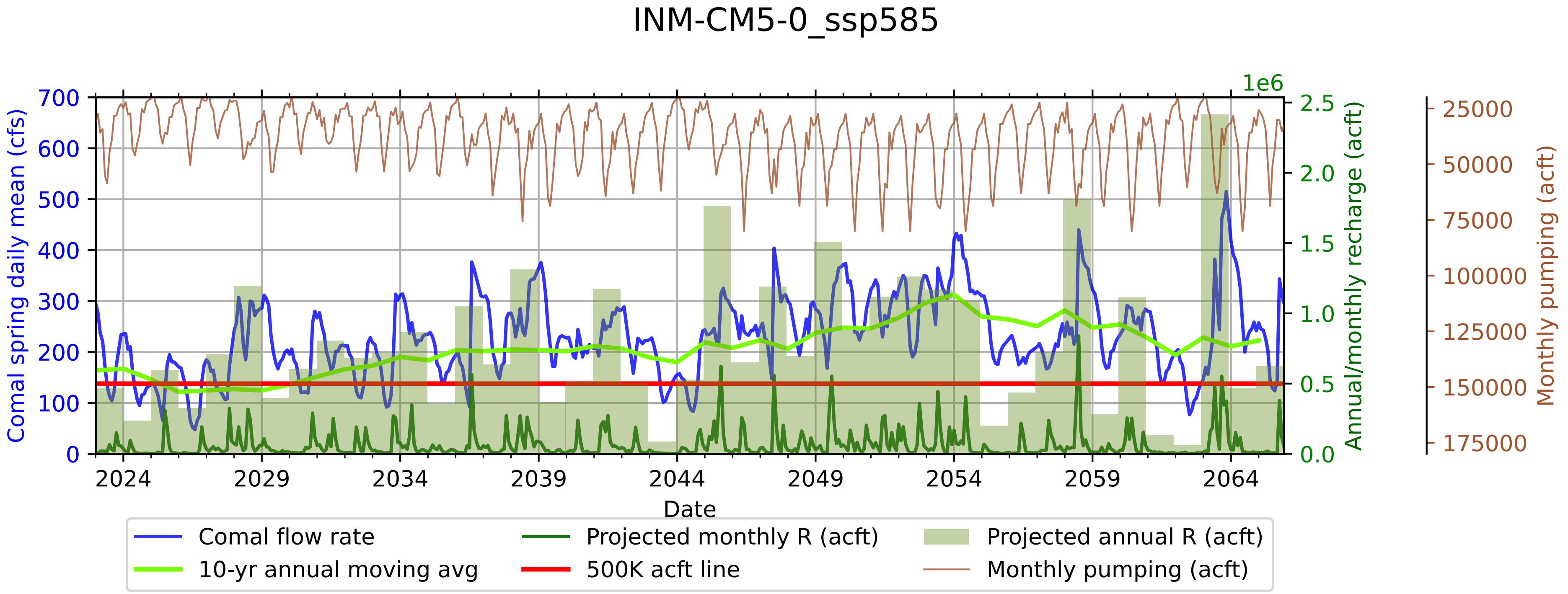




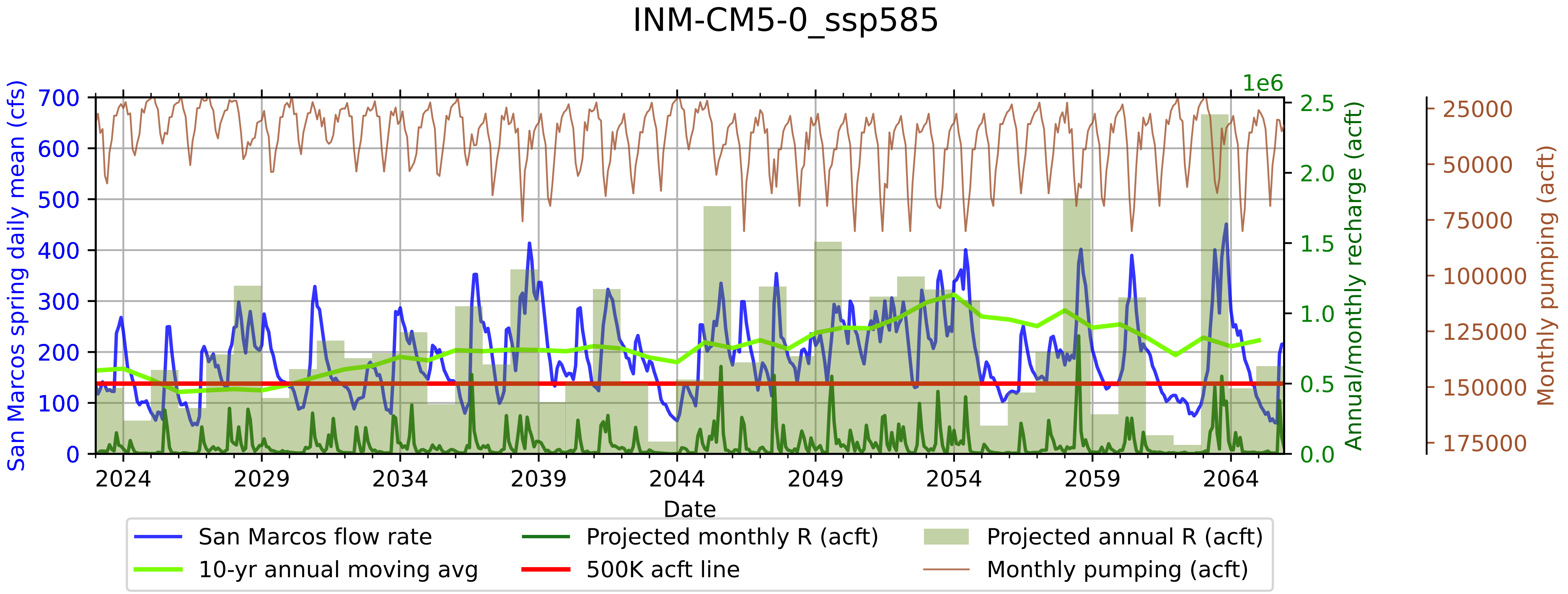
INM-CM5-0_ssp245
San Marcos spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
Date
0
100
200
300
400
500
600
700
0.00
0.25
0.50
0.75
1.00
1.25
1.50
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)


INM-CM5-0_ssp245
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

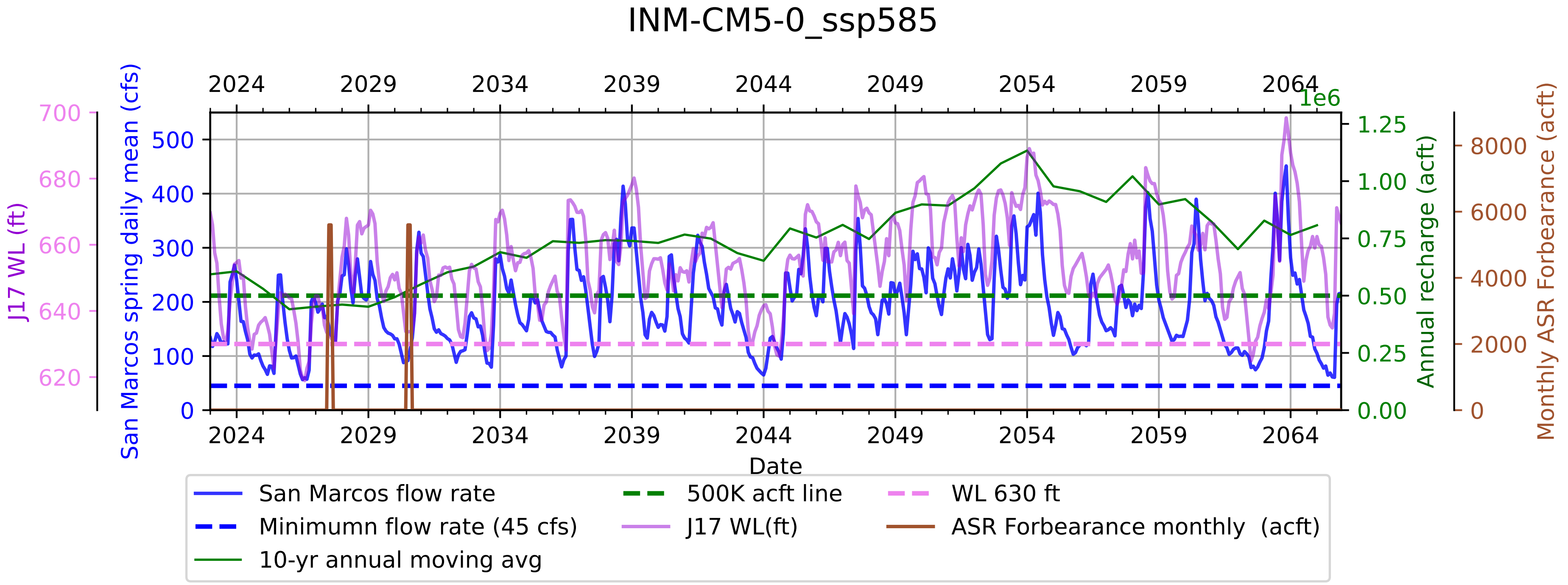

INM-CM5-0_ssp245
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

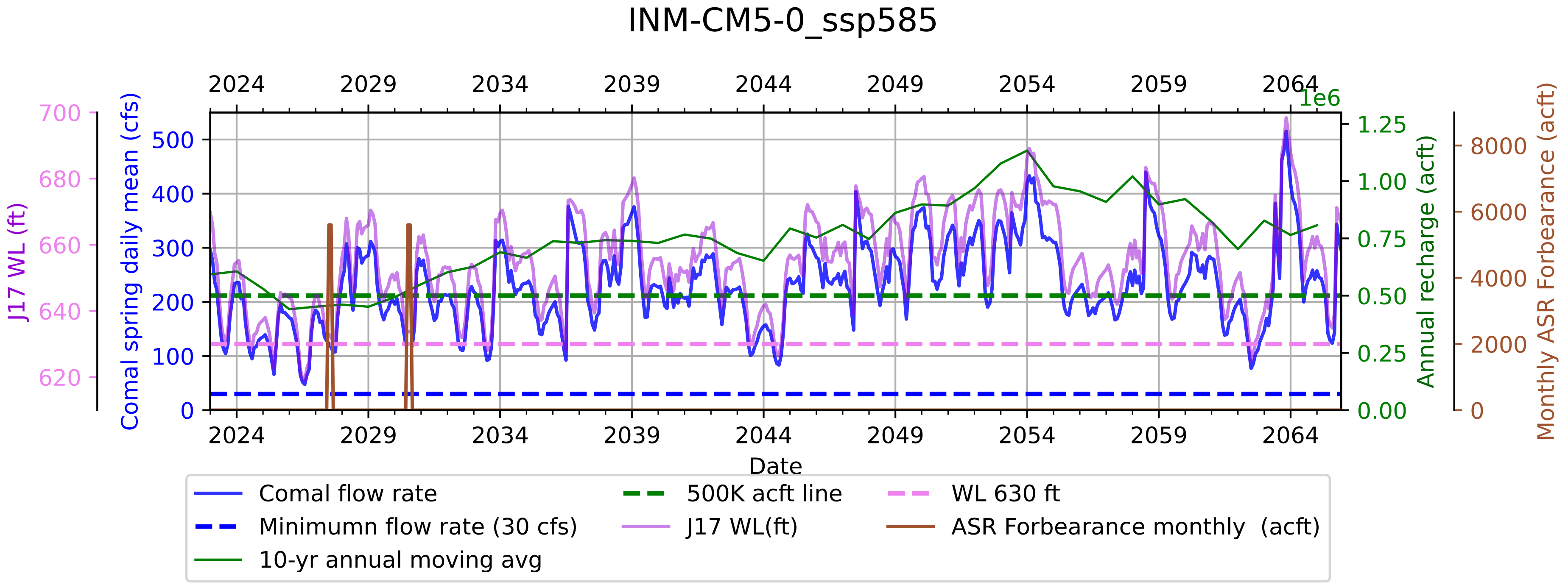


INM-CM5-0_ssp585
Comal spring daily mean (cfs)
700
600
500
400
300
200
100
0
1e6
2.5
2.0
1.5
1.0
0.5
0.0
Annual/monthly recharge (acft)
25000
50000
75000
100000
125000
150000
175000
Monthly pumping (acft)
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

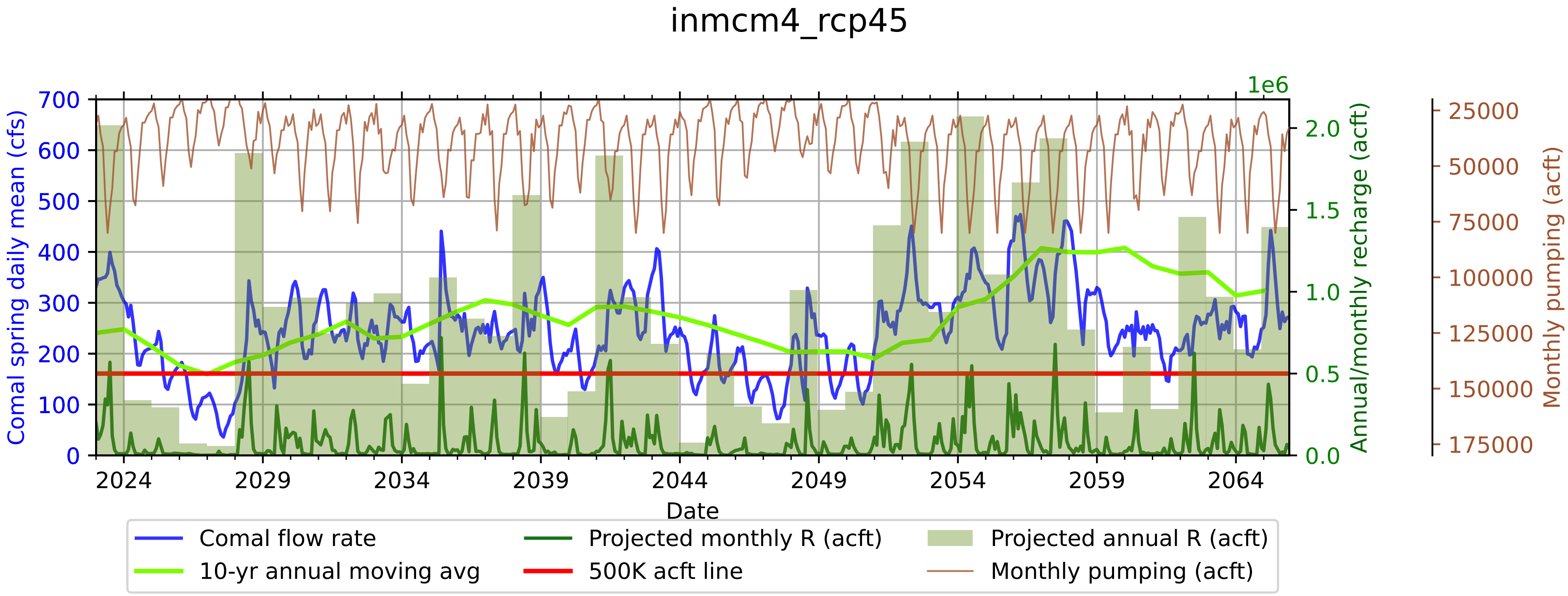


INM-CM5-0_ssp585
San Marcos spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
Annual/monthly recharge (acft)
0.0
0.5
1.0
1.5
2.0
2.5
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

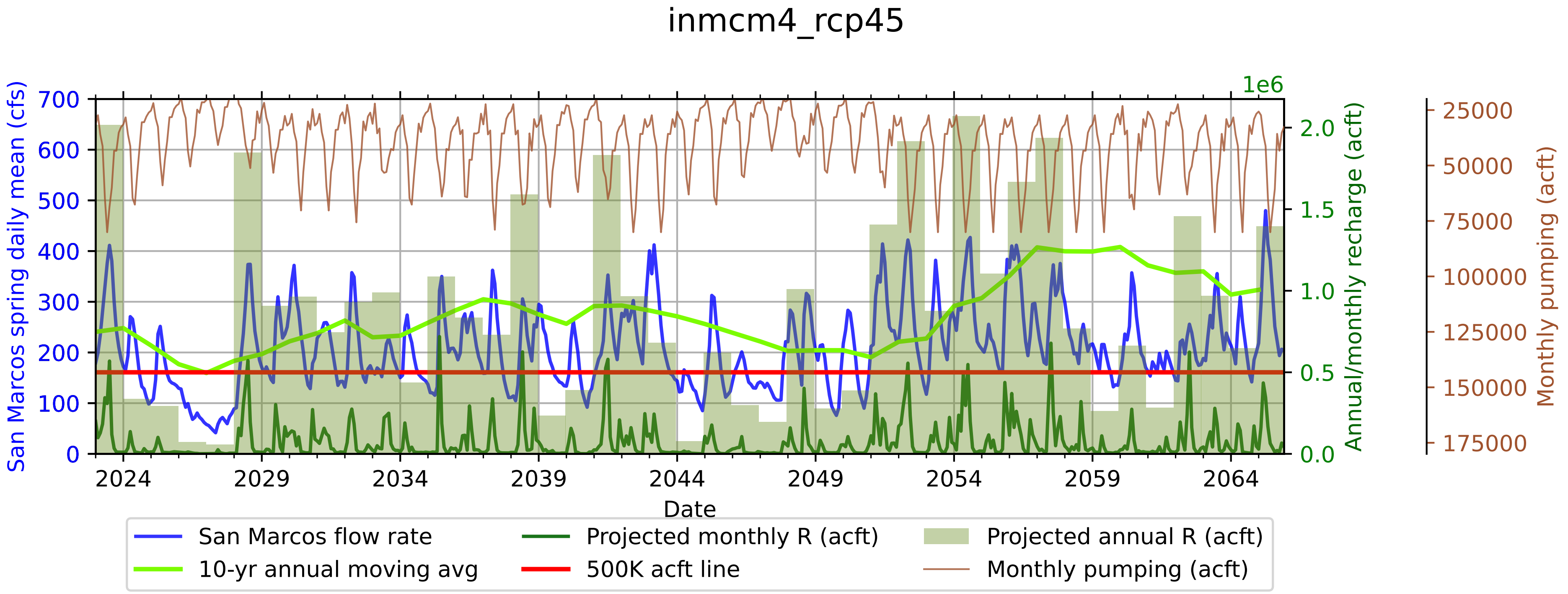

INM-CM5-0_ssp585
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
J17 WL (ft)
700
680
660
640
620
San Marcos spring daily mean (cfs)
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
8000
6000
4000
2000
0
Monthly ASR Forbearance (acft)
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)



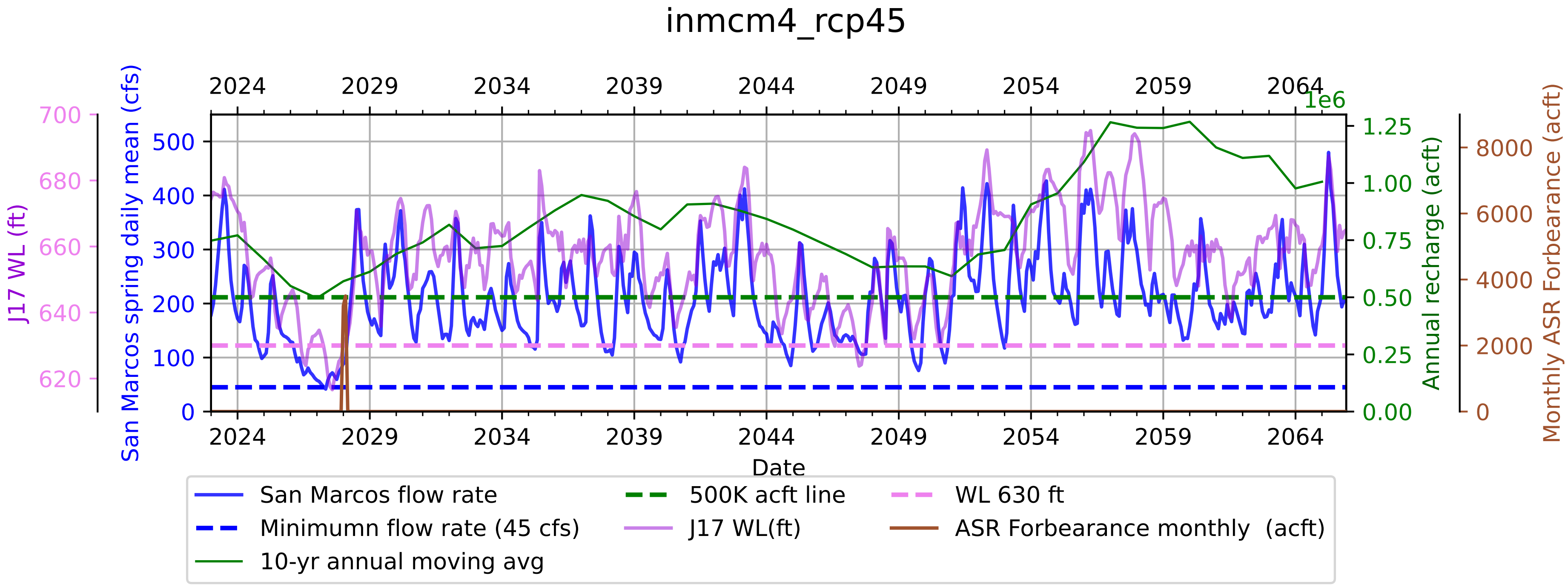
INM-CM5-0_ssp585
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
2024
2029
2034
2039
2044
2049
2054
2059
2064
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

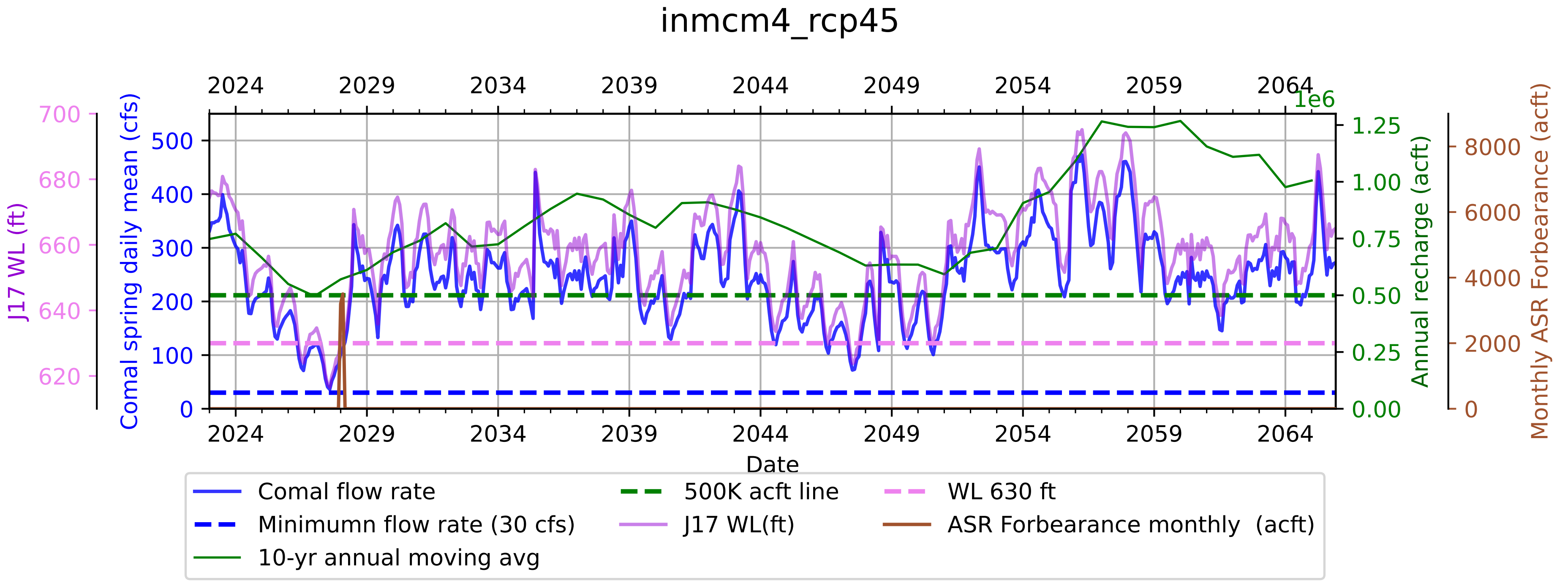


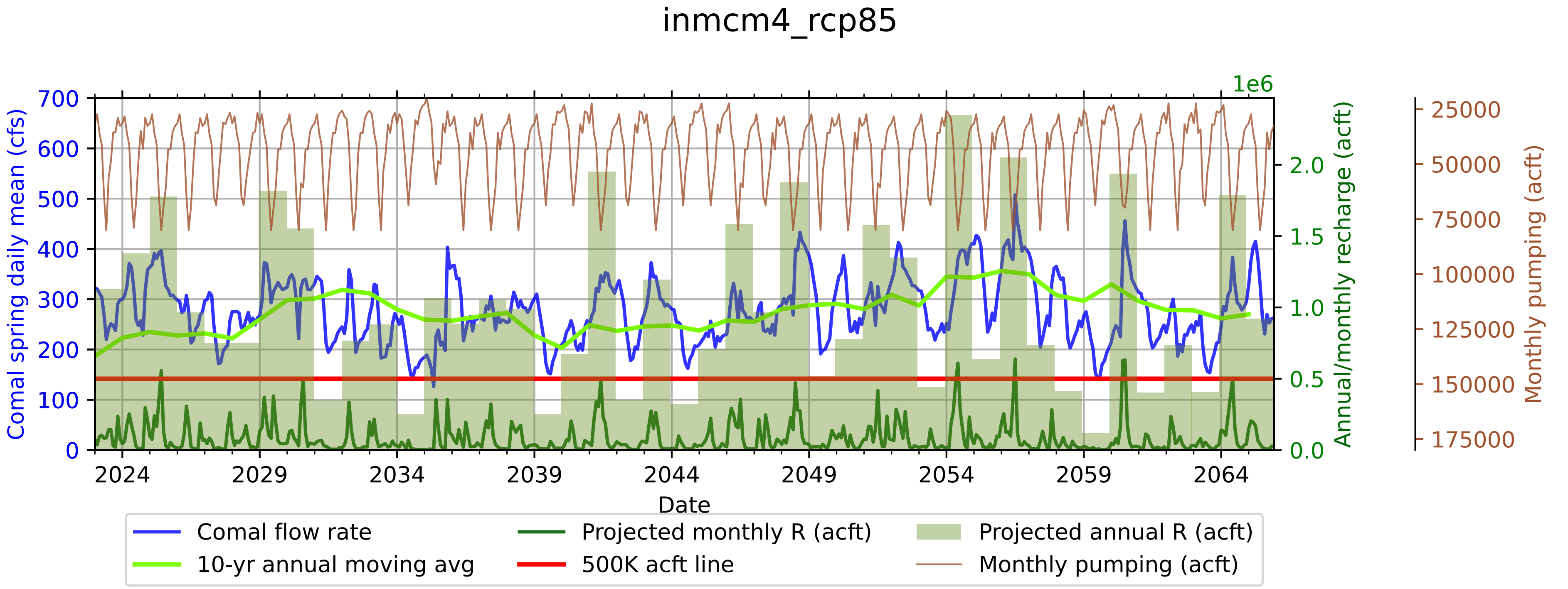
inmcm4_rcp45
1e6
Comal spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
700
600
500
400
300
200
100
0
2.0
1.5
1.0
0.5
0.0
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

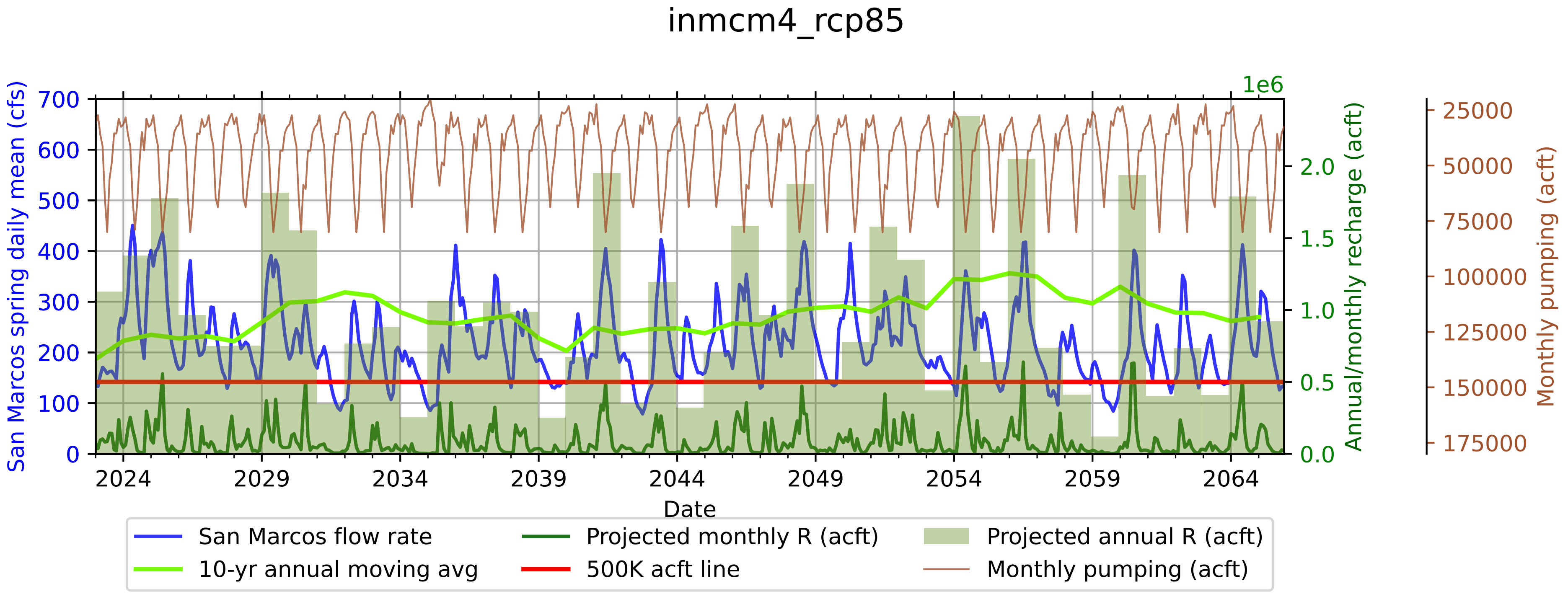


inmcm4_rcp45
San Marcos spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
Annual/monthly recharge (acft)
0.0
0.5
1.0
1.5
2.0
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

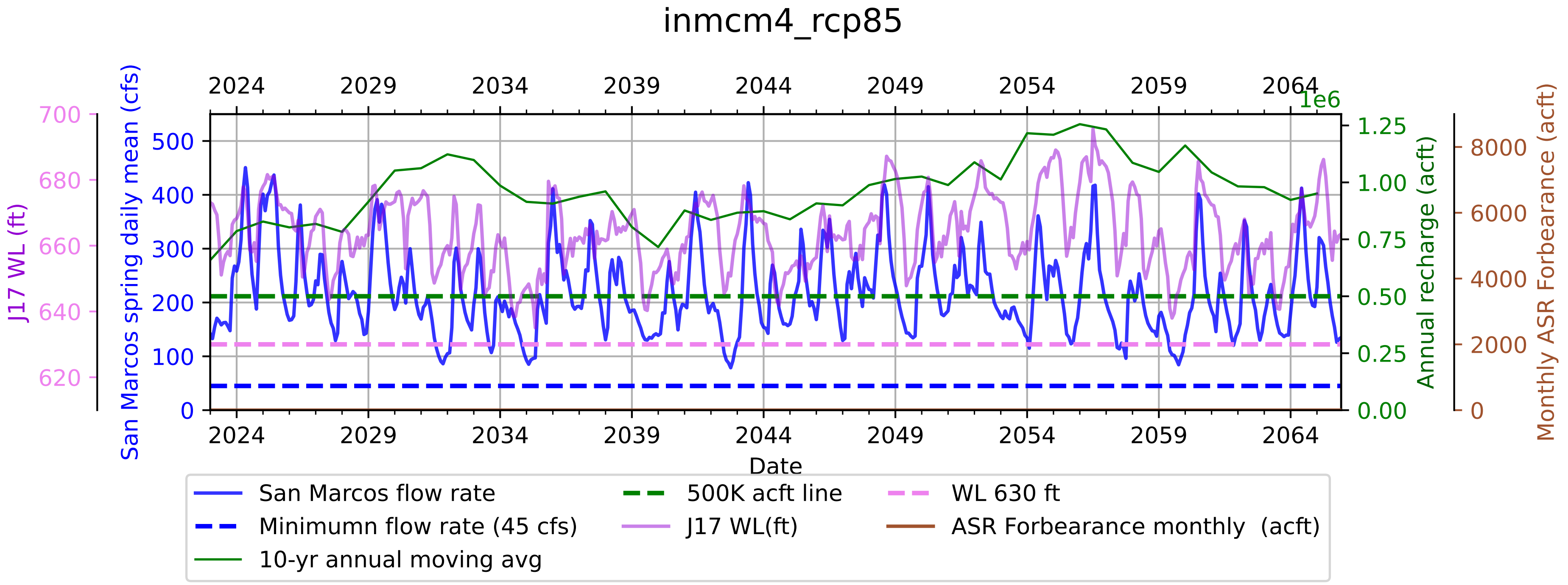

inmcm4_rcp45
J17 WL (ft)
700
680
660
640
620
San Marcos spring daily mean (cfs)
500
400
300
200
100
0
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
8000
6000
4000
2000
0
Monthly ASR Forbearance (acft)
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

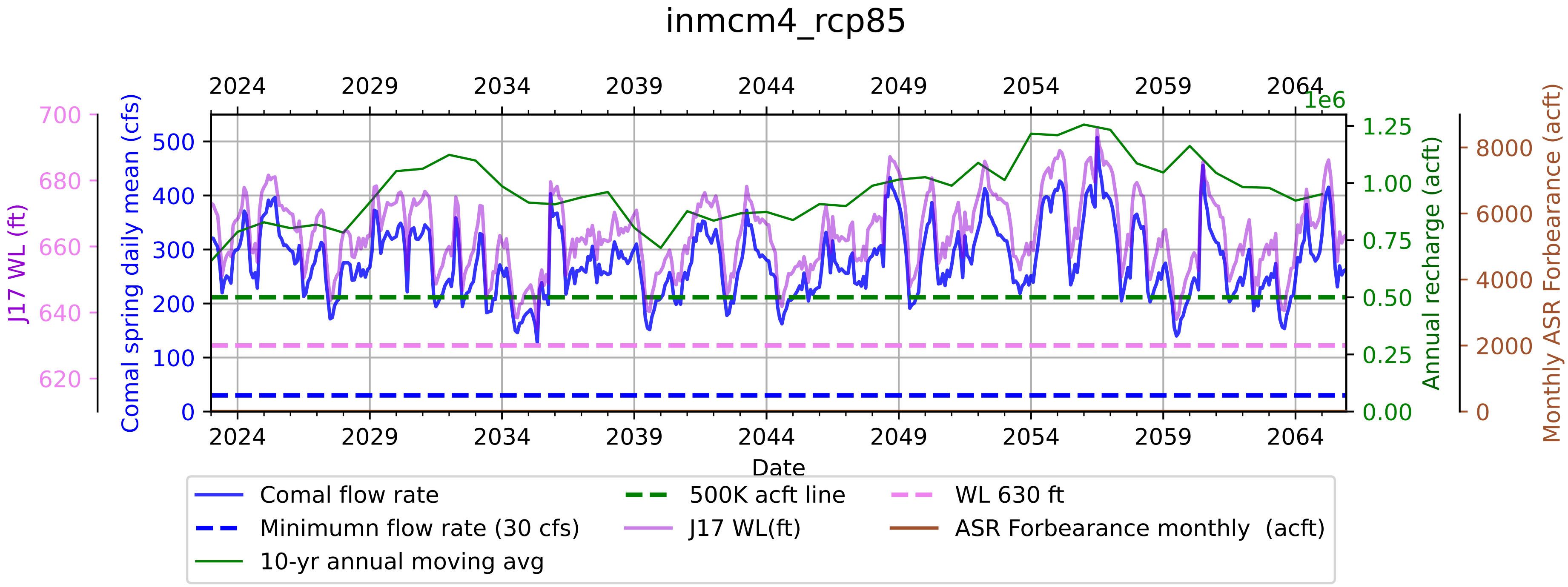

inmcm4_rcp45
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
2024
2029
2034
2039
2044
2049
2054
2059
2064
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)


inmcm4_rcp85
Comal spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

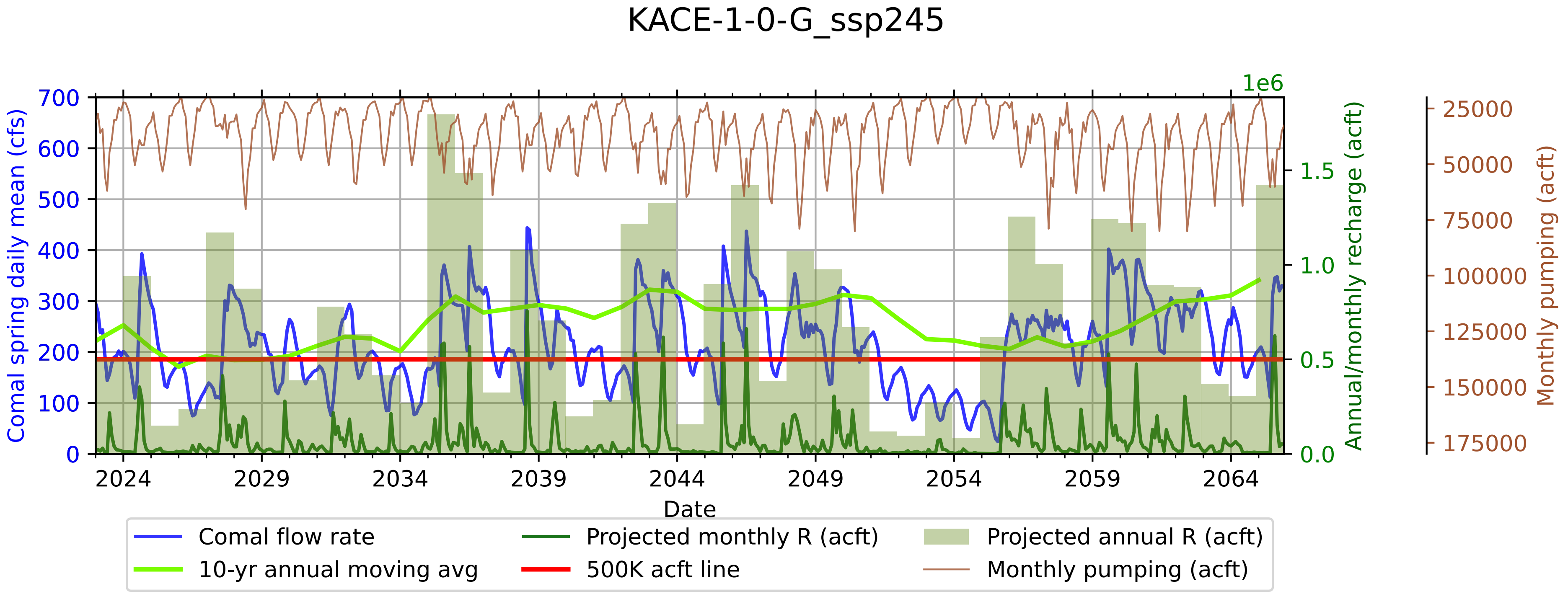


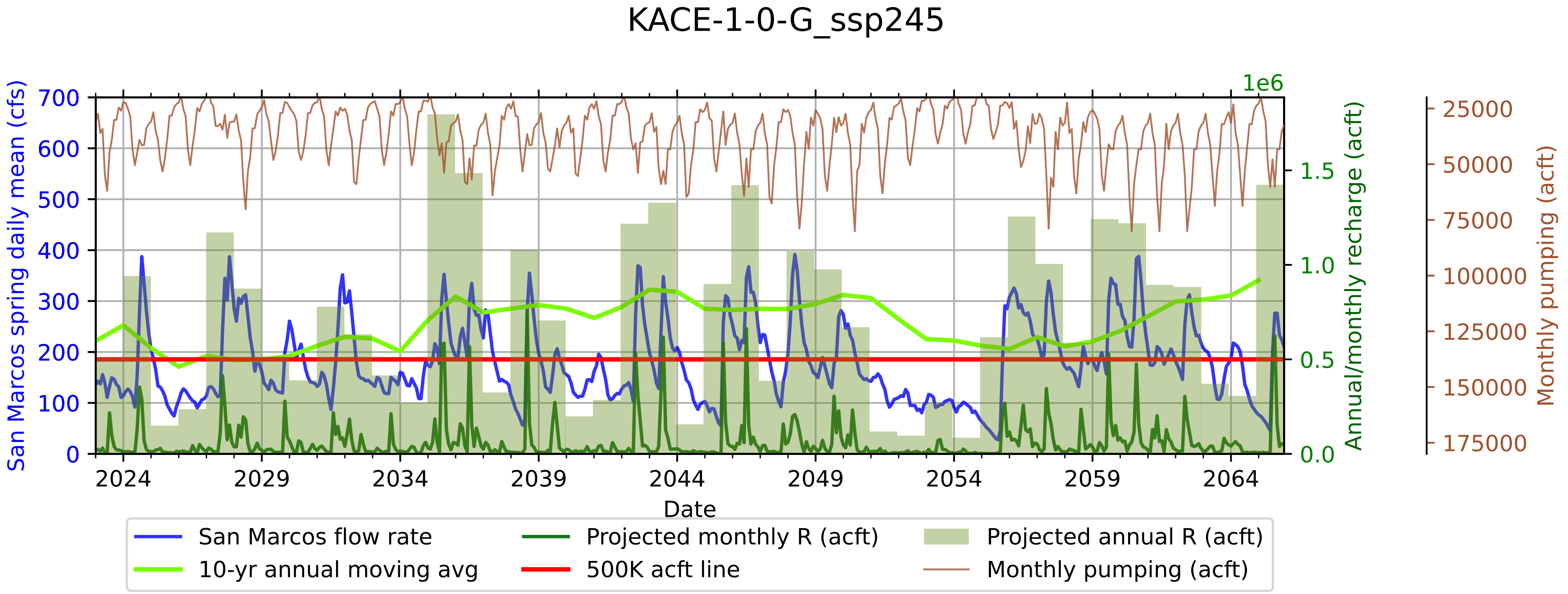
inmcm4_rcp85
San Marcos spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
0.0
0.5
1.0
1.5
2.0
Annual/monthly recharge (acft)
25000
50000
75000
100000
125000
150000
175000
Monthly pumping (acft)
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

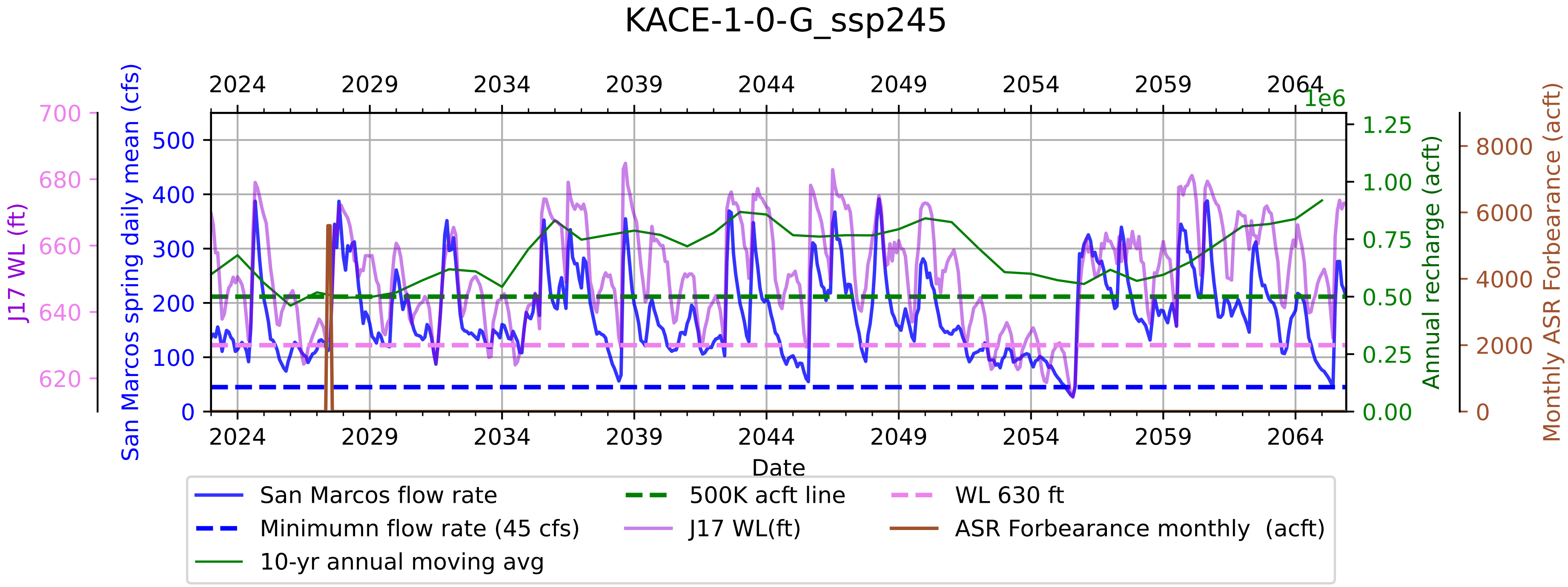

inmcm4_rcp85
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)



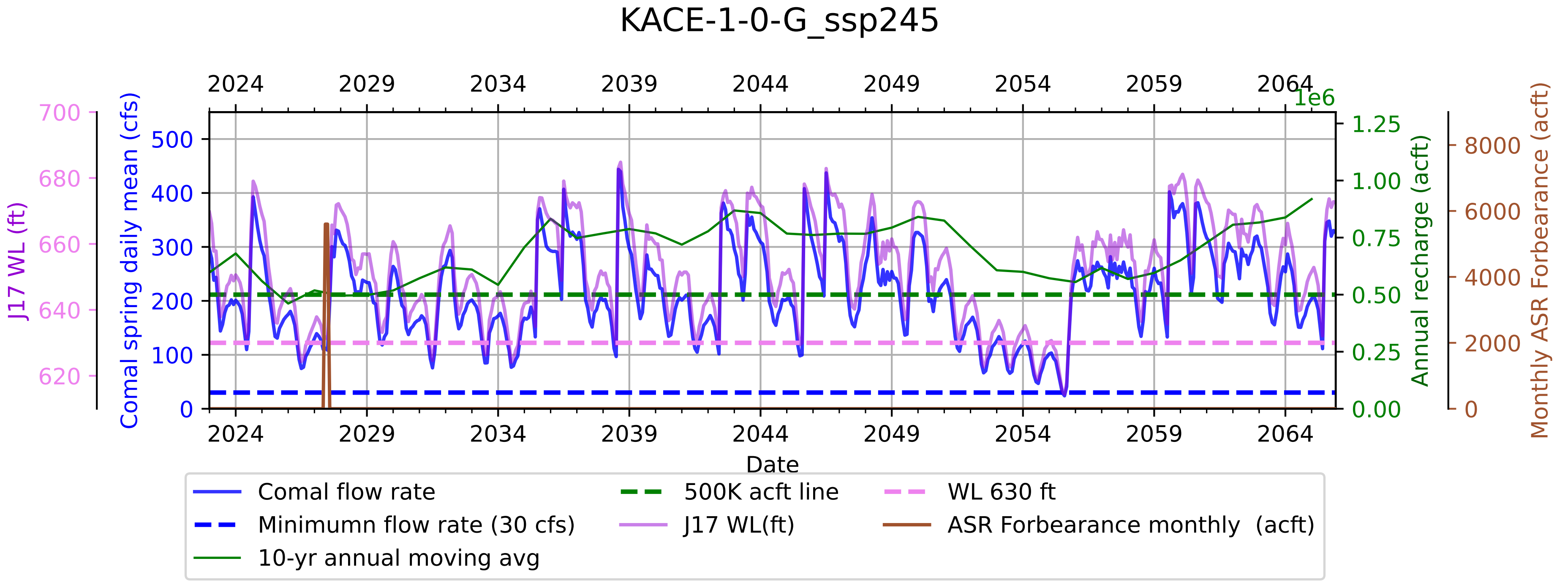
inmcm4_rcp85
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
2024
2029
2034
2039
2044
2049
2054
2059
2064
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)


KACE-1-0-G_ssp245
Comal spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
Annual/monthly recharge (acft)
0.0
0.5
1.0
1.5
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

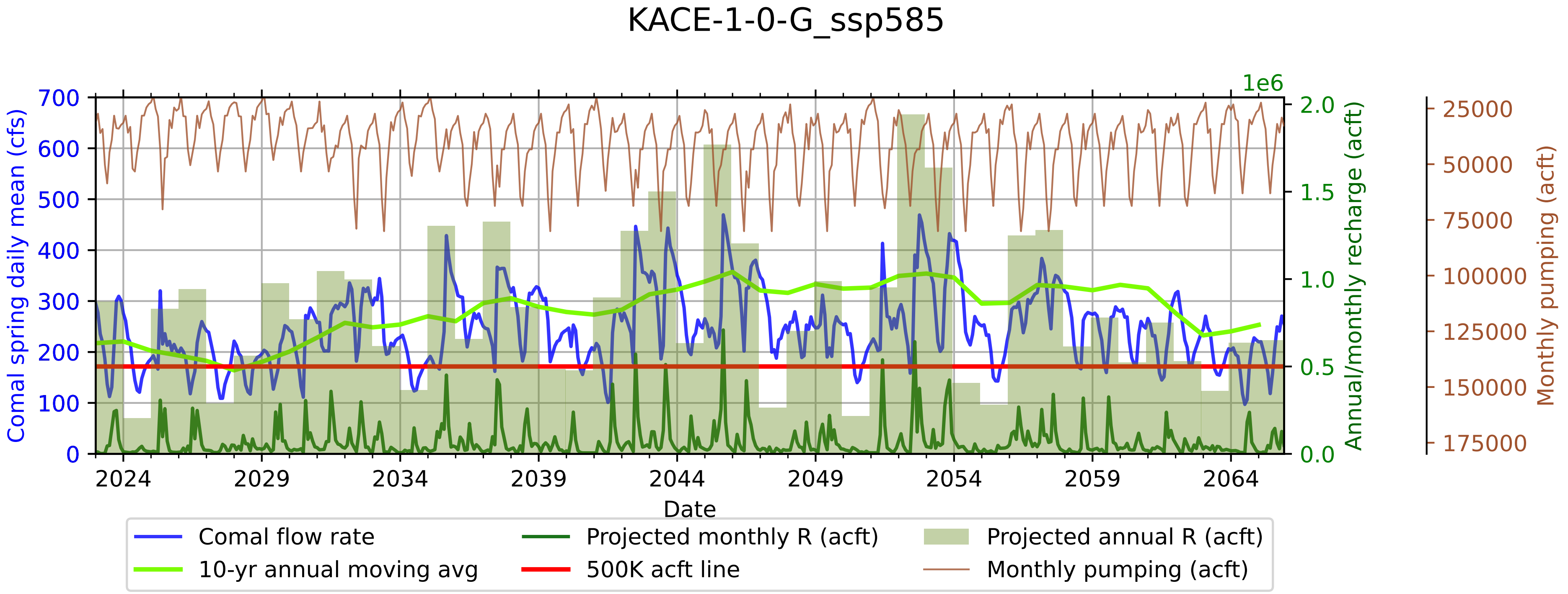

KACE-1-0-G_ssp245
San Marcos spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
Date
0
100
200
300
400
500
600
700
0.0
0.5
1.0
1.5
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



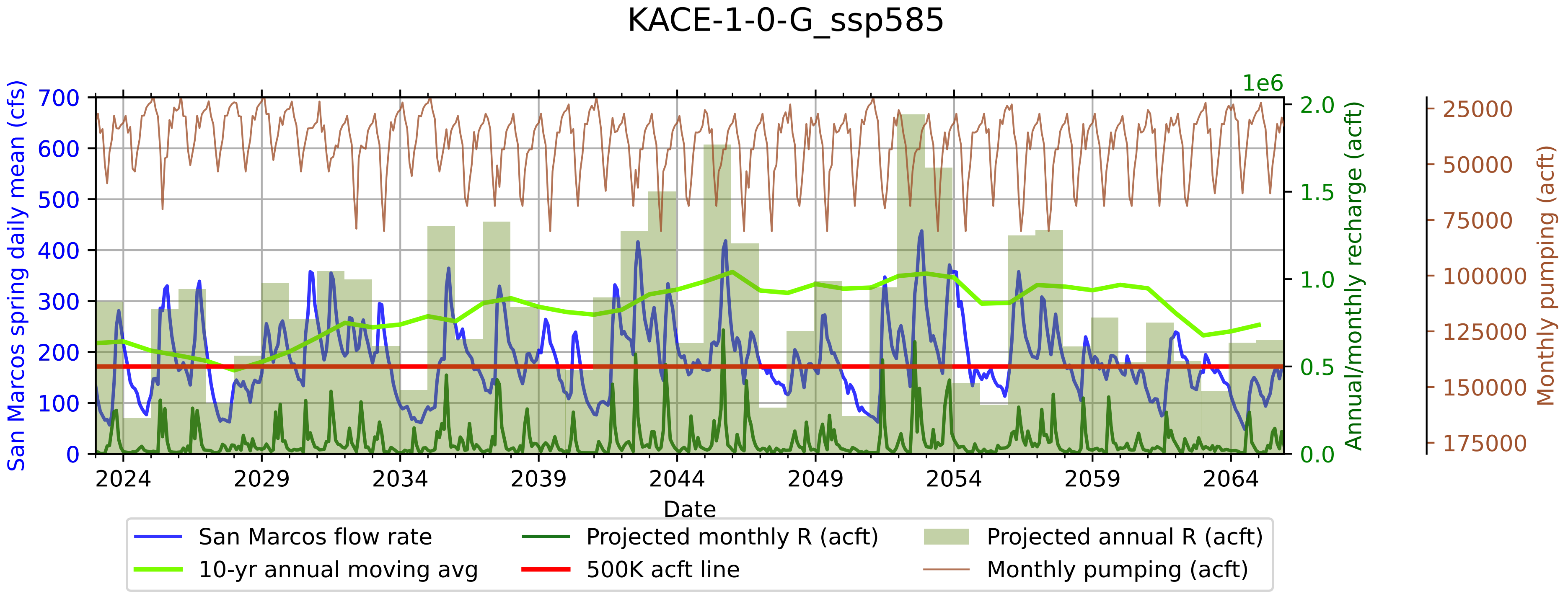
KACE-1-0-G_ssp245
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
J17 WL (ft)
700
680
660
640
620
San Marcos spring daily mean (cfs)
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
8000
6000
4000
2000
0
Monthly ASR Forbearance (acft)
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

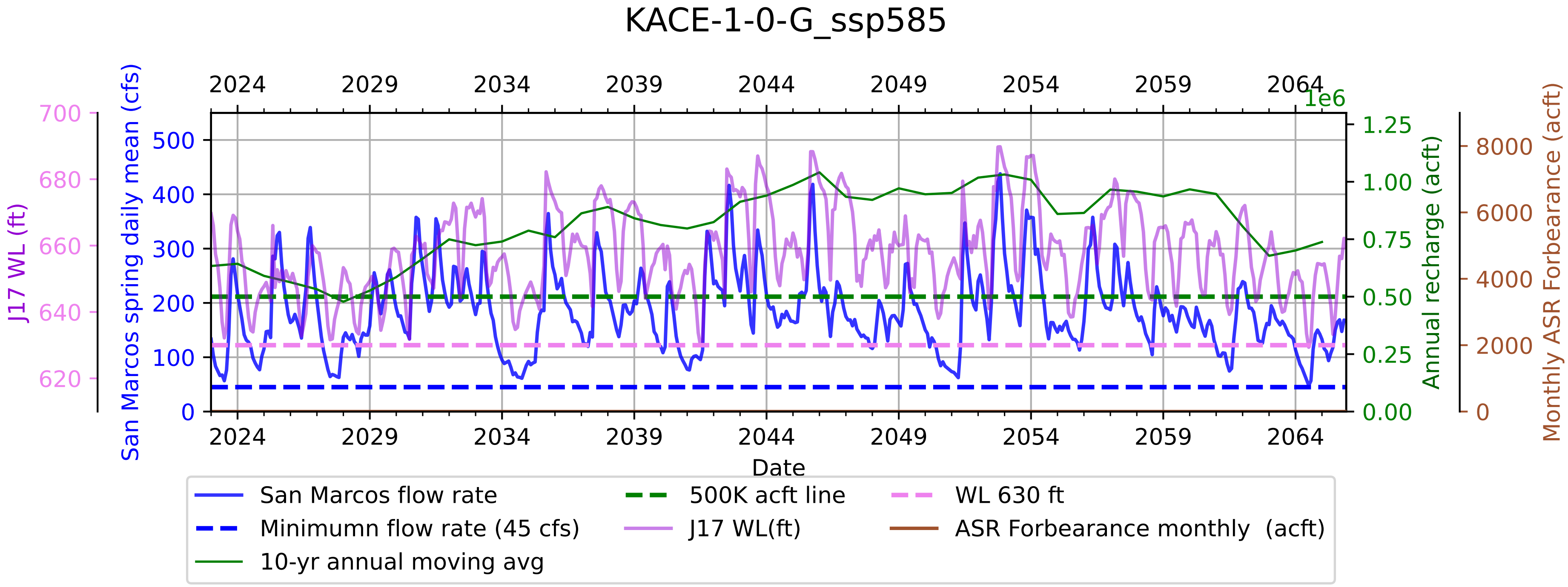


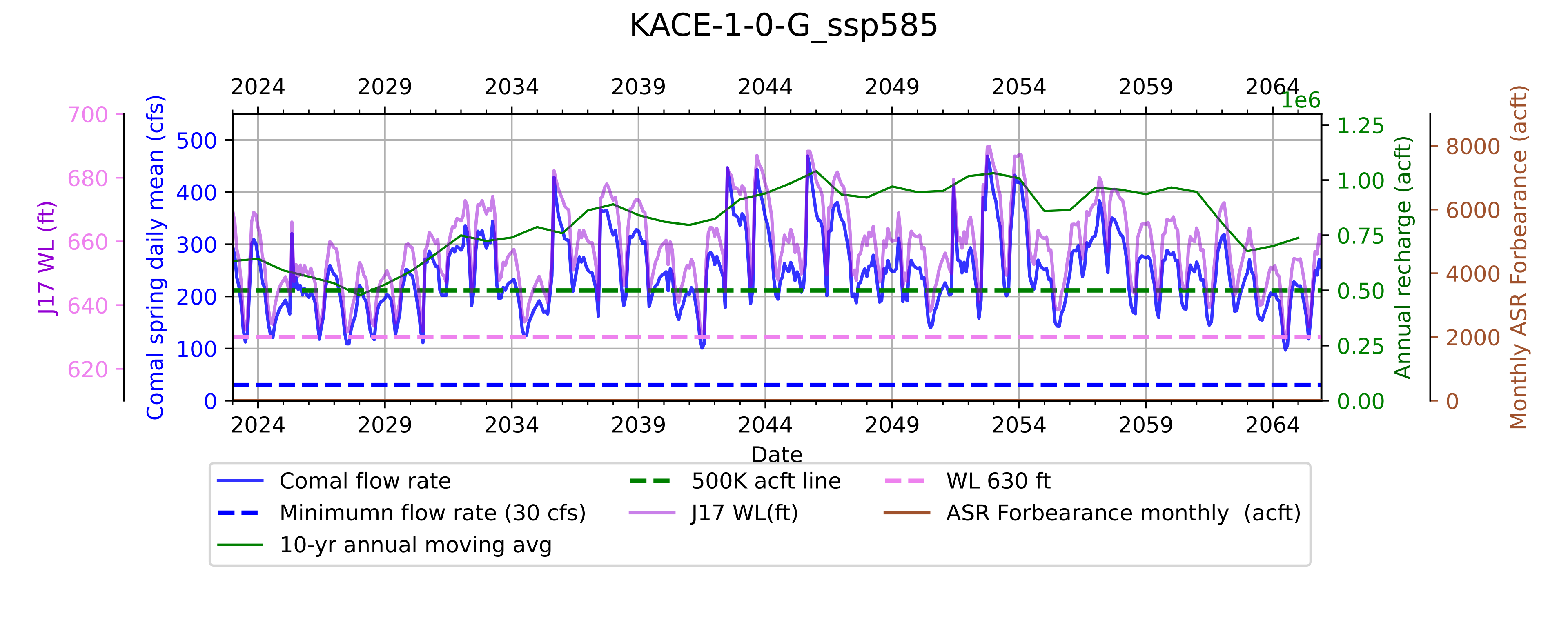
KACE-1-0-G_ssp245
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
J17 WL (ft)
700
680
660
640
620
Comal spring daily mean (cfs)
500
400
300
200
100
0
Annual recharge (acft)
1.25
1.00
0.75
0.50
0.25
0.00
Monthly ASR Forbearance (acft)
8000
6000
4000
2000
0
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)



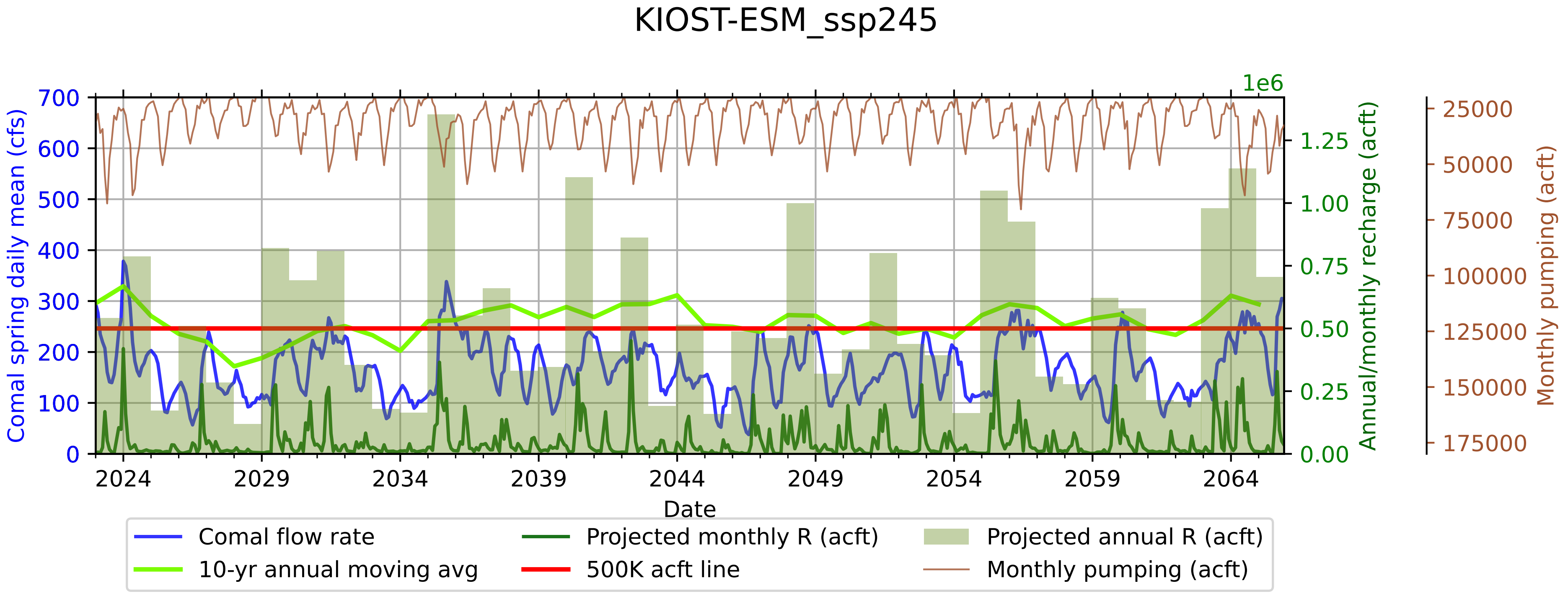
KACE-1-0-G_ssp585
Comal spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
Annual/monthly recharge (acft)
0.0
0.5
1.0
1.5
2.0
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)


KACE-1-0-G_ssp585
San Marcos spring daily mean (cfs)
Annual/monthly recharge (acft)
1e6
Monthly pumping (acft)
Date
0
100
200
300
400
500
600
700
0.0
0.5
1.0
1.5
2.0
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

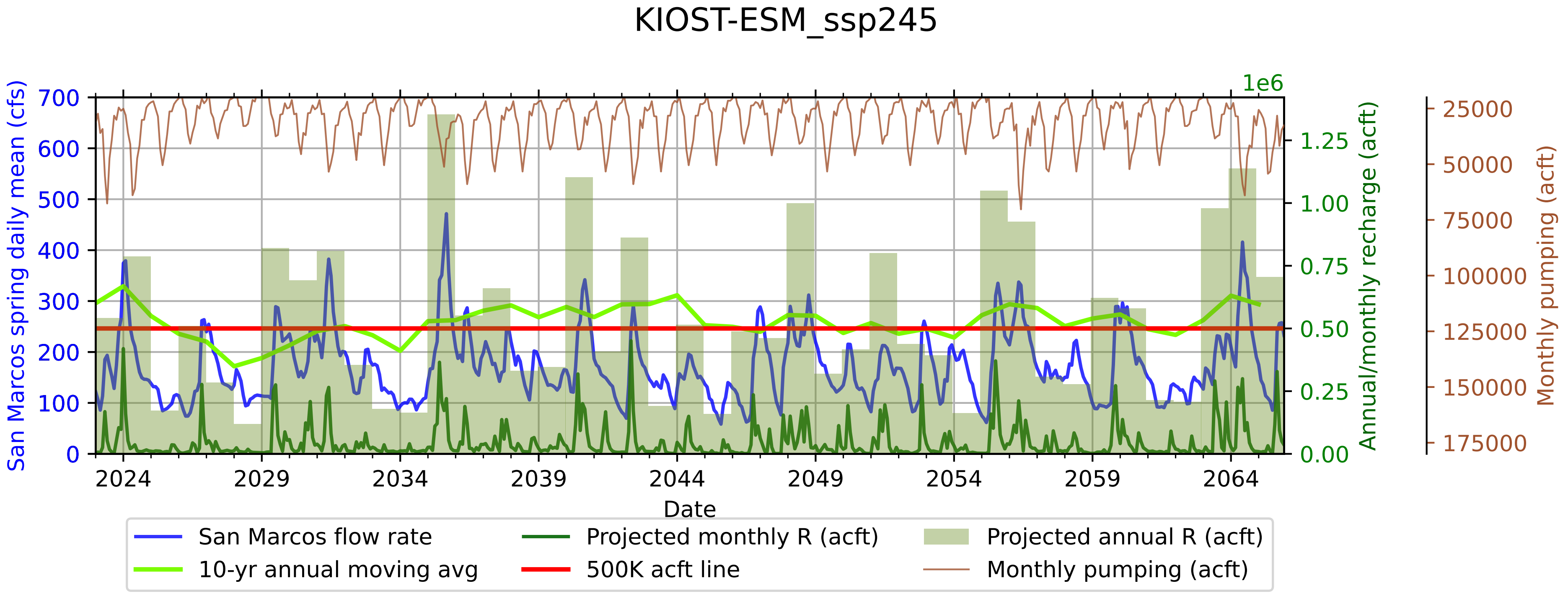

KACE-1-0-G_ssp585
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
2024
2029
2034
2039
2044
2049
2054
2059
2064
700
680
660
640
620
0
100
200
300
400
500
0.00
0.25
0.50
0.75
1.00
1.25
0
2000
4000
6000
8000
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

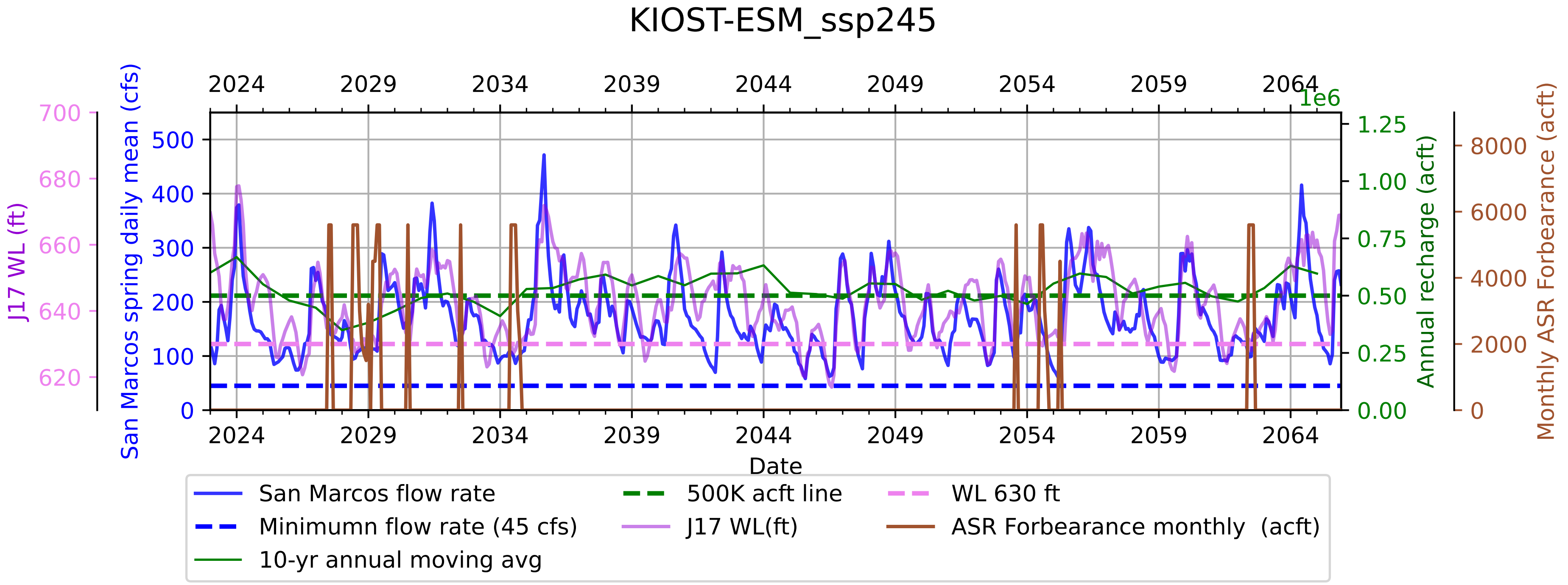


KACE-1-0-G_ssp585
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

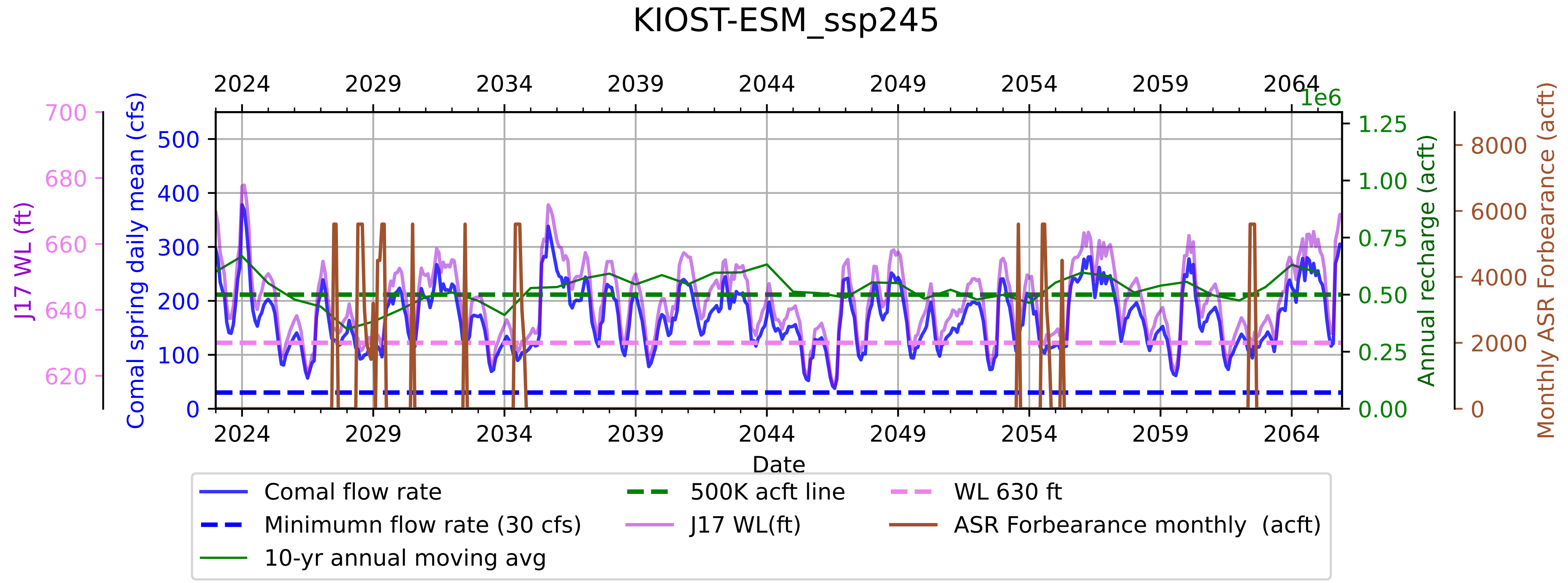


KIOST-ESM_ssp245
Comal spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

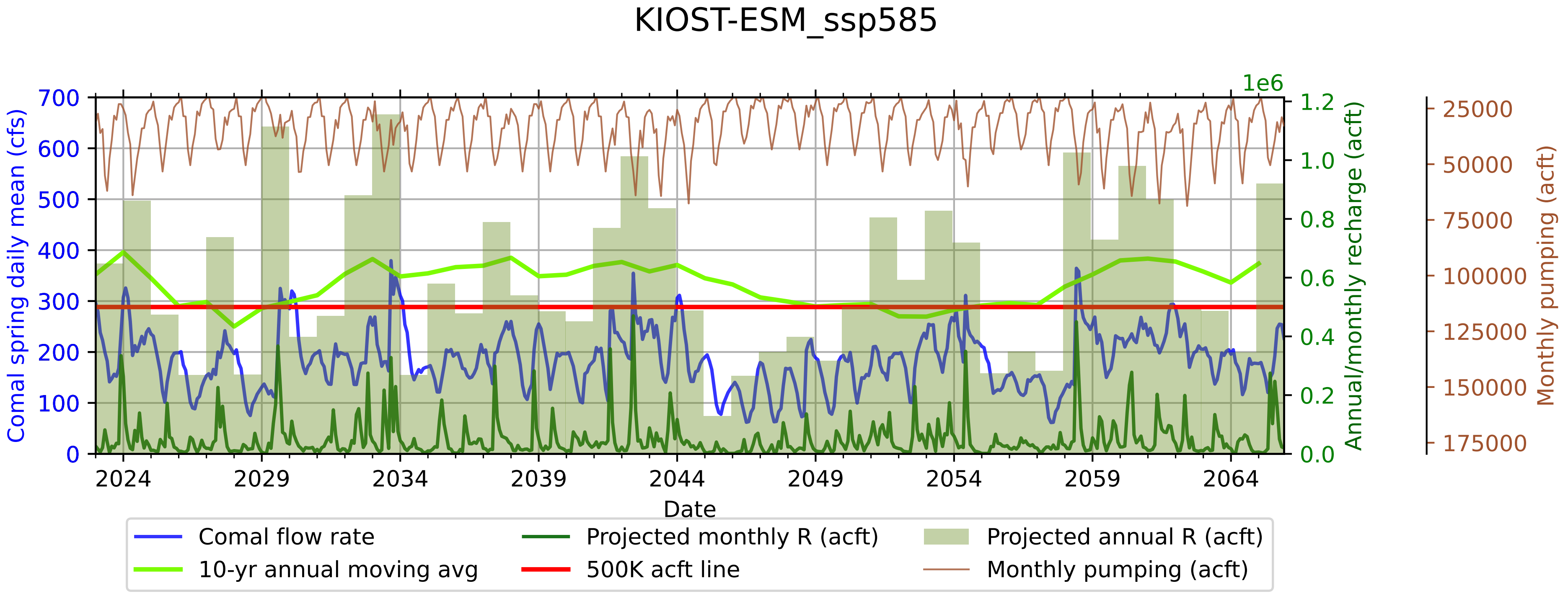

KIOST-ESM_ssp245
San Marcos spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
Annual/monthly recharge (acft)
0.00
0.25
0.50
0.75
1.00
1.25
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



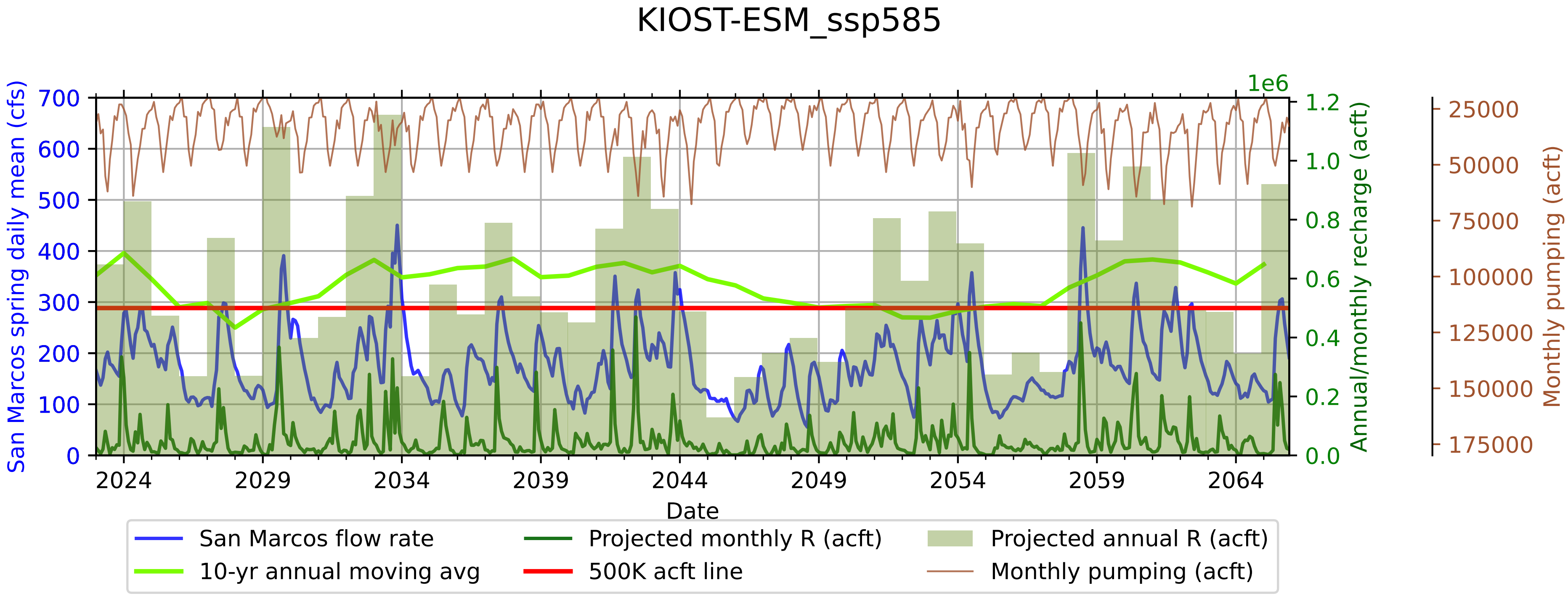
KIOST-ESM_ssp245
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)



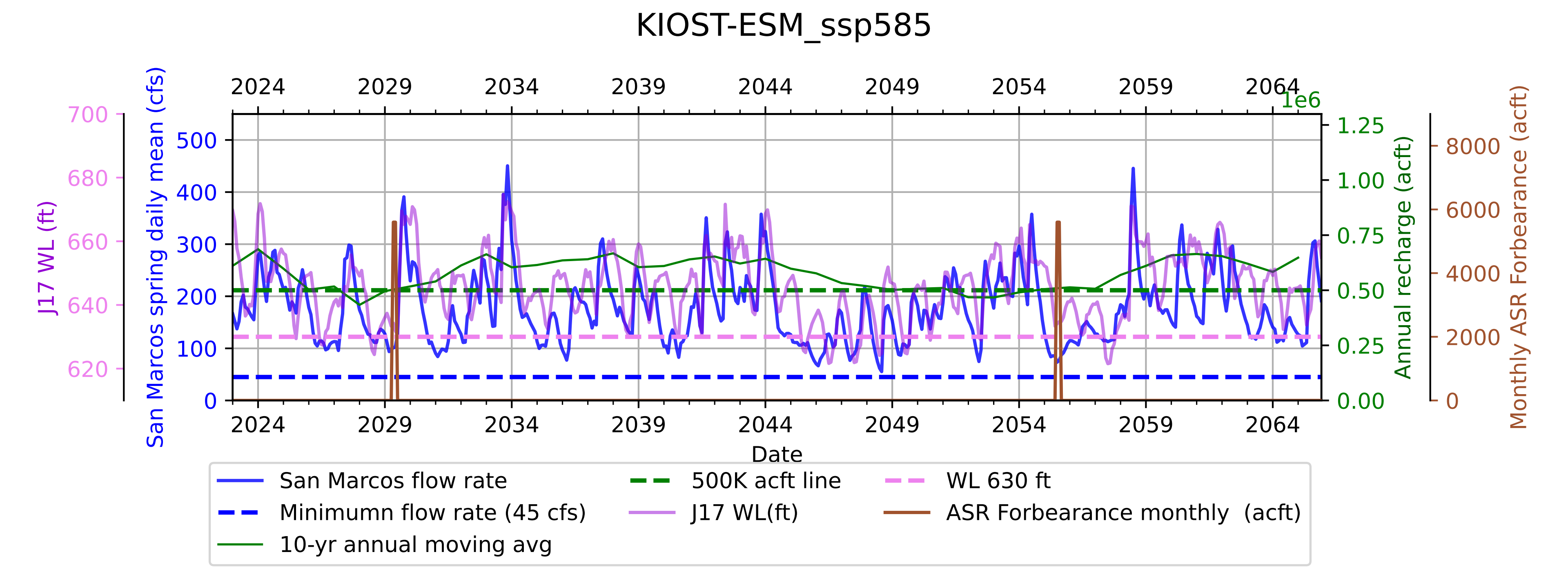
KIOST-ESM_ssp245
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
2024
2029
2034
2039
2044
2049
2054
2059
2064
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)



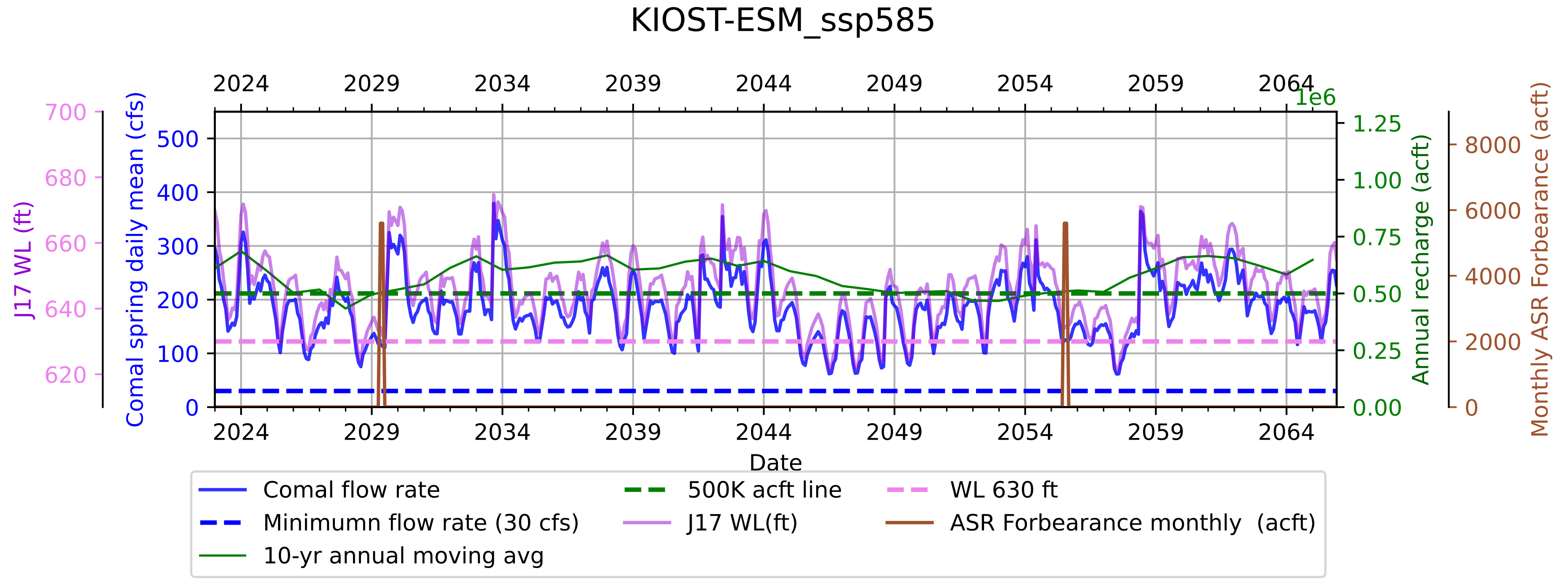
KIOST-ESM_ssp585
Comal spring daily mean (cfs)
700
600
500
400
300
200
100
0
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Annual/monthly recharge (acft)
25000
50000
75000
100000
125000
150000
175000
Monthly pumping (acft)
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



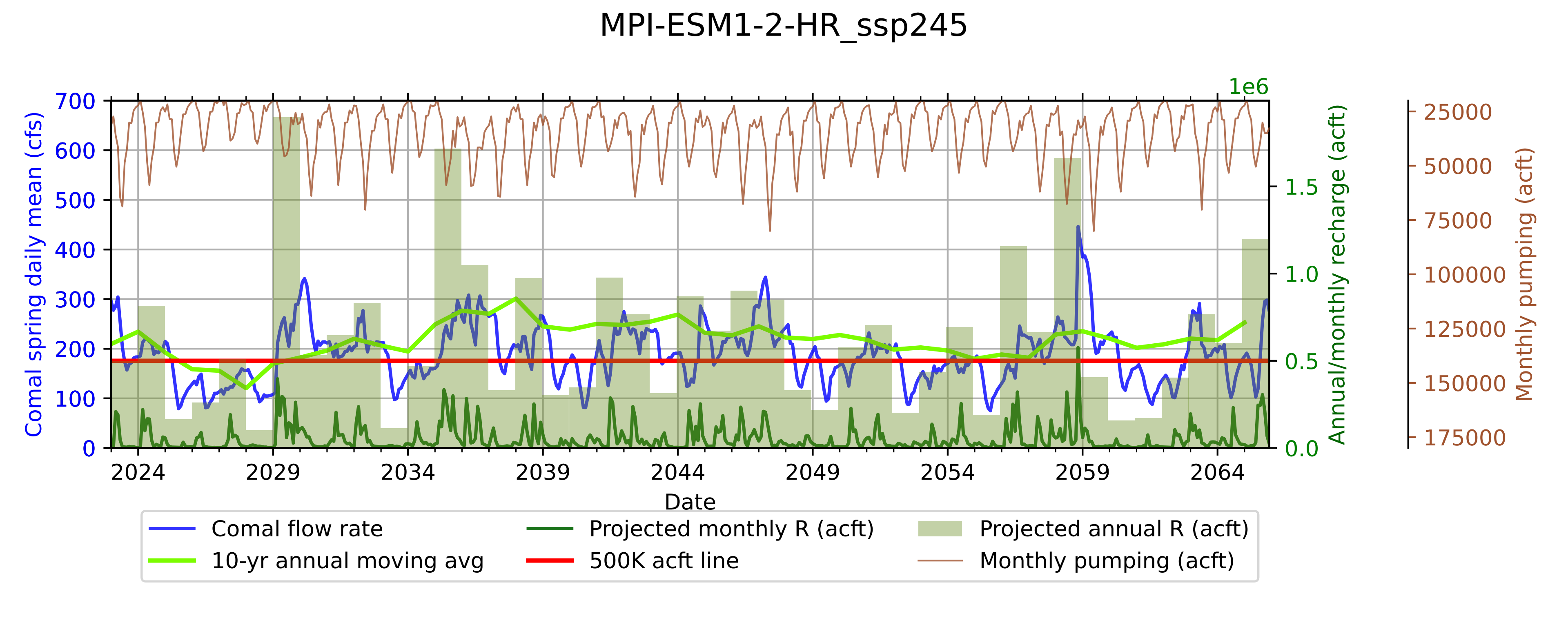
KIOST-ESM_ssp585
San Marcos spring daily mean (cfs)
Annual/monthly recharge (acft)
Monthly pumping (acft)
1e6
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

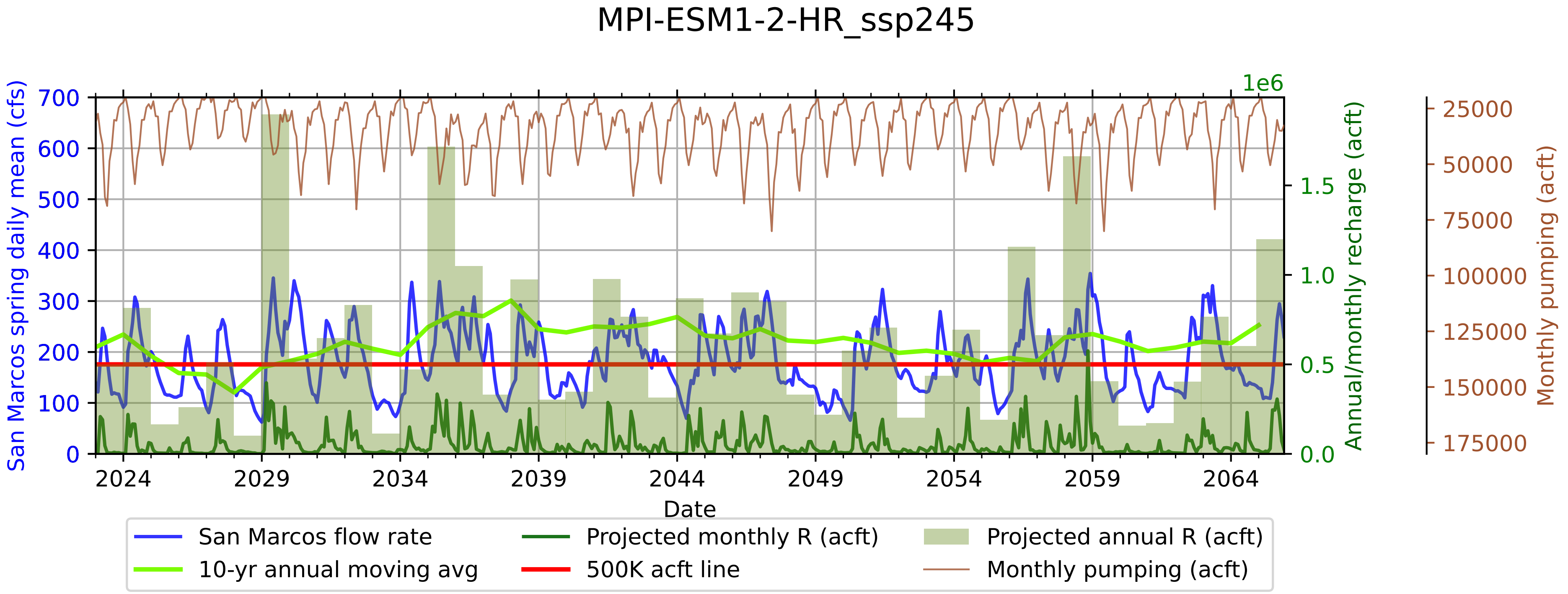


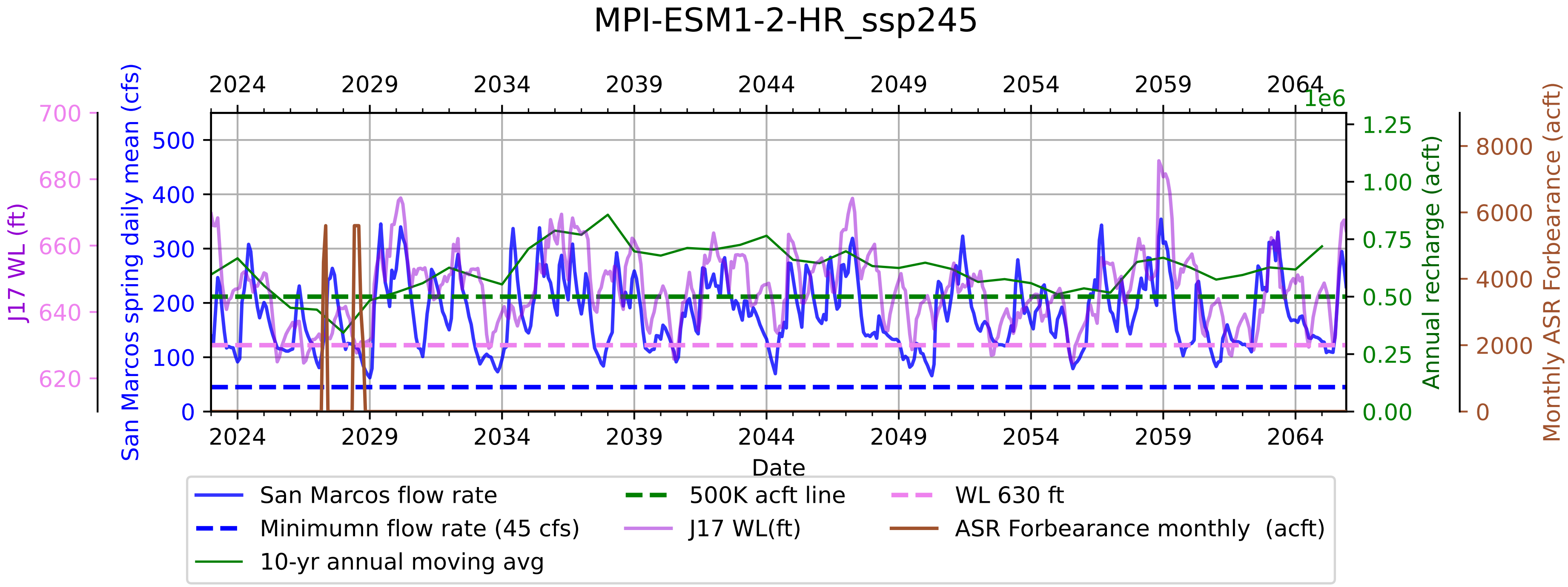
KIOST-ESM_ssp585
2024
2029
2034
2039
2044
2049
2054
2059
2064
1e6
700
680
660
640
620
J17 WL (ft)
500
400
300
200
100
0
San Marcos spring daily mean (cfs)
1.25
1.00
0.75
0.50
0.25
0.00
Annual recharge (acft)
8000
6000
4000
2000
0
Monthly ASR Forbearance (acft)
Date
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)



KIOST-ESM_ssp585
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
1e6
Monthly ASR Forbearance (acft)
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

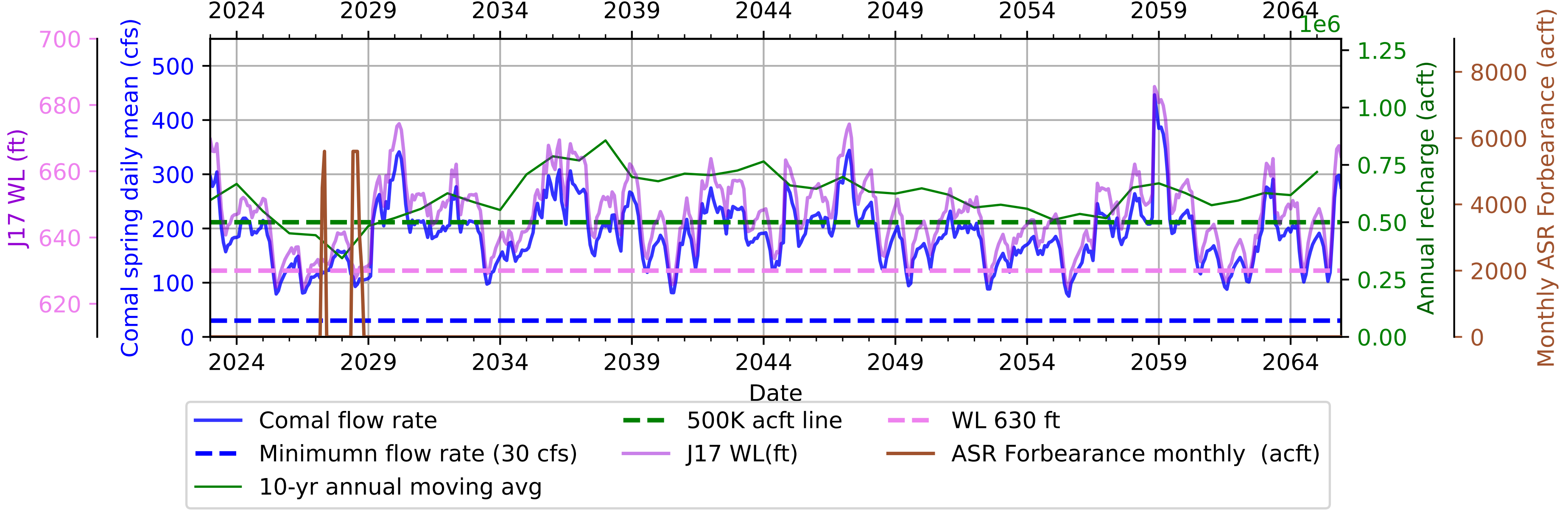

MPI-ESM1-2-HR_ssp245
Comal spring daily mean (cfs)
700
600
500
400
300
200
100
0
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
1e6
Annual/monthly recharge (acft)
1.5
1.0
0.5
0.0
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

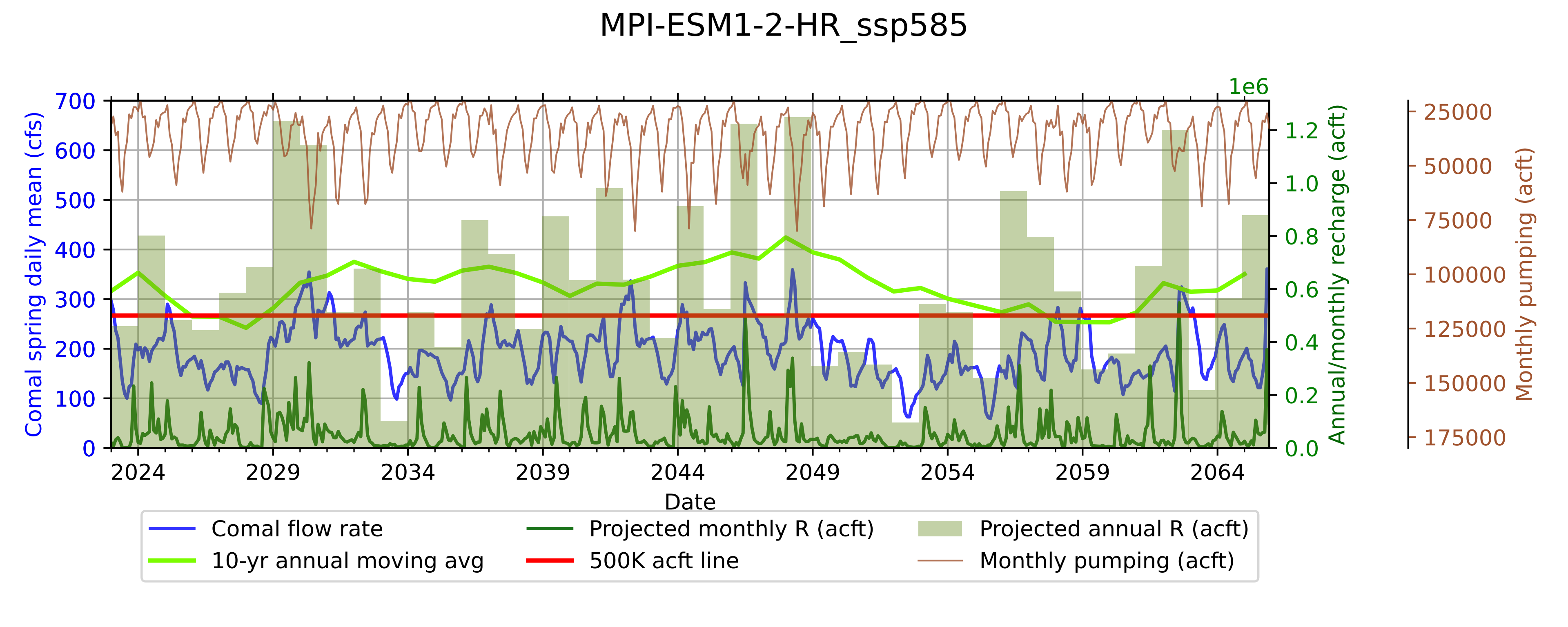

MPI-ESM1-2-HR_ssp245
San Marcos spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
Annual/monthly recharge (acft)
0.0
0.5
1.0
1.5
Monthly pumping (acft)
25000
50000
75000
100000
125000
150000
175000
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

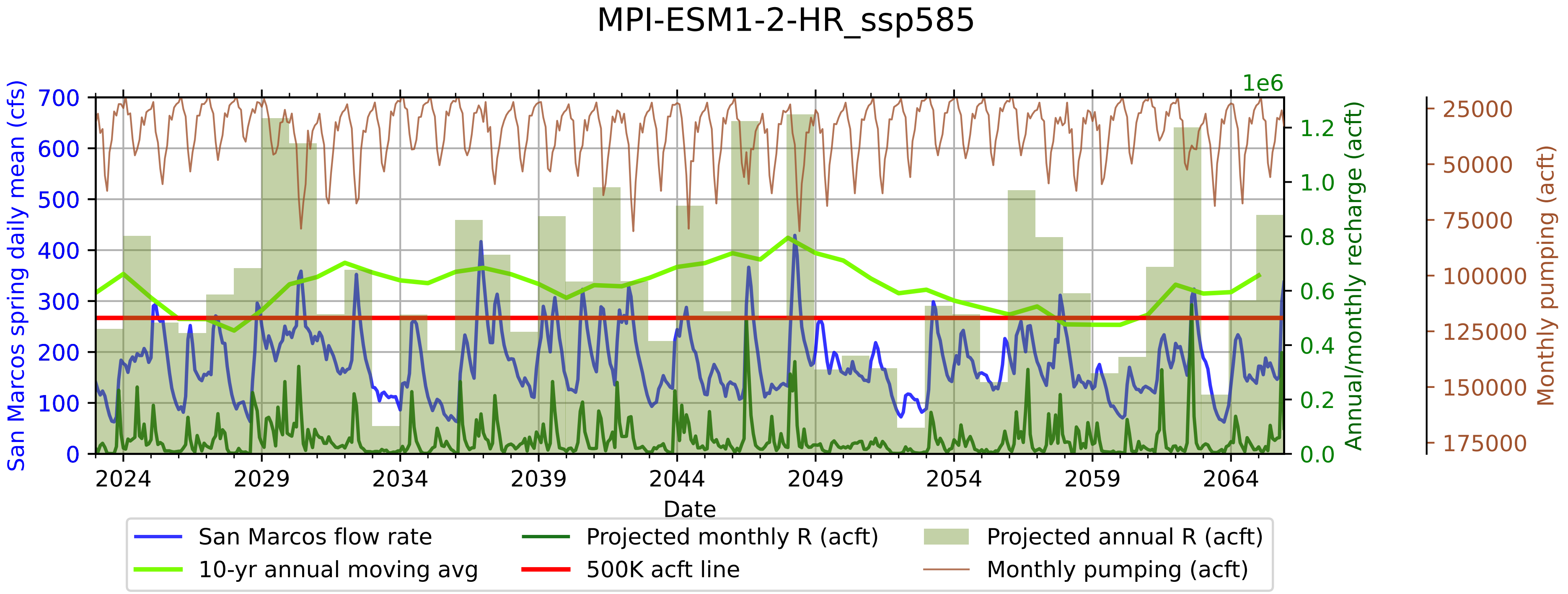


MPI-ESM1-2-HR_ssp245
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

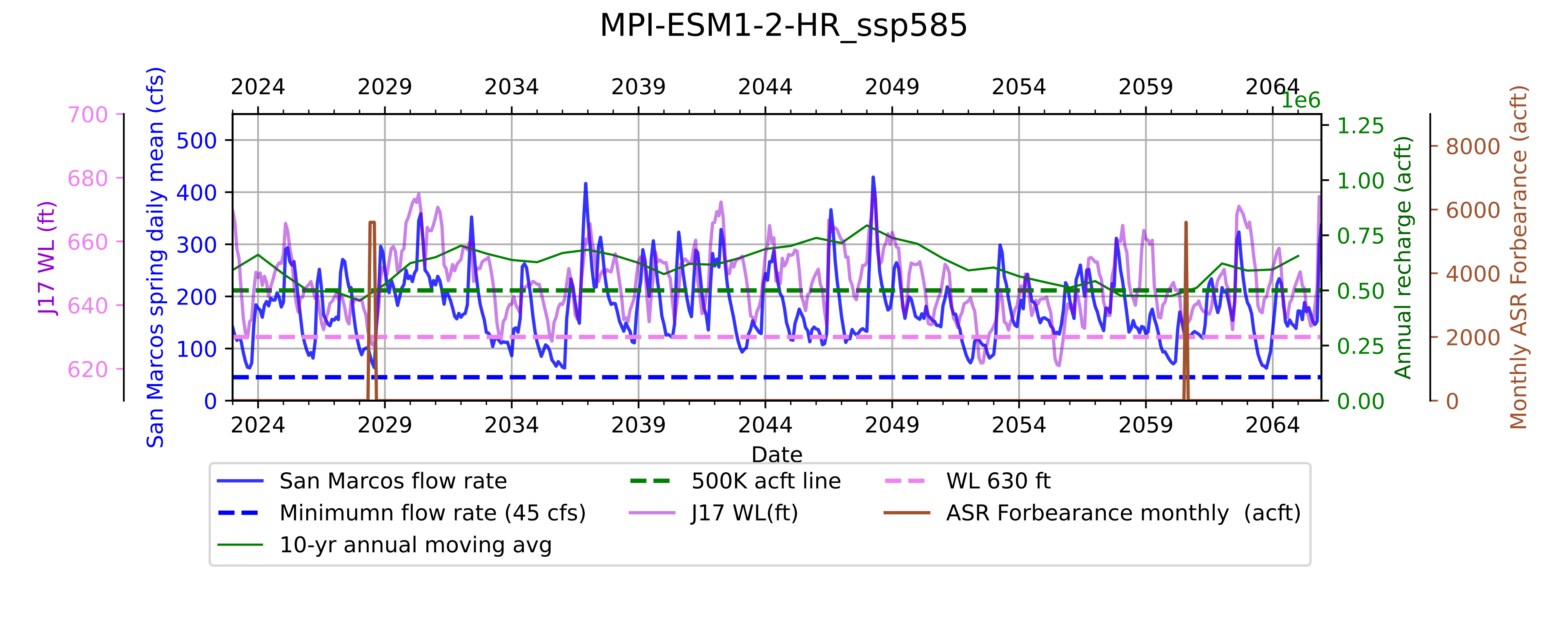
MPI-ESM1-2-HR_ssp245



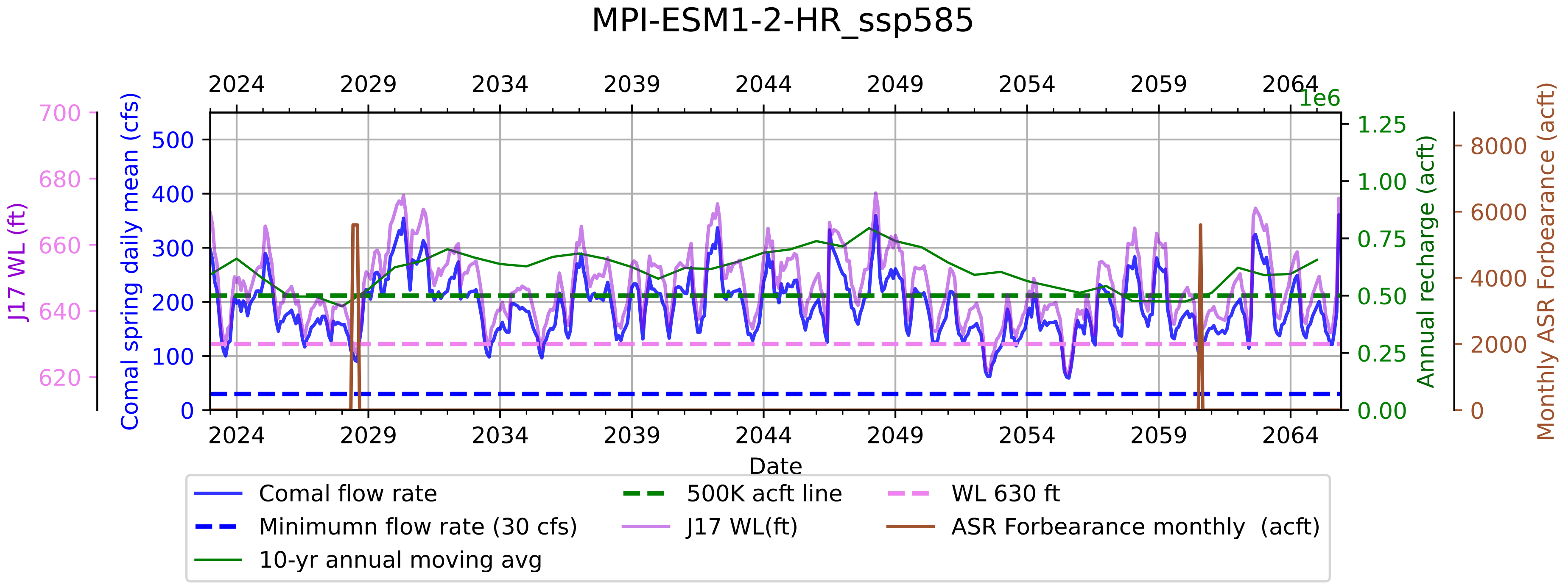

MPI-ESM1-2-HR_ssp585
Comal spring daily mean (cfs)
700
600
500
400
300
200
100
0
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Annual/monthly recharge (acft)
25000
50000
75000
100000
125000
150000
175000
Monthly pumping (acft)
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

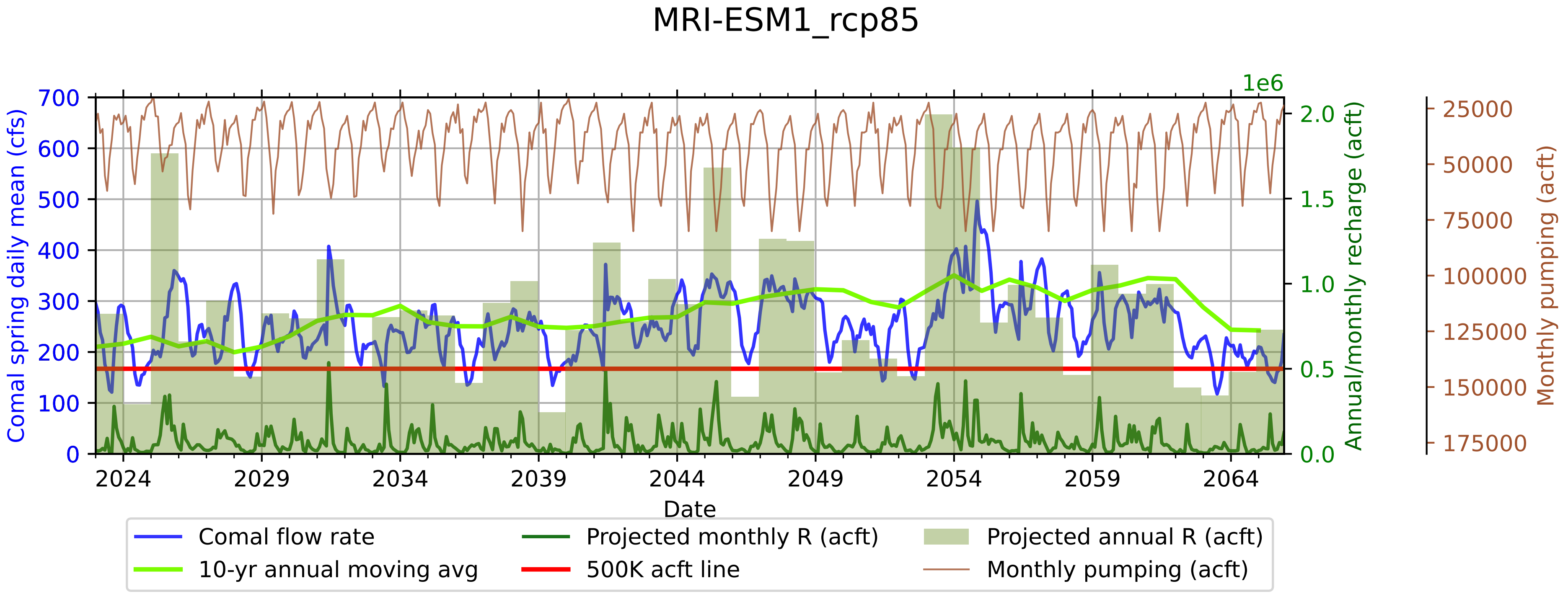


MPI-ESM1-2-HR_ssp585
San Marcos spring daily mean (cfs)
700
600
500
400
300
200
100
0
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Annual/monthly recharge (acft)
25000
50000
75000
100000
125000
150000
175000
Monthly pumping (acft)
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)

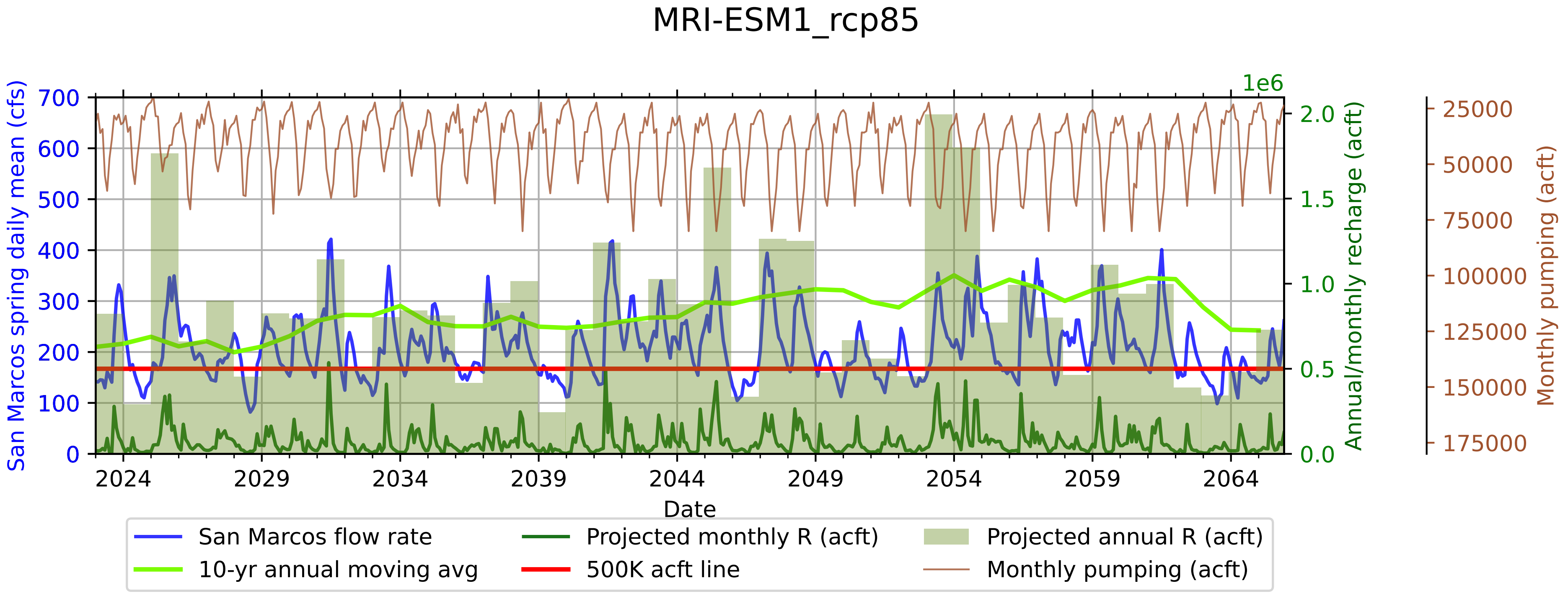


MPI-ESM1-2-HR_ssp585
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

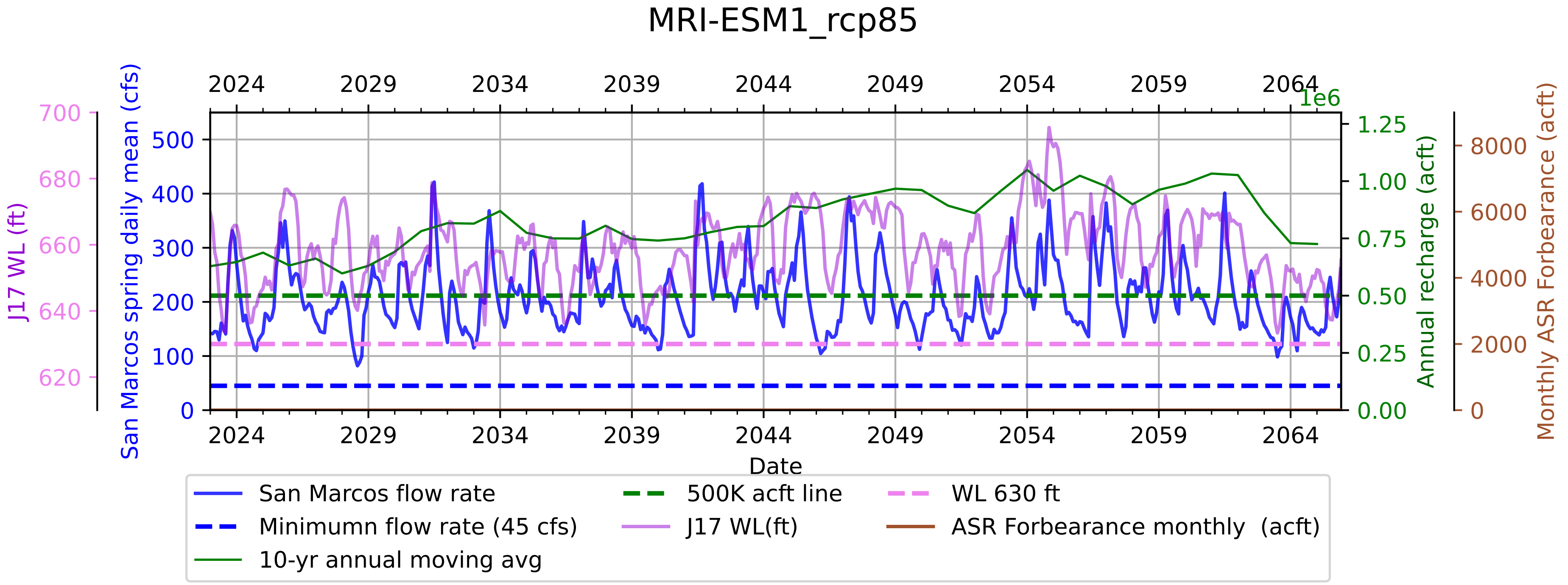

MPI-ESM1-2-HR_ssp585
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
1e6
Monthly ASR Forbearance (acft)
Date
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)



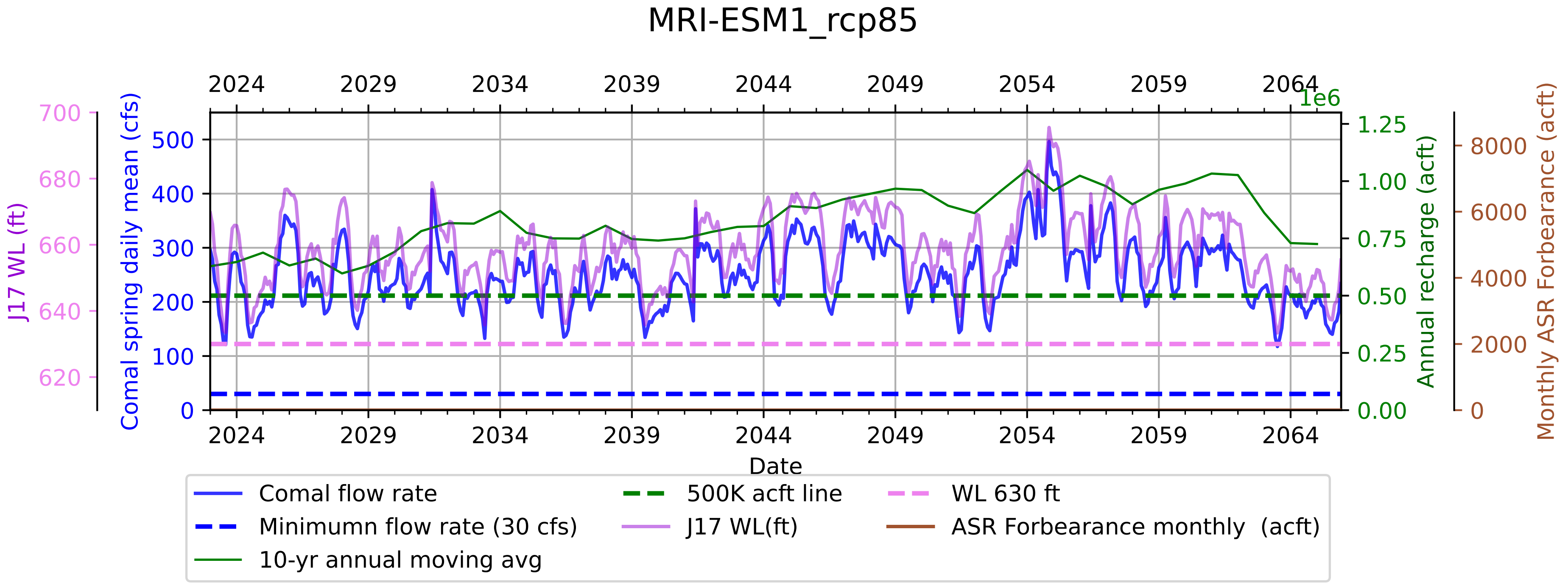
MRI-ESM1_rcp85
Comal spring daily mean (cfs)
700
600
500
400
300
200
100
0
1e6
2.0
1.5
1.0
0.5
0.0
Annual/monthly recharge (acft)
25000
50000
75000
100000
125000
150000
175000
Monthly pumping (acft)
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
Comal flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



MRI-ESM1_rcp85
San Marcos spring daily mean (cfs)
0
100
200
300
400
500
600
700
1e6
2.0
1.5
1.0
0.5
0.0
Annual/monthly recharge (acft)
25000
50000
75000
100000
125000
150000
175000
Monthly pumping (acft)
2024
2029
2034
2039
2044
2049
2054
2059
2064
Date
San Marcos flow rate
10-yr annual moving avg
Projected monthly R (acft)
500K acft line
Projected annual R (acft)
Monthly pumping (acft)



MRI-ESM1_rcp85
J17 WL (ft)
San Marcos spring daily mean (cfs)
Annual recharge (acft)
Monthly ASR Forbearance (acft)
1e6
Date
700
680
660
640
620
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
8000
6000
4000
2000
0
2024
2029
2034
2039
2044
2049
2054
2059
2064
San Marcos flow rate
Minimumn flow rate (45 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)


MRI-ESM1_rcp85
J17 WL (ft)
Comal spring daily mean (cfs)
Annual recharge (acft)
1e6
Monthly ASR Forbearance (acft)
Date
2024
2029
2034
2039
2044
2049
2054
2059
2064
Comal flow rate
Minimumn flow rate (30 cfs)
10-yr annual moving avg
500K acft line
J17 WL(ft)
WL 630 ft
ASR Forbearance monthly (acft)

Appendix C

SAMP Model Runs Inputs and Assumptions

To: EAHCP Committees

From: Nathan Pence, EAHCP Program Manager

Date: June 21, 2018

Subject: SAMP Model Runs Inputs and Assumptions

The purpose of this document is to detail the modeling inputs and assumptions included in the EAHCP Phase II MODFLOW model runs. As discussed in the Strategic Adaptive Management Process (SAMP) whitepaper (Pence – June 21, 2018; herein, whitepaper), several model runs will be conducted to examine predicted springflow provided by EAHCP springflow conservation measures as implemented through a repeat of the drought of record (DOR).

HDR was tasked with the original evaluation of springflow provided by springflow conservation measures through the DOR during the EARIP planning period (HDR 2011 - EAHCP Appendix K). The HDR report identified Comal springflow shortfalls during a repeat of the DOR. In 2017, the EAA completed an update and recalibration of the MODFLOW model of the San Antonio segment of the Edwards Aquifer (Liu et al., 2017). The updated model contains significant conceptual and structural updates along with increased amounts of recent hydrologic data used to train the model. This model has been examined by a model advisory committee, the original users of the HDR EARIP model, and the National Academy of Sciences.

In addition to an updated model, the EAHCP now has empirical data on the actual implementation of springflow conservation measures from 2013 - 2018 (namely, volume and geographical distribution of enrolled water in springflow protection programs – VISPO, ASR, RWCP). Also, EAA has updated usage and pumping data related to Federal exempt use, Domestic and Livestock exempt use and the new Limited Production Well exempt use. These data can be used to improve upon the assumptions made during the original HDR hydrologic simulations.

The updated MODFLOW model will be used to conduct three types of hydrologic simulations:

Baseline Runs: Model Runs 1. and 2. These model simulations will produce daily minimum springflows (1947-1958) and long-term average springflows (1947-2000) with the updated MODFLOW model using the model inputs from the HDR model runs. The purpose of these runs is to examine whether the springflow shortfalls identified during the HDR analysis still exists using the new model with the same model inputs.

SAMP Runs: actual **Model Runs 3. and 4.** These model simulations will produce daily minimum springflows (1947-1958) and long-term average springflows (1947-2000) with the updated MODFLOW model using the model inputs based on the first 5 years of EAHCP implementation. The purpose of these runs is to examine whether springflow shortfalls exist using the new MODFLOW model with actual implementation of EAHCP springflow protection measures as implemented.

SAMP Runs - Expanded Phase I CMs and/or Phase II CMs: **Model Run 5.** These model simulations will be conducted if springflow shortfalls still exist after analysis of SAMP Runs (Runs #3 and #4). The purpose of these runs would be to examine springflows under a different set of springflow conservation measures than currently exist in Phase I of the EACHP.

After model runs 1-5 are finalized and the specific set of additional Phase II conservation measures are determined (if any are needed), no additional modeling is anticipated until required for the rollover of the incidental take permit in 2028. This includes if the realized geographical distribution of enrollment in springflow conservation measure does not exactly match the assumptions presented in this document.

The remainder of this document details the pumping and flow protection conservation measure modeling inputs and assumptions behind each of the aforementioned MODFLOW model runs. For details regarding the construction of the HDR model or the EAA model, the reader is referred to HDR (2011) and Liu et al. (2017), respectively.

Model Runs 1 - Completed

This model run represents springflow for the period of 1947-1958 with the updated EAA model (Liu et al. 2017) using inputs from the original HDR analysis (HDR 2011). Specifically, the model run incorporates the full suite of springflow protection measures (VISPO, RWCP, ASR, STG 5) as implemented by HDR (2011). Results of this model run, in the format of estimated springflow at Comal and San Marcos springs, can be found in Appendix A. Additionally, these model runs have been presented to the Stakeholder, Implementing, and Science Committees as part of the ASR adaptive management process.

Model Run 2 – anticipated completion Fall 2018

This model run will estimate springflow from 1947-2000 and contains the same inputs as model run 1.

Model Runs 3 and 4 – anticipated completion Fall 2018 / Spring 2019

These model runs examine the same time periods as model runs 1 and 2 respectively, but use updated data gathered during implementation (2013-2018) of springflow protection measures. There are two overarching model assumptions that apply to model input for all conservation measures:

1. Forbearance measures are modeled at the county resolution, not at individual wells. The exception to this rule is for ASR forbearance at SAWS production wells during recovery (described below).

2. Uvalde County: based on the model representation of the Knippa Gap horizontal flow barrier (Liu et al. 2017), slightly more than half of the forbearance from conservation measures will be realized east of the Knippa Gap, as a majority of irrigated acreage occurs in the eastern half of Uvalde county.

Springflow Protection Assumptions for SAMP Model Runs 3 and 4:

VISPO

The VISPO program will be modeled using the 40,000 ac-ft/yr, enrollment set by the HCP (5.1.2.1). Currently, the program is fully enrolled. The modeled geographical distribution of enrolled water will be based on the geographical distribution of the current program (2018) and is shown in Table 1. The geographical distribution of water in the program is not expected to significantly change from 2018 through 2027. VISPO forbearance in any given year is simulated in the model when modeled J-17 is at or below 635 msl on October 1 of the previous year.

Table 1. SAMP model distribution of VISPO forbearance (reflective of 2013-2018 implementation).

County	Use	acft %	Total acft
Atascosa	Irrigation	0.87%	348.00
Bexar	Irrigation	6.00%	2,400.00
Hays	Irrigation	0.30%	120.00
Medina	Irrigation	27.95%	11,180.00
Uvalde	Irrigation	64.88%	25,952.00
		100.00%	40,000.00

<u>ASR</u>

Use of the SAWS ASR for springflow protection is divided into SAWS forbearance and injection activities and EAA forbearance activities (HCP 5.5.1).

SAWS ASR activities
The SAWS forbearance portion will be modeled by reducing pumping at 4 individual pump stations on the northeast side of the SAWS distribution system in an amount that on a monthly basis equals the amount of water available from the ASR. The SAWS forbearance and recovery of ASR water will be modeled following the same recovery schedule as used by the HDR (2011) simulations (Figure 1) and the ASR Interlocal Contract between the EAA and SAWS.

Since 2013, approximately 85,000 acft of water have been injected into the ASR on behalf of the EAHCP. The EAA anticipates filling the ASR to the 126,000 acft required (HCP 5.5.1) for recovery during a decadal DOR by 2021. HDR (2011) simulations assumed starting the DOR with 80,000 acft in storage, requiring injection over the course of the DOR (Figure 1). Model runs 3 and 4 assume beginning the DOR with 126,000 acft and no injection into ASR during the drought.

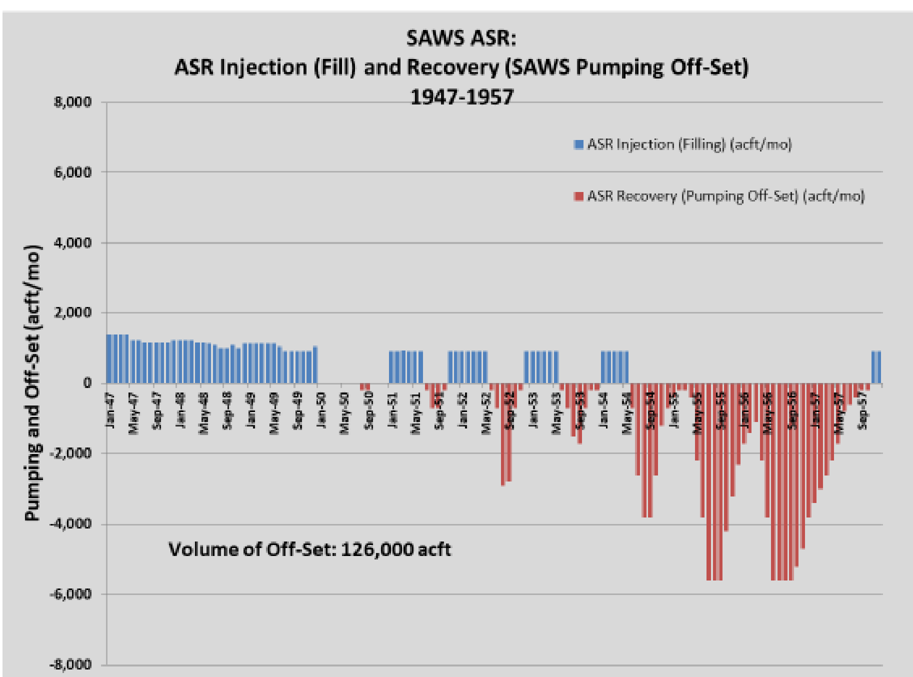


Figure 1. SAWS ASR recovery schedule during repeat of Drought of Record (taken from HDR 2011). The injection (blue bars) will not be modeled during SAMP modeling, as the ASR is full;

EAA ASR activities

The EAA forbearance portion is comprised of 50,000 acft/yr of forborne water. In 2027, 10,263.5 acft/yr will reside in long-term irrigation leases. Therefore, 50,000 ac-ft/yr included in the MODFLOW simulations is comprised of leased water (10,263.50 acft/yr) and anticipated irrigation and municipal/industrial forbearance agreements (Table 2). The geographical distribution of assumed irrigation forbearance agreements is based off the VISPO program, and the distribution of municipal/industrial leases is based on 2018 1-yr ASR leases. EAA forbearance activities are triggered in the model when the 10-year rolling recharge average is less than 500,000 acft/yr. Annual recharge estimates from the USGS are provided during the spring of the following year; forbearance activities would be initiated at the beginning of the next calendar year.

Table 2. SAMP model distribution of ASR forbearance.

Long-term leases: 10,263 acft as of 2027; actual enrollment

County	Use	acft %	Total acft
Atascosa	Irrigation	3.65%	375.00
Bexar	Irrigation	38.58%	3,959.93
Medina	Irrigation	41.88%	4,298.69
Uvalde	Irrigation	15.88%	1,629.88
		100.00%	10,263.50

Irrigation Forbearance: 29,736.50 acft; based on VISPO geographical distribution
(assumed no Hays, Comal or Atascosa County enrollment)

County	Use	acft %	Total acft
Atascosa	Irrigation	0.0%	0.0
Bexar	Irrigation	6.00%	1,784.19
Hays	Irrigation	0.0%	0.0
Medina	Irrigation	28.53%	8,485.31
Uvalde	Irrigation	65.47%	19,467.00
		100.00%	29,736.50

Municipal/Industrial Forbearance: 10,000 acft – geographical distribution based on 2018 1 yr ASR leases

County	Use	acft %	Total acft
Bexar	Muni/Industrial	51.59%	5175.69
Comal	Muni/Industrial	28.00%	2784.89
Hays	Muni/Industrial	0.01%	1.4
Medina	Muni/Industrial	4.40%	439.57
Uvalde	Muni/Industrial	16.00%	1598.45
		100.00%	10,000.00

RWCP

The RWCP program will be modeled using 10,000 ac-ft/yr enrollment set by the HCP (5.1.3). Currently, the program is fully enrolled. The modeled geographical distribution of enrolled water will be based on the geographical distribution of the current program. Table 3 displays the county level distribution of enrolled water.

Table 3. SAMP model distribution of RWCP forbearance.

County	Use	acft %	Total acft
Bexar	Irrigation	99.43%	9,943.00
Uvalde	Irrigation	0.57%	57.00
		100.00%	10,000.00

STAGE V reductions

Stage V critical period requires a 44% reduction in permitted use and applies to both the San Antonio and Uvalde pools. The critical period reductions are implemented in the model based on triggers outlined in the HCP and EAA rules.

Pumping Assumptions:

The SAMP model runs will simulate total annual pumping of 592,454 ac-ft for each year of the simulation. Annual pumping from the HDR 2011 modeling effort was 593,240 ac-ft. The distribution and timing of pumped water from all model runs will be the same as HDR runs. Pumping types in the updated model include the 572,000 ac-ft/yr permitted by the EAA Act along with Federal Exempt pumping, Limited Production Wells, and Domestic and Livestock pumping. A summary and calculations for the latter three pumping types are shown below.

Total Pumping:

- HDR EARIP Modeling = 593,240 acft
  573,037 (permitted) + 6,907 (federal) + 13,296 (domestic/livestock)
- SAMP Modeling = 592,454 acft
  572,000 (permitted) + 6,000 (federal) + 54 (LPW) + 14,400 (domestic/livestock)

Federal Exempt Pumping

HDR Modeling: 6,907 ac-ft/yr
SAMP pumping: 6,000 ac-ft/yr

Year	JBSA ac-ft	Hays ac-ft	Uvalde ac-ft	Total Reported
2007	6,714	193	0	6,907
2008	6,714	193	0	6,907
2009	4,483	309	169	4,961
2010	4,678	236	214	5,128
2011	5,160	195	28	5,383
2012	5,046	220	60	5,326
2013	-	195	209	404
2014	5,089	228	0	5,317
2015	-	230	0	230
2016	-	236	0	236

2017	-	254	-	254

Limited Production Wells Pumping

New EAA program in 2014
SAMP pumping: 54 ac-ft/yr (average 2015-2017)

Year	Registered Wells	ac-ft
2014	57	9.859
2015	108	47.196
2016	124	61.958
2017	128	50.622

Domestic and Livestock Pumping

HDR Modeling: 13,296 ac-ft/yr
SAMP pumping: 14,400 ac-ft/yr

Year	ac-ft
2010	13,600
2011	13,600
2012	13,700
2013	13,700
2014	13,900
2015	13,900
2016	13,900
2017	14,000

References

Liu, Angang, N Troshanov, J Winterle, A Zhang, and S Eason, 2017. Updates to the MODFLOW Groundwater Model of the San Antonio Segment of the Edwards Aquifer. 78 p. Available at: https://www.edwardsaquifer.org/science-and-maps/research-and-scientific-reports/science-document-library

HDR, 2011. Evaluation of Water Management Programs and Alternatives for Springflow Protection of Endangered Species at Comal and San Marcos Springs. 157 p. Available at: http://www.eahcp.org/index.php/document_library_selected?c=11&c=11

Appendix A. Model Run 1 results.