Appendix D | **2024 USFWS Correspondence**

Appendix D1 | **EAHCP Notification of Conclusion of Condition M in Comal River**

EDWARDS AQUIFER
AUTHORITY

February 5, 2024

Ms. Karen Myers
Field Supervisor
U.S. Fish and Wildlife Service
1505 Ferguson Lane
Austin, Texas 78754

RE: Comal River - Conclusion of Condition M Implementation (Permit TE63663A-1)

Dear Ms. Myers:

This letter is to inform you that the Permittees of the Edwards Aquifer Habitat Conservation Program (EAHCP) Incidental Take Permit, Number (ITP) TE63663A-1, have concluded the Condition M restoration restrictions in the Comal spring system implemented on July 25, 2023.

On February 5, 2024, the U.S. Geological Survey (#08169000) flow gage in the Comal River in New Braunfels, TX recorded discharge above 130 cfs. Since then, spring discharge has continued to increase and stabilize above the 130 cfs trigger. Based on recent rainfall, the limitations on habitat mitigation and restoration measures activated by Condition M of the ITP have concluded and implementation of those restrictions will no longer be required.

As flow levels persist above the springflow trigger, EAHCP contractors will resume aquatic and riparian restoration activities as scheduled and continue to monitor springflow discharge.

Please let me know if you have any questions.

Sincerely,

Scott D. Storment
Program Manager
Edwards Aquifer Habitat Conservation Plan

Appendix D2 | **EAHCP Notification of Conclusion of Condition M in San Marcos River**

EDWARDS AQUIFER
AUTHORITY

February 5, 2024

Ms. Karen Myers
Field Supervisor
U.S. Fish and Wildlife Service
1505 Ferguson Lane
Austin, Texas 78754

RE: San Marcos River - Conclusion of Condition M Implementation (Permit TE63663A-1)

Dear Ms. Myers:

This letter is to inform you that the Permittees of the Edwards Aquifer Habitat Conservation Program (EAHCP) Incidental Take Permit, Number (ITP) TE63663A-1, have concluded the Condition M restoration restrictions in the San Marcos spring system implemented on June 3, 2022.

On February 5, 2024, the U.S. Geological Survey (#08170500) flow gage in the San Marcos River, San Marcos, TX, recorded a discharge above 120 cfs. Since then, spring discharge has continued to increase and stabilize above the 120 cfs trigger. Based on recent rainfall, the limitations on habitat mitigation and restoration measures activated by Condition M of the ITP have concluded and implementation of those restrictions will no longer be required.

As flow levels persist above the springflow trigger, EAHCP contractors will resume aquatic and riparian restoration activities as scheduled and continue to monitor springflow discharge.

Please let me know if you have any questions.

Sincerely,

Scott D. Storment
Program Manager
Edwards Aquifer Habitat Conservation Plan

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Appendix D3 | **EAHCP Notification of Implementation of Condition M Restrictions in Comal**

EDWARDS AQUIFER
AUTHORITY

May 28, 2024

Ms. Karen Myers
Field Supervisor
Austin Ecological Services Field Office
U.S. Fish and Wildlife Service
1505 Ferguson Lane
Austin, Texas 78754

RE: Comal River - Implementation of Condition M of Permit TE63663A-1

Dear Ms. Myers:

This letter is to inform you that the Permittees of the Edwards Aquifer Habitat Conservation Program (EAHCP) Incidental Take Permit, Number TE63663A-1 (ITP), have reduced and suspended aquatic and riparian restoration activities as required by Condition M of the ITP in the Comal River system.

On May 22, 2024, the USGS flow gauge #081690000 Comal River at New Braunfels, Texas recorded a discharge of less than 130 cfs. Since then, the flow continues to decline. Based on these low flow conditions, habitat mitigation and restoration activities have been reduced to limit the disturbance of the substrate, water quality, plants, animals and invertebrates.

In 2014, the USFWS approved a clarification to the terms of Condition M and authorized the continuance of specific activities that may be implemented during low flow conditions. These covered measures and USFWS-approved activities are attached as Exhibit 1. Measures missing from the clarification table, such as riparian restoration, etc., will assume the original interpretation of Condition M as stated in the ITP.

As low flows persist, biological and water quality monitoring activities will be conducted to determine habitat availability and impacts to the Covered Species. Aquatic and riparian restoration restrictions will continue until the Comal River flow increases and stabilizes above the 130 cfs low flow trigger.

Please let me know if you have any questions.

Sincerely,

Scott D. Storment
EAHCP Program Manager

EXHIBIT 1

Comal Conservation Measures	Interpretation	Specific activities that may continue at all flows
Management of river flow between old and new channels of the Comal River (Section 5.2.1)	The actual management of the flow that is split between the New Channel and the Old Channel is designed to minimize and mitigate the impacts of incidental take in reduced flow conditions.	Manipulation of gates in accordance with the City of New Braunfels flow-split system standard operating procedures to be in accordance with EAHCP Table 5.3.
Restoration and maintenance of native aquatic vegetation (Section 5.2.2)	Maintenance of native aquatic vegetation includes gardening to increase preferred fountain darter habitat during reduced flow conditions.	Gardening, such as removal of non-native vegetation, in previously restored areas such as in the Old Channel and Landa Lake. Extra precautions, such as minimizing the number of gardeners in water, working from downstream to upstream and not tilling the substrate to remove vegetation will be employed to reduce disturbance of sediment.
Management of public recreational use (Section 5.2.3)	Continuing management of public recreation areas assures minimal impact and disturbance from recreational users.	Printing and distribution of educational materials, signage, and workshops.
Removal of decaying vegetation and dissolved oxygen management (Section 5.2.4)	The removal of the vegetative mats and the implementation of a dissolved oxygen management program helps to maintain healthy, preferred fountain darter habitat during reduced flows.	Gardening, such as the removal of decaying vegetation by working from a flat-bottom boat or kayak when practical, minimizing the number of workers in the water and working upstream to downstream to limit increased disturbance, such as pushing floating vegetative mats downstream.
Management of harmful non-native animal species (Sections 5.2.5 and 5.2.9)	Low flow conditions reduce the area that non-native fish have, making it easier to spear or net them. Greater numbers will be removed from the system at a time when they are most likely to cause damage.	Spear and bow fishing of non-native animals.
Prohibition of hazardous material transport (Section 5.2.7)	Not conducted in the aquatic ecosystem.	No further detail needed.

Comal Conservation Measures	Interpretation	Specific activities that may continue at all flows
Live bait prohibition (Section 5.2.9)	Not conducted in the aquatic ecosystem.	No further detail needed.
Litter collection and floating vegetation management (Section 5.2.10)	The removal of litter and removal of floating vegetation management has a positive effect on the system by helping to maintain habitat with a very limited impact on the substrate.	Removal of floating vegetation and litter by working from a barge, flatbottom boat or kayak when practical, with a minimum number of workers in the water that limits increased disturbance, such as pushing floating vegetative mats downstream. All areas for maintenance will be represented in vegetation maps.
Management of golf course diversions and operations (Section 5.2.11)	Continued planning and management of the Golf Course assures minimal impact or disturbance of the aquatic ecosystem.	No further detail needed.
Management of household hazardous wastes (Section 5.7.5)	Management of household, hazardous wastes is a terrestrial activity.	No further detail needed.

Appendix D4 | **EAHCP Notification of Implementation of Condition M Restrictions in San Marcos**

EDWARDS AQUIFER
AUTHORITY

June 27, 2024

Ms. Karen Myers
Field Supervisor
Austin Ecological Services Field Office
U.S. Fish and Wildlife Service
1505 Ferguson Lane
Austin, Texas 78754

RE: San Marcos River - Implementation of Condition M of Permit TE63663A-1

Dear Ms. Myers:

This letter is to inform you that the Permittees of the Edwards Aquifer Habitat Conservation Program (EAHCP) Incidental Take Permit, Number TE63663A-1 (ITP), have reduced and suspended habitat and riparian restoration activities as required by Condition M of the ITP in the San Marcos River system.

On June 20, 2024, the USGS flow gauge #08170500 San Marcos River at San Marcos, Texas (Sewell Park) recorded a discharge of less than 120 cfs. Since then, the flow continues to fluctuate between a range of 120 cfs and below. Based on these low flow conditions, habitat mitigation and restoration activities have been reduced to limit the disturbance of the substrate, water quality, plants, animals, and invertebrates.

In 2014, the USFWS approved a clarification to the terms of Condition M and authorized the continuance of specific activities that may be implemented during low flow conditions. These covered measures and USFWS-approved activities are attached as Exhibit 1. Measures missing from the clarification table, such as riparian restoration, etc., will assume the original interpretation of Condition M as stated in the ITP.

As low flows persist, biological and water quality monitoring activities will be conducted to determine habitat availability and impacts to the Covered Species. Habitat and riparian restoration restrictions will continue until the San Marcos River flow increases and stabilizes above the 120 cfs low flow trigger.

Please let me know if you have any questions.

Sincerely,

Scott D. Storment
EAHCP Plan Program Manager

EXHIBIT 1

San Marcos Conservation Measures	Interpretation	Specific activities that may continue at all flows
Enhancement and restoration of Texas WildRice (Sections 5.3.1 and 5.4.1)	Suspending gardening and maintenance of restored areas will allow non-native plants to regrow, negating the work already done.	Gardening, such as the removal of non-native plant regrowth, in previously restored areas, Sewell and City Park, in a manner that limits increased disturbance.
Management of public recreational use (Sections 5.3.2 and 5.4.2)	Continuing management of public recreation areas assures minimal impact and disturbance from recreational users.	University students are trained to assist the public, increase the awareness of the issues.
Management of aquatic vegetation and litter below Sewell Park (Section 5.3.3 and 5.4.3)	The removal of litter and removal of floating vegetation management has a positive effect on the system by helping to maintain habitat with a very limited impact on the substrate.	Removal of floating vegetation and litter by working from a barge, flatbottom boat or kayak when practical, with a minimum number of workers in the water to limit increased disturbance, such as pushing floating vegetative mats downstream. All areas for maintenance will be represented on vegetation maps.
Prohibition of hazardous materials transport (Section 5.3.4)	Management of household, hazardous wastes is a terrestrial activity	No further detail needed.
Reduction of non-native species introduction (Section 5.3.5 and 5.4.11)	Not conducted in the aquatic ecosystem.	No further detail needed.
Management of non-native plant species (Sections 5.3.8 and 5.4.12)	Removal of non-native plants is more efficient during low flows. Suspending this activity will allow non-native plants to regrow, negating work already done.	Gardening, such as removing one-meter sections adjacent to restored Texas Wild Rice stands from Spring Lake to Ramon Lucio park. All areas for maintenance will be represented on vegetation maps.
Management of harmful non-native and predator species (Sections 5.3.9 and 5.4.13)	Low flow conditions reduce the area that non-native fish have, making it easier to spear or net them. Greater numbers will be removed from the system at a time when they are most likely to cause damage.	Bow fishing of non-native animals from shore or flatbottom boats. Spear fishing will be done in the water.
Research programs in Spring Lake (Section 5.4.8)	Continuing review and education of researchers to ensure there is no impact on the Covered Species.	Research programs will not include boating related activities.

San Marcos Conservation Measures	Interpretation	Specific activities that may continue at all flows
Management of golf course and grounds (Section 5.4.9)	Continued planning and management of the Golf Course assures minimal impact or disturbance of the aquatic ecosystem.	No further detail needed.
State Scientific Areas (Section 5.6.1)	Continuing management of public recreation assures minimal impact or disturbance of the aquatic system at reduced flows.	Maintenance and installation of signage and barriers, by standing from a boat.
Implementation of septic system registration and permitting program (Section 5.7.3)	Not conducted in the aquatic ecosystem.	No further detail needed.
Management of potentially contaminated runoff (Section 5.7.4)	Construction of two sedimentation ponds to help reduce contaminated materials will not disturb covered species habitat.	No further detail needed.
Management of household hazardous wastes (Section 5.7.5)	Management of household, hazardous wastes is a terrestrial activity.	No further detail needed.

Appendix D5 | **EAHCP Notification of 2025 VISPO Forbearance Payments**

EDWARDS AQUIFER
AUTHORITY

October 28, 2024

Ms. Karen Myers
Field Supervisor
U.S. Fish and Wildlife Service
1505 Ferguson Ln.
Austin, TX 78754

RE: Informational Memorandum regarding the Edwards Aquifer Habitat Conservation Plan and Voluntary Irrigation Suspension Program Option Forbearance Agreements for 2025.

Dear Ms. Myers:

This letter is submitted on behalf of the Edwards Aquifer Authority (EAA), the San Antonio Water System (SAWS), the City of New Braunfels (CONB), the City of San Marcos (COSM), and Texas State University (collectively the Permittees of Incidental Take Permit (ITP) (TE63663A-1)) to inform the U.S. Fish and Wildlife Service on the implementation of the Voluntary Irrigation Suspension Program Option (VISPO) springflow protection measure as discussed in Section 5.5.1 of the Edwards Aquifer Habitat Conservation Plan (EAHCP).

The purpose of VISPO is to allow Edwards Aquifer Authority groundwater permit holders participating in the program to be financially compensated to suspend withdrawal of enrolled water during low springflow conditions. If the J-17 index well in San Antonio is at or below 635 feet above mean sea level (ft-msl) on October 1, VISPO participants are required to suspend use of their enrolled water for the entire calendar year that follows, beginning January 1.

On October 1, 2024, the J-17 index well was below 635 ft-msl. Therefore, beginning on January 1, 2025, VISPO participants are required to suspend withdrawals of enrolled water for the amounts agreed upon in their individual agreements.

If aquifer conditions improve dramatically, and J-17 is above 660 ft-msl on January 1, 2025, VISPO participants will have the option to not forbear the enrolled water. However, participants will forgo any payments for forbearance and the enrolled water will be subject to any Critical Period reductions in effect for 2025.

Kind regards,

Scott D. Storment
Program Manager
Edwards Aquifer Habitat Conservation Plan

EAHCP
EDWARDS AQUIFER
HABITAT CONSERVATION PLAN

Appendix D6 | **USFWS 5-Year Species Status Review of the Comal Springs Riffle Beetle**

Comal Springs Riffle Beetle
(*Heterelmis comalensis*)
5-Year Status Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
Austin, Texas
May 20, 2024

5-YEAR REVIEW

Species reviewed: Comal Springs riffle beetle (*Heterelmis comalensis*)

TABLE OF CONTENTS

5-YEAR REVIEW
Comal Springs riffle beetle (*Heterelmis comalensis*)

1.0 GENERAL INFORMATION

1.1 Reviewers:

Lead Regional or Headquarters Office:
Vanessa Burge, Recovery Biologist, Southwest Regional Office, Albuquerque, New Mexico, vanessa_burge@fws.gov

Lead Field Office:
Amelia Hunter, Fish and Wildlife Biologist, Austin Ecological Services Field Office, Austin, Texas, amelia_hunter@fws.gov

Cooperating Field Office(s):
Not Applicable

Cooperating Regional Office(s):
Not Applicable

1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service or USFWS) is required by section 4(c)(2) of the Endangered Species ESA (ESA) to conduct a status review of each listed species once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing as endangered or threatened is based on the species' status considering the five threat factors described in section 4(a)(1) of the ESA. These same five factors are considered in any subsequent reclassification or delisting decisions. In the 5-year review, we consider the best available scientific and commercial data on the species and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process including public review and comment.

1.3 Methodology used to complete the review:

The Service conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.12) as required by section 4(c)(2)(A) of the ESA (16 U.S.C. 1531 et seq.). The Service provides notice of status reviews via the Federal Register and requests new information on the status of the species (e.g., life history, habitat conditions, and threats). Data for this status review were solicited from interested parties through a Federal Register notice announcing this review on May 5, 2021 (86 FR 23976). The Austin

Ecological Services Field Office conducted this review and considered both new and previously existing information from federal and state agencies, municipal and county governments, non-governmental organizations, academia, and the public. The primary sources of information used in this analysis was the final rule listing the Comal Springs riffle beetle as endangered (62 FR 66295), revised critical habitat ruling for the Comal Springs riffle beetle (78 FR 63100), research published in scientific journals, and unpublished reports and data.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

86 FR 23976 May 5, 2021

1.4.2 Listing history:

Original Listing
FR notice: 62 FR 66295
Date listed: December 18, 1997
Entity listed: Comal Springs riffle beetle (*Heterelmis comalensis*)
Classification: Endangered

Revised Listing, if applicable
FR notice: Not Applicable
Date listed: Not Applicable
Entity listed: Not Applicable
Classification: Not Applicable

1.4.3 Associated Rulemakings:

The original designation of critical habitat, contained in the final rule, was published on July 17, 2007 (72 FR 39248). Critical habitat for Comal Springs riffle beetle was revised on November 22, 2013, in areas of occupied, spring-related aquatic habitat with designations for surface critical habitat but without additional subsurface designations (78 FR 63100). Springs, associated streams, and underground spaces immediately inside of or adjacent to springs, seeps, and upwellings are the primary components of the physical or biological features essential to the conservation of this species (50 CFR 17.95; 78 FR 63123).

1.4.4 Review History:

Not Applicable

1.4.5 Species' Recovery Priority Number at start of 5-year review:

2C

1.4.6 Recovery Plan or Outline

Name of plan or outline: Not Applicable
Date issued: Not Applicable
Dates of previous plans/amendment or outline, if applicable: Not Applicable

2.0 REVIEW ANALYSIS

Section 4 of the ESA (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species meets the definition of “endangered species” or “threatened species.” The ESA defines an “endangered species” as a species that is “in danger of extinction throughout all or a significant portion of its range,” and a “threatened species” as a species that is “likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” The ESA requires that we determine whether a species meets the definition of "endangered species" or "threatened species" due to any of the five factors described below.

Section 4(a) of the Act describes five factors that may lead to endangered or threatened status for a species. These include: A) the present or threatened destruction, modification, or curtailment of its habitat or range; B) overutilization for commercial, recreational, scientific, or educational purposes; C) disease or predation; D) the inadequacy of existing regulatory mechanisms; or E) other natural or manmade factors affecting its continued existence.

The identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an “endangered species” or a “threatened species.” In assessing whether a species meets either definition, we must evaluate all identified threats by considering the expected response of the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species—such as any existing regulatory mechanisms or conservation efforts. The Service recommends whether the species meets the definition of an “endangered species” or a “threatened species” only after conducting this cumulative analysis and describing the expected effect on the species now and in the foreseeable future.

2.1 Distinct Population Segment (DPS) policy (1996):

This is an invertebrate and DPS policy is not applicable.

2.2 Updated Information and Current Species Status

2.2.1 Biology and Habitat

2.2.1.1 New information on the species’ biology and life history:

Background

On the whole, riffle beetles are most associated with flowing water that has shallow riffles or rapids (Brown 1987, p. 253). The Comal Springs riffle beetle was first collected in 1976 at Comal Springs in Comal County, Texas and later discovered at San Marcos Springs in Hays County, Texas (Bosse et al. 1988, pp. 201-202; Barr 1993, pp. 31, 44; Gibson et al. 2008, p. 79). This species currently does not have a final recovery plan and this is the species' first 5-year review since listing in 1997.

Biology

Adult Comal Springs riffle beetles, which were first described in 1988, exhibit a reddish-brown coloration, possess eyes, and vary in length from 1.7-2.48 millimeters (0.07-0.09 inch) (Bosse et al. 1988, pp. 199, 202; Worsham and Julius 2017, p. 28). They respire through a plastron, facilitated by small, hydrophilic hairs that diffuse oxygen from the water into the body (Bosse et al. 1988, p. 199; Yee and Kehl 2015, pp. 1011, 1030). The hind wings of Comal Springs riffle beetles are short and non-functional, a subterranean characteristic that renders this species incapable of flight (Bosse et al. 1988, p. 201; Bowles et al. 2003, p. 379). Unlike other animals adapted to subterranean environments, Comal Springs riffle beetles do not possess additional features such as reduced or lack of eyes and pigmentation (Cooke et al. 2015, p. 117).

The larvae of Comal Springs riffle beetles are characterized by their elongated bodies, retractable heads, feature dorsal spines and a more flattened head capsule shape. These aquatic larvae develop anal gills used to retrieve oxygen from water (Brown 1987, p. 261). The pupae of Comal Springs riffle beetles are pale in color and possess setae that facilitate oxygen intake into the body. It is unknown whether the hydrophobic setae play a role in facilitating respiration underwater, possibly similar to the plastron observed in adult beetles (Huston and Gibson 2015, pp. 522-523).

Comal Springs riffle beetles are detritivores, feeding on organic matter sourced from terrestrial coarse and particulate materials scraped off substrates of microbial origin, including fungi and bacteria, as well as periphyton. This feeding behavior remains consistent irrespective of the canopy cover (Brown 1987, p. 262; Nowlin et al. 2017, pp. 16-18, 21, 27). A co-occurring listed species, the Comal Springs dryopid beetle (*Stygoparnus comalensis*), derives most of its food from the same organic matter sources but has a niche overlap of less than or equal to 1 percent with the riffle beetle at Comal Springs (Nair et al. 2021, p. 244).

Life History

Surveys of Comal Springs riffle beetles indicate they have asynchronous generations, likely due to the consistent water quality at occupied springs (Bowles et al. 2003, p. 376; BIO-WEST, Inc. 2006, p. 39). Other elmid beetles with stable environmental conditions can affect emergence timings and oviposition based on changes in water velocity or temperature and food availability (Passos et al. 2003, p. 34). There are no known indicators or mechanisms for emergence of the Comal Springs riffle beetle.

Female adult Comal Springs riffle beetles reproduce multiple times annually with up to 121 larvae produced in their lifetime (Kosnicki 2022, p. 2). In an egg deposition study, treatments with biofilm poly-cotton cloth as the substrate contributed to the most eggs hatching into viable larvae, suggesting the biofilms produced on the cotton cloth may be an important nutritional requirement for egg development (Worsham and Julius 2017, p. 12). Additionally, hatching success depends on the nutritional quality females received in captivity (Worsham and Julius 2017, p. 14).

Eggs have translucent shells facilitating damage-free observation of development (Worsham and Julius 2017, p. 11). Egg development and incubation occur for 21-25 days until hatching, which is longer than other riffle beetle species (e.g., 5-15 days) (Brown 1987, p. 254; Worsham and Julius 2017, p. 16). There is no evidence of diapause (i.e., period when development is delayed during unfavorable environmental conditions) during the incubation period either in captivity or in the wild (Bowles et al. 2003, p. 37; Worsham and Julius 2018, p. 3). Egg development starts with globular bodies like early cells of a zygote (i.e., 3 days), to more cell division and smaller cells developing (i.e., 7 days), to tissue differentiation with an embryo visible and budding appendage (i.e., 14-18 days), to a full developed larvae observable inside the egg with a faint red eye (i.e., 21 days) and hatching from the egg after 25 days (Worsham and Julius 2017, p. 15).

Larvae undergo six molts for a total of seven instars, reaching the final instar at 12 weeks (Cooke 2012, p. 28; Worsham and Julius 2017, p. 17). Similar to the adults, Comal Springs riffle beetle larvae feed on allochthonous material and acquire nutrients from associated microbial communities, particularly bacteria (Nair et al. 2021, p. 245). In captivity, larvae have been observed to persist in the final instar phase for over four months before pupating, possibly to assimilate nutrients necessary for the pupation process, due to inadequate habitat conditions, or because of food quality issues (Worsham and Julius 2017, pp. 17, 24). Notably, temperature variations within the range of 19-25 degrees Celsius (°C) (66-77 degrees Fahrenheit [°F]) were not found to significantly affect larval survival (Worsham and Julius 2017, p. 20).

The Comal Springs riffle beetle exhibits an extended period of larval development, leading to the emergence of delicate pupae, thus highlighting the complexity of its metamorphic process. The process of eclosion (i.e., hatching), during which larvae develop into pupae, takes approximately one month (Worsham and Julius 2017, p. 24). However, a more recent study provides detailed insights into the larval development, indicating that pupation occurs 38 weeks (8.8 months) post-hatching, with more than half of that duration spent in the 7th instar (Worsham and Julius 2018, p. 5).

Pupae for this species are capable of eclosing both underwater and right below the waterline possibly due to trapped air in their pupal case (Cooke 2012, p. 38; Huston and Gibson 2015, p. 523). Unfortunately, they are susceptible to damage, causing them to lose their hydrophobic qualities (Huston and Gibson 2015, p. 522). Following eclosion, adult individuals are initially light yellow in color (i.e., teneral) and gradually darken to an orange-brown, typical of mature adults. During this early stage of adulthood, the internal abdominal structure for determining sex is challenging to discern.

Adults in captivity have been reported to live up to a year with an average generation time of two years, although further research is needed (Bowles et al. 2003, p. 376; Worsham and Julius 2017, p. 24). The gut microbiome of captive adults, which is influenced by various factors, including a different and more diverse bacterial community than that of their wild counterparts, may be attributed to human contact, varying sources of water with differing geochemical concentrations within the aquifer, or locations within the aquifer between the two source counties. These factors could potentially alter the microbial community. Additionally, biofilm shedding from well water pipes at captive facilities may play a role (Mays et al. 2021, pp. 3, 9).

2.2.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, birth rate, seed set, germination rate, age at mortality, mortality rate, etc.), or demographic trends:

Little is known about limiting factors that may impact the abundance and distribution of the Comal Springs riffle beetle. Current abundance estimates only include samples collected at the surface.

Abundance of Comal Springs riffle beetles did not correlate significantly with water depth, current velocity, and distance downstream from the primary spring outlets (Bowles et al. 2003, pp. 370-371). Typical water depth in occupied habitat is 2-10 centimeters (cm) (1-4 inches (in)), but the beetle has been found in slightly deeper areas within the spring runs and around the spring upwellings at the impoundments (Bosse et al. 1988, p. 202; BIO-WEST, Inc. 2007, p. 23). A mark-recapture study retrieved < 1 percent of the 100 beetles marked, suggesting the population in the sampling area (western shoreline of Landa Lake) is large (Huston et al. 2015, p. 797).

Larval and adult Comal Springs riffle beetle populations at Comal Springs may reach their greatest densities (i.e., about five per square meter) in late fall through winter, but all life stages can be found throughout the year, suggesting multiple broods in a season with overlapping generations (Bowles et al. 2003, p. 396). Biomonitoring of all benthic macroinvertebrates in the Comal Springs system occurs biannually, during spring and fall, and was initially established in 2000 using driftnets. Targeted sampling of spring orifices, employing poly-cotton cloth traps, commenced in 2003 (BIO-WEST, Inc. 2003, pp. 37-41; BIO-WEST, Inc. 2004, p. 38). This particular species has been consistently collected within the Comal Springs system since 2003 (BIO-WEST, Inc. 2007, p. 39).

Notably, larvae of this species are captured in lower numbers during biomonitoring using the poly-cotton cloth method, suggesting potential differences in habitat preference or a sampling bias where the biofilms produced on the cloth are not preferred by this life stage (BIO-WEST, Inc. 2005, p. 65). It is important to consider these nuances in sampling methods, especially when interpreting biomonitoring data for different life stages. Additionally, there are no population estimates available for this species, and caution is advised against utilizing the numbers of beetles retrieved with this cloth method to estimate population trends due to the associated high error rate and large natural variability of the Comal Springs population (Huston et al. 2015, p. 796-797; EARIP HCP 2020, p. 4-108–4-109).

San Marcos Springs, another ecosystem where the Comal Springs riffle beetle is present with an established population, lacks comprehensive monitoring data for its springflow and is not included in the Edwards Aquifer Recovery Implementation Program (EARIP) Habitat Conservation Plan (HCP). Unfortunately, the absence of such data makes it challenging to determine the current status of the habitat. The uncertainty surrounding the springflow data for San Marcos Springs emphasizes the need for further investigation to assess and safeguard the habitat of the Comal Springs riffle beetle in this particular ecosystem.

2.2.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Although the Comal Springs riffle beetle is a genetically distinct species, the species is most closely related to but divergent from *H. glabra*; a species capable of flight associated with rivers and streams (Gonzales 2008, pp. 24-25). Bosse et al. (1988, p. 202) speculated that the Comal Springs riffle beetle likely evolved from an isolated population of *H. glabra*, which was substantiated by Gonzales (2008, p. 38).

Three populations of the Comal Springs riffle beetle had high genetic variation: two at Comal Springs (Spring Island and western shoreline of Landa Lake) and San Marcos Springs (Gonzales 2008, p. 32). This isolation is due to the lack of recent gene flow, but historically they had a common ancestral population (Gonzales 2008, p. 32).

Recent genetics suggests an even greater degree of isolation among populations (W. Coleman, unpublished data). The spring runs and backwater spring populations have dried up during drought periods and genetic bottlenecks were apparent (Gonzales 2008, p. 34). Dye tracing studies show a different water source for each of the three high-variance populations and informs the experienced bottlenecks during extensive drought periods (LBG-Guyton and Associates et al. 2004, pp. B-24, B-30; Johnson and Schindel 2008, pp. 12, 49, 59; Musgrove and Crow 2012, pp. 80, 86-87).

2.2.1.4 Taxonomic classification or changes in nomenclature:

Elmidae (Insecta: Coleoptera) is a family of true aquatic beetles distributed worldwide except for Antarctica with approximately 146 genera (Yee and Kehl 2015, p. 1030). There are 35 riffle beetle species in Texas, with four species in the genus *Heterelmis* (Nair et al. 2019, p. 1076; Barr 2021, p. 93).

2.2.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, pollinator availability, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Comal Springs riffle beetle are an epigean (i.e., surface-dwelling), groundwater obligate invertebrate known from two major spring systems: Comal Springs at the spring outlets and Landa Lake (Comal County, Texas) and San Marcos Springs at a few headwater springs of Spring Lake (Hays County, Texas) (Bosse et al. 1988, entire; Barr 1993, pp. 31, 44; Gibson et al. 2008, p. 79).

Due to their flightless nature, these beetles have low dispersal abilities, limiting them to crawling or drifting downstream to habitats with adequate food resources and within their preferred physicochemical range. Their highest abundance is within 20 cm (8 in) from a spring outlet, and they are absent at a 1-meter (m) (3 feet (ft)) distance when sampling the surface with cotton cloth traps (Cooke et al. 2015, pp. 114, 117-118; Huston et al. 2015, p. 797; Worsham and Julius 2017, p. 6). Specific springflow requirements and the extent of subterranean habitat usage by this species remain unknown; therefore, habitat management relies on maintaining historical conditions within the natural habitat for the species (LBG-Guyton and Associates et al. 2004, pp. C-4–C-5).

Comal Springs riffle beetle are also found in deeper habitats where diffuse springflows are present (BIO-WEST, Inc. 2005, p. 51; 2006, p. 39). Within these more lentic habitats, the beetles exhibit higher movement rates compared to a site at Comal Spring Run 3, suggesting their ability to seek more suitable microhabitat conditions despite their inability to disperse via flight (BIO-WEST, Inc. 2006, p. 39).

Previously, it was believed that the existence of this species at Comal Spring Run 4 was unlikely due to the lentic conditions and the dominance of a silt substrate (Bowles et al., 2003, p. 376). No specimens were identified in multiple surveys until 2020, when a few were collected by Texas State University (Nowlin and Worsham, 2015, p. 12; Nowlin, 2022, pers. comm.). Subsequent surveys of Comal Spring Run 4 did not reveal any further instances of this species, indicating that the finding in 2020 may be a one-time occurrence (Gibson, unpublished data).

2.2.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

Comal Springs riffle beetles inhabit gravel and cobble-dominated substrates with aquatic vegetation and submerged wood present (Brown 1972, p. 57; Bowles et al. 2003, p. 372). They are best captured within or around spring orifices, even at shallow water depths (Bowles et al. 2003, pp. 367, 373; Gibson et al. 2008, p. 77; Cooke et al. 2015, p. 117). Comal Springs riffle beetles, being ectothermic, exhibit a stenothermal adaption, preferring temperatures between 22.5-25.5°Celsisu (°C) (72.5-78°Fahrenheit (°F)) (Huey and Kingslover 1989, p. 131; Nair et al. 2023, pp. 2, 6). This preference restricts them primarily to these spring outlets because of a narrow tolerance to short-term temperature fluctuations (Nair et al. 2023, p. 6). In addition to their temperature preferences, these beetles are observed to avoid low concentrations of carbon dioxide and prefer dark spaces (Cooke et al. 2015, p. 115).

Continuous groundwater flows in San Marcos Springs result in nearly constant temperatures (2021 average: 22°C [72°F]) (Musgrove and Crow 2012, p. 47; Edwards Aquifer Authority 2022a, pp. 15–16). The flowing spring waters at San Marcos Springs at Spring Lake are clear with varying levels of dissolved oxygen, dependent on amount and source of discharge (less than 40 to 63 percent saturated, 2-7 milligram per liter [mg/L]) and few detections contaminants, such as of personal care products and pharmaceuticals (Tupa and Davis 1976, p. 182; Groeger et al. 1997, pp. 285-286; Nowlin and Schwartz 2012, pp. 65-67; EAA 2015, pp. 58-59). San Marcos Springs receives primarily regional recharge, but can be influenced by minor amounts of local recharge sources and/or saline groundwater for short periods, with water quality representative of shallow groundwater and no seasonality (Ogden et al. 1986, p. 120; LBG-Guyton Associates et al. 2004, p. B-43; Johnson and Schindel 2008, p. 60; Musgrove and Crow 2012, pp. 47, 80, 89; Nowlin and Schwartz 2012, p. 56).

The water temperature remains relatively stable at both the spring runs and Landa Lake at Comal Springs, measuring 20.7°C (69.3°F) and 23.9°C (75°F), respectively (BIO-WEST, Inc. 2021, p. 18). The spring runs maintain specific conductivity (579-587 micro siemens/centimeter (μS/cm)), and dissolved oxygen (5.1-5.2 mg/L), with few detections of contaminants, such as personal care products and pharmaceuticals (BIO-WEST, Inc. 2021, p. 18; EAA 2013, p. 62; EAA 2018, p. 5; EAA 2021a, pp. 27-36, 45-47).

Despite the general groundwater quality at Comal Springs, there has been a noticeable trend since the 1970s. While total dissolved solids and conductivity have been on the rise, they are currently stabilizing. Conversely, nitrates have doubled, with a median concentration of 2 mg/L, since the 1970s (Musgrove et al. 2016, pp. 462, 465, 467; EPA 2023a, unpaginated). These shifts in water quality within both streams and groundwater align with the escalation of impervious cover across the watershed (Kaushal et al. 2005, p. 13518; Baker et al. 2019, pp. 6494–6495; Castaño-Sánchez et al. 2020, p. 6). These alterations in water quality parameters may serve as a long-term indicator of the urbanization that has already transpired in the recharge zone.

2.2.1.7 Other:

The Comal Springs riffle beetle occurs in a limited range at a small number of localities with little or no ability to disperse between or beyond these localities. These characteristics make them susceptible to local extirpation and extinction (McKinney 1997 p. 499; Bowles et al. 2003 p. 380; O’Grady et al. 2004 p. 514). It is speculated that the riffle beetle may be able to retreat into spring openings or burrow down to the hyporheos (groundwater zone below the stream channel) during times of drought (Bowles et al. 2003 p. 359).

A severe drought or water contamination event could eliminate many or all the existing populations (Bowles et al. 2003 p. 380). Having a high number of individuals at a site provides no protection against extinction due to stochastic events. Dispersal beyond their extant range is unlikely, given the isolated nature of the spring headwater system dynamics and aquifer hydraulic connectivity that limit movement of individuals.

The areas inhabited by individuals of the species can be protected through localized conservation measures (e.g., intact riparian zones, springflow protection measures); however, the groundwater that provides water quality and quantity for the species can originate a significant distance from these habitats, and efforts that protect or conserve groundwater may be variable in their success and implementation. Even with the most effective management and recovery plans in place, the species remains vulnerable to devastating stochastic events such as floods or droughts that could eliminate the species.

2.2.1.8 Conservation Measures:

Water Quantity

The Edwards Aquifer Authority (EAA) is charged with protecting terrestrial and aquatic life, domestic and municipal water supplies, the operation of existing industries, and the economic development of the entire Edwards Aquifer (Chapter 626, Laws of the 73rd Texas Legislature, 1993). Aquifer management since these rules were implemented has been successful at controlling groundwater withdrawals to maintain springflows. By EAA estimates, Comal Springs would have likely ceased flowing during the 2014 drought period without current regulations (EAA 2015, p. 62). Currently, these regulations have been effective in managing the Edwards Aquifer and reducing the risk of substantial declines in spring flows at Comal and San Marcos springs.

Another important conservation measure is implementation of the City of San Antonio's Edwards Aquifer Protection Program (Stone and Schindel 2002, pp. 38-39; City of San Antonio 2023, pp. 3, 6). In 2000, the voters of San Antonio passed Proposition 3, a $65 million sales tax initiative, to fund the acquisition (i.e., fee-simple and conservation easements) of open space to protect the contributing and recharge zones of the aquifer in Bexar County (Romero 2018, p. 2). Protection of open space has the potential to reduce the impacts of development (e.g., run-off form impervious cover, fertilizer applications, and wastewater) on maintain aquifer recharge (Reilly and Carter 2018, pp. 3-2, 3-6; Romero 2018, pp. 5-6). That program was re-approved in 2005, 2010, and 2015 with additional funds to acquire open space (Reilly and Carter 2018, pp. 1-3–1-5). The effort was later expanded to acquire lands in Medina and Uvalde counties that contain larger portions of the contributing and recharge zones (Romero 2018, pp. 5-6, 8). The dedicated sales tax expired in 2021 with 97,124 hectares (240,000 acres) acquired under the Edwards Aquifer Protection Program (Siglo Group 2022, pp. 51-52). The City of San Antonio recently approved an alternative funding stream to support land acquisitions through the commitment of $100 million over ten years (City of San Antonio 2023, pp. 3, 6).

Water Quality

There are several laws and regulations to protect water quality that apply to the Edwards Aquifer. The Federal Safe Drinking Water Act of 1974, as amended, regulates pollution and sedimentation of public drinking water sources, including the Edwards Aquifer. This legislation mandates enforcement of drinking water standards established by the Environmental Protection Agency. The Texas Commission on Environmental Quality (TCEQ) is responsible for enforcement of these standards in Texas. Under the authority of the Texas Administrative Code (TAC) (30 TAC § 213), the TCEQ regulates activities having the potential for polluting the Edwards Aquifer and hydrologically connected surface streams through the Edwards Aquifer Protection Program or "Edwards Rules." The Edwards Rules require several water-quality protection measures for new development occurring in the recharge zone and portions of the contributing zone of the Edwards Aquifer. The TCEQ also prohibits facilities such as municipal solid waste landfills and waste disposal wells from being built in the recharge or transition zones.

Discharge from non-point residential or agricultural sources is one of the primary sources of pollution in the Edwards Aquifer. Texas has an extensive program for the management and protection of water that operates under State statutes and the Federal Clean Water Act. The Program includes regulatory programs such as the following: Texas Pollutant Discharge Elimination System, Texas Surface Water Quality Standards, and Total Maximum Daily Load Program (under Section 303(d) of the Clean Water Act).

The TCEQ's Texas Pollutant Discharge Elimination System program regulates discharges of pollutants to Texas surface water. Through the Pollutant Discharge Elimination System program, the TCEQ authorizes the discharge of stormwater and non-stormwater to surface waters in Texas associated with storm sewer systems and construction sites, which must meet the requirements of the Edwards Rules.

A watershed protection plan was accepted in 2018 by TCEQ for the Dry Comal Creek and Comal River Watershed by the City of New Braunfels. Dry Comal Creek has not met state water quality standard for bacteria, and the watershed protection plan is intended to address and reduce the elevated bacteria levels through management (TCEQ 2020, p. 1). Another watershed protection plan for the Upper San Marcos River was approved in 2018 by TCEQ. The watershed protection plan addresses the impairment of the Upper San Marcos River due to elevated total dissolved solids, and proactively addresses bacteria, nutrients, sediment, and future growth scenarios for the watershed (TCEQ 2018, p. 1).

The EAA has additional regulations (EAA rule 713) that apply to the recharge zone and five miles upgradient of the recharge zone. Much of the contributing zone occurs outside of the EAA jurisdiction (EARIP HCP 2020, pp. 1-4-1-5) and is not subject to these regulations. New development in the Edwards Aquifer recharge, transition, or contributing zones is reviewed by the TCEQ Edwards Aquifer Protection Program (30 TAC § 213.1). For the contributing zone, the rule covers activities that disturb more than two hectares (ha) (five acres (ac)) in Medina, Bexar, Comal, Kinney, Uvalde, Hays, Travis, and Williamson counties (30 TAC § 213.20). The contributing zone in Bandera, Kerr, and Kendall counties does not have additional protections under either program.

Several other entities also have measures to protect groundwater from contamination including the EAA's Aboveground Storage Tank Program, Agricultural Secondary Containment Assistance Program, and Abandoned Well Program among others (EAA 2022, entire). The San Antonio Water System implements several water quality protection measures including development regulations (i.e., Aquifer Quality Protection Ordinance No. 81491) for properties over the contributing and recharge zones, review of building permits and master development plans, regulation of underground storage tanks, commercial/industrial compliance, and an abandoned well program (San Antonio Water System 2022, unpaginated).

In addition to these state and federal regulations, a significant number of local regulations to protect water quality were implemented by the City of San Marcos, City of New Braunfels, EAA, and Texas State University as part of the EARIP HCP (EARIP HCP; see sub-section below). Texas Water Code (Chapter 36) allows groundwater districts, but not cities, to regulate groundwater, including groundwater quality. However, cities can regulate pollution at the surface that ultimately impacts groundwater quality.

Habitat Conservation Plan

The EARIP HCP was finalized in 2013, amended in 2020, and covers incidental take of listed species at Comal and San Marcos Springs for groundwater withdrawal, recreation, and other activities through 2028 (EARIP HCP 2020, entire). Permittees to the plan include the EAA, City of San Antonio acting through the San Antonio Water System, City of New Braunfels, City of San Marcos, and Texas State University (National Research Council 2015, pp. 25–26). The EARIP HCP includes activities to minimize and mitigate impacts and contribute to the recovery of the eleven Covered Species and addresses a variety of aquifer management issues, including ensuring springflow during a repeat of the Drought of Record (Payne et al. 2019, p. 200; EARIP HCP 2020, pp. 4-57–4-59, 4-62–4-66). Long-term commitments to protect listed species in the Edwards Aquifer beyond the HCP and the term of its associated section 10(a)(1)(b) permit are not currently in place.

The current EARIP HCP biological goals that center on management, flow-related, and population objectives for the Comal Springs riffle beetle (EARIP HCP 2020, p. 4-11–4-16). The Comal Springs/River management objectives are "Not exceed a 10 percent deviation (daily average) from historically recorded water quality conditions (long-term average) in the Edwards Aquifer as measured issuing from the spring openings at Comal Springs" and to restore riparian habitat adjacent to spring openings to reduce sedimentation after rain events. Additionally, maintain specific median beetle population densities (as measured by numbers per lure) at three locations within the Comal Springs ecosystem. These biological goals do not include the Comal Springs riffle beetle population at San Marcos Springs.

A captive refugia and associated research is funded by the EARIP HCP through a contract (Contract # 16-822-HCP) with the Service's San Marcos Aquatic Resource Center and Uvalde National Fish Hatchery (EARIP HCP 2020, p. 5-

3). The contract was established to protect species left vulnerable to extirpation throughout a significant portion of their range due to a limited geographic distribution of the population and will preserve the capacity for these species to be re-established in the event of the loss of population due to a catastrophic event, such as the unexpected loss of springflow or a chemical spill. Research activities expand knowledge on habitat requirements, biology, life histories, and effective reintroduction techniques for the species.

2.2.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms):

2.2.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Water Quantity

A primary threat to the habitat of the Comal Springs riffle beetle is the potential loss of springflows and reduced water quantity underground brought on by groundwater withdrawals from the southern segment of the Edwards Aquifer. Springflows at Comal and San Marcos springs ecosystems are tied inseparably to water usage for the southern segment of the Edwards Aquifer. Groundwater pumping to meet municipal, industrial, and irrigation uses, is a widely recognized threat to the persistence of subsurface and surface groundwater-dependent ecosystems (Danielopol et al. 2003, pp. 109-112; Eamus et al. 2016, pp. 317, 333-335; Mammola et al. 2019, pp. 645-646). Removal of groundwater from an aquifer leads to water level decline, especially if discharge of groundwater significantly exceeds recharge (Theis 1940, pp. 278-280; Alley et al. 2002, pp. 1,986; Foster and Chilton 2003, pp. 1,961-1,962). Declining aquifer levels can result in springflow decline or failure, loss of stream and creek base-flow, and/or drying of water-filled caverns (Springer and Stevens 2009, pp. 9-10; Eamus et al. 2016, pp. 316-318, 333-335).

If not replenished through recharge, groundwater discharged through wells and springs is removed from aquifer storage (i.e., total amount of water in aquifer), and with absent or much reduced recharge, persistent groundwater removal would initially lead to decline and/or cessation in springflows (Lindgren et al. 2004, p. 41). Like other karst aquifers, water levels of the Edwards Aquifer fluctuate with recharge (i.e., distribution, amount, and intensity of rainfall) and discharge (i.e., wells or springs) (Petitt and George 1956, p. 49; Buszka 1987, pp. 24-27; Maclay 1995, pp. 48, 52; Worthington et al. 2003, p. 4; Lindgren et al. 2004 pp. 40-41, 45). Prolonged dry periods result in declines in aquifer, but water levels rebound rapidly with return of precipitation (Petitt and George 1956, p. 49). Groundwater pumping has exceeded recharge multiple times with water levels rebounding with increased rainfall (Petitt and George 1956, p. 49). The longest period was the Drought of Record (a three-year period when aquifer recharge was at its lowest recorded level) during the mid-1950s (Arnow 1959, pp. 27-29). At one point, Comal Springs stopped flowing from June 13 through November 3, 1956, during the Drought of Record (Puente 1976, p. 22; Barr 1993, p. 61).

In the early 1990s, federal litigation (i.e., *Sierra Club vs. Secretary of the Interior* [No. MO-91-CA-069] United States District Court for the Western District of Texas) resulted in the creation of the EAA in 1993 by the State of Texas to manage groundwater withdrawals (i.e., by nonexempt wells) from the southern segment and limit Edwards Aquifer pumping authorized through permits (National Research Council 2015, pp. 24-26; Hardberger 2019, pp. 193-194; Payne et al. 2019, p. 199). During the 2007 legislative session, the Texas Legislature increased the annual maximum amount of pumping that could be authorized by permits to 705,551 megaliters (ML) (572,000 acre-feet (af)) and directed the EAA to adopt and enforce a "Critical Period Management" plan establishing targeted withdrawal reductions during times of drought to achieve the water, species, and species habitat conservation goals established in the agency's enabling legislation (80th Texas Legislature, 2007, Senate Bill 3). Aquifer management since these rules were implemented have been successful at reducing groundwater withdrawals, but currently do not account for future droughts that may be worse than the Drought of Record. The Stage V Critical Period Management that currently exists is also tied to the Edwards Aquifer Recovery Implementation Program Habitat Conservation Plan (EARIP HCP) but could be subject to change after species recovery.

Springflows have been protected at Comal and San Marcos springs during recent droughts in the 2000s and 2010s because of groundwater pumping restrictions from the EAA during periods of drought. During the 2008-2009 drought, springflows remained at sufficient levels to maintain resiliency for the EARIP HCP’s Covered Species (above 2.3 cubic meters per second (m^3/s) [80 cubic feet per second (cfs)]) (USGS station 08169000). By EAA estimates, Comal Springs likely would have gone dry during the 2014 drought without the enforcement of Critical Period Management (EAA 2015, pp. 1, 62).

While a repeat Drought of Record has not occurred, modeling indicates that the Critical Period Management plan during Phase II of the EARIP HCP will maintain springflows above 0.85 m^3/s (30 cfs) at Comal Springs and above 1.3 m^3/s (45 cfs) at San Marcos Springs during a Drought of Record. However, the plan is currently unable to return springflows at either spring system to 2.3 m^3/s (80 cfs) within six months (EARIP HCP 2020, pp. 4-58, 4-66). Future droughts may also be more severe than the Drought of Record, and current aquifer management does not account for this.

Groundwater will continue to be a source of water in the future as urban populations increase. Predicted water demands for the four counties within the San Antonio pool (i.e., Hays, Comal, Bexar, Medina) are projected to increase by 48 percent in the year 2070, surpassing the capacity of existing supplies

(Texas Water Development Board 2021, p. A-2–A-3). Strategies identified by the State of Texas and Groundwater Conservation Districts for these counties are contingent on funding and infrastructure availability (Texas Water Development Board 2021, entire).

The springflows required to support resilient populations are species-specific and contingent on habitat use and requirements. According to the biological opinion (USFWS 2013, p. 129) associated with the EARIP HCP, the issuance of the Incidental Take Permit for the EARIP HCP is not likely to jeopardize the continued existence of the Comal Springs riffle beetle or adversely modify its critical habitat. Modeled springflows during Phase II project Comal Spring flows to remain at approximately 1.4 m^3/s (50 cfs) during a repeat Drought of Record, surpassing the springflows during the Drought of Record when it ceased for four months in 1956 (USFWS 2013, pp. 32, 91, 103-108).

Springflows crucial for the survival of the Comal Springs riffle beetle were not considered in the 1995 recovery plan or quantitative delisting criteria. The springflows influencing the Comal Springs riffle beetle and its habitat may vary from those affecting other surface species. For instance, at 0.9 m^3/s (30 cfs) at spring runs 2 and 3 of Comal Springs do not provide surface habitat for invertebrates (EAHCP 2020, pp. 4-97–4-98). The USFWS determined that 0.9 m^3/s (30 cfs) during a repeat Drought of Record is not likely to jeopardize the Comal Springs riffle beetle (USFWS 2013, p. 129).

Water sources such as seeps along the western shoreline of Landa Lake and upwellings near Spring Island, are expected to persistently offer habitat support during low-flow conditions within the Comal Springs ecosystem (USFWS 2013, p. 100). San Marcos Springs at Spring Lake, unlike historical droughts and the Drought of Record, has maintained its flow throughout recorded history (Nace and Pluhowski 1965, pp. 81–87; Ogden et al. 1986, pp. 117–118; LBG-Guyton Associates et al. 2004, p. B45; USFWS 2013, pp. 104-105).

The Comal Springs riffle beetle, despite enduring the severe drought of the mid-1950s without being extirpated, likely suffered adverse effects from unregulated aquifer pumping, given its aquatic nature. Evidence suggests that despite surviving the drought without being extirpated, the Comal Springs population was likely impacted by the prolonged absence of water at the surface during that period (Arnow 1959, pp. 27-29; Barr 1993, pp. 61-62). It is reasonable to expect that individuals could have been stranded and possibly extirpated due to receding groundwater levels. The negative impact on the beetle could have been further exacerbated if adults were confined to the vicinity of spring openings due to potential terrestrial requirements of the immature stages and a narrow tolerance in water quality (Barr 1993, pp. 61-62; Cooke 2012, p. 41).

Moreover, there is uncertainty regarding the riffle beetle's ability to escape unfavorable conditions resulting from catastrophic drought in their habitat.

Studies suggest that the species might attempt to follow the water into the aquifer as drying occurs, but their adaptability to surviving extended periods of drying or stagnation, especially in the absence of a water management plan accommodating their needs, remains questionable (Cooke 2012, p. 30; Nair et al. 2023, p. 6). The current water management plan for the Edwards Aquifer plays a crucial role in the survival of the Comal Springs riffle beetle by ensuring consistent springflow. If this management were to cease, leading to longer periods of drying, the species would face detrimental consequences, as it is not well-equipped to endure extended periods of aridity, exposure to high temperatures (median lethal temperature at 27°C [81°F] for the Comal Springs riffle beetle), or stagnation (Cooke et al. 2015, pp. 119-120; Nair et al. 2023, pp. 4-6).

Water Quality

Water quality at Comal and San Marcos springs ecosystems where the Comal Springs riffle beetle is found are influenced by groundwater and surface water. These two spring ecosystems depend on groundwater flow from the southern segment of the Edwards Aquifer. This segment of the aquifer is fed by many stream systems that enter the aquifer through recharge features. The Edwards Aquifer is vulnerable to contamination because the limestone and carbonate rocks are highly permeable and exposed at the surface in the recharge zone (Clark 2000, pp. 1-2, 8-9; Burri et al. 2019, p. 150). Contaminants, commonly linked to urban and suburban activities such as residential and commercial development, industrial operations, transportation infrastructure, and waste disposal, tend to accumulate in higher concentrations within the shallow areas of recharge zones, especially in regions characterized by urban land uses (Wilson 2011, pp. 1-2; Lin and Gong 2016, pp. 384-385; Opsahl et al. 2018, p. 58).

Abandoned groundwater wells are a source of potential contamination from shallow groundwater into subsurface habitat and affect water quality at the springs. Shallower wells (< 300 m [< 984 ft]) are less likely than deeper wells to intercept older groundwater that received cumulative, diluted inputs of pollutants across the aquifer and therefore are more likely to intercept anthropogenic contaminants coming directly from the surface than deeper wells (Musgrove et al. 2014, pp. 69, 73). The EAA funds a needs-based abandoned well closure assistance program to assist well owners with proper well plugging in cooperation with San Antonio Water System to locate and plug abandoned wells (EAA 2021b, pp. 50-53). Likewise, former oil wells require maintenance decades after plugging (cement plugs in a steel pipe) and can blowout underground and break free under artesian pressure if not properly maintained (Gold 2022, entire).

Oil and gas transmission pipelines are another potential source of hazardous material spills on the contributing and recharge zones of the aquifer. The "development and production of oil, gas, or a geothermal resource within the jurisdiction of the Texas Railroad Commission" are not considered regulated activities "having the potential for polluting the Edwards Aquifer and hydrologically connected surface water in order to protect existing and potential uses of groundwater and maintain Texas Surface Water Quality Standards" (Texas Natural Resource Conservation Commission 1996, p. 1). Consequently, the construction and maintenance of these pipelines are not subject to guidance mitigating impacts to karst features such as voids, and development of these pipelines are not subject to the Edwards Aquifer rules (Texas Natural Resource Conservation Commission 1996, entire).

Nitrogen is highly soluble and a threat to groundwater quality and a stressor to groundwater-dependent taxa (Castaño-Sánchez et al. 2020, pp. 6, 11; Banerjee et al. 2023, pp. 3–6). Panther Canyon well (State well number 6823302), recorded nitrate (2 mg/L) present in 2003 (Texas Water Development Board 2023, unpaginated). Nitrate concentrations over 1 mg/L are indicative of anthropogenic inputs, which have been recorded historically at Comal Springs and have doubled over the last 70 years (median concentration 2 mg/L) (Dubrovsky et al. 2010, p. 79; Musgrove et al. 2016, pp. 462, 465, 467; Castaño-Sánchez et al. 2020, p. 6). These changes in water quality in streams and groundwater correspond with increases in impervious cover over a watershed (Kaushal et al. 2005, p. 13,518; Baker et al. 2019, pp. 6494–6495; Castaño-Sánchez et al. 2020, p, 6). These water quality parameter changes may be a long-term indication of urbanization that has already occurred across the recharge zone.

Nitrates and orthophosphate consistently emerge from Spring Run 1 at Comal Springs, and are typically present at low concentrations (2 mg/L) (U.S. Geological Survey 2023, unpaginated). The current drought has significantly decreased flow, and thus dilution of contaminants are slowed at Comal Springs; recent data resulted in 3 mg/L of nitrate measured at Spring Run 2 at Comal Springs (West 2023, unpaginated). While safe for humans, it is unknown what effect these elevated nutrients will have over time within the aquifer food web and if conditions would become more favorable for surface species to colonize further underground (Notenboom et al. 1994, pp. 482–484, 490; Opsahl et al. 2018, p. 3).

Riffle beetles, including the Comal Springs riffle beetle, generally thrive in highly oxygenated water near saturation, and any contamination that poses a threat to diminish this water quality could have adverse effects on their survival (Elliott 2008, pp. 198-199). Despite the environmental tolerances of the Comal Springs riffle beetle being unknown, hindering quantitative assessments of stressors on its populations, other riffle beetle species worldwide are recognized as indicators of good water quality and are sensitive to contamination (Brown 1972, p. 53; USFWS 2019, p. 16; Sotomayor et al. 2023, p. 1).

Volatile organic compounds have been detected at one spring ecosystem and generally these events are rare (Johnson and Schindel 2014, p. 21). There is one documented diesel spill (i.e., naphthalene) that occurred in 2000 at Spring Run 7 at Comal Springs (Ogden et al. 1986, p. 126; Gibson et al. 2008, p. 75). It is unknown what effect this had on the subterranean community.

Although water quality in the Edwards Aquifer is generally good, several studies have detected contaminants in groundwater from the southern segment including nitrates, herbicides, pesticides, and polycyclic aromatic hydrocarbons, among many others (Fahlquist and Ardis, 2004 pp. 7-8, 10; Johnson et al. 2009, pp. 10-13, 23-26, 31-35; Musgrove et al. 2014, pp. 67, 69-71; Opsahl et al. 2018, p. 58; Opsahl et al. 2020, pp. 17-30). For example, contaminants have exceeded public drinking water standards in springwater and surface water recharging the aquifer, including antimony, arsenic, lead, lithium, and tetrachloroethene (Johnson et al. 2009, p. 45). However, groundwater contamination has not been shown to be widespread or with large numbers of substances present in concentrations that exceed drinking water standards (Bush et al. 2000, pp. 1-2, 14-21; Fahlquist and Ardis 2004, pp. 7-8, 10; Johnson et al. 2009, 44, 47; Opsahl et al. 2018, p. 58; Opsahl et al. 2020, pp. 17-30; EARIP HCP 2020, pp. 3-40-3-42).

Some of the sources of water quality degradation include impervious cover and stormwater runoff, construction activities, recharge from irrigation return flow (i.e., water that is not lost from evapotranspiration on laws or to stream runoff), wastewater discharge, transportation infrastructure, and hazardous materials spills resulting from development within the watersheds that contribute groundwater flows to spring habitats (van der Kamp 1995, pp. 11-15; Cantonati et al. 2012, entire; Passarello et al. 2012, pp. 29–34; Lapworth et al. 2012, entire). Land-use changes, particularly increases in impervious cover, are known stressors to aquatic systems and are difficult to predict, model, and remediate (Sharp 2010, p. 3; Coles et al. 2012, p. 65). Future development in the recharge and contributing zones are likely to decrease water quality because of the increased risk of contamination entering the aquifer.

Forested land with limited human disturbances contributes to high-quality recharge (Dudley and Stolten, 2003, pp. 11, 58; Shah et al. 2022, p. 120, 396), while rural and exurban land uses contribute to groundwater contamination from leaking sewage, refuse dumping, and dead, decaying livestock (Sui et al. 2015, p. 21; Katz 2019, p. 565; EARIP HCP 2020, pp. 5-43). Septic systems are a likely source of nutrients (EARIP HCP 2020, p. 5-43; Sui et al. 2015, p. 21). Once a source of pollution enters groundwater, it can be difficult if not impossible to track, intercept, and remediate because of karst conduit complexity (Humphreys 2011, p. 297). Since water quality in the Edwards Aquifer is generally good, this indicates that local sources of water pollution can disproportionately affect water quality in portions of the aquifer.

Urban and agricultural land uses dominate the artesian zone in the southern segment. Low- to high-density urban development occurs across much of the former, while agriculture dominates the latter county. Land use across the southern segment of the Edwards Aquifer plays a major role in groundwater and surface water quality. The presence of agriculture, residential and commercial developments, industrial facilities, military installations, and transportation infrastructure are correlated with increased presence of many contaminants (Bush et al. 2000, pp. 6-9; Fahlquist and Ardis 2004, p. 7; Johnson et al. 2009, p. 46; Wilson 2011, pp. 1-2; Musgrove et al. 2014, pp. 69-71; Opsahl et al. 2018, p. 58; Opsahl et al. 2020, pp. 17-30).

To examine projected land-use changes in the urban centers intersecting Edwards Aquifer groundwater, we used the U.S. Environmental Protection Agency's (EPA 2019, unpaginated) Integrated Climate and Land-Use Scenarios. These outputs produce spatially explicit projections of population and land-use that are based on the Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios. The combination of SSP5-RCP8.5 illustrates a higher population growth and higher emissions, and a faster rate of human population growth consistent with the Texas Demographic Center population projections for Bexar County and the San Antonio-New Braunfels Metropolitan Area (EPA 2017, pp. 34-35, 46; Texas Demographic Center 2022, unpaginated). Within the Edwards Aquifer artesian, recharge, and contributing zones (543,498 has [1,343,014 ac]), developed land-use classes are projected to grow from 21 percent in 2020 to 27 percent developed by 2050. When examining delineated areas at a finer scale around Comal and San Marcos springs using the Integrated Climate and Land-Use Scenarios, the area around Comal Springs is projected to increase in development from 66 percent to 82 percent developed and the San Marcos Springs area is projected to increase from 44 percent to 65 percent developed by 2050. These areas may be important to assess more immediate impacts from groundwater contamination.

Based on the Integrated Climate and Land-Use Scenario results, projections of developed land-uses and population growth will continue to expand outward outside of the major metropolitan areas, San Antonio and Austin, Texas. Over time, these alterations have the potential to affect recharge rates, leading to deteriorating groundwater quality as a result of heightened runoff from impervious surfaces in suburban and urban areas or septic systems that are poorly managed and prone to leakage in exurban areas (Berube et al. 2006, pp. 10, 38; Barkfield 2022, p. 2).

The U.S. Census Bureau (2020, unpaginated) ranked several of the counties in the recharge and contributing zones of Comal and San Marcos springs (adjacent to Sessom Springs in Hays County, Texas) among the fastest growing in the United States from April 2010 to July 2019: Hays County was the second fasting growing county with a 46.5 percent population increase, Comal County the fourth fastest growing county with a 43.9 percent population increase, and

Kendall County the fifth fastest growing county with a 42.1 percent population increase. Since 2000, these three counties have doubled in population and have seen substantial associated development. Projections indicate that the human population of Bexar, Comal, Hays, and Kendall counties will continue to increase substantially over the next three decades.

Conversion of natural habitat to urban, suburban, and exurban development is likely to accompany this population growth. Under a high human population growth scenario, land use projections suggest that large areas west and north of Bexar County will be converted to increasingly more urbanized land-use classes by 2100 (EPA 2019, unpaginated). Much of the exurban and suburban development is postulated to occur outside of municipal boundaries in unincorporated areas of counties where land use regulations (e.g., restrictions on impervious cover) are non-existent (Siglo Group 2022, pp. 13-14). Run-off from existing and expanded impervious cover in sensitive areas of the aquifer could affect groundwater quality over time. New contaminant sources are expected to be added to the region as increased human populations and expanded development continues; many existing contaminant sources will persist.

A review of research studies found that impacts to aquatic species are seen with impervious cover of 10 percent or more (Center for Watershed Protection 2003, p. 97). Although the studies were focused on stream systems, we assume that shallow groundwater habitats would have similar impacts because shallow groundwater ultimately flows into streams through discharge features. While physical parameters may be different (e.g., higher oxygen, lower temperatures, higher conductivity) in the shallow groundwater, pollutants entering both systems would be the same.

The EAA does not have explicit impervious cover limits in the recharge zone, with the intent that structural best management practices will protect water quality (Greater Edwards Aquifer Alliance 2010, p. 3). The TCEQ shares responsibility in protecting the Edwards Aquifer through impervious cover limits through a construction permit review process for development proposals of more than 20 percent impervious cover that includes structural best management practices (30 TAC § 213).

Hays County also limits impervious cover to 15 percent within conservation lands on the recharge zone confined and limits impervious cover to 20 percent outside of the recharge zone (Hays County 2017, p. 204). Lastly, Hays County limits commercial property within the recharge zone not exceed 35 percent impervious cover or 65 percent if outside of the recharge zone (Hays County 2017, p. 207). Comal County has goals to minimize impervious cover within the city of New Braunfels to limits of 26 percent per parcel (Design Workshop, Inc. 2012, pp. 4–5).

While the efforts to implement such limits are intended to help ameliorate at least some water quality impacts, these percentages are nonetheless higher than 10 percent, and each project approval does not account for the cumulative impact of combined impervious cover amounts within each county. Likewise, most lands over the contributing zone are not managed with land use regulations (e.g., impervious cover restrictions) (Siglo Group 2022, pp. 13–14).

Habitat Disturbance- Flooding

Surface habitat modification can occur as the result of flooding. Flash flooding is common throughout the Edwards Plateau (Woodruff and Wilding 2008, pp. 614-616). However, channel modification and the elimination of riparian zones can increase the severity of flooding (Schoof 1980, p. 697). Depending on the severity of floods, they can either deposit or increase suspended sediment loads over species habitat or scour substrate and vegetation from species habitat under high velocities (Griffin 2006, pp. 57-58, 61, 64; BIO-WEST, Inc. 2016, p. 26; BIO-WEST, Inc. 2019b, pp. 14, 17; Schwartz et al. 2020, pp. 12). It is possible that species may also be washed away in floods, though this has not been studied for the Comal Springs riffle beetle. Record flooding occurred in the San Marcos River in 2015 and scoured large amounts of aquatic vegetation (BIO-WEST, Inc. 2016, p. vi, 48). Floods have deposited finer sediments (e.g., silt) over invertebrate surface habitat at Comal and San Marcos springs, reducing springflow and quality of habitat (BIO-WEST, Inc. 2002, p. 11; Gibson 2022, pers. comm.).

2.2.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Comal Springs riffle beetle specimens are collected for scientific study and two refugia populations. Such collections have not been documented to negatively impact total wild population numbers. At present, this species is not recognized for their commercial worth, and there is no evidence of overexploitation, making overutilization insignificant as a threat.

2.2.2.3 Disease or predation:

Fungal bodies have been observed growing outside of live riffle beetle joints, but not in Comal Springs riffle beetles (Gibson 2022, pers. comm.). Fungi have not been observed on living Comal Springs riffle beetles, but benign fungal parasites on *Dryops* species have been documented (Brown 1987, p. 266). Filamentous fungi have been documented on deceased wild and captive Comal Springs riffle beetle larvae and adults, but whether the fungi were the cause of the mortality or occurred post-mortem is uncertain (Worsham and Gibson 2022, pers. comm.).

Obligate ectoprotozoans are found around the mouth and faces of wild Comal Springs riffle beetles which decrease in number over time in captivity where access to wild, living food resources are not provided. It is uncertain what extent of parasitism has on this species, but the protozoans are likely receiving shredded food from the beetles and are benign (Brown 1987, pp. 266, 269).

The amount of predation that occurs in the wild has not been examined for this species. Blind, fragile subterranean species such as the Comal Springs riffle beetle may be more susceptible to predation once the species enter surface waters (Brown 1987, p. 263; Barr 1993, pp. 63-64). Fishes compete for prey expelled from the aquifer at discharge features (e.g., spring openings). Researchers have seen Mexican tetras (*Astyanax mexicanus*), sunfish (*Lepomis* sp.), and mosquitofish (*Gambusia* sp.) congregating at spring openings waiting for the driftnet to be removed and consuming the bycatch, including subterranean invertebrates (BIO-WEST, Inc. 2003, p. 42). Macroinvertebrates such as the Comal Springs riffle beetle are a part of the food chain, and it is assumed any number of individuals removed from the listed macroinvertebrate populations through typical levels of predation are likely to be negligible.

2.2.2.4 Inadequacy of existing regulatory mechanisms:

Under this factor, we examine the stressors identified within the other factors as ameliorated or exacerbated by any existing regulatory mechanisms or conservation efforts. Section 4(b)(1)(A) of the ESA requires that the Service consider "those efforts, if any, being made by any State or foreign nation, or any political subdivision of a State or foreign nation, to protect such species…" In relation to Factor D under the ESA, we interpret this language to require the Service to consider relevant Federal, State, and Tribal laws, regulations, and other such binding legal mechanisms that may ameliorate or exacerbate any of the threats we describe in threat analyses under the other four factors or otherwise enhance the species' conservation. Our consideration of these mechanisms is described in detail within each of the threats or stressors to the Comal Springs riffle beetle (see discussion under the other Factors). Much of the information under Section 2.2.2.1 should also be considered as relevant here because it is often the inadequacy of existing regulations that contributes to habitat loss and degradation for this species.

The recharge and contributing zones to the Edwards Aquifer continue to experience rapid human population growth and conversion of natural habitat to developed land-use types, which continues to threaten water quality. Much of the contributing zone is not under the same regulations to protect water quality as the recharge zone, even though much of the water that recharges the aquifer originates in the contributing zone. Regulatory mechanisms that protect water in the Edwards Aquifer are crucial to the future survival of the Comal Springs riffle beetle. Federal, State, and local laws and regulations have improved water quality and quantity protection but could be insufficient to prevent ongoing impacts to the species and their habitats from water quality degradation, reduction in water quantity, and surface disturbance of spring sites, and are unlikely to prevent further impacts to the species in the future. Knowledge of the source, accumulation, and transport of these compounds in the aquifer are lacking and investigations into their effects on the habitat quality are necessary for the recovery of the Comal Springs riffle beetle and for sustainable use of the aquifer (Danielopol et al. 2004, pp. 187-188; Opsahl et al. 2018, p. 2).

Under Texas Parks and Wildlife Code (Chapter 68) and TAC (31 TAC § 65.171-65.176), the Texas Parks and Wildlife Department is authorized to add species to the agency's List of State Threatened and Endangered Nongame Species and List of State Endangered, Threatened, and Protected Native Plants. The Comal Springs riffle beetle is also state listed. The Texas Parks and Wildlife Department prohibits the taking, possession, transportation, or sale of any animal species that are state listed as threatened or endangered. No protections are provided for habitat required by species.

While the EAA was granted regulatory authority by the Texas Legislature, there have been several legal challenges to the EAA permitting program. For example, in court cases *Edwards Aquifer Authority v. Day* (2012, Supreme Court of Texas No. 08-0964) and *Edwards Aquifer Authority v. Bragg* (2013, Court of Appeals of Texas No. 04-11-00018-CV), courts awarded landowners compensation for groundwater permits that were denied by the EAA due to lack of historical usage. The ruling for *Edwards Aquifer Authority v. Day* by the Texas Supreme Court argued that there was no reason to treat groundwater differently than oil and gas and recognized groundwater as real property. In both cases, landowners owned the land prior to enactment of new groundwater pumping regulations. There remains a lack of clarity with Texas groundwater law that results in ongoing legal challenges regarding groundwater regulation, and these could impact the EAA's ability to regulate the aquifer in the future.

The EAA manages and issues permits for groundwater withdrawals within the Edwards Aquifer through conservation and drought management. The EAA's jurisdiction is limited to the Edwards Aquifer in Uvalde, Medina, Bexar, and portions of Comal, Guadalupe, Hays, and Caldwell counties. The contributing zone in Bandera, Kerr, and Kendall counties do not have additional protections under either program. Thus, the EAA's water quality regulations do not protect most of the contributing zone, which may ultimately reduce the water quality of the Edwards Aquifer.

As described above, TCEQ regulates activities that have the potential to pollute the Edwards Aquifer and hydrologically connected surface streams under the same Edwards Aquifer Protection Program or "Edwards Rules" and for the same counties. This means areas of the contributing zone do not have additional protections that could affect the amount and quality of recharge that enters the

Edwards Aquifer, resulting in lower water quality protection for the aquifer and the Comal or San Marcos ecosystems.

Likewise, this agency does not address development or other land use, impervious cover limitations, some nonpoint source pollution, or application of fertilizers and pesticides over the recharge zone (30 TAC § 213.31). Changes to how surface water and the Trinity Aquifer are managed are likely to change the amount that can be sustainably pumped from the Edwards Aquifer during drought conditions. For example, the Hays-Trinity Groundwater Conservation District also manages groundwater that influences the water at the San Marcos Springs ecosystem.

2.2.2.5 Other natural or manmade factors affecting its continued existence:

Global climate change is already affecting many regions' biodiversity, with stressors driven by increasing temperatures and extreme climatic events and will continue to in the near-term (Intergovernmental Panel on Climate Change 2023, pp. 5, 15). Over the last 115 years, the global averaged surface air temperature has increased by 1.0°C (1.8°F) with recent decades being the warmest in 1,500 years (Vose et al. 2017, pp. 186, 188). With the highly karstic permeability of the Edwards Aquifer, climate change and variability strongly influence this vulnerable aquifer that relies heavily on rainfall for recharge (Mace and Wade 2008, p. 659; Taylor et al. 2013, p. 312; Ding and McCarl 2019, p. 11; Nielsen-Gammon et al. 2020, p. 9). The Fourth U.S. National Climate Assessment (U.S. Global Change Research Program 2018, pp. 1,002-1,003) presents the Edwards Aquifer as a case study in vulnerability to climate change, citing the shallow karst aquifer as especially sensitive to climate change, and the regional population growth and development as exacerbating the effects of decreased water supply during droughts. While average rainfall is not projected to change significantly in central Texas, the distribution of precipitation is anticipated to change with more extreme droughts and extreme rain events (Geos Institute 2016, pp. 14-15).

Increasing temperatures will also create drier conditions due to increased evapotranspiration (Loáiciga and Schofield 2019, p. 224). Extreme droughts in Texas are more likely than they were 40-50 years ago (Rupp et al. 2012, p. 1,054; Nielsen-Gammon et al. 2020, entire). A recent study predicts megadroughts in Texas, more severe than have been seen for the past thousand years, that will occur before 2100 (Nielsen-Gammon et al. 2020, entire). Droughts worse than the Drought of Record occurred since the 1600s and are not uncommon in the region (Mauldin 2003, entire; Cleaveland et al. 2011, entire). It is not possible to ensure that there will be adequate flow to these springs without planning for more extreme droughts than the Drought of Record (Loáiciga and Schofield 2019, p. 236; Mace 2019, p. 212). The sustainable water yield for the Edwards Aquifer will decrease in a dry climate (EARIP HCP

2020, pp. 3-12, 3-31, 3-43; Loáiciga and Schofield 2019, pp. 223, 235-236) while human demand for groundwater will increase (EARIP HCP 2020, pp. 3-10–3-11), making it more challenging to balance groundwater use for human needs and ecosystem function. In 2010, Texas set a record for lowest rainfall with similar conditions persisting until 2013 (Nielsen-Gammon 2012, p. 59; National Research Council 2015, p. 168). Heavy rainfall leading to floods may also become more common from extreme precipitation events and may result in increased habitat disturbance due to movement of materials and scouring.

Average air temperature in Texas has risen 1.5°C (2.7°F) since the early 1900s (National Oceanic and Atmospheric Administration 2022, unpaginated). Future air temperature changes will depend on the amount of future greenhouse gas emissions (U.S. Global Change Research Program 2018, p. 995). Based on current projections of greenhouse gas emissions, air temperature is projected to increase 2.0-2.8°C (3.6-5.1°F) by 2050, and 2.4–4.7°C (4.4–8.4°F) by 2100 for the southern Great Plains (U.S. Global Change Research Program 2018, p. 995). Projections by Sharif (2018, p. 4) predict a greater rise in air temperature by 2100, 2.7-5.6°C (5-10°F). Studies have not explicitly addressed groundwater temperature increases for the Edwards Aquifer. Based on other research into changes in groundwater temperature, it is reasonable to expect that groundwater temperature will increase as air temperature increases, with a possible lag in groundwater temperature increase (Mahler and Bourgeais 2013, p. 295). Groundwater temperature also increases with urbanization and vegetation removal (Benz et al. 2017, entire). This could further increase groundwater temperatures as more development occurs. Groundwater temperature typically increases with depth due to geothermal heat flow, although this also varies locally with other variables such as vertical groundwater flow (Bense and Kurylyk 2017, pp. 1, 8). This suggests that deeper water would not provide a long-term buffer to increasing temperatures.

Surface water temperature will also increase during warm months. Data from the EAA indicates greater temperature fluctuations downstream from the springs due to increased exposure time to ambient temperatures and runoff from rain events (BIO-WEST, Inc. 2019a, p. 20; BIO-WEST, Inc. 2019b, p. 16). Low spring discharge is also a mechanism that increases the water's exposure time to ambient temperature. Thus, both future droughts and increased ambient temperature are likely to increase the surface water temperature. Thus, both future droughts and increased ambient temperature are likely to increase the surface water temperature. Continuous temperature data for the springs began in 2000, and groundwater temperature at Comal and San Marcos springs are relatively constant (BIO-WEST, Inc. 2019b, p. 16). Continuous water temperature monitoring in the Comal River should indicate whether water temperatures rise in the future.

Comal Springs riffle beetles are ectothermic macroinvertebrates with a limited thermal tolerance and a confined habitat centered around freshwater springs originating from the aquifer (Cooke et al. 2015, pp. 114, 117-118; Huston et al. 2015, p. 797; Worsham and Julius 2017, p. 6; Nair et al. 2023, entire). Due to the reduction of functioning wings for rapid dispersal, these beetles encounter difficulties when exposed to short periods of elevated temperatures (~ 3°C increase [5.4°F]). Such temperature spikes can adversely affect their metabolic response, overall longevity, and their ability to migrate to habitats with more favorable and less stressful conditions (Bosse et al. 1988, p. 201; Bowles et al. 2003, p. 379; Nair et al. 2023, p. 6).

Groundwater-dependent species with similar thermal tolerances and adaptive traits are constrained by their inability to migrate and face challenges relocating due to specific habitat requirements (Kløve et al. 2014, p. 263; Castaño-Sánchez et al. 2020, p. 7; Simčič and Sket 2021, entire; Becher et al. 2022, pp. 4–5). Some groundwater-dependent species would likely be incapable of adapting to modified temperatures in the medium to long-term and less capable, due to restricted dispersal capabilities, to flee rising temperature conditions than more generalist surface species (Culver and Pipan 2009, pp. 207–208; Taylor et al. 2013, pp. 324–325; Mammola et al. 2019, p. 646). Moreover, de-watered voids may emerge, prompting speculation that the species will attempt to follow the receding water into the aquifer, presumably seeking preferable water quality conditions (Cooke 2012, p. 30; Nair et al. 2023, p. 6). The potential for these riffle beetles to escape unfavorable conditions resulting from catastrophic drought in their habitat is uncertain. Nonetheless, considering the known challenges faced by this stenothermal, groundwater-dependent species in terms of migration and adapting to modified temperatures, it seems unlikely that the Comal Springs riffle beetle possesses a high degree of adaptability.

An assessment by U.S. Geological Survey evaluated the projected future vulnerability through 2050 of the Comal Springs riffle beetle and rated it as moderately vulnerable to climate change (Stamm et al. 2015, pp. 1, 40, 42, 47). Moderately vulnerable is defined as "abundance and/or range extent within geographical area assessed likely to decrease by 2050." While the rate of water temperature change in their habitat remains unknown, its potential impacts on water quality are significant. Increased water temperature can lead to the alteration of contaminant mobilization, changes in recharge rates, stimulation of metabolic processes, and disruption of biogeochemical processes such as the carbon or nitrogen cycle (Kløve et al. 2014 p. 263; Castaño-Sánchez et al. 2020 p. 7; Simčič and Sket 2021 entire; Becher et al. 2022 pp. 4–5). These mechanisms collectively contribute to a decline in water quality, affecting both subsurface and surface environments.

Therefore, the adaptive capacity ectothermic animals have to environmental changes is presumed to be low. For ectothermic macroinvertebrates, vulnerability to climate change depends on thermal sensitivity and the speed at which their buffered environment undergoes alterations (Pallarés et al. 2021, p. 487; Delić et al. 2022, p. 2). This will require more research globally to fully understand vulnerability of these aquifer ecosystems and their subterranean communities (Mammola et al. 2019, pp. 646–647; Hose et al. 2022, entire).

2.3 Synthesis

There are currently two genetically isolated populations of the Comal Springs riffle beetle in Texas. Demographic data, captive refugia research, and the five-factor threats analysis (Section 2.2.2) are collectively not indicative of the need for a change in listing status recommendation for the Comal Springs riffle beetle. Comal Springs riffle beetle populations rely on continuous management and protective measures to preserve habitat, prevent silt accumulation, manage groundwater pumping for optimal springflow, supply terrestrial organic matter for the food web, and maintain sufficient water availability and quality for overall ecosystem health. In conclusion, it is our recommendation that a change in classification is not warranted at this time.

3.0 RESULTS

3.1 Recommended Classification:

No change is needed

3.2 New Recovery Priority Number (indicate if no change; see 48 FR 43098):

No Change Recommended; see 48 FR 43098, September 21, 1983 & 48 FR 51985, November 15, 1983 - Correction)

Brief Rationale:

Primary stressors to Comal Springs riffle beetle populations are the loss of springflows and decreases in subsurface habitat due to drawdown of the Edwards Aquifer and reductions in water quality from development and land-use changes. Research suggests that contamination of groundwater has not been historically widespread, is at relatively low concentrations currently, and the subterranean ecosystems do not exhibit significant signs of degradation (Hutchins 2018, pp. 481–482). Current conservation, flow protection, and water quantity optimization measures in place have been effective in meeting biological objectives for EARIP HCP Covered Species, including the Comal Springs riffle beetle (National Research Council 2018, p. 109). Given projected human population increases, associated expansion of exurban, suburban, and urban development and climate change-induced droughts for south-central Texas, the impact on groundwater habitat quality and aquifer recharge into the future remains uncertain (Loáiciga and Schofield 2019, p. 224; National Oceanic and Atmospheric Administration 2022, unpaginated). The sustainable water output for the Edwards Aquifer could decrease in a dry climate while human demand for groundwater would increase, making it more challenging to balance groundwater use for human needs and ecosystem function, and thus, the EARIP HCP’s Comal Springs riffle beetle’s viability (Loáiciga and Schofield 2019, pp. 223, 235–236; EARIP HCP 2020, pp. 3-10–3-11, 3-12, 3-31, 3-43; Nielsen-Gammon et al. 2020, pp. 9–10).

In terms of viability, the Comal Springs riffle beetle occupies a restricted range of two genetically distinct populations as a narrow endemic species only occurring in groundwater-dependent spring ecosystems supplied by the Edwards Aquifer and are highly susceptible to extinction from perturbations that would affect water quantity and quality in the Edwards Aquifer and ongoing management is needed to maintain resiliency. Further, the absence of data to inform how these threats directly impact Comal Springs riffle beetle populations precludes a more detailed assessment of these impacts. Thus, our analysis does not warrant a change in recommended classification or recovery priority number. Therefore, we recommend the Comal Springs riffle beetle retain its classification as endangered due to its conservation-reliant status.

3.3 Listing and Reclassification Priority Number, if reclassification is recommended (see 48 FR 43098):

Reclassification (from Threatened to Endangered) Priority Number:
Reclassification (from Endangered to Threatened) Priority Number:
Delisting (Removal from list regardless of current classification) Priority Number:

Brief Rationale:

Not applicable

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

- Incorporate habitat-centered biological goals and objectives during EARIP HCP renewal process to promote protection of suitable habitat quality and quantity and species resiliency.
- Continue water quantity and quality monitoring at accessible spring and well sites within and the areas that recharge the occupied spring ecosystems for habitat quality.
- While there is a general understanding habitat quality decreases as silt accumulates and reduces springflow and water quality, the absence of quantitative studies linking variations in silt-free habitat to Comal Springs riffle beetle population estimates adds complexity, highlighting the need for research to understand the direct and indirect impacts of sedimentation on habitat suitability and food resources (National Research Council 2018, p. 46).
- Currently, there is a lack of sufficient biological and habitat data for the San Marcos Springs population. It is recommended that status surveys of the San Marcos ecosystem in Hays County, Texas are conducted to assess the health and status of this Comal Springs riffle beetle population. Texas State University's Meadows Center for Water and the Environment, responsible for overseeing Spring Lake which houses a genetically distinct population of the species, plays a pivotal role in their conservation efforts. The recent decrease in flow from Hotel Spring during the summer of 2023 underscores the vulnerability of this beetle population, which heavily depends on consistent, high-quality spring flow at San Marcos Springs (BIO-WEST, Inc. 2023, pp. vii, 15; Nair et al. 2023, p. 6). Collaboration with the Meadows Center for Water and The Environment and the EAA is essential to addressing these challenges which would improve our knowledge

regarding current population resiliency and the assurance of redundancy of this genetically distinct population into the future.

- Conduct research to reduce sources of nitrate into the Comal Springs ecosystem through coordination with agencies, public education, and other non-governmental organizations.
- Establish conservation easements or fund land purchases within the contributing and recharge zones of the Edwards Aquifer for the benefit of the Comal Springs riffle beetle and to ensure adequate springflow is sustained through droughts. Additionally, a site-prioritization tool could be developed to support decision making about strategic land acquisitions.
- To the extent possible, reduce increases in impervious surfaces or clearing of forest within the recharge areas supporting the species.
- Continue captive propagation research:
    - Conduct ongoing research to enhance captive propagation techniques.
    - Implementing a targeted microbial management strategy in captivity, informed by comprehensive microbiome analyses, to mitigate potential disruptions caused by factors described in Mays et al. (2021, pp. 3, 9), such as human contact and biofilm shedding from well water pipes. This proactive measure is essential for ensuring the resilience and sustainability of the captive populations over the long term.
    - Develop the capacity to produce offspring on-demand, anticipating standard operating procedures to inform action for potential catastrophic events or extirpation in the wild.
    - Formulate a comprehensive reintroduction plan based on research findings, ensuring the ability to replenish populations as needed.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of Comal Springs riffle beetle (*Heterelmis comalensis*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

FIELD OFFICE APPROVAL:

Acting Lead Field Supervisor, Fish and Wildlife Service, Austin Ecological Services Field Office

Approve ____

Appendix D7 | **USFWS 5-Year Species Status Review of the Comal Springs Dryopid Beetle**

Comal Springs Dryopid Beetle
(*Stygoparnus comalensis*)
5-Year Status Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
Austin, Texas
May 21, 2024

5-YEAR REVIEW

Species reviewed: Comal Springs dryopid beetle (*Stygoparnus comalensis*)

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5-YEAR REVIEW
Comal Springs dryopid beetle (*Stygoparnus comalensis)*

1.0 GENERAL INFORMATION

1.1 Reviewers:

Lead Regional or Headquarters Office:
Vanessa Burge, Recovery Biologist, Southwest Regional Office, Albuquerque, New Mexico, vanessa_burge@fws.gov

Lead Field Office:
Amelia Hunter, Fish and Wildlife Biologist, Austin Ecological Services Field Office, Austin, Texas, amelia_hunter@fws.gov

Cooperating Field Office(s):
Not Applicable

Cooperating Regional Office(s):
Not Applicable

1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service or USFWS) is required by section 4(c)(2) of the Endangered Species ESA (ESA) to conduct a status review of each listed species once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing as endangered or threatened is based on the species' status considering the five threat factors described in section 4(a)(1) of the ESA. These same five factors are considered in any subsequent reclassification or delisting decisions. In the 5-year review, we consider the best available scientific and commercial data on the species and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process including public review and comment.

1.3 Methodology used to complete the review:

The USFWS provides notice of status reviews via the *Federal Register* and requests new information on the status of the species (e.g., life history, habitat conditions, and threats). Data for this status review were solicited from interested parties through a *Federal Register* notice announcing this review on May 5, 2021 (86 FR 23976). The Austin Ecological Services Field Office conducted this review and considered both new and previously existing information from federal and state agencies, municipal and county governments, non-governmental organizations, academia, and the public. The primary sources of information used in this analysis was the final rule listing the Comal Springs dryopid beetle as endangered (62 FR 66295), revised critical habitat ruling for the Comal Springs dryopid beetle (78 FR 63100), research published in scientific journals, and unpublished reports and data.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

86 FR 23976 May 5, 2021

1.4.2 Listing history:

Original Listing
FR notice: 62 FR 66295
Date listed: December 18, 1997
Entity listed: Comal Springs dryopid beetle (*Stygoparnus comalensis*)
Classification: Endangered

Revised Listing, if applicable
FR notice: Not Applicable
Date listed: Not Applicable
Entity listed: Not Applicable
Classification: Not Applicable

1.4.3 Associated Rulemakings:

Critical habitat for Comal Springs dryopid beetle was revised on November 22, 2013, in areas of occupied, spring-related aquatic habitat with designations for surface and subsurface critical habitat (78 FR 63100). The original critical habitat designation encompassed only surface critical habitat and did not include any designation for subsurface critical habitat (72 FR 39248). Springs, associated streams, and underground spaces immediately inside of or adjacent to springs, seeps, and upwellings are the primary components of the physical or biological features essential to the conservation of this species (50 CFR 17.95; 78 FR 63120).

1.4.4 Review History:

Not Applicable

1.4.5 Species' Recovery Priority Number at start of 5-year review:

1C

1.4.6 Recovery Plan or Outline

Name of plan or outline: Not Applicable
Date issued: Not Applicable
Dates of previous plans/amendment or outline, if applicable: Not Applicable

2.0 REVIEW ANALYSIS

Section 4 of the ESA (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species meets the definition of "endangered species" or "threatened species." The ESA defines an "endangered species" as a species that is "in danger of extinction throughout all or a significant portion of its range," and a "threatened species" as a species that is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The ESA requires that we determine whether a species meets the definition of "endangered species" or "threatened species" due to any of the five factors described below.

Section 4(a) of the Act describes five factors that may lead to endangered or threatened status for a species. These include: A) the present or threatened destruction, modification, or curtailment of its habitat or range; B) overutilization for commercial, recreational, scientific, or educational purposes; C) disease or predation; D) the inadequacy of existing regulatory mechanisms; or E) other natural or manmade factors affecting its continued existence.

The identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an "endangered species" or a "threatened species." In assessing whether a species meets either definition, we must evaluate all identified threats by considering the expected response of the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species—such as any existing regulatory mechanisms or conservation efforts. The Service recommends whether the species meets the definition of an "endangered species" or a "threatened species" only after conducting this cumulative analysis and describing the expected effect on the species now and in the foreseeable future.

2.1 Distinct Population Segment (DPS) policy (1996):

Not Applicable

2.2 Updated Information and Current Species Status

2.2.1 Biology and Habitat

2.2.1.1 New information on the species' biology and life history:

Background

The Comal Springs dryopid beetle (*Stygoparnus comalensis*) is the only subterranean-adapted member of the family Dryopidae (Insecta: Coleoptera) (Barr and Spangler 1992, pp. 40-41). The first Comal Springs dryopid beetles were collected in 1987 in Comal County, Texas, from Comal Springs and later discovered at Fern Bank and Sessom springs in Hays County, Texas (Barr and Spangler 1992, p. 41; Barr 1993, pp. 31, 53-55; Kosnicki and Julius 2019, p. 3). This is the first 5-Year Review since the species' listing in 1997.

Biology

Unique morphological distinctions include vestigial (i.e., poorly developed and non-functioning) eyes and wings and eight-segmented antennae (Barr and Spangler 1992, p. 47). Adult Comal Springs dryopid beetles have a slender body with a length of 3-3.7 millimeters (mm) (0.12-0.16 inches (in)) and are unable to swim (Barr and Spangler 1992, p. 47; Nowlin et al. 2022, p. 20). Adults respire through a plastron (i.e., small, hydrophilic hairs that diffuse oxygen from the water into the body), limiting them to habitats with high dissolved oxygen (Brown 1987, p. 260; Barr and Spangler 1992, pp. 43-49; Yee and Kehl 2015, p. 1011).

Larvae lack eyes, are elongate, cylindrical, and yellowish-brown in color, with wedge-shaped teeth (i.e., tridentate) with a fusiform (i.e., round) head (Barr and Spangler 1992, pp. 44, 49). Larvae develop a terrestrial breathing apparatus called spiracles to breathe air, unlike other Coleopteran larvae that use anal gills to breathe in water (Barr and Spangler 1992, p. 50). Mature larvae are approximately 6-8 mm (0.24-0.31 in) long (Barr and Spangler 1992, p. 49).

Life History

Comal Spring dryopid females in captivity produce several clutches of eggs over many months with a maximum capacity of 10-14 eggs, independent of body size (Kosnicki and Julius, 2019 pp. 12-13). The most productive captively held female was estimated to potentially produce up to 130 eggs in her lifetime, but fecundity estimates could not be ascertained (Kosnicki and Julius 2019, p. 13).

Under captive conditions, eggs require two to three months to incubate above water before hatching with a 22 percent hatching success (Kosnicki and Julius 2019, p. 13). It is unknown if eggs can hatch underwater or if humid conditions are necessary for development (Kosnicki and Julius 2019, p. 20). It is uncertain how eggs laid in subterranean voids can access air spaces to reach the next life stage and if those spaces are available underground.

A study of Comal Springs dryopid beetle larva observed early instar individuals burrowing into conditioned poplar wood dowels and sycamore leaves to hide, with later instar larvae observed excavating trenches into the dowel, which served as both a food source and shelter (Kosnicki and Julius 2019, pp. 7, 15-18). A single Comal Springs dryopid beetle larva was produced and grew from approximately 2-10 mm (0.08-0.40 inch (in)) in length over nine months, suggesting development of larvae may only take one year (Fries et al. 2004, p. 10; Kosnicki and Julius 2019, p. 4). Larvae are estimated to have six instars (i.e., molts), with an average of 22.4 days per instar (Kosnicki and Julius 2019, p. 16). The pupal stage for this species has not been observed (Kosnicki and Julius 2019, pp. 1, 20). Likewise, eclosion (i.e., hatching) and associated environmental cues, if they exist, have not been researched.

Some wild caught adult Comal Springs dryopid beetles have survived in captivity for 11 to 21 months, but the lifespan of this species remains unknown (Barr and Spangler 1992, p. 51; Fries et al. 2004, p. 10). There is no research on survival rates of wild surface or subterranean aquatic locations of this species and if they differ (Barr 1993, p. 52). A beetle that lived for a year in captivity experienced a decrease in plastron surface area to the time of death, hypothesizing abrasion of the setae (i.e., bristle-like hairs) occurred or aging (Fries et al. 2004, p. 10).

2.2.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, birth rate, seed set, germination rate, age at mortality, mortality rate, etc.), or demographic trends:

Little is known about limiting factors that may impact the abundance and distribution of the Comal Springs dryopid beetle. Current abundance estimates only include samples collected at the surface.

Fluctuations in the numbers of dryopid beetles and larvae have been observed by researchers for reasons that remain unknown. However, it is established that droughts can lead to a reduction in springflow, prompting the species to seek shelter and preferred water quality further down in the aquifer. Conversely, during periods of record-high springflows, the beetles may be dislodged into surface waters downstream due to their slow and fragile nature (Barr 1993, p. 54). This non-swimming, flightless aquatic beetle faces limited opportunities for expanding its range. This species is rarely collected, likely because its preferred habitat is challenging to sample (BIO-WEST, Inc. 2007, p. 39; Gibson et al. 2008, p. 77).

Drift and kick netting surveys in the 1990s resulted in the collection of just 10 adults during a month sampling period and only four larvae at a subset of the sites sampled (Barr and Spangler 1992, pp. 41, 51; Barr 1993, pp. 54, 41). Fewer dryopid beetle individuals were captured when flows and aquifer levels increased (i.e., as measured at San Antonio reference well, J-17) (Barr 1993, p. 55). Most species were collected at low-volume springs (i.e., spring runs 2 and 4 at Comal Springs and Fern Bank Springs) compared to the high-volume spring run 1 and 3 at Comal Springs (Barr 1993, p. 55).

Surveys in 2003 collected an average of 0.3 beetles/day at spring runs 1-3 of Comal Springs (Fries et al. 2004, pp. 6-7). At Fern Bank Springs, no subterranean species were caught at the pool or hillside sites (Gibson et al. 2008, p. 76). The species has been confirmed at Fern Bank Springs in 2003, when a single larva was collected after 398 hours of sampling spring orifices with drift nets (Gibson et al. 2008, p. 77). A more recent sampling effort from a spring emanating from the bluff of the Blanco River adjacent to the spring property suggested dryopid beetles at this site are productive with 31 adults and eight larvae collected (Nowlin et al. 2022, pp. 8, 15, 24). Additionally, the species was also captured at Sessom Springs in Hays County but have not been detected since 2017 (USFWS 2017, pp. 20-21, 24; Clough 2022, p. 1).

2.2.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Population structure suggests genetic differentiation between the three major spring ecosystems (i.e., Comal, Sessom, and Fern Bank springs) occupied by the species with no evidence of recent gene flow (Nowlin et al. 2022, pp. 12-13, 23-24). This variation is not associated with their feeding niche, trophic ecology, or morphology (Nowlin et al. 2022, p. 4).

2.2.1.4 Taxonomic classification or changes in nomenclature:

Dryopidae (Insecta: Coleoptera) is a family of long-toed water beetles distributed worldwide except for Australia and Antarctica with approximately 300 species (Yee and Kehl 2015, p. 1029). In North America, there are five genera and 13 described species of dryopids (Shepard 2002, p. 122). The Comal Springs dryopid beetle is the only subterranean adapted member of this family and is the only species in the genus *Stygoparnus* (Barr and Spangler 1992, pp. 40-41).

2.2.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, pollinator availability, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Comal Springs dryopid beetles are groundwater obligate invertebrates and spring endemics that have not been observed outside of spring ecosystems. This suggests that individuals of the species are not distributed throughout the aquifer and may be confined to small areas once at the surface (62 FR 66295). The species occurs in the aquifer at distances up to 110 meters (m) (360 feet (ft)) from spring outlets, somewhere within the groundwater-surface water interface (78 FR 63103). Additionally, they are more frequently caught at low-flow springs like Fern Bank Springs and spring runs 2 and 4 at Comal Springs and terrestrial margin seeps, compared to higher-flow springs like spring runs 1 and 3 at Comal Springs.

The first Comal Springs dryopid beetles were discovered in 1987 in Comal County, Texas, specifically at spring run 2 in Comal Springs (Barr and Spangler 1992, p. 41). Since then, specimens have been identified at various locations within Comal Springs, including spring runs 1, 3, 4, 5, and 7 at Comal Springs, the western shoreline and Spring Island areas of Landa Lake (i.e., impounded section of the Comal Springs system), Panther Canyon well (i.e., a shallow well 110 m (360 ft) upslope of Comal Springs) (Barr 1993, pp. 31, 53-55; BIO-WEST, Inc. 2004, p. 34; Fries et al. 2004, pp. 9, 14-15; Gibson et al. 2008, pp. 76-77).

Additionally, two locations in Hays County, Texas have been identified: Sessom Springs and Fern Bank Springs (32 km (20 mi) northeast of Comal Springs), specifically at the easternmost orifice (i.e., "hill 3") and Cove Spring (Barr 1993, pp. 31, 53-55; BIO-WEST, Inc. 2004, p. 34; Fries et al. 2004, pp. 9, 14-15; Gibson et al. 2008, pp. 76-77; Kosnicki and Julius 2019, p. 3).

2.2.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

Comal Springs dryopid beetle adults inhabit subterranean spaces associated with springs issuing from the Edwards Aquifer, and their association with the surface can only be hypothesized (Barr and Spangler 1992, p. 52). Specific habitat requirements for this species are unknown given the difficulty of humans accessing their subsurface habitat (Gibson et al. 2008, p. 77). It is also unknown if this species can re-enter the subterranean aquifer once it has emerged or been discharged from springs (Barr 1993, p. 52). Specific springflow requirements and the breadth of subterranean habitat this species uses are unknown; habitat management relies on assuring historical conditions are maintained within the natural habitat for the species (LBG-Guyton and Associates et al. 2004, pp. C-4–C-5).

Comal Springs dryopid beetles are collected from the clear headwater spring orifices consisting of coarse sand and angular cobbles or along seeps of the terrestrial margin where soil, fallen leaves, and rocks line the surface 5-31 centimeters (cm) (2-12 in) deep (Barr and Spangler 1992, p. 41). Roots and organic debris associated with the aquifer and spring outlets may act as substrate for growth of microorganisms for food and may provide shelter (Gibson et al. 2008, p. 77; 77 FR 64274). They are attracted to flowing water sources in captive settings, working against the flow to stay near a food source (Kosnicki and Julius 2019, pp. 11, 19).

They have not been observed feeding on leaf litter fragments, but greater than 75 percent of their diet is derived from terrestrial organic matter (Barr and Spangler 1992, p. 51; Nair et al. 2021, pp. 240, 242; Nowlin et al. 2022, pp. 16-19). Comal Springs dryopid beetle adults feed on photosynthetic (i.e., terrestrial) organic matter energy sources (e.g., biofilms) scraped from surfaces such as rocks, wood, and vegetation and not periphyton-based organic matter; detritus, leaf litter, and decaying roots (Simon et al. 2003, p. 2404; Hutchins et al. 2016, pp. 1536, 1538; Nowlin et al. 2017, pp. 16-18; Nair et al. 2021, pp. 240, 242). A co-occurring species, the Comal Springs riffle beetle (*Heterelmis comalensis*), derives most of its food from the same organic matter sources, but has a less than or equal to 1 percent niche overlap with the dryopid beetle at Comal Springs (Nair et al. 2021, p. 244). Larvae are presumed to occupy moist soils along the margins of surface aquatic habitats and are presumed to have the capacity to inhabit air-filled pockets within the ceilings of the spring orifices where organic debris may serve as shelter and act as substrate for growth of microorganisms on which it feeds (Barr and Spangler 1992, pp. 41, 51-52).

The principal habitat at Comal Springs (spring runs) maintains a fairly stable water temperature (20.7°Celsius (°C) (69.3°Fahrenheit (°F)), specific conductivity (579-587 micro siemens/centimeter (µs/cm)), and dissolved oxygen (5.1-5.2 milligram per liter [mg/L]), with few detections of contaminants (BIO-WEST, Inc. 2021, p. 18; EAA 2013, p. 62; EAA 2018, p. 5; EAA 2021a, pp. 27-36, 45-47). Conditions further down in Landa Lake and Spring Island are typically warmer (23.9 °C [75°F]) (BIO-WEST, Inc. 2021b, p. 18).

However, total dissolved solids and conductivity at Comal Springs have trended upward since the 1970s, but are stabilizing, while nitrates have doubled (median concentration 2 mg/L) since the 1970s (Musgrove et al. 2016, pp. 462, 465, 467; EPA 2023a, unpaginated, EPA 2023b, unpaginated). These changes in water quality in streams and groundwater correspond with increases in impervious cover over a watershed (Kaushal et al. 2005, p. 13518; Baker et al. 2019, pp. 6494–6495; Castaño-Sánchez et al. 2020, p, 6).). These water quality parameter changes may be a long-term indication of urbanization that has already occurred across the recharge zone.

Information for habitat conditions at Fern Bank Springs are incomplete due to lack of access. The best available information indicates that the shallow spring waters at Fern Bank Springs are neutral (pH 7.2) shallow waters, water temperature averaging 21°C (70°F), supersaturated with oxygen (6.8-7.4 mg/L; 98-100 percent saturation), and are relatively constant (Barr 1993, p. 40; Fries et al. 2004, pp. 4, 13).

The surface of Sessom Springs is covered with concrete along a road, and access to the water emerging from the aquifer is facilitated through PVC piping hammered into the spring openings for sampling. This unique infrastructure, coupled with the concrete overlay, not only raises questions about the beetles' potential habitat, as they have been observed to also reside at the surface in other spring environments, but also means that there is a notable reduction of terrestrial organic matter compared to a more natural riparian area. According to one report, adult beetles at Sessom Springs occupy a much more limited area compared to other populations of the species (Nowlin et al. 2022, pp. 4, 16). Water quality has not been documented at Sessom Springs. While the springs are likely fed by regional groundwater flow, the possibility of contributions from surface water flows, possibly comprising Sessom Creek water with known higher non-point source contaminant levels upstream of the springs, adds an additional layer of uncertainty regarding this site (Loiácomo 2019, p. 42; EAA 2022, pp. 24, 52-53).

2.2.1.7 Other:

Biological Constraints and Needs

The Comal Springs dryopid beetle occurs in a limited range at a small number of localities with little or no ability to disperse between or beyond these localities. These characteristics make them susceptible to local extirpation and extinction (McKinney 1997, p. 499; O'Grady et al. 2004, p. 514). A severe drought or water contamination event could eliminate many or all the existing populations. Having a high number of individuals of the species at a site provides no protection against extinction due to stochastic events. Dispersal beyond their extant range is unlikely, given the isolated nature of the spring headwater system dynamics and aquifer hydraulic connectivity that limit movement of individuals.

The areas inhabited by individuals of the species can be protected through localized conservation measures (e.g., intact riparian zones, springflow protection measures); however, the groundwater that provides water quality and quantity for the species can originate a significant distance from these habitats, and efforts that protect or conserve groundwater may be variable in their success and implementation. Although some of the threats can be adequately addressed, the inherent problems associated with narrow endemics in isolated habitats will always be present. Even with the most effective management and recovery plans in place, the species remains vulnerable to devastating stochastic events such as floods or droughts that could eliminate the species.

Fern Bank Springs Private Ownership

Fern Bank Springs is privately-owned, located 8 km (5 mi) east of Wimberley, Texas off a bank of the Blanco River at an elevation of 235 m (770 ft) (Barr 1993, p. 39). Fern Bank Springs discharges from a cave and the stream cascades into a manmade pool and continues down the bluff into the Blanco River just upstream of the Edwards Aquifer recharge zone (Fries et al. 2004, p. 8; Gibson et al. 2008, p. 76; Johnson et al. 2012, pp. 79-80). The property is relatively undeveloped, and access is rarely granted to researchers (Barr 1993, p. 39). Thus, evaluation of habitat conditions, current population or demographic data, documented changes in land-use activities, or ability to conduct future recovery actions and activities are not achievable at this time.

2.2.1.8 Conservation Measures:

Groundwater Quantity

The Edwards Aquifer Authority (EAA) is charged with protecting terrestrial and aquatic life, domestic and municipal water supplies, the operation of existing industries, and the economic development of the entire Edwards Aquifer (Chapter 626, Laws of the 73rd Texas Legislature, 1993). Aquifer management since these rules were implemented have been successful at controlling groundwater withdrawals to maintain springflows. By EAA estimates, Comal Springs would have likely ceased flowing during the 2014 drought period without current regulations (EAA 2015, p. 62). Currently, these regulations have been effective in managing the Edwards Aquifer and reducing the risk of substantial declines in spring flows at Comal and San Marcos Springs.

Another important conservation measure is implementation of the City of San Antonio's Edwards Aquifer Protection Program (Stone and Schindel 2002, pp. 38-39; City of San Antonio 2023, pp. 3, 6). In 2000, the voters of San Antonio passed Proposition 3, a $65 million sales tax initiative, to fund the acquisition (i.e., fee-simple and conservation easements) of open space to protect the contributing and recharge zones of the aquifer in Bexar County (Romero 2018 p. 2). Protection of open space has the potential to reduce the impacts of development (e.g., run-off form impervious cover, fertilizer applications, and wastewater) on maintain aquifer recharge (Reilly and Carter 2018, pp. 3-2, 3-6; Romero 2018, pp. 5-6). That program was re-approved in 2005, 2010, and 2015 with additional funds to acquire open space (Reilly and Carter 2018, pp. 1-3–1-5). The effort was later expanded to acquire lands in Medina and Uvalde counties that contain larger portions of the contributing and recharge zones (Romero 2018, pp. 5-6, 8). The dedicated sales tax expired in 2021 with 97,124 hectares (ha) (240,000 acres (ac)) acquired under the Edwards Aquifer Protection Program (Siglo Group 2022, pp. 51-52). The City of San Antonio recently approved an alternative funding stream to support land acquisitions through the commitment of $100 million over ten years (City of San Antonio 2023, pp. 3, 6).

Groundwater Quality

There are several laws and regulations to protect water quality that apply to the Edwards Aquifer. The Federal Safe Drinking Water Act of 1974, as amended, regulates pollution and sedimentation of public drinking water sources, including the Edwards Aquifer. This legislation mandates enforcement of drinking water standards established by the Environmental Protection Agency. The Texas Commission on Environmental Quality (TCEQ) is responsible for enforcement of these standards in Texas. Under the authority of the Texas Administrative Code (TAC) (30 TAC § 213), the TCEQ regulates activities having the potential for polluting the Edwards Aquifer and hydrologically connected surface streams through the Edwards Aquifer Protection Program or "Edwards Rules." The Edwards Rules require several water-quality protection measures for new development occurring in the recharge zone and portions of the contributing zone of the Edwards Aquifer. The TCEQ also prohibits facilities such as municipal solid waste landfills and waste disposal wells from being built in the recharge or transition zones.

Discharge from non-point residential or agricultural sources is one of the primary sources of pollution in the Edwards Aquifer. Texas has an extensive program for the management and protection of water that operates under State statutes and the Federal Clean Water Act. The Program includes regulatory programs such as the following: Texas Pollutant Discharge Elimination System, Texas Surface Water Quality Standards, and Total Maximum Daily Load Program (under Section 303(d) of the Clean Water Act).

The TCEQ's Texas Pollutant Discharge Elimination System program regulates discharges of pollutants to Texas surface water. Through the Pollutant Discharge Elimination System program, the TCEQ authorizes the discharge of stormwater and non-stormwater to surface waters in Texas associated with storm sewer systems and construction sites, which must meet the requirements of the Edwards Rules.

A watershed protection plan was accepted in 2018 by TCEQ for the Dry Comal Creek and Comal River Watershed by the City of New Braunfels. Dry Comal Creek has not met state water quality standard for bacteria, and the watershed protection plan is intended to address and reduce the elevated bacteria levels through management (TCEQ 2020, p. 1). Another watershed protection plan for the Upper San Marcos River was approved in 2018 by TCEQ. The watershed protection plan addresses the impairment of the Upper San Marcos River due to elevated total dissolved solids, and proactively addresses bacteria, nutrients, sediment, and future growth scenarios for the watershed (TCEQ 2018, p. 1).

The EAA has additional regulations (EAA rule 713) that apply to the recharge zone and five miles upgradient of the recharge zone. Much of the contributing zone occurs outside of the EAA jurisdiction (EARIP HCP 2020, pp. 1-4, 1-5) and is not subject to these regulations. New development in the Edwards Aquifer recharge, transition, or contributing zones is reviewed by the TCEQ Edwards Aquifer Protection Program (30 TAC § 213.1). For the contributing zone, the rule covers activities that disturb more than two hectares (five acres) in Medina, Bexar, Comal, Kinney, Uvalde, Hays, Travis, and Williamson counties

(30 TAC § 213.20). The contributing zone in Bandera, Kerr, and Kendall counties does not have additional protections under either program.

Several other entities also have measures to protect groundwater from contamination including the EAA's Aboveground Storage Tank Program, Agricultural Secondary Containment Assistance Program, and Abandoned Well Program among others (EAA 2022, entire). The San Antonio Water System implements several water quality protection measures including development regulations (i.e., Aquifer Quality Protection Ordinance No. 81491) for properties over the contributing and recharge zones, review of building permits and master development plans, regulation of underground storage tanks, commercial/industrial compliance, and an abandoned well program (San Antonio Water System 2022, unpaginated).

In addition to these state and federal regulations, a significant number of local regulations to protect water quality were implemented by the City of San Marcos, City of New Braunfels, EAA, and Texas State University as part of the Edwards Aquifer Recovery Implementation Program Habitat Conservation Plan (EARIP HCP; see sub-section below). Texas Water Code (Chapter 36) allows groundwater districts, but not cities, to regulate groundwater, including groundwater quality. However, cities can regulate pollution at the surface that ultimately impacts groundwater quality.

Habitat Conservation Plan

The Edwards Aquifer Recovery Implementation Program Habitat Conservation Plan (EARIP HCP) was finalized in 2013, amended in 2020, and covers incidental take of these species for groundwater withdrawal, recreation, and other activities through 2028 (EARIP HCP 2020, entire). Permittees to the plan include the EAA, City of San Antonio acting through the San Antonio Water System, City of New Braunfels, City of San Marcos, and Texas State University (National Research Council 2015, pp. 25–26). The EARIP HCP includes activities to minimize and mitigate impacts and contribute to the recovery of the eleven Covered Species and addresses a variety of aquifer management issues, including ensuring springflow during a repeat of the drought of record (Payne et al. 2019, p. 200; EARIP HCP 2020, pp. 4-57–4-59, 4-62–4-66). Long-term commitments to protect listed species in the Edwards Aquifer beyond the HCP and the term of its associated section 10(a)(1)(b) permit are not currently in place. However, a new habitat conservation plan is expected in 2028.

The current EARIP HCP biological goal that centers on water quality for the Comal Springs dryopid beetle is: "Not exceed a 10 percent deviation (daily average) from historically recorded water quality conditions (long-term average) in the Edwards Aquifer as measured issuing from the spring openings at Comal Springs"; there are no habitat-centered biological goals or biological objectives specific to this species.

A captive refugia and associated research is funded by the EARIP HCP through a contract (Contract # 16-822-HCP) with two USFWS facilities in San Marcos and Uvalde, Texas (EARIP HCP 2020 p. 5-3). The contract was established to protect species left vulnerable to extirpation throughout a significant portion of their range due to a limited geographic distribution of the population and will preserve the capacity for these species to be re-established in the event of the loss of population due to a catastrophic event, such as the unexpected loss of springflow or a chemical spill. Research activities expand knowledge on habitat requirements, biology, life histories, and effective reintroduction techniques for the species.

2.2.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms):

2.2.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Water Quantity

A primary threat to the habitat of the Comal Springs dryopid beetle is the potential loss of springflows and reduced water quantity underground brought on by groundwater withdrawals from the southern segment of the Edwards Aquifer. Springflows at Comal, Sessom, and Fern Bank springs ecosystems are tied inseparably to water usage for the southern segment of the Edwards Aquifer. Groundwater pumping to meet municipal, industrial, and irrigation uses, is a widely recognized threat to the persistence of subsurface and surface groundwater-dependent ecosystems (Danielopol et al. 2003, pp. 109-112; Eamus et al. 2016, pp. 317, 333-335; Mammola et al. 2019, pp. 645-646). Removal of groundwater from an aquifer leads to water level decline, especially if discharge of groundwater significantly exceeds recharge (Theis 1940, pp. 278-280; Alley et al. 2002, pp. 1,986; Foster and Chilton 2003, pp. 1,961-1,962). Declining aquifer levels can result in springflow decline or failure, loss of stream and creek base-flow, and/or drying of water-filled caverns (Springer and Stevens 2009, pp. 9-10; Eamus et al. 2016, pp. 316-318, 333-335).

If not replenished through recharge, groundwater discharged through wells and springs is removed from aquifer storage (i.e., total amount of water in aquifer), and with absent or much reduced recharge, persistent groundwater removal would initially lead to decline and/or cessation in springflows (Lindgren et al. 2004, p. 41). Like other karst aquifers, water levels of the Edwards Aquifer fluctuate with recharge (i.e., distribution, amount, and intensity of rainfall) and discharge (i.e., wells or springs) (Petitt and George 1956, p. 49; Buszka 1987, pp. 24-27; Maclay 1995, pp. 48, 52; Worthington et al. 2003, p. 4; Lindgren et al. 2004 pp. 40-41, 45). Prolonged dry periods result in declines in aquifer, but water levels rebound rapidly with return of precipitation (Petitt and George 1956, p. 49). Groundwater pumping has exceeded recharge multiple times with water levels rebounding with increased rainfall (Petitt and George 1956, p. 49). The longest period was the drought of record (a three-year period when aquifer recharge was at its lowest recorded level) during the mid-1950s (Arnow 1959, pp. 27-29). At one point, Comal Springs stopped flowing from June 13 through November 3, 1956, during the drought of record (Puente 1976, p. 22; Barr 1993, p. 61).

In the early 1990s, federal litigation (i.e., *Sierra Club vs. Secretary of the Interior* [No. MO-91-CA-069] United States District Court for the Western District of Texas) resulted in the creation of the EAA in 1993 by the State of Texas to manage groundwater withdrawals (i.e., by nonexempt wells) from the southern segment and limit Edwards Aquifer pumping authorized through permits (National Research Council 2015, pp. 24-26; Hardberger 2019, pp. 193-194; Payne et al. 2019, p. 199). During the 2007 legislative session, the Texas Legislature increased the annual maximum amount of pumping that could be authorized by permits to 705,551 megaliters (572,000 acre-feet) and directed the EAA to adopt and enforce a "Critical Period Management" plan establishing targeted withdrawal reductions during times of drought to achieve the water, species, and species habitat conservation goals established in the agency's enabling legislation (80th Texas Legislature, 2007, Senate Bill 3). Aquifer management since these rules were implemented have been successful at reducing groundwater withdrawals, but currently do not account for future droughts that may be worse than the drought of record. The Stage V Critical Period Management that currently exists is also tied to the Edwards Aquifer Recovery Implementation Program Habitat Conservation Plan (EARIP HCP) but could be subject to change after species recovery.

Springflows have been protected at Comal Springs during recent droughts in the 2000s and 2010s because of groundwater pumping restrictions from the EAA during periods of drought. During the 2008-2009 drought, springflows remained at sufficient levels to maintain resiliency for the EARIP HCP’s Covered Species (above 2.3 cubic meters per second (m^3/s) (80 cubic feet per second (cfs)) (USGS station 08169000). By EAA estimates, Comal Springs likely would have gone dry during the 2014 drought without the enforcement of Critical Period Management (EAA 2015, pp. 1, 62).

The former owner of Fern Bank Springs, spanning from the 1800s to 2009, asserted that the springs never ran dry, even during the drought of record (EARIP HCP 2020, p. 3-30). The best data currently available does not show any variation in the springflow of Fern Bank Springs, indicating it is a perennial spring. However, it is important to note that this site lacks a gauge and is only sporadically monitored for discharge (Barr 1993, p. 39).

Sessom Springs, another ecosystem where the Comal Springs dryopid beetle is present with an established population, lacks comprehensive monitoring data for its springflow. Unfortunately, the absence of such data makes it challenging to determine the current status of the habitat. The uncertainty surrounding the springflow data for Sessom Springs emphasizes the need for further investigation to assess and safeguard the habitat of the Comal Springs dryopid beetle in this particular ecosystem.

The potential impact of extended periods of low flow and drying conditions on the Comal Springs dryopid beetle remains unclear. This uncertainty is primarily attributed to the limited availability of life history and abundance data. One hypothesis suggests that if adult females lay eggs at the surface, the negative effects of drying may be more pronounced (Barr 1993, pp. 61-62). Nevertheless, uncertainties persist regarding the species' egg-laying behavior and the environmental cues involved, such as whether it occurs underground or on the surface (Section 2.2.1.1).

While a repeat drought of record has not occurred, modeling indicates that the Critical Period Management plan during Phase II of the EARIP HCP will maintain springflows above 0.85 m^3/s (30 cfs) at Comal Springs and above 1.3 m^3/s (45 cfs) at San Marcos Springs during a drought of record. However, the plan is currently unable to return springflows at either spring system to 2.3 m^3/s (80 cfs) within six months (EARIP HCP 2020, pp. 4-58, 4-66). Future droughts may also be more severe than the drought of record, and current aquifer management does not account for this.

Groundwater will continue to be a source of water in the future as city populations increase. Predicted water demands for the four counties within the San Antonio pool (i.e., Hays, Comal, Bexar, Medina) are projected to increase by 48 percent in the year 2070, insufficient to fulfill using existing supplies (Texas Water Development Board 2021, p. A-2–A-3). Strategies identified by the State of Texas and Groundwater Conservation Districts for these counties are contingent on funding and infrastructure availability (Texas Water Development Board 2021, entire).

Springflows needed to sustain resilient populations are species-specific and contingent on habitat use and requirements. The biological opinion (USFWS 2013, p. 129) associated with the EARIP HCP concluded that the issuance of the Incidental Take Permit for the EARIP HCP is not likely to jeopardize the continued existence of the Comal Springs dryopid beetle or destroy or adversely modify their designated critical habitat. Modeled springflows for conditions during Phase II project Comal Spring flows to remain at approximately 1.4 m^3/s (50 cfs) during a repeat drought of record (USFWS 2013, pp. 32, 91, 100), greater than the springflows during the drought of record when it ceased for four months in 1956.

Springflows for the Comal Springs dryopid beetle were not included in the 1995 recovery plan or quantitative delisting criteria. The springflows affecting the Comal Springs dryopid beetle and its habitat may differ from other surface species. For example, at 0.9 m^3/s (30 cfs) at spring runs 2 and 3 of Comal Springs do not provide surface habitat for invertebrates (EAHCP 2020, pp. 4-97–4-98). The USFWS determined that 0.9 m^3/s (30 cfs) during a repeat drought of record is not likely to jeopardize the Comal Springs dryopid beetle (USFWS 2013, p. 129). Water from Panther Canyon well, seeps along the western shoreline of Landa Lake, and within upwellings near Spring Island are expected to continue providing habitat during low flow conditions within the Comal Springs ecosystem.

Despite surviving the drought of record during the mid-1950s without being extirpated, the Comal Springs dryopid beetle likely suffered adverse effects from unregulated aquifer pumping during that drought period due to their aquatic nature when the springs remained dry for several months (Arnow 1959, pp. 27-29; Barr 1993, pp. 61-62). Additionally, it is reasonable to expect that populations of the species may be stranded and extirpated by receding groundwater. The Comal Springs dryopid beetle could be even more negatively impacted if adults are restricted to the vicinity of spring openings because of the potential terrestrial requirements of the immature stages (Barr 1993, pp. 61-62).

Moreover, for the other two populations of Comal Springs dryopid beetles at Fern Bank and Sessom springs, there is great uncertainty regarding the impacts of extended cessation of springflows. The unique ecological conditions of these habitats further complicate predictions, as they may have different hydrological dynamics compared to the main Comal Springs habitat. This lack of data poses significant challenges in understanding the vulnerabilities of these populations to changes in water quantity.

In summary, the potential cessation of springflows poses a significant concern for the Comal Springs population, given their need for consistent water sources. Additionally, this dryopid beetle is not likely adapted to surviving long periods of drying or stagnation (depending on the duration and severity), especially if the current water management plan for the Edwards Aquifer accommodating the water quantity needs of the Comal Springs dryopid beetle were to cease.

Water Quality

Water quality at Comal, Sessom, and Fern Bank springs ecosystems where the Comal Springs dryopid beetle is found are influenced by groundwater and surface water. These three spring ecosystems depend on groundwater flow from the southern segment of the Edwards Aquifer. This segment of the aquifer is fed by many stream systems that enter the aquifer through recharge features.

The Edwards Aquifer is vulnerable to contamination because the limestone and carbonate rocks are highly permeable and exposed at the surface in the recharge zone (Clark 2000, pp. 1-2, 8-9; Burri et al. 2019, p. 150). Contaminants, commonly linked to urban and suburban activities such as residential and commercial development, industrial operations, transportation infrastructure, and waste disposal, tend to accumulate in higher concentrations within the shallow areas of recharge zones, especially in regions characterized by urban land uses (Wilson 2011, pp. 1-2; Lin and Gong 2016, pp. 384-385; Opsahl et al. 2018, p. 58).

There are currently no established groundwater quality standards for subterranean ecosystems, and the concentrations of pollutants that could harm subterranean species remain unclear (Hinsby et al. 2008, p. 10; Manenti et al. 2021, p. 2). However, subterranean fauna are likely to exhibit greater vulnerability to contaminants and a longer recovery period from stochastic events compared to surface fauna because of their inherent limitations, including a lack of adaptations to pollutants, isolation within their habitat, and restricted dispersal abilities, all of which render them sensitive to environmental disturbances (Hose 2005, p. 961; Di Lorenzo et al. 2019, pp. 293–294, 300; Hose et al. 2022, p. 2206).

Although water quality in the Edwards Aquifer is generally good, several studies have detected contaminants in groundwater from the southern segment including nitrates, herbicides, pesticides, and polycyclic aromatic hydrocarbons, among many others (Fahlquist and Ardis, 2004 pp. 7-8, 10; Johnson et al. 2009, pp. 10-13, 23-26, 31-35; Musgrove et al. 2014, pp. 67, 69-71; Opsahl et al. 2018, p. 58; Opsahl et al. 2020, pp. 17-30). For example, contaminants have exceeded public drinking water standards in springwater and surface water recharging the aquifer, including antimony, arsenic, lead, lithium, and tetrachloroethene (Johnson et al. 2009, p. 45). However, groundwater contamination has not been shown to be widespread or with large numbers of substances present in concentrations that exceed drinking water standards (Bush et al. 2000, pp. 1-2, 14-21; Fahlquist and Ardis 2004, pp. 7-8, 10; Johnson et al. 2009, 44, 47; Opsahl et al. 2018, p. 58; Opsahl et al. 2020, pp. 17-30; EARIP HCP 2020, pp. 3-40-3-42).

Some sources of water quality degradation include impervious cover and stormwater runoff, construction activities, recharge from irrigation return flow (i.e., water that is not lost from evapotranspiration on laws or to stream runoff), wastewater discharge, transportation infrastructure, and hazardous materials spills resulting from development within the watersheds that contribute flows to subterranean habitats (Passarello et al. 2012, pp. 29–34; Lapworth et al. 2012, entire).

Forested land with limited human disturbances contributes to high-quality recharge (Dudley and Stolten, 2003 pp. 11, 58; Shah et al. 2022, p. 120,396), while rural and exurban land uses contribute to groundwater contamination from leaking sewage, refuse dumping, and dead livestock (Sui et al. 2015, p. 21; Katz 2019, p. 565; EARIP HCP 2020, pp. 5-43). Septic systems are a likely source of nutrients (EARIP HCP 2020, p. 5-43; Sui et al. 2015, p. 21). Once a source of pollution enters groundwater, it can be difficult if not impossible to track, intercept, and remediate because of karst conduit complexity (Humphreys 201,1 p. 297). Since water quality in the Edwards Aquifer is generally good, this indicates that local sources of water pollution can disproportionately affect water quality in portions of the aquifer.

Oil and gas transmission pipelines are another potential source of hazardous material spills on the contributing and recharge zones of the aquifer. The "development and production of oil, gas, or a geothermal resource within the jurisdiction of the Texas Railroad Commission" are not considered regulated activities "having the potential for polluting the Edwards Aquifer and hydrologically connected surface water in order to protect existing and potential uses of groundwater and maintain Texas Surface Water Quality Standards" (Texas Natural Resource Conservation Commission 1996, p. 1). Consequently, the construction and maintenance of these pipelines are not subject to guidance mitigating impacts to karst features such as voids, and development of these pipelines are not subject to the Edwards Aquifer rules (Texas Natural Resource Conservation Commission 1996, entire).

Abandoned groundwater wells are a source of potential contamination from shallow groundwater into subsurface habitat. Shallower wells (< 300 m [< 984 ft]) are less likely than deeper wells to intercept older groundwater that received cumulative, diluted inputs of pollutants across the aquifer and therefore are more likely to intercept anthropogenic contaminants coming directly from the surface than deeper wells (Musgrove et al. 2014, pp. 69, 73). The EAA funds a needs-based abandoned well closure assistance program to assist well owners with proper well plugging in cooperation with San Antonio Water System to locate and plug abandoned wells (EAA 2021b, pp. 50-53). Likewise, former oil wells require maintenance decades after plugging (cement plugs in a steel pipe) and can blowout underground and break free under artesian pressure if not properly maintained (Gold 2022, entire).

Nitrogen is highly soluble and a threat to groundwater quality and a stressor to subterranean taxa (Castaño-Sánchez et al. 2020, pp. 6, 11; Banerjee et al. 2023, pp. 3–6). Panther Canyon well (State well number 6823302) recorded nitrate (2 mg/L) present in 2003 (Texas Water Development Board 2023, unpaginated). Nitrates and orthophosphate consistently emerge from spring run 1 at Comal Springs and are typically present at low concentrations (2 mg/L) (U.S. Geological Survey 2023, unpaginated). The current drought has significantly decreased flow, and thus dilution of contaminants are slowed at Comal Springs; recent data resulted in 3 mg/L of nitrate measured at spring run 2 at Comal Springs (West 2023, unpaginated). While safe for humans, it is unknown what effect these elevated nutrients will have over time within the aquifer food web, and if conditions would become more favorable for surface species to colonize further underground (Notenboom et al. 1994, pp. 482–484, 490; Opsahl et al. 2018, p. 3). The Comal Springs dryopid beetle's environmental tolerances are unknown, hindering quantitative assessments of this stressors' impact on its populations. Additionally, there are no established groundwater quality standards for subterranean ecosystems, making harmful impacts to the species from existing pollutant concentrations unclear (Hinsby et al. 2008, p. 10; Manenti et al. 2021, p. 2).

Volatile organic compounds have been detected at one spring ecosystem and generally these events are rare (Johnson and Schindel 2014, p. 21). There is one documented diesel spill (i.e., naphthalene) that occurred in 2000 at spring run 7 at Comal Springs (Ogden et al. 1986, p. 126; Gibson et al. 2008, p. 75). It is unknown what effect this had on the subterranean community.

Urban and agricultural land uses dominate the artesian zone in the southern segment. Low- to high-density urban development occurs across much of the former, while agriculture dominates the latter county. Land use across the southern segment of the Edwards Aquifer plays a major role in groundwater and surface water quality. The presence of agriculture, residential and commercial developments, industrial facilities, military installations, and transportation infrastructure are correlated with increased presence of many contaminants (Bush et al. 2000, pp. 6-9; Fahlquist and Ardis 2004, p. 7; Johnson et al. 2009, p. 46; Wilson 2011, pp. 1-2; Musgrove et al. 2014, pp. 69-71; Opsahl et al. 2018, p. 58; Opsahl et al. 2020, pp. 17-30).

To examine projected land-use changes in the urban centers intersecting Edwards Aquifer groundwater, we used the EPA's (2019, unpaginated) Integrated Climate and Land-Use Scenarios. These outputs produce spatially explicit projections of population and land-use that are based on the Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios. The combination of SSP5-RCP8.5 illustrates a higher population growth and higher emissions, and a faster rate of human population growth consistent with the Texas Demographic Center population projections for Bexar County and the San Antonio-New Braunfels Metropolitan Area (EPA 2017, pp. 34-35, 46; Texas Demographic Center 2022, unpaginated). Within the Edwards Aquifer artesian, recharge, and contributing zones (543,498 hectares [1,343,014 acres]), developed land-use classes are projected to grow from 21 percent in 2020 to 27 percent developed by 2050. When examining delineated areas at a finer scale around Comal and San Marcos springs using the Integrated Climate and Land-Use Scenarios, the area around Comal Springs is projected to increase in development from 66 percent to 82 percent developed and the San Marcos Springs area is projected to increase from 44 percent to 65 percent developed by 2050. These areas may be important to assess more immediate impacts from groundwater contamination. Alternatively, the area around Fern Bank Springs is not projected to have substantial changes in development use classes.

Based on the Integrated Climate and Land-Use Scenario results, projections of developed land-uses and population growth will continue to expand outward outside of the major metropolitan areas. Over time, these alterations have the potential to affect recharge rates, leading to deteriorating groundwater quality as a result of heightened runoff from impervious surfaces in suburban and urban areas or septic systems that are poorly managed and prone to leakage in exurban areas (Berube et al. 2006, pp. 10, 38; Barkfield 2022, p. 2).

The U.S. Census Bureau (2020, unpaginated) ranked several of the counties in the recharge and contributing zones of Comal and San Marcos springs (adjacent to Sessom Springs in Hays County, Texas) among the fastest growing in the United States from April 2010 to July 2019: Hays County was the second fasting growing county with a 46.5 percent population increase, Comal County the fourth fastest growing county with a 43.9 percent population increase, and Kendall County the fifth fastest growing county with a 42.1 percent population increase. Since 2000, these three counties have doubled in population and have seen substantial associated development. Projections indicate that the human population of Bexar, Comal, Hays, and Kendall counties will continue to increase substantially over the next three decades.

Conversion of natural habitat to urban, suburban, and exurban development is likely to accompany this population growth. Under a high human population growth scenario, land use projections suggest that large areas west and north of Bexar County will be converted to increasingly more urbanized land-use classes by 2100 (EPA 2019, unpaginated). Much of the exurban and suburban development is postulated to occur outside of municipal boundaries in unincorporated areas of counties where land use regulations (e.g., restrictions on impervious cover) are non-existent (Siglo Group 2022, pp. 13-14). Run-off from existing and expanded impervious cover in sensitive areas of the aquifer could affect groundwater quality over time. New contaminant sources are expected to be added to the region as increased human populations and expanded development continues; many existing contaminant sources will persist.

Land-use changes, particularly increases in impervious cover, are known stressors to aquatic systems and are difficult to predict, model, and remediate (Sharp 2010, p. 3; Coles et al. 2012, p. 65). Future development in the recharge and contributing zones are likely to decrease water quality because of the increased risk of contamination entering the aquifer. Additionally, nitrate runoff from surface water recharge leads to increased nitrate concentrations in the aquifer, and concentrations over 1 mg/L are indicative of anthropogenic inputs, which have been recorded historically at Comal Springs and have doubled over the last 70 years (median concentration 2 mg/L) (Dubrovsky et al. 2010, p. 79; Musgrove et al. 2016, pp. 462, 465, 467; Castaño-Sánchez et al. 2020, p. 6). These changes in water quality in streams and groundwater correspond with increases in impervious cover over a watershed (Kaushal et al. 2005, p. 13518; Baker et al. 2019, pp. 6494–6495; Castaño-Sánchez et al. 2020, p, 6).). These water quality parameter changes may be a long-term indication of urbanization that has already occurred across the recharge zone.

A review of research studies found that impacts to aquatic species are seen with impervious cover of 10 percent or more (Center for Watershed Protection 2003, p. 97). Although the studies were focused on stream systems, we assume that shallow groundwater habitats would have similar impacts because shallow groundwater ultimately flows into streams through discharge features. While physical parameters may be different (e.g., higher oxygen, lower temperatures, higher conductivity) in the shallow groundwater, pollutants entering both systems would be the same.

The EAA does not have explicit impervious cover limits in the recharge zone, with the intent that structural best management practices will protect water quality (Greater Edwards Aquifer Alliance 2010, p. 3). The TCEQ shares responsibility in protecting the Edwards Aquifer through impervious cover limits through a construction permit review process for development proposals of more than 20 percent impervious cover that includes structural best management practices (30 TAC § 213).

Hays County limits impervious cover to 15 percent within conservation lands on the recharge zone confined and limits impervious cover to 20 percent outside of the recharge zone (Hays County 2017 p. 204). Hays County also limits commercial property within the recharge zone not exceed 35 percent impervious cover or 65 percent if outside of the recharge zone (Hays County 2017 p. 207). Additionally, Comal County has goals to minimize impervious cover within the city of New Braunfels to limits of 26 percent per parcel (Design Workshop, Inc. 2012, pp. 4–5).

While the efforts to implement such limits are intended to help ameliorate at least some water quality impacts, these percentages are nonetheless higher than 10 percent, and each project approval does not account for the cumulative impact of combined impervious cover amounts within each county. Likewise, most lands over the contributing zone are not managed with land use regulations (e.g., impervious cover restrictions) (Siglo Group 2022, pp. 13–14).

Habitat Disturbance- Flooding

Surface habitat modification can occur as the result of flooding. Flash flooding is common throughout the Edwards Plateau (Woodruff and Wilding 2008, pp. 614-616). However, channel modification and the elimination of riparian zones can increase the severity of flooding (Schoof 1980, p. 697). Depending on the severity of floods, they can either deposit or increase suspended sediment loads over species habitat or scour substrate and vegetation from species habitat under high velocities (Griffin 2006, pp. 57-58, 61, 64; BIO-WEST, Inc. 2016, p. 26; BIO-WEST, Inc. 2019b, pp. 14, 17; Schwartz et al. 2020, pp. 12). It is possible that species may also be washed away in floods, though this has not been studied for the Comal Springs dryopid beetle. Record flooding occurred in the San Marcos River in 2015 and scoured large amounts of aquatic vegetation

(BIO-WEST, Inc. 2016, p. vi, 48). Floods have deposited finer sediments (e.g., silt) over invertebrate surface habitat at Comal and Sessom springs, reducing springflow and quality of habitat (BIO-WEST, Inc. 2002, p. 11; Gibson 2022, pers. comm.).

Recreation

Historically, Comal Springs served as a recreational site. Researchers at spring run 2 observed negative effects on the habitat, as prohibited-use signs were ignored and not enforced (Barr 1993, p. 62). By 1992, the area faced heavy human traffic with activities like swimming and wading, resulting in low or no captures of Comal Springs dryopid beetles (Barr 1993, pp. 30, 62; Arsuffi et al. 1993, p. 22). Additionally, subterranean invertebrate diversity reached its lowest point between spring runs 1 through 3 during this period (Arsuffi 1993, p. 21). These historical recreational impacts may have had unknown consequences on the broader invertebrate community at that time. Currently, Comal Springs rules are enforced by park rangers. Unauthorized access to the spring runs are strictly prohibited, and individuals must obtain prior authorization from the park manager to access these areas for activities such as research and habitat restoration projects. Documentation must be provided on-site before any work is conducted at the springs.

2.2.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Comal Springs dryopid beetle specimens are collected for scientific study and two refugia populations. Such collections which have not been documented to negatively impact total wild population numbers. At present, this species is not recognized for their commercial worth, and there is no evidence of overexploitation, making overutilization insignificant as a threat.

2.2.2.3 Disease or predation:

Fungi have not been observed on living Comal Springs dryopid beetles, but benign fungal parasites on *Dryops* beetle species have been documented (Brown 1987, p. 266). Filamentous fungi have been documented on deceased wild and captive Comal Springs dryopid beetle larvae and adults, but whether the fungi were the cause of the mortality or occurred post-mortem is uncertain (Worsham and Gibson 2022, pers. comm.).

The amount of predation that occurs in the wild has not been examined for this species. Blind, fragile subterranean species such as the Comal Springs dryopid beetle may be more susceptible to predation once the species enter surface waters (Brown 1987, p. 263; Barr 1993, pp. 63-64). Fishes compete for prey expelled from the aquifer at discharge features (e.g., spring openings). Researchers have seen Mexican tetras (*Astyanax mexicanus*), sunfish (*Lepomis* sp.), and mosquitofish (*Gambusia* sp.) congregating at spring openings waiting for the driftnet to be removed and consuming the bycatch, including subterranean invertebrates (BIO-WEST, Inc. 2003, p. 42). Macroinvertebrates such as the Comal Springs dryopid beetle are a part of the food chain, and it is assumed any number of individuals removed from the listed macroinvertebrate populations through typical levels of predation are likely to be negligible.

2.2.2.4 Inadequacy of existing regulatory mechanisms:

Under this factor, we examine the stressors identified within the other factors as ameliorated or exacerbated by any existing regulatory mechanisms or conservation efforts. Section 4(b)(1)(A) of the ESA requires that the USFWS consider "those efforts, if any, being made by any State or foreign nation, or any political subdivision of a State or foreign nation, to protect such species…". In relation to Factor D under the ESA, we interpret this language to require the USFWS to consider relevant Federal, State, and Tribal laws, regulations, and other such binding legal mechanisms that may ameliorate or exacerbate any of the threats we describe in threat analyses under the other four factors or otherwise enhance the species' conservation. Our consideration of these mechanisms is described in detail within each of the threats or stressors to the Comal Springs dryopid beetle (see discussion under the other Factors). Much of the information under Section 2.2.2.1 should also be considered as relevant here because it is often the inadequacy of existing regulations that contributes to habitat loss and degradation for this species.

The recharge and contributing zones to the Edwards Aquifer continue to experience rapid human population growth and conversion of natural habitat to developed land-use types, which continues to threaten water quality. Much of the contributing zone is not under the same regulations to protect water quality as the recharge zone, even though much of the water that recharges the aquifer originates in the contributing zone. Regulatory mechanisms that protect water in the Edwards Aquifer are crucial to the future survival of the Comal Springs dryopid beetle. Federal, State, and local laws and regulations have improved water quality and quantity protection but could be insufficient to prevent ongoing impacts to the species and their habitats from water quality degradation, reduction in water quantity, and surface disturbance of spring sites, and are unlikely to prevent further impacts to the species in the future. Knowledge of the source, accumulation, and transport of these compounds in the aquifer are lacking and investigations into their effects on the habitat quality are necessary for the recovery of the Comal Springs dryopid beetle and for sustainable use of the aquifer (Danielopol et al. 2004, pp. 187-188; Opsahl et al. 2018, p. 2).

Under Texas Parks and Wildlife Code (Chapter 68) and TAC (31 TAC § 65.171-65.176), the Texas Parks and Wildlife Department is authorized to add species to the agency's List of State Threatened and Endangered Nongame

Species and List of State Endangered, Threatened, and Protected Native Plants. The Comal Springs dryopid beetle is also state listed. The Texas Parks and Wildlife Department prohibits the taking, possession, transportation, or sale of any animal species that are state listed as threatened or endangered. State law prohibits commerce in threatened and endangered plants and prohibits collection of listed plant species from public land without a permit. However, prosecutions for these prohibited actions are rare and the burden of proof to prosecute is high, which can result in unauthorized take of state listed species. In addition, it is likely that at the time of recovery the species would no longer be state listed. Because Comal Springs dryopid beetle is conservation reliant, it would be expected that delisting would increase threats identified in the listing determination, unless there are other mechanisms to continue conservation efforts.

While the EAA was granted regulatory authority by the Texas Legislature, there have been several legal challenges to the EAA permitting program. For example, in court cases *Edwards Aquifer Authority v. Day* (2012, Supreme Court of Texas No. 08-0964) and *Edwards Aquifer Authority v. Bragg* (2013, Court of Appeals of Texas No. 04-11-00018-CV), courts awarded landowners compensation for groundwater permits that were denied by the EAA due to lack of historical usage. The ruling for *Edwards Aquifer Authority v. Day* by the Texas Supreme Court argued that there was no reason to treat groundwater differently than oil and gas and recognized groundwater as real property. In both cases, landowners owned the land prior to enactment of new groundwater pumping regulations. There remains a lack of clarity with Texas groundwater law that results in ongoing legal challenges regarding groundwater regulation, and these could impact the EAA's ability to regulate the aquifer in the future.

The EAA manages and issues permits for groundwater withdrawals within the Edwards Aquifer through conservation and drought management. The EAA's jurisdiction is limited to the Edwards Aquifer in Uvalde, Medina, Bexar, and portions of Comal, Guadalupe, Hays, and Caldwell counties. The contributing zone in Bandera, Kerr, and Kendall counties do not have additional protections under either program. Thus, the EAA's water quality regulations do not protect most of the contributing zone, which may ultimately reduce the water quality of the Edwards Aquifer.

As described above, TCEQ regulates activities that have the potential to pollute the Edwards Aquifer and hydrologically connected surface streams under the same Edwards Aquifer Protection Program or "Edwards Rules" and for the same counties. This means areas of the contributing zone do not have additional protections that could affect the amount and quality of recharge that enters the Edwards Aquifer, resulting in lower water quality protection for the aquifer and the Comal, Fern Bank, or Sessom ecosystems.

Likewise, this agency does not address development or other land use, impervious cover limitations, some nonpoint source pollution, or application of fertilizers and pesticides over the recharge zone (30 TAC § 213.31). Changes to how surface water and the Trinity Aquifer are managed are likely to change the amount that can be sustainably pumped from the Edwards Aquifer during drought conditions. For example, the Hays-Trinity Groundwater Conservation District also manages groundwater that influences the water at Sessom or Fern Bank springs ecosystems.

2.2.2.5 Other natural or manmade factors affecting its continued existence:

Global climate change is already affecting many regions' biodiversity, with stressors driven by increasing temperatures and extreme climatic events and will continue to in the near-term (Intergovernmental Panel on Climate Change 2023, pp. 5, 15). Over the last 115 years, the global averaged surface air temperature has increased by 1.0°C (1.8°F) with recent decades being the warmest in 1,500 years (Vose et al. 2017, pp. 186, 188). With the highly karstic permeability of the Edwards Aquifer, climate change and variability strongly influence this vulnerable aquifer that relies heavily on rainfall for recharge (Mace and Wade 2008, p. 659; Taylor et al. 2013, p. 312; Ding and McCarl 2019, p. 11; Nielsen-Gammon et al. 2020, p. 9). The Fourth U.S. National Climate Assessment (U.S. Global Change Research Program 2018, pp. 1,002-1,003) presents the Edwards Aquifer as a case study in vulnerability to climate change, citing the shallow karst aquifer as especially sensitive to climate change, and the regional population growth and development as exacerbating the effects of decreased water supply during droughts. While average rainfall is not projected to change significantly in central Texas, the distribution of precipitation is anticipated to change with more extreme droughts and extreme rain events (Geos Institute 2016, pp. 14-15).

Increasing temperatures will also create drier conditions due to increased evapotranspiration (Loáiciga and Schofield 2019, p. 224). Extreme droughts in Texas are more likely than they were 40-50 years ago (Rupp et al. 2012, p. 1,054; Nielsen-Gammon et al. 2020, entire). A recent study predicts megadroughts in Texas, more severe than have been seen for the past thousand years, that will occur before 2100 (Nielsen-Gammon et al. 2020, entire). Droughts worse than the drought of record occurred since the 1600s and are not uncommon in the region (Mauldin 2003, entire; Cleaveland et al. 2011, entire). It is not possible to ensure that there will be adequate flow to these springs without planning for more extreme droughts than the drought of record (Loáiciga and Schofield 2019, p. 236; Mace 2019, p. 212). The sustainable water yield for the Edwards Aquifer will decrease in a dry climate (EARIP HCP 2020, pp. 3-12, 3-31, 3-43; Loáiciga and Schofield 2019, pp. 223, 235-236) while human demand for groundwater will increase (EARIP HCP 2020, pp. 3-10–3-11), making it more challenging to balance groundwater use for human needs and ecosystem function. In 2010, Texas set a record for lowest rainfall with similar conditions persisting until 2013 (Nielsen-Gammon 2012, p. 59; National Research Council 2015, p. 168). Heavy rainfall leading to floods may also become more common from extreme precipitation events and may result in increased habitat disturbance due to movement of materials and scouring.

Average air temperature in Texas has risen 1.5°C (2.7°F) since the early 1900s (National Oceanic and Atmospheric Administration 2022, unpaginated). Future air temperature changes will depend on the amount of future greenhouse gas emissions (U.S. Global Change Research Program 2018, p. 995). Based on current projections of greenhouse gas emissions, air temperature is projected to increase 2.0-2.8°C (3.6-5.1°F) by 2050, and 2.4–4.7°C (4.4–8.4°F) by 2100 for the southern Great Plains (U.S. Global Change Research Program 2018, p. 995). Projections by Sharif (2018, p. 4) predict a greater rise in air temperature by 2100, 2.7–5.6°C (5–10°F). Studies have not explicitly addressed groundwater temperature increases for the Edwards Aquifer. Based on other research into changes in groundwater temperature, it is reasonable to expect that groundwater temperature will increase as air temperature increases, with a possible lag in groundwater temperature increase (Mahler and Bourgeais 2013, p. 295). Groundwater temperature also increases with urbanization and vegetation removal (Benz et al. 2017, entire). This could further increase groundwater temperatures as more development occurs. Groundwater temperature typically increases with depth due to geothermal heat flow, although this also varies locally with other variables such as vertical groundwater flow (Bense and Kurylyk 2017, pp. 1, 8). This suggests that deeper water would not provide a long-term buffer to increasing temperatures.

Some subterranean-adapted species would likely be incapable of adapting to modified temperatures in the medium to long-term and less capable, due to restricted dispersal capabilities, to flee rising temperature conditions than surface-adapted species (Culver and Pipan 2009, pp. 207–208; Taylor et al. 2013, pp. 324–325; Mammola et al. 2019, p. 646). Subterranean-adaptations in ectothermic animals allow for small fluctuations in temperature, but increased temperatures due to climate change can affect subterranean diversity by altering mobilization of contaminants (i.e., change in recharge rates through the unsaturated zone) and disruption to biogeochemical processes (e.g., carbon and nitrogen cycle) (Kløve et al. 2014, p. 263; Castaño-Sánchez et al. 2020, p. 7). Water quality at the subsurface and surface is also likely to decrease with increased water temperature. Therefore, the adaptive capacity ectothermic animals have to environmental changes is presumed to be low.

Surface water temperature will also increase during warm months. Data from the EAA indicates greater temperature fluctuations downstream from the springs due to increased exposure time to ambient temperatures and runoff from rain events (BIO-WEST, Inc. 2019a, p. 20; BIO-WEST, Inc. 2019b, p. 16). Low spring discharge is also a mechanism that increases the water's exposure time to ambient temperature. Thus, both future droughts and increased ambient temperature are likely to increase the surface water temperature. Thus, both future droughts and increased ambient temperature are likely to increase the surface water temperature. Continuous temperature data for the springs began in 2000, and groundwater temperature at Comal Springs is relatively constant (BIO-WEST, Inc. 2019b, p. 16). Continuous water temperature monitoring in the Comal River should indicate whether water temperatures rise in the future.

There is currently no information on whether increased temperatures can affect different life stages or reproduction of the Comal Springs dryopid beetle, or how quickly water temperature will change in their habitat into the future. For ectothermic animals (e.g., macroinvertebrates), overall vulnerability to climate change will depend on thermal sensitivity and how quickly their buffered environment changes (Pallarés et al. 2021, p. 487; Delić et al. 2022, p. 2). Species with similar tolerances and adaptive traits have no opportunity to migrate and are unlikely to successfully relocate due to its specific habitat requirements (Kløve et al. 2014, p. 263; Castaño-Sánchez et al. 2020, p. 7; Simčič and Sket 2021, entire; Becher et al. 2022, pp. 4–5). We are uncertain if this species could flee from undesirable conditions caused by catastrophic drought in their habitat. There could be voids that become de-watered, and we assume the species will make attempts to follow the water down into the aquifer as drying occurs.

An assessment by U.S. Geological Survey evaluated the projected future vulnerability through 2050 of the Comal Springs dryopid beetle and rated it as moderately vulnerable to climate change (Stamm et al. 2015, pp. 1, 40, 42, 47). Moderately vulnerable is defined as "abundance and/or range extent within geographical area assessed likely to decrease by 2050". There is currently no information indicating whether increased temperatures would affect different life stages or reproduction of the Comal Springs dryopid beetle or how quickly groundwater temperature will change in the Edwards Aquifer in response to climate change at the surface. Without more information, it is unknown to what extent these temporally delayed changes to the aquifer would have on this dryopid beetle and if the species would have sufficient time and have appropriate traits to adapt. These are important factors that require more research globally to fully understand vulnerability of these aquifer ecosystems and their subterranean communities (Mammola et al. 2019, pp. 646–647; Hose et al. 2022, entire).

2.3 Synthesis

There are currently three genetically isolated populations of the Comal Springs dryopid beetle in Texas. There is currently no recovery plan for the beetle and no species status assessment has fully evaluated the species viability. Available demographic data, captive refugia research, and the five-factor threats analysis (Section 2.2.2) are collectively not indicative of the need for a change in listing status recommendation for the Comal Springs dryopid beetle. Comal Springs dryopid beetle populations rely on continuous management and protective measures to preserve habitat, prevent silt accumulation, manage groundwater pumping for optimal springflow, supply terrestrial organic matter for the food web, and maintain sufficient water availability and quality for overall ecosystem health. In conclusion, it is our recommendation that a change in classification is not warranted at this time.

3.0 RESULTS

3.1 Recommended Classification:

No change is needed

3.2 New Recovery Priority Number (indicate if no change; see 48 FR 43098):

No Change Recommended; see 48 FR 43098, September 21, 1983 & 48 FR 51985, November 15, 1983 - Correction)

Brief Rationale:

Primary stressors for the Comal Spring dryopid beetle are loss of springflow and decreases in subsurface habitat due to drawdown of the Edwards Aquifer and reductions in water quality from development and land-use changes. Research suggests that contamination of groundwater has not been historically widespread, is at relatively low concentrations currently, and the subterranean ecosystems do not exhibit significant signs of degradation (Hutchins 2018, pp. 481–482). Current conservation, flow protection, and water quantity optimization measures in place have been effective in meeting biological objectives for the EARIP HCP's Covered Species, including the Comal Springs dryopid beetle, under which the EARIP HCP and regulations are reducing groundwater withdrawal pressure (National Research Council 2018, p. 109).

Given the projected increases in development and climate change-induced droughts in South Central Texas, the associated impacts from these activities on groundwater quality and aquifer recharge into the future remains uncertain (Loáiciga and Schofield 2019, p. 224; National Oceanic and Atmospheric Administration 2022, unpaginated). The sustainable water output for the Edwards Aquifer could decrease in a dry climate while human demand for groundwater would increase, making it more challenging to balance groundwater use for human needs and ecosystem function, and thus, the Comal Springs dryopid beetle's viability (Loáiciga and Schofield 2019, pp. 223, 235–236; EARIP HCP 2020, pp. 3-10–3-11, 3-12, 3-31, 3-43; Nielsen-Gammon et al. 2020, pp. 9–10).

In terms of viability (Smith et al. 2018, entire), the Comal Springs dryopid beetle occupies a restricted range of three genetically distinct populations as a narrow endemic species only occurring in the Edwards Aquifer and associated spring ecosystems and are highly susceptible to extinction from perturbations that would affect water quantity and quality in the Edwards Aquifer and ongoing management is needed to maintain resiliency. Further, the absence of data to inform how these threats directly impact Comal Springs dryopid beetle populations precludes a more detailed assessment of these impacts. Thus, our analysis does not warrant a change in recommended classification or recovery priority number. Therefore, we recommend the Comal Springs dryopid beetle retain its classification as endangered due to its conservation-reliant status.

3.3 Listing and Reclassification Priority Number, if reclassification is recommended (see 48 FR 43098):

Reclassification (from Threatened to Endangered) Priority Number:
Reclassification (from Endangered to Threatened) Priority Number:
Delisting (Removal from list regardless of current classification) Priority Number:

Brief Rationale:

Not applicable

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

- Explore various sampling techniques or increase the frequency of sampling using existing methods to enhance the collection of Comal Springs dryopid beetles at Sessom Springs. This will contribute to a better understanding of this population's status and the overall health of the habitat.
- Conduct status surveys at the Fern Bank ecosystem in Hays County, Texas to assess the status and health of this population. We recommend that these surveys also introduce goals to improve habitat conditions through landowner cooperation if recommended or crucial to improve species' resiliency and preserve redundancy of this genetically distinct population.
- Incorporate habitat-centered biological goals and objectives during EARIP HCP renewal process to promote protection of suitable habitat quality and quantity and species resiliency.
- Conduct a comprehensive assessment, including a dye-tracing study, to delineate the watershed and groundwater flowpaths contributing to springflow at Sessom Springs. This will help determine the respective contributions of regional groundwater and/or local Sessom Creek flow, providing critical insights into water sources. Such analysis will enable targeted efforts to enhance water quality remediation and maintain springflows through best management practices, especially during drought conditions.
- Conduct survey efforts focused on sampling for the Comal Springs dryopid beetle at wells and springs between the three occupied spring ecosystems to inform patterns of genetic diversity and understand the lack of gene flow between these locations. This may be coupled with research to better understand groundwater basin connectivity between the Comal, Fern Bank, and Sessom springs ecosystems.
- Continue water quantity and quality monitoring at accessible spring and well sites within and the areas that recharge the occupied spring ecosystems for habitat quality.
- Conduct research to reduce sources of nitrate into the Comal ecosystem through coordination with agencies, public education, and other non-governmental organizations.

- Establish conservation easements or fund land purchases within the contributing and recharge zones of the Edwards Aquifer for the benefit of the Comal Springs dryopid beetle and to ensure adequate springflow is sustained through droughts. Additionally, a site-prioritization tool could be developed to support decision making about strategic land acquisitions.
- To the extent possible, prevent or reduce increases in impervious surfaces or clearing of forest within the recharge areas supporting the species.
- Continue captive propagation research:
    - Conduct ongoing research to enhance captive propagation techniques.
    - Develop the capacity to produce offspring on-demand, anticipating standard operating procedures to inform action for potential catastrophic events or extirpation in the wild.
    - Formulate a comprehensive reintroduction plan based on research findings, ensuring the ability to replenish populations as needed.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of Comal Springs dryopid beetle (*Stygoparnus comalensis*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service, Austin Ecological Services Field Office

Approve ____

Appendix D8 | **USFWS 5-Year Species Status Review of the Peck's Cave Amphipod**

Peck's Cave Amphipod
(Stygobromus pecki)
5-Year Status Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
Austin, Texas
March 28, 2024

5-YEAR REVIEW
Species reviewed: Peck's cave amphipod (*Stygobromus pecki*)
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5-YEAR REVIEW
Peck's cave amphipod (*Stygobromus pecki)*

1.0 GENERAL INFORMATION

1.1 Reviewers:

Lead Regional or Headquarters Office:
Vanessa Burge, Recovery Biologist, Southwest Regional Office, Albuquerque, New Mexico, vanessa_burge@fws.gov

Lead Field Office:
Amelia Hunter and Michael Warriner, Fish and Wildlife Biologist, Austin Ecological Services Field Office, Austin, Texas, amelia_hunter@fws.gov, michael_warriner@fws.gov

Cooperating Field Office(s):
Not Applicable

Cooperating Regional Office(s):
Not Applicable

1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service or USFWS) is required by section 4(c)(2) of the Endangered Species ESA (ESA) to conduct a status review of each listed species once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing as endangered or threatened is based on the species' status considering the five threat factors described in section 4(a)(1) of the ESA. These same five factors are considered in any subsequent reclassification or delisting decisions. In the 5-year review, we consider the best available scientific and commercial data on the species and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process including public review and comment.

1.3 Methodology used to complete the review:

The Service conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.12) as required by section 4(c)(2)(A) of the ESA (16 U.S.C. 1531 et seq.). The Service provides notice of status reviews via the *Federal Register* and requests new information on the status of the species (e.g., life history, habitat conditions, and threats). Data for this status review were solicited from interested parties through a *Federal Register* notice announcing this review on May 5, 2021 (86 FR 23976) with a subsequent correction for that notice published on February 26, 2024 (89 FR 12868). The Austin Ecological Services Field Office conducted this review and considered both new and previously existing information from federal and state agencies, municipal and county governments, non-governmental organizations, academia, and the public. The primary sources of information used in this analysis was the final rule listing the Peck's cave amphipod as endangered (62 FR 66295), revised critical habitat ruling for the Peck's cave amphipod (78 FR 63100), research published in scientific journals, and unpublished reports and data.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

86 FR 23976 May 5, 2021

1.4.2 Listing history:

Original Listing
FR notice: 62 FR 66295
Date listed: December 18, 1997
Entity listed: Peck's cave amphipod (*Stygobromus pecki*)
Classification: Endangered

Revised Listing, if applicable
FR notice: Not applicable
Date listed: Not applicable
Entity listed: Not applicable
Classification: Not applicable

1.4.3 Associated Rulemakings:

In a petition dated September 9, 1974, the Conservation Committee of the National Speleological Society requested that the Service to list *Stygobromus* (=*Stygonectes*) *pecki*. The species was included in a notice of review published on April 28, 1975 (40 FR 18476). A "warranted but precluded" finding regarding several species in that petition was made on October 12, 1983, and published on January 20, 1984 (49 FR 2485). The same determination was repeated for Peck's cave amphipod in subsequent years.

The species was included as a category 2 candidate in comprehensive notices of review published on May 22, 1984 (49 FR 21664), January 6, 1989 (54 FR 554), and November 21, 1991 (56 FR 58804). Category 2 candidates were species for which data in the Service's possession indicated that listing was possibly appropriate, but substantial data on biological vulnerability and threats were not known or on file to support proposed rules. Peck's cave amphipod was elevated to category 1 status in the 1994 notice of review (59 FR 58982). Category 1 candidates were those species that the Service had on file substantial information on biological vulnerability and threats to support a proposal to list. As published in the *Federal Register* on February 28, 1996 (61 FR 7596), candidate category 2 status was discontinued, and only category 1 species are currently recognized as candidates for listing purposes.

Critical habitat for Peck's cave amphipod was revised on November 22, 2013, in areas of occupied, spring-related aquatic habitat with designations for surface and subsurface critical habitat (78 FR 63101). The original critical habitat designation encompassed only surface critical habitat and did not include any designation for subsurface critical habitat (72 FR 39248). Springs, associated streams, and underground spaces immediately inside of or adjacent to springs, seeps, and upwellings are the primary components of the physical or biological features essential to the conservation of this species (50 CFR 17.95).

1.4.4 Review History:

Not applicable

1.4.5 Species' Recovery Priority Number at start of 5-year review:

2C

1.4.6 Recovery Plan or Outline

Name of plan or outline: Not Applicable
Date issued: Not Applicable
Dates of previous plans/amendment or outline, if applicable: Not Applicable

2.0 REVIEW ANALYSIS

Section 4 of the ESA (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species meets the definition of "endangered species" or "threatened species." The ESA defines an "endangered species" as a species that is "in danger of extinction throughout all or a significant portion of its range," and a "threatened species" as a species that is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The ESA requires that we determine whether a species meets the definition of "endangered species" or "threatened species" due to any of the five factors described below.

Section 4(a) of the Act describes five factors that may lead to endangered or threatened status for a species. These include: A) the present or threatened destruction, modification, or curtailment of its habitat or range; B) overutilization for commercial, recreational, scientific, or educational purposes; C) disease or predation; D) the inadequacy of existing regulatory mechanisms; or E) other natural or manmade factors affecting its continued existence.

The identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an "endangered species" or a "threatened species." In assessing whether a species meets either definition, we must evaluate all identified threats by considering the expected response of the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species—such as any existing regulatory mechanisms or conservation efforts. The Service recommends whether the species meets the definition of an "endangered species" or a "threatened species" only after conducting this cumulative analysis and describing the expected effect on the species now and in the foreseeable future.

2.1 Distinct Population Segment (DPS) policy (1996):

Not Applicable

2.2 Updated Information and Current Species Status

2.2.1 Biology and Habitat

2.2.1.1 New information on the species' biology and life history:

Background

Peck's cave amphipods are groundwater obligate crustaceans that inhabit subterranean habitats, have restricted ranges, and can potentially occupy deep groundwater niches (Holsinger 1967, p. 119; Arsuffi 1993, p. 14). The species was first collected in 1964 at Comal Springs in Comal County, Texas and later collected at Hueco Springs, 7 kilometers (4 miles) north of Comal Springs, in 2003 (Holsinger 1967, pp. 117, 119; Fries et al. 2004, p. 5; Gibson et al. 2008, pp.76-81). This is the first 5-Year Review for the amphipod since the species' listing in 1997.

Biology

The Peck's cave amphipod, despite its shallow groundwater and spring-associated distribution, exhibits both surface and deeper groundwater characteristics (Holsinger 1967, p. 143; Fries et al. 2004, p. 7). It has no eyes and lacks mechanoreceptors for prey detection beyond direct interaction but can detect and avoid light (Nowlin et al. 2015, pp. 49-50; Nowlin et al. 2016, p. 30; Kosnicki and Julius 2019, p. 21). In both captivity and natural habitats, these amphipods typically inhabit the space beneath leaf substrate or interstitial spaces between rocks, displaying a preference for shelter rather than swimming freely or exposed at the surface (Arsuffi 1993, p. 14; Fries et al. 2004, p. 8).

The Peck's cave amphipod, a top invertebrate predator in food webs at both spring run 3 and Spring Island locations within the Comal Springs ecosystem, consumes organic from both the surface (e.g., photosynthetic) and groundwater ecosystems (e.g., chemolithoautotrophic) (Hutchins et al. 2016, p. 1536; Kosnicki and Julius 2019, pp. 20-21; Nair et al. 2020, p. 10; Nair et al. 2021, p. 239, 242). These food sources vary based on local vegetation and environmental characteristics, impacting the amphipod's dietary options (Nair et al 2021, p. 242). Therefore, this species is considered a shallow phreatic zone specialist, adept at adapting its feeding strategy to different environments and available food resources and may be able to switch to alternative food sources when environmental conditions are reduced or altered (Nowlin and Worsham 2015, pp. 45, 49, 51). This may explain why *Stygobromus sp.* amphipods from the Comal Springs ecosystem have orange hues due to carotenoid-rich food resources compared to the opaque hues of individuals observed at Hueco Springs ecosystem (Fries et al. 2004, p. 5; Gibson et al. 2008, p. 77).

Peck's cave amphipods can adapt their feeding strategy to reduced or altered environmental conditions by switching to an alternative food source between the locations at Comal Springs spring run 3 (wood biofilm-based food chain) and Spring Island (periphyton-based food chain) (Nowlin and Worsham 2015, pp. 45, 49, 51). In laboratory studies, Peck's cave amphipod showed lower metabolic rates and better energy reserves when starved compared to surface amphipod species, *Sicifera* (*Synurella*) sp., indicating their metabolic strategies match that of deep phreatic organisms of low or infrequent food accessible systems, despite its association with shallower groundwater habitat (Nair et al. 2020, pp. 9-10). This suggests a possible evolutionary history of the Peck's cave amphipod occurred at deeper depths over an undetermined period (Nair et al., 2020 p. 11).

Life History

The mating behavior of this amphipod is unknown, but larger females have been known to cannibalize smaller males (Nowlin et al. 2016, p. 31). In captivity, wild adult females can produce approximately 10 eggs per female, with a hatching success rate of 24 percent and an average incubation time of 49.7 ± 12.4 days (Fries et al. 2004, p. 9; Kosnicki and Julius 2019, p. 11). Brooding females have been observed cannibalizing juveniles outside of the marsupium (i.e., a type of brooding pouch of a female crustacean) or when eggs drop with agitation (Nowlin et al. 2016, p. 31; Kosnicki and Julius 2019, p. 12; Service 2019, p. 57).

The eggs require more than 32 days to survive their first molting event to become neonates (i.e., newborns), and they go through multiple molts over an average period of 50 days to reach the final adult life stage under stressful captive conditions (Kosnicki and Julius 2019, pp. 11-12, 20). Juvenile Peck's cave amphipods reach sexual maturity between the sixth and eight instars, which likely depend on available food resources and temperatures (Kosnicki and Julius 2019, p. 19).

Subterranean amphipods in general have life cycles that vary from 4–10-year life spans (Wellborn et al. 2015, p. 788). Wild-caught Peck's cave amphipods have survived in captivity for three years and have successfully achieved F2 generations, which is an indication that habitat conditions in captivity are suitable and promising for future reintroduction efforts (BIO-WEST, Inc. 2007, p. 40).

2.2.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, birth rate, seed set, germination rate, age at mortality, mortality rate, etc.), or demographic trends:

Little is known about limiting factors that may impact the abundance and distribution of the Peck's cave amphipod because the subterranean habitats they inhabit are largely inaccessible to humans aside from these wells and springs. Current abundance estimates only include samples collected at the surface.

The species' reclusive nature and life history adds complexity to determine abundance, as individuals spend most of their lives underground. Thus, no population estimates are available for the Peck's cave amphipod. Mature and immature life stages have been collected only near spring outlets, from seeps along the spring runs, and from a shallow groundwater well in Panther Canyon, further complicating such estimation efforts (Gibson et al. 2008, p. 76).

A 1992 study indicated these cave amphipods were abundant in Comal Springs (spring runs 1, 2, 3, and 4) driftnet samples, with 271 individuals, and one specimen at a new locality, Hueco Springs, over 96 hours of combined drift time (Barr 1993, pp. 37, 56-57). The species was abundant at all spring runs but spring run 4 (spring run 1: 78; spring run 2: 62; spring run 3: 130; spring run 4: 1) (Barr 1993, p. 56).

Surveys in 2003 collected an average of 9.2/day were collected at Comal Springs (spring runs 1, 2, and 3) and an average of 1.2/day at Hueco Springs (Fries et al. 2004, pp. 6-7; Gibson et al. 2008, p. 79). Individual cave amphipods were more abundant and easily accessible via hand collection or driftnetting at Comal Springs compared to Hueco Springs, with other sampling evidence to suggest Peck's cave amphipods inhabit a deeper section at Hueco Springs compared to the Comal Springs sampling locations (Fries et al. 2004, p. 7).

Biomonitoring for all benthic macroinvertebrates in the Comal Springs system was established in 2000 and occurs every spring and fall using driftnets (BIO-WEST, Inc. 2003, pp. 37-41). The Peck's cave amphipod was discovered at the western shoreline and upwellings in Landa Lake (BIO-WEST, Inc. 2004, p. 37). Between 2017 and 2021 with over 29 sampling events, the long-term median number of Peck's cave amphipods collected per cubic meter (m^3) of water is $0.25/m^3$ (8.8 per cubic foot [ft^3]) (BIO-WEST, Inc. 2021, pp. 39-40). However, without access to their subterranean habitat, little can be evaluated in terms of their actual population sizes or abundances within their entire habitat at this time using current available methodology.

2.2.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Genetic analysis using mitochondrial DNA sequences indicated high levels of differentiation within and among Peck's cave amphipod localities, but they were found to contain sequences from two distinct haplotype groups with deep divergence (Ethridge et al. 2013, p. 233, 235). The two haplotypes were not geographically separated, and they co-occurred and often in similar proportions. This observation, in addition to the hydrogeology of the Comal ecosystem, suggests Peck's cave amphipod is composed of two sub-populations that at one time were separated and now converge between surface habitats at Comal Springs and migration present within the Comal ecosystem (Nice and Lucas 2015, pp. 18, 22; Lucas et al. 2016, pp. 8, 12).

Measurements of genetic diversity across populations of *Stygobromus* spp. show Peck's cave amphipod to be comparable to populations of congeneric species from central Texas. Future sampling would be beneficial for estimation of population size (Nice and Lucas 2015, pp. 42-44).

2.2.1.4 Taxonomic classification or changes in nomenclature:

The original description of the Peck's cave amphipod (*Stygobromus pecki*) placed this species in the genus *Stygonectes* (Holsinger 1967, entire), which was later synonymized by into the genus *Stygobromus* and placed into the *flagellatus* group (Holsinger 1967, entire). This species is also referred to in some references as the "Peck stygobromid" or "Peck's cave scud" (40 FR 18477; McLaughlin et al. 2005, p.145).

2.2.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, pollinator availability, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Various researchers have examined amphipod assemblages from springs, caves, and wells from neighboring counties, without finding the Peck's cave amphipod elsewhere, beyond the known occurrences at Comal and Hueco spring ecosystems (Holsinger 1967, entire; Holsinger and Longley, 1980 entire; Barr 1993, entire; Gibson et al. 2008, entire). This suggests that individuals of the species may be confined to small areas surrounding the spring openings and are not distributed throughout the aquifer.

The collection of Peck's cave amphipods at Panther Canyon well lends support to early characterizations of the *flagellatus* group suggesting they inhabit deeper groundwater niches compared to other amphipod groups found above the water table and in hyporheic (i.e., saturated sediments near a streambed gravel or river) habitats (Holsinger 1967, pp. 143, 159).This distinction in partitioned niche habitat zones were also exhibited at Hueco Springs, with Peck's cave amphipods found more prevalent at deeper sites than others in the genus, *Stygobromus russelli* (Gibson et al. 2008, p. 80).

To what extent the subterranean connections between Hueco and Comal Springs are inhabited by this amphipod are unknown (72 FR 39255). Presumably an interconnected area, the subterranean portion of this habitat provides for feeding, growth, survival, and reproduction of the Peck's cave amphipod. Both springs have local and regional groundwater contributions, with Comal Springs having a more phreatic, older origin than Hueco Springs (Ogden et al. 1986, pp. 80, 124; Rothermel and Ogden 1987, p. 76). These groundwater sources can intermix when aquifer levels are high and separate during severe droughts. This regional flowpath connection could explain the distribution of Peck's cave amphipods over these two spring systems (Gibson et al. 2008, p. 75).

2.2.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

Peck's cave amphipod inhabits the shallow, subterranean spaces associated with thermally stable spring orifices issuing from the Edwards (Balcones Fault Zone) Aquifer (herein referred to as the "Edwards Aquifer") (Holsinger 1967, p. 119). It is unknown if this species can re-enter the subterranean aquifer once it has emerged or discharged through the springs (Barr 1993, p. 52). Specific springflow requirements and how much subterranean habitat this species uses is unknown; management relies on assuring historical conditions are maintained within the natural habitat for the species (LBG-Guyton and Associates et al. 2004, pp. C-4–C-5).

This cave amphipod is likely an omnivore and upon reaching the surface, consumes terrestrial-derived organic matter from riparian vegetation sources (78 FR 63100; Nair et al. 2021, p. 3). In the Comal ecosystem, this cave amphipod occupies a higher trophic level as a predator consuming other surface aquatic crustaceans (Nowlin et al. 2017, pp. 15-16). Therefore, riparian areas adjacent to the spring ecosystem provide a necessary role in the nutrient cycle for the food web of this invertebrate and influence its habitat distribution.

The principal habitat at Comal Springs (spring runs and Landa Lake) maintains a fairly stable water temperature at both locations (69.3 and 75 °F [20.7 and 23.9 °C]) and conductivity (579-587 micro-Siemens/centimeter), low levels of dissolved oxygen (5.06-5.23 milligrams/liter [mg/L]), with few detections of contaminants, such as personal care products and pharmaceuticals (BIO-WEST, Inc. 2021, p. 18; EAA 2013, p. 62; EAA 2018, p. 5; EARIP HCP 2021, pp. 27-36, 45-47). Nevertheless, other anthropogenic contaminants have been identified as concerning and may be relevant to the species. For example, nitrate runoff from surface water recharge results in elevated nitrate concentrations within the aquifer. Nitrate levels exceeding 1 mg/L suggest the presence of anthropogenic inputs and urbanization in the recharge zone, a trend documented historically at Comal Springs. Over the past 70 years, these concentrations have doubled (median concentration 2 mg/L), posing a concerning threat to the ecological health of Comal Springs and highlighting the detrimental impact of human activities on the local aquifer system (Dubrovsky et al. 2010, p. 79; Musgrove et al. 2016, pp. 462, 465, 467; Castaño-Sánchez et al. 2020, p. 6).

Information for habitat conditions at Hueco Springs are incomplete due to lack of access. The best available information indicates that the shallow spring waters at Hueco Springs are relatively constant with near neutral (pH 6.8 to 7.0), range in temperature between 69.3-70.7 °F (20.7-21.5 °C), supersaturated with oxygen (5.0-6.8 mg/L; over 100 percent saturation), and few detections contaminants, such as of personal care products and pharmaceuticals (Fries et al. 2004, pp. 4, 13; EAA 2015, pp. 56-58; EAA 2018, p. 5).

2.2.1.7 Other:

Biological Constraints and Needs

Peck’s cave amphipod occurs in a limited range at a small number of localities with little or no ability to disperse between or beyond these localities. These characteristics make them susceptible to local extirpation and extinction (McKinney 1997, p. 499; O’Grady et al. 2004, p. 514). A severe drought or water contamination event could eliminate many or all the existing sub-populations. Having a high number of individuals at a site provides no protection against extinction due to stochastic events. Dispersal beyond their extant range is unlikely, given the isolated nature of the spring headwater system dynamics and aquifer hydraulic connectivity that limit movement of individuals.

The areas inhabited by individuals of the species can be protected through localized conservation measures (e.g., intact riparian zones, springflow protection measures); however, the groundwater that provides water quality and quantity for the species can originate a significant distance from these habitats, and efforts that protect or conserve groundwater may be variable in their success and implementation. Although some of the threats can be adequately addressed, the inherent problems associated with narrow endemics in isolated habitats will always be present. Even with the most effective management and recovery plans in place, the species remains vulnerable to devastating stochastic events such as floods or droughts that could eliminate the species.

Hueco Springs Private Ownership

The primary spring within the Hueco Springs ecosystem is on undeveloped land, but other satellite springs are located within a privately owned campground (78 FR 63109). Of the two major spring orifices, the large spring on the west side stops flowing during severe drought events, and the spring on the east side of River Road typically stops flowing during the driest months each year (Puente 1976, pp. 25-27; Guyton and Associates 1979, p. 46; Ogden et al. 1986, p. 122; Barr 1993, p. 36). These springs are located on private property, and researchers are rarely granted access to this site. Thus, evaluation of habitat conditions, current sub-populations or demographic data, documented changes in land-use activities, or ability to conduct future recovery actions and activities are not achievable at this time.

2.2.1.8 Conservation Measures:

Groundwater Quantity

The Edwards Aquifer Authority (EAA) is charged with protecting terrestrial and aquatic life, domestic and municipal water supplies, the operation of existing industries, and the economic development of the entire Edwards Aquifer (Chapter 626, Laws of the 73rd Texas Legislature, 1993). Aquifer management since these rules were implemented has been successful at controlling groundwater withdrawals to maintain springflows. By EAA estimates, Comal Springs would have likely ceased flowing during the 2014 drought period without current regulations (EAA 2015, p. 62). Currently, these regulations have been effective in managing the Edwards Aquifer and reducing the risk of substantial declines in spring flows at Comal Springs.

Another important conservation measure is implementation of the City of San Antonio's Edwards Aquifer Protection Program (Stone and Schindel 2002, pp. 38-39; City of San Antonio 2023, pp. 3, 6). In 2000, the voters of San Antonio passed Proposition 3, a $65 million sales tax initiative, to fund the acquisition (i.e., fee-simple and conservation easements) of open space to protect the contributing and recharge zones of the aquifer in Bexar County (Romero 2018, p. 2). Protection of open space has the potential to reduce the impacts of development (e.g., run-off form impervious cover, fertilizer applications, and wastewater) on maintain aquifer recharge (Reilly and Carter 2018, pp. 3-2, 3-6; Romero 2018, pp. 5-6). That program was re-approved in 2005, 2010, and 2015 with additional funds to acquire open space (Reilly and Carter 2018, pp. 1-3–1-5). The effort was later expanded to acquire lands in Medina and Uvalde counties that contain larger portions of the contributing and recharge zones (Romero 2018, pp. 5-6, 8). The dedicated sales tax expired in 2021 with 97,124 hectares (240,000 acres) acquired under the Edwards Aquifer Protection Program (Siglo Group 2022, pp. 51-52). The City of San Antonio recently approved an alternative funding stream to support land acquisitions through the commitment of $100 million over ten years (City of San Antonio 2023, pp. 3, 6).

Groundwater Quality

There are several laws and regulations to protect water quality that apply to the Edwards Aquifer. The Federal Safe Drinking Water Act of 1974, as amended, regulates pollution and sedimentation of public drinking water sources, including the Edwards Aquifer. This legislation mandates enforcement of drinking water standards established by the Environmental Protection Agency. The Texas Commission on Environmental Quality (TCEQ) is responsible for enforcement of these standards in Texas. Under the authority of the Texas Administrative Code (30 TAC § 213), the TCEQ regulates activities having the potential for polluting the Edwards Aquifer and hydrologically connected surface streams through the Edwards Aquifer Protection Program or "Edwards Rules." The Edwards Rules require a number of water-quality protection measures for new development occurring in the recharge zone and portions of the contributing zone of the Edwards Aquifer. The TCEQ also prohibits facilities such as municipal solid waste landfills and waste disposal wells from being built in the recharge or transition zones.

Discharge from non-point residential or agricultural sources is one of the primary sources of pollution in the Edwards Aquifer. Texas has an extensive program for the management and protection of water that operates under State statutes and the Federal Clean Water Act. The Program includes regulatory programs such as the following: Texas Pollutant Discharge Elimination System, Texas Surface Water Quality Standards, and Total Maximum Daily Load Program (under Section 303(d) of the Clean Water Act).

The TCEQ's Texas Pollutant Discharge Elimination System program regulates discharges of pollutants to Texas surface water. Through the Pollutant Discharge Elimination System program, the TCEQ authorizes the discharge of stormwater and non-stormwater to surface waters in Texas associated with storm sewer systems and construction sites, which must meet the requirements of the Edwards Rules.

A watershed protection plan was accepted in 2018 by TCEQ for the Dry Comal Creek and Comal River Watershed by the City of New Braunfels. Dry Comal Creek has not met state water quality standard for bacteria, and the watershed protection plan is intended to address and reduce the elevated bacteria levels through management (TCEQ 2020, p.1).

The EAA has additional regulations (EAA rule 713) that apply to the recharge zone and five miles upgradient of the recharge zone. Much of the contributing zone occurs outside of the EAA's jurisdiction (Edwards Aquifer Habitat Conservation Plan 2020, pp. 1-4, 1-5) and is not subject to these regulations.

New development in the Edwards Aquifer recharge, transition, or contributing zones is reviewed by the TCEQ Edwards Aquifer Protection Program (30 TAC § 213.1). For the contributing zone, the rule covers activities that disturb more than two hectares (five acres) in Medina, Bexar, Comal, Kinney, Uvalde, Hays, Travis, and Williamson counties (30 TAC § 213.20). The contributing zone in Bandera, Kerr, and Kendall counties does not have additional protections under either program.

Several other entities also have measures to protect groundwater from contamination including the EAA's Aboveground Storage Tank Program, Agricultural Secondary Containment Assistance Program, and Abandoned Well Program among others (EAA 2022, entire). The San Antonio Water System implements several water quality protection measures including development regulations (i.e., Aquifer Quality Protection Ordinance No. 81491) for properties over the contributing and recharge zones, review of building permits and master development plans, regulation of underground storage tanks, commercial/industrial compliance, and an abandoned well program (San Antonio Water System 2022, unpaginated).

In addition to these state and federal regulations, a significant number of local regulations to protect water quality were implemented as part of the Edwards Aquifer Recovery Implementation Program Habitat Conservation Plan (EARIP HCP; see sub-section below). Additionally, Texas Water Code (Chapter 36) allows groundwater districts, but not cities, to regulate groundwater, including groundwater quality. However, cities can regulate pollution at the surface that ultimately impacts groundwater quality.

Habitat Conservation Plan

The EARIP HCP was finalized in 2013, amended in 2020, and covers incidental take of these species for groundwater withdrawal, recreation, and other activities through 2028 (EARIP HCP 2020, entire). Permittees to the plan include the EAA, City of San Antonio acting through the San Antonio Water System, City of New Braunfels, City of San Marcos, and Texas State University (National Research Council 2015, pp. 25–26). The EARIP HCP includes activities to minimize and mitigate impacts and contribute to the recovery of the eleven Covered Species and addresses a variety of aquifer management issues, including ensuring springflow during a repeat of the drought of record (Payne et al. 2019, p. 200; EARIP HCP 2020, pp. 4-57–4-59, 4-62–4-66). Long-term commitments to protect listed species in the Edwards Aquifer beyond the HCP and the term of its associated section 10(a)(1)(b) permit are not currently in place. However, a new habitat conservation plan is expected in 2028.

The current EARIP HCP biological goal centers on water quality for the Peck's cave amphipod is: "Not exceed a 10 percent deviation (daily average) from historically recorded water quality conditions (long-term average) within the

Edwards Aquifer as measured issuing from the spring openings at Comal Springs"; there are no habitat biological goals or biological objectives specific to this species.

A captive refugia (operation and maintenance) and associated research is funded by the EARIP HCP through a contract (Contract # 16-822-HCP) with the Service at facilities in San Marcos and Uvalde, Texas (EARIP HCP 2020, p. 5-3). The contract was established to protect species left vulnerable to extirpation throughout a significant portion of their range due to a limited geographic distribution of the population and will preserve the capacity for these species to be re-established in the event of the loss of a sub-population due to a catastrophic event, such as the unexpected loss of springflow or a chemical spill. Research activities expand knowledge on habitat requirements, biology, life histories, and effective reintroduction techniques for the species.

2.2.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms):

2.2.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Water Quantity

A primary threat to the habitat of the Peck's cave amphipod is the potential loss of springflows and reduced water quantity underground brought on by groundwater withdrawals from the southern segment of the Edwards Aquifer and other activities. Springflows at Comal and Hueco springs are tied inseparably to water usage for the southern segment of the Edwards Aquifer. Groundwater pumping to meet municipal, industrial, and irrigation uses is a widely recognized threat to the persistence of subsurface and surface groundwater-dependent ecosystems (Danielopol et al. 2003, pp. 109-112; Eamus et al. 2016, pp. 317, 333-335; Mammola et al. 2019, pp. 645-646). Removal of groundwater from an aquifer leads to water level decline, especially if discharge of groundwater significantly exceeds recharge (Theis 1940, pp. 278-280; Alley et al. 2002, pp. 1,986; Foster and Chilton, 2003 pp. 1961-1962). Declining aquifer levels can result in springflow decline or failure, loss of stream and creek base-flow, and/or drying of water-filled caverns (Springer and Stevens 2009, pp. 9-10; Eamus et al. 2016, pp. 316-318, 333-335).

If not replenished through recharge, groundwater discharged through wells and springs is removed from aquifer storage (i.e., total amount of water in aquifer), and with absent or much reduced recharge, persistent groundwater removal would initially lead to decline and/or cessation in springflows (Lindgren et al. 2004, p. 41). Like other karst aquifers, water levels of the Edwards Aquifer fluctuate with recharge (i.e., distribution, amount, and intensity of rainfall) and discharge (i.e., wells or springs) (Petitt and George 1956, p. 49; Buszka 1987, pp. 24-27; Maclay 1995, pp. 48, 52; Worthington et al. 2003, p. 4; Lindgren et al. 2004, pp. 40-41, 45). Prolonged dry periods result in declines in aquifer water levels but rebound rapidly with return of precipitation (Petitt and George 1956, p. 49). Groundwater pumping has exceeded recharge multiple times with water levels rebounding with increased rainfall (Petitt and George 1956, p. 49). The longest period was the drought of record (a three-year period when aquifer recharge was at its lowest recorded level) during the mid-1950s (Arnow 1959, pp. 27-29). At one point, Comal Springs stopped flowing from June 13 through November 3, 1956, during the drought of record (Puente 1976, p. 22).

In the early 1990s, federal litigation (i.e., *Sierra Club v. Secretary of the Interior* [No. MO-91-CA-069] United States District Court for the Western District of Texas) resulted in the creation of the EAA in 1993 by the State of Texas to manage groundwater withdrawals (i.e., by nonexempt wells) from the southern segment and limit Edwards Aquifer pumping authorized through permits (National Research Council 2015, pp. 24-26; Hardberger 2019, pp. 193-194; Payne et al. 2019 p. 199). During the 2007 legislative session, the Texas Legislature increased the annual maximum amount of pumping that could be authorized by permits to 705,551 megaliters (572,000 acre-feet) and directed the EAA to adopt and enforce a "Critical Period Management" plan establishing targeted withdrawal reductions during times of drought to achieve the water, species, and species habitat conservation goals established in the agency's enabling legislation (80th Texas Legislature, 2007, Senate Bill 3). Aquifer management since these rules were implemented have been successful at reducing groundwater withdrawals, but currently do not account for future droughts that may be worse than the drought of record. The Stage V Critical Period Management that currently exists is also tied to the Edwards Aquifer Habitat Conservation Plan (EARIP HCP) but could be subject to change after species recovery.

Springflows have been protected at Comal Springs during recent droughts in the 2000s and 2010s because of groundwater pumping restrictions from the EAA during periods of drought. During the 2008-2009 drought, springflows remained at sufficient levels to maintain resiliency for species (above 80 cubic feet per second [cfs] (2.3 cubic meters per second (m^3/s)]) (USGS station 08169000). By EAA estimates, Comal Springs likely would have gone dry during the 2014 drought without the enforcement of Critical Period Management (EAA 2015, pp. 1, 62).

However, regardless of pumping, Hueco Springs may receive water from the Trinity Aquifer (Otero 2007, pp. 18, 21). Of the two major spring orifices, the large spring on the west side stops flowing during severe drought events and the spring on the east side of River Road typically stops flowing during the driest months each year (Puente 1976, pp. 25-27; Guyton and Associates 1979, p. 46; Ogden et al. 1986, p. 122; Barr 1993, p. 36).

Groundwater will continue to be a source of water in the future as city populations increase. For the four counties within the San Antonio pool (i.e., Hays, Comal, Bexar, Medina), predicted water demands increase 48 percent in the year 2070, insufficient to fulfill using existing supplies (Texas Water Development Board 2021, p. A-2–A-3). The State of Texas and Groundwater Conservation Districts for these counties have identified surface and groundwater management supply strategies that could supplement the forecasted needs of each county but are contingent on funding and infrastructure availability (Texas Water Development Board 2021, entire).

While a repeat drought of record has not occurred, modeling indicates that the Critical Period Management plan during Phase II (current phase) of the EARIP HCP will maintain springflows above 30 cfs (0.85 m^3/s) at Comal Springs and above 45 cfs (1.3 m^3/s). However, the Critical Period Management plan is currently unable to return springflows at either spring system to 80 cfs (2.3 m^3/s) within six months (EARIP HCP 2020, pp. 4-58, 4-66), which is necessary to reduce threats of prolonged lowered springflows on population viability. Future droughts may also be more severe than the drought of record and current aquifer management does not account for this.

Springflows needed to sustain resilient populations is species-specific, and contingent on habitat use and requirements. The biological opinion (Service 2013, p. 129) associated with the EARIP HCP concluded that the issuance of the Incidental Take Permit for the EARIP HCP is not likely to jeopardize the continued existence of the Peck’s cave amphipod or destroy or adversely modify their designated critical habitat. Modeled springflows for conditions during Phase II projected Comal Spring flows to remain at approximately 50 cfs (1.4 m^3/s) during a repeat drought of record (Service 2013, pp. 32, 91, 100). The 27 cfs (0.8 m^3/s) at Comal Springs is greater than the springflows during the drought of record, when springflows ceased for four months in 1956.

Springflows for the Peck’s cave amphipod were not included in the 1995 recovery plan or quantitative delisting criteria. The springflows that affect the Peck’s cave amphipod and its habitat may differ from other surface species. For example, at 30 cfs (0.9 m^3/s) at Comal Springs, runs 2 and 3 do not provide surface habitat for invertebrates (EARIP HCP 2020, pp. 4-97–4-98). The Service determined that 30 cfs (0.9 m^3/s) during a repeat drought of record is not likely to jeopardize the Peck’s cave amphipod (Service 2013 p. 129). Water from Panther Canyon well, seeps along the western shoreline of Landa Lake, and within upwellings near Spring Island are expected to continue to provide habitat during low flow conditions. The Peck’s cave amphipod may be able to use subterranean habitat, but it is possible genetic diversity at some sub-populations may be lost (Service 2013, pp. 100, 104, 110; Lucas et al. 2016, pp. 6, 12).

The Peck's cave amphipod survived the drought of record during the mid-1950s, which resulted in cessation of flow at Comal Springs from June 13 through November 3, 1956, and were not extirpated (Arnow 1959, pp. 27-29; Barr 1993, p. 61). However, given that they are fully aquatic and that no water was present in the springs for a period of several months, they were probably negatively impacted by the unregulated aquifer pumping during this record drought in the 1950s. Hueco Springs is documented to have gone dry in the past and dries yearly in the summer, but due to lack of access we cannot determine the health and numbers of the sub-population within this spring ecosystem (Barr 1993, p. 36; U.S. Geological Survey 2023a, unpaginated).

This cave amphipod is not likely adapted to surviving long periods of drying or stagnation (depending on the duration and severity), especially if the current water management plan for the Edwards Aquifer that accommodates the needs of these invertebrates were to cease.

Water Quality

Water quality at Comal and Hueco springs are influenced by groundwater and surface water. Both systems depend on groundwater flow from the southern segment of the Edwards Aquifer. This segment of the aquifer is fed by many stream systems that enter the aquifer through recharge features.

The Edwards Aquifer is vulnerable to contamination because the limestone and carbonate rocks are highly permeable and exposed at the surface in the recharge zone (Clark 2000, pp. 1-2, 8-9; Burri et al. 2019, p. 150). Contaminants, commonly linked to urban and suburban activities such as residential and commercial development, industrial operations, transportation infrastructure, and waste disposal, tend to accumulate in higher concentrations within the shallow areas of recharge zones, especially in regions characterized by urban land uses (Wilson 2011, pp. 1-2; Lin and Gong 2016, pp. 384-385; Opsahl et al. 2018, p. 58).

There are currently no established groundwater quality standards for subterranean ecosystems, and the concentrations of pollutants that could harm subterranean species remain unclear (Hinsby et al. 2008, p. 10; Manenti et al. 2021, p. 2). However, subterranean fauna are likely to exhibit greater vulnerability to contaminants and a longer recovery period from stochastic events compared to surface fauna because of their inherent limitations, including a lack of adaptations to pollutants, isolation within their habitat, and restricted dispersal abilities, all of which render them sensitive to environmental disturbances (Hose 2005, p. 961; Di Lorenzo et al. 2019, pp. 293–294, 300; Hose et al. 2022, p. 2206).

Although water quality in the Edwards Aquifer is generally good, several studies have detected contaminants in groundwater from the southern segment including nitrates, herbicides, pesticides, and polycyclic aromatic hydrocarbons, among many others (Fahlquist and Ardis 2004, pp. 7-8, 10; Johnson et al. 2009, pp. 10-13, 23-26, 31-35; Musgrove et al. 2014, pp. 67, 69-71; Opsahl et al. 2018, p. 58; Opsahl et al. 2020, pp. 17-30). For example, contaminants have exceeded public drinking water standards in springwater and surface water recharging the aquifer, including antimony, arsenic, lead, lithium, and tetrachloroethene (Johnson et al. 2009, p. 45). However, groundwater contamination has not been shown to be widespread or with large numbers of substances present in concentrations that exceed drinking water standards (Bush et al. 2000, pp. 1-2, 14-21; Fahlquist and Ardis 2004, pp. 7-8, 10; Johnson et al. 2009, 44, 47; Opsahl et al. 2018, p. 58; Opsahl et al. 2020, pp. 17-30; EARIP HCP 2020, pp. 3-40-3-42).

Some of the sources of water quality degradation include impervious cover and stormwater runoff, construction activities, recharge from irrigation return flow (i.e., water that is not lost from evapotranspiration on laws or to stream runoff), wastewater discharge, transportation infrastructure, and hazardous materials spills resulting from development within the watersheds that contribute flows to subterranean habitats (Passarello et al. 2012, pp. 29–34; Lapworth et al. 2012, entire). Hueco Springs is situated adjacent to River Road, a popular route for recreational activities along the Guadalupe River. Due to its high recreational traffic, there is a potential vulnerability to road runoff and spills associated with the frequent passage of vehicles (62 FR 66295).

Forested land with limited human disturbances contributes to high-quality recharge (Dudley and Stolten, 2003, pp. 11, 58; Shah et al. 2022, p. 120396), while rural and exurban land uses contribute to groundwater contamination from leaking sewage, refuse dumping, and dead livestock (Sui et al. 2015, p. 21; Katz 2019, p. 565; EARIP HCP 2020, pp. 5-43). Septic systems are a likely source of nutrients (EARIP HCP 2020, p. 5-43; Sui et al. 2015, p. 21). Once a source of pollution enters groundwater, it can be difficult if not impossible to track, intercept, and remediate because of karst conduit complexity (Humphreys 2011, p. 297). Since water quality in the Edwards Aquifer is generally good, this indicates that local sources of water pollution can disproportionately affect water quality in portions of the aquifer.

Oil and gas transmission pipelines are another potential source of hazardous material spills on the contributing and recharge zones of the aquifer. The "development and production of oil, gas, or a geothermal resource within the jurisdiction of the Texas Railroad Commission" are not considered regulated activities "having the potential for polluting the Edwards Aquifer and hydrologically connected surface water in order to protect existing and potential uses of groundwater and maintain Texas Surface Water Quality Standards" (Texas Natural Resource Conservation Commission 1996 p. 1). Consequently, the construction and maintenance of these pipelines are not subject to guidance mitigating impacts to karst features such as voids, and development of these pipelines are not subject to the Edwards Aquifer rules (Texas Natural Resource Conservation Commission 1996, entire).

Abandoned groundwater wells are a source of potential contamination from shallow groundwater into subsurface habitat. Shallower wells (< 300 m [< 984 ft]) are less likely than deeper wells to intercept older groundwater that received cumulative, diluted inputs of pollutants across the aquifer and therefore are more likely to intercept anthropogenic contaminants coming directly from the surface than deeper wells (Musgrove et al. 2014, pp. 69, 73). The EAA funds a needs-based abandoned well closure assistance program to assist well owners with proper well plugging in cooperation with San Antonio Water System to locate and plug abandoned wells (EAA 2021, pp. 50-53). Likewise, former oil wells require maintenance decades after plugging (cement plugs in a steel pipe) and can blowout underground and break free under artesian pressure if not properly maintained (Gold 2022, entire).

Nitrogen is highly soluble and a threat to groundwater quality and a stressor to subterranean taxa (Castaño-Sánchez et al. 2020, pp. 6, 11; Banerjee et al. 2023, pp. 3–6). Panther Canyon well (State well number 6823302), recorded nitrate (2 mg/L) present in 2003 (Texas Water Development Board 2023, unpaginated). Nitrates and orthophosphate consistently emerge from spring run 1 at Comal Springs, and they are typically present at low concentrations (2 mg/L) (U.S. Geological Survey 2023b, unpaginated). The current drought has significantly decreased flow and thus dilution of contaminants are slowed at Comal Springs and recent data resulted in 3 mg/L of nitrate measured at spring run 2 at Comal Springs (West 2023, unpaginated). While safe for humans, it is unknown what effect these elevated nutrients will have over time within the aquifer food web and if conditions would become more favorable for surface species to colonize further underground (Notenboom et al. 1994, pp. 482–484, 490; Opsahl et al. 2018, p. 3). The cave amphipod’s environmental tolerances are unknown, hindering quantitative assessments of this stressors' impact on its sub-populations. Additionally, there are no established groundwater quality standards for subterranean ecosystems, making pollutant concentrations' harm unclear.

Volatile organic compounds have been detected at these spring ecosystems but are rare (Johnson and Schindel 2014, p. 21). There is one documented diesel spill (i.e., naphthalene) that occurred in 2000 at spring run 7 at Comal Springs and emerged at Hueco Springs, further validating their groundwater connection (Ogden et al. 1986, p. 126; Gibson et al. 2008, p. 75). It is unknown what effect this had on the subterranean community.

Urban and agricultural land uses dominate the artesian zone in the southern segment. Low- to high-density urban development occurs across much of the former, while agriculture dominates the latter county. Land use across the southern segment of the Edwards Aquifer plays a major role in groundwater and surface water quality. The presence of agriculture, residential and commercial developments, industrial facilities, military installations, and transportation infrastructure are correlated with increased presence of many contaminants (Bush et al. 2000, pp. 6-9; Fahlquist and Ardis 2004, p. 7; Johnson et al. 2009, p. 46; Wilson 2011, pp. 1-2; Musgrove et al. 2014, pp. 69-71; Opsahl et al. 2018, p. 58; Opsahl et al. 2020, pp. 17-30).

To examine projected land-use changes in the urban centers intersecting Edwards Aquifer groundwater, we used the EPA's (2019, unpaginated) Integrated Climate and Land-Use Scenarios. These outputs produce spatially explicit projections of population and land-use that are based on the Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios. The combination of SSP5-RCP8.5 illustrates a higher population growth and higher emissions, and a faster rate of human population growth consistent with the Texas Demographic Center population projections for Bexar County and the San Antonio-New Braunfels Metropolitan Area (Environmental Protection Agency 2017, pp. 34-35, 46; Texas Demographic Center 2022, unpaginated). Within the Edwards Aquifer artesian, recharge, and contributing zones (543,498 ha^2 [134,3014 ac^2]), developed land-use classes are projected to grow from 21 percent in 2020 to 27 percent developed by 2050. When examining delineated areas at a finer scale around Comal Springs using the Integrated Climate and Land-Use Scenarios, population is also projected to increase in development from 66-82 percent developed. These areas may be important to assess more immediate impacts from groundwater contamination. Alternatively, the area around Hueco Springs is not projected to have noticeable changes in development use classes.

Based on the Integrated Climate and Land-Use Scenario results, projections of developed land-uses and population growth will continue to expand outward outside of the major metropolitan areas, San Antonio and Austin, Texas. Over time, these alterations have the potential to affect recharge rates, leading to deteriorating groundwater quality as a result of heightened runoff from impervious surfaces in suburban and urban areas or septic systems that are poorly managed and prone to leakage in exurban areas (Berube et al. 2006, pp. 10, 38; Barkfield 2022, p. 2).

The U.S. Census Bureau (2020, unpaginated) ranked several of the counties in the recharge and contributing zones of Comal Springs among the fastest growing in the United States from April 2010 to July 2019: Hays County was the second fasting growing county with a 46.5 percent population increase, Comal County the fourth fastest growing county with a 43.9 percent population increase, and Kendall County the fifth fastest growing county with a 42.1 percent population increase. Since 2000, these three counties have doubled in population and have seen substantial associated development. Projections indicate that the human population of Bexar, Comal, Hays, and Kendall counties will continue to increase substantially over the next three decades.

Conversion of natural habitat to urban, suburban, and exurban development is likely to accompany this population growth. Under a high human population growth scenario, land use projections suggest that large areas west and north of Bexar County will be converted to increasingly more urbanized land-use classes by 2100 (EPA 2019, unpaginated). Much of the exurban and suburban development is postulated to occur outside of municipal boundaries in unincorporated areas of counties where land use regulations (e.g., restrictions on impervious cover) are non-existent (Siglo Group 2022, pp. 13-14). Run-off from existing and expanded impervious cover in sensitive areas of the aquifer could affect groundwater quality over time. New contaminant sources are expected to be added to the region as increased human populations and expanded development continues; many existing contaminant sources will persist.

Land-use changes, particularly increases in impervious cover, are known stressors to aquatic systems and are difficult to predict, model, and remediate (Sharp 2010, p. 3; Coles et al. 2012, p. 65). Future development in the recharge and contributing zones are likely to decrease water quality because of the increased risk of contamination entering the aquifer. Additionally, nitrate runoff from surface water recharge leads to increased nitrate concentrations in the aquifer, and concentrations over 1 milligram per liter (mg/L) are indicative of anthropogenic inputs, which have been recorded historically at Comal Springs and have doubled over the last 70 years (median concentration 2 mg/L) (Dubrovsky et al. 2010, p. 79; Musgrove et al. 2016, pp. 462, 465, 467; Castaño-Sánchez et al. 2020, p. 6). These changes in water quality in streams and groundwater correspond with increases in impervious cover over a watershed (Kaushal et al. 2005, p. 13518; Baker et al. 2019, pp. 6494–6495; Castaño-Sánchez et al. 2020, p, 6).). These water quality parameter changes may be a long-term indication of urbanization that has already occurred across the recharge zone.

A review of research studies found that impacts to aquatic species are seen with impervious cover of 10 percent or more (Center for Watershed Protection 2003, p. 97). Although the studies were focused on stream systems, we assume that shallow groundwater habitats would have similar impacts because shallow groundwater ultimately flows into streams through discharge features. While physical parameters may be different (e.g., higher oxygen, lower temperatures, higher conductivity) in the shallow groundwater, pollutants entering both systems would be the same.

The EAA does not have explicit impervious cover limits in the recharge zone, with the intent that structural best management practices will protect water quality (Greater Edwards Aquifer Alliance 2010, p. 3). The TCEQ shares responsibility in protecting the Edwards Aquifer through impervious cover limits through a construction permit review process for development proposals of more than 20 percent impervious cover that includes structural best management practices (30 TAC § 213). Additionally, Comal County has goals to minimize impervious cover within the city of New Braunfels to limits of 26 percent per parcel (Design Workshop, Inc. 2012, pp. 4–5).

These percentages are all higher than 10 percent, and each project approval does not account for the cumulative impact of combined impervious cover amounts within each county. Likewise, most lands over the contributing zone are not managed with land use regulations (e.g., impervious cover restrictions) (Siglo Group 2022, pp. 13–14).

Habitat Disturbance- Flooding

Surface habitat modification can occur as the result of flooding. Flash flooding is common throughout the Edwards Plateau (Woodruff and Wilding 2008, pp. 614-616). However, channel modification and the elimination of riparian zones can increase the severity of flooding (Schoof 1980, p. 697). Depending on the severity of floods, they can either deposit or increase suspended sediment loads over species habitat or scour substrate and vegetation from species habitat under high velocities (Griffin 2006, pp. 57-58, 61, 64; BIO-WEST, Inc. 2016, p. 26; BIO-WEST, Inc. 2019a, pp. 14, 17; Schwartz et al. 2020, pp. 12). During wet periods, flows at Hueco Springs are highly responsive to storm events. These events increase flows and dilutes higher quality springflows with greater proportions of local recharge, which may include increased loads of contaminants (Ogden et al. 1986, pp. 118, 125, 127; Musgrove and Crow 2012, pp. 53, 56-57). It is possible that individuals of species may also be washed away in floods, though this has not been studied for the Peck's cave amphipod. Floods have deposited finer sediments (e.g., silt) over invertebrate surface habitat within the Spring Island area within Comal Springs, reducing springflow and quality of habitat (BIO-WEST, Inc. 2002, p. 11; Gibson 2022, pers. comm.).

2.2.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Peck's cave amphipod specimens are collected for scientific study and two refugia populations. Such collections which have not been documented to negatively impact total wild population numbers. At present, this species is not recognized for their commercial worth, and there is no evidence of overexploitation, making overutilization insignificant as a threat.

2.2.2.3 Disease or predation:

Disease and parasitism is rarely observed for the Peck's cave amphipod. A nematode (*Amphibiocapillaria texensis*) and an acanthocephalan (*Dendronucleata americana*) parasite have been observed in Texas blind and San Marcos salamanders (*Eurycea rathbuni*; *E. nana*) and *Hyalella* amphipod species (likely as an intermediate host), which other *Stygobromus* taxa may serve as a possible intermediate host within the parasites' life cycle (Moravec and Huffman 2000, entire; Worsham and Gibson 2022, pers. comm.).

A facultative ectoparasite (e.g., rotifers, Phylum Rotifera) can be found on the gills of other amphipod taxa of this aquifer ecosystem but has not been observed in Peck's cave amphipods and needs further investigation (Worsham and Gibson 2022, pers. comm.).

Seen in other members of the subphylum Crustacea (e.g., prawn, crab, and lobster juveniles and adults), a rickettsia-like bacterium causes milky haemolymph disease and can be treated (Nunan et al. 2010, p. 105, 111). This syndrome has been identified in other *Stygobromus* sp., softening exoskeletons and killing the individual (Worsham and Gibson 2022, pers. comm.). It is unknown if the Peck's cave amphipod is affected by this disease and what extent contact with other infected freshwater crustaceans at the surface have on this species.

The amount of predation that occurs in the wild has not been examined for this species. Blind, fragile subterranean species such as the Peck's cave amphipod may be more susceptible to predation once they enter surface waters (Barr 1993, pp. 63-64). Fishes compete for prey expelled from the aquifer at discharge features (e.g., spring openings). Researchers have seen Mexican tetras (*Astyanax mexicanus*), sunfish (*Lepomis* sp.), and mosquitofish (*Gambusia* sp.) congregating at spring openings waiting for the driftnet to be removed and consume the bycatch, including subterranean invertebrates (BIO-WEST, Inc. 2003, p. 42). Macroinvertebrates are a part of the food chain, and it is assumed any number of individuals removed from the Peck's cave amphipod sub-populations through typical levels of predation are negligible.

2.2.2.4 Inadequacy of existing regulatory mechanisms:

Under this factor, we examine the stressors identified within the other factors as ameliorated or exacerbated by any existing regulatory mechanisms or conservation efforts. Section 4(b)(1)(A) of the ESA requires that the USFWS consider "those efforts, if any, being made by any State or foreign nation, or any political subdivision of a State or foreign nation, to protect such species…". In relation to Factor D under the ESA, we interpret this language to require the USFWS to consider relevant Federal, State, and Tribal laws, regulations, and other such binding legal mechanisms that may ameliorate or exacerbate any of the threats we describe in threat analyses under the other four factors or otherwise enhance the species' conservation. Our consideration of these mechanisms is described in detail within each of the threats or stressors to the species (see discussion under the other Factors). Much of the information under Section 2.2.2.1 should also be considered as relevant here because it is often the inadequacy of existing regulations that contributes to habitat loss and degradation for these species.

The recharge and contributing zones to the Edwards Aquifer continue to experience rapid human population growth and conversion of natural habitat to development, which continues to threaten water quality. Much of the contributing zone is not under the same regulations as the recharge zone to protect water quality, even though much of the water that recharges the aquifer originates in the contributing zone. Regulatory mechanisms that protect water in the Edwards Aquifer are crucial to the future survival of the Peck's cave amphipod. Federal, State, and local laws and regulations have improved water quality and quantity protection but could be insufficient to prevent ongoing impacts to the species and their habitats from water quality degradation, reduction in water quantity, and surface disturbance of spring sites, and are unlikely to prevent further impacts to the species in the future. Knowledge of the source, accumulation, and transport of these compounds in the aquifer are lacking and investigations into their effects on the habitat quality are necessary for the recovery of the Peck's cave amphipod and for sustainable use of the aquifer (Danielopol et al. 2004, pp. 187-188; Opsahl et al. 2018, p. 2).

Under Texas Parks and Wildlife Code (Chapter 68) and TAC (31 TAC § 65.171-65.176), the Texas Parks and Wildlife Department is authorized to add species to the agency's List of State Threatened and Endangered Nongame Species and List of Endangered, Threatened, and Protected Native Plants. The seven species in this plan are also state listed. The Texas Parks and Wildlife Department prohibits the taking, possession, transportation, or sale of any animal species that are state listed as threatened or endangered. State law prohibit commerce in threatened and endangered plants, and also prohibits collection of listed plant species from public land without a permit. However, prosecutions for these prohibited actions are rare and the burden of proof to prosecute is high, which can result in unauthorized take of state listed species. In addition, it is likely that at the time of recovery they would no longer be state listed. Because the Peck's cave amphipod is conservation reliant, it would be expected that delisting would increase threats identified in the listing determination, unless there are other mechanisms to continue conservation efforts.

While the EAA was granted regulatory authority by the Texas Legislature, there have been several legal challenges to the EAA permitting program. For example, in court cases *Edwards Aquifer Authority v. Day* (2012, Supreme Court of Texas No. 08-0964) and *Edwards Aquifer Authority v. Bragg* (2013, Court of Appeals of Texas No. 04-11-00018-CV), courts awarded landowners compensation for groundwater permits that were denied by the EAA due to lack of historical usage. The ruling for *Edwards Aquifer Authority v. Day* by the Texas Supreme Court argued that there was no reason to treat groundwater differently than oil and gas and recognized groundwater as real property. In both cases, landowners owned the land prior to enactment of new groundwater pumping regulations. There remains a lack of clarity with Texas groundwater law that results in ongoing legal challenges regarding groundwater regulation, and these could impact the EAA's ability to regulate the aquifer in the future.

The EAA manages and issues permits for groundwater withdrawals within the Edwards Aquifer through conservation and drought management. The EAA's jurisdiction is limited to the Edwards Aquifer in Uvalde, Medina, Bexar, and portions of Comal, Guadalupe, Hays, and Caldwell counties. The contributing zone in Bandera, Kerr, and Kendall counties do not have additional protections under either program. Thus, the EAA's its water quality regulations do not protect most of the contributing zone, which may ultimately reduce the water quality of the Edwards Aquifer.

As described above, TCEQ regulates activities that have the potential to pollute the Edwards Aquifer and hydrologically connected surface streams under the same Edwards Aquifer Protection Program or "Edwards Rules" and for the same counties. This means areas of the contributing zone do not have additional protections that could affect the amount and quality of recharge that enters the Edwards Aquifer, resulting in lower water quality protection for the aquifer and the Comal and Hueco ecosystems.

Likewise, this agency does not address development or other land use, impervious cover limitations, some nonpoint source pollution, or application of fertilizers and pesticides over the recharge zone (30 TAC § 213.31). Changes to how surface water and the Trinity Aquifer are managed are likely to change the amount that can be sustainably pumped from the Edwards Aquifer during drought conditions. For example, the Hays-Trinity Groundwater Conservation District also manages groundwater that influences the water at San Marcos Springs.

2.2.2.5 Other natural or manmade factors affecting its continued existence:

Global climate change is already affecting many regions' biodiversity, with stressors driven by increasing temperatures and extreme climatic events and will continue to in the near-term (Intergovernmental Panel on Climate Change 2023, pp. 5, 15). Over the last 115 years, the global averaged surface air temperature has increased by 1.0°C (1.8°F) with recent decades being the warmest in 1,500 years (Vose et al. 2017, pp. 186, 188). With the highly karstic permeability of the Edwards Aquifer, climate change and variability strongly influence this vulnerable aquifer that relies heavily on rainfall for recharge (Mace and Wade 200,8 p. 659; Taylor et al. 2013, p. 312; Ding and McCarl 2019, p. 11; Nielsen-Gammon et al. 2020, p. 9). The Fourth U.S. National Climate Assessment (U.S. Global Change Research Program 2018, pp. 1,002-1,003) presents the Edwards Aquifer as a case study in vulnerability to climate change, citing the shallow karst aquifer as especially sensitive to climate change, and the regional population growth and development as exacerbating the effects of decreased water supply during droughts. While average rainfall is not projected to change significantly in central Texas, the distribution of precipitation is anticipated to change with more extreme droughts and extreme rain events (Geos Institute 2016, pp. 14-15).

Increasing temperatures will also create drier conditions due to increased evapotranspiration (Loáiciga and Schofield 2019, p. 224). Extreme droughts in Texas are more likely than they were 40-50 years ago (Rupp et al. 2012, p. 1,054; Nielsen-Gammon et al. 2020, entire). A recent study predicts megadroughts in Texas, more severe than have been seen for the past thousand years, that will occur before 2100 (Nielsen-Gammon et al. 2020, entire). Droughts worse than the drought of record occurred since the 1600s and are not uncommon in the region (Mauldin 2003, entire; Cleaveland et al. 2011, entire). It is not possible to ensure that there will be adequate flow to these springs without planning for more extreme droughts than the drought of record (Loáiciga and Schofield 2019, p. 236; Mace 2019, p. 212). The sustainable water yield for the Edwards Aquifer will decrease in a dry climate (EARIP HCP 2020, pp. 3-12, 3-31, 3-43; Loáiciga and Schofield 2019, pp. 223, 235-236) while human demand for groundwater will increase (EARIP HCP 2020, pp. 3-10-3-11), making it more challenging to balance groundwater use for human needs and ecosystem function. In 2010, Texas set a record for lowest rainfall (March–May; June–August) and with similar conditions persisting until 2013 (Nielsen-Gammon 2012, p. 59; National Research Council 2015, p. 168). Heavy rainfall leading to floods may also become more common from extreme precipitation events and may result in increased habitat disturbance due to movement of materials and scouring.

Air temperature in Texas has risen 1°C (2°F) since the early 1900s (Geos Institute 2016, p. 4). Future air temperature changes will depend on the amount of future greenhouse gas emissions (U.S. Global Change Research Program 2018, p. 995). Based on current projections of greenhouse gas emissions, air temperature is projected to increase 2.0-2.8°C (3.6-5.1°F) by 2050, and 2.4–4.7°C (4.4–8.4°F) by 2100 for the southern Great Plains (U.S. Global Change Research Program 2018, p. 995). Projections expect a greater rise in air temperature by 2100, 2.7–5.6°C (5–10°F) (Sharif 2018, p. 4). Studies have not explicitly addressed groundwater temperature increases for the Edwards Aquifer. Based on other research into changes in groundwater temperature, it is reasonable to expect that groundwater temperature will increase as air temperature increases, with a possible lag in groundwater temperature increase (Mahler and Bourgeais 2013, p. 295). Groundwater temperature also increases with urbanization and vegetation removal (Benz et al. 2017, entire). This could further increase groundwater temperatures as more development occurs. Groundwater temperature typically increases with depth due to geothermal heat flow, although this also varies locally with other variables such as vertical groundwater flow (Bense and Kurylyk 2017, pp. 1, 8). This suggests that deeper water would not provide a long-term buffer to increasing temperatures.

Some subterranean-adapted species would likely be incapable of adapting to modified temperatures in the medium to long-term and less capable, due to restricted dispersal capabilities, to flee rising temperature conditions than surface-adapted species (Culver and Pipan 2009, pp. 207–208; Taylor et al. 2013, pp. 324–325; Mammola et al. 2019, p. 646). Subterranean-adaptations in ectothermic animals allow for small fluctuations in temperature, but increased temperatures due to climate change can affect subterranean diversity by altering mobilization of contaminants (i.e., change in recharge rates through the unsaturated zone) and disruption to biogeochemical processes (e.g., carbon and nitrogen cycle) (Kløve et al. 2014, p. 263; Castaño-Sánchez et al. 2020, p. 7). Water quality at the subsurface and surface is also likely to decrease with increased water temperature. For example, as dissolved oxygen decreases and microbial activity increases (Bates et al. 2008, p. 43). Therefore, the adaptive capacity ectothermic animals have to environmental changes is presumed to be low.

For instance, in periods of low rainfall, two main spring outlets at Hueco Springs cease their flow, particularly during droughts and the driest months annually (Puente 1976, pp. 25-27; Guyton and Associates 1979, p. 46; Ogden et al. 1986, p. 122; Barr 1993, p. 36; Otero 2007, pp. 18, 21). However, little is known how this affects the sub-population of Peck's cave amphipods because this site is located on private property, and researchers are rarely granted access.

Surface water temperature will also increase during warm months. Data from the EAA indicates greater temperature fluctuations downstream from the springs due to increased exposure time to ambient temperatures and runoff from rain events (BIO-WEST, Inc. 2019b, p. 20). Low spring discharge is also a mechanism that increases the water's exposure time to ambient temperature. Thus, both future droughts and increased ambient temperature are likely to increase the surface water temperature. Continuous temperature data for the springs began in 2000, and groundwater temperature at Comal Springs is relatively constant (BIO-WEST, Inc. 2019b, p. 20). Continuous water temperature monitoring in the Comal River should indicate whether water temperatures rise in the future.

There is currently no information on whether increased temperatures can affect different life stages or reproduction of the Peck's cave amphipod, or how quickly water temperature will change in their habitat into the future. For ectothermic animals (e.g., macroinvertebrates), overall vulnerability to climate change will depend on thermal sensitivity and how quickly their buffered environment changes (Pallarés et al. 2021, p. 487; Delić et al. 2022, p. 2). Species with similar tolerances and adaptive traits have no opportunity to migrate and are unlikely to successfully relocated due to its specific habitat requirements (Kløve et al. 2014, p. 263; Castaño-Sánchez et al. 2020, p. 7; Simčič and Sket 2021, entire; Becher et al. 2022, pp. 4–5). We are uncertain if this species could flee from undesirable conditions caused by catastrophic drought in their habitat. There could be voids that become de-watered, and we assume the species make attempts to follow the water down into the aquifer as drying occurs.

An assessment by U.S. Geological Survey evaluated the projected future vulnerability through 2050 of the Peck's cave amphipod and rated it as moderately vulnerable to climate change (Stamm et al. 2015, pp. 1, 40, 42, 47). Moderately vulnerable is defined as "abundance and/or range extent within geographical area assessed likely to decrease by 2050". There is currently no information indicating whether increased temperatures would affect different life stages or reproduction of the Peck's cave amphipod, or how quickly groundwater temperature will change in the Edwards Aquifer in response to climate change at the surface. Without more information, it is unknown to what extent these temporally delayed changes to the aquifer would have on this cave amphipod and if they would have sufficient time and have appropriate traits to adapt. These are important factors that require more research globally to fully understand vulnerability of these aquifer ecosystems and their subterranean communities (Mammola et al. 2019, pp. 646–647; Hose et al. 2022, entire).

2.3 Synthesis

There are currently two sub-populations of the Peck's cave amphipod in Texas. There is no recovery plan or species status assessment to fully evaluate species viability published at this time. However, available demographic data, captive refugia research, and the five-factor threats analysis (Section 2.2.2) are collectively not indicative for a change in listing status recommendation for the Peck's cave amphipod. Peck's cave amphipod sub-populations rely on continuous management and protective measures to preserve habitat, prevent silt accumulation and manage groundwater pumping for optimal springflow, supply terrestrial organic matter for the food web, and maintain sufficient water availability and quality for overall ecosystem health. In conclusion, it is our recommendation that a change in classification is not warranted at this time.

3.0 RESULTS

3.1 Recommended Classification:

No change is needed

3.2 New Recovery Priority Number (indicate if no change; see 48 FR 43098):

No Change Recommended; see 48 FR 43098, September 21, 1983 & 48 FR 51985, November 15, 1983 - Correction)

Brief Rationale:

The primary stressors are the loss of spring flows and decreases in subsurface habitat due to drawdown of the Edwards Aquifer and reductions in water quality from development and land-use changes. Research suggests that contamination of groundwater has not been historically widespread, is at relatively low concentrations currently, and the subterranean ecosystems do not exhibit significant signs of degradation (Hutchins 2018, pp. 481–482). Current conservation, flow protection, and water quantity optimization measures in place have been effective in meeting biological objectives for the Covered Species, including the Peck's cave amphipod, under which the EARIP HCP and regulations are reducing groundwater withdrawal pressure (National Research Council 2018, p. 109). Given the projected increases in development and climate change-induced droughts in South Central Texas, the impact on groundwater habitat quality and aquifer recharge into the future remains uncertain (Loáiciga and Schofield 2019, p. 224; National Oceanic and Atmospheric Administration 2022, unpaginated). The sustainable water output for the Edwards Aquifer could decrease in a dry climate while human demand for groundwater would increase, making it more challenging to balance groundwater use for human needs and ecosystem function, and thus, the Peck's cave amphipod's viability (Loáiciga and Schofield 2019, pp. 223, 235–236; EARIP HCP 2020, pp. 3-10–3-11, 3-12, 3-31, 3-43; Nielsen-Gammon et al. 2020, pp. 9–10).

In terms of viability, the Peck's cave amphipod occupies a restricted range of two sub-populations as a narrow endemic species (redundancy) only occurring in the Edwards Aquifer and associated spring ecosystems (representation) and are highly susceptible to extinction from perturbations that would affect water quantity and quality in the Edwards Aquifer and ongoing management is needed to maintain resiliency. Further, the absence of data to inform how these threats directly impact Peck's cave amphipod sub-populations precludes a more detailed assessment of these impacts. Thus, our analysis does not warrant a change in recommended classification or recovery priority number.

Therefore, we recommend the Peck's cave amphipod retain its classification as endangered due to its conservation-reliant status.

3.3 Listing and Reclassification Priority Number, if reclassification is recommended (see 48 FR 43098):

Reclassification (from Threatened to Endangered) Priority Number:
Reclassification (from Endangered to Threatened) Priority Number:
Delisting (Removal from list regardless of current classification) Priority Number:

Brief Rationale:

Not Applicable

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

- If possible given workload and priorities, a Species Status Assessment could be conducted to guide the development of a revised recovery plan.
- Continue to plan and implement regular surveys that monitor Peck's cave amphipod occurrence, habitat condition, groundwater and surface water quality, as well as any

potential threat to the Peck's cave amphipod from disease and parasitism (Section 2.2.2.3).

- Status survey at the Hueco Springs ecosystem in Comal County to assess species persistence, abundance, and habitat health of this sub-population, in addition to improving habitat conditions and landowner cooperation. Currently, the status of this sub-population is unknown.
- Continue to investigate the extent of groundwater watersheds between the Comal and Hueco ecosystems, including eDNA or physical sampling in between the sites when available, in order to get a more accurate representation of drainage areas and habitat connectivity and gene flow.
- Incorporate habitat-centered biological goals and objectives during EARIP HCP renewal process to promote protection of suitable habitat quality and quantity and species resiliency.
- Establish conservation easements or fund land purchases within the contributing and recharge zones of the Edwards Aquifer for the benefit of the Peck's cave amphipod and to ensure adequate springflow is sustained through droughts. Additionally, a site-prioritization tool could be developed to support decision making about strategic land acquisitions.
- Research to reduce sources of nitrate into the Comal ecosystem through coordination with agencies, public education, and other non-governmental organizations.
- To the extent possible, prevent or reduce increases in impervious surfaces or clearing of forest within the recharge areas supporting the species.
- Continuation of the captive propagation research:
  - Conduct ongoing research to enhance captive propagation techniques.
  - Develop the capacity to produce offspring on-demand, anticipating standard operating procedures to inform action for potential catastrophic events or extirpation in the wild.
  - Formulate a comprehensive reintroduction plan based on research findings, ensuring the ability to replenish populations as needed.
- Continue water quantity and quality monitoring at accessible spring and well sites within and areas that recharge the Comal ecosystem.
- Continue to measure genetic variability among sub-populations of the Peck's cave amphipod in order to evaluate gene flow, population structure, and estimate population sizes. These data can inform captive husbandry practices to preserve genetic diversity in the refugia population and future recovery plan implementation.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of the Peck's cave amphipod

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: Not applicable

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service, [Austin Ecological Services Field Office]

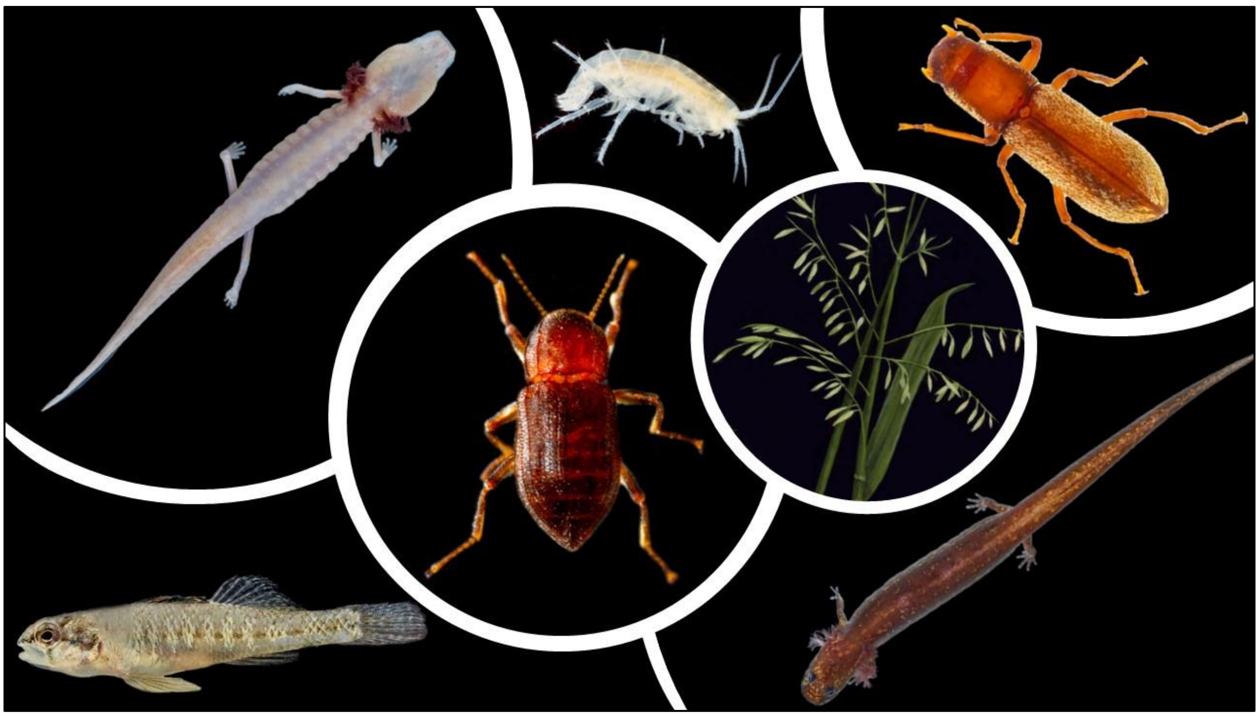
Approve ____

Appendix D9 | **USFWS's Draft Recovery Plan Released September 10, 2024**

Draft Recovery Plan for the Southern Edwards Aquifer Springs and Associated Aquatic Ecosystems, Second Revision

Fountain darter (*Etheostoma fonticola*), Peck's cave amphipod (*Stygobromus pecki*), Comal Springs riffle beetle (*Heterelmis comalensis*), Texas wild-rice (*Zizania texana*), San Marcos salamander (*Eurycea nana*), Texas blind salamander (*Eurycea rathbuni*), and Comal Springs dryopid beetle (*Stygoparnus comalensis*)

<u>Revision History</u>
Original Version: 1985
First Revision: 1996



U.S. Fish and Wildlife Service
Southwest Region
Albuquerque, NM

Purpose and Disclaimer

This document presents the U.S. Fish and Wildlife Service (USFWS) plan for the conservation of southern Edwards Aquifer springs and associated aquatic ecosystem species. The recovery plan is the second part of the USFWS's 3-part recovery planning framework and includes the statutorily required elements pursuant to section 4(f) of the Endangered Species Act (ESA). This recovery plan is informed by the first part of the framework, a Species Biological Report (SBR) (USFWS 2024a, entire). The SBR report delivers foundational science for informing decisions related to the ESA and includes an analysis of the best available scientific and commercial information regarding a species' life history, biology, and current and future conditions that characterizes the species' viability (i.e., ability to sustain populations in the wild over time) and extinction risk. We have also prepared a Recovery Implementation Strategy (RIS), the third part of the framework (USFWS 2024b, entire). The RIS is an easily updateable operational plan that is separate and complementary to the recovery plan that details the on-the-ground recovery activities needed to complete the recovery actions contained in the recovery plan.

Recovery plans describe the envisioned recovered state for a listed species (when it should no longer meet the ESA definitions of a threatened species or endangered species) and include a recovery strategy, recovery criteria, recovery actions, and the estimates of time and cost needed to achieve recovery. Plans are published by the USFWS and are often prepared with the assistance of recovery teams, contractors, State agencies, and others. Recovery plans do not necessarily represent the views, official positions, or approval of any individuals or agencies involved in plan formulation, other than the USFWS. They represent the official position of the USFWS only after they have been signed by the Regional Director as approved. Recovery plans are guiding and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation.

Acknowledgements

We dedicate a special thanks to former fish and wildlife biologist, Pat Connor (USFWS, Austin Ecological Services Field Office) for gathering source material used to inform the revision of this recovery plan.

We are grateful to the people who have contributed their expertise, perspectives, and dedication to these species' recovery efforts over the last four decades. In particular, we would like to express our gratitude to the previous Recovery Team members, the Permittees and staff of the Edwards Aquifer Recovery Implementation Plan - Habitat Conservation Plan, the local communities within the recovery area, and the general public.

In addition to the people identified above, the following USFWS staff reviewed and provided comments on previous drafts of this plan: Katie Bockrath, Ph.D., Justin Crow, Randy Gibson, Chris Hathcock, and Desiree Moore, Ph.D. (San Marcos Aquatic Resources Center); Pete Diaz (Texas Fish and Wildlife Conservation Office); Karen Myers, Christina Williams, and Michael

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Cover page images courtesy of Kristin Simanek (USFWS) and John and Kendra Abbott (Abbott Nature Photography).

Lead Authors

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An electronic copy of the Draft Recovery Plan will be made available at the USFWS Environmental Conservation Online System (ECOS):

- ECOS species profile webpage for Comal Springs dryopid beetle;
- ECOS species profile webpage for Comal Springs riffle beetle;
- ECOS species profile webpage for fountain darter;
- ECOS species profile webpage for Peck's cave amphipod;
- ECOS species profile webpage for San Marcos salamander;
- ECOS species profile webpage for Texas blind salamander; and
- ECOS species profile webpage for Texas wild-rice

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1.0 Introduction

This Recovery Plan describes criteria for determining when the southern Edwards Aquifer springs and associated aquatic ecosystem species should be considered for delisting, lists site-specific actions that will be necessary to meet those criteria, and estimates the time and cost to achieve recovery. Additionally, a brief summary of information on the species' biology and status are included, along with a brief discussion of factors limiting their populations. A detailed discussion of these and other topics pertinent to the recovery of the southern Edwards Aquifer springs and associated aquatic ecosystem species can be found in the Species Biological Report (SBR) (USFWS 2024a, entire). Detailed on-the-ground activities implementing recovery actions can be found in the Recovery Implementation Strategy (RIS). The RIS and SBR are finalized separately from the Recovery Plan and will be updated on a routine basis. This document presents the USFWS plan for the conservation and recovery of the ESA-listed species of the southern Edwards Aquifer springs and associated aquatic ecosystems.

The southern Edwards Aquifer springs and associated aquatic ecosystem species are the Comal Springs dryopid beetle (*Stygoparnus comalensis*), Comal Springs riffle beetle (*Heterelmis comalensis*), fountain darter (*Etheostoma fonticola*), Peck's cave amphipod (*Stygobromus pecki*), San Marcos salamander (*Eurycea nana*), Texas blind salamander (*Eurycea rathbuni*), and Texas wild-rice (*Zizania texana*). All these species are endangered except for the San Marcos salamander, which is threatened. These species were listed under the ESA in 1975 (Texas blind salamander and fountain darter, 40 FR 44412), 1978 (Texas wild-rice, 43 FR 17910), 1980 (San Marcos salamander, 45 FR 47355), and 1997 (Comal Springs dryopid beetle, Comal Springs riffle beetle, and Peck's cave amphipod, 62 FR 66295). Changes to the species since the 1996 revision of the recovery plan include the removal of the San Marcos gambusia (*Gambusia georgei*) due to extinction (88 FR 71644) and the addition of the three invertebrate species (the beetles and amphipod) that were listed in 1997.

The species included in this Recovery Plan are all aquatic and depend on adequate groundwater and/or springflows in the southern segment of the Edwards Aquifer in Comal and Hays counties, Texas (see the SBR for hydrology information (USFWS 2024a, Section 1.1)). Receiving water from the Edwards Aquifer, Comal and San Marcos springs are the largest springs in Texas and host the only known populations of some species included in this plan. A few species have distributions that extend downstream in the Comal River and the upper San Marcos River. These are spring-dependent rivers, reliant on groundwater from the Edwards Aquifer, with relatively constant temperature and water chemistry. Genetically distinct populations of the Comal Springs dryopid beetle are found at Fern Bank Springs (Fries et al. 2004, pp. 9, 14-15; Gibson et al. 2008, pp. 76-77) and the Peck's Cave amphipod at Hueco Springs (Holsinger 1967, entire; Barr 1993, entire; Fries et al. 2004, p. 5; Gibson et al. 2008, pp.76-81; Ethridge et al. 2013, entire). Fern Bank Springs and Hueco Springs are two more springs that receive water from the Edwards Aquifer.

The location and habitat requirements of each species vary (Section 1.1.1 Management Units, below). The SBR (USFWS 2024a, Sections 1.2-1.8) provides additional background information on these species. The Texas blind salamander occurs in the subsurface of the Edwards Aquifer in the San Marcos area, including some caves and wells (Uhlenhuth 1921, p. 87; Russell 1976, pp. 1-4; Longley 1978, pp. 12-18; Chippindale 2009, pp. 8-11). This salamander is also expelled from springs in Spring Lake (receiving groundwater from the Edwards Aquifer). The San Marcos salamander is found at the headwaters of the San Marcos River and in Spring Lake (Tupa and Davis 1976, p. 191; Nelson 1993, pp. 19-20; Diaz et al. 2015, p. 317) and relies on interstitial spaces and vegetation for habitat (Diaz et al. 2015, pp. 307, 316).

The fountain darter and Texas wild-rice occur further downstream from the springs than the other species, with both species historically occurring throughout the upper San Marcos River (Jordan and Gilbert 1886, pp. 21-23 USFWS 2019, entire, BIO-WEST, Inc. 2023, p. 27). Texas wild-rice relies on cool, clear springwater for photosynthesis and establishes better in gravel and sand substrates overlying Crawford black silt and clay (Vaughan 1986, p. 17; Poole and Bowles 1999, entire; Saunders et al. 2001, p. 24). The fountain darter relies on submerged aquatic vegetation for habitat (Dowden 1968, pp.19-20; Phillips et al. 2011, entire; Edwards and Bonner 2022, entire). The fountain darter also occurs throughout the Comal River (Hubbs and Strawn 1957, p. 38; Schenck and Whiteside 1976, pp. 700-702).

The Comal Springs dryopid beetle occurs in springs, associated streams, and saturated subterranean pore spaces, including wells and springs at Landa Lake (an impoundment of the Comal River), in the New Braunfels, San Marcos, and Wimberley, Texas areas, all within the Edwards Aquifer (Barr and Spangler 1992, p. 41; Barr 1993, pp. 31, 53-55; BIO-WEST, Inc. 2004, p. 34; Fries et al. 2004, pp. 9, 14-15; Gibson et al. 2008, pp. 76-77; Kosnicki and Julius 2019a, p. 3). Peck's cave amphipod occurs in springs, associated streams, and saturated subterranean pore spaces in the New Braunfels area, including Panther Canyon Well (Holsinger 1967, p. 119; Barr 1993, pp. 56-57; Fries et al. 2004, pp. 5, 14; Gibson et al. 2008, pp.76-81). Comal Springs riffle beetle occurs immediately inside of or adjacent to springs, seeps, and upwellings where plant roots are inundated or otherwise influenced by aquifer water in the New Braunfels and San Marcos, Texas areas and is also found near Landa Lake spring openings (Bosse et al. 1988, entire; Barr 1993, pp. 31, 44; BIO-WEST, Inc. 2005, p. 51; 2006, p. 39; Gibson et al. 2008, p. 79; Nowlin and Worsham, 2015, p. 12).

Primary threats to the seven species are the loss of groundwater and/or springflows and decreases in suitable habitat due to drawdown of the Edwards Aquifer (see SBR, USFWS 2024a, Section 2.1.1). These species are also sensitive to declines in water quality (see SBR, USFWS 2024a, Section 2.1.2). Metropolitan areas and smaller municipalities along the eastern extent of the southern segment of the Edwards Aquifer are experiencing rapid human population growth and urban development that is expected to affect groundwater quality and quantity (see SBR, USFWS 2024a, Sections 2.1.1 and 2.1.2). Climate change-driven aridity combined with withdrawal of groundwater could lead to decreased springflows (see SBR, USFWS 2024a, Section 2.5). Additional threats that could decrease water quantity and quality include hazardous spills, direct or indirect habitat destruction through alterations of natural flow regimes, habitat disturbance or habitat modification by humans (e.g., recreational activities, dam building, concrete filling, excavation, bank stabilization, and control of aquatic vegetation), and nonnative species (see SBR, USFWS 2024a, Section 2.1). The fountain darter, San Marcos salamander, and Texas blind salamander are also subject to diseases and parasites that may affect their population resiliency (see SBR, USFWS 2024a, Section 2.3). These threats have necessitated the use of captive propagation efforts to ensure the long-term survival of these seven species until threats are abated. The SBR (USFWS 2024a, Section 2.0) further describes the threats to these species.

1.1 Recovery Strategy

The recovery strategy provides a concise overview of the envisioned recovered state for the southern Edwards Aquifer springs and associated aquatic ecosystems species, describes the USFWS's chosen approach to achieve it, and includes the rationale for why the approach was chosen. Specifically, the recovery strategy articulates how the plan's statutory elements (recovery criteria, recovery actions, and estimates of time and cost) will work together to achieve the southern Edwards Aquifer springs and associated aquatic ecosystems species' recovery.

Each species in this plan has naturally low redundancy of one to three populations in its historical range, as described in the SBR (USFWS 2024a, Section 1.0). Redundancy is the ability of the species to withstand catastrophic events. The species also have naturally low representation from occurring exclusively in ecosystems in the Edwards Aquifer. Each of these species is dependent on water and environmental conditions specific to the Edwards Aquifer. Representation is the ability of the species to adapt to both near-term and long-term changes in its physical and biological environment. Therefore, the USFWS does not think that there are actions we can take to increase natural redundancy and representation of these species, although captive refugia populations can increase redundancy. The primary focus of the criteria is improving the resiliency (i.e., having self-sustaining viable populations) of existing populations and reducing anthropogenic, or human-caused, threats. Long-term viability would require that the threats to these species be ameliorated or actively managed to levels that ensure resilient populations. Habitat would be restored and conserved such that sufficient habitat quantity and quality is maintained to support the long-term survival of each species. The overall recovery strategy involves preserving, restoring, and managing species' aquatic habitats, along with the water resources necessary to support resilient populations and the ecosystems on which they depend. Based on the current status and description of threats provided in the SBR (USFWS 2024a, entire), the strategy will involve:

Protecting and restoring the spring and spring-fed ecosystems throughout each species' range from ongoing threats. These threats include losses in water quality and water quantity, nonnative species, disease and parasites, and habitat disturbance, both now and into the future. Efforts to ensure population resiliency and reduce exposure to stressors will include:

1) Monitoring population resiliency, ongoing effects of threats to resiliency, and effectiveness of conservation management actions;
2) Using captive refugia to increase redundancy and protect against catastrophic events; and
3) Collaborating with partners and engaging with the public to achieve conservation goals in balance with community needs.

1.1.1 Management Units

The range of these species has been classified into four management units (Table 1; Figures 1-5). These geographically distinct management units are not regulatory in nature; the boundaries of these management units do not identify individual properties that require protection but are described solely to facilitate recovery and management decisions. Management Units do not represent distinct population segments. The Management Units represent both the potential extent of habitat within the species' ranges and the biologically distinct areas where recovery actions (Section 2.0) should take place that will eliminate or ameliorate threats. Management Units are individually necessary to conserve genetic distinctiveness, demographic robustness, important life history stages, or other features necessary for the long-term sustainability of the species. All Management Units where a species is present must be recovered to achieve recovery of that species.

Comal Ecosystem Management Unit

The Comal Ecosystem Management Unit includes multiple springs that together are called Comal Springs, as well as associated spring runs, Landa Lake, the Comal River, Panther Canyon well, and saturated subterranean pore spaces in designated critical habitat (78 FR 63100) (Figure 2). See the SBR for more details on the hydrology of and threats to this ecosystem, and on the habitat distribution of individual species within the management unit (USFWS 2024a, entire).

San Marcos Ecosystem Management Unit

The San Marcos Ecosystem Management Unit includes multiple springs that together are called San Marcos Springs, Spring Lake, the upper San Marcos River from the headwaters until the confluence with the Blanco River, subsurface habitat including private caves and wells that intersect the Edwards Aquifer in the San Marcos area, and Sessom Springs (Figure 3). See the SBR for more details on the hydrology of and threats to this ecosystem, and on the habitat distribution of individual species within the management unit (USFWS 2024a, entire).

Hueco Ecosystem Management Unit

The Hueco Ecosystem Management Unit includes multiple springs that together are called Hueco Springs, including downstream upwellings and side seeps (also referred to as satellite springs), and saturated subterranean pore spaces in designated critical habitat (78 FR 63100) (Figure 4). See the SBR for more details on the hydrology of and threats to this ecosystem, and on the habitat distribution of individual species within the management unit (USFWS 2024a, entire).

Fern Bank Ecosystem Management Unit

The Fern Bank Ecosystem Management Unit includes multiple springs that together are called Fern Bank Springs and saturated subterranean pore spaces in designated critical habitat (78 FR 63100) (Figure 5). However, additional features on the site, such as the cave and cave stream, are not included because the species within this Recovery Plan are not known to inhabit these areas (78 FR 63100). See the SBR for more details on the hydrology of and threats to this ecosystem, and on the habitat distribution of individual species within the management unit (USFWS 2024a, entire).

Table 1. Management unit occupancy for each species from the southern Edwards Aquifer springs and associated aquatic ecosystems.

Species	**Management Unit Occupancy**
Comal Springs dryopid beetle	San Marcos, Comal, and Fern Bank Ecosystems
Comal Springs riffle beetle	San Marcos and Comal Ecosystems
Fountain darter	San Marcos and Comal Ecosystems
Peck's cave amphipod	Comal and Hueco Ecosystems
San Marcos salamander	San Marcos Ecosystem
Texas blind salamander	San Marcos Ecosystem
Texas wild-rice	San Marcos Ecosystem

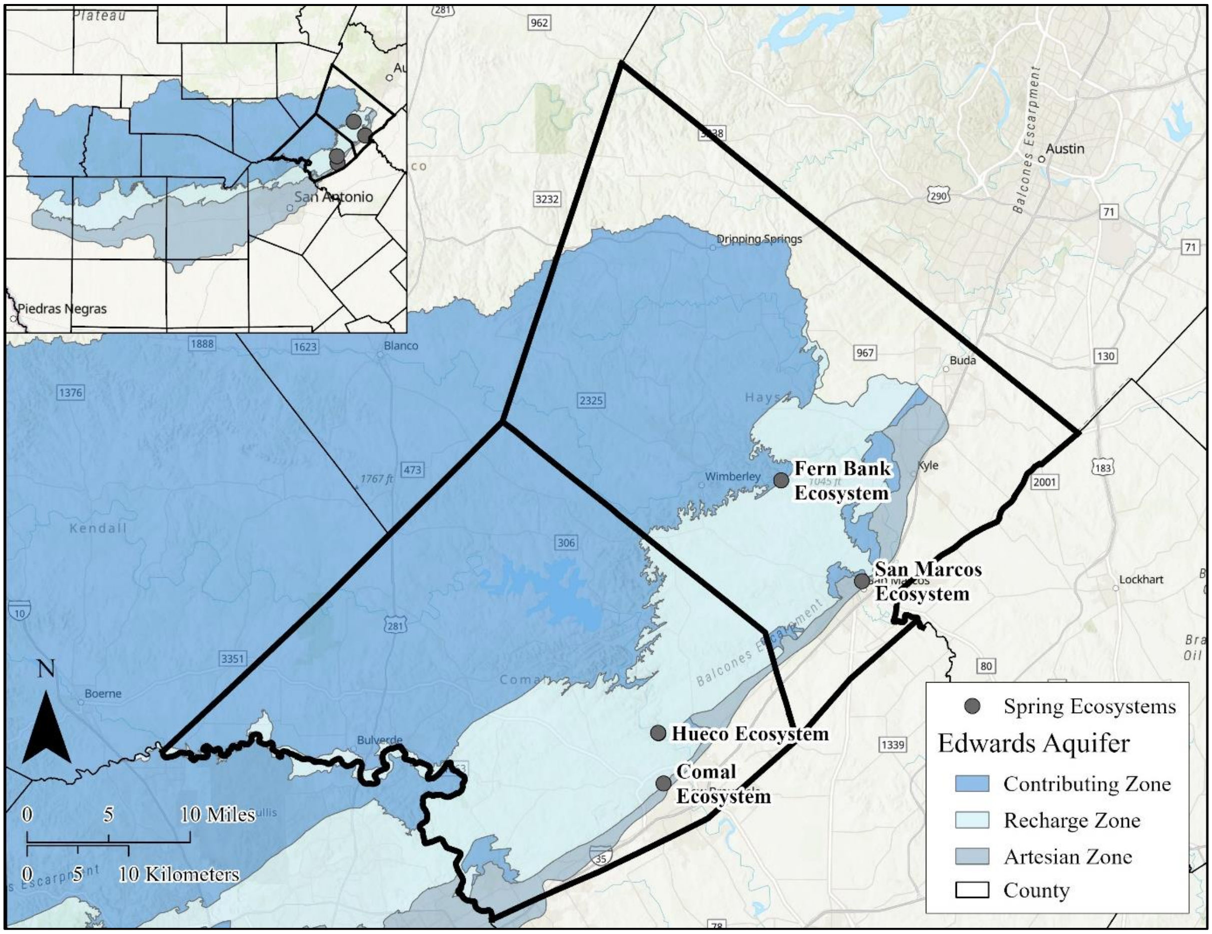

Figure 1. The four management units (Comal, San Marcos, Hueco, and Fern Bank ecosystems) for the southern Edwards Aquifer springs and associated aquatic ecosystems species in Comal and Hays counties, Texas.

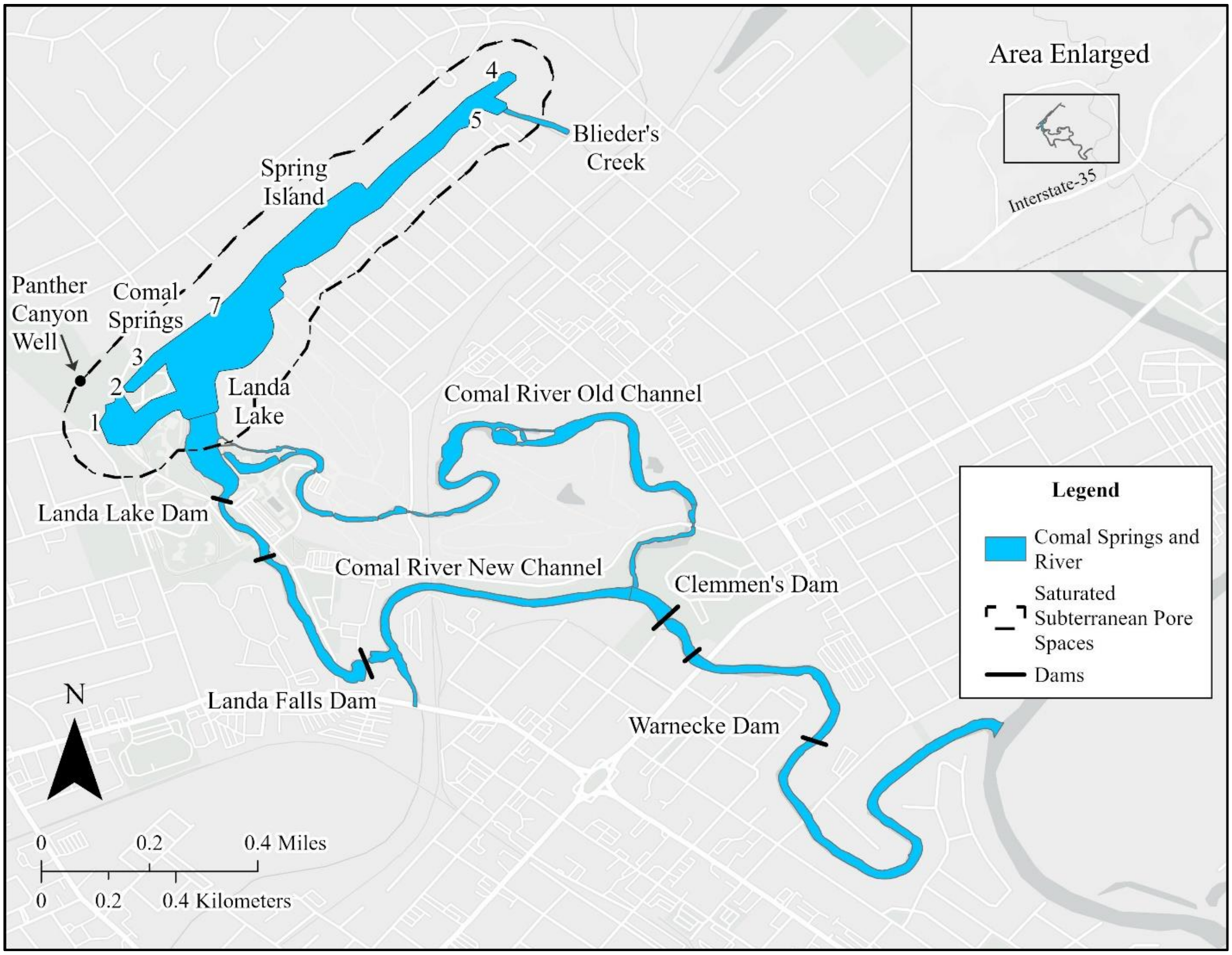

Figure 2. Map of the Comal Ecosystem Management Unit showing the Comal Springs ecosystem, the Comal River, and designated critical habitat surrounding Landa Lake in Comal County, Texas. Numbers on map indicate spring run locations referenced in this Recovery Plan.

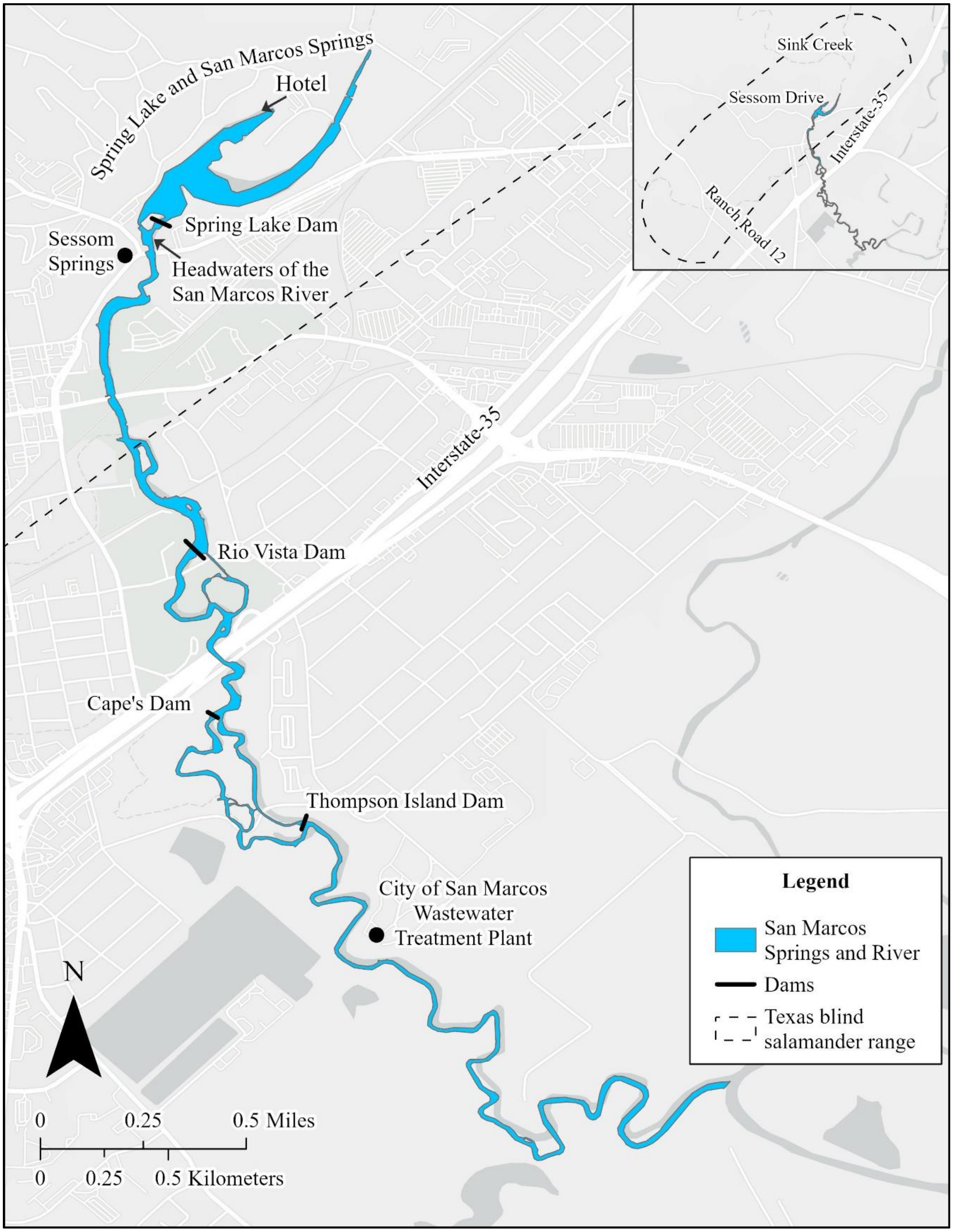

Figure 3. Map of the San Marcos Ecosystem Management Unit. The dotted outline encompasses subsurface habitat including private caves and wells that intersect the Edwards Aquifer in the San Marcos area.

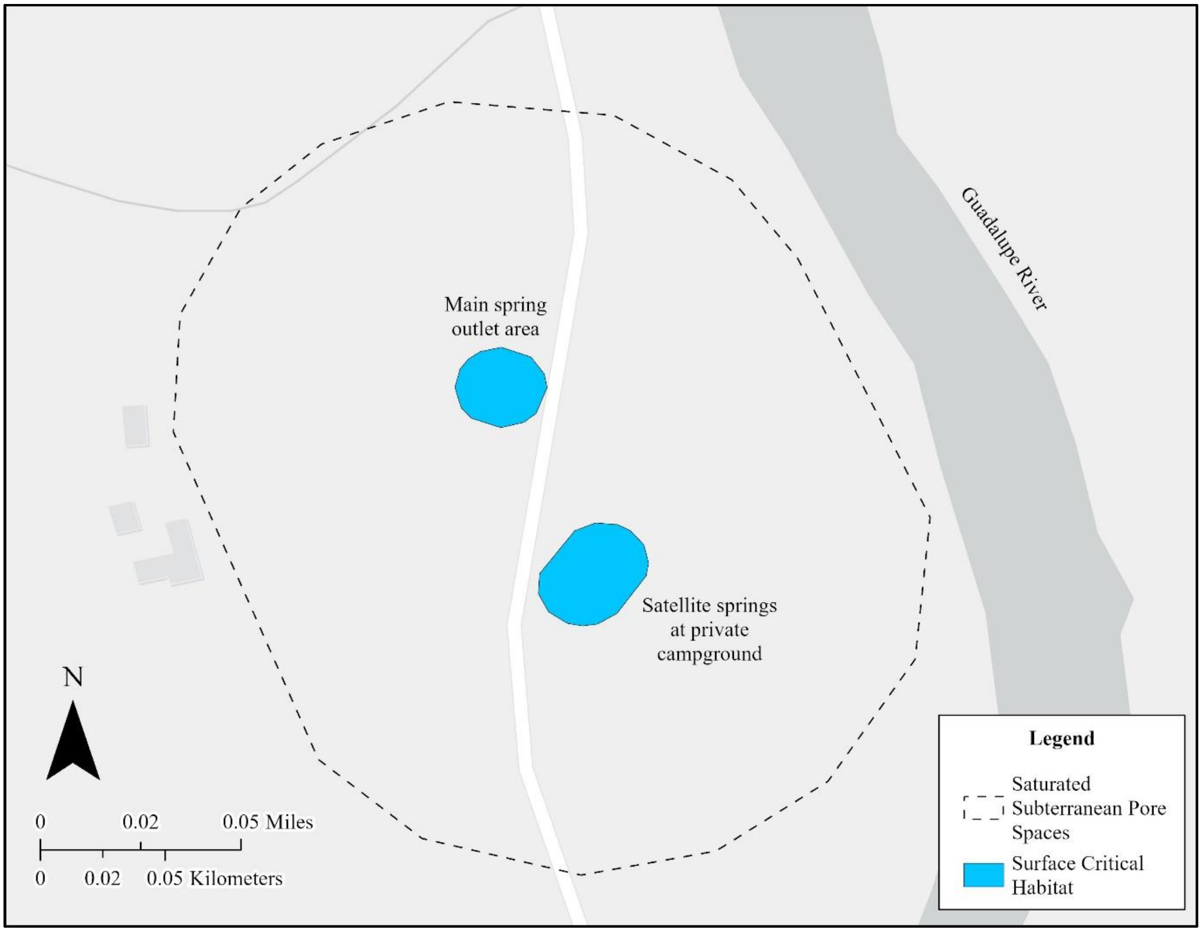

Figure 4. Map of the Hueco Ecosystem Management Unit showing the two major spring outlets at Hueco Springs and designated critical habitat adjacent to the Guadalupe River in Comal County, Texas.

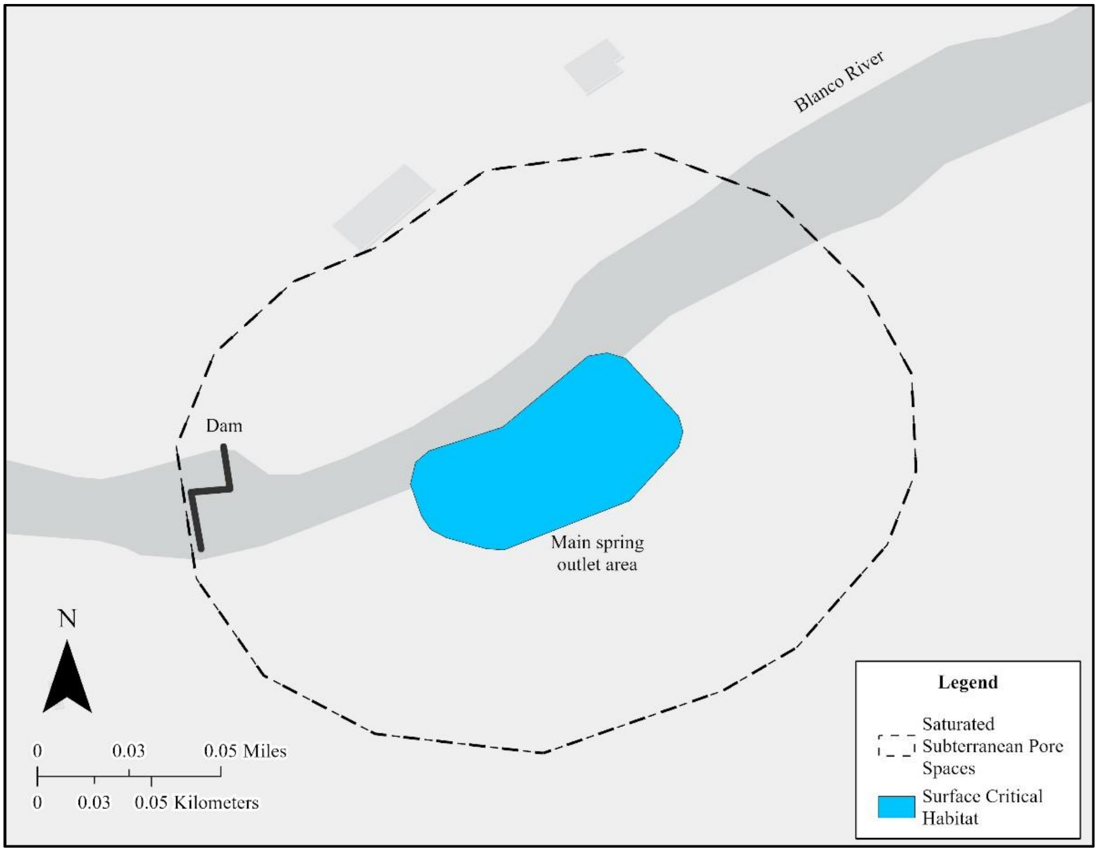

Figure 5. Map of the Fern Bank Ecosystem Management Unit showing the main spring outlet of Fern Bank Springs and subsurface designated critical habitat adjacent to the Blanco River in Hays County, Texas.

2.0 Criteria

Recovery criteria are statutorily required objective, measurable descriptions of a recovered state for threatened and endangered species, as described in 4(f)(1)(b)(ii) of the ESA. Recovery criteria describe the conditions of resiliency, redundancy, representation, and threat abatement that indicate when southern Edwards Aquifer springs and associated aquatic ecosystem species may no longer meet the ESA definitions of an endangered species or threatened species. Recovery criteria present our best estimate of a species' recovered condition at the time of recovery plan development. Changes in available information, technologies, and our understanding of the species over time might mean that the recovered state envisioned by the recovery criteria differs from our assessment in a later status determination.

All the species included in this plan, except for the San Marcos salamander, are currently endangered species; accordingly, this Recovery Plan includes both downlisting and delisting criteria. While the downlisting criteria do not apply to the San Marcos salamander, this species will also benefit from progress on the downlisting criteria. The species addressed in this recovery plan may be considered for downlisting and delisting when the following criteria have been met. Downlisting and delisting criteria are subject to revision as additional information becomes available about the species' biology and threats. Justifications for the criteria are below in Section 2.3.

2.1 Downlisting Criteria

The following are objective, measurable criteria, which, when met, would result in a determination that the Comal Springs dryopid beetle, Comal Springs riffle beetle, fountain darter, Peck's cave amphipod, Texas blind salamander, and Texas wild-rice could be considered for reclassification as threatened species. The San Marcos salamander is currently a threatened species; therefore, the downlisting criteria do not apply to this species. A detailed analysis of threats and summary of the threats to the seven southern Edwards Aquifer springs and associated ecosystem species is further described in the SBR (USFWS 2024a, entire).

1. All populations of each species, in all management units where the species is present, maintain sufficient resiliency for 18 consecutive years.

   For **surface species** (fountain darter, Comal Springs riffle beetle, and Texas wild-rice), sufficient resiliency will be achieved when:

   a. Populations do not trend toward a decline and do return to the cumulative mean after short-term fluctuations;
   b. Populations do not fluctuate below the cumulative mean of non-drought years (defined as the mean of previous years that Comal or San Marcos springs did not decrease below 100 cubic feet per second) by more than 10% in a given year;
   c. Populations do not decline from the cumulative mean of non-drought years more than 25% during drought years when Comal or San Marcos springs decreases below 100 cubic feet per second; and
   d. Populations do not decline from the cumulative mean of non-drought years more than 50% during a repeat of the drought of record (defined here as a three-year period when aquifer recharge was at its lowest recorded level of 397,800 acre-feet total for 1954-1956).

   Methods used for animal species (fountain darter, Comal Springs riffle beetle) should estimate population size (based on, e.g., capture-recapture, depletion) rather than using counts of individuals as a surrogate to estimate population.

   For **subsurface species** (Comal Springs dryopid beetle, Peck's cave amphipod, and Texas blind salamander), sufficient resiliency is achieved when: surface species have also achieved sufficient resiliency, subsurface species are observed biannually from known spring outflows during nondrought conditions, and subsurface species are observed in accessible subsurface habitat (e.g., caves, wells) during all springflows when wet.

2. All species: Habitat is restored and maintained within each management unit in the areas described below (see the SBR for additional information on habitat within each management unit; USFWS 2024a, Section 1.0). The habitat restoration should achieve a level that supports resilient populations as described in Downlisting Criterion 1. This initiative should include restoration of terrestrial riparian areas aimed at minimizing runoff into adjacent aquatic habitat for the benefit of all species, while also providing suitable habitat and food resources for the Comal Springs dryopid beetle, Peck's cave amphipod, and Comal Springs riffle beetle. The habitat restoration may occur with existing hydromorphological modifications. However, if there are any additional hydromorphological modifications, they should support

a more natural ecosystem condition (e.g., impoundment removal, dechannelization, natural substrate) instead of leading to a more unnatural ecosystem. While it is expected that habitat may change during droughts and floods (e.g., siltation during low flows, loss of substrate or vegetation), the habitat management plan described in Downlisting Criterion 3 should restore habitat in the locations described here. After completion, the habitat restoration should be maintained for at least 18 years.

Comal Ecosystem:

- Comal Springs dryopid beetle: Spring runs 1 through 5 and 7, western shoreline, and spring island. These areas maintain the primary constituent elements that were identified in the rule designating critical habitat (78 FR 63100). Panther Canyon well remains undisturbed.
- Comal Springs riffle beetle: Spring runs 1 through 3, western shoreline, and spring island. These areas maintain the primary constituent elements that were identified in the rule designating critical habitat (78 FR 63100).
- Fountain darter: At least 100,000 square meters (10 hectares [24.7 acres]) of native submerged aquatic vegetation when flows are above 100 cubic feet per second (cfs) (2.8 cubic meters per second [m^3/s]), with a diversity of species that are demonstrated to provide fountain darter habitat (see SBR, USFWS 2024a, Section 1.5.3). Vegetation should be distributed through Landa Lake, spring runs, and the old and new channel.
- Peck's cave amphipod: Spring runs 1 through 4 and 7, western shoreline, and spring island. These areas maintain the primary constituent elements that were identified in the rule designating critical habitat (78 FR 63100). Panther Canyon well remains undisturbed.

San Marcos Ecosystem:

- Comal Springs dryopid beetle: Sessom Springs area. This area maintains the primary constituent elements that were identified in the rule designating critical habitat (78 FR 63100).
- Comal Springs riffle beetle: Hotel area (see Figure 3). This area maintains the primary constituent elements that were identified in the rule designating critical habitat (78 FR 63100).
- Fountain darter: At least 40,000 square meters (4 hectares [9.9 acres]) of native submerged aquatic vegetation in the Upper San Marcos River (not including Spring Lake) when flows are above 2.3 m^3/s (80 cfs), with a diversity of native species that are demonstrated to provide fountain darter habitat (see SBR, USFWS 2024a, Section 1.5.3). This amount of vegetation is in addition to any Texas wild-rice in the river. Abundant vegetation also continues to exist in Spring Lake for fountain darters. Vegetation should be distributed through Spring Lake and the Upper San Marcos River until the confluence with the Blanco River, with the expectation that vegetation density will be higher in the upstream reaches. This number does not include the Martindale area. Additional research will be needed to evaluate the possible fountain darter habitat in the Martindale area.

- Texas blind salamander: Cave habitat remains unmodified and undisturbed.
- Texas wild-rice: At least 20,000 square meters (2 hectares [4.9 acres]) of Texas wild-rice is maintained in the upper San Marcos River, including areas that are shallow enough to allow for natural seeding. Texas wild-rice should be distributed through the Upper San Marcos River to the City of San Marcos wastewater treatment plant outfall.

Hueco Ecosystem:

- Peck's cave amphipod: Designated surface critical habitat maintains the primary constituent elements that were identified in the rule designating critical habitat (78 FR 63100). If this site becomes accessible, habitat should be evaluated to assess the potential need for additional restoration and management.

Fern Bank Ecosystem:

- Comal Springs dryopid beetle: Designated surface critical habitat maintains the primary constituent elements that were identified in the rule designating critical habitat (78 FR 63100). If this site becomes accessible, habitat should be evaluated to assess the potential need for additional restoration and management.

3. All species: There is a habitat management plan that is fully implemented and focuses on habitat restoration and reducing habitat degradation for all waters and lands associated with management units to ensure that habitat continues to sustain resilient populations of each species. The habitat management plan should address how habitat will be managed when the needs of different listed species conflict, along with management of threats to habitat, including recreation, runoff, drought, floods, and harmful non-native species. The habitat management plan will be fully implemented in all management units for the species for at least 18 years.

4. All species: The daily average discharge during the 18-year period in the Comal River exceeds 6.4 m^3/s (225 cfs) including the drought of record, and the minimum daily average flow is not less than 0.9 m^3/s (30 cfs). In the San Marcos River, the daily average discharge during the 18-year period exceeds 140 cfs (4 m^3/s) including the drought of record, and the minimum daily average flow is not less than 1.3 m^3/s (45 cfs). The duration of minimum daily average flows in both rivers must not exceed six months and is followed by three months of 2.3 m^3/s (80 cfs) or greater to ensure adequate habitat and water quality. Achievement of this criterion will be measured using continuous monitoring data from streamflow gages at Comal and San Marcos springs (USGS 08168710 and 08170000) for a minimum of 18 years.

   Hueco Springs is located close to Comal Springs and Hueco Springs shows a similar flow pattern to Comal Springs during droughts based on U.S. Geological Survey gages (Hueco Springs gage 0816800 and Comal Springs gage 08168710). Therefore, Comal Springs will be used as a surrogate for the Hueco Springs flows needed. For Fern Bank Springs, more information will need to be gathered to evaluate the water quantity that is adequate for recovery. A groundwater management plan or equivalent conservation agreement should ensure adequate water quantity that is fully implemented for a minimum of 18 years. It is possible that future habitat restoration or management may be able to reduce the flows necessary to maintain adequate habitat, in which case these flow thresholds should be reevaluated.

5. All species: Water quality consistently meets or exceeds established Environmental Protection Agency (EPA) numeric criteria for protection of aquatic life throughout the areas where the species are present (EPA 2022, unpaginated). Water temperature in surface habitat does not exceed 25°C (77°F) near springs (areas within spring runs, Spring Lake, the main spring outlets at Sessom, Landa Lake, Spring Island, Panther Canyon well, Hueco Springs, and Fern Bank Springs), other surface habitat does not exceed this temperature at least 50% of the days per year at the substrate, and downstream surface habitat at the substrate does not exceed 27°C (81°F). Conductivity is 560-650 microsiemens per centimeter in the San Marcos Management Unit and 560-610 microsiemens per centimeter in the Comal Management Unit during conditions that do not contain surface runoff from rainfall. Turbidity is generally less than 1.0 in spring water and habitat. Measurements should only be considered during baseflow conditions that do not contain surface runoff. Areas of very shallow habitat during drought conditions should not be considered for this criterion. This criterion will be achieved when these standards are met throughout the species habitat within each management unit, as described in Criterion 2, above, during quarterly sampling for 18 years. For Fern Bank and Hueco springs, more information will need to be gathered to evaluate the expected conductivity, turbidity, pH, and temperature at these springs. Research may also be needed to evaluate species-specific groundwater quality needs if there is a concern that the EPA numeric criteria for aquatic life may not adequately address water quality needs.

6. All species: A self-sustaining refugia population in captivity is capable of maintaining at least 90% of the genetic diversity from the wild for 10 years without collections, as determined by population genetic modeling and a population with lambda of 0.95 or greater. This captive population may be used for population reintroduction and augmentations, or emergency refugia in case of catastrophic loss in the wild. This minimum target captive population size should be 500 individuals unless new science indicates that another number is more appropriate for these goals. If research compromises individuals for these goals, those individuals should not be included as part of the refugia population. There should be refugia populations for every species population in the San Marcos Ecosystem, and for every management unit for the three invertebrate species (Table 1).

7. Fountain darter and Texas blind salamander: Disease and parasites do not negatively affect the resiliency of (defined as no more than 20% of individuals sampled) any wild population for 10 years.

2.2 Delisting Criteria

A delisting decision will involve evaluating the five statutory factors (i.e., threats), which were also evaluated when the species were listed, as specified in section 4(a)(1) of the ESA. The following delisting criteria address the threats in the listing rule and reflect our best assessment of what needs to be achieved based on our current understanding of the species and its environment. Circumstances can change in unpredictable ways, so it is not a requirement for delisting that all criteria be met. For example, a species may be able to tolerate one ongoing threat if another is eliminated or reduced. Conversely, all criteria could be met but delisting may not be warranted should, for example, a catastrophic event or new threat arise. Recovery of the southern Edwards Aquifer springs and associated aquatic ecosystem species will require entirely self-sustaining populations made possible by a reduction of threats within the known range. The interim goal is long-term stability of the species. Justifications for the criteria are found in Section 2.3.

The following are objective, measurable criteria which, when met, could result in a determination that the Comal Springs dryopid beetle, Comal Springs riffle beetle, fountain darter, Peck's cave amphipod, San Marcos salamander, Texas blind salamander, and Texas wild-rice be removed from the Threatened and Endangered species list:

1. All species: All populations maintain resiliency for 45 consecutive years and are expected to maintain resiliency in the future. Populations will be considered resilient when they meet the definition described in Downlisting Criterion 1 above. For the San Marcos salamander, the criterion for surface species should be followed.

2. All species: Habitat can sustain resilient populations and is restored as described above in Downlisting Criterion 2, maintained for at least 45 years, and anticipated to remain restored in perpetuity due to the actions of the habitat management plan described in Downlisting Criterion 3. Habitat for the San Marcos salamander is not included in Downlisting Criterion 2 and should meet the criteria provided for all species, as well the following for the San Marcos ecosystem: Approximately 6000 square meters (0.6 hectares [1.5 acres]) of unembedded cobble and gravel substrate with low macrophyte cover is maintained through Spring Lake and the upper 50 meters (164 feet) of the river when flows are above 2.3 m^3/s (80 cfs) and maintain at least 3000 square meters (0.3 hectares [0.7 acres]) of unembedded substrate when flows are below 2.3 m^3/s (80 cfs). Surface habitat should connect to a groundwater source, such as a spring.

3. All species: Future habitat degradation is prevented through a habitat management plan as described above in Downlisting Criterion 3. The habitat management plan will be fully implemented for at least 45 years and anticipated to continue in perpetuity.

4. All species: The flows in Downlisting Criterion 4 are achieved for 45 years. Flows are expected to continue in perpetuity through actions of a fully implemented water management plan.

5. All species: Groundwater quality in Downlisting Criterion 5 is achieved for 45 years and there is no indication that water quality is degrading over time, as determined by increasing trends in nutrients, conductivity, or contaminants.

6. All species: Captive populations continue to be maintained as described in Downlisting Criterion 6. This will continue until the five years of post-delisting monitoring is completed.

7. Fountain darter, San Marcos salamander, Texas blind salamander: Disease and parasites do not affect the resiliency of any wild population for 45 years as defined in Downlisting Criterion 7 and are not anticipated to for the foreseeable future.

2.3 Justification for Criteria

Justification for timeframe to downlisting and delisting: Drought can affect the success of most of the criteria. Therefore, multiple droughts should occur prior to downlisting and delisting the species to ensure that the criteria continue to be met in these conditions. These timeframes were established by evaluating the amount of time between droughts at Comal Springs. Comal Springs was used because it has more data available than Hueco Springs and Fern Bank Springs. While data exists for San Marcos Springs, this spring has decreased below 2.83 m^3/s (100 cfs) more frequently than has Comal Springs. Therefore, using the amount of time between droughts at Comal Springs is a more protective estimate that focuses on more severe droughts.

Severe droughts will provide better information for how the species habitat and water quality respond to low flows than less severe droughts, as severe droughts have more negative effects to the species. Since 1950, the median amount of time between droughts that caused flows to decrease below 2.83 m^3/s (100 cfs) at Comal Springs was nine years, with a range of 5-18 years. Thus, for most of the criteria (downlisting criteria 1-5 and delisting criteria 1-5), 18 years was established as the minimum amount of time to downlist the species once all the downlisting criteria have been met; this timeframe will usually include two droughts, with at least one drought, that bring(s) Comal Springs below 2.83 m^3/s (100 cfs). To delist species, a timeframe of 45 years was used because this is the median amount of time for five droughts to occur that previously decreased Comal Springs flows below 2.83 m^3/s (100 cfs). This timeframe will ensure that species resiliency and the recovery criteria are assessed through multiple severe droughts prior to delisting. Table 2 has a list of droughts for the Comal Springs ecosystem. If droughts of the magnitude considered here occur sooner than the time estimates for downlisting and delisting, and if the species remains resilient during these droughts, then it may be possible to delist the species sooner than the times estimated.

Justification for resilient populations: The existence of resilient populations allows a species to better withstand and recover from environmental variability and stochastic perturbations relative to populations that are not resilient. Because there is natural low redundancy (i.e., few populations) for each of these species, it is important that all populations are resilient to reduce the extinction risk and improve the species' long-term viability. Species viability is further discussed in the SBR (USFWS 2024a, Section 3.0). For animal species, it is important to use methods that estimate population size rather than counts, because habitat conditions may affect the ability to detect individual animals and affect count data. However, the Comal Springs riffle beetle currently lacks an established methodology for accurate population size estimation.

Further investigation is required to address these complexities and enhance the accuracy of population assessments for this species. For subsurface populations that cannot be easily quantified by monitoring, it is unlikely that accurate population estimates can be obtained. However, surface populations of other species may be used as surrogates because all the species within this plan share the primary threats of water quantity and water quality. It is expected that Fern Bank and Hueco springs will not flow during extreme droughts, preventing counts at these times. Subsurface species at Fern Bank and Hueco springs are expected to persist in the subsurface, and counts may continue once springflows return. Drought of record conditions are expected to negatively affect the species, but these events are rare. If the frequency of droughts comparable to the drought of record increases, then additional measures may be needed for species recovery.

Justification for habitat and habitat management: Resilient populations are dependent on the quality and quantity of habitat present in the management units. The habitat used by each species is described further in the SBR (USFWS 2024a, Section 1). The amount and areas of habitat included are areas where the species are already known to occur and in amounts that are already demonstrated to be possible from previous studies. The habitat at Comal and San Marcos Management Units requires ongoing management due to recreational activities, non-native species, runoff, and habitat modifications that have altered the ecosystem. The invertebrate species use the riparian zone as a foraging area and shelter (see SBR, USFWS 2024a, Sections 1.2.3, 1.3.3, and 1.4.3). Maintenance of riparian vegetation is important to these species' persistence. These habitat management plans will also need to balance the conflicting habitat needs of different species when habitat overlaps (e.g., fountain darter and Texas wild-rice habitat) to ensure adequate habitat for each species. Although subsurface habitat may not require the same type of management as surface habitat, caves and wells hosting these species still need protection from human activities and impacts (e.g., vandalism and contamination due to surface run-off). Habitat disturbance and non-native species are further discussed as threats to these species in the SBR (2024a, Sections 2.1.3 and 2.1.4). Habitat at Hueco and Fern Bank Management Units are under private ownership, and knowledge is limited on which restoration activities may be needed, but some examples that may be needed include channel restoration, recreation control, vegetation restoration, and sediment removal. Habitat management plans put in place at the Hueco and Fern Bank Management Units would improve security regarding maintaining species redundancy and genetic diversity and would potentially improve habitat conditions if promoted through partnerships.

For fountain darters, the amount of total vegetation for the Comal River and Upper San Marcos River (excluding Spring Lake) aligns with estimates from the 1990s (Linam 1993, p. 12; Linam et al. 1993, p. 345). For the Upper San Marcos River, this was extrapolated from the proportion of transects without vegetation (561/1812) for a river of 102,000 square meters (10.2 hectares [25.2 acres]) to estimate approximately 70,420 square meters (70.4 hectares [174 acres]) of vegetation in the 1990s. However, the amount of Texas wild-rice was lower in this study and will need to be balanced with needs for the fountain darter. It is also expected that vegetation will naturally fluctuate and will not always occur at the maximum possible amount. While the amount of vegetation in Spring Lake is not quantified, it is plentiful and should not require management unless there are major ecosystem changes. In 2022, fountain darters were found in the Martindale area (see SBR, USFWS 2024a, Sections 1.5.2). Research is needed to understand the extent of habitat in the area and its possible importance for fountain darter recovery.

For San Marcos salamanders, 6,000 square meters (0.6 hectares [1.5 acres]) of habitat aligns with what was found by previous studies (Diaz et al. 2015, p. 317). Although this is a small portion of the designated critical habitat, Spring Lake is larger than the area would be naturally because of the impoundment, and it is unlikely that the impoundment increases salamander habitat. It is important for surface habitat to connect to the subsurface habitat to allow salamanders to move between the surface and subsurface. Surface connectivity between springs should also be included when feasible.

Justification for water quantity and water management plan: Natural spring and subsurface groundwater flows capable of supporting resilient populations are critical to the survival of these species. The species included in this plan are dependent on groundwater from the aquifer. Groundwater pumping, in concert with climate change-driven aridity (i.e., increased drought conditions), will continue to be a threat to these species into the future. Groundwater pumping along with decreased aquifer recharge could lead to declines in aquifer levels and declines or cessation of spring flows necessary for each species. Water quantity is further discussed as a threat to these species in the SBR (USFWS 2024a, Section 2.1.1). By working with groundwater conservation districts and other partners to establish a groundwater management plan, a mechanism can be established that will protect adequate flows for these species. During drought, measures are established to ensure that flows and/or subsurface habitat do not drop below critical levels, ensuring that populations continue to persist. However, surface habitat is still affected by low flows. Low flows increase sedimentation, algae, the effects of recreation, and habitat that becomes unwetted, so it is important that flows do not remain low for extended periods of time. It is possible that future work may determine that habitat management may be able to mitigate for some of these effects. Hueco Springs is expected to experience extended dry periods, and subsurface water levels must be adequate for the invertebrate populations to persist. To ensure flows during all foreseeable conditions, these measures need to account for a drought of record and future rainfall scenarios affected by climate change. Tracer tests and a contamination event suggest a potential regional groundwater connection between Hueco Springs and Comal springs, though further testing is needed (Ogden et al. 1986, pp. 122-126; Gibson et al. 2008, p. 75). Hueco Springs shows a pattern similar to Comal Springs during droughts based on U.S. Geological Survey gages (Hueco Springs gage 0816800 and Comal Springs gage 08168710). Therefore, we are using Comal Springs as a surrogate for Hueco Springs. Fern Bank Springs does not have a gage to measure flows. Research will need to further evaluate what water quantity is adequate to achieve recovery at Fern Bank and Hueco springs. Currently there is little information to evaluate what water quantity is necessary at Fern Bank and Hueco springs and where water from Fern Bank Springs originates.

Justification for water quality: Adequate water quality is critical to the survival of these species. No alternative sites exist for these species to occupy (i.e., the species naturally have low redundancy). It is critical that groundwater, spring water, and surface water of an adequate quality be maintained to enable persistence of these species. Water quality is further discussed as a threat to these species in the SBR (2024a, Section 2.1.2). EPA numeric criteria are used because specific thresholds are not known for several of these species. Conductivity, temperature, and turbidity are known to affect the listed species. Increased conductivity is associated with decreased abundance of some Texas *Eurycea* species and is associated with increased contaminants and impervious cover (Bowles et al. 2006, pp. 115-118). Texas wild-rice requires clean and clear water with low turbidity (Poole and Bowles 1999, entire). Turbidity also has been shown to decrease prey items consumed by fountain darters in lab experiments (Swanbrow Becker et al. 2016, entire) and impairs the ability of fountain darters to detect and respond to predators in lab experiments (Swanbrow Becker and Gabor 2012, p. 117). Temperature and conductivity have historically been relatively constant in the groundwater (EAA 2022, pp. 27-28), and changes in temperature may not be tolerated by these species. Low springflows during droughts increase fluctuations in surface water temperature. Temperature likely affects the ability of Peck's cave amphipod to reach maturity (Kosnicki and Julius 2019b, p. 19). The rate of growth was lower in other central Texas *Eurycea* salamanders when they were exposed to higher temperatures (Crow et al. 2016, p. 331). Fountain darter reproduction is negatively impacted above 24°C (75.2°F), with almost no reproduction above 26°C (78.8°F) (McDonald et al. 2007, pp. 311, 314-316). While fountain darters should be able to persist for short periods with warmer temperatures, periods of lower temperatures throughout fountain darter habitat are important for recruitment. Because the characteristics of rainwater are different than groundwater and spring water, measurements taken during periods of runoff from rain will not be representative of typical water quality.

Justification for captive populations: Until threats to these species are ameliorated, extirpations or extinctions from the wild are possible due to stochastic or catastrophic events. Maintaining captive refugia of sufficient size to reestablish wild populations helps ensure that reintroduction after extirpation is possible. Maintaining genetic diversity for an extended period of time without collections from the wild is important in case reintroduction could not occur quickly after extirpation. Because the number of individuals needed to maintain genetic diversity long-term without collections from the wild has not been evaluated, 500 individuals was used based on population management studies (Franklin 1980, entire; Lande and Barrowclough 1987, entire) for the captive refugia until more specific information is available for how many individuals are needed. There are many reasons immediate reintroduction may not be possible, including ongoing threats in the wild or insufficient understanding and evaluation of the species or habitat needs to inform a successful reintroduction. Once threats to the species are ameliorated and post-delisting monitoring is completed, captive populations would no longer be required.

For the three invertebrate species, each population exhibits a high degree of genetic structure, with no evidence of contemporary gene flow, and significant differentiation between management units (see SBR, USFWS 2024a, Section 1.2.1, 1.3.2, and 1.4.2). Representatives from each management unit should be maintained in captivity separately to safeguard genetic diversity (i.e., evolutionarily significant units). The fountain darter population in the Comal River is derived from the San Marcos River and would not need separate representation in the refugia (see SBR, USFWS 2024a, Section 1.5.2).

Justification for disease and parasites: Population resiliency is further degraded by the presence of diseases within a habitat. Habitat management plans will need to be updated to respond accordingly to changes in severity and diversity of disease threats. Currently, salamanders may contract microsporidia and chytrid (*Batrachochytrium dendrobatidis*). There is a potential future threat of another chytrid, *B. salamandrivorans*, that could impact salamanders. Fountain darters may be infected by nonnative gill parasites and large-mouth bass virus. Disease and parasites are further discussed as a threat to these species in the SBR (USFWS 2024a, Section 2.3). Research targeting unknown or novel pathogens will improve treatment procedures and prevent future population declines.

Table 2. Droughts resulting in monthly mean flows below 2.83 m^3/s (100 cfs) at Comal Springs.

Dates	**Duration of Low Flows (months)**	**Minimum Monthly Flow (m^3/s [cfs])**
08/1954-03/1957	23	0 (0)
07/1967-08/1967	2	2.23 (78.7)
05/1984-09/1984	5	0.93 (32.8)
07/1989-10/1989	4	2.14 (75.4)
07/1996-08/1996	2	2.59 (91.5)
08/2014-10/2014	3	2.09 (73.9)
10/2022-10/2023	5	1.82(64.3)

Table 3. Downlisting and delisting criteria by species. The San Marcos salamander is threatened and does not have downlisting criteria.

Criteria	**Comal Springs riffle beetle**	**Comal Springs dryopid beetle**	**Fountain darter**	**Peck's cave amphipod**	**San Marcos salamander**	**Texas blind salamander**	**Texas wild-rice**
Downlisting 1-6	X	X	X	X		X	X
Downlisting 7			X			X	
Delisting 1-6	X	X	X	X	X	X	X
Delisting 7			X		X	X	

3.0 Recovery Actions

Recovery actions are the statutorily required, site-specific management actions needed to achieve recovery criteria, as described in section 4(f)(1)(B)(i) of the ESA. The USFWS assigns recovery action priority numbers (1-3) to rank recovery actions. The assignment of priorities does not imply that some recovery actions are of low importance, but instead implies that lower priority items may be deferred while higher priority items are being implemented. Recovery action priority numbers are based on the following:

Priorities for recovery actions are assigned using the following guidelines:

> Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
>
> Priority 2: An action that must be taken to prevent a substantial decline in species population/habitat quality or some other substantial negative effect short of extinction.
>
> Priority 3: All other actions necessary to meet the recovery objectives. The assignment of these priorities does not imply that some recovery actions are of low importance, but instead implies that lower priority items may be deferred while higher priority items are being implemented.

Implementation of the recovery actions will involve participation from State and Federal agencies, non-federal landowners, non-governmental organizations, academia, and the public. The on-the-ground activities or specific tasks associated with each action will be included in a separate RIS (USFWS 2024b, entire). The RIS is intended to be an adaptable operational plan stepped down from the recovery actions. We intend to update specific activities in the RIS with our conservation partners to design tasks that are feasible and effective and take our partners' interests and abilities into consideration.

As stated in the Disclaimer, Recovery Plans are advisory documents, not regulatory documents. A recovery plan does not commit any entity to implementing the recommended strategies or actions contained within it for a particular species, but rather provides guidance for ameliorating threats (Table 4) and implementing proactive conservation measures, as well as providing context for implementation of other sections of the ESA, such as section 7(a)(2) consultations on Federal agency actions, development of Habitat Conservation Plans, or the establishment of experimental populations under section 10(j).

Recovery Action 1. Ensure Adequate Water Quantity and Quality within the Southern Edwards Aquifer and Management Units. Priority 1.

This action will include the protection of groundwater quantity and quality that would improve or protect habitat quality for each of the management units. Conservation water management agreements, groundwater management plans, or equivalent, will be developed, implemented, and fulfilled to ensure adequate surface and groundwater to maintain springflow and water quality at each of the management units. Evaluate if additional land in the recharge and contributing zone should be protected to maintain groundwater quality. Watershed protection plans that include stormwater treatment, wastewater discharges, and hazardous spill prevention and response should also be implemented to protect water quality. Monitoring should evaluate the effectiveness of different water quality and quantity protections.

Recovery Action 2. Protect and Restore Habitat in Waters and on Lands Within and Adjacent to the Management Units. Priority 1.

Habitat within the management units, including springs, caves, subsurface habitat, streams, and riparian zones, should be restored and protected for each species. Adequate buffers of natural vegetation should be maintained around the aquatic habitats to support and maintain ecological integrity. Protections may include, but are not limited to, land management activities, ordinances, land acquisition from willing sellers, long-term conservation agreements, and habitat management plans. The plans should address and plan to resolve threats to habitat including local development, runoff, recreation, habitat modification and destruction, and non-native species.

Recovery Action 3: Establish and Implement Captive Refugia Populations with a Captive Population Management Plan and Reintroduction Plan. Priority 1 for San Marcos salamander, Texas blind salamander, Texas wild-rice; Priority 2 for Comal Springs riffle beetle, Comal Springs dryopid beetle, Peck's cave amphipod, fountain darter.

Until the threats to these species are ameliorated, extinction from the wild is possible due to stochastic or catastrophic events. Populations of these species should be maintained in captive refugia as a means of preventing extinction in case of such events. The captive management plan and reintroduction plan should account for situations in which species cannot be reintroduced immediately, and where several reintroduction attempts may be necessary. This will likely require genetic management and captive propagation of each species. Development of these plans will require determining the needs of the species in captivity, financial resources to support the efforts, plans for emergency collections during catastrophic events, and the steps needed for reintroduction in case of extirpation from the wild. Research may also be needed to test techniques for captive population management and reintroduction.

Recovery Action 4: Promote Edwards Aquifer Species Conservation and Recovery through Outreach, Education, and Cooperation. Priority 3.

Proactive outreach and education will be achieved by management agencies and partners to the local communities through events, workshops, and social media. Outreach efforts should use strategies to seek out broad participation, including by those who may not pursue conservation-focused events. Incentives and education should be offered to private landowners, land managers, and businesses to encourage active cooperation needed to aid the recovery of these species. Working with landowners adjacent to habitat and near contributing streams should be prioritized.

Recovery Action 5: Establish and Implement Effective Disease and Parasite Protocols. Priority 2.

This recovery action is specific to the fountain darter, San Marcos salamander, and Texas blind salamander. Effective protocols to control and eliminate diseases and parasites that affect population resiliency should be created and implemented. An array of protocols may be necessary for captive refugia compared to wild populations. Monitoring of diseases and parasites will be necessary to assess whether protocols are effective. This recovery action is rated Priority 2 because diseases and parasites are currently not primary threats to population resiliency. This action should be considered as Priority 1 if the effects of diseases or parasites increase and degrade population resiliency.

Recovery Action 6. Monitor Progress Toward Criteria within the Management Units: *Priority 3.*

This action would implement formal monitoring plans that provide information needed to evaluate species status and trends. Monitoring will further facilitate the assessment of climate change impacts on species and their habitats as well as efficacy of habitat restoration efforts. Specific associated activities will be described in the RIS. Monitoring should continue for five years after delisting, as required by the 1988 amendments to the ESA.

Table 4. Needs and threats to address for Edwards Aquifer species, recovery actions that will address threats, and the criteria to which the actions contribute. Endangered Species Act (ESA) listing factor abbreviations described below are habitat loss and degradation (A), disease or predation (C), inadequacy of existing regulatory mechanisms (D), and other natural or manmade factors affecting the species continued existence (E). The listing factor for the over-utilization of the species for commercial, recreational, scientific, or educational purposes (B) is not currently a threat to these species and is not included in the table.

Threat or Need	**ESA Listing Factor**	**Downlisting Criteria**	**Delisting Criteria**	**Recovery Action**
Water Quantity	A, D, E	4	4	1, 4, 6
Water Quality	A, D, E	5	5	1, 4, 6
Habitat Quality	A, D, E	2, 3	2, 3	1, 2, 4, 6
Captive Refugia/ Redundancy	n/a	6	6	3
Disease and Parasites	C	7	7	5, 6
Resiliency	n/a	1	1	1, 2, 4, 5, 6

4.0 Time and Cost Estimates

Estimates of time and cost, as defined in section 4(f)(1)(B)(iii) of the ESA, must reflect, to the maximum extent practicable, the total amount of time and costs it will take to achieve the recovery (delisting) of the Edwards Aquifer springs and associated aquatic ecosystems species. The cost estimates provided do not account for possible future inflation.

Estimated costs include only project-specific contract, staff, or operations costs in excess of base budgets. They do not include budgeted amounts that support ongoing agency staff responsibilities. This recovery plan does not commit the USFWS or any partners to carry out a particular recovery action or expend the estimated funds.

We expect the status of these species to improve in such a way that we may downlist to threatened status in approximately 33-38 years (Table 5), following the adoption of this recovery plan, and cost approximately $313,275,000. This estimate excludes specific costs for the San Marcos salamander, a threatened species. Where possible, species-specific costs have been deducted. However, in cases where only aggregate costs for captive refugia management and monitoring were provided, these costs have been distributed equally among the species.

We estimate that the full implementation of the Recovery Actions would improve the status of the Edwards Aquifer springs and associated aquatic ecosystems such that species could be delisted within 60-65 years (Table 5), following the adoption of this recovery plan, for a total of approximately $533,265,000 (including $313,275,000 to downlisting plus an additional $219,990,000; Table 6). This time estimate includes up to 20 years to complete the Recovery Actions that are not ongoing until recovery, and 45 years for the Recovery Criteria to be met after the Recovery Actions are completed. These timeframes are based on expectation of full funding without delay, implementation of the Recovery Actions and RIS, high degree of success in executed actions, and full cooperation of partners.

While most recovery actions are anticipated to take the same amount of time for each species, Recovery Actions 2 and 3 will vary by species. While Recovery Action 2 could be complete within 10 years if initiated immediately, Fern Bank and Hueco springs are privately owned and are not immediately accessible to implement Recovery Action 2. Therefore, we assume these sites could be accessed within 10 years if outreach and cooperation with private landowners is successful. This delay extends the time of recovery for two of the three invertebrate species (i.e., Comal Springs dryopid beetle and Peck's cave amphipod) to 65 years, while the other species could be recovered after 60 years.

Recovery Action 3 also varies by species based on the current status of captive breeding for the species. There is more work that is needed for successfully creating self-sustaining populations of the Comal Springs riffle beetle, Comal Springs dryopid beetle, and Peck's cave amphipod than there is for the other species. Thus, the time estimate for completing this action is 15 years for the invertebrates and 10 years for other species. However, this does not change the overall timeline to recovery because the captive refugia will continue to function until 5 years post delisting.

The cost estimates are further broken down through comparisons of ongoing and new costs (Table 7) and by Management Unit (Table 8). Ongoing costs encompass existing financial commitments allocated through established partnerships or funding arrangements, contributing to ongoing species recovery efforts through ongoing projects or initiatives. In contrast, new costs include expenses required for implementing recovery actions or initiating new projects not covered by existing funding. These expenditures would expand or enhance species recovery efforts beyond current initiatives, representing financial resources needed for future endeavors.

Table 5. Estimated time necessary to complete recovery actions and achieve delisting.

Recovery Action	**Time to Complete Action**	**Implementation Time Needed**	**Total Time**
1. Ensure Adequate Water Quantity and Quality within the Southern Edwards Aquifer and Management Units	15 years	18 years downlisting, 45 years delisting	60 years
2. Protect and Restore Habitat in Waters and on Lands Within and Adjacent to the Management Units	10-20 years, varies by species	18 years downlisting, 45 years delisting	55-65 years
3. Establish and Implement Captive Refugia Populations with a Captive Population Management Plan and Reintroduction Plan	10-15 years, varies by species	10 years downlisting, continue until 5 years post-delisting	Does not affect recovery timeline, continue until 5 years post delisting
4. Promote Edwards Aquifer Species Conservation and Recovery through Outreach, Education, and Cooperation	Ongoing until delisting and does not affect the overall timeline	n/a	n/a
5. Establish and Implement Effective Disease and Parasite Protocols for (Fountain Darter and Salamanders)	15 years	10 years downlisting, continue until delisting	60 years
6. Monitor Progress Toward Criteria within the Management Units	Ongoing	Continue until 5 years post-delisting	Does not affect recovery timeline, continue until 5 years post-delisting
Total Time to Recovery			**60-65 years**

Table 6. Estimated cost for recovery actions necessary to move towards recovery of the Southern Edwards Aquifer springs and associated aquatic ecosystems species. Each action likely includes costs that could not be reasonably estimated at this time. Costs are based on 60-65 years to achieve recovery.

Recovery Actions	**Estimated Cost**
1. Ensure Adequate Water Quantity and Quality within the Southern Edwards Aquifer and Management Units	$306,632,000
2. Protect and Restore Habitat in Waters and on Lands Within and Adjacent to the Management Units	$60,421,000
3. Establish and Implement Captive Refugia Populations with a Captive Population Management Plan and Reintroduction Plan	$57,861,000
4. Promote Edwards Aquifer Species Conservation and Recovery through Outreach, Education, and Cooperation	$37,050,000
5. Establish and Implement Effective Disease and Parasite Protocols	$2,873,000
6. Monitor Progress Toward Criteria within the Management Units	$68,428,000
Total estimated cost of recovery actions	**$533,265,000**

Table 7. Estimated costs for recovery actions, differentiating between ongoing costs and new costs. Costs are based on 60-65 years to achieve recovery.

Recovery Actions	Ongoing Cost	New Cost
1. Ensure Adequate Water Quantity and Quality within the Southern Edwards Aquifer and Management Units	$302,707,000	$3,925,000
2. Protect and Restore Habitat in Waters and on Lands Within and Adjacent to the Management Units	$57,098,000	$3,323,000
3. Establish and Implement Captive Refugia Populations with a Captive Population Management Plan and Reintroduction Plan	$55,980,000	$1,881,000
4. Promote Edwards Aquifer Species Conservation and Recovery through Outreach, Education, and Cooperation	$37,050,000	$0
5. Establish and Implement Effective Disease and Parasite Protocols	$2,873,000	$0
6. Monitor Progress Toward Criteria within the Management Units	$68,428,000	$0
Total estimated costs	**$524,136,000**	**$9,129,000**

Table 8. Estimated costs for recovery actions, separated by management unit, where applicable. Costs are based on 60-65 years to achieve recovery.

Recovery Actions	**All Management Units**	**Comal Ecosystem Management Unit**	**San Marcos Ecosystem Management Unit**	**Fern Bank Ecosystem Management Unit**	**Hueco Ecosystem Management Unit**
1. Ensure Adequate Water Quantity and Quality within the Southern Edwards Aquifer and Management Units	$306,414,000	$0	$193,000	$25,000	$0
2. Protect and Restore Habitat in Waters and on Lands Within and Adjacent to the Management Units	$0	$15,579,000	$41,619,000	$1,764,000	$1,460,000
3. Establish and Implement a Captive Population Management Plan and Reintroduction Plan	$57,861,000	$0	$0	$0	$0
4. Promote Edwards Aquifer Species Conservation and Recovery through Outreach, Education, and Cooperation	$37,050,000	$0	$0	$0	$0
5. Establish and Implement Effective Disease and Parasite Protocols	$0	$1,686,000	$1,186,000	$0	$0
6. Monitor Progress Toward Criteria within the Management Units	$0	$27,708,000	$27,708,000	$6,506,000	$6,506,000
Total estimated cost of recovery actions by management unit	**$401,325,000**	**$44,974,000**	**$70,706,000**	**$8,294,000**	**$7,966,000**

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Appendix D10 | **EAHCP's Request for Extending Draft Recovery Plan Public Comment Period**

EDWARDS AQUIFER
AUTHORITY

October 28, 2024

Ms. Karen Myers
Field Supervisor
U.S. Fish and Wildlife Service
1505 Ferguson Lane
Austin, Texas 78754

RE: Draft Recovery Plan Public Comment Period Extension Request

Dear Ms. Myers:

The Edwards Aquifer Habitat Conservation Plan respectfully requests an extension of the public comment period for the *Draft Recovery Plan for Seven Listed Species of the Edwards Aquifer*, currently scheduled to close on November 12, 2024. Our organization, Permittees and stakeholders are committed to contributing meaningful input to ensure the success of this plan; however, additional time is required to thoroughly review the proposed actions and provide thoughtful, well-informed comments.

Extending the comment period by 30 days would allow for broader engagement and ensure all voices are heard in this important process.

Thank you for your attention to this request. We look forward to your response.

Sincerely,

Scott D. Storment
Program Manager
Edwards Aquifer Habitat Conservation Plan

Appendix D11 | **EAHCP's Comments on the Draft Recovery Plan**

Karen Myers
Project Leader, Austin Ecological Services Field Office
U.S. Fish and Wildlife Service
1505 Ferguson Lane
Austin, Texas 78754
Sent via email to esaustininfo@fws.gov

Re: Comments on the Draft Recovery Plan for the Southern Edwards Aquifer Springs and Associated Aquatic Ecosystems, Second Revision

Ms. Meyers:

The Edwards Aquifer Habitat Conservation Plan (EAHCP) program is currently coordinating closely with the U.S. Fish and Wildlife Service (Service) to renew its incidental take permit, which expires on March 31, 2028. The goals of this permit renewal process are to extend the duration of the incidental take permit beyond 2028 and to improve the EAHCP to ensure its long-term success.

This permit renewal is a multi-year planning process. Presently, the process is in the "Analyze and Sign-off" Phase, during which stakeholders and the Permittees consider changes to key components of the EAHCP prior to completing an amended Administrative Draft EAHCP. The Administrative Draft EAHCP is anticipated by the end of 2025. As you are aware, the EAHCP has been implementing extensive conservation measures and monitoring for 11 years on the species addressed by the 2024 *Draft Recovery Plan for the Southern Edwards Aquifer Springs and Associated Aquatic Ecosystems, Second Revision* (2024 Draft Recovery Plan). The EAHCP monitoring program therefore represents one of the most comprehensive and long-term data sets on these species. Through this monitoring program, EAHCP staff and their consultants have developed a unique understanding of the ecology of these species.

It is from this perspective that we offer the following comments on the 2024 Draft Recovery Plan. Our goal with these comments is to help align the recovery criteria and recommended recovery actions with the current EAHCP and its expected direction in the EAHCP permit renewal. We also offer these comments to help ensure that recovery criteria and actions are practicable, feasible, and achievable. Our goal is the same as that of the Service—to ultimately recover and de-list these species or prevent their listing.

Native Vegetation Coverage

We request that the Service reconsider the appropriateness of the Linam 1993 and Linam et al. 1993 studies when determining the total amount of vegetation for recovery criteria. These studies were conducted over 30 years ago and included all non-native aquatic vegetation and 1980s and

1990s recreation levels that are very outdated. Since the implementation of the EAHCP, there has been a focused and extensive removal of non-native aquatic vegetation in the Comal and San Marcos systems. EAHCP efforts over the past decade to remove non-native vegetation and reestablish native vegetation have shown that native vegetation coverage does not replace non-native vegetation coverage in equal proportion. Non-native vegetation, such as *Hydrilla* and *Hygrophila*, are often more tolerant and can survive and expand in more areas, including shade, where native vegetation often cannot get established or be sustained. Instead of aligning recovery criteria with the Linam studies, we request that the Service establish recovery criteria for vegetation coverage that is more aligned to what has been observed in the Comal and San Marcos systems recently. These observations are documented in the EAHCP Annual Reports, mostly recently in 2024 for the 2023 monitoring year (Edwards Aquifer Habitat Conservation Plan - 2023 Annual Report). Using current observations is important because aquatic recreation levels have increased dramatically since the Linam studies. Aquatic recreation levels and timing are an important determinant of non-native aquatic vegetation. Only the current observations by the EAHCP take into account current recreational levels.

The table and figure taken from the EAHCP Biological Monitoring Program 2023 Annual Report for the **Comal Springs/River Aquatic Ecosystem** below compares total submerged aquatic vegetation (SAV) coverage from full-system mapping conducted in the Comal Springs System in 2013, 2018 and 2023.

Table 1. **A comparison of the notable changes in rooted aquatic vegetation assemblages observed in the 2013, 2018, and 2023 HCP Benchmark mapping events.**

Taxa	2013 Coverage (m^2)	2018 Coverage (m^2)	2023 Coverage (m^2)
Cabomba	8,195	9,129	10,338
Hygrophila	26,612	13,796	22,424
Ludwigia	1,859	3,028	2,505
Nuphar	4,316	1,387	1,463
Sagittaria	7,330	10,061	14,186
Vallisneria	37,886	31,882	29,013
Other species	3,535	4,117	5,497
Total coverage	**89,733**	**73,400**	**85,426**

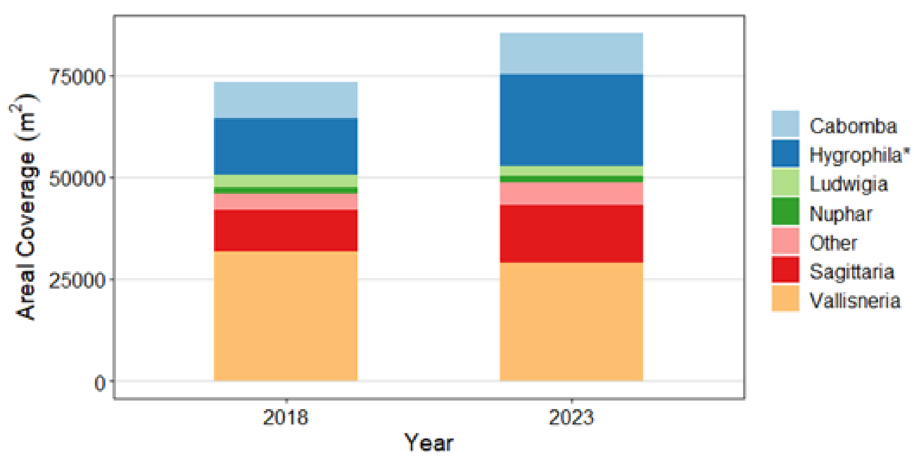


Figure 1. **Rooted aquatic vegetation (m^2) composition among taxa from HCP benchmark mapping events in the Comal Springs and River in 2018 and 2023.**

At present, there is approximately 85,000 m^2 of SAV in the Comal system that are experiencing present day natural and anthropogenic pressures, of which approximately 25 percent is non-native *Hygrophila* in downstream reaches.

The table and figure taken from the EAHCP Biological Monitoring Program 2023 Annual Report for the **San Marcos Springs/River Aquatic Ecosystem** below compares total SAV coverage from full-system mapping conducted in 2013, 2018 and 2023.

Table 3. **A comparison of the notable changes in vegetation assemblages observed in the 2013, 2018, and 2023 HCP Benchmark mapping events.**

Taxa	2013 Coverage (m^2)	2018 Coverage (m^2)	2023 Coverage (m^2)
Cabomba	3,114	1,039	5,080
Colocasia	5,370	863	1,939
Hydrilla	18,927	12,685	6,045
Hygrophila	10,778	7,112	4,720
Ludwigia	139	330	415
Potamogeton	3,053	1,233	118
Sagittaria	2,556	3,485	1,948
Nuphar	123	125	287
Hydrocotyle	173	220	613
Zizania	4,892	10,224	15,317
Other species	4,238	1,058	1,865
Total	**53,363**	**38,374**	**38,347**

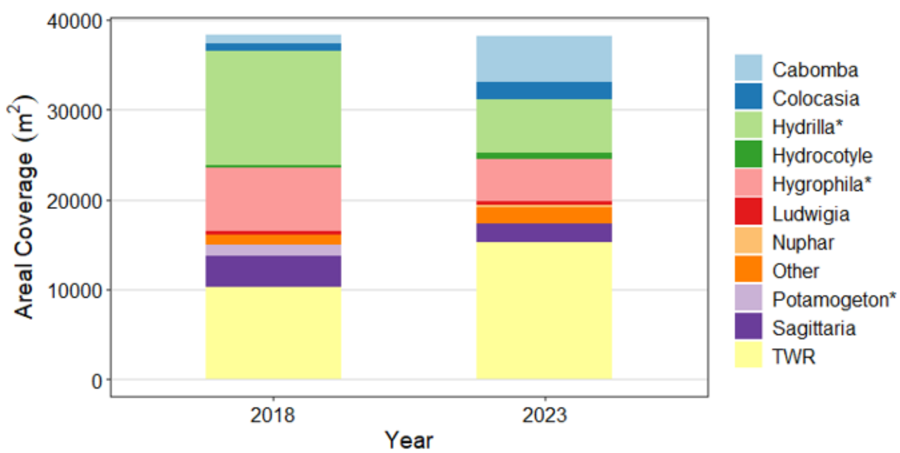


Figure 7. **Aquatic vegetation (m^2) composition among taxa during full system mapping of the San Marcos Springs and River in 2018 and 2023.**

Currently, there is approximately 38,500 m^2 of SAV in the San Marcos River including over 11,000 m^2 of Texas wild-rice and approximately 28 percent of non-native coverage of *Hydrilla* and *Hygrophila*. This does not include the approximately 50,000 m^2 of native and non-native SAV in Spring Lake.

The 2024 Draft Recovery Plan proposes for fountain darter minimum criteria for downlisting of 100,000 m^2 and 40,000 m^2 of *native* vegetation coverage in the Comal and San Marcos springs systems, respectively. We do not believe these criteria are feasible, for the following reasons.

- The Linam studies upon which these coverage criteria are based included non-native vegetation coverage, not just native vegetation coverage.
- As demonstrated by over 10 years of work and monitoring, reestablished native vegetation coverage does not replace non-native vegetation coverage in a 1:1 ratio. Native vegetation will cover less proportional space than non-native vegetation in these systems. That reality needs to be factored into the downlisting criteria.

- No data exist suggesting that these systems can achieve these native vegetative coverage criteria given current natural and anthropogenic pressures on these systems from recreation and other uses.

Texas Wild-Rice Coverage

We request that the Service reconsider the 20,000 m^2 coverage criteria for Texas wild-rice in the San Marcos Springs System because we question whether this extent of coverage is achievable and whether it is in balance with the habitat needs of fountain darter and San Marcos salamander.

Historical and recent coverage trends of Texas wild-rice coverage do not indicate that 20,000 m^2 of coverage is achievable. Texas wild-rice coverage in 1989 was approximately 1,000 m^2 (see Figure 12 below taken from *Analysis of Species Requirements in Relation to Spring Discharge Rates and Associated Withdrawal Reductions and Stages for Critical Period Management of the Edwards Aquifer* (The Edwards Aquifer Area Expert Science Subcommittee for the Edwards Aquifer Recovery Implementation Program 2009), also referred to as the J-Charge report.

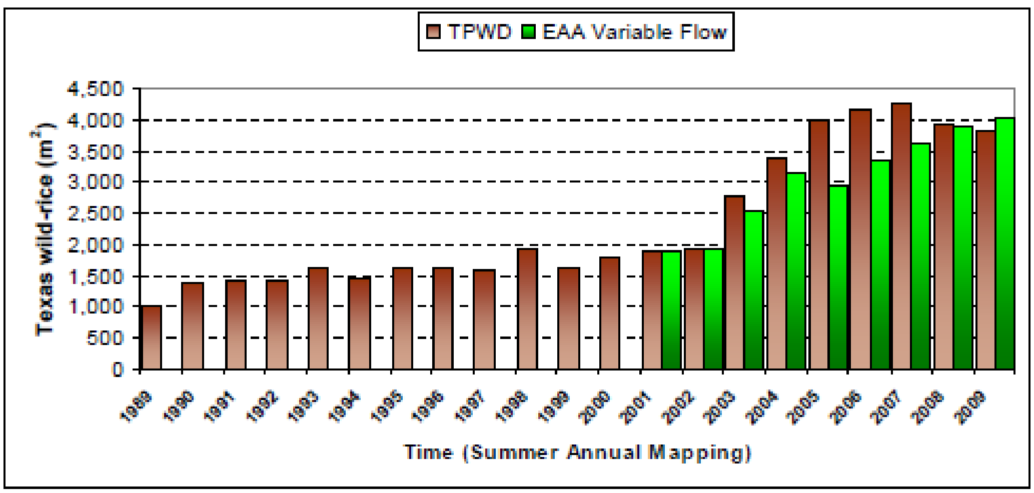
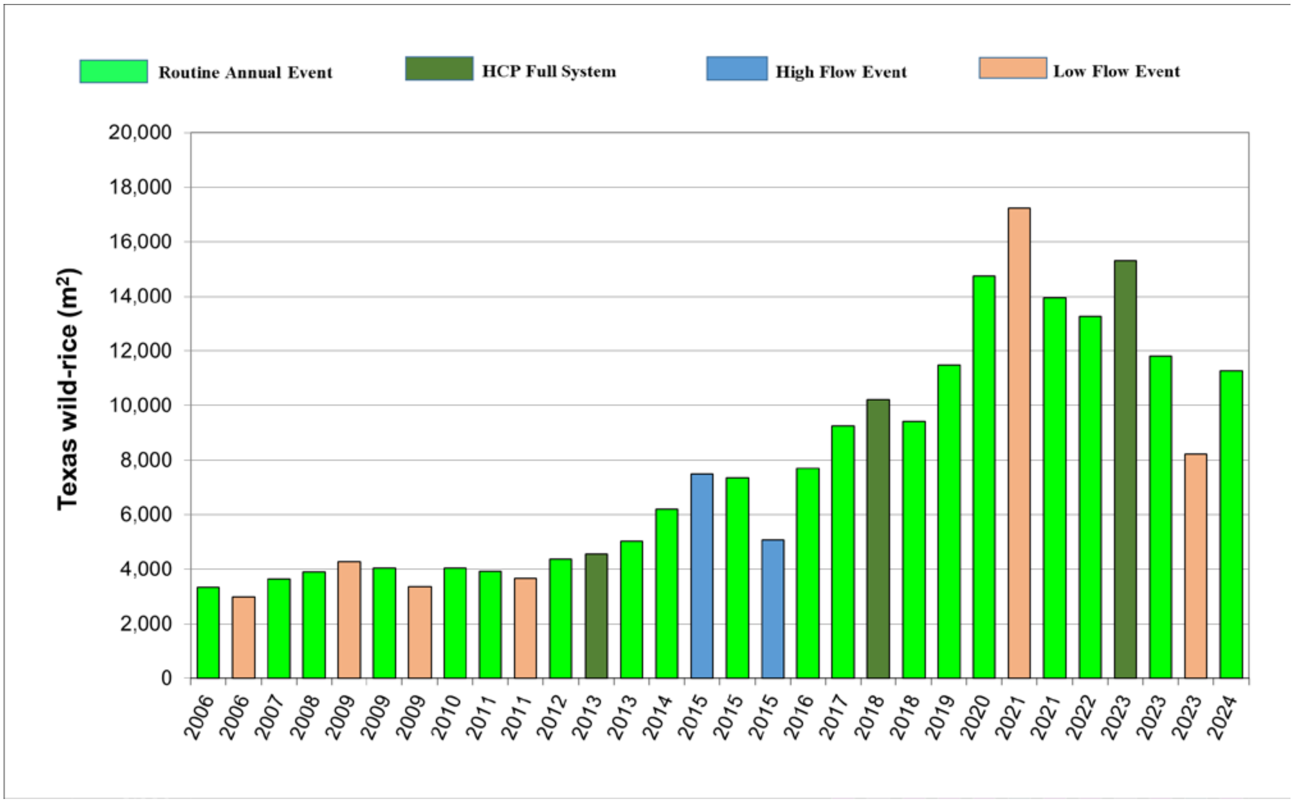


Figure 12: Total Texas wild-rice coverage (square meters [m^2]) on an annual basis as reported by Texas Parks and Wildlife Department and the Edwards Aquifer Authority variable flow study (only summer annual mapping results presented).

Texas wild-rice has persisted since 1989, and the coverage of wild-rice has greatly improved during implementation of the EAHCP (see the second Texas wild-rice figure below [2006 though summer 2024]). This persistence and improvement during the EAHCP, and the persistence evaluation documented in BIO-WEST and ICF (2024) (EAHCP Permit Renewal Biological Goals and Objectives Memorandum) indicates that the present day HCP management practices along with natural and anthropogenic pressures in the San Marcos River support Texas wild-rice coverage consistently in the 8,000 to 12,000 m^2 range. The ability to temporarily support higher coverage is possible as documented from 2020 to 2023 (12,000 to 15,000 m^2). However, this period included the temporary COVID-19 restrictions on recreation during the summer of 2020. As such, we contend these coverage levels represent a maximum and would not be a sustainable minimum coverage over time.



The downlisting criterion for Texas wild-rice should take into account the trade-off with fountain darter habitat quality. Texas wild-rice is one of the lowest quality SAV types with respect to fountain darter habitat. Figure 14 taken directly from the EAHCP Permit Renewal Biological Goals and Objectives Memorandum (BIO-WEST and ICF 2024) demonstrates the SAV preferences of the fountain darter in both the Comal and San Marcos systems with over 20 years of quantitative data. As evident in the figure below, Texas wild-rice is the lowest quality SAV type with respect to fountain darter habitat, by a substantial margin. Only open substrate areas support lower densities of fountain darters.

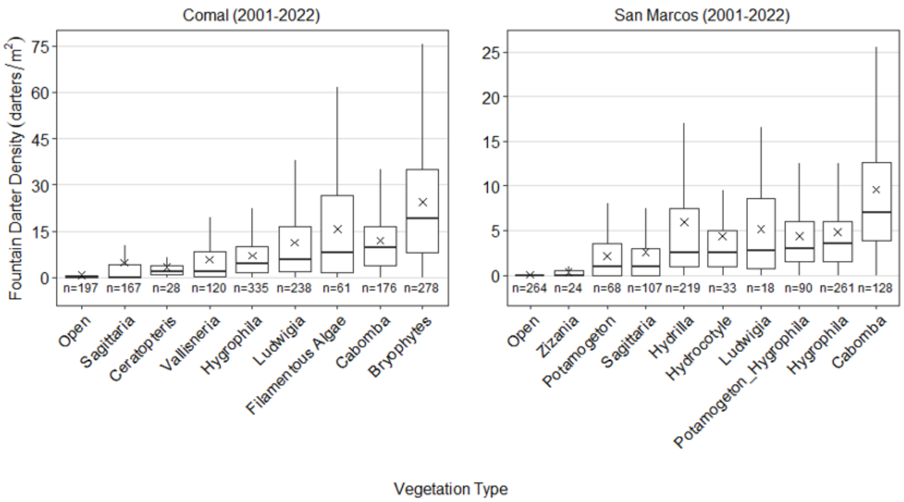
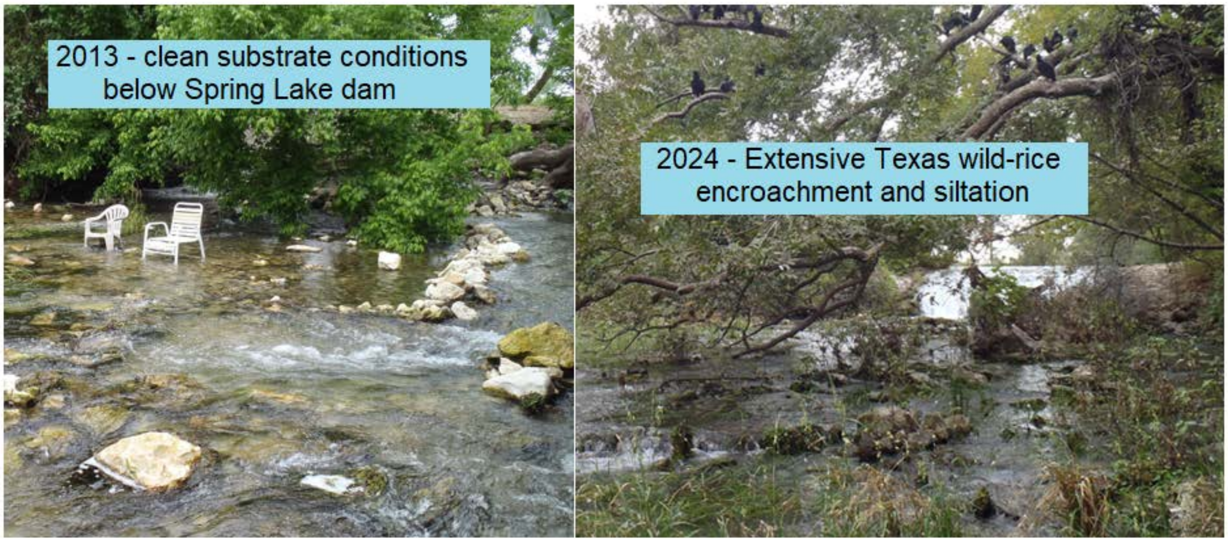


Figure 14. Boxplots Displaying Drop-net Densities among Vegetation Types in the Comal and San Marcos Spring Systems. ***Notes: The "x" denotes the mean, the thick horizontal line in each box is the median, and the upper and lower bounds of each box represent the interquartile range. Whiskers represent minimum and maximum values up to 1.5 times the interquartile range.***

The target extent of Texas wild-rice coverage also needs to be considered in relation to the habitat conditions for San Marcos salamander. The considerable expansion of Texas wild-rice below Spring Lake Dam over the past decade has led to increased siltation in San Marcos salamander habitat. This has caused salamander habitat below the dam to be reduced in both area and quality. Please refer to the before and after photographs of San Marcos salamander habitat since the implementation of the EAHCP.

Because of the limited area for these three species and their co-occurrence, the Service must consider the implications that the Texas wild-rice downlisting criteria will have on fountain darter and San Marcos salamander. Because fountain darter and San Marcos salamander have more limited habitat areas and conditions than Texas wild-rice in the San Marcos River, and because Texas wild-rice can reduce habitat quality and area of both species, we encourage the Service to prioritize fountain darter and San Marcos salamander over Texas wild-rice in circumstances where they overlap.



Three-month Pulse Condition of 80 cfs
The daily average (225 cfs and 140 cfs) and minimum daily average (30 cfs and 45 cfs) springflow criteria referenced for both systems, respectively, in the 2024 Draft Recovery Plan are accounted for within the EAHCP Critical Period Management framework. The 2024 Draft Recovery Plan also notes that minimum springflows be followed by three months of 80 cfs or greater; however, there are no means in the existing EAHCP springflow protection measures to meet this criterion, nor are there feasible options to meet it. For this reason, the EAHCP Permittees have approved recommendations to remove this 80 cfs criterion from the EAHCP Biological Goals and Objectives in the permit renewal process and replace it with a 3-year rolling average criterion that better supports the species needs and is more practical within the context of springflow protection measures (BIO-WEST and ICF 2024). We recommend that the Service consider removing this 80 cfs criterion or consider replacing it with the 3-year rolling average.

Thank you for the opportunity to comment on the 2024 Draft Recovery Plan. The EAHCP Permittees intend to continue to coordinate closely with the Service throughout the EAHCP permit renewal process to ensure alignment, as appropriate, between the conservation strategy of the EAHCP and the recovery goals of the Southern Edwards Aquifer Springs listed species. If you have any questions regarding these comments, please contact me at 210.884.2054.

Sincerely,

Scott Storment

Scott Storment
EAHCP Program Manager
Executive Director of the Threatened and Endangered Species Department
Edwards Aquifer Authority