Comprehensive and Critical Period Monitoring Program to Evaluate the Effects of Variable Flow On Biological Resources in the San Marcos Springs/River Aquatic Ecosystem

Final 2012 Annual Report

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EXECUTIVE SUMMARY

This annual summary report presents a synopsis of methodology used and an account of sampling activities conducted during two Comprehensive Monitoring sampling efforts on the San Marcos Springs/River ecosystem in 2012. For ease of comparison, the data are reported in an annual report format similar to previous reports (BIO-WEST 2001a, b - 2012a, b).

Flows in the San Marcos River began the year below the historic average, but spring rains bumped flows above 200 cubic feet per second (cfs) from April to July. This was the first time since October 2010 that flows were above 200 cfs. Summer and fall saw little rainfall resulting in flows declining to below 125 cfs to end the year. The minimum discharge in 2012 was 100 cfs (this occurred several times in January). These lower than average flows are a reflection of the ongoing drought in Central Texas. Close to spring inputs there was little variation in water temperatures even though flows were below average. Water temperatures were highest at Sessom's Creek (tributary heavily influenced by runoff) and Rio Vista Dam (where water is pooled by the rapids downstream).

Total amounts of aquatic vegetation in each of the three reaches (Spring Lake Dam, City Park, and I-35) were below the fall and spring averages observed in this study. Vegetation at the City Park Reach is most susceptible to seasonal changes due to varying amounts of recreation. In 2012, vegetation increased over winter, and decreased by the end of summer with large areas in the upper section (where recreation pressure is greatest) denuded of vegetation. This boom/bust cycle is typical of this reach, and is the result of increased recreation pressure combined with effects of the extended drought. Aquatic vegetation at the Spring Lake Dam reach follows a similar pattern as City Park with plants growing over winter, and decreasing by fall. Recreation pressure here is also significant in summer since it is adjacent to a popular swimming area and high density housing, but recently-constructed educational signs may provide value. The greatest impacts on aquatic vegetation in recent years have been observed within the I-35 Reach. Since Rio Vista Dam was transformed into a flow-through rapid in 2006, sedimentation has apparently increased resulted in decreased depths and higher velocities, leading to much lower coverage of vegetation, especially in the upper section of this reach. Additionally, two large riparian trees have fallen into the river within this reach, diverting flow and scouring out areas that were previously covered in vegetation. By fall 2012, total area of aquatic vegetation dropped below 300 square meters (m^2), the lowest ever observed in this study. These impacts are significant because the largest patches of *Cabomba* are found here which hold higher densities of fountain darters relative to other San Marcos aquatic vegetation. This section will continue to be closely monitored for other major changes in habitat.

Coverage of Texas wild-rice (*Zizania texana*) increased by 16% since 2011 resulting in the highest amount (4,367.1 m^2) observed in the San Marcos River since the inception of the study. The largest increases were observed within the upper-third of the river where most of the wild-rice is located. Although one large stand at Sewell Park continues to shrink due to sedimentation blocking flow from the upstream end; however, other plants in the area continue to flourish. Texas wild-rice from the City Park Reach to Bicentennial Park increased by 35% from 2011. Coverage of wild-rice in areas downstream changed little over the year. Physical observations of vulnerable Texas wild-rice plants documented changes in several individual plants during 2012. More plants were emergent and flowering in spring than in fall. Vegetation mats covering wild-rice were less prevalent in 2012 compared to previous years, likely a result of slightly higher flows. The mats can inhibit photosynthesis and cause plants to die if they are not pushed off (either manually or during higher flow events).

Population estimates of fountain darters (*Etheostoma fonticola*) were relatively high in spring 2012, but decreased to the lowest estimate observed in the study (2000 – 2012) by fall. These estimates are based on aquatic vegetation coverage and consequently follow the same pattern. Continued effects of the dam and recreation pressure during the summer both caused decreases in aquatic vegetation coverage in the I-35 Reach. This was exacerbated by a fallen tree which diverted flow and scoured out a previously vegetated area. As discharge increases, the number of fountain darters in each drop net tends to decrease. This may be a result of clumping of darters into limited habitat under lower flows. *Cabomba* (native) and *Hydrilla* (non-native) exhibit the highest densities of fountain darters in the San Marcos River. These densities are typically lower than in the Comal River system. Dip net data reflects the importance of filamentous algae and bryophytes present in Spring Lake to fountain darter reproduction. These two vegetation types hold the highest densities of darters in both the Comal and San Marcos systems, but are not found in the San Marcos River downstream of Spring Lake.

San Marcos salamander (*Eurycea nana*) densities were typically higher than average in 2012 at all sites. The highest densities were observed at the Hotel Reach where bryophytes are abundant resulting in higher quality habitat. Salamander densities in this area were higher than the study average in both spring and fall. Densities of salamanders rebounded at the Riverbed Reach in 2012 after construction activities in 2011 led to fewer salamanders. Numbers were slightly above the study average for both spring and fall. Throughout the study, salamander densities have been most variable at Sample Area 21 (~ 5 meters from the dam) because it is below Spring Lake Dam in an area of public access. This site exhibits higher velocities and typically less aquatic vegetation than areas in Spring Lake. Additionally, rocks that salamanders use for cover are often moved due to recreation activities. While spring densities were similar to previous years, the density in fall was the second highest recorded in the study. Educational signage recently placed in this area is designed to increase public awareness of the sensitive species present, and will hopefully reduce habitat disturbance.

In conclusion, although Central Texas continues to be plagued by a drought, 2012 monitoring activities suggest that populations of threatened and endangered species in the San Marcos Springs/River Ecosystem continue to persist despite the mixed effects of the drought. In fact, coverage of Texas wild-rice reached a new monitoring plan high. Similarly, San Marcos salamander densities were above study averages. In contrast, fountain darter population estimates reached a new low in 2012. However, a spring rebound in population estimates is typically experienced, and is expected by spring 2013. Should continued low flows persist in summer 2013, fountain darter habitat loss will likely continue due to the combined effects of persistent low flows and recreation within study reaches. Therefore, continued monitoring of aquatic vegetation communities and fountain darter populations is particularly important in coming years. Additionally, continued monitoring of all study components will allow for assessing the effectiveness of Edward's Aquifer Habitat Conservation Plan (EAHCP) activities being implemented in 2013 and beyond.

METHODS

Study Location

The upper San Marcos River is part of the Edwards Aquifer system, and extends from its origin as a series of spring upwellings in Spring Lake to the confluence with the Blanco River in Hays County. The upper portion of the river is characterized by near constant water temperatures (21°C ± 2°C, Ono et al. 1983) and relatively constant flow. This portion of the river also includes several endemic organisms that are federally listed as threatened or endangered, including: Texas wild-rice, San Marcos salamander, San Marcos gambusia (*Gambusia georgei*), Comal Springs riffle beetle (*Heterelmis comalensis*), and fountain darter. This section of the river is located within an urban area, and is subjected to a substantial amount of recreational use. As such, sites were chosen in this section of the river to better understand the interactions between the biota, the surrounding environment, and recreational users of this unique ecosystem (Figure 1).

During 2012, two comprehensive sampling efforts (spring and fall) were conducted in the San Marcos River system. The 2012 sampling schedule included the following components during each sampling effort unless otherwise noted:

Aquatic Vegetation
- Texas wild-rice survey
- GPS mapping within study reaches

Water Quality
- Thermistor placement
- Thermistor retrieval
- Fixed-station photography
- Point water quality measurements

San Marcos Salamander Observations
- Snorkel/SCUBA surveys

Texas Wild-Rice Physical Observations
- Cross-section data
- Physical measurements

Fountain Darter Sampling
- Drop nets
- Dip nets
- Visual observations

Low-Flow Sampling

There were no low-flow sampling events in 2012. Full system sampling is triggered at 100 cfs (daily average flow at nearest USGS gage) and reliant upon evaluation and approval from Edward's Aquifer Authority personnel.

High-Flow Sampling

There were no high-flow sampling events in 2012. Full system sampling is triggered at 385 cfs (daily average flow at nearest USGS gage) and reliant upon evaluation and approval from Edward's Aquifer Authority personnel.

San Marcos Springflow

All San Marcos River discharge data were acquired from the United States Geologic Survey (USGS) water resources division. Some of these data are provisional (as indicated in the disclaimer on the USGS website), and as such, may be subject to revision at a later date. According to the disclaimer, "recent data provided by the USGS in Texas – including stream discharge, water levels, precipitation, and components from water-quality monitors – are preliminary and have not received final approval" (USGS 2012). The discharge data for the San Marcos River were taken from USGS gage 08170500 at the University Drive Bridge. This site represents the cumulative discharge of the springs that form the San Marcos River system. In addition to the cumulative discharge measurements that were used to characterize this ecosystem during sampling, spot measurements of water velocity were taken during each sampling event using a Marsh-McBirney velocity meter.

San Marcos Water Quality

The objectives of the water quality analysis are: delineating and tracking water chemistry throughout the ecosystem; monitoring controlling variables (i.e., flow, temperature) with respect to the biology of each ecosystem; monitoring any alterations in water chemistry that may be attributed to anthropogenic activities; and evaluating consistency with historical water quality information. Due to the consistency in water quality conditions measured over the first several years of sampling, the water quality component of this study was reduced in 2003. One important component for maintenance of long-term baseline data is temperature loggers (thermistors), which are placed throughout the river. In addition, fixed station photography continues to provide visual proof of changes in the system. Conventional physico-chemical parameters (water temperature, conductivity, pH, dissolved oxygen, water depth at sampling point, and observations of local conditions) were taken in all drop net sampling sites using a multiprobe water quality sonde.

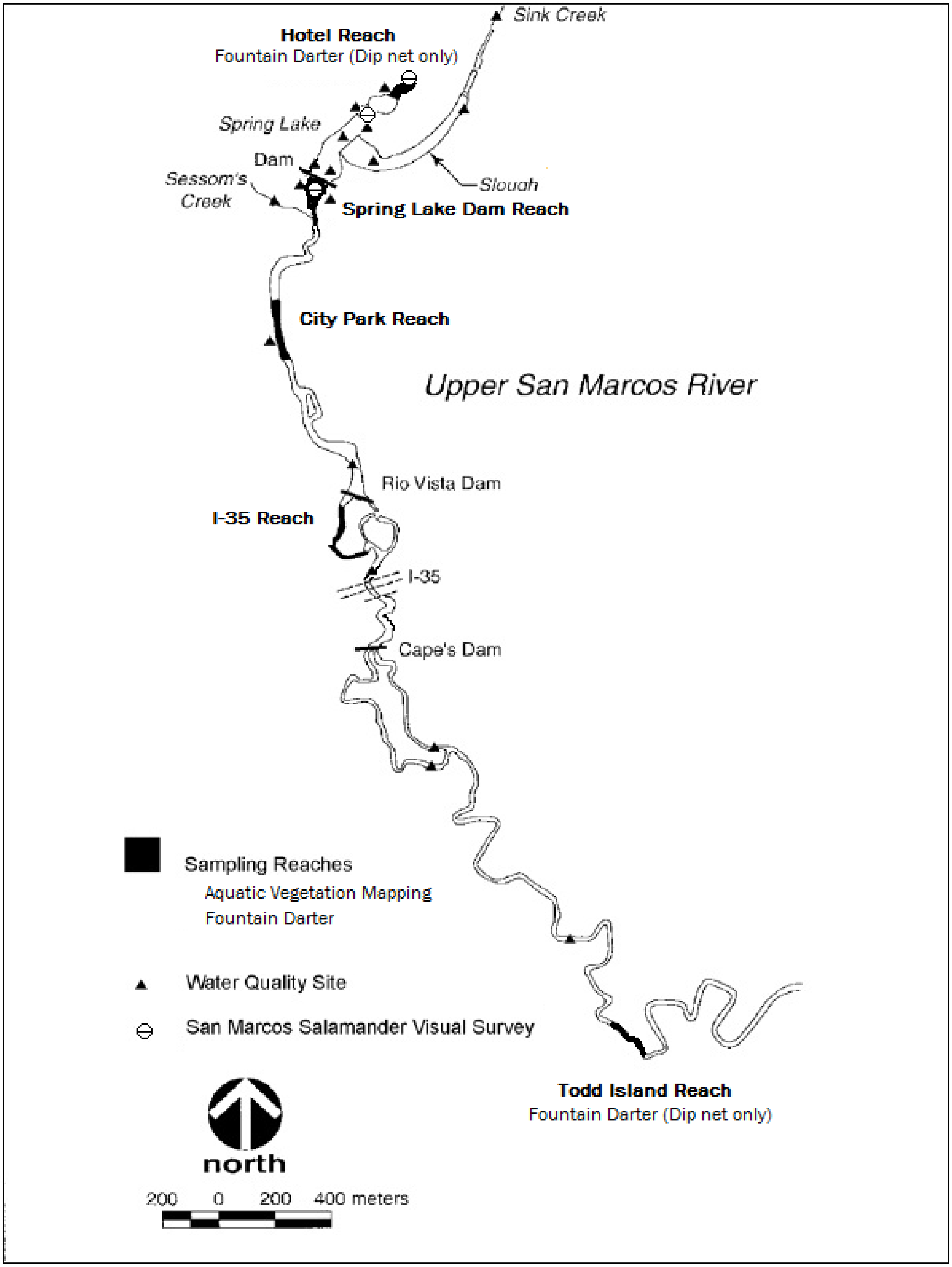


Figure 1. Upper San Marcos River water quality and biological sampling areas.


Measuring standard water quality parameters (Thompson's island)


Fixed station photo facing upstream (City Park)


Fixed station photo facing across channel (City Park)


Fixed station photo facing downstream (City Park)

Aquatic Vegetation Mapping

The aquatic vegetation mapping effort consisted of mapping all of the vegetation in each of three study reaches (Spring Lake Dam, City Park, and I-35). In addition, annual Texas wild-rice monitoring was performed in summer in the entire San Marcos River (to the most downstream Texas wild-rice plant which is near the treatment plant outfall). Mapping was conducted using a Trimble Pro-XH global positioning system (GPS) unit with real-time differential correction capable of sub-meter accuracy. The Pro-XH receiver was linked to a Trimble Recon Windows CE device (or similar device) with TerraSync software that displays field data as they are gathered and improves efficiency and accuracy. The GPS unit was placed in a 10.6 feet (ft) Necky Rip kayak with the GPS antenna mounted on the bow. The aquatic vegetation was identified and mapped by gathering coordinates while maneuvering the kayak around the perimeter of each vegetation type at the water's surface. Vegetation stands that measured between 0.5 and 1.0 m in diameter were mapped by recording a single point. Vegetation stands less than 0.5 m in diameter were not mapped.

GPS and kayak equipment used during aquatic vegetation mapping

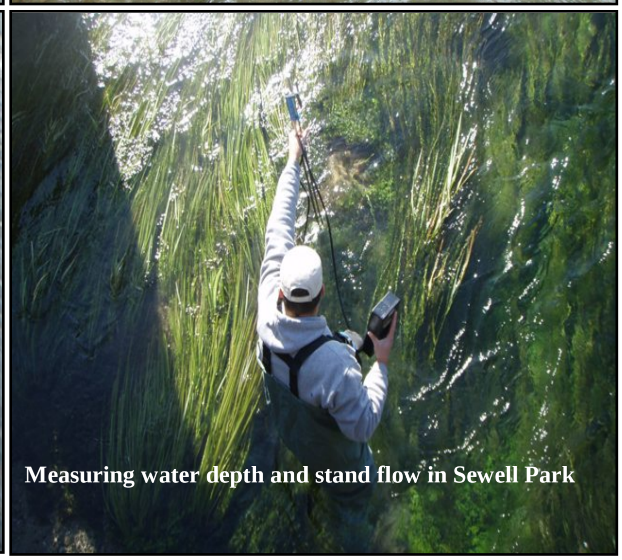
Texas Wild-Rice Physical Observations

At the beginning of the initial sampling activities for this project in 2000, Texas wild-rice stands throughout the San Marcos River were assessed and documented as being in "vulnerable" areas if they possessed one or more of the following characteristics: (1) occurred in shallow water (< 0.5 feet), (2) revealed extreme root exposure because of substrate scouring, or (3) generally appeared to be in poor condition. Monitoring activities associated with "vulnerable" stands were designed following discussions with Dr. Robert Doyle, currently with Baylor University, and Ms. Paula Power, formerly with the United States Fish and Wildlife Service (USFWS) Aquatic Resource Center, San Marcos. The areal coverage of Texas wild-rice stands in vulnerable locations were determined in 2012 by GPS mapping (described above), but some smaller stands were measured using maximum length and maximum width. The length measurement was taken at the water surface parallel to streamflow and included the distance between the base of the roots to the tip of the longest leaf. The width was measured at the widest point perpendicular to the stream current (this usually did not include roots). The length and width measurements were used to calculate the area of each stand according to a method used by the Texas Parks and Wildlife Department (J. Poole, TPWD, pers. comm.) in which percent cover was estimated for the imaginary rectangle created from the maximum length and maximum width measurements.

Recording GPS positions of Texas wild-rice in I-35 Reach

Measuring area of Texas wild-rice at Thompson's Island

Partially emergent stand of Texas wild-rice



Measuring water depth and stand flow in Sewell Park

Qualitative observations were also made on the condition of each vulnerable Texas wild-rice stand. These qualitative measurements included the following categories: the percent of the stand that was emergent (and how much of that was in seed), the percent covered with vegetation mats or algae buildup, any evidence of foliage predation, and a categorical estimation of root exposure.

Flow measurements were taken at the upstream edge of each Texas wild-rice stand and depth was measured at the shallowest point in the stand. Data on velocity, depth, and substrate composition were collected at 1-m intervals along cross-sections in the river in each area where Texas wild-rice plants were monitored. To complement all of the measurements made during each survey, photo sets were made for each of the sampling events in 2012.

Fountain Darter Sampling

Drop Net Sampling

A drop net is a sampling device used by the USFWS to sample fountain darters and other fish species in the Comal and San Marcos Springs/River ecosystems. The design of the net is such that it encloses a known area (2 square meters [m^2]) and allows thorough sampling by preventing escape of fishes occupying that area. A large dip net (1 m^2) is used within the drop net and is swept along the length of the river substrate 15 times to ensure complete enumeration of all fish trapped within the net. For sampling during this study, a drop net was placed in randomly selected sites within specific aquatic vegetation types. The vegetation types used in each reach were defined at the beginning of the study as the dominant species found in that reach. Sampling sites were randomly selected per dominant vegetation type from a grid overlain on the most recent map (created using GPS-collected data during the previous week) of that reach.

Drop netting in the City Park Reach

At each location, the vegetation type, height, and areal coverage were recorded, along with substrate type, mean column velocity, velocity at 15 cm above the bottom, water temperature, conductivity, pH, and dissolved oxygen. In addition, vegetation type, height, and areal coverage, along with substrate type, were noted for the adjacent area within three meters of the net. Fountain darters were identified, enumerated, measured for total length, and returned to the river at the point of collection. The same measurements were taken for the first 25 individuals of all other fish species. For species other than fountain darters, only the first 25 were measured and the rest were simply counted. Fish not readily identifiable in the field were preserved for identification in the laboratory. All live giant ramshorn snails (*Marisa cornuarietis*) were counted, measured, and destroyed, while a categorical abundance was recorded (i.e., none, slight, moderate, or heavy) for the exotic Asian snails (*Melanoides tuberculatus* and *Tarebia granifera*) and the Asian clam (*Corbicula* sp.). A total count of crayfish (*Procambarus* sp.) and grass shrimp (*Palaemonetes* sp.) was also recorded for each dip net sweep.

Drop Net Data Analysis

The fisheries data collected with drop nets were analyzed in several ways. First, fountain darter densities in the various vegetation types were calculated using the complete San Marcos River dataset (2000-2012). Comparing density values between vegetation types provides valuable information on species/habitat relationships. These average density values were then used with aquatic vegetation mapping data on total coverage of each vegetation type to create estimates of the population abundance in each reach (fountain darter density within a vegetation type x total coverage of that vegetation type in a given reach). Because there were generally only two drop net samples in each vegetation type within each reach, density estimates between sampling efforts had variation. Population estimates based on those densities are influenced by this variation. Part of the variation were due to changes in environmental conditions (discharge, temperature, etc.) that had occurred since the last sample, but part was due to natural variation between samples. Without adding samples (the total number is limited by federal permit and time constraints) it is impossible to tell how much of the variation is attributed to each source within a given sampling effort. Using the average density of fountain darters across all samples for a given vegetation type does not account for changes in density across samples (differences associated with changes in environmental conditions), but the increased sample size substantially reduces the high natural variability. This type of comparison between samples, where density values are held constant across all samples, is based entirely upon changes in vegetation composition and abundance between sampling efforts. Because these abundance estimates use the same density values across sites and seasons, and do not include estimates of fountain darters found in vegetation types that are not sampled with drop nets, the absolute numbers generated with this method have some uncertainty associated with them. Thus, the estimates are presented as relative comparisons by normalizing the data to the maximum estimate (the absolute value of all samples are converted to a percentage of the maximum value).

In addition to density and abundance calculations, drop net data were also used to generate length-frequency histograms for each season sampled. Analysis of these data, along with length-frequency data generated from dip netting, allows for inferences into reproductive seasonality.

Dip Net Sampling

In addition to drop net sampling for fountain darters, a dip net of approximately 40 cm x 40 cm (1.6-millimeter [mm] mesh) was used to sample all habitat types within each reach. Collecting was generally done while moving upstream through a reach. An attempt was made to sample all habitat types within a reach. Habitats thought to contain fountain darters, such as along or in clumps of certain types of aquatic vegetation, were targeted and received the most effort. Areas deeper than 1.4 m were not sampled. Fountain darters collected by this method were identified, measured, recorded as number per dip net sweep, and returned to the river at the point of collection. The numbers of native and exotic snails were also enumerated and recorded for each dip.

To balance the effort expended across sampling events, a predetermined time constraint was used for each reach (Hotel Reach – 0.5 hour, City Park Reach – 1.0 hour, I-35 Reach – 1.0 hour). The areas of fountain darter collection were marked on a base map of the reach, and these same areas were revisited in subsequent surveys. In 2009, to assess changes occurring on the lower river, a new sample reach was added on the lower San Marcos River in Section 12 near Todd Island (Figure 1). Though information relating the number of fountain darters by vegetation type was not gathered by this method (as in the drop net sampling) it did permit a more thorough exploration of various habitats within the reach. Also, spending a comparable length of time sampling the entirety of each reach allowed comparisons to be made between the data gathered during each sampling event.

Dip Net Data Analysis

Dip net data were used to identify periods of fountain darter reproductive activity since this method was more likely to sample small fountain darters (<15 mm) along shoreline habitats. This size-class is indicative of recent reproduction since fountain darters of this size should be <60 days old (Brandt et al. 1993). The dip net data provided a valuable second method of sampling fountain darters in the same sample reaches as drop netting, which allowed a more complete characterization of fountain darter dynamics in a sample reach. The dip net data were analyzed by visually evaluating graphs of length-frequency distribution for each sample reach.

Presence/Absence Dip netting

Presence/Absence dip netting was initiated on the San Marcos River during spring 2006. This method is designed to be a quick, efficient, and repetitive means of monitoring the fountain darter population. Also, since it is less destructive than drop netting, it can be conducted during extremely low flow periods without harming critical habitat.

During each sample, fifty sites were distributed among three sample reaches based on total area, diversity of vegetation, previous fountain darter abundance estimates, and overall biological importance of each reach. Fourteen sites are chosen in the Spring Lake Dam Reach, 22 sites are chosen in the City Park Reach, and 14 sites are chosen in the I-35 Reach. Several sites are chosen in each of the dominate vegetation types in each reach. However, since vegetation coverage changes often, the number of sites within each vegetation type fluctuates slightly between samples.

Four dips were conducted at each site for a total of 200 dips per sample period. After each dip, presence or absence of fountain darters was noted and the entire contents of the net were placed into a plastic tub with river water to avoid recapturing organisms. After all dips were completed at a site, all organisms were released near the site of capture.

San Marcos Salamander Visual Observations

Visual observations were made in areas previously described as habitat for San Marcos salamanders (Nelson 1993) (Figure 1). All surveys were conducted at the head of the San Marcos River and included two areas in Spring Lake and one area below Spring Lake Dam adjacent to the Clear Springs Apartments. The upstream-most area in the lake was adjacent to the old hotel (known as the Hotel Reach) and was identified as site 2 in Nelson (1993). The other site (known as Riverbed) in Spring Lake was deeper (~6 m) and located directly across from the Aquarena Springs boat dock. This site was identified as site 14 in Nelson (1993). The final sampling area was located just below Spring Lake Dam in the eastern spillway (site 21, Nelson 1993) and was subdivided into three smaller areas for a greater coverage of suitable habitat. San Marcos salamander densities in the three subdivisions below Spring Lake Dam were averaged as one.

SCUBA gear was used to sample habitats in Spring Lake, while a mask and snorkel were used in the site below Spring Lake Dam. For each sample, an area of macrophyte-free rock was outlined using flagging tape, and three timed surveys (5 minutes each) were conducted by turning over rocks >5 cm wide and noting the number of San Marcos salamanders observed underneath. Following each timed search, the total number of rocks surveyed was noted in order to estimate the number of San Marcos salamanders per rock in the area searched. The three surveys were averaged to yield the number of San Marcos salamanders per rock. The density of suitable sized rocks at each sampling site was determined by using a square frame constructed out of steel rod to take random samples within the area. Three random samples were taken in each area by blindly throwing the 0.25 m^2 frame into the sampling area and counting the number of appropriately sized rocks. The three samples were then averaged to yield a density estimate of the rocks in the sampling area. The area of each site was determined by physically measuring each sampling area.

An important note about these San Marcos salamander density estimates is that extrapolating beyond the area sampled into surrounding habitats would not necessarily yield accurate values, particularly in the Hotel Reach. This is because the area sampled was selected based on the presence of silt-free rocks and relatively low algal coverage (compared to adjacent areas) during each survey. Much of the habitat surrounding the sampling areas is usually densely covered with aquatic macrophytes and algae, and provides a three-dimensional habitat structure that support different densities of San Marcos salamanders. The estimates created from this work are valuable for comparing between trips, but any estimates of a total population size derived from this work should be viewed with caution.

OBSERVATIONS

The BIO-WEST project team conducted the study components for the 2012 Comprehensive sampling events on the dates shown in Table 1.

Table 1. Study components of the 2012 sampling events.

EVENT	DATES
Spring	
Vegetation Mapping	May 1, 3 - 4
Texas wild-rice physical observations	May 16
Fountain Darter Sampling	May 5 - 9
San Marcos Salamander Observations	May 3
Summer	
Texas wild-rice mapping	June 20 - 27
Fall	
Vegetation Mapping	Oct. 23 - 25
Texas wild-rice physical observations	Nov. 2
Fountain Darter Sampling	Oct. 29 – 30, Nov. 7
San Marcos Salamander Observations	Nov. 15

San Marcos Springflow

While springflows started the year below the historic average, flows did not drop below 100 cfs at any time in 2012. Spring rains pushed flows above the historic monthly average in March, but by mid-July flows dropped below average, and stayed below for the remainder of 2012 (Figure 2). A minimum daily mean flow of 100 cfs (Table 2) was reached several times in January, this flow is intermediate between the minimum flows of 2010 (163 cfs) and 2011 (88 cfs). The maximum mean daily discharge (241 cfs) in 2012 was reached on March 29 coinciding with several precipitation events in spring. Even with these rain events the extended drought in Central Texas continues, exemplified by the fact that discharge in the San Marcos River has not exceeded 300 cfs in over 5 years (since October 22, 2007 Figure 3). Figure 3 illustrates this recent lack of high flows, with few peaks indicating large rainfall and/or flooding events since 2007. Discharge in the San Marcos River in 2012 was similar to 2010, but lack of rainfall in fall and winter led to flows declining towards 120 cfs at the end of the year.

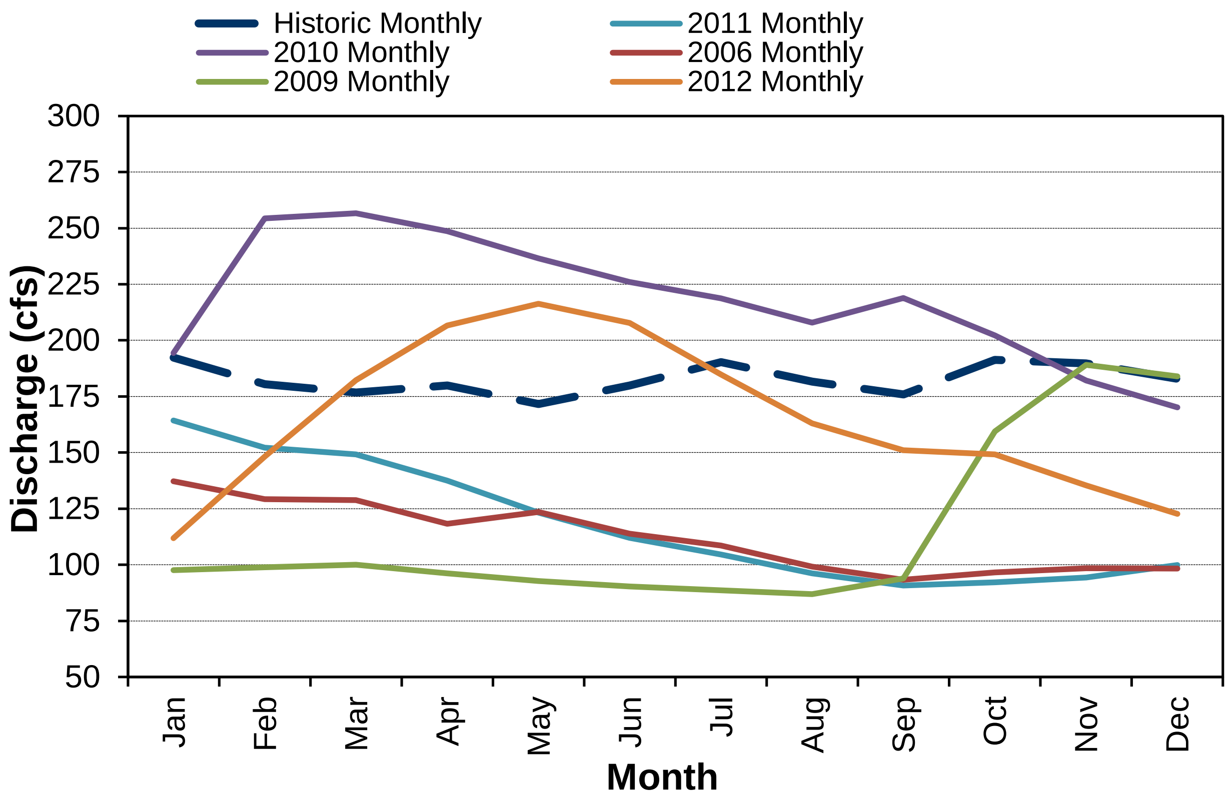


Figure 2. Mean monthly discharge (cfs) in the San Marcos River during the 1956-2012 period of record.

Table 2. Minimum and maximum discharges (cfs) in the San Marcos River since the beginning of the study in 2000.

Year	Minimum Discharge	Maximum Discharge
2000	108	397
2001	167	1,019
2002	157	668
2003	156	332
2004	146	1,280
2005	136	361
2006	90	145
2007	101	971
2008	97	217
2009	83	206
2010	163	273
2011	88	173
2012	100	241

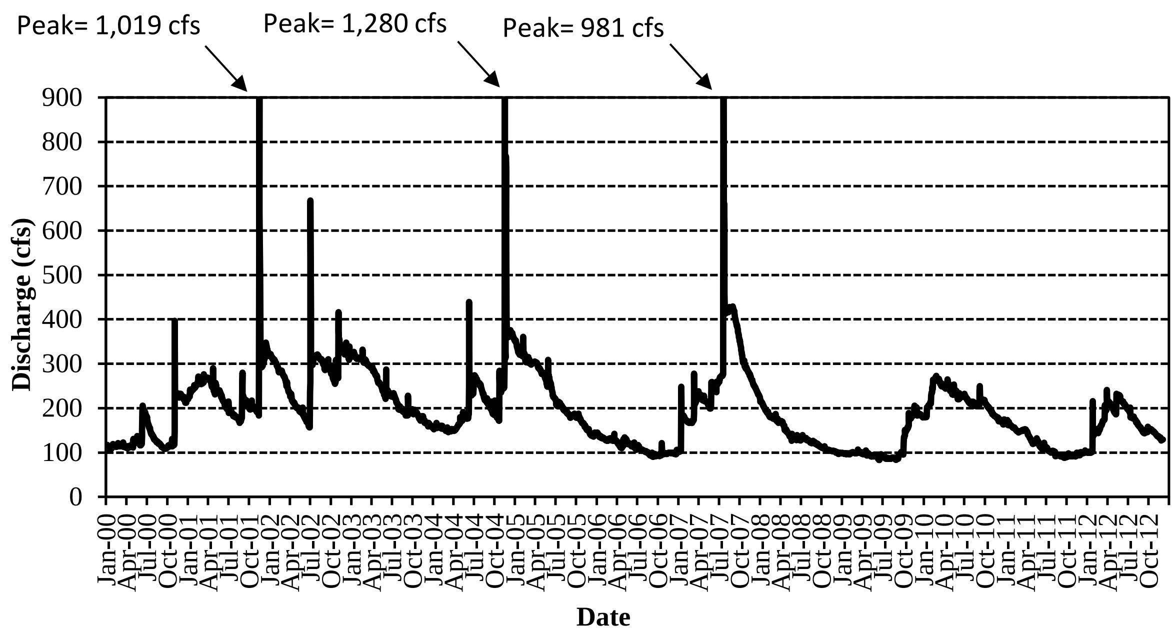


Figure 3. Daily average discharge (cfs) for the San Marcos River since the beginning of the study in 2000.

Water Quality Results

The continuously sampled water temperature data provide information regarding fluctuations due to atmospheric conditions, and springflow influences in the San Marcos River from 2000 - 2012. Water temperature data for the City Park and I-35 sites are presented in Figure 4, and additional graphs for all reaches can be found in Appendix B. Temperature monitors collect data every 10 minutes; however, to condense this into a more manageable dataset, graphs and analysis are based on four-hour averages of this data. Occasional gaps in data are due to thermistors being lost/stolen or malfunctioning. As expected, thermistors closest to spring inputs (farthest upstream) display relatively constant water temperatures. Further downstream, ambient conditions exhibit a greater influence on water temperature due to increased exposure time and runoff from rain events. The graph in Figure 4 displays this relationship with higher temperature fluctuations at the downstream thermistor (I-35) compared to the thermistor that is closer to spring inputs (City Park). Only the Sessom's Creek thermistor, which is not located in the main river, exceeded TCEQ's water quality standard of 26.67 ºC, and this only happened once (2 hour running average) in all of 2012.

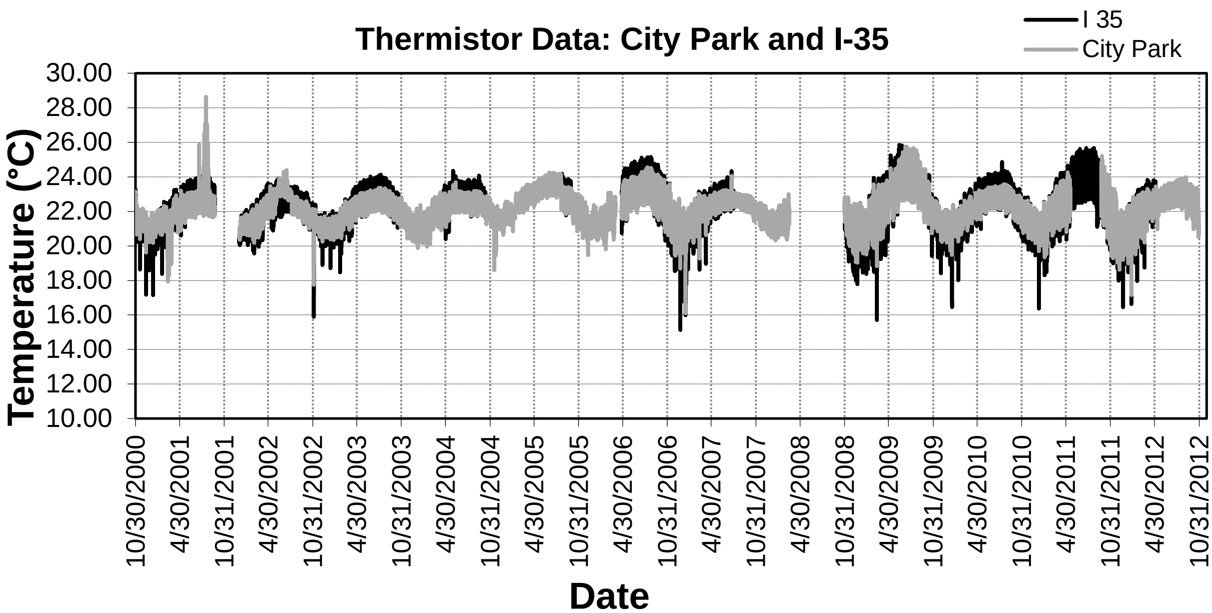


Figure 4. Thermistor data from the City Park and I-35 sites.

Aquatic Vegetation Mapping

Maps of the aquatic vegetation observed during each sample effort can be found in the Appendix A map pockets. The maps are organized by individual reach with successive sampling trips ordered by date of occurrence. It is difficult to make broad generalizations about seasonal and other trip-to-trip characteristics since most changes occur in such fine detail; however, some of the more interesting observations are described below.

City Park Reach

Between the fall (2011) and spring (2012) sampling efforts, vegetation coverage in the City Park Reach expanded and total vegetation increased from 3,300.9 m^2 (fall 2011) to 4,148.5 m^2 (spring 2012). This trend has been repeated throughout much of the study (Figure 5) because of lower recreation in winter compared to summer. This trend is most apparent in the middle section of the reach where recreation is concentrated due to several popular access points. *Hydrilla* dominates in this section, and over winter this plant increased from 1,393.0 m^2 to 2,164.9 m^2. Recreation pressure in summer once again uprooted many of these plants leading to *Hydrilla* only covering 1,385.0 m^2 of the reach in fall. As before, most of *Hydrilla* plant loss was in the middle of the reach where recreation pressure is highest. Another non-native plant, *Hygrophila*, exhibited a similar trend. From fall 2011 (540.9 m^2) to spring 2012 (938.9 m^2) it reestablished in parts of the upper section of the reach, but by fall 2012 (653.1 m^2) it decreased with much of the loss in the upper section. Although these two non-native plants typically have lower densities of fountain darters (*Hydrilla* – 6.3/m^2, *Hygrophila* – 5.1/m^2) compared to native plants, they are still important habitat because they are so ubiquitous throughout the San Marcos River.

The mixture of *Potamogeton*/*Hygrophila* typically yields intermediate fountain darter densities (4.7/m^2). Over the last several years it has been decreasing in surface area because much of the *Hygrophila* has died off/been uprooted leaving sparse stands of *Potamogeton*. As such, this mixture decreased in coverage from fall 2011 (374.7 m^2) to spring 2012 (312.4 m^2), and further into fall 2012 (298.0 m^2) with much of the change occurring in the upper section of the reach. Unlike most other plants in the City

Park Reach, Texas wild-rice exhibited a continual increase from fall 2011 (222.2 m^2) to fall 2012 (400.5 m^2). This near doubling in coverage was concentrated in the lower section of the reach where trampling of plants is inhibited due to greater depths.

In 2012, the typical boom/bust cycle in the City Park Reach was observed, but as in recent years the total amount of vegetation in the reach continues to be below average for both spring and fall (Figure 5). Over the last several years it appears that spring growth is not making up for the losses that occur over summer. Whether this is a reflection of increased recreation pressure or effects of the extended drought (or both), continued monitoring will allow us to better assess these long-term trends.

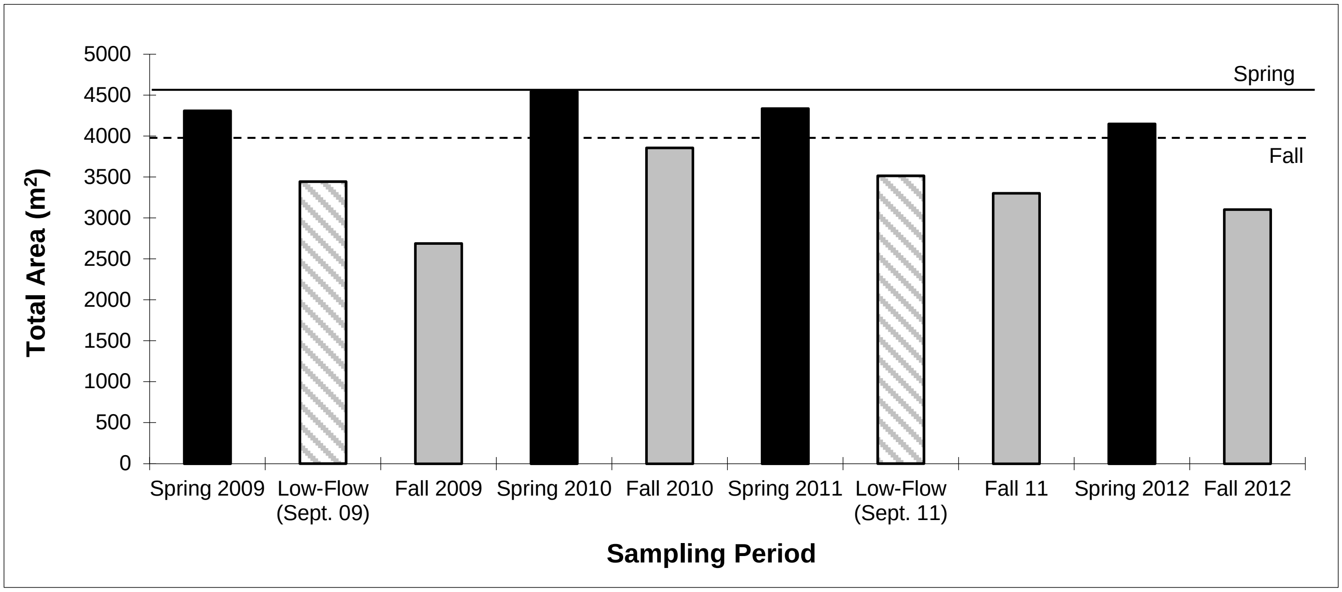


Figure 5. Changes in total aquatic vegetation area in the City Park Reach from 2009 to 2012. (Spring [solid] and Fall [dashed] lines represent study averages).

I-35 Reach

Since 2009, total vegetation in the I-35 Reach has been declining and remains well below the fall and spring averages (Figure 6). Following the low-flow Critical Period event in 2011, total vegetation declined by nearly 200 m^2 and 2012 saw this decline continue at a rapid pace. Though no bathymetric data has been collected, it appears that the I-35 reach is getting shallower, especially in the upper section of the reach. As a result, velocities have increased and few plants have managed to gain a foothold in this section. With several access points in this reach (there are parks on both sides of the river), there is likely a significant amount of recreation pressure (though less than City Park) that may be causing disturbance to plants in the I-35 Reach.

Total vegetation decreased slightly from fall 2011 (488.3 m^2) to spring 2012 (466.5 m^2). *Hydrilla* and *Hygrophila* decreased most over this period likely because these plants are located in shallow areas (middle and uppers sections of the reach) that are prone to disturbance. Texas wild-rice also decreased slightly, but these plants often change as they are predominantly rooted in shallow areas with higher velocities. By fall 2012, however, total vegetation decreased to the lowest amount (289.3 m^2) ever observed in the study (since 2000). Not only was this the least amount of vegetation observed, total coverage has never dropped below 400 m^2. A large section of mixed vegetation in the middle section of the I-35 Reach that has flourished since 2000 is now virtually gone with only a small amount of *Hydrilla* and *Sagittaria* remaining. This includes the loss of a Texas wild-rice plant. This area was scoured out due to a large tree which fell into the river and diverted most of the flow through what was previously a large eddy, thus scouring the vegetation. *Hygrophila* decreased by 7X with only a small patch remaining in the lower section of the reach. *Hydrilla* decreased by nearly half, while *Cabomba* dropped below 100 m^2 total area. This is important because *Cabomba* holds the highest densities ($8.6/m^2$) of fountain darters for vegetation types sampled in the San Marcos River. In addition, the I-35 Reach is the only sampled reach that has large patches of this plant. *Cabomba* prefers deep, low-velocity, silty backwaters and eddies, and this habitat type has become much less common in this reach. Since the removal of Rio Vista Dam and the installation of a more flow-through obstruction (Rio Vista Rapids), the I-35 Reach has become more dynamic with shifting banks and depths. It appears that the river is still adjusting to this change in hydrology, and changes in aquatic vegetation in this reach seem to be primarily related to sediment movement and channel reconfiguration. Continued monitoring is essential to understanding these relatively rapid changes in habitat conditions.

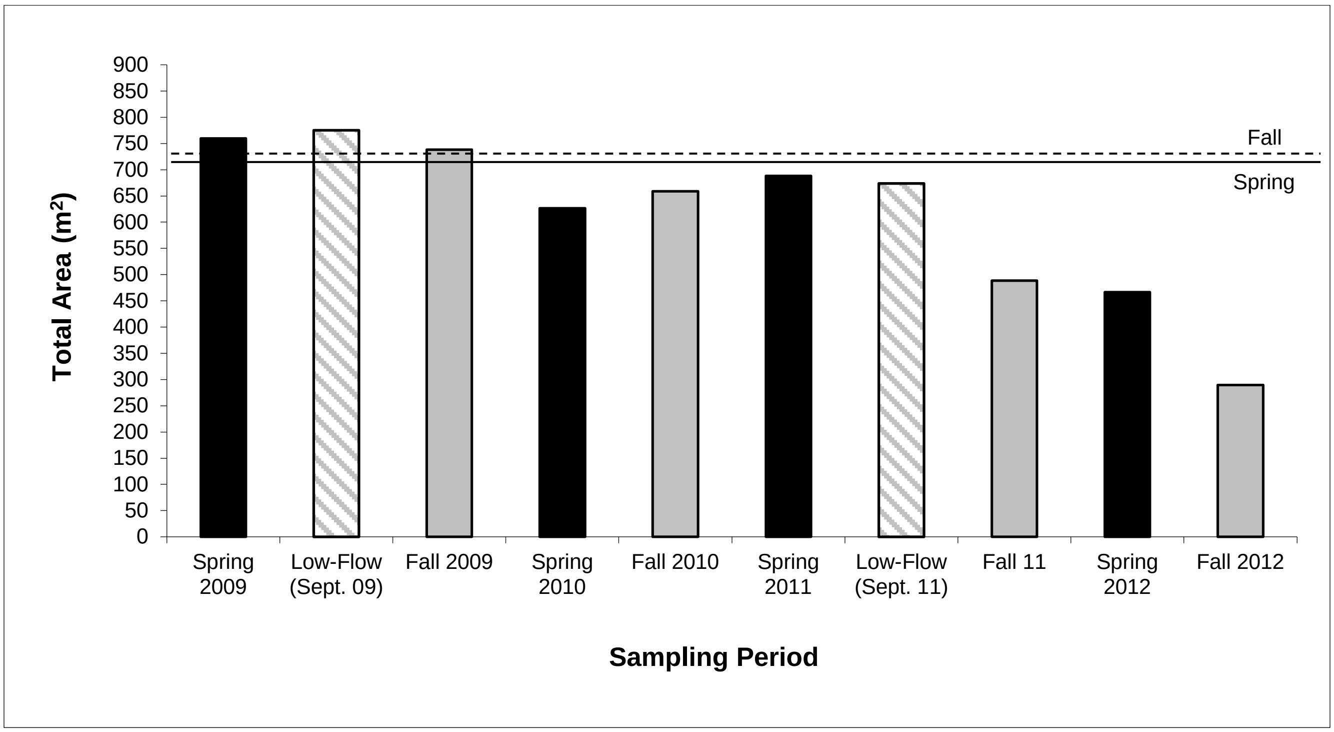


Figure 6. Changes in total aquatic vegetation area in the I-35 Reach from 2009 to 2012. (Spring [solid] and Fall [dashed] lines represent study averages)

Spring Lake Dam

Similar to the I-35 Reach, the Spring Lake Dam Reach has undergone some changes due to shifting banks and sedimentation. The downstream section of this reach is affected by sediment being contributed by runoff from Sessom's Creek. Although the effects of this sedimentation are greater downstream in Sewell Park, total vegetation in the Spring Lake Dam Reach has also experienced a decline over the last several years (Figure 7). Total vegetation increased from fall 2011 (1,028.8 m^2) to spring 2012 (1,212.5 m^2), but this is still below the spring average. Non-native plants like *Hygrophila* and *Hydrilla* increased in the middle sections of the reach, while native plants like *Potamogeton* and Texas wild-rice followed a similar pattern. Several smaller Texas wild-rice plants grew together in the middle and upper sections of the reach to form more continuous plants. These increases are likely due to decreased recreation pressure over winter as observed in other parts of the San Marcos River.

By fall 2012 total vegetation had decreased (1,091.3 m^2), and although it was below the long-term study average, coverage was still higher than in fall 2011. Some decreases were noted in *Hydrilla* as *Potamogeton* took over space occupied by this non-native plant. Texas wild-rice also decreased slightly to 397.2 m^2 in fall due to some plants fracturing. This spring to fall drop in vegetation coverage is common, and the magnitude of the drop was much less in 2012 than in previous low-flow years (2006, 2011). This reach will continue to be closely observed since it is prone to disturbance and also home to a significant amount of Texas wild-rice.

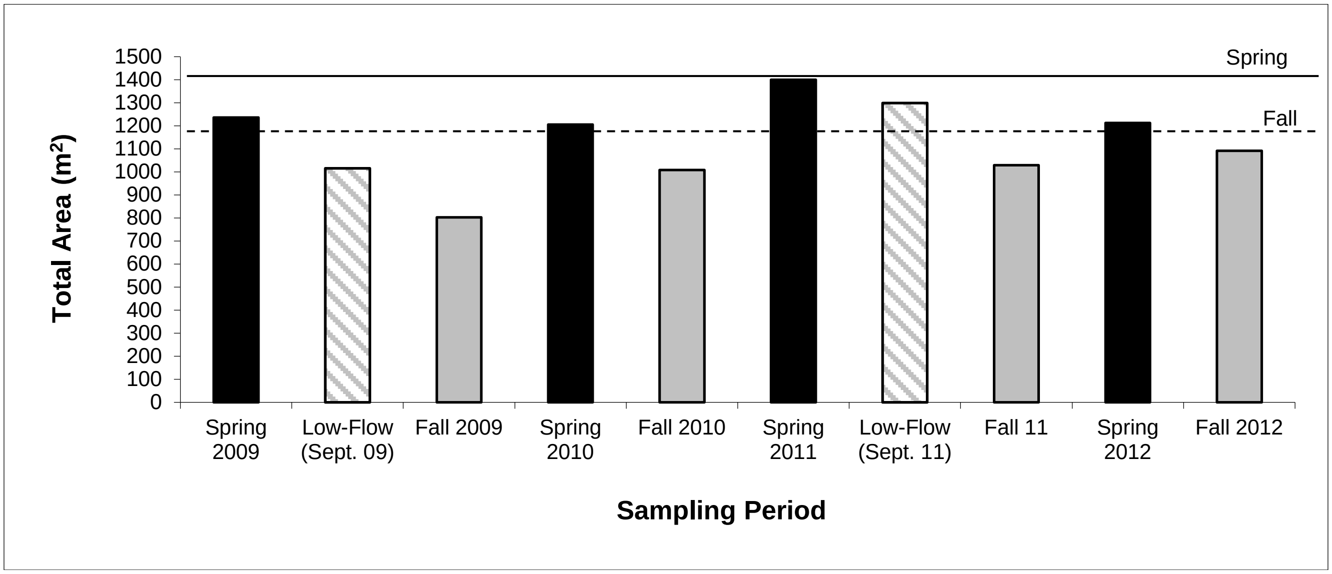


Figure 7. Changes in total aquatic vegetation area in the Spring Lake Dam Reach from 2009 to 2012. (Spring [solid] and Fall [dashed] lines represent study averages)

Texas Wild-rice Annual Mapping

Texas wild-rice maps for the entire San Marcos River broken out by map segment for each sampling period can be found in the map pockets in Appendix A. Despite the drought in Central Texas, Texas wild-rice flourished. Total surface area in the San Marcos River in 2012 was 4,367.1 m^2, the highest amount since the inception of the study (Table 3). This represents a 16% increase since the low-flow Critical Period Event in 2011. As in most years, most of these changes in growth occurred in the first 2 miles of the river where 88% of Texas wild-rice resides. This section of the river is sinuous, closer to spring inputs, and compared to the other mapped sections has lower velocities. In addition, these sections are where most of the recreation pressure is found. Multiple access points, high density housing, and proximity to the university contribute to this pressure. In most years this contributes to losses in the Texas wild-rice community, but in 2012 these pressures did not seem to affect plants in the upper sections of the San Marcos River. Much of these increases are a result of smaller plants growing together and filling in gaps, but some new plants also appeared in 2012.

Much of the growth in Texas wild-rice took place within the initial 1/3rd mile (Map 1, Appendix A). This section saw 12% growth from 2011 (2,289.7 m^2) to 2012 (2,604.8 m^2). Although one large plant in Sewell Park continues to be a fraction of what it once was, several plants just upstream of University Dr. grew together forming two large Texas wild-rice plants. The plant at Sewell Park grew in total area slightly, but sedimentation and the resulting colonization by terrestrial plants continues to out-compete the native wild-rice. The decrease in velocities along the river right section of the river leads to sedimentation, and is the result of Sessom's Creek bringing in sediment upstream of University Dr. This area upstream (BobDog Island) blocks flow downstream at Sewell Park leading to fine sediments settling out and decreasing depths in this reach. Most of the Texas wild-rice that is flourishing in this section is found in deeper water with constant flows. This site is closely monitored as it is considered a "vulnerable" plant (see Texas Wild-Rice Physical Observations section below). The highest growth of Texas wild-rice took place in the next section (Map 2, Appendix A), where total coverage increased by 35% from 2011 (550.6 m^2) to 2012 (843.9 m^2). This expansion in total surface area was mostly a result of established plants growing larger in areas where recreation effects are lessened because of greater depths. This includes a large plant just downstream of the railroad bridge (and Hopkins St.) that typically flourishes in deeper water (> 3.0 feet). A slight decrease in coverage (2%) was observed in the reach near I-35 (Map 4, Appendix A), where several vulnerable plants were uprooted. These plants are in areas where depths are minimal (typically <0.3 ft.) and are prone to being uprooted as a result. Texas wild-rice in the downstream reaches (Maps 5 – 7, Appendix A) changed little from 2011 to 2012.

Overall, Texas wild-rice experienced its best year of growth since the study began. This may be a result of higher than average flows (Figure 2) coinciding with the beginning of the growing season allowing Texas wild-rice plants an advantage early in the year before the pressures of recreation and lower summer flows took their toll.

Table 3. Total areal coverage (m^2) of Texas wild-rice (*Zizania texana*) within each study reach in 2011 – 2012. Note: Total area includes plants in Spring Lake.

Sampling Period	Map 1	Map 2	Map 3	Map 4	Map 5	Map 6	Map 7	Total Area (m^2)
Summer 2011	2,470.6	607.5	367.3	379.0	20.5	5.2	66.6	**3,916.8**
Critical Period 1 2011	2,289.7	550.6	342.2	392.4	33.3	4.0	59.4	**3,671.6**
Summer 2012	2,604.9	843.9	412.5	386.4	43.3	8.8	52.4	**4,367.1**

Texas Wild-Rice Physical Observations

Texas wild-rice observations were conducted two times during 2012. These observations were made during comprehensive sampling events (spring and fall) in May and November. Previously, two observation periods were conducted in 2010 during normal flow conditions, and four observation periods were conducted in 2011 during low-flow conditions in summer and the Comprehensive Monitoring Effort in spring and fall. The dates of these observations are presented chronologically along with the corresponding average daily discharge value in Table 4. In 2012, observations were made on vulnerable stands within the Sewell Park Reach and the I-35 Reach, and the Thompson's Island Reach was visited during each event to determine whether any new plants established in the reach. The total coverage of Texas wild-rice observed in each "vulnerable" stand in the San Marcos River is presented in Table 5, and observations of trends in areal coverage within each study reach are discussed below. More detailed graphs on observations of root exposure, herbivory, emergence, flowering and seeding stands, coverage by floating vegetation, stand depth, and stand flow are found in Appendix B.

Three small Texas wild-rice plants that were newly established in the I-35 Reach in 2011 (Plants 4a, 4b, and 4c) were gone by the spring 2012 observation period. Also during the past year, a fallen tree across the river-right side and middle of the channel near Plant 5 in the I-35 Reach has increasingly reduced flows to Texas wild-rice plants immediately downstream of the tree. Since the tree fell, sedimentation has occurred around these plants, vegetation mats commonly collect on the tree branches in the river and often extend across some of the Texas wild-rice plants, and stand flows have increased at plants on the river-left side of the river (including at Plant 5). The plants near the fallen tree now occur in shallower water and in silt (which could wash away during a high flow event) and do not appear as healthy in color or size as they did previously. Therefore, two of the stands immediately downstream of the fallen tree (named Plants 11 and 12) in the I-35 Reach were included in the vulnerable stand observations in 2012.

Table 4. The dates of Texas wild-rice observations conducted in 2010-2012 and the corresponding average daily discharge in the San Marcos River.

Texas Wild-Rice Observation Period	Event Type	Date	Average Daily Discharge (cfs)
2010 Spring	Spring Comprehensive Sampling	21 April 2010	254
2010 Fall	Fall Comprehensive Sampling	25 October 2010	198
2011 Spring	Spring Comprehensive Sampling	27 April 2011	127
2011 TWR1	<120 cfs Observation	2 September 2011	93
2011 CP1	Critical Period 1	21 September 2011	89
2011 Fall	Fall Comprehensive Sampling	7-8 November 2011	95
2012 Spring	Spring Comprehensive Sampling	16 May 2012	230
2012 Fall	Fall Comprehensive Sampling	2 November 2012	142

Average stand flows in both the Sewell Park Reach and I-35 Reach were higher than normal during the spring 2012 observation, but decreased to near average stand flows during the fall (Appendix B). Following 2011, a year in which less than 10% of vulnerable stands experienced shallow water conditions (<0.5 feet depth) during summer and fall, vulnerable stands did not experience shallow water conditions in 2012 (Appendix B). In spring 2012, almost 30% of the vulnerable TWR stands were emergent in the Sewell Park Reach and approximately 22% were emergent in the I-35 Reach. The percentage of emergent plants decreased by the fall observation event, to approximately 15% at Sewell Park and 4% at I-35. In a similar pattern, the percentage of flowering and seeding vulnerable stands in spring 2012 was approximately 20% at Sewell Park and 10% at I-35. The percentage of flowering and seeding stands decreased in the fall to 3% and 2.5%, respectively. The amount of vulnerable stands covered by floating vegetation mats in Sewell Park decreased between fall 2011 (40%) and spring 2012 event (4%) and remained low during the fall 2012 event (7%). As is typical, vulnerable stands in the I-35 Reach had a low incidence (3% in spring; less than 1% in fall) of floating vegetation mats covering them in 2012.

From fall 2011 to spring 2012, Texas wild-rice plants at Sewell Park grew by 17% (Table 5). Most of this growth took place in the large plants along river-left that have been depleted in recent years due to sedimentation. The decreased flow on this side of the river (as described in the previous section) can lead to large vegetation mats lying on top of wild-rice plants because flows are too low to push them downstream. This is a possible reason why these plants decreased by 23% from spring 2012 to fall 2012. Additionally, recreation pressure over summer likely led to some of these plants being uprooted. Vulnerable plants in the I-35 Reach followed a similar trend increasing by 39% from fall 2011 to spring 2012, but decreasing by 25% by fall 2012. Much of these changes are apparent in two large plants just upstream of I-35. These plants typically exhibit growth when flows are higher (like spring 2012) because vegetation mats do not get snagged by reproductive culms. However, when flows are lower vegetation mats often shade these plants for long periods of time, thus inhibiting growth.

Table 5. Areal coverage (m^2) of Texas wild-rice vulnerable stands during each sampling period between fall 2009-fall 2012.

REACH-STAND NO.[a]	Fall 2009	Spring 2010	Fall 2010	Spring 2011	TWR 1	CP 1	Fall 2011	Spring 2012	Fall 2012
Sewell Park - 1	-	-	-	-	-	-	-	-	-
Sewell Park - 2	113.6	154.4	177	122.5	nm	81.7	83.8	116.0	64.0
Sewell Park – 3									
Sewell Park - 4 & 5	41.6	44.4	36.7	46.8	nm	36.9	27.7	27.9	41.1
Sewell Park - 6	0.4	0.7	2.2	0.9	nm	1.3	***Gone***	-	-
Sewell Park - 7 & 8	219.8	300.8	276.6	323.3	nm	308.3	175.2	202.8	162.7
Total Area	**375.4**	**500.2**	**492.4**	**493.5**	**-**	**428.1**	**286.6**	**346.9**	**267.8**
I-35 – 4a	-	-	-	-	-	-	0.2		
I-35 – 4b	-	-	-	-	-	0.1	0.2	41.6 [b]	16.3
I-35 – 4c	-	-	-	-	-	0.04	0.09		
I-35 - 5	0.5	0.1	0.8	0.7	0.4	0.4	0.4	6.2	5.1
I-35 - 6	0.3	0.3	***Gone***	-	-	-	-	17.7 [c]	4.4
I-35 - 7	11.0	11.6	13.4	16.6	nm	18.6	18.2	19.4	19.4
I-35 - 8	134.6	111.2	109.7	104.5	nm	100.6	106.4	125.2	107.4
I-35 – 9	3.0	36.6	28.6	6.7	nm	5.3	2.9	9.5	7.8
I-35 – 10	12.2			24.8	nm	23.8	19.2	21.5	19.7
I-35 – 11 [b]	-	-	-	-	-	-	-	-	-
I-35 – 12 [b]	-	-	-	-	-	-	-	-	-
Total Area	**161.6**	**159.8**	**152.4**	**153.3**	**-**	**148.7**	**147.5**	**241.1**	**180.1**
Thompson's Island Reach	*Gone*	-	-	-	-	-	-	-	-
Total Area	***Gone***	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

[a] Many stands grew together to form individual stands after the first sampling period.
[b] A new plant was chosen because the previous plant 4 is no longer present.
[c] A new plant was chosen because the previous plant 6 is no longer present.

Fountain Darter Sampling Results

Drop Nets

In 2012, drop netting was conducted on the San Marcos River in the annual spring (May 7) and fall (Oct. 29) sampling events. The number of drop net sites and vegetation types sampled in each reach per event is presented in Table 6. The drop net site locations are depicted on the aquatic vegetation maps (Appendix A) for the respective reaches per sampling event and resulting data sheets are found in Appendix C.

Table 6. Drop net sites and vegetation types sampled in each reach.

CITY PARK REACH	I-35 REACH
Bare Substrate (2)	Bare Substrate (2)
Hygrophila (2)	*Hygrophila* (2)
Hydrilla (2)	*Hydrilla* (2)
Potamogeton/Hygrophila (2)	*Cabomba* (2)
Total (8)	**Total (8)**

A total of 225 fountain darters were captured from drop nets in 2012, with 142 captured during the spring and 83 captured in the fall. Over the course of the study, the number of darters captured per sampling effort has ranged from 24 in February 2002 to 616 in April 2007. To examine long-term trends in the fountain darter population relative to flow, abundance of fountain darters in each sample period were plotted over mean daily discharge throughout the study period (Figure 8). Due to the highly variable data no distinct discharge-abundance relationships are obvious from this analysis.

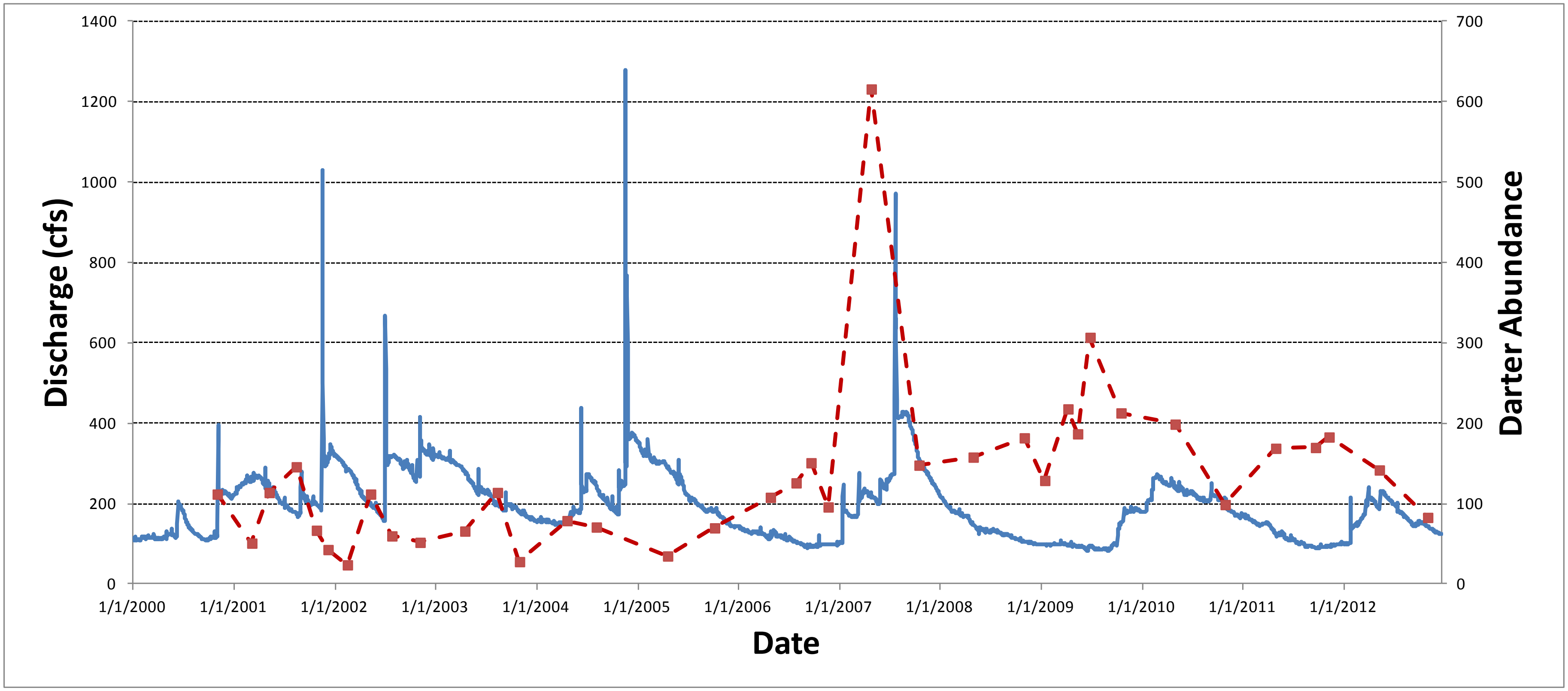


Figure 8. Mean daily discharge (blue line) and fountain darter abundance in drop net samples (red dotted line) over the study period.

To further explore the relationship between darter abundance and discharge, a scatterplot of daily mean discharge for each sample date and fountain darter abundance was developed (Figure 9). These data show that as discharge increases, the number of fountain darters captured in each drop net event tends to decrease. This trend may represent clumping of darters into limited habitat under low flows, but may also be influenced by decreased drop net efficiency under high flows.

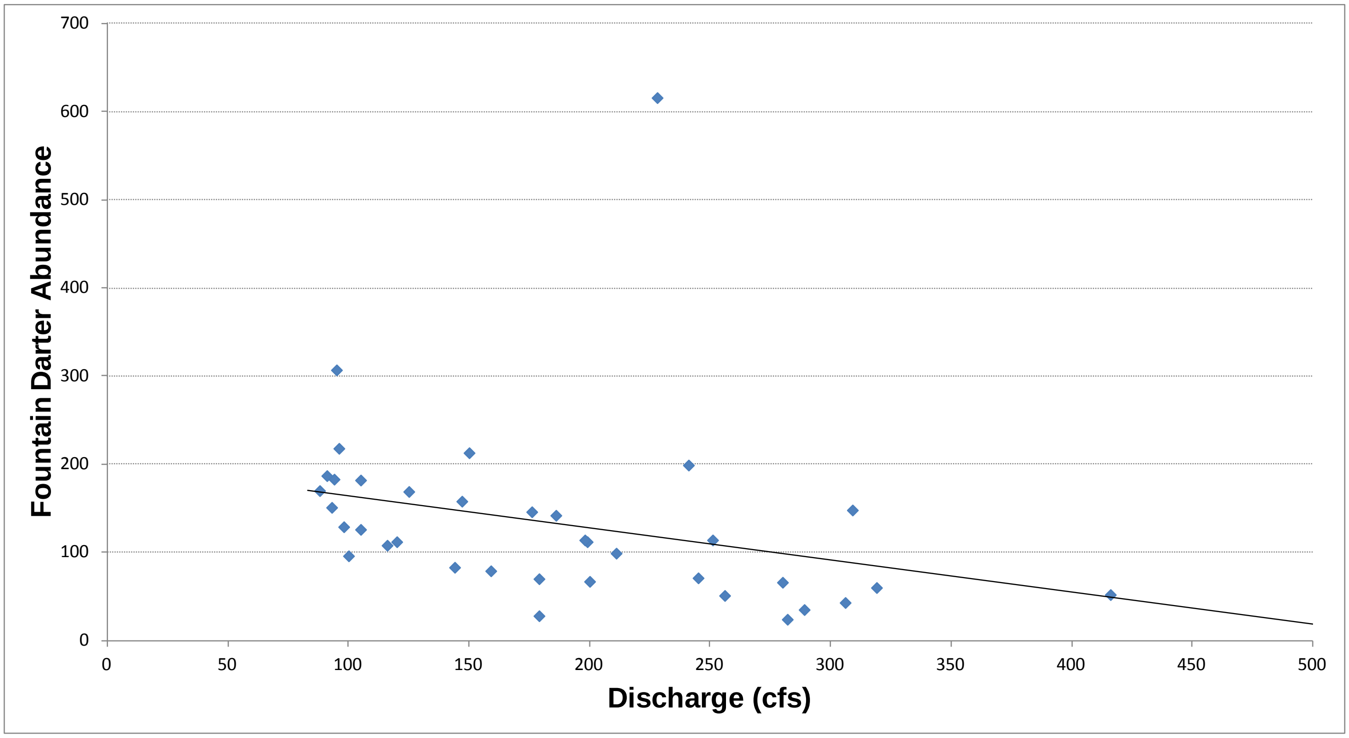


Figure 9. Scatterplot of fountain darter abundance in drop net samples versus daily mean discharge on each sample date.

Submerged aquatic vegetation is a critical component of fountain darter habitat in the San Marcos River, as demonstrated by the density of darters in open habitats (0.1/m^2) versus vegetated habitats (4.7-8.4/m^2) (Figure 10). However, fountain darter density varies considerably between vegetation types, demonstrating that some vegetation types provide more suitable habitat than others. For example, fountain darter densities calculated from drop netting data are high in the native vegetation type *Cabomba* (8.4/m^2), yet considerably lower in non-native *Hygrophila* (5.1/m^2). Fountain darter densities in native *Potamogeton* (5.6/ m^2) and non-native *Hydrilla* (6.3/m^2) are intermediate. *Potamogeton* and *Hygrophila* often grow together, and the density within this native/non-native mix is 4.7 darters/ m^2 (Figure10).

Although there is variation in densities between vegetation types in the San Marcos River drop net data, the magnitude of this variation is considerably smaller than in the Comal Springs/River ecosystem (BIO-WEST 2013). In the Comal, certain vegetation types such as filamentous algae and bryophytes exhibit higher densities (22-28 fountain darters/m^2), resulting in an overall greater number of darters. Filamentous algae and bryophytes provide dense cover at the substrate level, and also harbor large numbers of invertebrates that fountain darters commonly feed on. In the San Marcos system, filamentous algae and bryophytes are only found in the Spring Lake Reach. Although this area is not sampled by drop netting, dip net data confirms a high abundance of fountain darters in these vegetation types within Spring Lake.

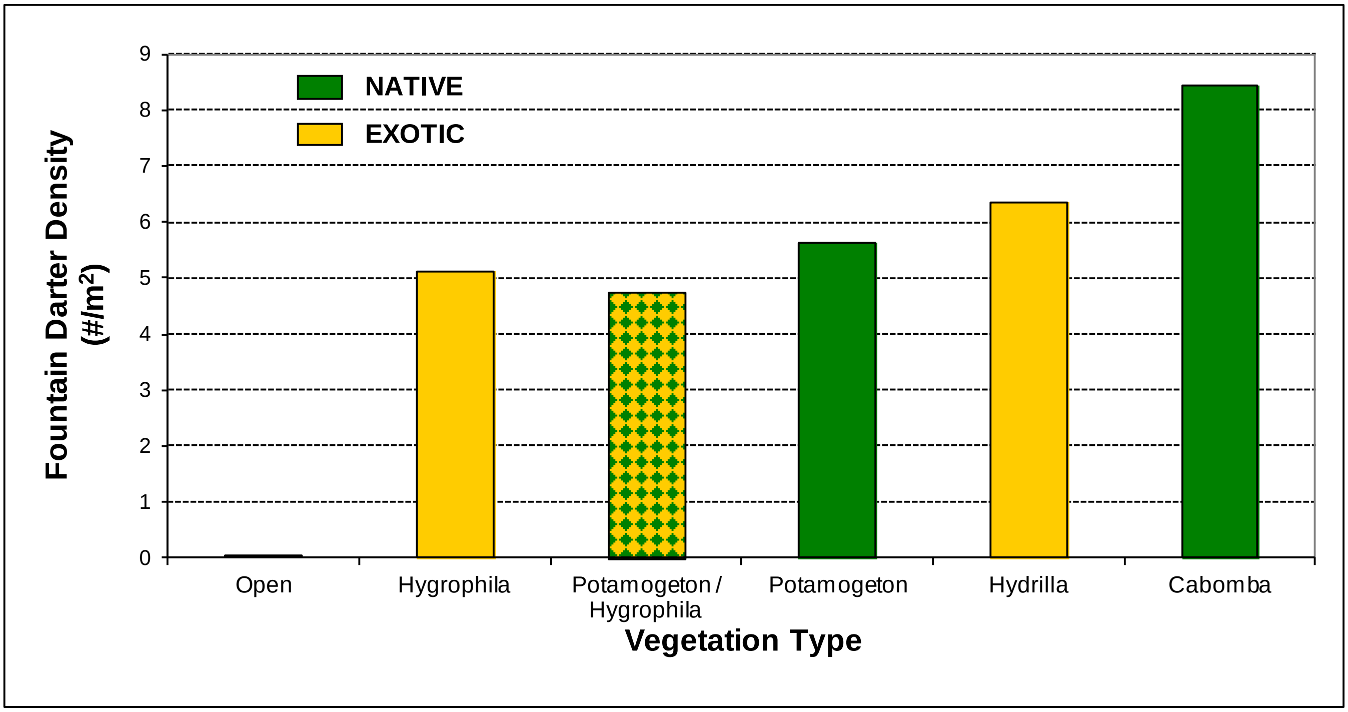


Figure 10. Density of fountain darters collected by vegetation type in the San Marcos Springs/River ecosystem (2000-2012).

The length frequency distributions for fountain darters collected by drop net from the San Marcos Springs/River ecosystem during each 2012 sampling event are presented in Figure 11 (data collected in previous years are presented in Appendix B). Laboratory studies have shown that darters of 16 mm TL are approximately 63 days old (Brandt et al. 1993). Therefore, presence of fountain darters this size and smaller suggests recent reproduction. Although fountain darters are known to spawn year-round, spring collections from the City Park and I-35 Reach typically have a larger proportion of small darters, suggesting increased reproductive activity in late winter/early spring. However, this typical trend was not observed in 2012 data, which exhibited the highest proportion of small darters (<16 mm) in the fall sampling event at City Park. Length frequency data from dip net sampling showed a similar pattern, with the highest number of small fountain darters (5-15 mm TL) occurring at the City Park Reach during the fall sampling event. No known changes in flow or habitat conditions coincided with this atypical pattern in length frequencies observed in the City Park Reach. However, limited reproductive success suggested by length frequency data from the I-35 Reach is not surprising given changes to habitat that continue to occur in this reach following modification of Rio Vista Dam. Since modification of Rio Vista Dam in 2006, this reach has become gradually shallower and swifter, and overall coverage of aquatic vegetation has declined.

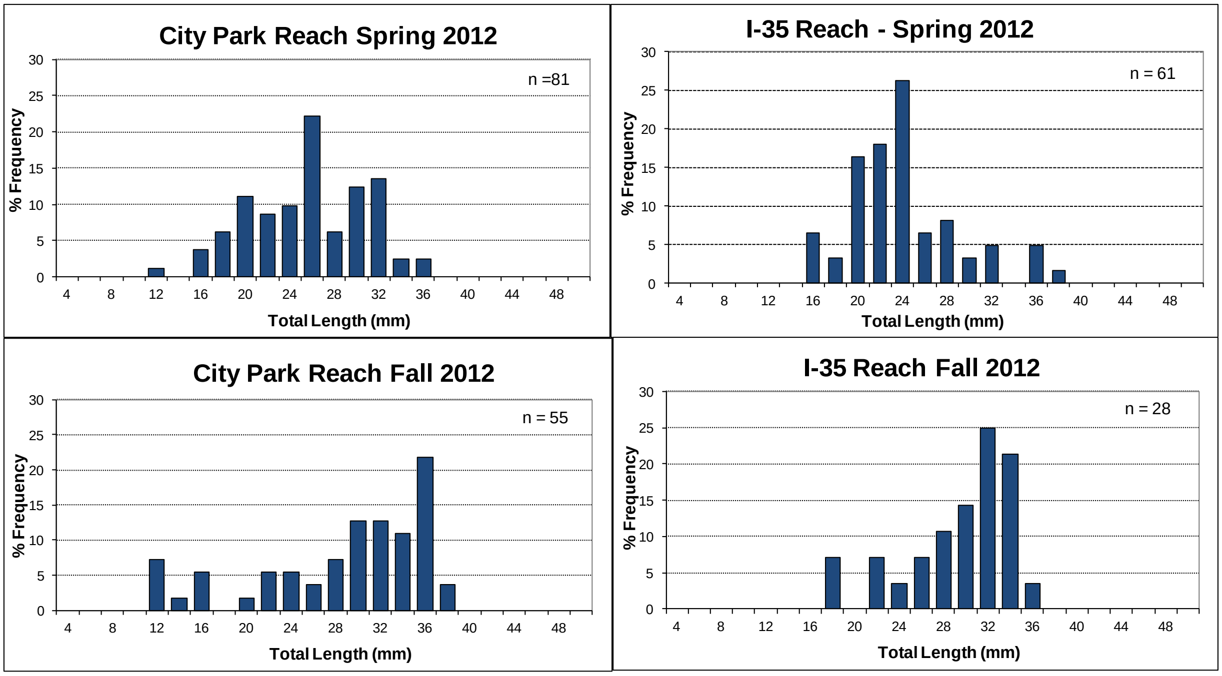


Figure 11. Length frequency distributions of fountain darters collected from each reach of the San Marcos River during each 2012 sampling event.

Estimates of fountain darter population abundance (Figure 12) were based on changes in vegetation composition and abundance and average density of fountain darters found in each, as described in the methods section. Data from the Spring Lake Dam Reach were not included in these estimates because drop net sampling was not conducted there.

Since there is less variation in the average density of fountain darters found among vegetation types in the San Marcos River than in the Comal River, population estimates are less variable between samples. However, trends in the two systems are similar. High flows typically result in scouring of vegetation, and thus, lower population estimates. Fountain darter population estimates under low flows are variable, but impacts have been noted. In the City Park Reach, low flows combined with heavy summer recreational traffic result in trampling of much of the submerged vegetation in the summer. This decline in overall coverage of aquatic vegetation leads to a reduction in fountain darter population estimates during summer and fall seasons. This trend seems exacerbated in recent years as summer flows have remained relatively low and recreational pressure continues to increase. As a result, large spring to fall swings in population estimates are present from 2009-2012, culminating in the lowest population estimate of the study in fall 2012. During this period, good vegetation conditions in spring months result in high population estimates, but as summer progresses recreational impacts decrease the overall coverage of aquatic vegetation resulting in a low population estimate in summer and fall. Aquatic vegetation in this reach seems to recover well during the cooler winter months with reduced recreation, and estimates usually rebound by the spring sampling effort. However, such large spring to fall shifts were not noted during the early years of the study, and are therefore attributed to increased recreational traffic in combination with low summer flows in recent years. Additionally, although a spring rebound in population estimates has occurred in each of the last three years, spring population estimates have steadily declined from 2010 to 2012. This suggests that habitat conditions are not recovering to previous levels after summer impacts. Therefore, continued monitoring of fountain darter populations and vegetation communities within these study reaches will be critical in coming years, especially with implementation of EAHCP activities which could influence habitat conditions in these reaches.

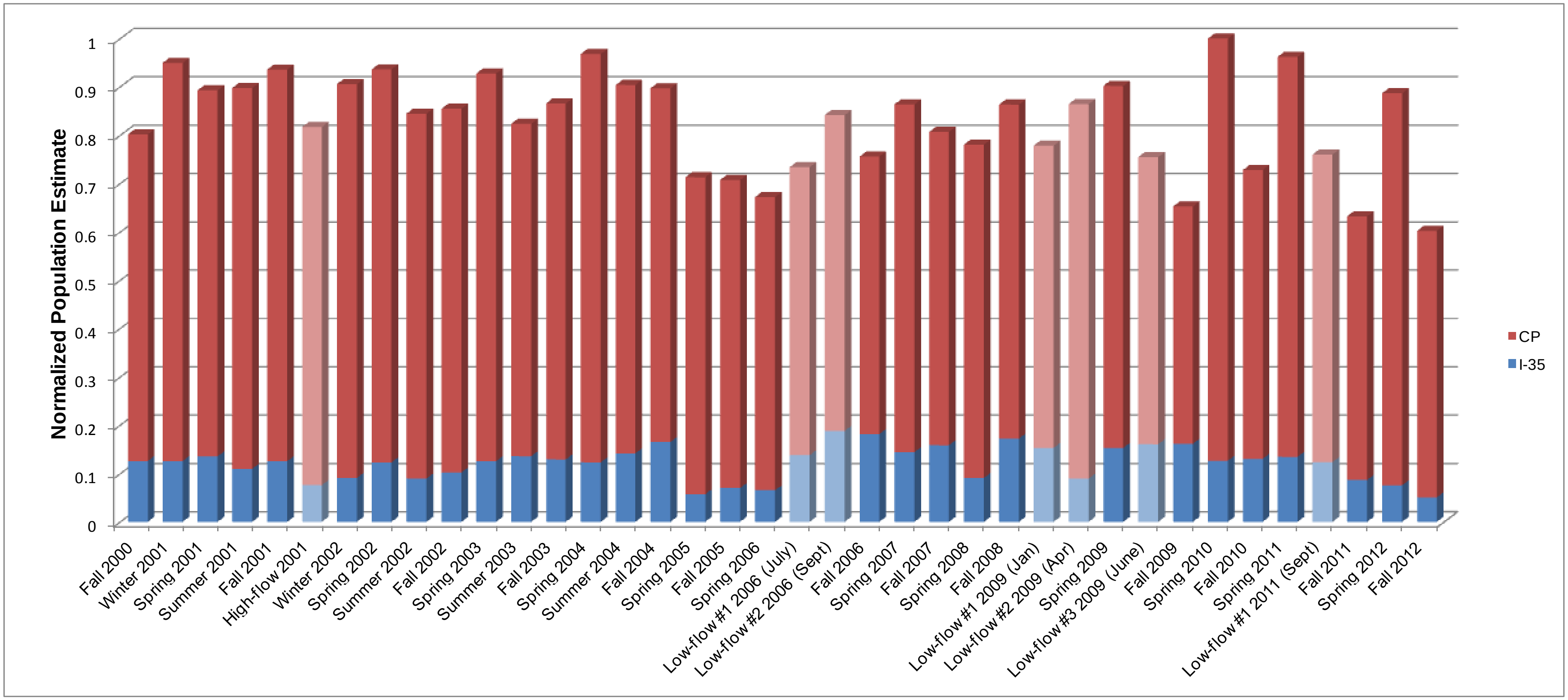


Figure 12. Population estimates of fountain darters in the San Marcos River; values are normalized to a proportion of the maximum observed in any single sample. Lighter colors represent critical period sampling events.

In addition to fountain darters, there have been 41,164 fishes representing at least 27 other taxa collected by drop netting since 2000 (Table 7). Of these, seven species are considered introduced or exotic to the San Marcos Springs/River ecosystem. Commonly captured exotic or introduced species include the rock bass (*Ambloplites rupestris*), Rio Grande cichlid (*Cichlasoma cyanoguttatum*), redbreast sunfish (*Lepomis auritus*), and the sailfin molly (*Poecilia latipinna*). Although these species are not native to the system, most have been established for decades, and negative impacts to the fountain darter have not been noted. However, one exotic fish of particular concern is the armadillo del rio (*Hypostomus plecostomus*). These fish are not commonly captured in drop nets, but are known to be extremely abundant in the system. This herbivorous species feeds by scraping algae/periphyton from the river substrate, and therefore, has the potential to alter the food chain - impacting fountain darter habitat and food supplies. Therefore, continued monitoring and management of the *H. plecostomus* population in the San Marcos River is crucial.

Table 7. Fish species and the number of each collected during drop-net sampling in the San Marcos Springs/River ecosystem from 2000-2012.

Family	Scientific Name	Common Name	Status	Number Collected	
				2012	2000-2012
Lepisosteidae	*Lepisosteus oculatus*	Spotted gar	Native	0	1
Cyprinidae	*Cyprinella venusta*	Blacktail shiner	Native	0	6
	Dionda nigrotaeniata	Guadalupe roundnose minnow	Native	2	46
	Notropis amabilis	Texas shiner	Native	5	70
	Notropis chalybaeus	Ironcolor shiner	Native	8	131
	Notropis sp.	Unknown shiner	Native	0	4
Catostomidae	*Moxostoma congestum*	Gray redhorse	Native	0	2
Characidae	*Astyanax mexicanus*	Mexican tetra	Introduced	10	38
Ictaluridae	*Ameiurus melas*	Black bullhead	Native	0	1
	Ameiurus natalis	Yellow bullhead	Native	7	115
	Noturus gyrinus	Tadpole madtom	Native	0	4
Loricariidae	*Hypostomus plecostomus*	Armadillo del rio	Introduced	1	44
Poeciliidae	*Gambusia* sp.	Mosquitofish	Native	1162	38439
	Poecilia latipinna	Sailfin molly	Introduced	1	147
Centrarchidae	*Ambloplites rupestris*	Rock bass	Introduced	36	566
	Lepomis auritus	Redbreast sunfish	Introduced	5	67
	Lepomis cyanellus	Green sunfish	Native	0	8
	Lepomis gulosus	Warmouth	Native	8	31
	Lepomis macrochirus	Bluegill	Native	0	76
	Lepomis megalotis	Longear sunfish	Native	0	18
	Lepomis microlophus	Redear sunfish	Native	0	2
	Lepomis miniatus	Redspotted sunfish	Native	85	1004
	Lepomis sp.	Sunfish	Native/Introduced	3	161
	Micropterus salmoides	Largemouth bass	Native	6	52
Percidae	*Etheostoma fonticola*	Fountain darter	Native	225	4,928
	Percina apristis	Guadalupe darter	Native	0	16
	Percina carbonaria	Texas logperch	Native	0	1
Cichlidae	*Cichlasoma cyanoguttatum*	Rio Grande cichlid	Introduced	5	98
	Oreochromis aureus	Blue tilapia	Introduced	0	16
Total				1569	46,092

Another exotic species of concern is the giant ramshorn snail (*Marisa cornuarietis*). This herbivorous snail elicits concern because of its negative impacts to aquatic vegetation in the Comal River during the early 1990s (Horne et al. 1992, Arsuffi et al.1993). No giant ramshorn snails were collected during drop netting on the San Marcos River in 2012. However, during dip net surveys in 2012, 15 giant ramshorn snails were collected from one small area within the I-35 Reach. Additionally, giant ramshorn snail numbers seem to be increasing recently in some segments of the Comal River. Close monitoring of this species will continue because of the impact this exotic species can have on the vegetation community under higher densities.

Dip Nets

Timed dip net collections were conducted twice on the San Marcos River during 2012: May 9 (spring) and November 7 (fall). Each section where dip net collections were conducted is depicted in Figure 13. Section numbers are included to be consistent with the USFWS classification system for the San Marcos River. In 2009, to assess changes occurring on the lower river, a new sample reach was added on the lower San Marcos River in Section 12 near Todd Island. Data gathered from the Hotel Reach at Spring Lake are presented in Figure 14, and data from all other sections are graphically represented in Appendix B.

The overall number of fountain darters collected in the Hotel Reach by dip netting is typically much greater than that found in the other two reaches. Filamentous algae and bryophytes present in this area provide the highest quality habitat found in the San Marcos Springs/River ecosystem. It should be noted that lower abundance at the Hotel Reach in fall 2010 resulted from moving the sampling area to a nearby location due to construction in the usual sampling area (Figure 14). Almost all samples collected from the Hotel Reach during the study period contained individuals in the smallest size class (5-15mm). This size class represents fountain darters <60 days old (Brandt et al. 1993) and their presence in all seasons indicate year-round reproduction in Spring Lake.

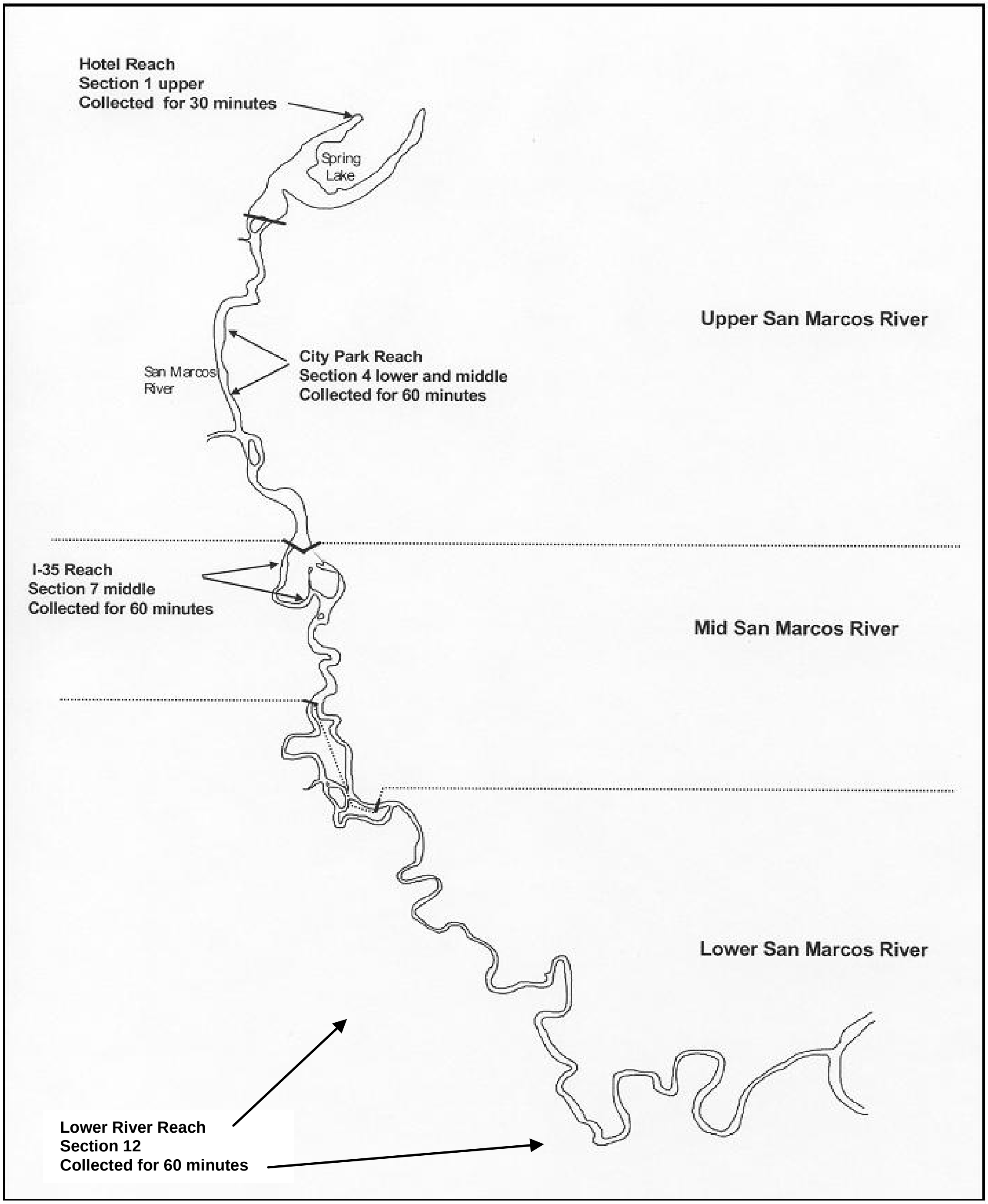


Figure 13. Areas where fountain darters were collected with dip nets, measured, and released in the San Marcos River.

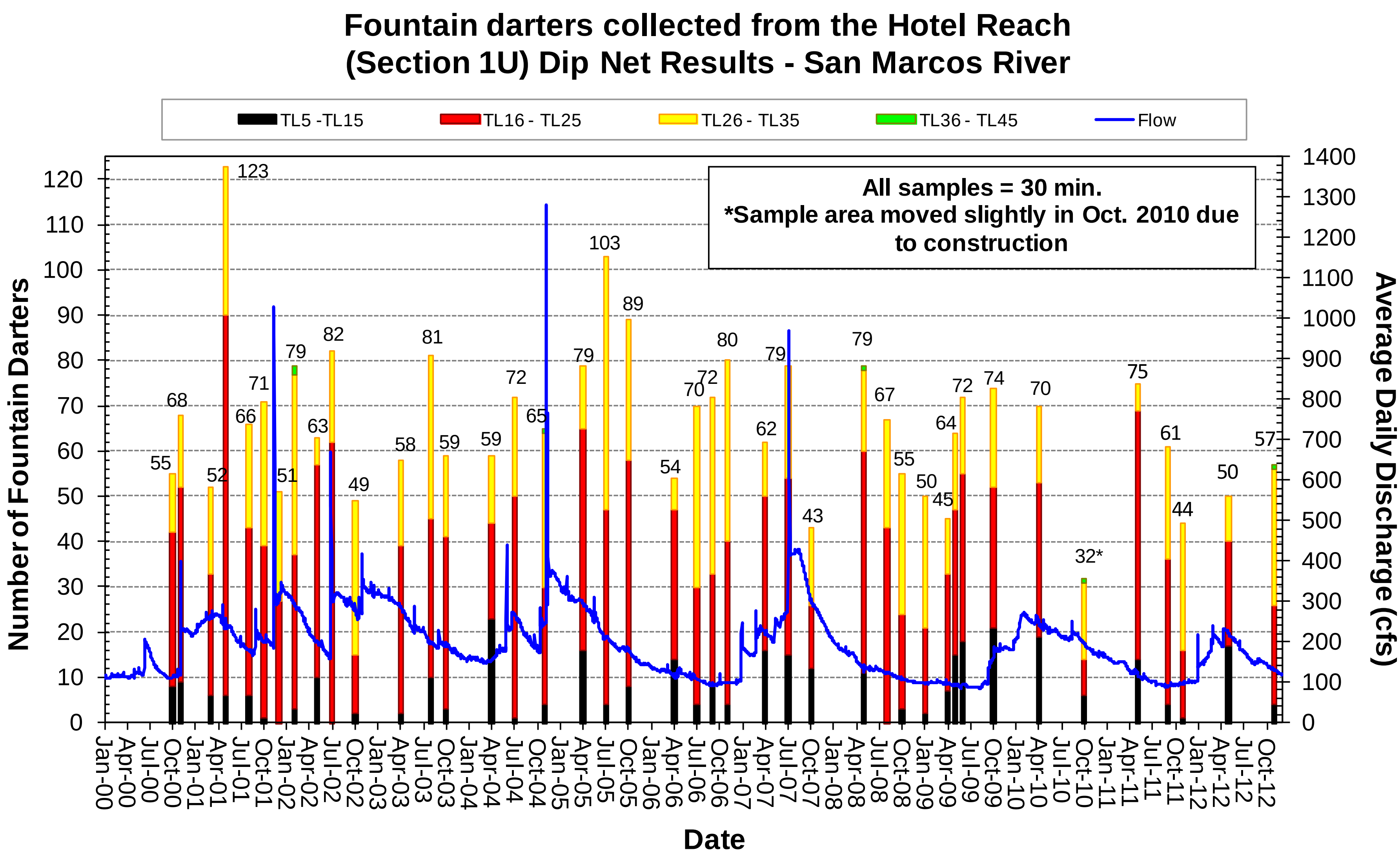


Figure 14. Number of fountain darters collected from the Hotel Reach (section 1 upper) of the San Marcos Springs/River ecosystem using dip nets.

Presence/Absence Dipnetting

Presence/Absence Dipnetting was conducted on the San Marcos River during the annual spring (May 4) and fall (October 30) sampling events. The percentage of sites in which fountain darters were present varied from 56% in spring to 50% in fall. Figure 15 demonstrates the variance observed in this metric since 2006. The average percent of sites occupied by fountain darters is 50%, and the blue box encompasses the 5th-95th percentiles. Values observed in 2012 were similar to those documented previously.

Although this technique does not provide detailed data on habitat use, and does not allow for quantification of population estimates, it does provide a quick and less intrusive method of examining large-scale trends in the fountain darter population. Data collected thus far provide a good baseline for comparison in future critical period events.

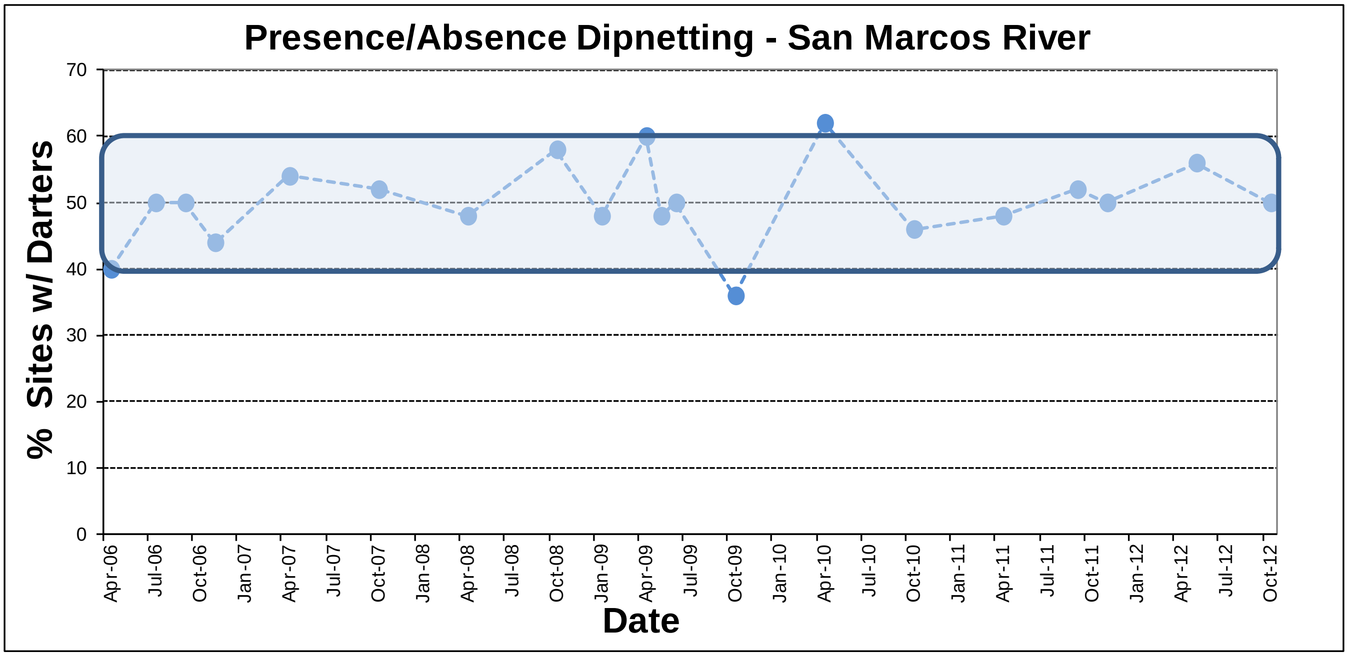


Figure 15. Percentage of sites (N = 50) in which fountain darters were present. Blue box encompasses 5th – 95th percentile.

San Marcos Salamander Visual Observations

For all sites and seasons in 2012, salamander densities were above the historical average in the San Marcos River and Spring Lake (Figures 16 – 18). Sample area 2 (Hotel Reach – near the upstream end of Spring Lake) has the highest densities of salamanders due to an abundance of bryophytes which provide good habitat. Salamander density in spring 2012 (17.5/m^2) was slightly higher than fall 2011 (17.1/m^2) and density in fall 2012 (19.3/m^2) was the highest fall density observed since 2001.

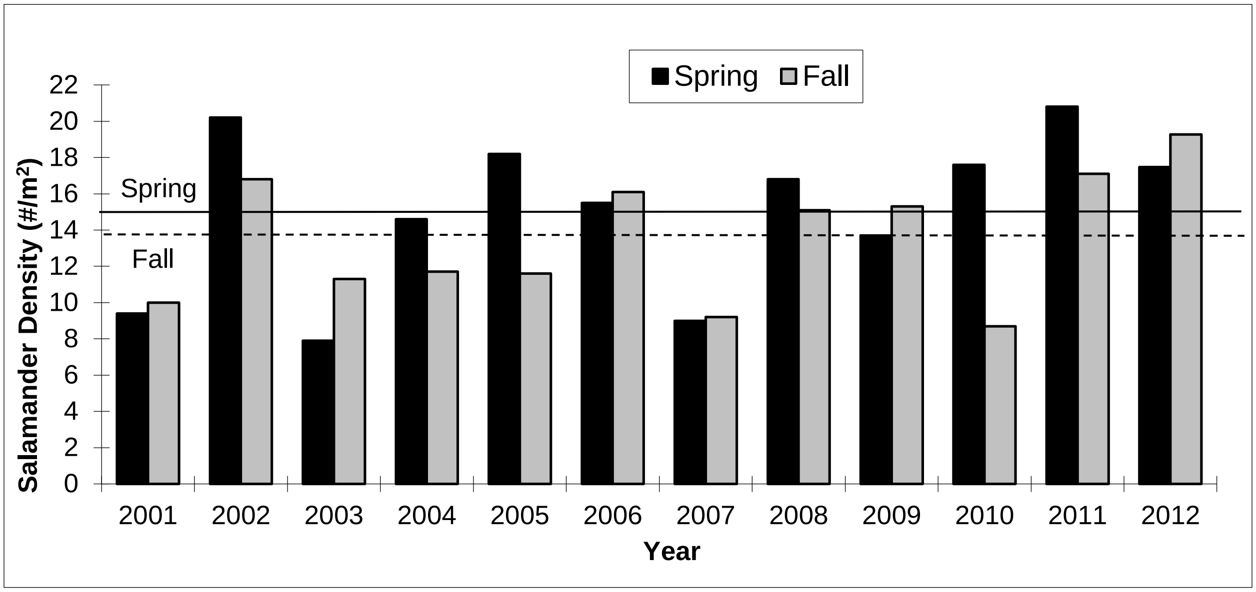


Figure 16. Salamander densities at sample area 2 (Hotel Reach) for spring and fall 2001-2012. (Spring [solid] and Fall [dashed] lines represent study averages)

Sample area 14 (Riverbed Reach) is also located within Spring Lake, but is downstream of sample area 2. A 52% reduction in densities occurred in 2011 (likely due to construction activities), but numbers appeared to rebound by 2012. Both spring (14.4/m^2) and fall (12.4/m^2) densities were higher than the study average, and spring densities had nearly doubled since the previous fall (2011 – 7.6/m^2).

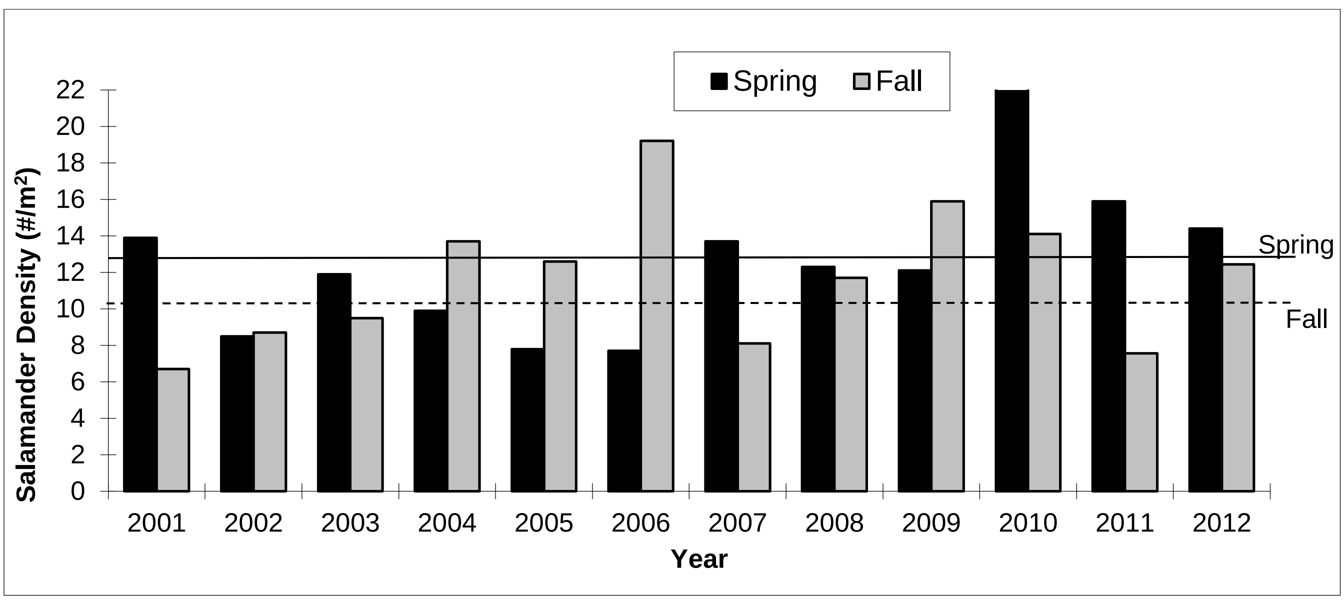


Figure 17. Salamander densities at sample area 14 (Riverbed Reach) for spring and fall 2001-2012. (Spring [solid] and Fall [dashed] lines represent study averages)

Sample area 21 is the only site within the San Marcos River. This site is located within an area with heavy recreation, and rocks (preferred salamander habitat) are often moved by river users. As a result, densities here are often lower than at other sites. This may explain why densities decreased by 51% from fall 2011 (14.0/m^2) to spring 2012 (6.9/m^2). By fall 2012 however, densities (13.7/m^2) were similar to that of 2011. In fact salamander density at Sample Area 21 was the second highest in the study. Educational signs and recent EAHCP publicity may have contributed to decreased recreational impacts in this reach. Continued monitoring of these sites will aid in understanding how changes in spring flow, vegetation composition, and recreation pressure can affect this federally-threatened species.

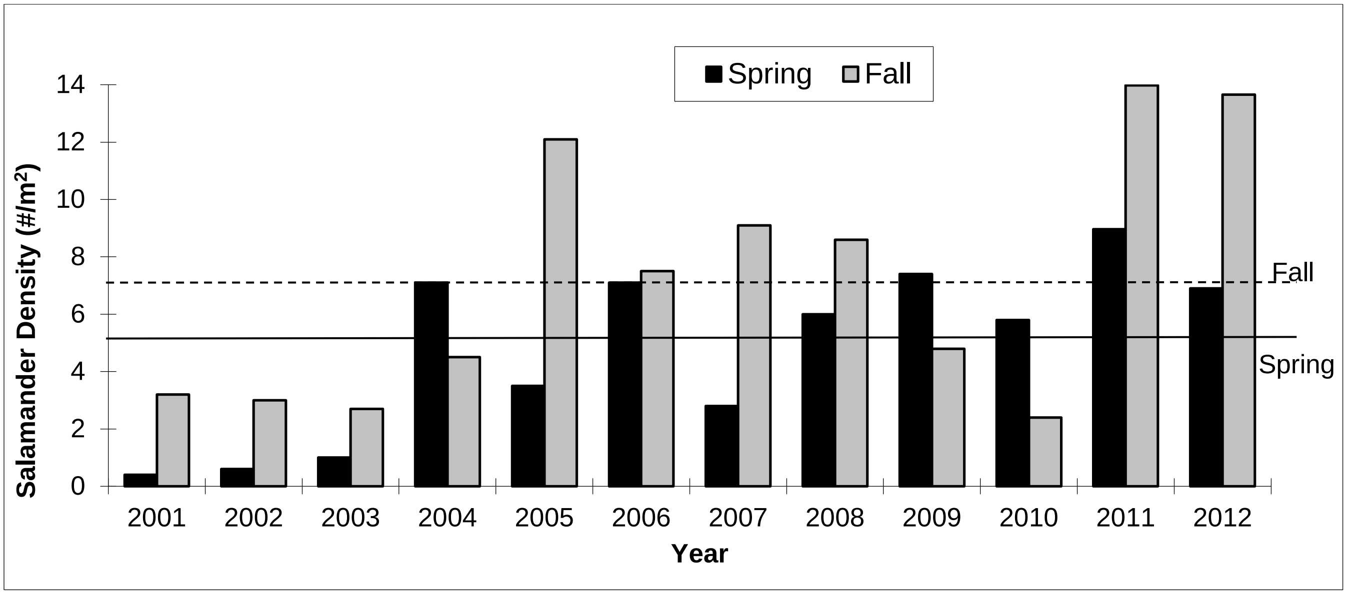


Figure 18. Salamander densities at sample area 21 (Spring Lake Dam Reach) for spring and fall 2001-2012. (Spring [solid] and Fall [dashed] lines represent historical averages)

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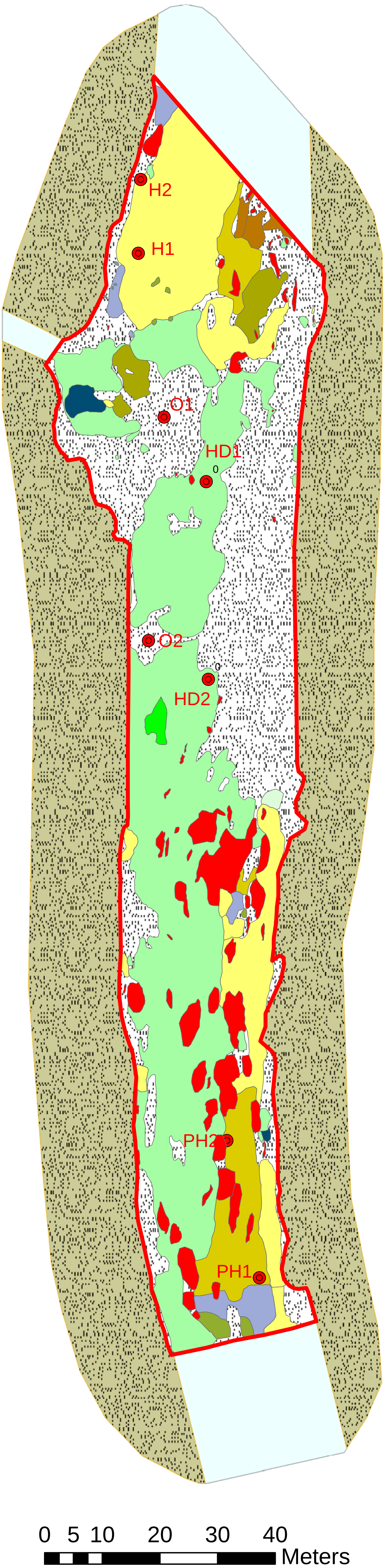
APPENDIX A:
AQUATIC VEGETATION MAPS

City Park Reach

San Marcos River Aquatic Vegetation
City Park - Spring
May 1, 2012

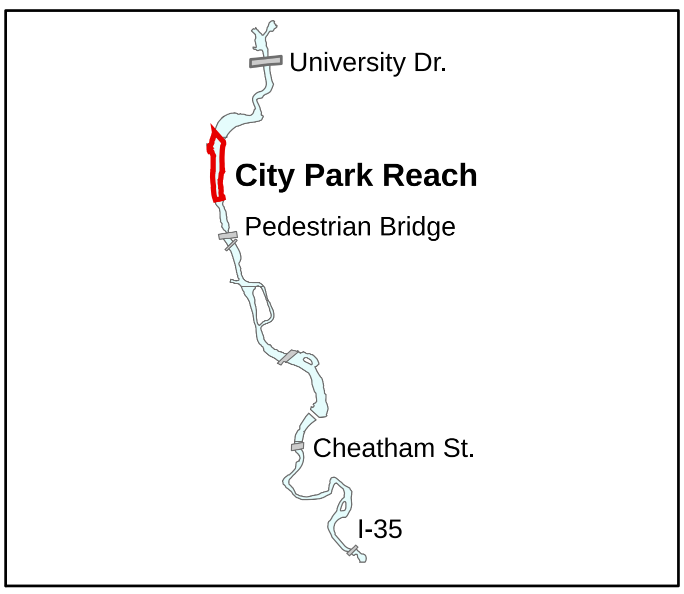


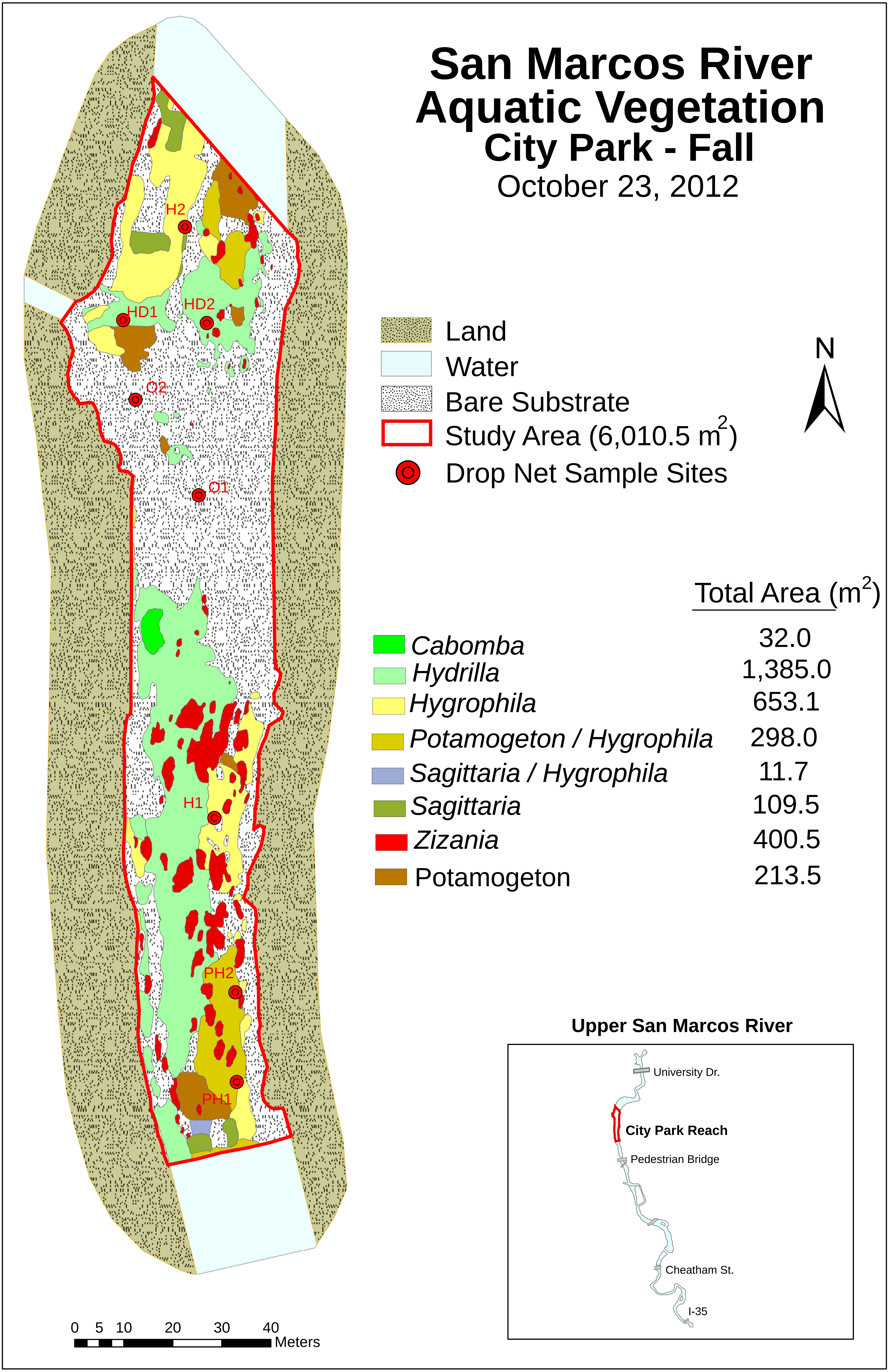
- Land
- Water
- Bare Substrate
- Study Area (6,010.5 m^2)
- Drop Net Sample Sites

N

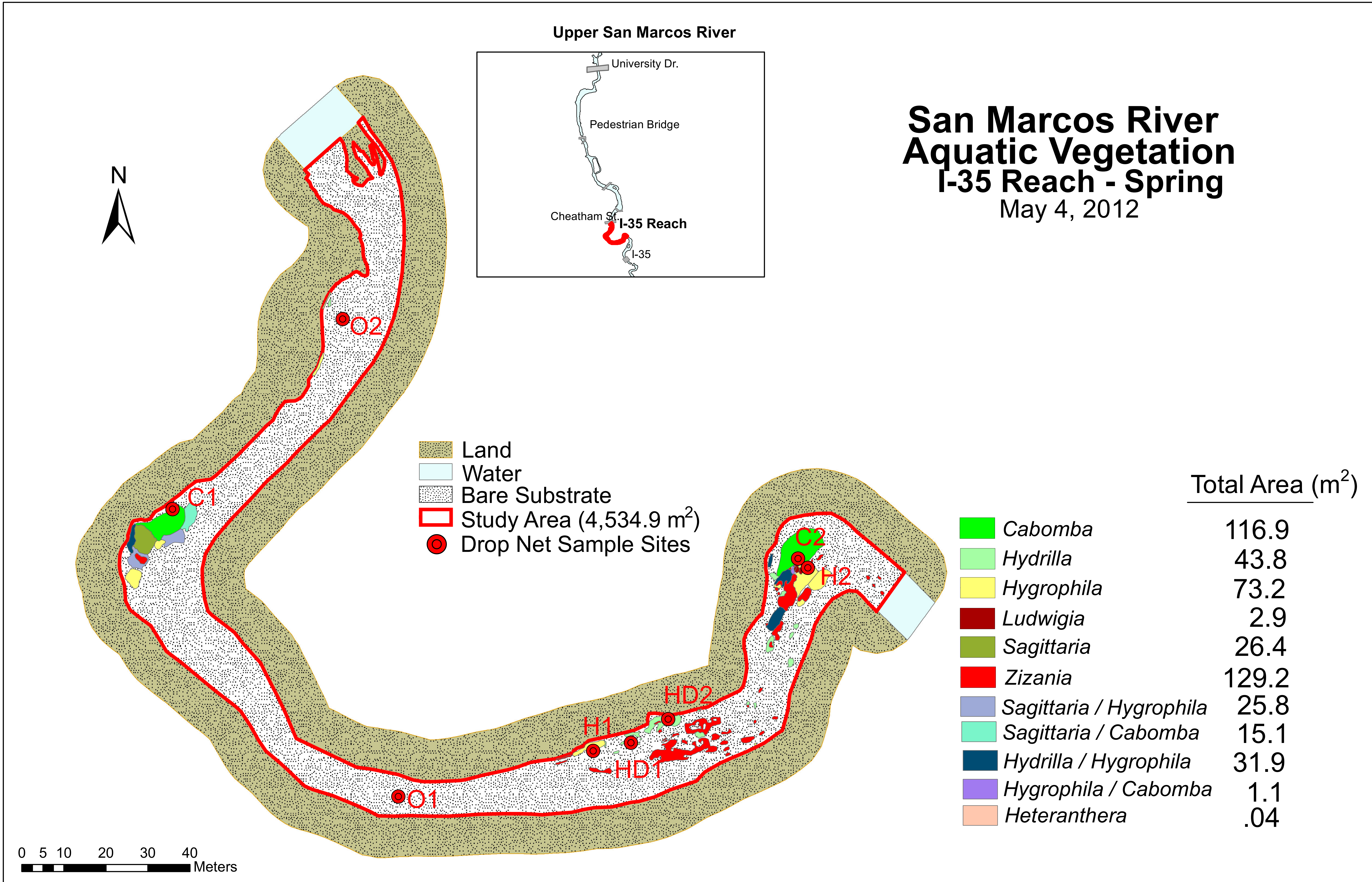
	Total Area (m^2)
Cabomba	19.6
Hydrilla	2,164.9
Hygrophila	938.9
Hydrilla/ Hygrophila	29.6
Potamogeton / Hydrilla	102.9
Potamogeton / Hygrophila	312.4
Sagittaria / Hygrophila	107.9
Sagittaria	26.9
Vallisneria	9.3
Zizania	397.5
Ceratopteris	0.7
Potamogeton	37.4

Upper San Marcos River

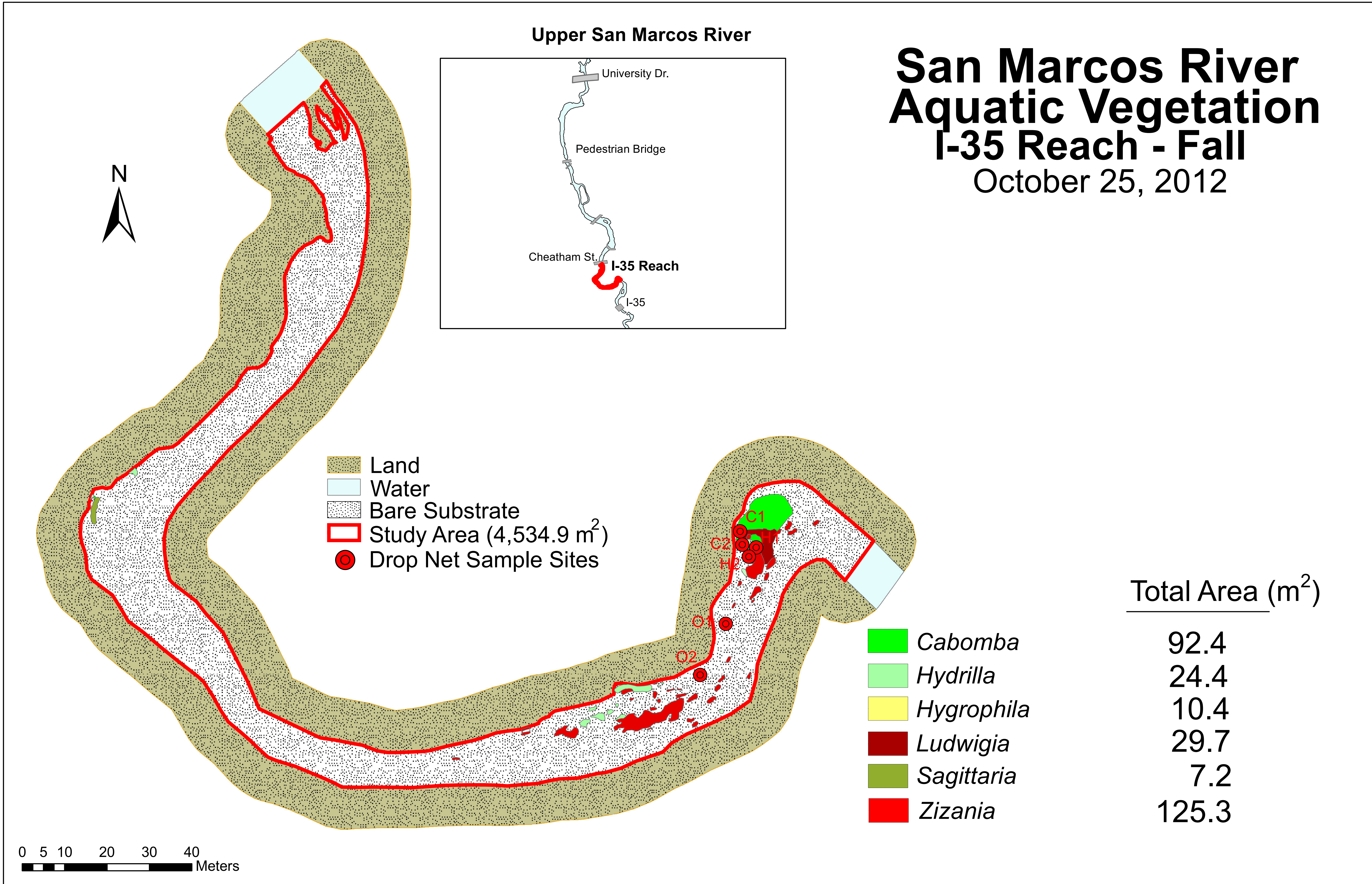



San Marcos River
Aquatic Vegetation
City Park - Fall
October 23, 2012
Land
Water
Bare Substrate
Study Area (6,010.5 m2)
Drop Net Sample Sites
N
Total Area (m2)
Cabomba 32.0
Hydrilla 1,385.0
Hygrophila 653.1
Potamogeton / Hygrophila 298.0
Sagittaria / Hygrophila 11.7
Sagittaria 109.5
Zizania 400.5
Potamogeton 213.5
H2
HD1
HD2
O2
O1
H1
PH2
PH1
0 5 10 20 30 40
Meters
Upper San Marcos River
University Dr.
City Park Reach
Pedestrian Bridge
Cheatham St.
I-35

IH-35 Reach



San Marcos River
Aquatic Vegetation
I-35 Reach - Spring
May 4, 2012
Upper San Marcos River
University Dr.
Pedestrian Bridge
Cheatham St.
I-35 Reach
I-35
N
Land
Water
Bare Substrate
Study Area (4,534.9 m2)
Drop Net Sample Sites
O2
C1
C2
H2
HD2
H1
HD1
O1
Total Area (m2)
Cabomba 116.9
Hydrilla 43.8
Hygrophila 73.2
Ludwigia 2.9
Sagittaria 26.4
Zizania 129.2
Sagittaria / Hygrophila 25.8
Sagittaria / Cabomba 15.1
Hydrilla / Hygrophila 31.9
Hygrophila / Cabomba 1.1
Heteranthera .04
0 5 10 20 30 40
Meters



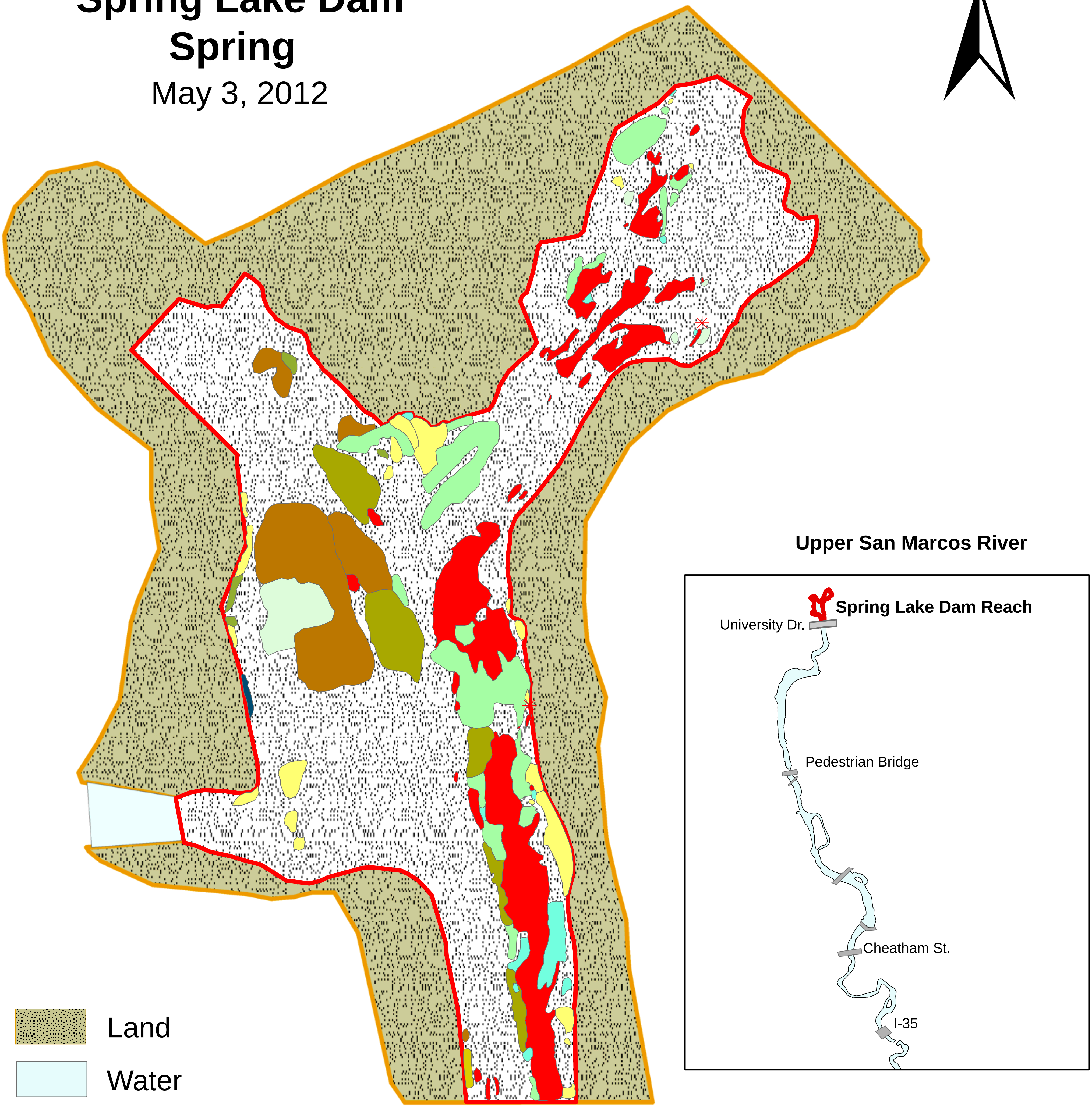
San Marcos River
Aquatic Vegetation
I-35 Reach - Fall
October 25, 2012
Upper San Marcos River
University Dr.
Pedestrian Bridge
Cheatham St.
I-35 Reach
I-35
N
Land
Water
Bare Substrate
Study Area (4,534.9 m2)
Drop Net Sample Sites
C1
C2
H1
H2
O1
O2
Total Area (m2)
Cabomba 92.4
Hydrilla 24.4
Hygrophila 10.4
Ludwigia 29.7
Sagittaria 7.2
Zizania 125.3
0 5 10 20 30 40
Meters

Spring Lake Dam Reach

San Marcos River Aquatic Vegetation
Spring Lake Dam Spring

May 3, 2012

N

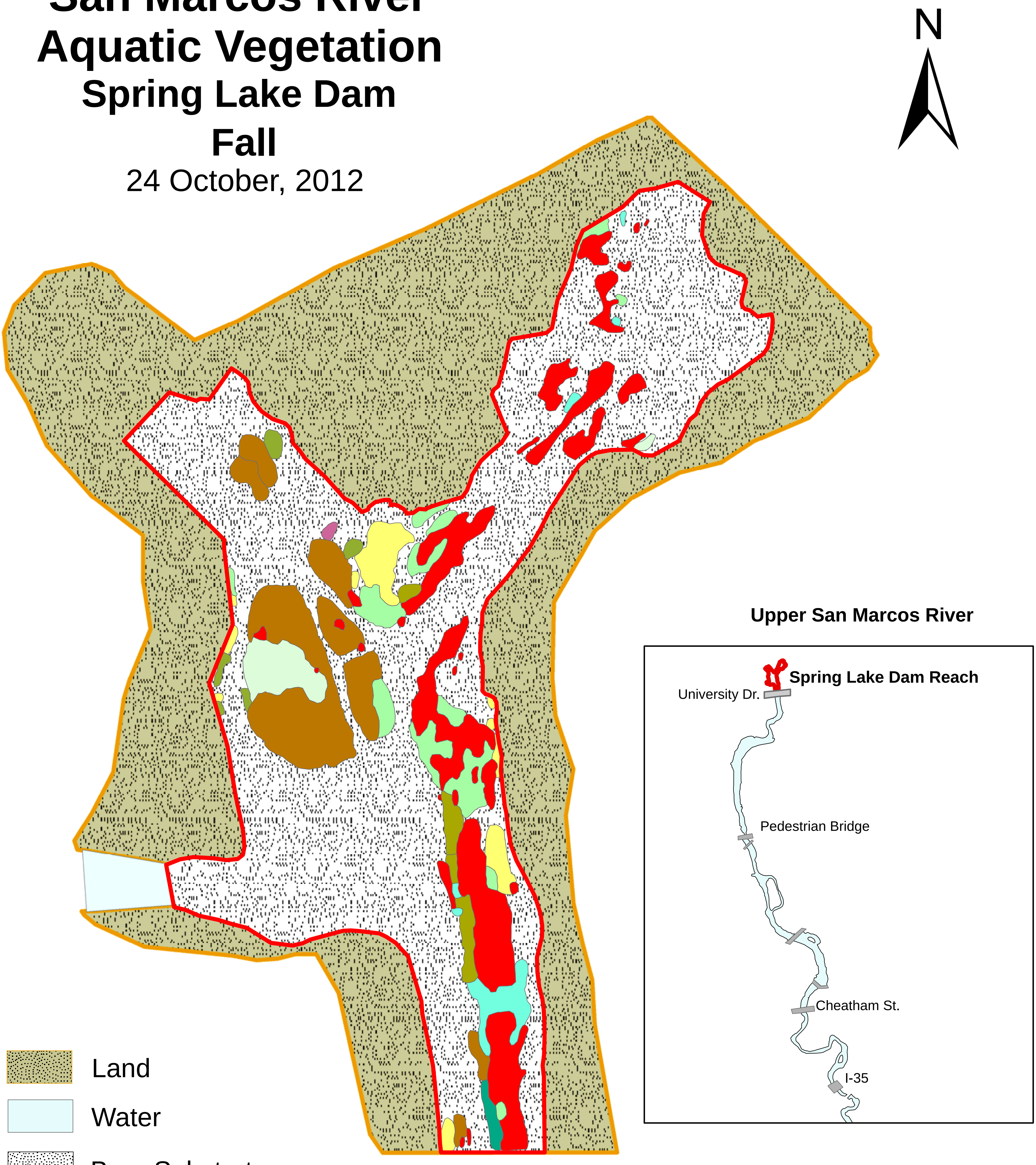


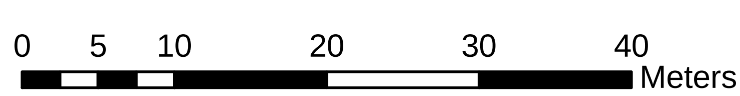
0 5 10 20 30 40 Meters

- Land
- Water
- Bare Substrate
- Study Area (3,250.2 m^2)
- ✳ Small *Zizania* Plants

	Total Area (m^2)		Total Area (m^2)
Hydrilla	221.8	*Zizania*	427.6
Hydrocotyle	33.5	*Vallisneria*	59.4
Hygrophila	96.2	*Potamogeton / Hydrilla*	129.2
Potamogeton	228.2	*Potamogeton / Hygrophila*	4.3
Sagittaria	9.1	*Hydrilla / Hygrophila*	30.4

San Marcos River Aquatic Vegetation
Spring Lake Dam
Fall
24 October, 2012





- Land
- Water
- Bare Substrate
- Study Area (3,250.2 m^2)
- Small *Zizania* Plants

	Total Area (m^2)
Hydrilla	122.8
Hydrocotyle	50.3
Hygrophila	83.3
Potamogeton	300.8
Sagittaria	19.2

	Total Area (m^2)
Zizania	397.2
Vallisneria	61.8
Potamogeton / Hydrilla	41.4
Potamogeton / Hydrocotyle	11.5
Ceratophyllum	3.1

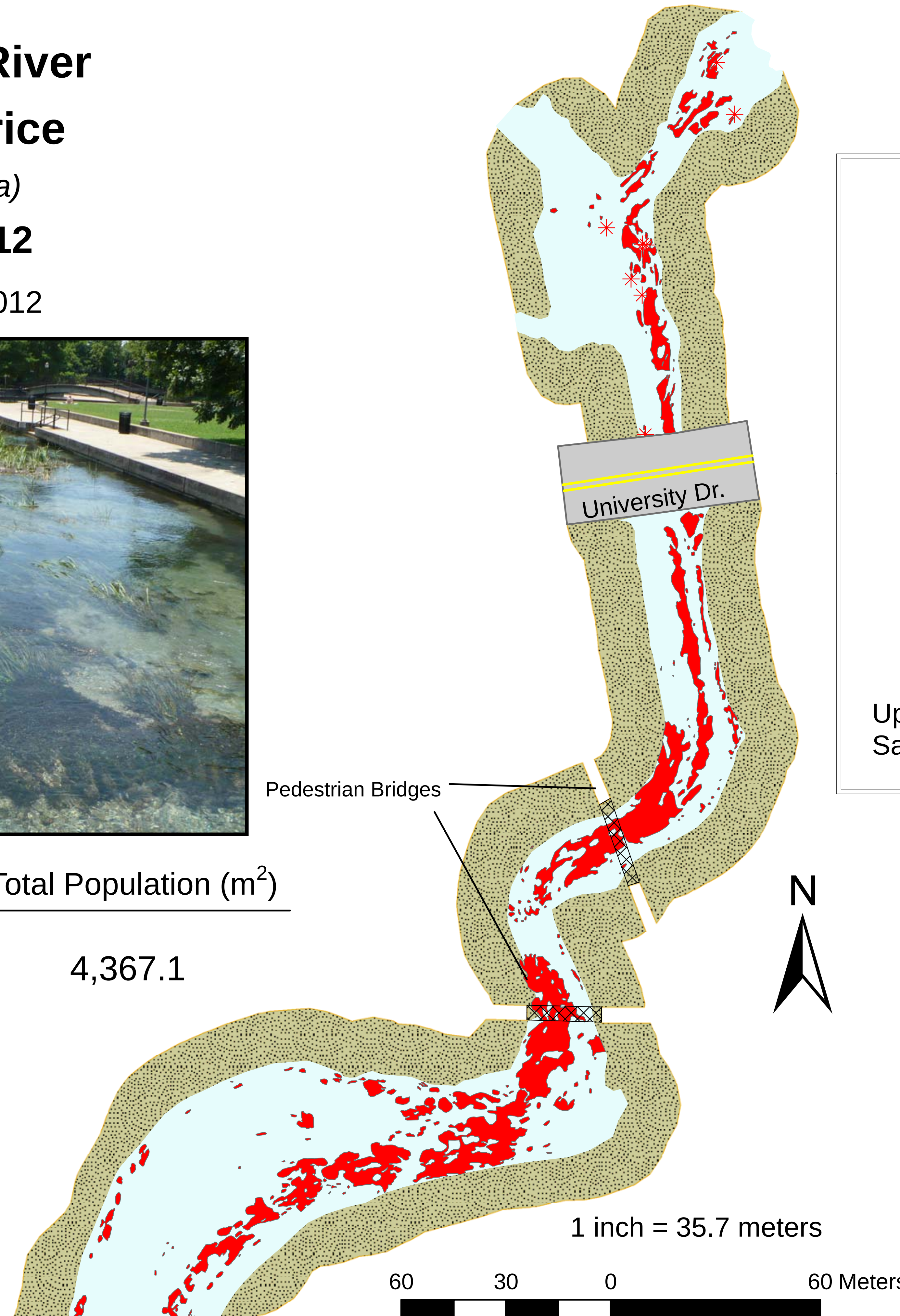
Texas Wild-Rice

San Marcos River
Texas wild-rice
(Zizania texana)

Summer 2012

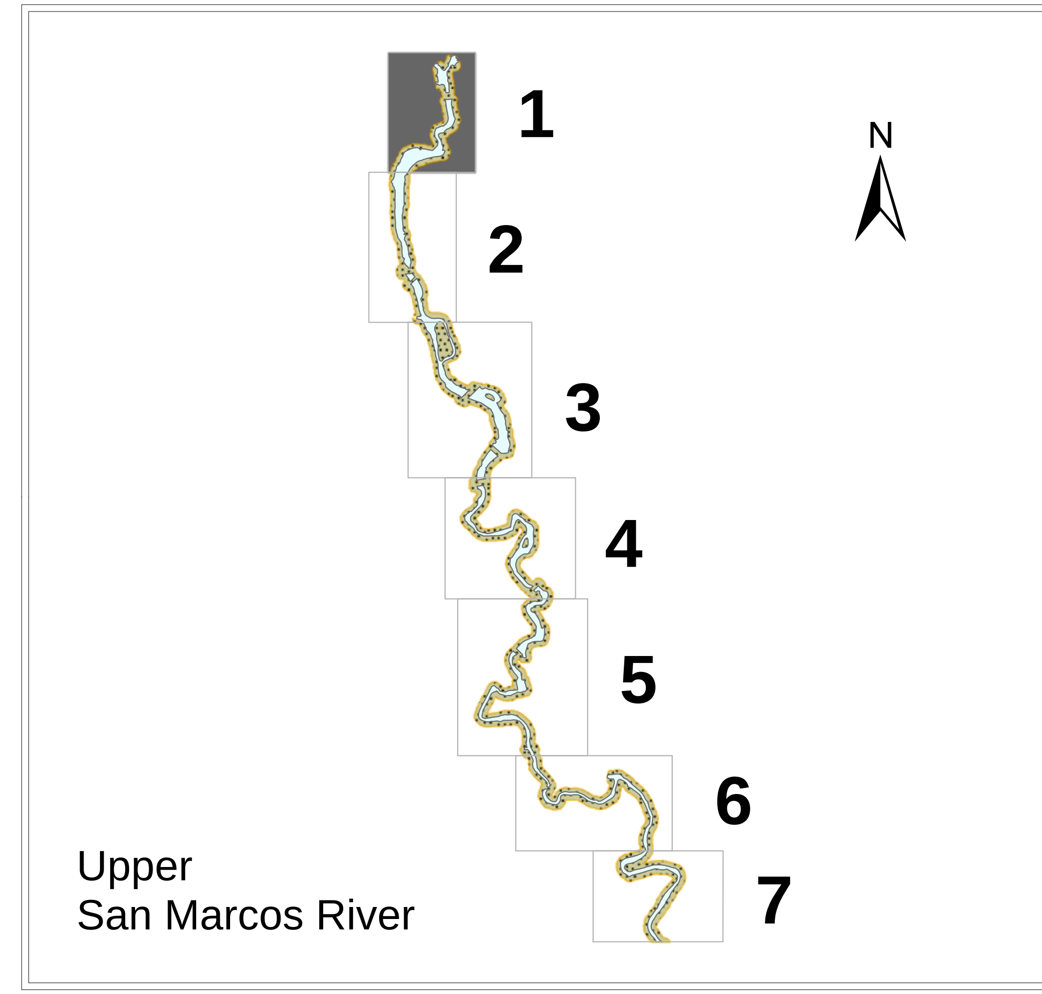
August 3 - 10, 2012

	Map 1 (m^2)	Total Population (m^2)
Zizania	2,604.9	4,367.1
Small *Zizania* Plants		



1 inch = 35.7 meters

Project Location



BIO-WEST, Inc.

EDWARDS AQUIFER AUTHORITY

San Marcos River
Texas wild-rice

(Zizania texana)

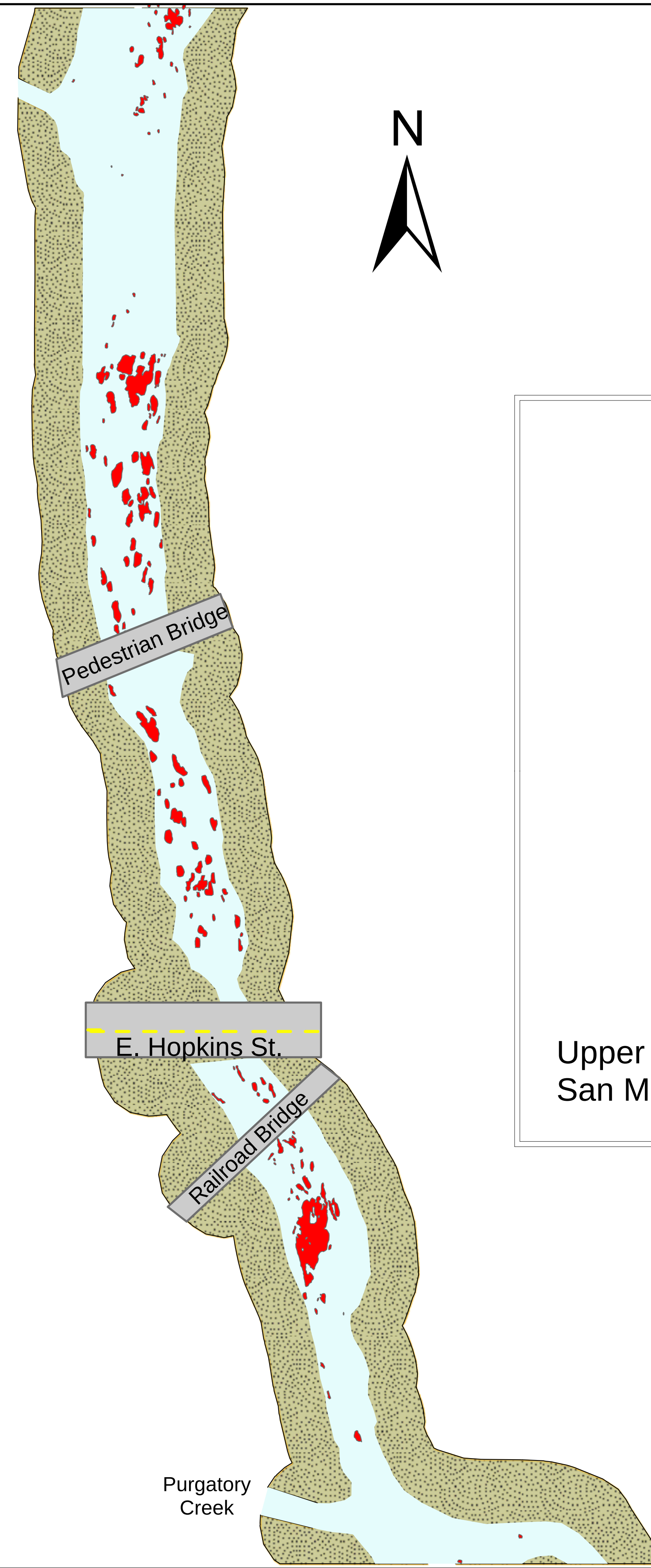
Summer 2012

August 3 - 10, 2012

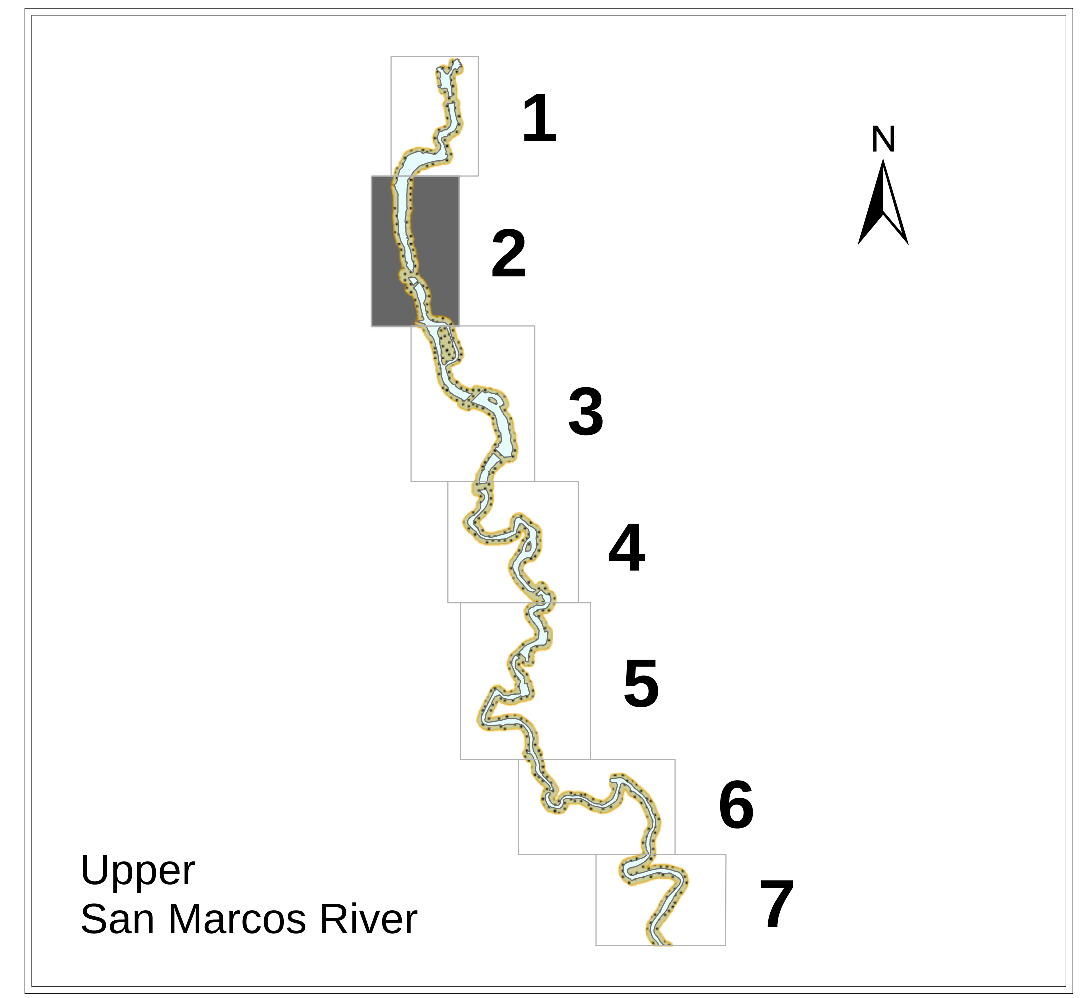
	Map 2 (m^2)	Total Population (m^2)
Zizania	843.9	4,367.1

1 inch = 45.8 meters

60 30 0 60 Meters



Project Location



BIO-WEST, Inc.

EDWARDS AQUIFER AUTHORITY

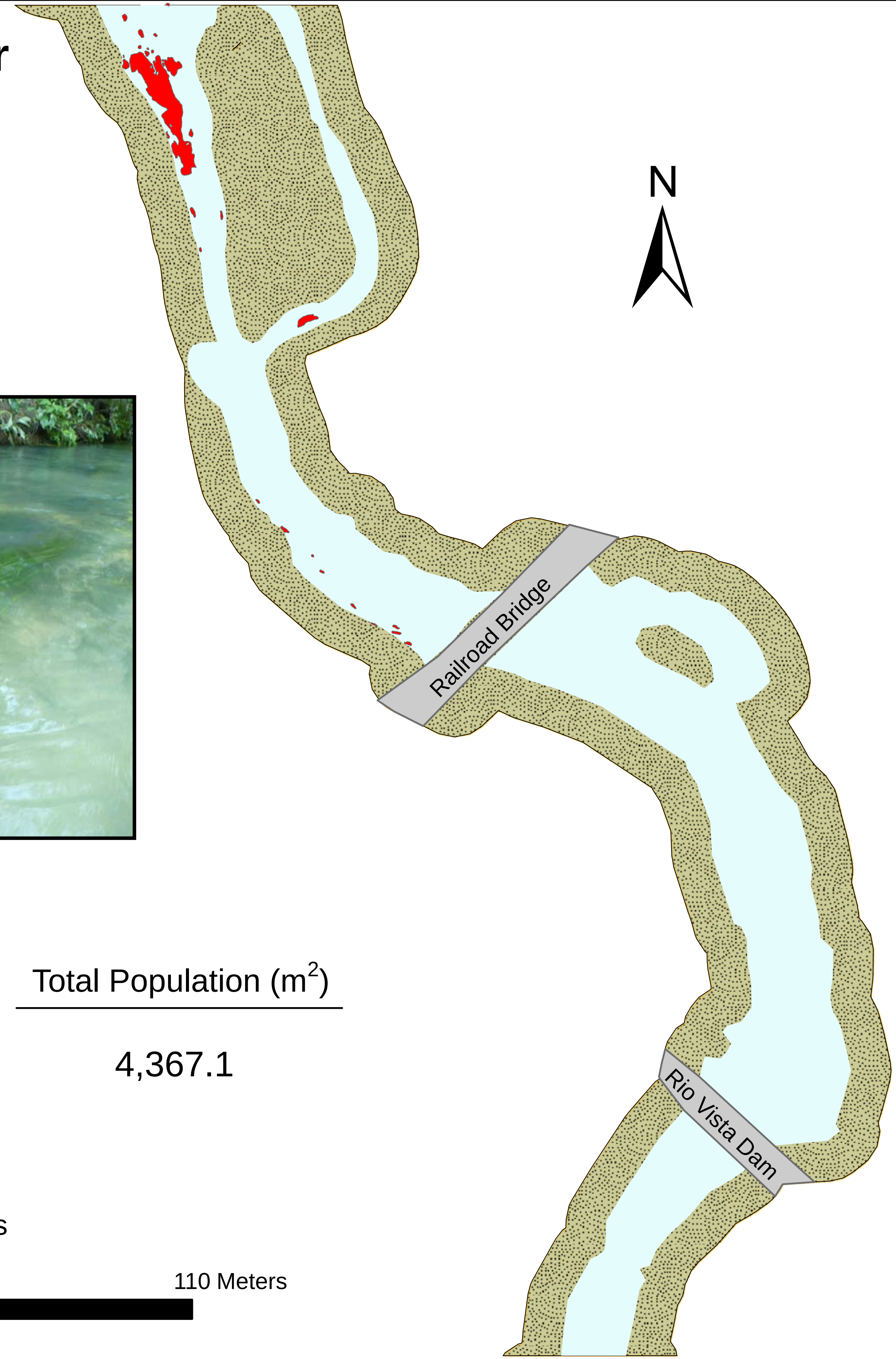
San Marcos River

Texas wild-rice

(Zizania texana)

Summer 2012

August 3 - 10, 2012

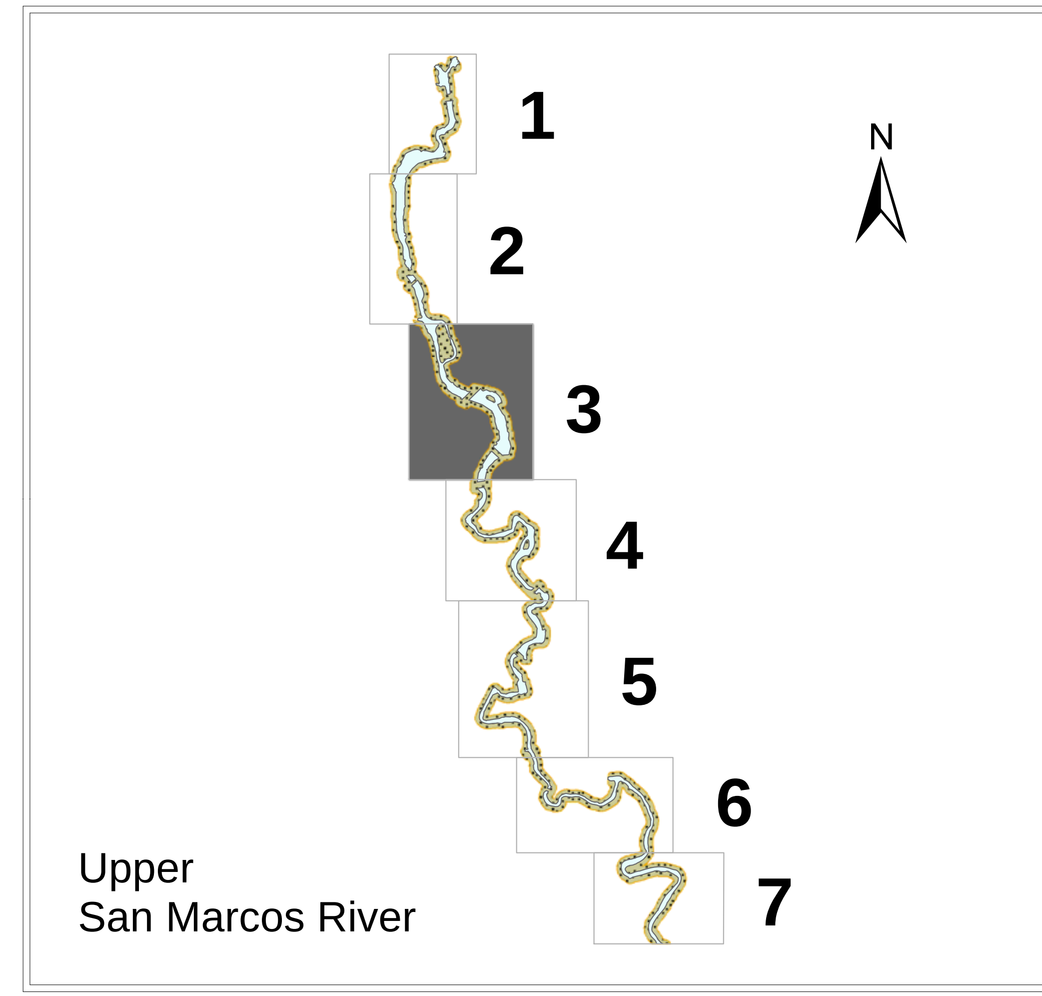


	Map 3 (m^2)	Total Population (m^2)
Zizania	412.5	4,367.1

1 inch = 48 meters

110 55 0 110 Meters

Project Location

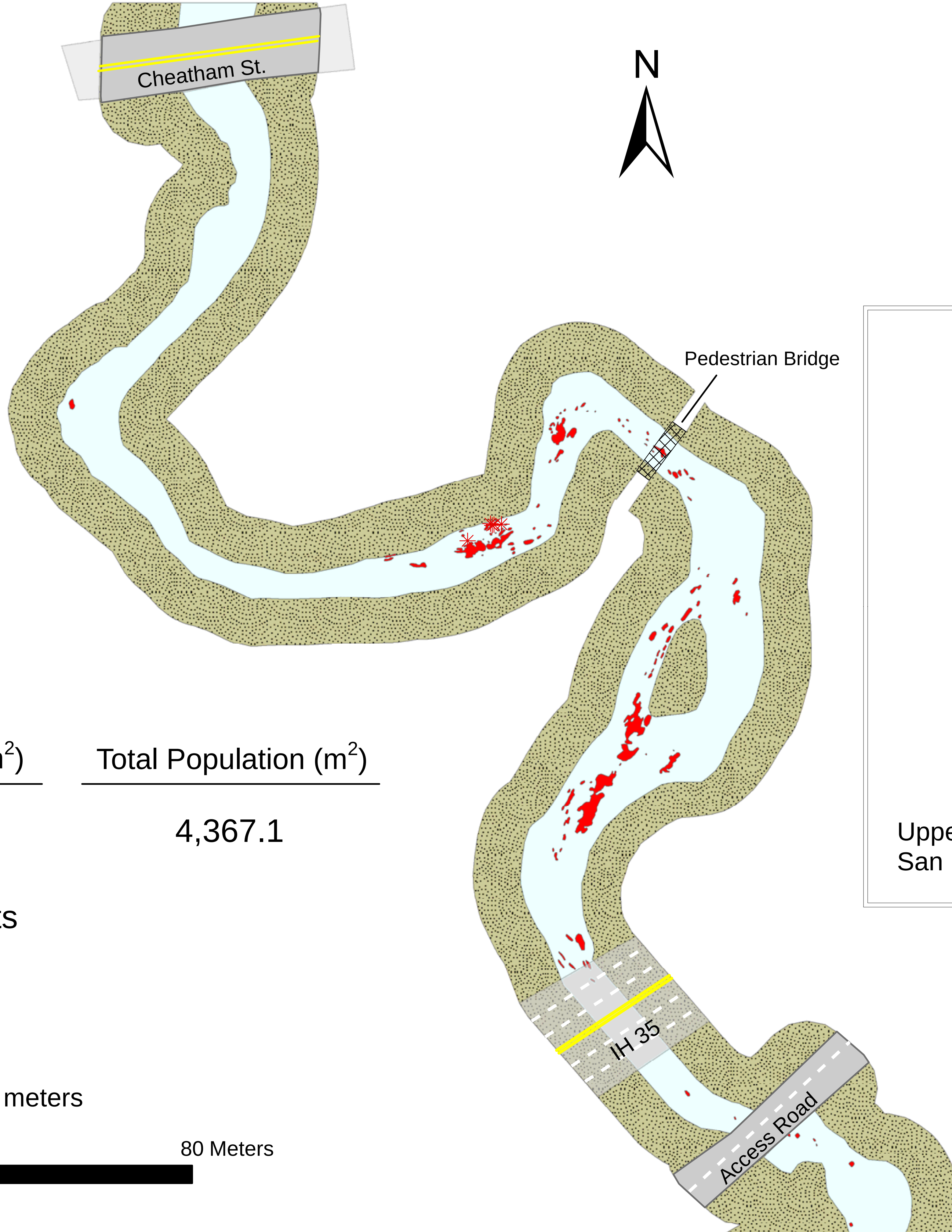


BIO-WEST, Inc.

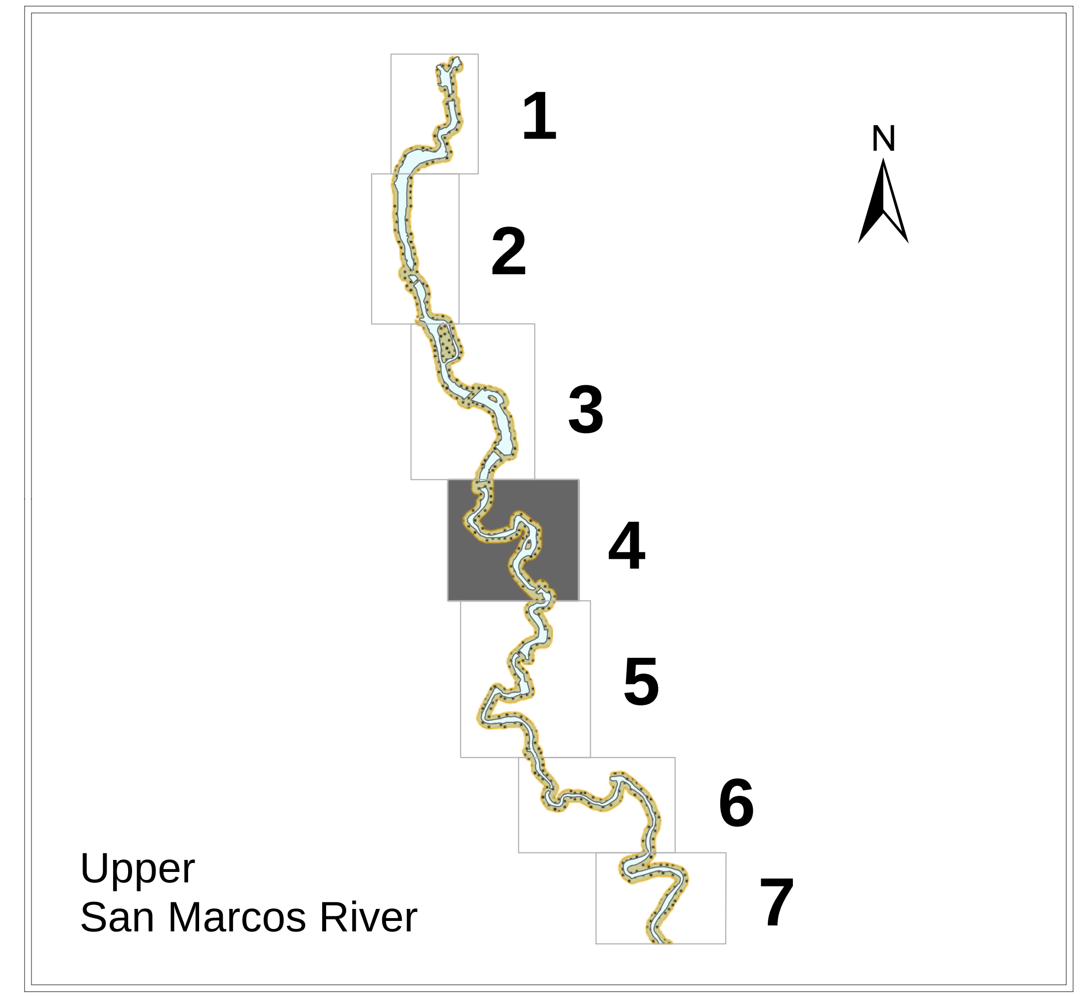
EDWARDS AQUIFER AUTHORITY

San Marcos River
Texas wild-rice
(Zizania texana)

Summer 2012
August 3 - 10, 2012



Project Location



		Map 4 (m^2)	Total Population (m^2)
■	*Zizania*	386.4	4,367.1
✳	Small *Zizania* Plants		

1 inch = 37.2 meters

80 40 0 80 Meters

BIO-WEST, Inc.

EDWARDS AQUIFER AUTHORITY

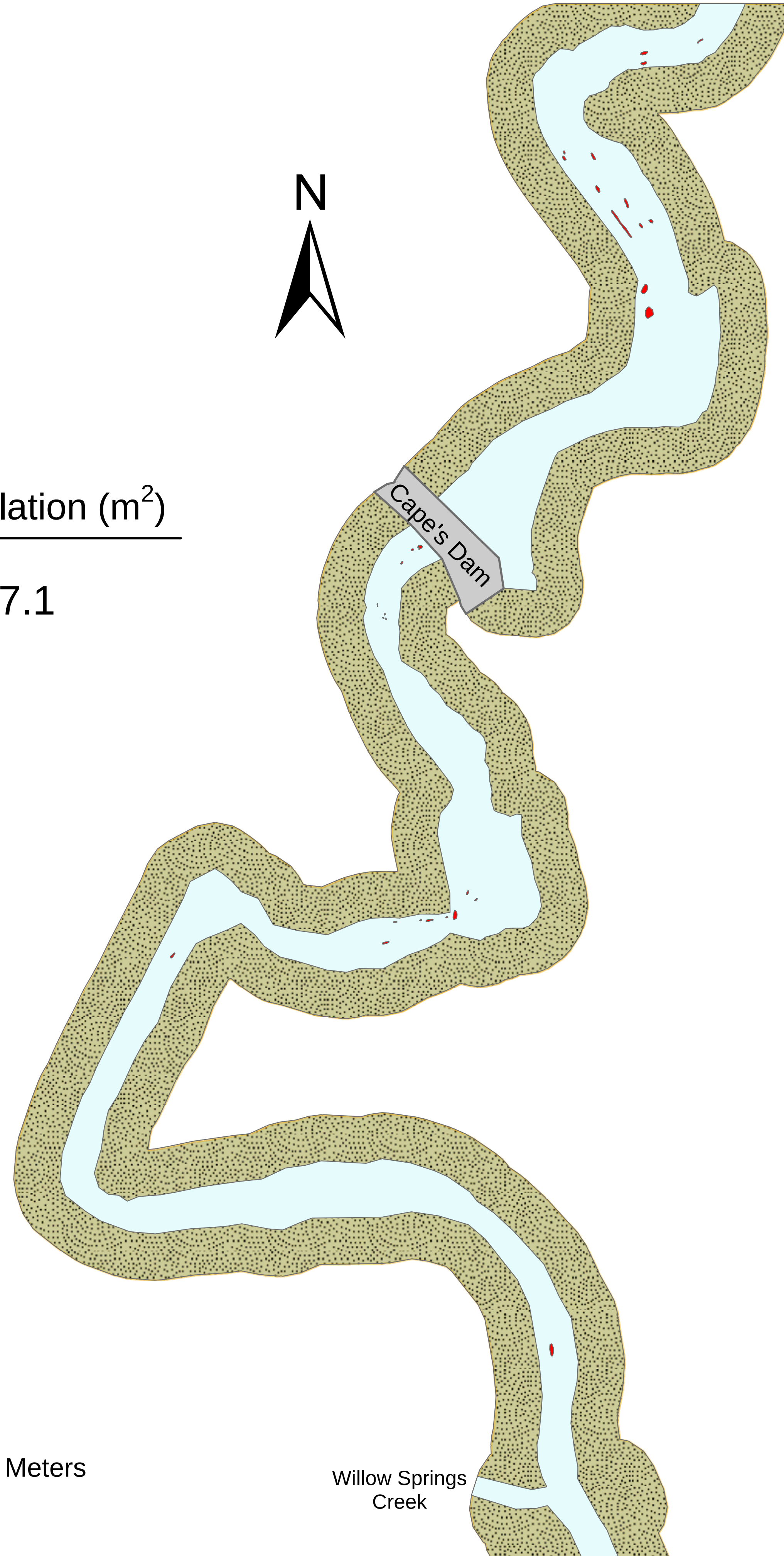
San Marcos River
Texas wild-rice

(Zizania texana)

Summer 2012

August 3 - 10, 2012

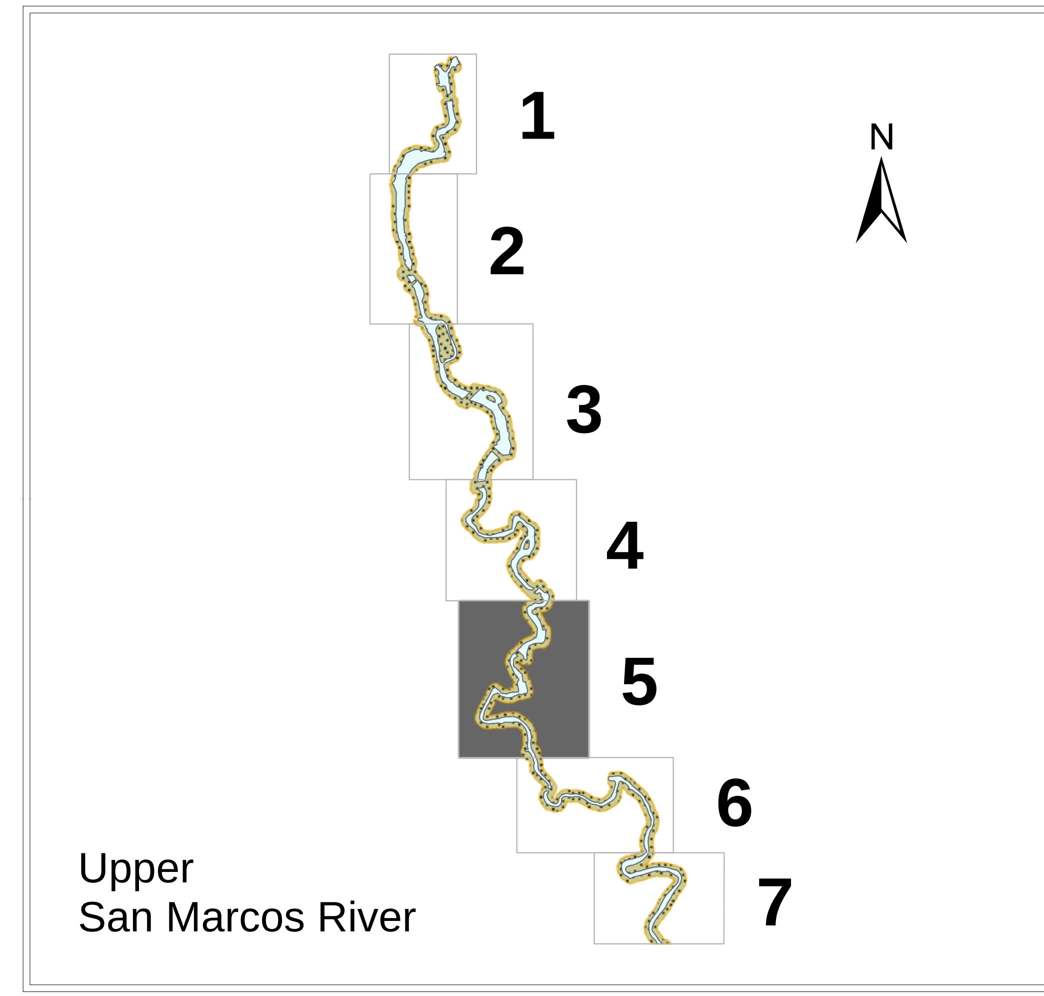
	Map 5 (m^2)	Total Population (m^2)
Zizania	43.3	4,367.1



1 inch = 48.1 meters

120 60 0 120 Meters

Project Location



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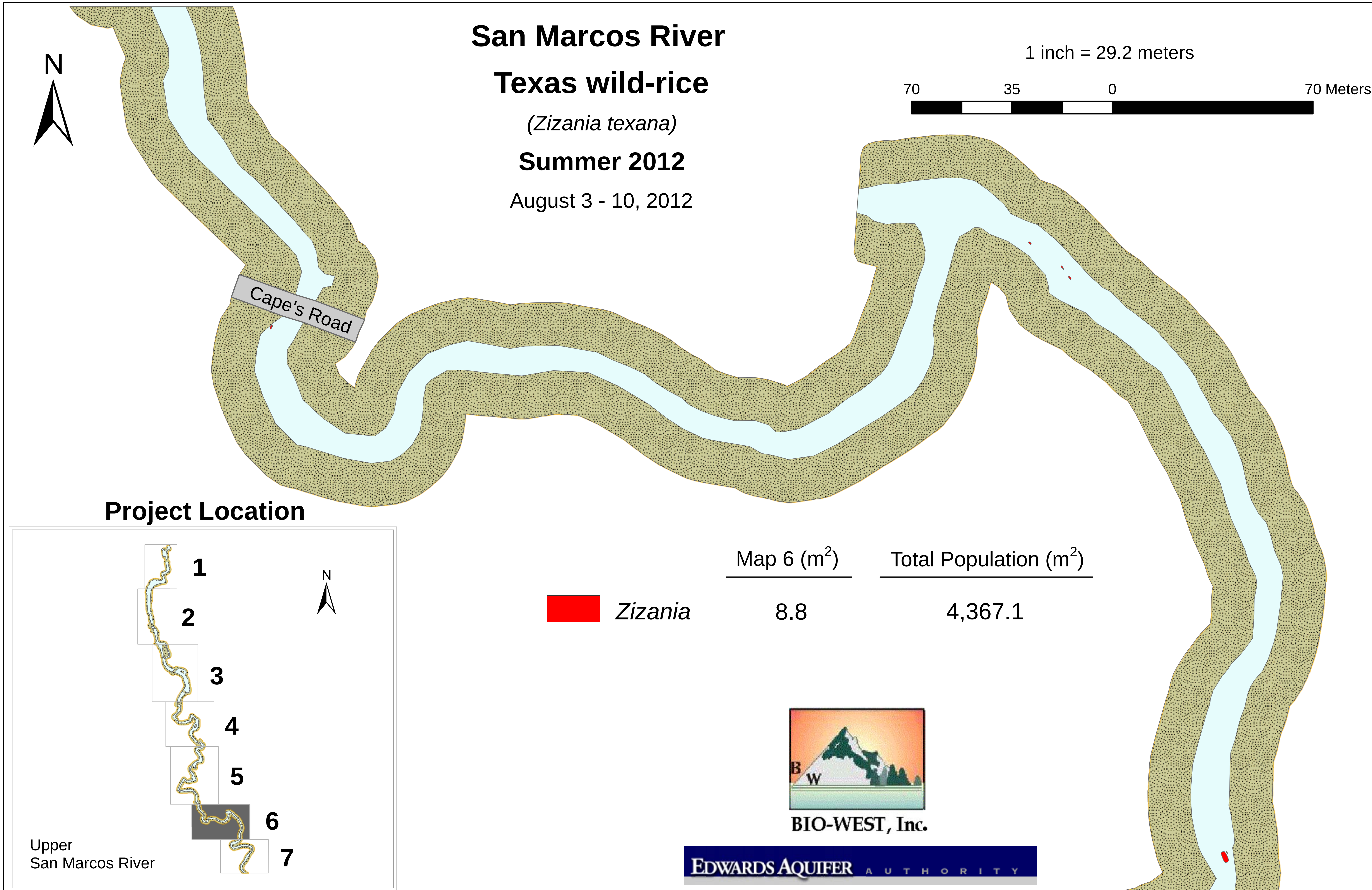

San Marcos River
Texas wild-rice
(Zizania texana)
Summer 2012
August 3 - 10, 2012
1 inch = 29.2 meters
70
35
0
70 Meters
N
Cape's Road
Project Location
1
2
3
4
5
6
7
N
Upper
San Marcos River
Map 6 (m2)
Total Population (m2)
Zizania
8.8
4,367.1
BIO-WEST, Inc.
EDWARDS AQUIFER AUTHORITY

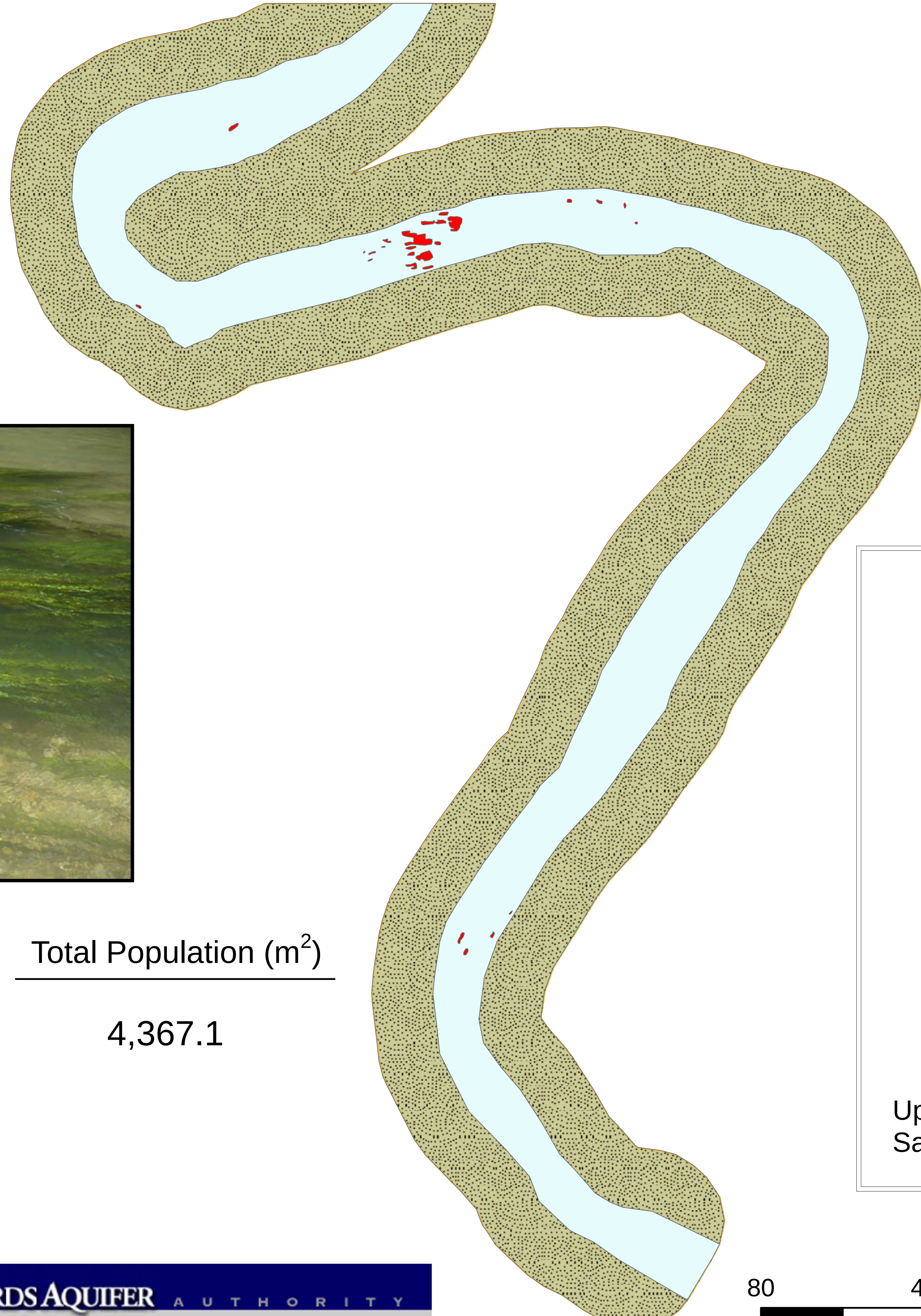
San Marcos River

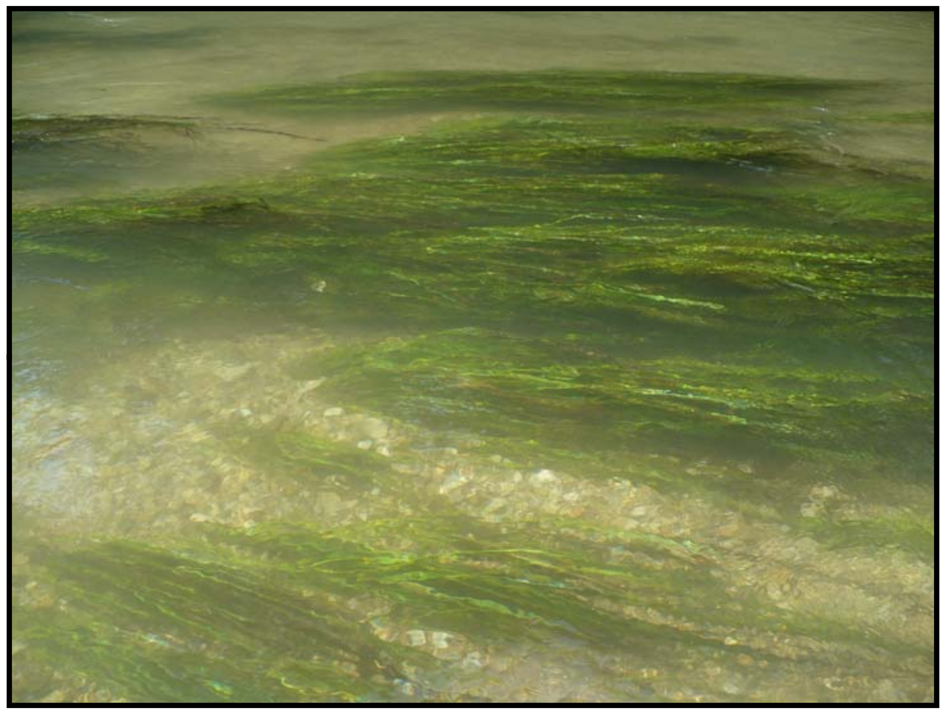
Texas wild-rice

(Zizania texana)

Summer 2012

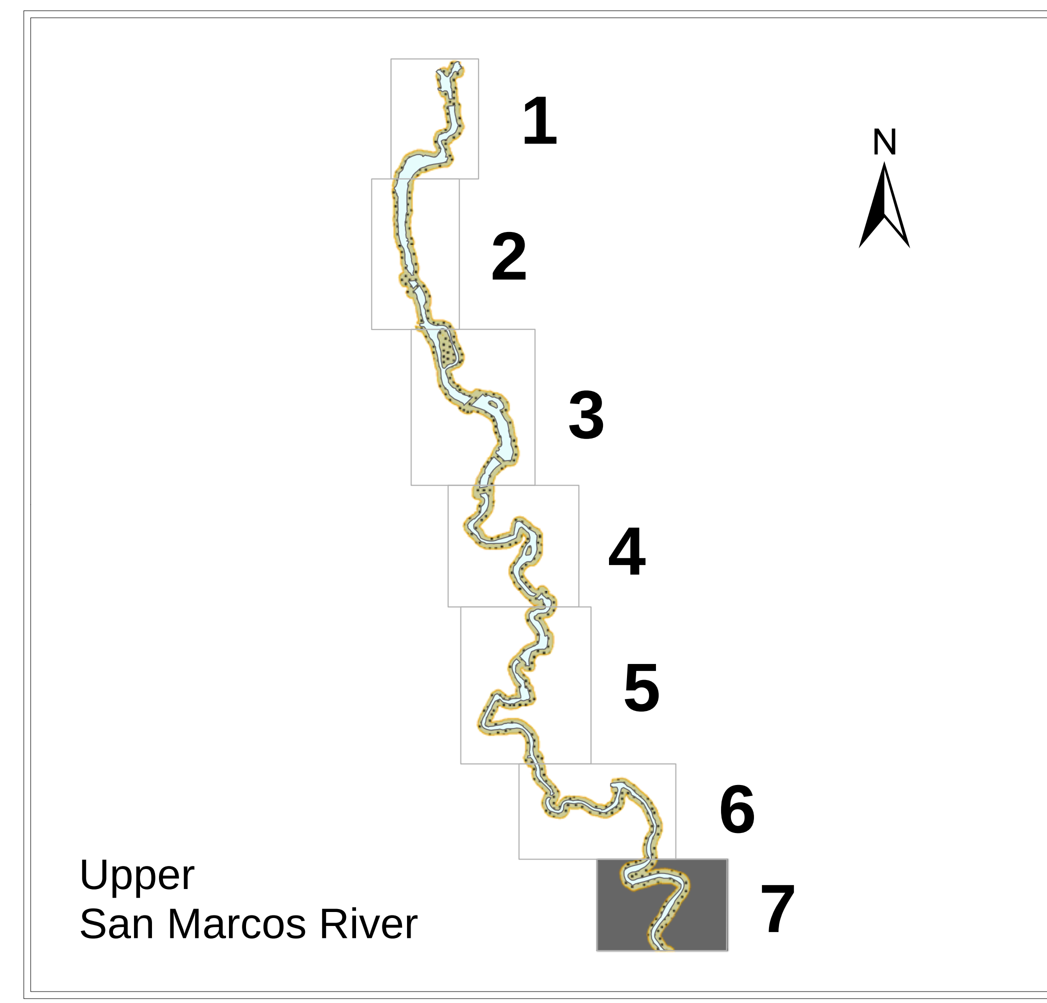
August 3 - 10, 2012





	Map 7 (m^2)	Total Population (m^2)
Zizania	52.4	4,367.1

Project Location



N

1 inch = 30.6 meters

80 40 0 80 Meters

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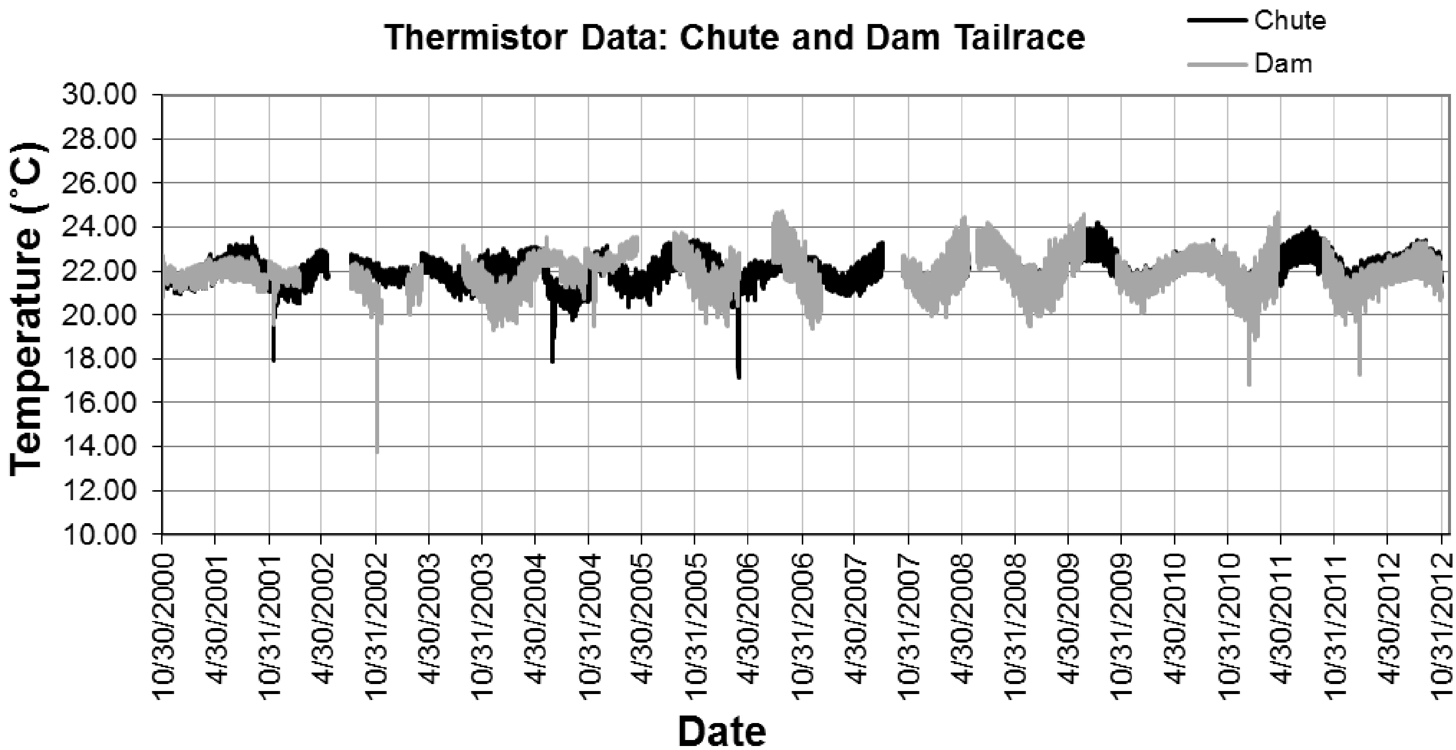
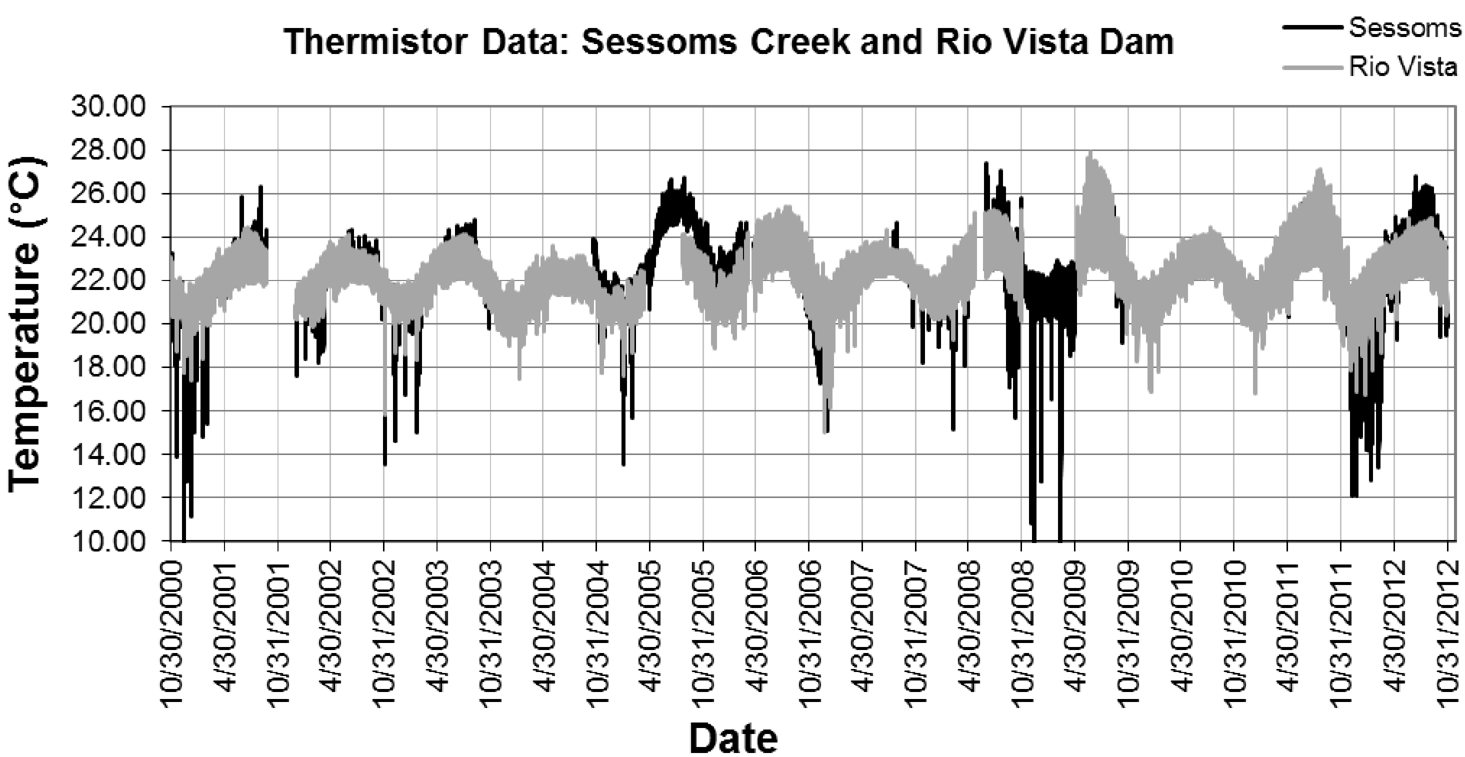
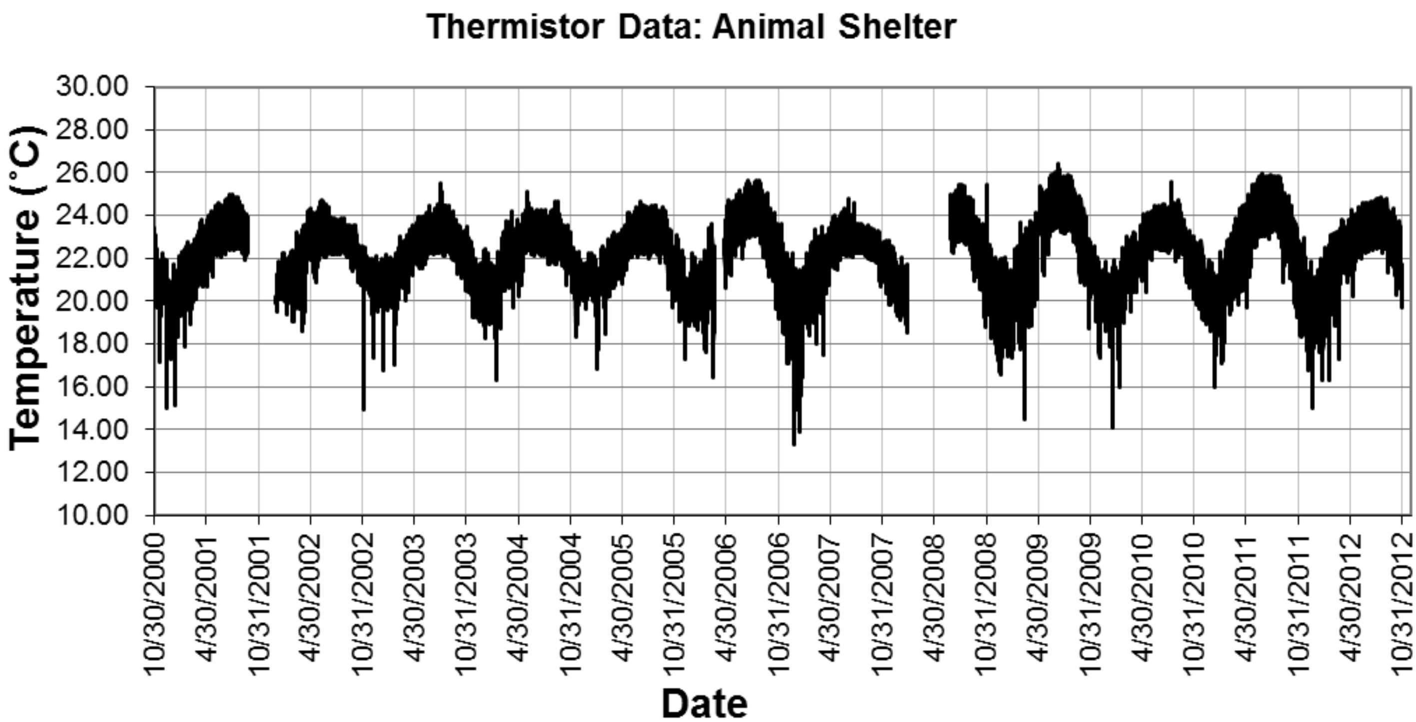
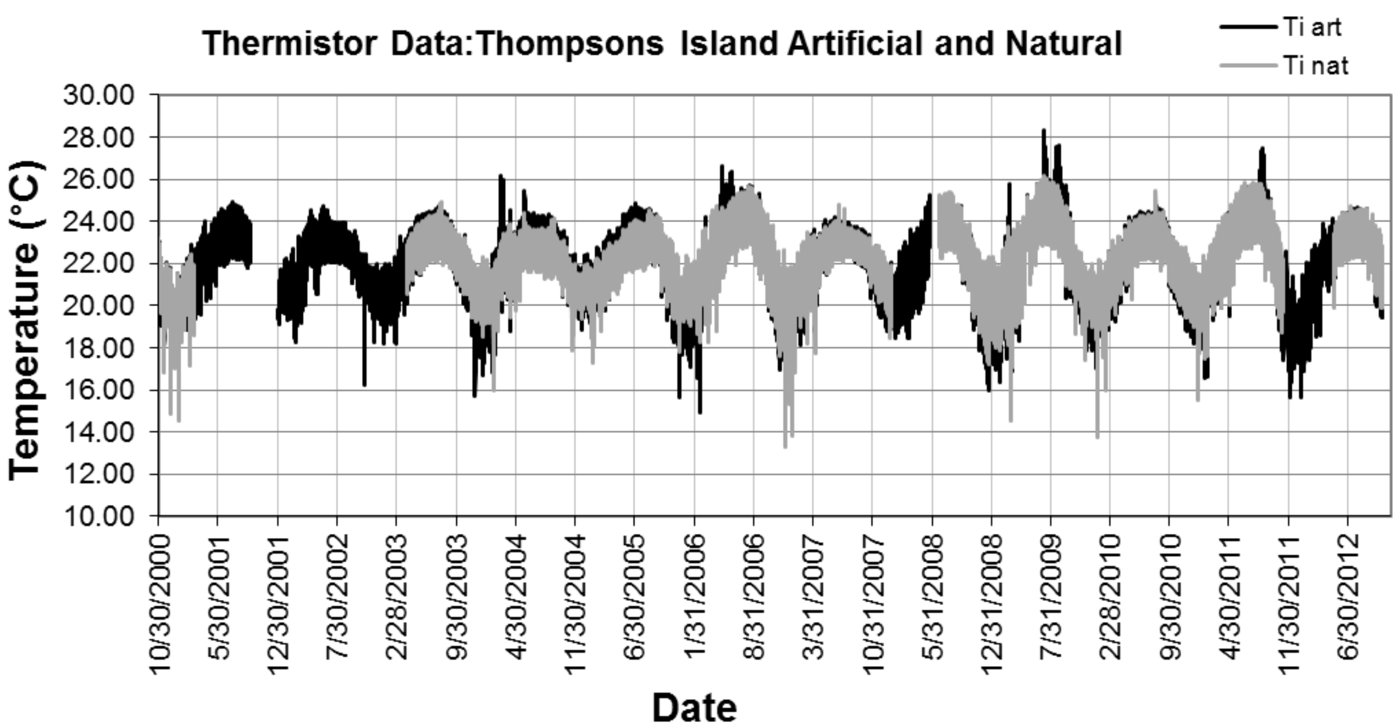
Appendix B:
Data and Graphs

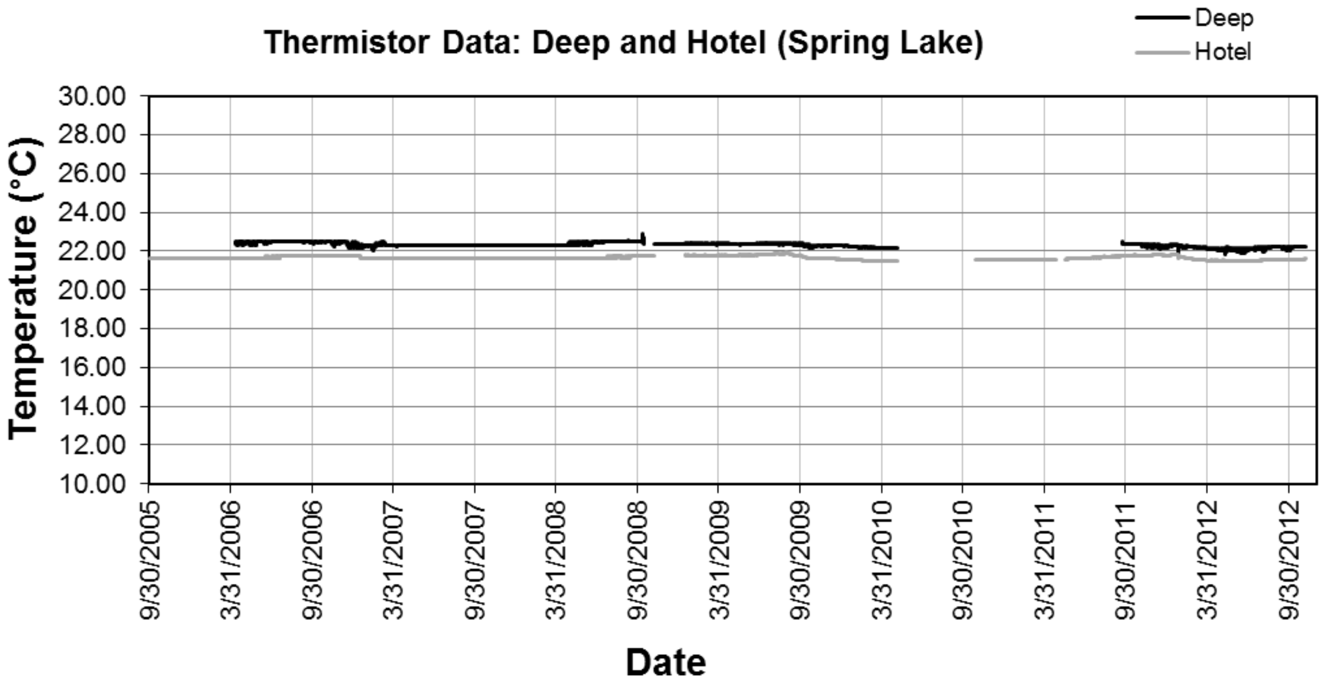
Water Quality
And
Thermistor Graphs


Thermistor Data: Chute and Dam Tailrace
Chute
Dam
Temperature (˚C)
30.00
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
10/30/2000
4/30/2001
10/31/2001
4/30/2002
10/31/2002
4/30/2003
10/31/2003
4/30/2004
10/31/2004
4/30/2005
10/31/2005
4/30/2006
10/31/2006
4/30/2007
10/31/2007
4/30/2008
10/31/2008
4/30/2009
10/31/2009
4/30/2010
10/31/2010
4/30/2011
10/31/2011
4/30/2012
10/31/2012
Date


Thermistor Data: Sessoms Creek and Rio Vista Dam
Sessoms
Rio Vista
Temperature (°C)
30.00
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
10/30/2000
4/30/2001
10/31/2001
4/30/2002
10/31/2002
4/30/2003
10/31/2003
4/30/2004
10/31/2004
4/30/2005
10/31/2005
4/30/2006
10/31/2006
4/30/2007
10/31/2007
4/30/2008
10/31/2008
4/30/2009
10/31/2009
4/30/2010
10/31/2010
4/30/2011
10/31/2011
4/30/2012
10/31/2012
Date

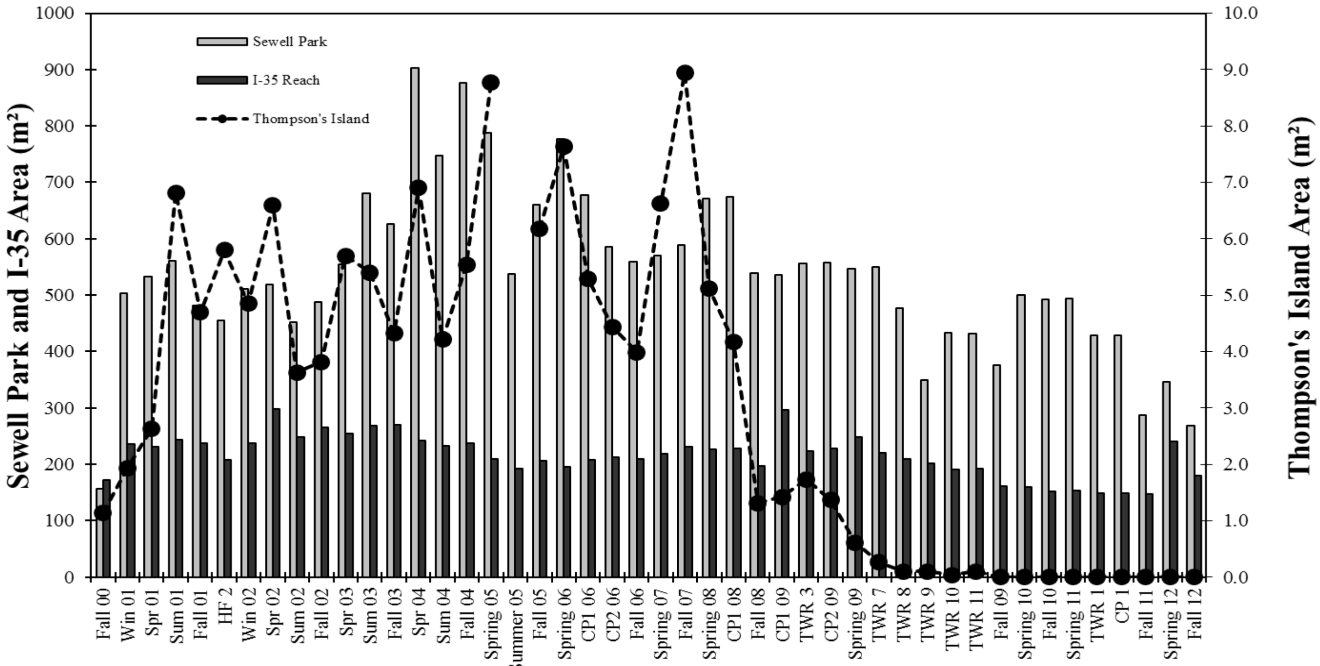

Thermistor Data: Animal Shelter
Temperature (°C)
30.00
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
10/30/2000
4/30/2001
10/31/2001
4/30/2002
10/31/2002
4/30/2003
10/31/2003
4/30/2004
10/31/2004
4/30/2005
10/31/2005
4/30/2006
10/31/2006
4/30/2007
10/31/2007
4/30/2008
10/31/2008
4/30/2009
10/31/2009
4/30/2010
10/31/2010
4/30/2011
10/31/2011
4/30/2012
10/31/2012
Date


Thermistor Data:Thompsons Island Artificial and Natural
Ti art
Ti nat
Temperature (°C)
30.00
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
10/30/2000
5/30/2001
12/30/2001
7/30/2002
2/28/2003
9/30/2003
4/30/2004
11/30/2004
6/30/2005
1/31/2006
8/31/2006
3/31/2007
10/31/2007
5/31/2008
12/31/2008
7/31/2009
2/28/2010
9/30/2010
4/30/2011
11/30/2011
6/30/2012
Date

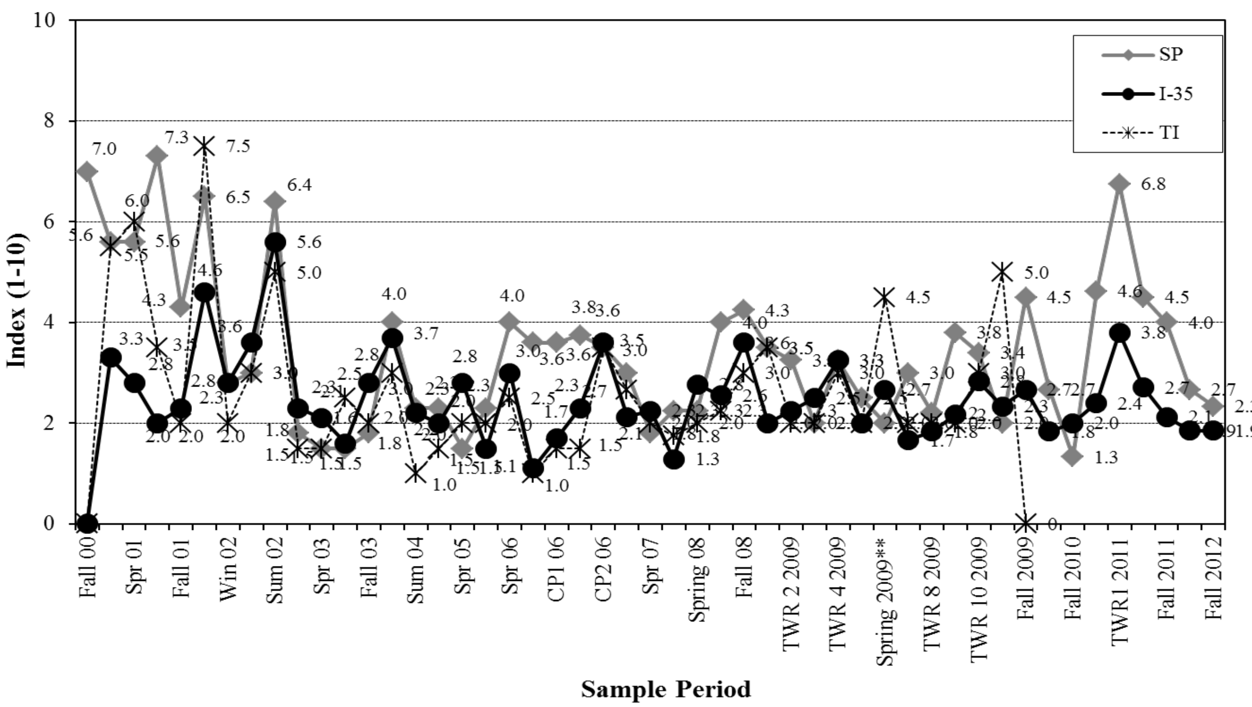

Thermistor Data: Deep and Hotel (Spring Lake)
Deep
Hotel
Temperature (°C)
30.00
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
9/30/2005
3/31/2006
9/30/2006
3/31/2007
9/30/2007
3/31/2008
9/30/2008
3/31/2009
9/30/2009
3/31/2010
9/30/2010
3/31/2011
9/30/2011
3/31/2012
9/30/2012
Date

Texas Wild-Rice Observation Data

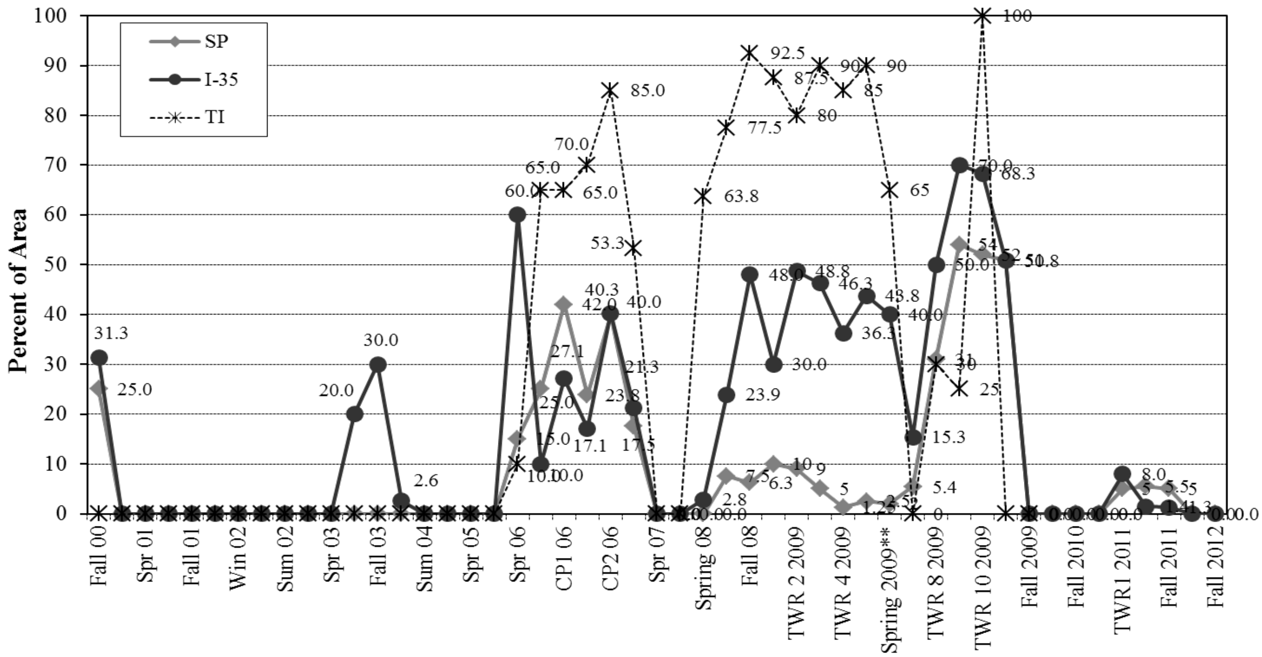
TWR Area by Season



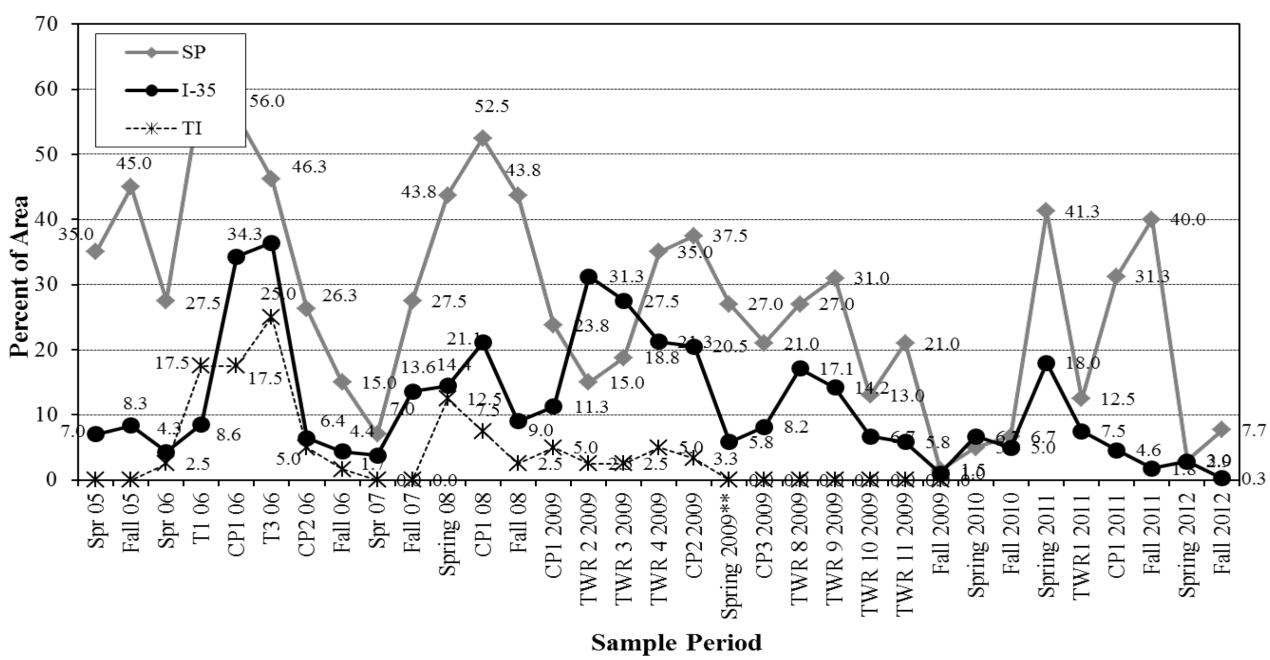
Index of Root Exposure for TWR Stands



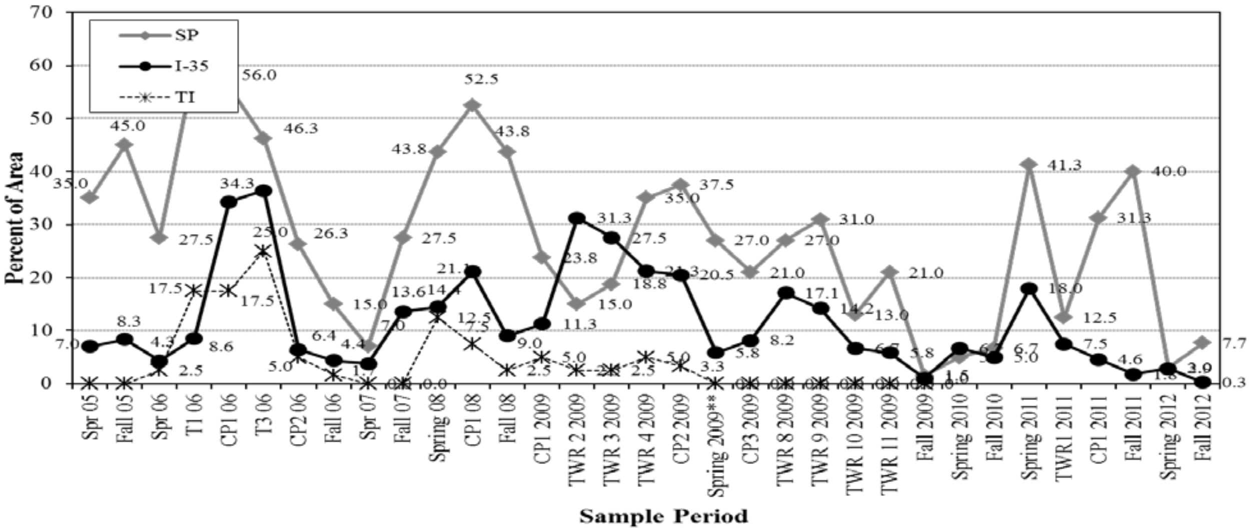
Percent of TWR Stands < 0.5 Feet



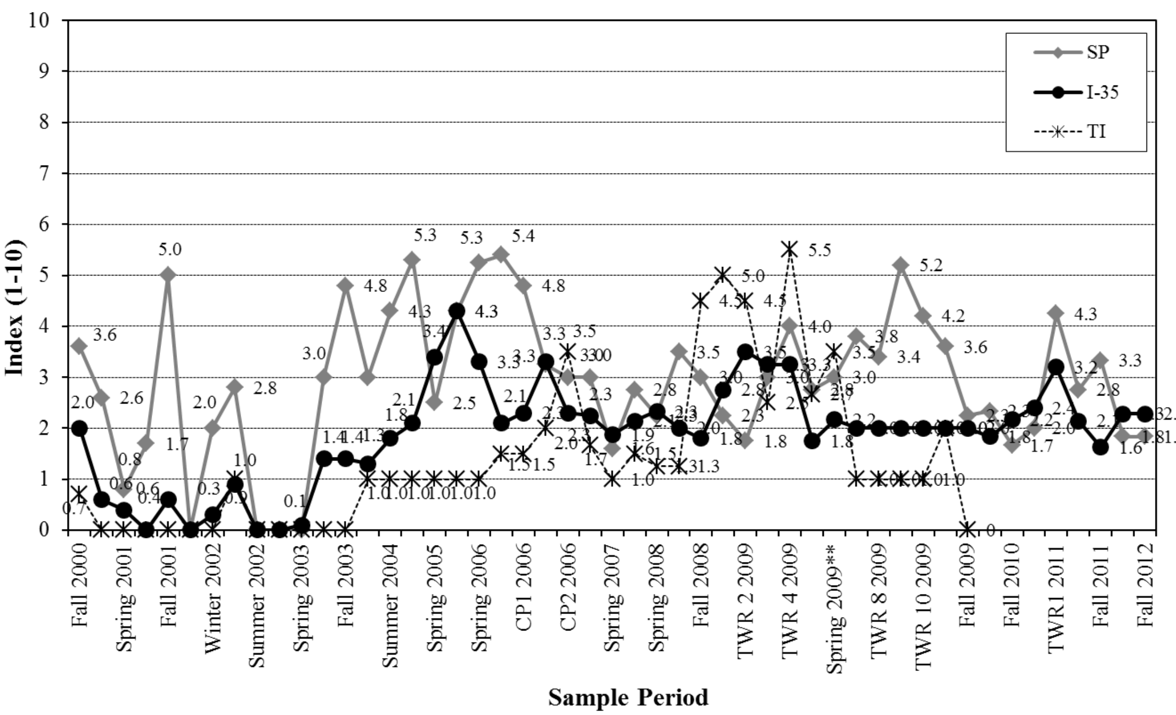
Percent of TWR Covered by Vegetation Mats



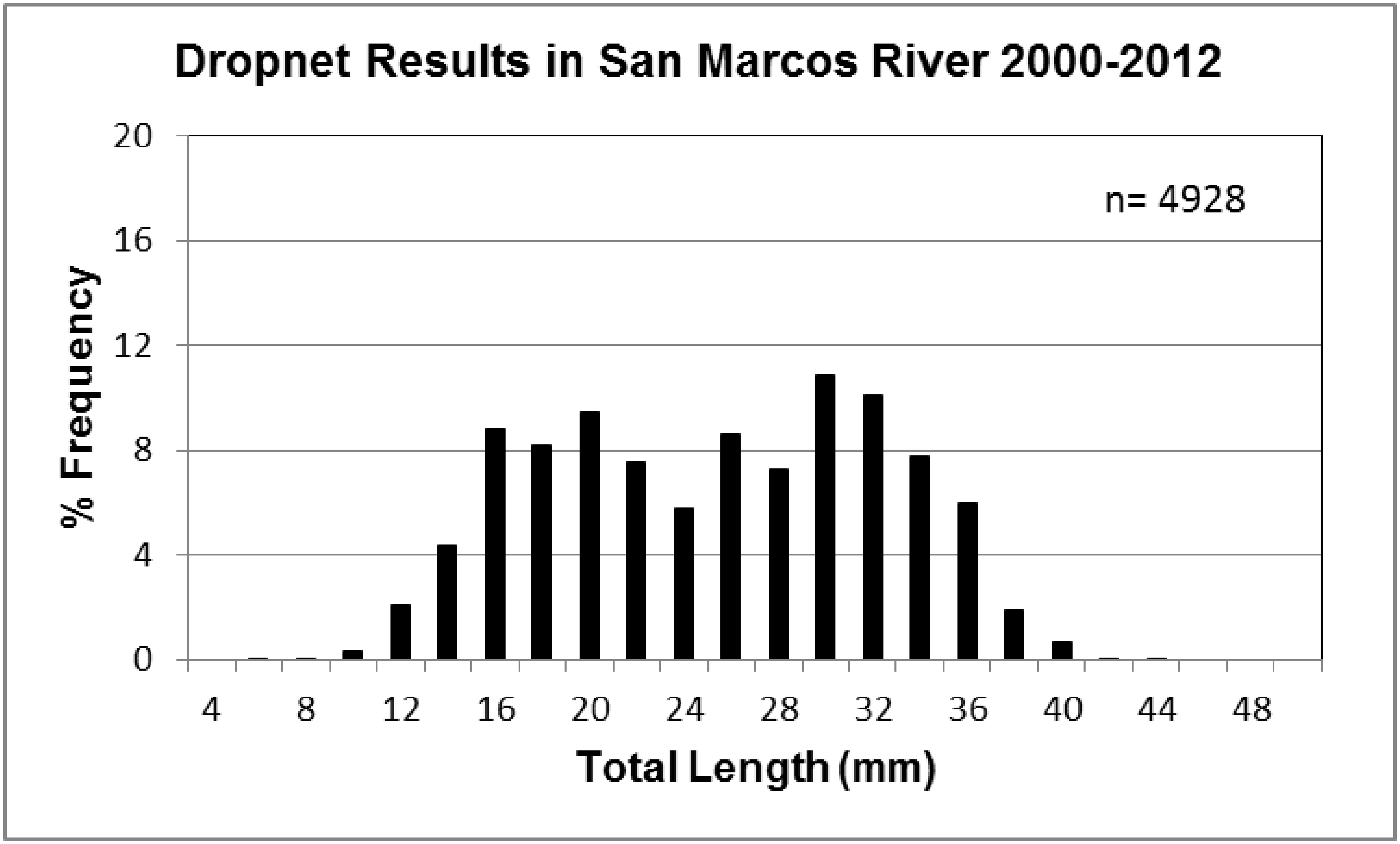
Percent of TWR Covered by Vegetation Mats



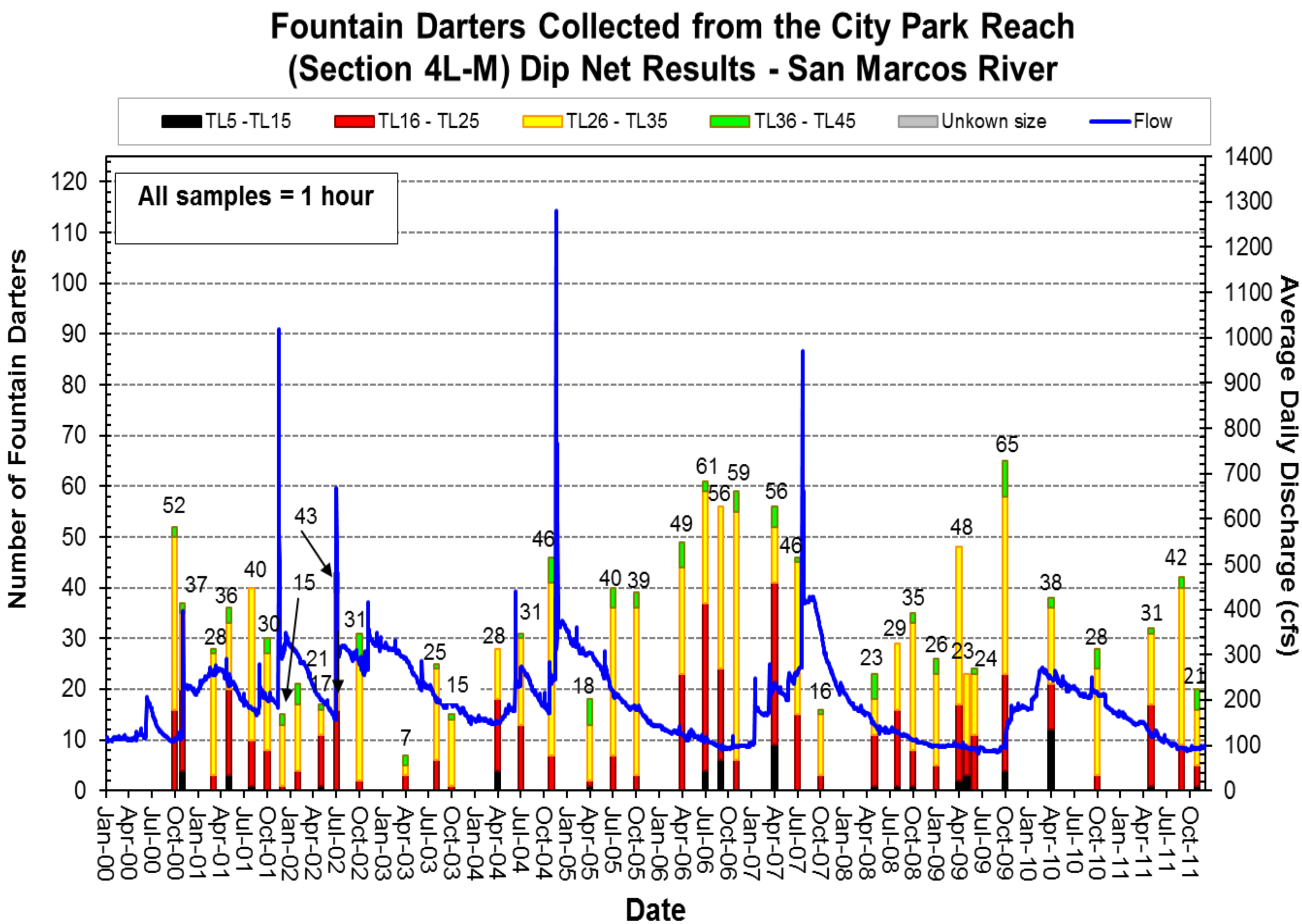
Index of Herbivory for TWR Stands



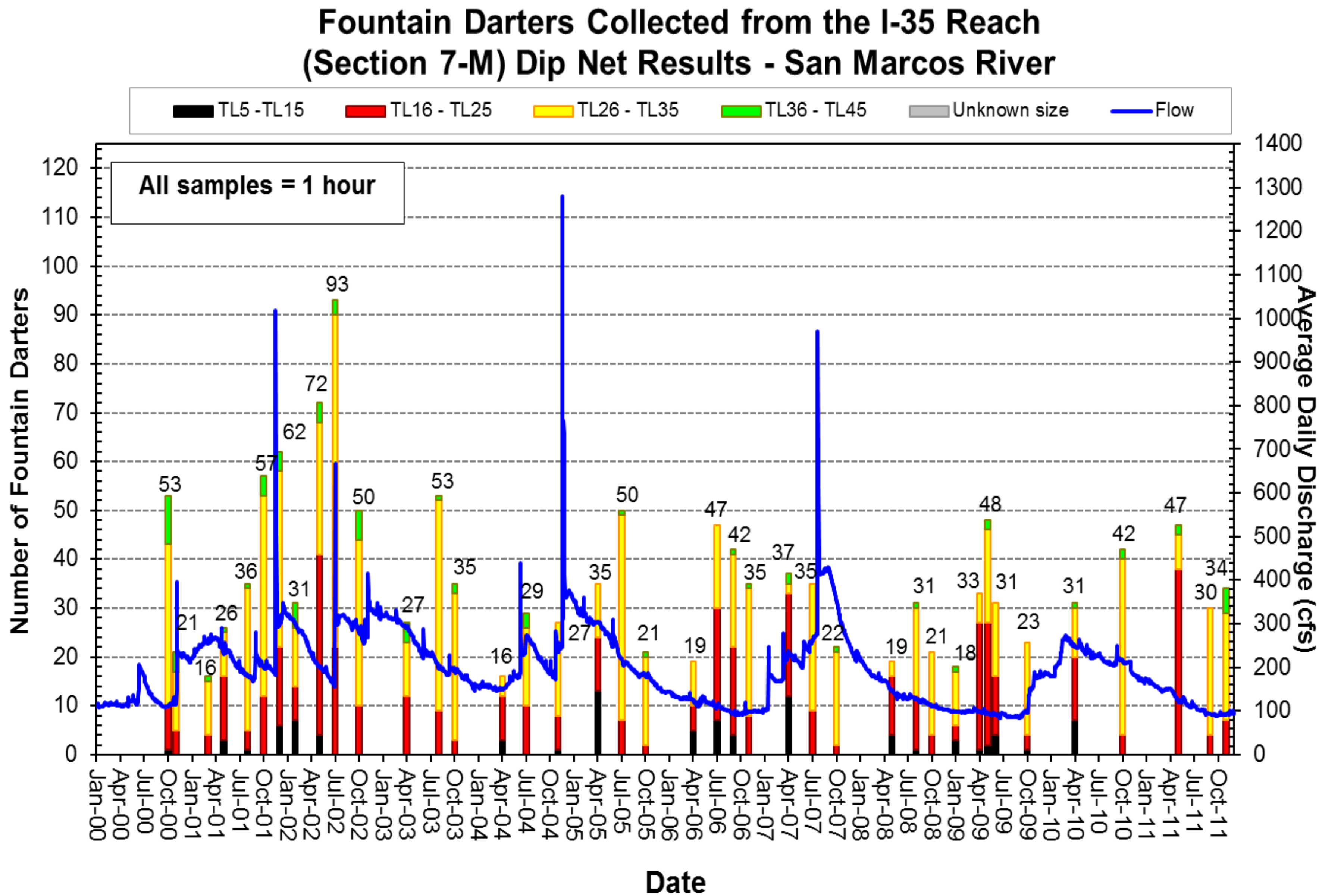
Drop net Graphs

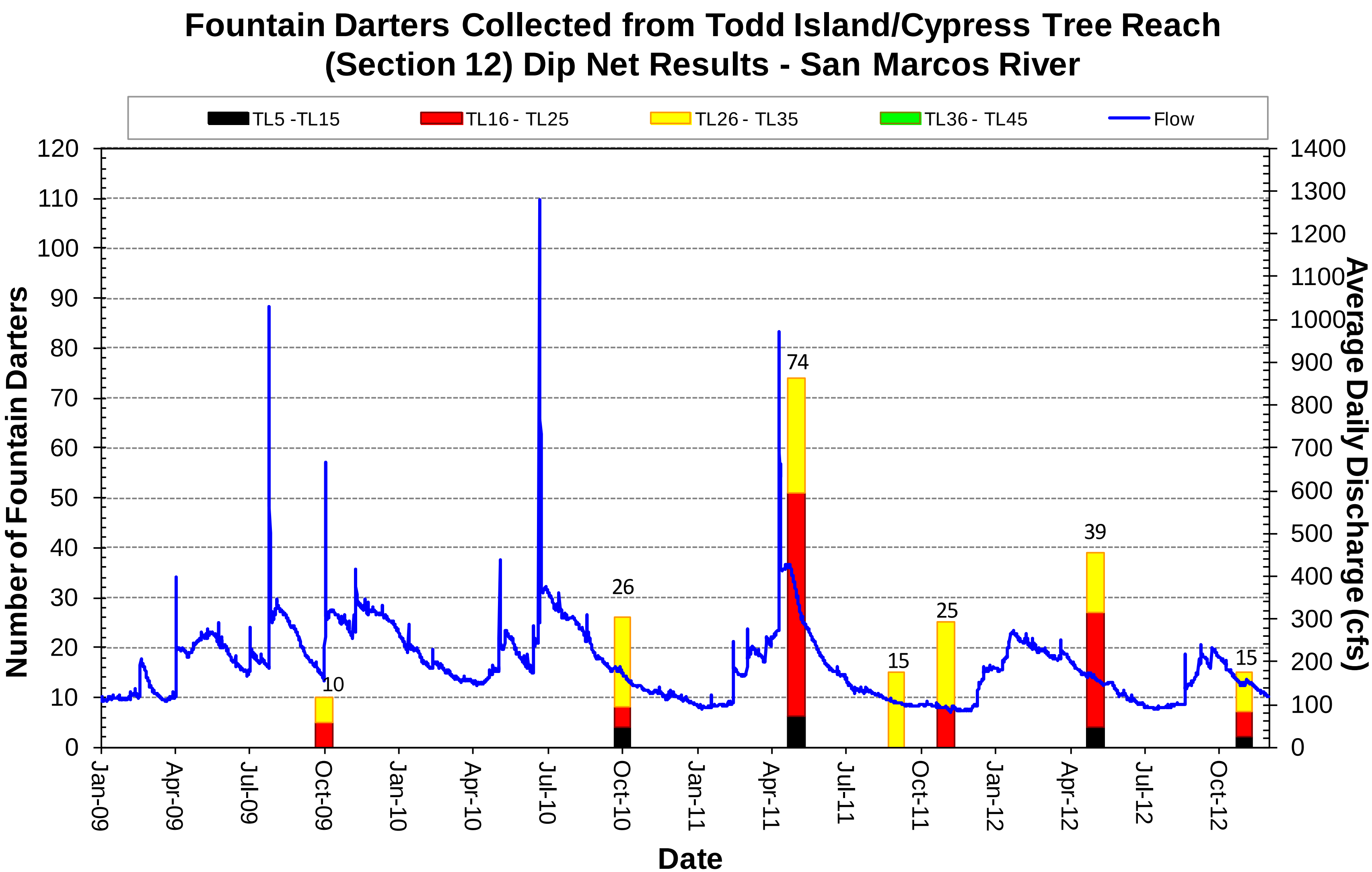

Dropnet Results in San Marcos River 2000-2012
n= 4928
% Frequency
0
4
8
12
16
20
4
8
12
16
20
24
28
32
36
40
44
48
Total Length (mm)

Dip Net Graphs



Fountain Darters Collected from the City Park Reach
(Section 4L-M) Dip Net Results - San Marcos River
TL5 -TL15
TL16 - TL25
TL26 - TL35
TL36 - TL45
Unkown size
Flow
All samples = 1 hour
Number of Fountain Darters
Average Daily Discharge (cfs)
Date


Fountain Darters Collected from the I-35 Reach
(Section 7-M) Dip Net Results - San Marcos River
TL5 -TL15
TL16 - TL25
TL26 - TL35
TL36 - TL45
Unknown size
Flow
All samples = 1 hour
Number of Fountain Darters
Average Daily Discharge (cfs)
Date
53
21
16
26
36
57
62
31
72
93
50
27
53
35
16
29
27
35
50
21
19
47
42
35
37
35
22
19
31
21
18
33
48
31
23
31
42
47
30
34



Fountain Darters Collected from Todd Island/Cypress Tree Reach
(Section 12) Dip Net Results - San Marcos River
TL5 -TL15
TL16 - TL25
TL26 - TL35
TL36 - TL45
Flow
Number of Fountain Darters
Average Daily Discharge (cfs)
Date
10
26
74
15
25
39
15
Jan-09
Apr-09
Jul-09
Oct-09
Jan-10
Apr-10
Jul-10
Oct-10
Jan-11
Apr-11
Jul-11
Oct-11
Jan-12
Apr-12
Jul-12
Oct-12

Appendix C:
Drop Net Raw Data
(Not Available Online)