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 2008 ANNUAL REPORT

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EXECUTIVE SUMMARY

This annual summary report presents a synopsis of methodology used and an account of sampling activities including sampling conditions, locations, and data obtained during Comprehensive Monitoring Efforts conducted on the San Marcos Springs/River ecosystem in 2008. Very few precipitation events in the region contributed to below average flows in the river throughout the year. Discharge peaked at the beginning of the year and continued to decline through December where flows declined below 100 cubic feet per second (cfs). This flow level is designed to trigger Critical Period sampling. However, because the Fall Comprehensive Effort was completed in late October / early November at approximately 106 cfs, it was determined that a full Critical Period sampling event will be performed in January 2009 (approximately 60 days post Fall Comprehensive sampling) provided flows remain below 100 cfs. Critical Period sampling did occur in the summer of 2008 when flows dropped below 120 cfs in the San Marcos River and vulnerable stands of Texas wild-rice (*Zizania texana*) were monitored.

All continuous temperature monitoring stations were upgraded with new thermistors in 2008 to prevent temperature drift which has been documented in long-term employment of such devices. As in previous years, thermistor data revealed near constant water temperatures near spring inputs, and more variable readings further downstream. The highest and lowest water temperatures in the system occurred at Sessom's Creek which is a flashy stream draining an urban environment. Extreme low water temperatures occur here following winter precipitation events, and during the summer, lack of precipitation leads to stagnant water and higher temperatures (since there are no spring inputs into this stream). Water temperatures were more constant nearest Spring Lake where most spring inputs are found.

For the fountain darter (*Etheostoma fonticola*), habitat use is largely influenced by aquatic vegetation, and assessments of habitat availability were conducted by mapping vegetation in the study reaches during each sampling event. With flows below average in 2008 there was a greater potential for anthropogenic disturbance because vegetation in shallow water areas became more accessible to recreation. This was observed at the Spring Lake Dam Reach between summer and fall where a section of Texas wild-rice plants appeared to be uprooted in the eastern spillway below Spring Lake. In addition, many rocks were moved to create dams and other structures in the area. This is similar to what occurred in summer 2006 (BIO-WEST 2007), but there was not nearly as much vegetation physically uprooted in 2008. This area will continue to be closely monitored as lower flow conditions persist into 2009.

Vegetation in the City Park Reach increased by spring 2008, but decreased by fall. Lower flows in 2008 made typically deeper sections of this reach accessible to foot traffic during the summer and fall. As a result, *Hydrilla* decreased in surface are in the middle section of the reach. *Hygrophila* was one of the few vegetation types that increased when it filled in a section previously dominated by *Sagittaria* in the upper section of the City Park Reach. Texas wild-rice decreased by 16% in this reach in 2008. Several Texas wild-rice plants along the cement wall on river left were uprooted likely due to the increased foot traffic along this busy section of river. Texas wild-rice in deeper sections of the reach appeared to be unaffected by the lower than average flows in 2008. *Hygrophila* grew substantially in the I-35 Reach in 2008 in both the upper and lower sections. *Cabomba* (vegetation that supports the highest densities of fountain darters in the San Marcos River) increased by 22% in 2008 in the I-35 Reach. Physical processes (likely related to the reconstruction of Rio Vista Dam) continued to change the shape of the river in this reach in 2008. A small gravel bar has been created just downstream of Cheatham Street, and the bank expanded along river right in the upper section of the reach. As a result, several small Texas wild-rice plants have been reduced to 2-3 leaves per plant, or uprooted completely.

Texas wild-rice increased 7 percent in surface area from 2007 and was the highest amount recorded by BIO-WEST since the inception of the study in 2001. As in previous years, most of the growth took place in the upper reaches of the San Marcos River. Continued growth in the Spring Lake Dam Reach and plants growing together in the Sewell Park area by summer contributed to this increase. A large plant located in a shallow area near Rio Vista Park became more fragmented in 2008 and will be closely monitored during lower flow conditions in 2009. With fewer flushing flows in 2008, vegetation mats became more prevalent in the river and covered many Texas wild-rice plants. The presence of these mats and lower than average flow conditions led to changes in physical appearance of many Texas wild-rice stands. Emergence was higher at most stands as plants put culms above the water surface. Vegetation mats blanketing stands led to several plants becoming yellowed from lack of sunlight. The emergent conditions coupled with more shallow areas led to higher levels of herbivory than recorded in 2007. Root exposure was also high in 2008. Although the physical appearance of Texas wild-rice was altered in 2008 compared to observations during average and high flow years, most Texas wild-rice stands increased in area in 2008. The durational component of these lower flow conditions will be closely studied should flows continue below average in 2009 as these extended conditions may increase the amount of stress on Texas wild-rice.

Direct sampling of the fountain darter occurred in the same reaches mapped for aquatic vegetation, with the most recent mapping determining the stratified random sample locations. The suitability of the various vegetation types (as measured by fountain darter density) continues to be considerably lower in the San Marcos River when compared with the Comal River. As in 2007, fountain darter densities were highest in *Cabomba* and *Hydrilla*. *Cabomba* is a native vegetation type, while *Hydrilla* is non-native and considered to be very invasive. More fountain darters were found in the spring at the I-35 Reach than at the City Park Reach due to the presence of *Cabomba*. As in previous years, fountain darters collected in dip net sampling were most abundant at the Hotel Reach. This section has high amounts of filamentous algae and bryophytes, which are preferred habitats for the fountain darter. Length frequency analysis confirmed a spring reproductive peak of this endangered fish at all river sites. Fountain darter reproduction continues to be a year-round phenomenon within Spring Lake. Exotic species of fishes were present in all sampled reaches,

San Marcos salamander (*Eurycea nana*) densities increased at both Spring Lake sites in 2008 while decreasing slightly at the site below Spring Lake dam. Of the federally-listed species in the San Marcos system, the San Marcos salamander appears to be the least affected by lower flow conditions periodically observed over the time period covered by this study. The impacts when observed are typically due to increased recreational use of the river. Populations of San Marcos salamanders in Spring Lake have remained stable throughout the seven plus years of monitoring.

The past several years have exhibited different yearly flow regimes leading to a very informative flow sequence in the San Marcos River. After the lower flows of 2006, 2007 was a relatively average flow year, while 2008 was again considerably below average. Overall, the biological communities in the river have responded well to the flow sequence experienced these past several years. Texas wild-rice continues to increase in overall coverage (albeit site-specific reductions have been experienced in more vulnerable areas as to be expected). Fountain darter and San Marcos salamander estimates continue to indicate healthy reproducing populations. If the current drought continues, 2009 may provide a valuable opportunity to examine how these species and their habitats respond to extended durations of lower flow conditions or more extreme low-flow conditions. The continuation of this study and other ongoing efforts to further monitor and explore variable flow conditions in the San Marcos River will enhance the understanding of these species requirements and resiliency.

METHODS

Study Location

The upper San Marcos River is part of the Edwards Aquifer system, and extends approximately 3 kilometers (km) from it's origin as a series of springs welling 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 $\pm$ 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 recreation 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 2008, two comprehensive sampling efforts (Spring and Fall) and a modified summer sampling effort were conducted in the San Marcos River system. In addition, lower flows during early summer 2008 triggered some Critical Period Texas wild-rice physical observations. The 2008 sampling schedule included the following components two times during spring and fall unless otherwise noted:

<u>Aquatic Vegetation Mapping</u>
- Texas wild-rice annual survey (summer only)

<u>Water Quality</u>
- Thermistor Placement
- Thermistor Retrieval
- Fixed Station Photography
- Point Water Quality Measurements

<u>San Marcos Salamander Observations</u>

<u>Texas Wild-Rice Physical Observations</u>
- Cross-section data
- Physical measurements

<u>Fountain Darter Sampling</u>
- Drop Nets
- Dip Nets (includes summer sampling)
- Visual Observations

Low-Flow Sampling

In December 2008, flows declined below 100 cfs. This flow level is designed to trigger a full Critical Period sampling event. However, because the Fall Comprehensive Effort was recently completed in late October / early November at approximately 106 cfs, it was determined a full Critical Period sampling event would be performed in January 2009 (approximately 60 days post Fall Comprehensive sampling) provided flows remain below 100 cfs. Critical Period sampling did occur in early summer 2008 when flows dropped below 120 cfs in the San Marcos River and vulnerable stands of Texas wild-rice were monitored.

High-Flow Sampling

There were no high-flow sampling events in 2008.

San Marcos Springflow

All San Marcos River discharge data were acquired from the United States Geologic Survey (USGS) water resources division. The 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 2008). 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 SonTek® FlowTracker with handheld unit.

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, but the two components necessary for maintenance of long-term baseline data, temperature loggers (thermistors) and fixed station photography were continued. In addition, conventional physico-chemical parameters (water temperature, conductivity compensated to 25°C, pH, dissolved oxygen, water depth at sampling point, and observations of local conditions) were taken at the surface, mid-depth, and near the bottom (when applicable) in all drop-net sampling sites using a Hydrolab Quanta. When flow conditions trigger Critical Period events in the future, the full spectrum of water quality sampling parameters will be measured, including water quality grab samples and standard parameters from each of the water quality sites in the San Marcos River (Figure 1).

In October 2008, new thermistors (Tidbit v2) were employed as a replacement for all existing thermistors at each site. This periodic replacement is designed to prevent temperature drift which has been documented in long-term employment of such devices. Thermistors were placed in the same select water quality stations along the San Marcos River and downloaded at regular intervals to provide continuous monitoring (recording data every 10 minutes) of water temperatures in these areas. The thermistor locations will not be described in detail here to minimize the potential for equipment tampering.

In addition to the water quality collection effort, a long-term record of habitat conditions has been maintained with fixed station photography. Fixed station photographs allowed for temporal habitat evaluations and included an upstream, a cross-stream, and a downstream picture; these were taken at each water quality site depicted in Figure 1.

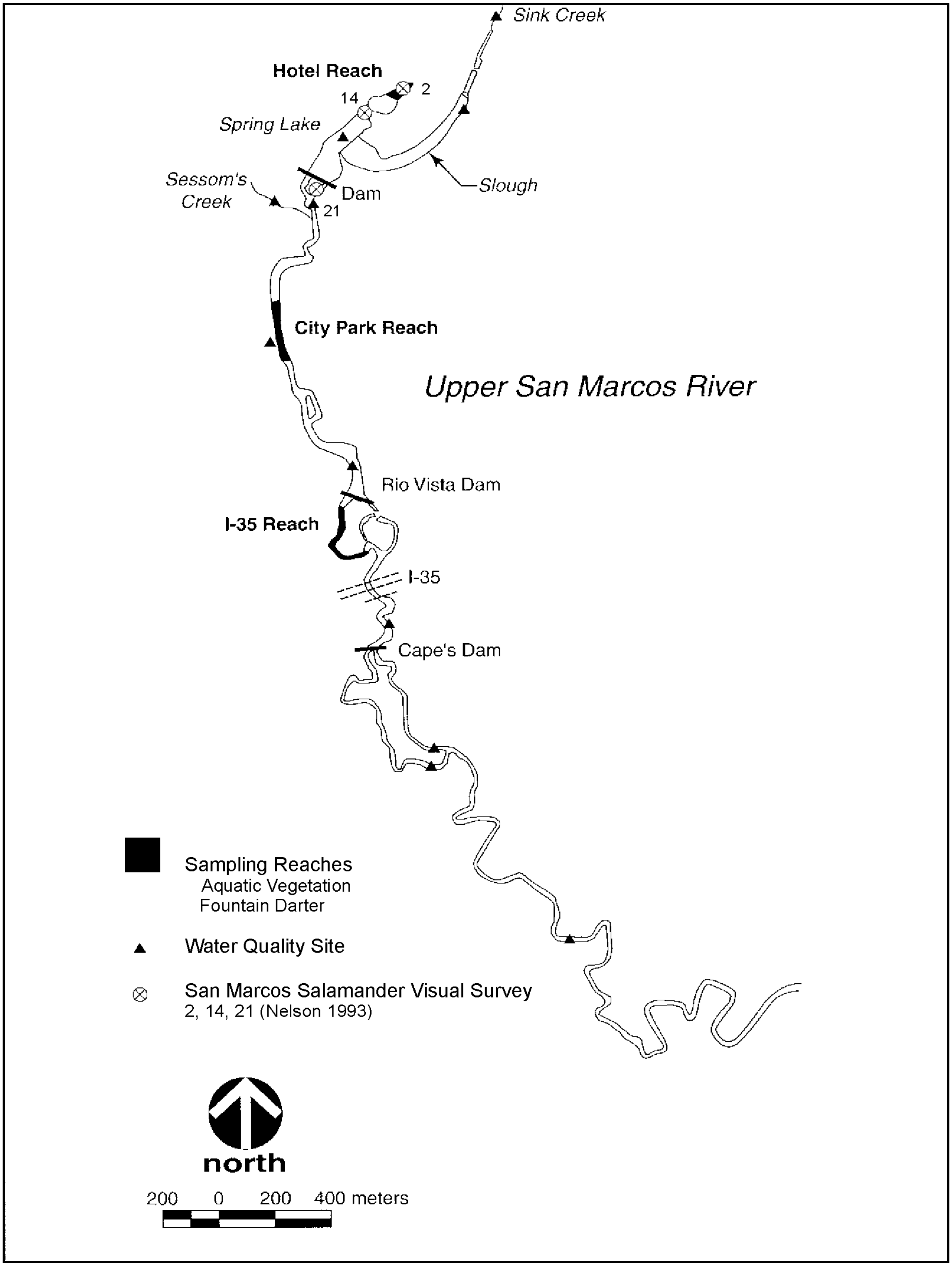

Figure 1. Upper San Marcos River water quality and biological sampling areas.

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). 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 with TerraSync software that displays field data as they are gathered and improves efficiency and accuracy. The GPS unit was placed in a 10 feet (ft) Perception Swifty 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 (Fall 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, (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 USFWS National Fish Hatchery and Technology Center, San Marcos. The aerial coverage of Texas wild-rice stands in vulnerable locations were determined in 2008 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.

Texas wild-rice at the I35 Reach

Qualitative observations were also made on the condition of each 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. Notes were also made regarding the observed (or presumed) impacts of recreational activities. Each category was assigned a number from 1 to 10 for each stand, with 10 representing the most significant impact.

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, several photo sets were made for each of the sampling events in 2008.

Fountain Darter Sampling Methods

Drop Netting

A drop net is a type of sampling device previously used by the U.S. Fish and Wildlife Service (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 for each Comprehensive sampling event from a grid overlain on the most recent map (created using GPS-collected data during the previous week) of that reach.

Drop netting on the San Marcos River during Fall 2008

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 all adjacent 3-m cell areas. 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 all other fish species, except abundant species for which only the first 25 were measured, and the rest were counted. Fish species 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 tuberculata* and *Thiara granifera*) and the Asian clam (*Corbicula* sp.). A total count of crayfish (*Procambarus* sp.) and grass shrimp (*Palaemontes* 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 dataset (2000-2008). 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 by sampling effort 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 the given reach). Because there were generally only two drop net samples in each vegetation type within each reach, density estimates between sampling efforts had great variation and population estimates based on those densities are greatly influenced by this variation. Part of the variation is 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 difficult 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).

Dip Netting

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 means 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. 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 were also useful for identifying trends in edge habitat use by fountain darters since this method focused on that habitat type. In some instances, changes that were observed in fountain darter distribution and abundance in the main channel were not observed in the edge habitat. In that way, 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.

Dip Net Techniques Evaluation

In 2008, presence/absence dip netting was conducted on the San Marcos River during the spring (April 24) and fall (October 29) sampling events. 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 (Table 1). 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 and time of day was recorded.

Table 1. Distribution of 50 dip net sites among three reaches and three vegetation types in 2008.

SPRING LAKE DAM REACH	CITY PARK REACH	I - 35 REACH
Hygrophila (2)	*Hygrophila* (2)	*Hygrophila* (2)
Hydrilla (6)	*Hydrilla* (10)	*Hydrilla* (6)
Potamogeton (6)	*Potamogeton/Hygrophila* (10)	*Cabomba* (6)
Total (14)	**Total (22)**	**Total (14)**

San Marcos Salamander Visual Observations

Visual observations were made in areas previously described as habitat for San Marcos salamanders (Nelson 1993). 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 four smaller areas for a greater coverage of suitable habitat. San Marcos salamander densities in the four 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 2008 Comprehensive sampling events and one Texas wild-rice critical period sampling as shown in Table 2.

Table 2. Study components of the 2008 sampling events.

EVENT	DATES	EVENT	DATES
Spring Sampling		**Fall Sampling**	
Vegetation Mapping	Apr 14 - 17	Vegetation Mapping	Oct 20 - 22
Texas wild-rice Physical Observations	Apr 25	Texas wild-rice Physical Observations	Oct 24
Fountain Darter Sampling	Apr 24, 28 - 29	Fountain Darter Sampling	Oct 29 - 31
San Marcos Salamander Observations	Apr 29	San Marcos Salamander Observations	Nov 6
Summer Sampling		**Critical Period (< 120 cfs)**	
Texas wild-rice Annual Survey Fountain Darter Dip Net Sampling	July 25 - Aug 5 Aug 1	Texas wild-rice Physical Observations	June 26

San Marcos Springflow

Rainfall amounts were below average over the Edwards Aquifer in 2008. As a result, flows steadily declined in the San Marcos River throughout the year (Figure 2). With the exception of early January, flows were below 200 cfs the entire year and below 100 cfs for most of December. The lowest recorded discharge in 2008 for the San Marcos River was 97 cfs, which occurred on December 15 (Table 3). Flows this low were not recorded at any time in 2007. Although flows were considerably lower in 2008, only one Critical Period activity was conducted and only one full Critical Period event was triggered. The one activity conducted was Texas wild-rice physical measurements on June 26 when discharge dropped below 120 cfs. As part of the protocol, physical measurements of Texas wild-rice were recorded on several vulnerable stands in the river. In addition, the one full Critical Period event that was triggered (yet postponed to better evaluate the durational component of lower flows) led to a January 2009 full Critical Period event (not discussed in this 2008 annual report). The highest recorded discharge in the San Marcos River occurred on January 1 at 217 cfs. Average monthly discharge dropped below the historic average in early March, and due to lack of significant rainfall events, further decreased with each passing month (Figure 3). If this major drought continues in Central Texas, several Critical Period sampling events may be triggered in 2009 and help provide a better understanding of the effects of continued low-flow or more extreme low-flows on the flora and fauna of the San Marcos River.

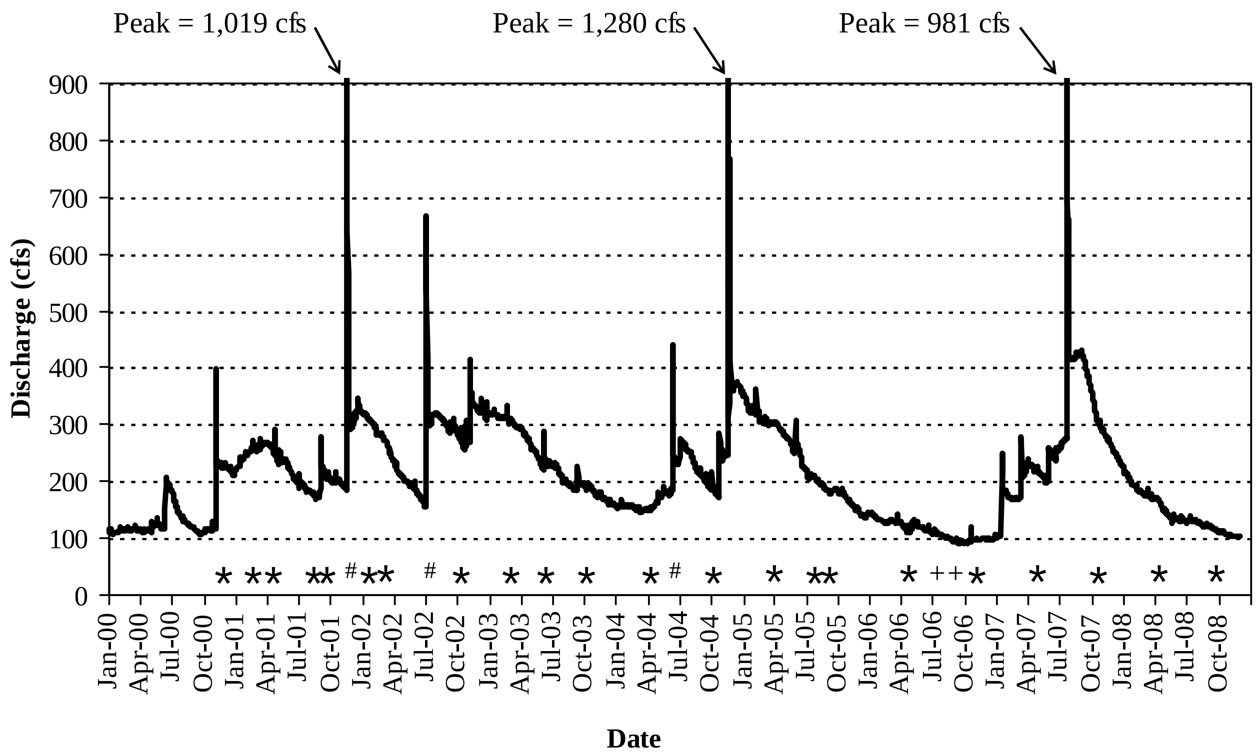

Figure 2. Mean daily discharge in the San Marcos River during the study period; approximate dates for quarterly (*), high-flow (#), and low-flow sampling efforts (+) are indicated.

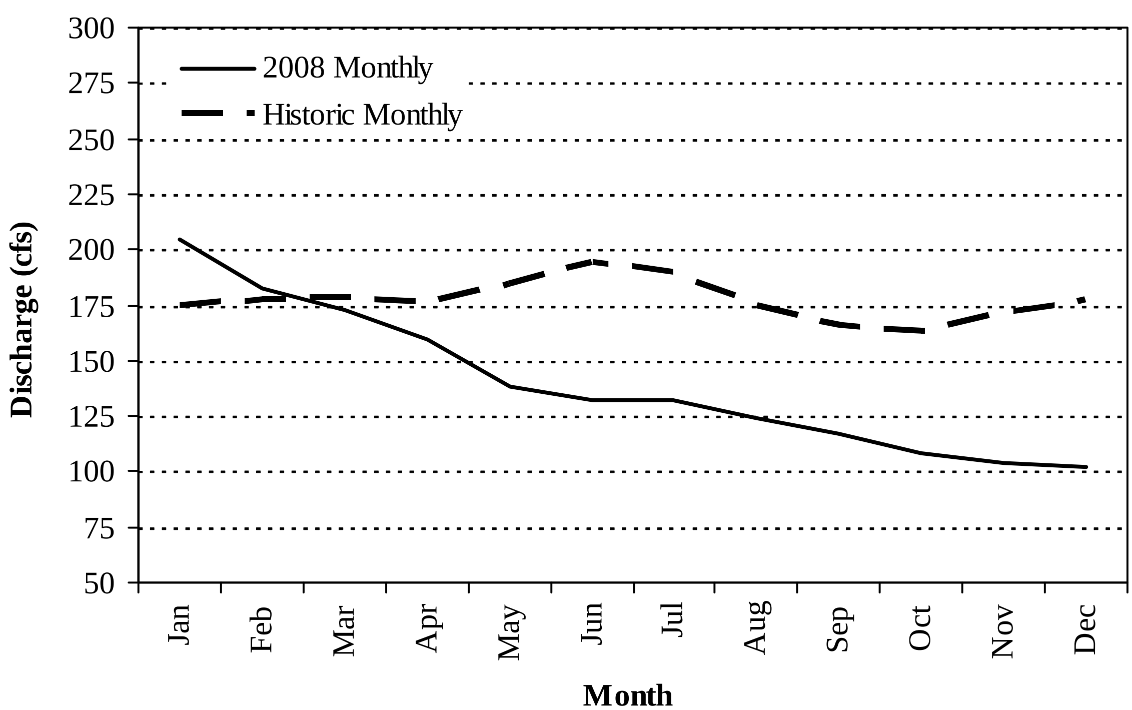

Figure 3. Mean monthly discharge in the San Marcos River during the 1956-2008 period of record.

Table 3. Lowest discharge (cfs) during each year of the study and the date on which it occurred.

Year	Discharge	Date
2000	108	Sept. 18
2001	167	Aug. 19
2002	157	Jun. 28
2003	156	Dec. 29
2004	146	Mar. 8
2005	136	Dec. 17
2006	90	Sept. 8
2007	101	Jan. 1
2008	97	Dec. 15

San Marcos Water Quality

The thermistor temperature data for the Sessom's Creek and Rio Vista Dam sites are presented in Figure 4, and additional graphs can be found in Appendix B. The continuously sampled water temperature data provide a significant amount of information regarding fluctuations due to atmospheric conditions and springflow influences in the San Marcos River. Due to several loggers experiencing temperature drift, all existing Tidbit® temperature loggers were replaced with new thermistors in October 2008 (see picture). Although, springflow was lower throughout 2008, water temperatures nearest to spring inputs remained relatively constant. At the Dam and Chute tailrace sites (nearest spring inputs at Spring Lake), the majority of recorded temperatures only fluctuated between 20 °C and 24 °C. The largest water temperature fluctuations were observed at Sessom's Creek (15.1 °C to 27.4 °C) because this is a stream that is highly channelized and drains an urban area. As a result, precipitation events often bring colder rainfall, and extended periods of drought lead to elevated water temperatures. Observations of larger temperature variations were also observed further downstream away from spring (near-constant temperatures) inputs. The overall relationship at these sites is more directly associated with air temperature (also, air temperatures strongly influence precipitation temperatures). Water temperatures did not exceed the TCEQ water quality standards value (26.67 ˚C) in 2008 except at the Sessom's Creek site.

New thermistor temperature loggers installed in 2008

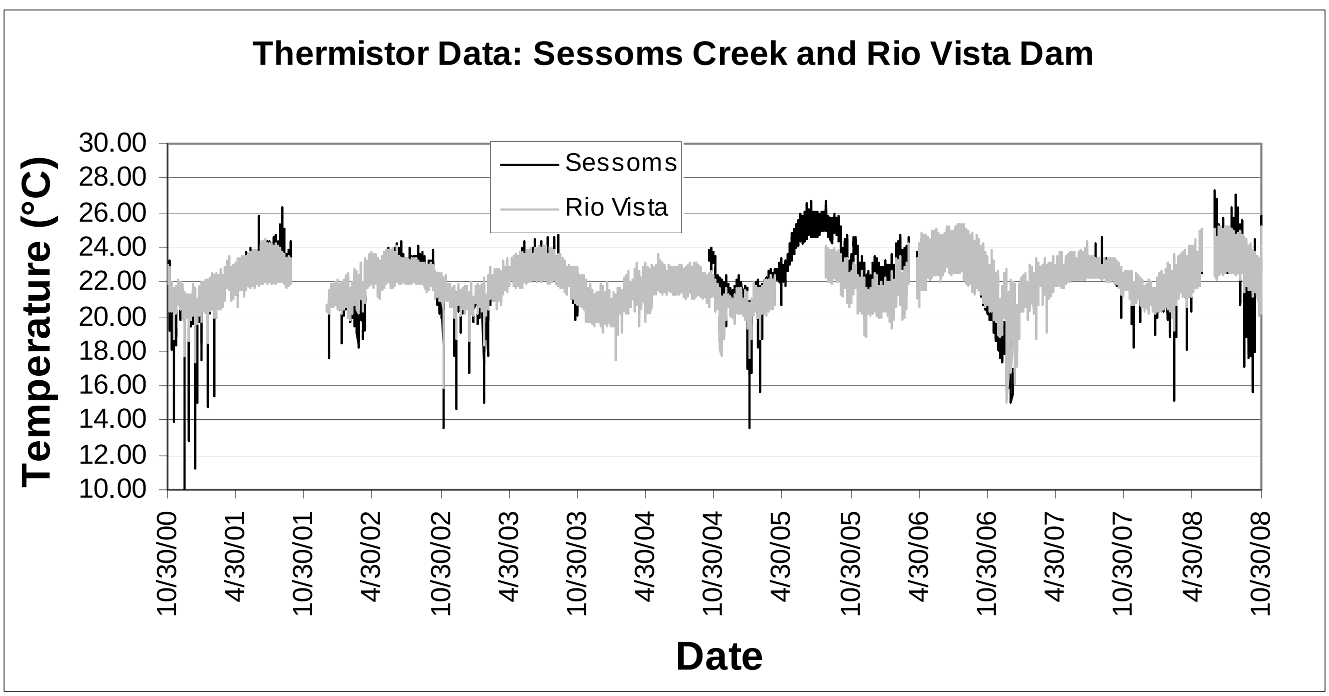

Figure 4. Thermister temperature data from the Sessom's Creek and Rio Vista Dam sites for the entire study period.

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 in order by date of occurrence. It is difficult to make sweeping 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.

Spring Lake Dam Reach

Vegetation in the Spring Lake Dam Reach continued to recover from recreation impacts in 2006 to expand into many areas in spring 2008 that were bare in 2007. For example, total vegetation coverage increased to 2,009.6 m^2 in this reach by spring. *Hydrilla* was more prevalent in 2008 where the two arms of the reach converge. Although, a large amount was found in the spring (186.9 m^2), fragmentation in the eastern arm led to a large decrease in aerial coverage of this invasive plant by fall (75.8 m^2). This plant also grew together with *Potamogeton* to cover much of the middle section of the reach (355.4 m^2). A large patch of *Potamogeton* was established near the dam in spring and grew even larger by fall in this area that had previously been bare substrate. However, by fall, *Potamogeton* coverage decreased by nearly 65% to 258.5 m^2. Vegetation decreases going into the fall are typical in this reach after the high level of recreational activity that is commonly observed each summer. *Hygrophila* stands continued to be sparse in this reach, and changed little in coverage from spring (16.8 m^2) to fall (16.4 m^2) 2008. As precipitation levels were much decreased in 2008, BobDog Island (an area of land at the mouth of Sessom's Creek) changed little in area in lower flows because there were few rain events bringing sediment out of Sessom's Creek.

Texas wild-rice continued to increase in aerial coverage in this reach after the significant mechanical disturbance observed in September 2006 when 73% of the surface area of this plant was reduced (BIO-WEST 2007). By spring 2008, total coverage in the Spring Lake Dam Reach had increased to 384.8 m^2. Most of this increase took place in the eastern arm of the reach with many mid-sized plants growing together. Several other plants that had previously been small rootwads grew several leaves contributing to this growth even though river flow continued to decline. Unfortunately by fall 2008, fracturing of the plants due to mechanical disturbance seemed to begin anew. As in 2006, several man-made dams and rock structures were present in the eastern arm of this reach. The presence of these structures is a clear indication that a substantial amount of recreation was occurring in this section of the reach during the summer months. In addition, a man-made dam was present in the lower section of the reach blocking flow to several small *Potamogeton* plants (which were not present in the fall sampling event – see picture below). As a result of this fracturing of plants, Texas wild-rice surface area decreased by 23% to 295.7 m^2. It is less clear if this decrease was due to people uprooting plants purposefully or if it was just a by-product of the increased amount of recreation and moving of rocks in this area. It is becoming clear though that as flows decrease to lower levels in the San Marcos River an increase in recreation in summer months can have considerable impacts on the Texas wild-rice population in the Spring Lake Dam Reach.

Man-made dam at the Spring Lake Dam Reach

City Park Reach

Decreased recreational use of the river over the winter in this reach likely led to an increase of vegetation coverage in this area for spring 2008. *Hydrilla* was the dominant plant in the reach covering 1,789.1 m^2, while a *Potamogeto*n/*Hygrophila* mix covered 1,080.6 m^2. At the top and bottom of the reach a *Potamogeton*/*Hydrilla* mix covered much of the area in the middle of the river (1,003.9 m^2). By fall 2008, *Hydrilla* coverage had decreased slightly (to 1,618.5 m^2) with most of that loss coming in the middle of the reach where a walking path that develops most summers (especially in lower flows) was present. *Hygrophila* increased in 2008 (112.1 m^2 to 142.2 m^2) filling in areas occupied by *Sagittaria* in the upper section of the reach. *Hygrophila* also grew into pure *Potamogeton* stands that were present in the spring resulting in a 95% decrease in *Potamogeton* (most of these stands became part of a *Potamogeton*/*Hygrophila* mix). Overall, vegetation area in the City Park Reach decreased 771.7 m^2 by fall 2008.

In the most recent lower than average flow year (2006), Texas wild-rice exhibited a decrease in overall coverage in the San Marcos River in many cases due to mechanical disturbance from recreation. This appeared to be the case in the City Park Reach in 2008. From spring to fall 2008, Texas wild-rice decreased by 16% (343.5 m^2 to 288.6 m^2) in this reach. Nearly all of this decrease occurred along the river left side of the reach where recreation is most common. On this side is a long cement wall where swimmers, tubers, etc. frequently get in and out of the river. When flows are lower (as in 2008) people are able to stand along this wall where in higher flow years it is usually too deep for this to occur. The mechanical disturbance of people walking along the substrate here likely led to many of the plants being uprooted. Throughout the rest of the reach where water depths are greater and vegetation is denser, the Texas wild-rice plants appeared unchanged (and in some cases grew larger). However, Texas wild-rice surface area within this reach was still higher (288.6 m^2) than it was at the end of 2007 (272.6 m^2). Because this reach is near campus and is a major destination point for recreation, vegetation will continue to be changed based partly on the number of people using the area. If flows continue to decrease into the summer months in 2009, the vegetation in this reach may be highly susceptible to mechanical disturbance.

I-35 Reach

This reach presents difficulties in obtaining accurate GPS coordinates when the canopy is dense (i.e., spring and summer); therefore, small discrepancies are apparent in the exact location of individual stands between samples. In addition, some estimates of total coverage may be less precise than in other reaches. The surface area of *Hygrophila* nearly doubled from fall 2007 to spring 2008 (51.1 m^2 to 96.4 m^2) and further increased by fall 2008 (110.9 m^2). These increases took place when many small individual plants grew larger in the middle and lower sections of the reach. *Hydrilla* was common in the lower section of the reach where it mixed with algae in the spring (246.9 m^2) and was still prevalent in the fall in the same section (291.6 m^2). This highly invasive plant does not seem to be increasing dramatically in this reach, but will continue to be closely monitored because much of it grows adjacent to Texas wild-rice. *Cabomba* occurs in this reach because of suitable conditions along the outside bends in the river (lentic backwaters, deep silty substrates). This vegetation type is important because it provides the highest-quality fountain darter habitat (of those sampled quantitatively) in the San Marcos River, but it is also highly susceptible to flood events. This plant increased by 22% in 2008 (150.6 m^2 to 193.1 m^2). Most of this growth took place in the lower section of the reach where the channel is deep and velocities are low.

As a result of the new Rio Vista Dam, physical processes in the upper section of the I-35 Reach continue to change the shape of the river and the vegetation growing there. Near Cheatham Street Bridge several small gravel bars have formed in the middle of the channel. The bank along the river-right side of the reach in the upper portions increased by fall 2008 leading to several plants disappearing (see picture on next page). This area is also encroaching on several small Texas wild-rice plants. As a result, these plants have decreased in area substantially (including some only consisting of two leaves each), and may be gone by the next sampling period. These plants notwithstanding, Texas wild-rice in this reach increased in 2008 (119.4 m^2 to 123.5 m^2) with plants in the lower section of the reach growing larger. This section will continue to be monitored closely (including mapping new lines for the banks of the river) to understand how channel changes may affect existing aquatic vegetation.

Example of channel changes in the I-35 Reach

Texas Wild-Rice Surveys

Maps generated from the annual Texas wild-rice mapping survey in 2008 of the San Marcos River (downstream of Spring Lake) can be found in Appendix A.

Flows in the San Marcos River exhibited a gradual decline in the river for 2008. However, overall area of Texas wild-rice increased from 2007 and was higher than has ever been recorded by BIO-WEST since the inception of the study in 2001 (3,897.7 m^2, Table 4). Considering the mechanical damage witnessed in 2006, this increase highlights the resiliency of the Texas wild-rice. In the summer of 2008, many of the plants in the Spring Lake Dam Reach that had been denuded of their leaves in 2006 grew back to form healthy looking plants. This was likely assisted by the increased flows of 2007 making it more difficult for people to get to the deeper areas of this reach where many of the Texas wild-rice plants reside. In addition, signs were put up along the shore at the Spring Lake Dam Reach near where the plants had been pulled out in 2006. These signs educate river users by explaining the importance of the endangered animals and plants in the river and the detrimental effects habitat degradation can have in the river. A 10% increase in coverage in the upper reaches of the San Marcos River from 2007 to 2008 (Map 1, Appendix A) was observed. Increased growth of Texas wild-rice was observed in the Sewell Park area even though a large patch of emergent plants continued to occupy a large area in the middle of a large Texas wild-rice plant. Even though large vegetation mats were observed in the area between Sewell Park and the City Park Reach, most plants appeared to be healthy (some exceptions included the yellowing of some plants that had been under these mats for extended periods of time).

Table 4. Total coverage of Texas wild-rice (m^2) in the San Marcos River as measured by the TPWD for 1996-2006 and BIO-WEST in 2001-2008.

Year/Event	1998	1999	2000	2001[a]	High-Flow[a]	2002	2003
TPWD	1,949.0	1,644.9	1,791.1	1,895.6		1,916.3	2,776.0
BIO-WEST				1,901.2	1,765.9	1,913.2	2,560.7

Year/Event	2004	2005	2006[b]	Low-Flow[c]	2007	2008
TPWD	3,390.0	3,992.7	4,161.1		4,277.5	3,909.4
BIO-WEST	3,145.3	2,949.7	3,335.7	3,000.4	3,646.4	3,897.7

[a]Total coverage values obtained in this study are included for the summer and high-flow events in 2001.

[b]Total coverage values obtained during a Critical Period low-flow event (July 27 – August 5, 2006).

[c]Total coverage values obtained during a second Critical Period low-flow event (September 20 – October 3, 2006).

Texas wild-rice decreased by 1% in the City Park Reach and downstream with surface area decreasing by 7.2 m^2 from 2007 to 2008 in the San Marcos River (Map 2, Appendix A). This negligible decrease is probably a result of a few small plants getting uprooted in this section. Further downstream, Texas wild-rice decreased by 5% from 396.6 m^2 in 2007 to 376.7 m^2 in 2008 (Map 3, Appendix A). In this section there is a large plant located in a shallow area adjacent to Rio Vista Park and a walking trail. As a result, recreation is heavier in this section (people fishing/swimming, tubers stopping and walking in the shallow area) and the plant was more fragmented than in previous years. This area will need to be monitored closely to see how possible further low-flows affect the plant in the future. Texas wild-rice surface areas in the I-35 Reach and downstream were virtually unchanged from 2007 (decreased by 0.5 m^2, Map 4, Appendix A). Near Capes' Dam in the lower reaches of the San Marcos River, surface area of the endangered plant increased 6.1 m^2 from 2007 (Map 5, Appendix A). A few new plants were found in this reach and two smaller plants grew together. Two Texas wild-rice plants immediately downstream of where the artificial channel at Thompson's Island enters the San Marcos River disappeared leading to a decrease of 3.8 m^2 in 2008 (Map 6, Appendix A). A 42% increase in surface area of Texas wild-rice was observed in the lowest mapped section in 2008 (Map 7, Appendix A). Most of this increase took place in the area where in 2003 several plants had been planted by the USFWS. Many of the plants here grew together to form larger plants. Although this area is in shallower depths when flows are lower (as in 2008), it is far removed from recreation centers, and therefore receives considerably less mechanical disturbance due to people.

With below average flows likely to continue into 2009, Texas wild-rice may be vulnerable due to shallower depths in many areas. The lower air temperatures in central Texas in winter may provide a decrease in recreational visits, providing some reprieve to Texas wild-rice plants in shallow areas. Further sampling efforts in the beginning of 2009 will increase our knowledge of how these plants react to more extended low-flow periods.

Texas Wild-Rice Physical Observations

Total coverage of Texas wild-rice observed during 2008 in each “vulnerable” stand is presented in Table 5, and observations on trends in areal coverage are discussed by reach below. More detailed graphs on observations of root exposure, herbivory, emergence, etc. are found in Appendix B. Physical observations were conducted three times in 2008 at each of the vulnerable stands. Although surface areas of Texas wild-rice decreased at all vulnerable stands in fall, they were not the lowest areas recorded in the study (Figure 5). In addition, in fall 2008, the surface areas of stands at Sewell Park and I-35 were within the variation observed during the study.

Sewell Park Reach

As flows in the San Marcos River decreased throughout 2008, water level fell in Sewell Park and decreased both water level and point flow measurements at all vulnerable stands in this reach. The total area of Texas wild-rice increased between fall 2007 (588.8 m^2) and the spring 2008 sampling (672 m^2), and remained similar (674.3 m^2) going into the summertime critical period in 2008. However, with continued decreasing flows into the fall, total area of Texas wild-rice in this reach was 20% lower in fall 2008 (538.9 m^2). Discharge conditions in 2008 resulted in an increase in the amount of emergent stands and areas of shallow water (<0.5 feet). During the spring comprehensive sampling event, none of the Texas wild-rice in this section was found in water less than 0.5 feet, and vegetation mats covered over 40% of the stands (Appendix B). Root exposure and plant herbivory appeared to be minimal, and 50% of the vulnerable stands appeared to be flowering and/or seeding. Due to the water depth, just over 55% of the stands in this area were emergent.

During the summertime critical period sampling event, water levels were lower and just under 10% of the plant stands were in water <0.5 feet deep. The number of emergent plants and the number of stands covered with vegetation mats both increased 10% from the spring, while the number of flowering and seeding plants decreased slightly. Root exposure and herbivory of the plants both increased in severity from the spring sampling event.

By the fall comprehensive sampling event, water levels were still low, but fewer Texas wild-rice plants were found in water less than 0.5 feet deep. The amount of flowering plants was similar to the summertime critical period (>40%), with this species continuing to reproduce through most of the year. Emergence was also beginning to decrease, and fewer vegetation mats covered the stands than in the summer. Floating vegetation that has dislodged from upstream areas is easily caught on Texas wild-rice leaves and stems in the shallower areas. Thick vegetation mats covering plants in vulnerable areas can have detrimental effects (see picture below), as they can lead to reproductive failure due to the mats limiting emergence of culms, and reduce photosynthesis by blocking sunlight resulting in achlorotic leaves (Power 1996). Root exposure increased into the fall, especially on plants in the vulnerable stand SP-6. Plant herbivory decreased slightly in the fall, but was still higher than levels observed in 2007 (Appendix B).

Table 5. Texas wild-rice areal coverage (m^2) for each stand by sampling period (2008 only).

REACH-STAND NO.	Spring 2008[a]	Critical Period 1 2008[a]	Fall 2008[a]
Sewell Park-1	-	-	-
Sewell Park-2 Sewell Park-3	238.6	236.5	138.8
Sewell Park-4 Sewell Park-5	41.6	42.6	41.0
Sewell Park-6	53.3	56.2	25.9
Sewell Park-7 Sewell Park-8	338.5	339.0	333.2
Total Area	**672.0**	**674.3**	**538.9**
I-35-1	0.6	0.1	-
I-35-2	0.01	0.01	-
I-35-3	1.0	0.8	2.1
I-35-4	0.6	0.4	0.2
I-35-5	2.0	1.7	2.3
I-35-6 I-35-7	31.2	32.4	40.4
I-35-8	191.3	192.1	152.7
Total Area	**226.6**	**227.5**	**197.7**
Thompson's Island - 1	-	-	-
Thompson's Island - 2	2.6	2.5	1.1
Thompson's Island – 2a	0.3	0.3	-
Thompson's Island – 3	1.7	1.3	0.2
Thompson's Island – 3a	0.5	0.1	-
Total Area	**5.1**	**4.2**	**1.3**

[a] Areas reflect results of cross-section measurements and not GPS mapping at Thompson's Island.

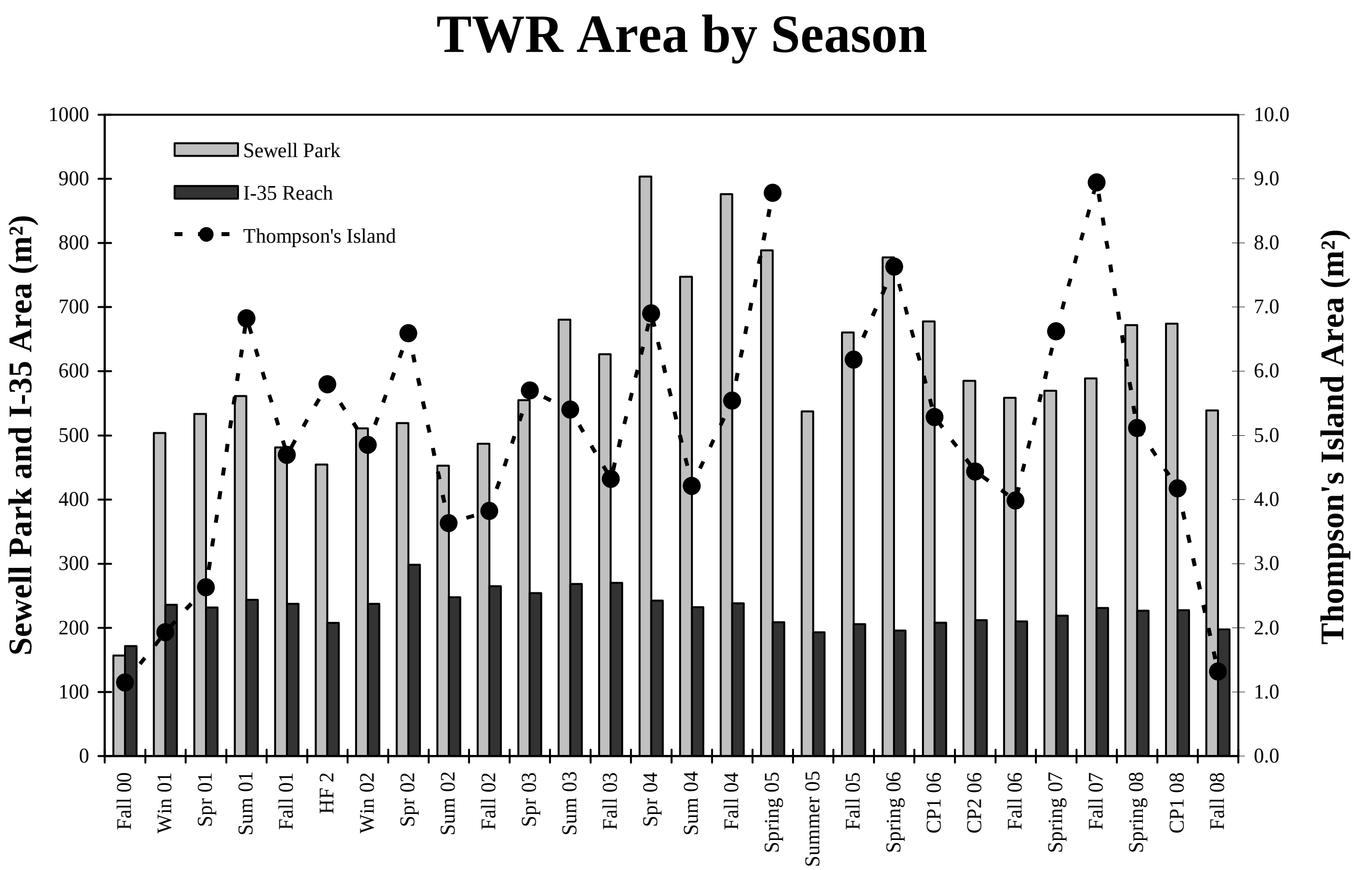

Figure 5. Total area of Texas wild-rice in vulnerable stands 2000 – 2008.

Vegetation mats covering Texas wild-rice in the Sewell Park Reach in spring 2008

I-35 Reach

Average areal coverage of Texas wild-rice "vulnerable" stands in the I-35 reach remained relatively unchanged from fall 2007 (230.8 m^2) to spring 2008 (226.6 m^2) and the summer critical period in 2008 (227.5 m^2). However, following the decreasing flows in the San Marcos throughout 2008, areal coverage of Texas wild-rice decreased 13% by the fall (197.5 m^2). Specifically, plants I35-1 and I35-2 disappeared between the summertime critical period and the fall sampling events, and plant I35-8 was considerably reduced in size. Plants in this reach were relatively unaffected by recreation because this reach is farther away from recreational areas (City Park, Sewell Park). As a result of less recreation in this reach, Texas wild-rice plants were much less fragmented by mechanical disturbance.

Emergence in this reach remained relatively constant between spring and the critical period 2008, at >20% (Appendix B). Most of the emergent plants were plants 6, 7, and 8 because they are in a shallow area of the reach. However, with the low discharge conditions in 2008, the water level in the upper section of the reach was lower than in previous years. While no plants were found in water <0.5 feet deep in 2007, this increased in 2008 from approximately 3% in the spring to 24% during the summertime critical period to 48% in the fall. Flowering or seeding culms were observed on approximately 10% of the plants in the spring, slightly fewer in the summer, and on 26% of the plants in the fall. Fewer vegetation mats were found in this reach as compared to the Sewell Park reach, with almost 15% of the plants covered with vegetation mats in the spring. This increased to approximately 21% in the summer, and decreased to less than 10% in the fall. Herbivory on plants within this reach was slightly higher in spring 2008 (most of it concentrated on plants 5, 6, 7, and 8) than in 2007, but decreased throughout 2008. Root exposure was also higher here in 2008 than in 2007, and increased between the spring and the fall sampling events. Root exposure was particularly evident on plants I35-3 and I35-5, where portions of the plant had very exposed roots (see photographs below) (Appendix B).

Example of very low root exposure level (left) and very high level of root exposure (right) on Texas wild-rice plants

Thompson's Island Reach (Natural)

The average coverage of Texas wild-rice in "vulnerable" areas within this reach decreased from fall 2007 (6.6 m^2) to spring 2008 (5.1 m^2), and continued to decrease to 4.2 m^2 in the summer critical period and 1.3 m^2 in the fall. The two newer Texas wild-rice plants near existing plants 2 and 3 (2a and 3a) discovered in 2006 and 2007 disappeared by the fall 2008 sampling event. These plants had been in water a few inches deeper than the plants 2 and 3 but had not exhibited high levels of root exposure in 2007 or 2008.

Due to low discharge conditions and subsequent lower water levels along this reach in 2008, over 60% of the plant stands here were found in water <0.5 feet deep in the spring. With decreasing flow throughout the year, these shallow areas increased and 78% of the stands were in water <0.5 feet in the summer critical period, increasing to 93% of the stands in the fall (Appendix B). Over 50% of the plants were emergent in the spring, with just over 10% of the plants flowering or seeding. Both emergence and the amount of flowering and seeding plants decreased by the summertime critical period sampling event, with an average of 6% emergence and 3% seeding. Going into the fall, both emergence and seeding plants increased, with 88% of the plants emergent and 10% of these seeding. Vegetation mat cover of the plants was highest in the spring (13%), and decreased during the year to 8% in the summer and 3% in the fall. Likely as a result of the low water levels, herbivory increased in this area in the fall because the plants were highly exposed in slow moving water. Root exposure increased from 2007 to 2008, and continued to increase throughout 2008, although most of this exposure occurred on plant 2. As noted above, neither plants 2a or 3a exhibited high levels of root exposure prior to their disappearance.

Fountain Darter Sampling

Drop Netting

The number of drop net sites and vegetation types sampled per reach 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. Number of drop net sites within each vegetation type sampled per reach (2008).

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 Drop Net Samples (8)	**Total Drop Net Samples (8)**

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 (0.0/m^2) versus vegetated habitats (4.7-6.6/m^2) (Figure 6). 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 highest in the native vegetation type *Cabomba* (6.6/m^2), yet lower in non-native *Hygrophila* (4.7/m^2) (Figure 6). Fountain darter densities in *Hydrilla* and *Potamogeton/Hygrophila* are intermediate (5.6/m^2 and 5.0/m^2, respectively).

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. In the Comal, certain vegetation types such as filamentous algae and bryophytes exhibit extremely high densities (23.0 and 25.3 fountain darters/m^2, respectively), resulting in an overall greater number of darters. In the San Marcos, filamentous algae and bryophytes are only found in Spring Lake. Although this area is not sampled by drop netting, dip net data confirms a high abundance of darters in Spring Lake.

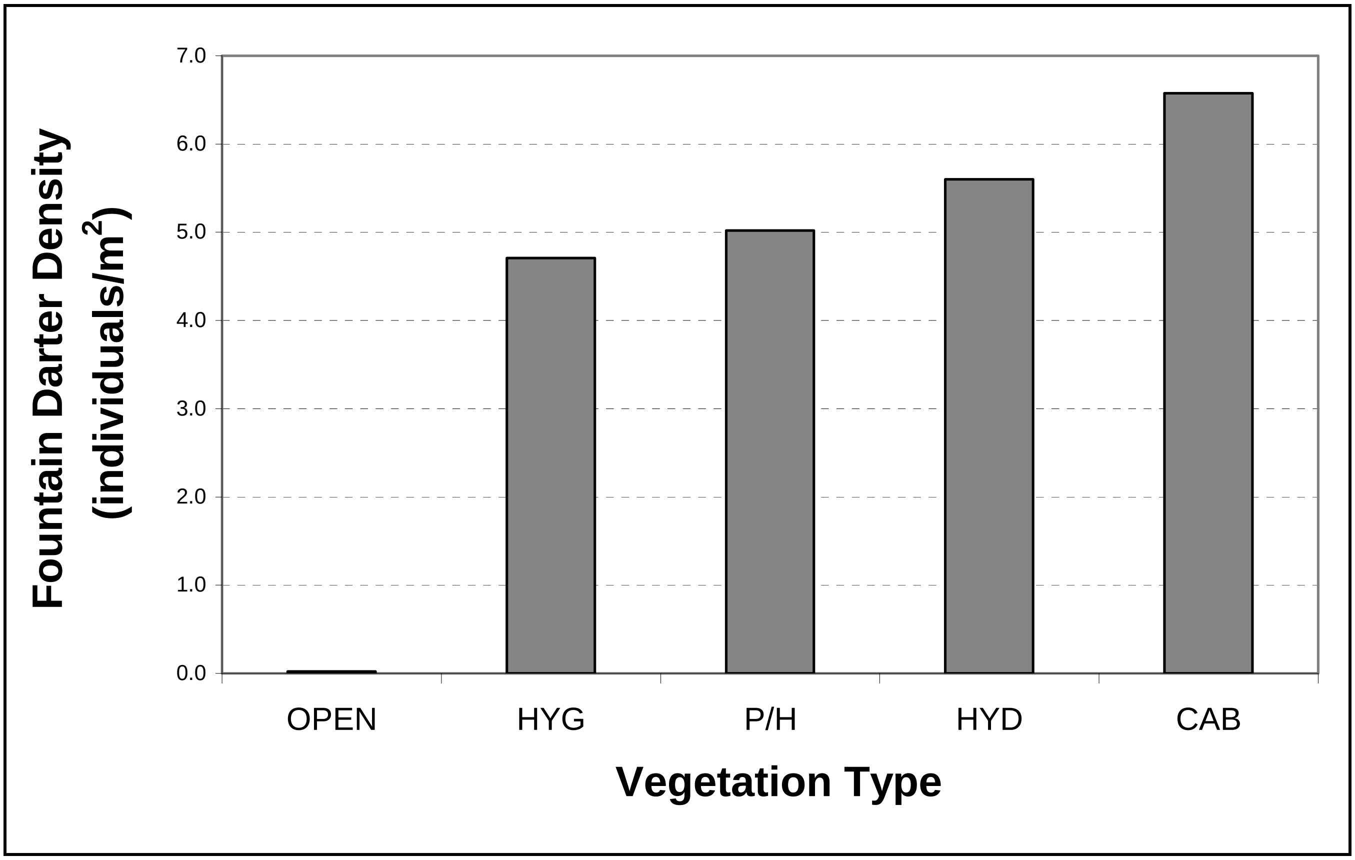

Figure 6. Density of fountain darters collected within different vegetation types in the San Marcos Springs / River ecosystem (2000-2008). HYG – *Hygrophila*, P/H – *Potamogeton* / *Hygrophila*, HYD – *Hydrlla*, CAB – *Cabomba*.

The size-class distribution for fountain darters collected by drop netting from the San Marcos Springs/River ecosystem during all sampling events combined in 2008 is presented in Appendix B. The distribution is similar to the distribution observed throughout the project and is typical of a healthy fish assemblage. When examined by reach and sample (Figures 7 and 8) the size-class distributions reveal trends similar to those observed in the Comal Springs/River ecosystem. Fall samples from both reaches are dominated by larger individuals while juvenile fountain darters are most abundant in spring samples suggesting a spring reproductive peak. However, it is not uncommon to capture darters less than 15mm total length in fall samples, suggesting that some reproduction occurs throughout the year in certain areas.

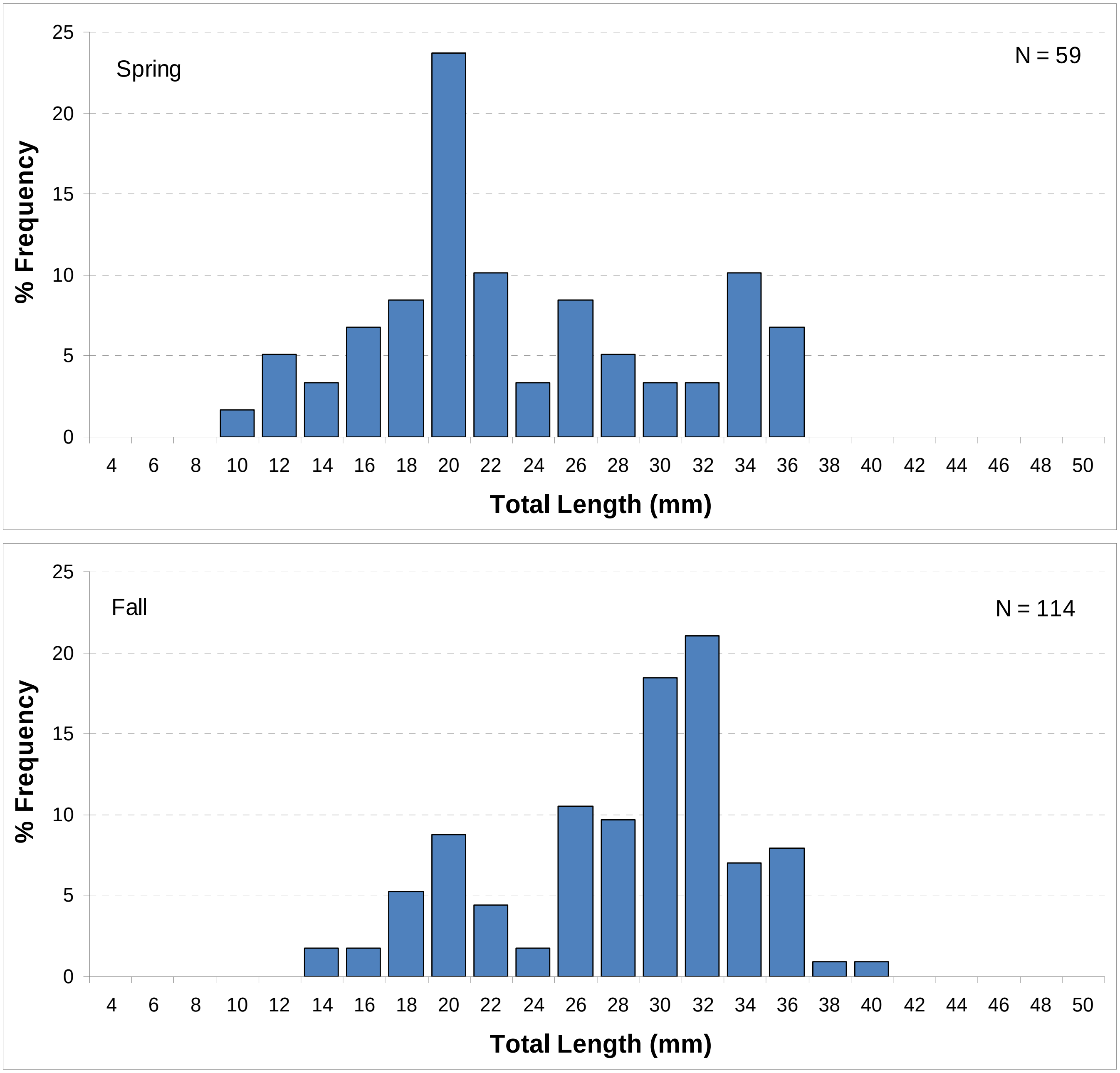

Figure 7. Length frequency distribution of fountain darters collected in samples from the City Park Reach in 2008.

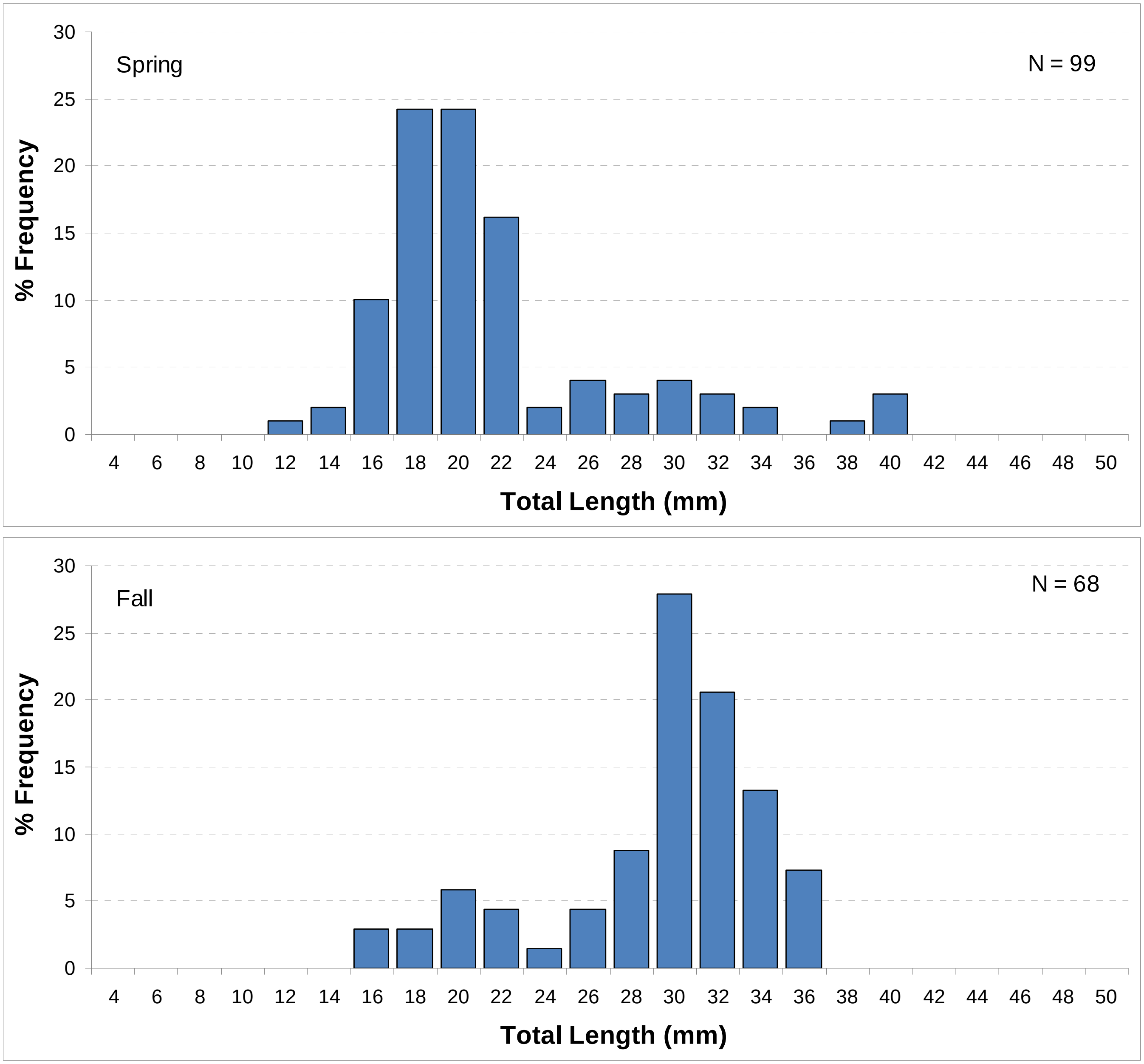

Figure 8. Length frequency distribution of fountain darters collected in samples from the I-35 Reach in 2008.

Estimates of fountain darter population abundance 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. There is little variation in the average density of fountain darters found among vegetation types in the San Marcos River. Therefore, changes in vegetation coverage do not have dramatic impacts on fountain darter abundance, and population estimates are less variable between samples than in the Comal Springs/River ecosystem (Figure 9). As in the Comal River, high-flows result in scouring of vegetation and thus, lower population estimates.

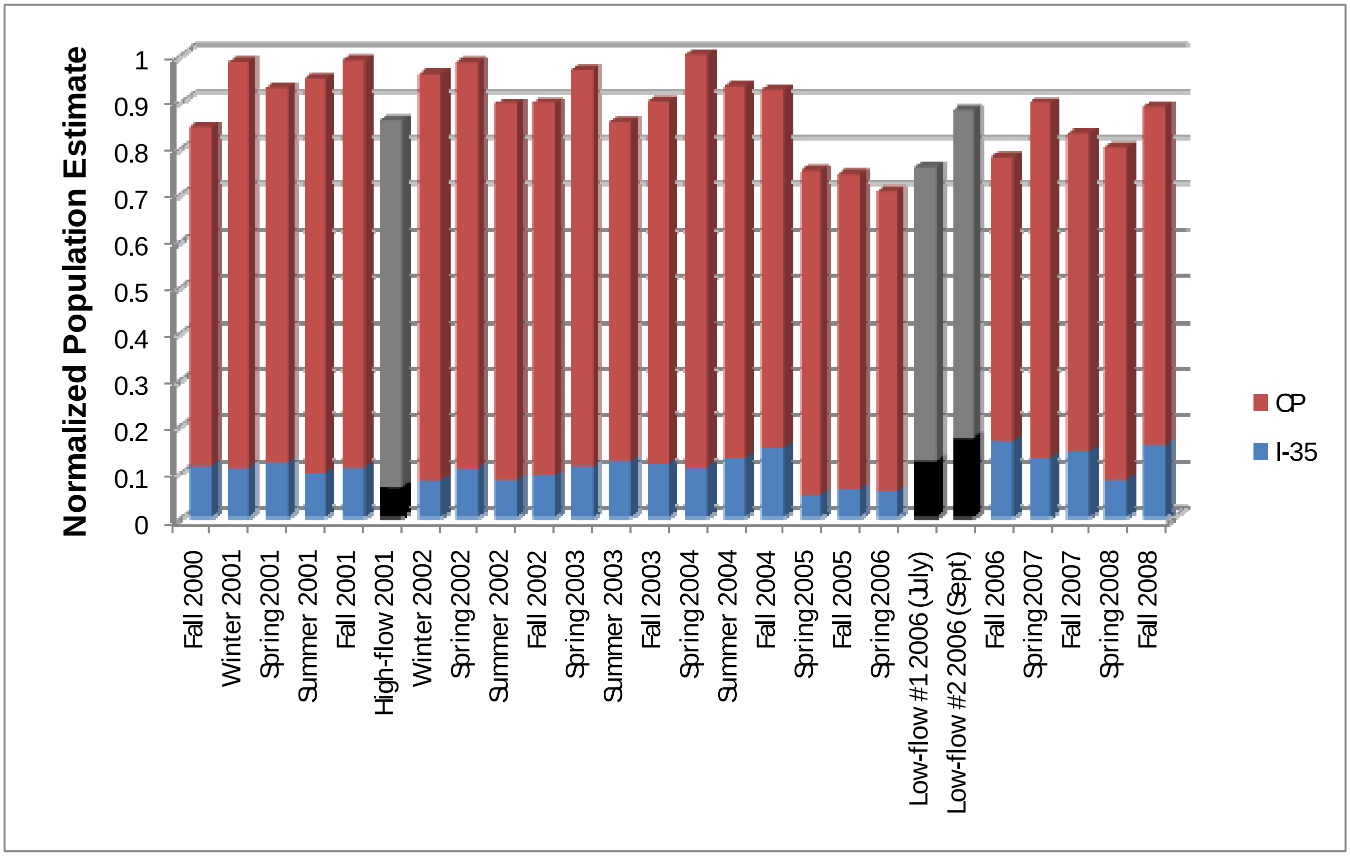

Figure 9. Population estimates of fountain daters in the San Marcos River (CP = City Park Reach, I-35 = I-35 Reach); values are normalized to a proportion of the maximum observed in any single sample. Black and gray columns represent critical period sampling events.

In addition to fountain darters, there have been 22,592 fishes representing at least 25 other taxa collected by drop netting since 2001 (Table 7). Of these, 8 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 sailfin molly (*Poecilia latipinna*). Although these species are introduced to the system, most have been established for decades, and negative impacts to the fountain darter have not been noted. However, one exotic species of particular concern is the suckermouth catfish (*Hypostomus plecostomus.*). Although these fish are rarely captured in drop nets, based on visual observations they are extremely abundant in the system. This herbivorous species has the potential to drastically affect the vegetation community and thus impact fountain darter habitats and food supplies.

Table 7. Fish species and the number of individuals collected during drop net sampling in the San Marcos Springs / River ecosystem from 2001-2008.

COMMON NAME	SCIENTIFIC NAME	STATUS	NUMBER COLLECTED	
			2008	2001-2008
Rock bass	*Ambloplites rupestris*	Introduced	37	359
Black bullhead	*Ameiurus melas*	Native	0	2
Yellow bullhead	*Ameiurus natalis*	Native	6	77
Mexican tetra	*Astyanax mexicanus*	Introduced	0	18
Rio Grande cichlid	*Cichlasoma cyanoguttatum*	Introduced	6	45
Guadalupe roundnose minnow	*Dionda nigrotaeniata*	Native	7	46
Fountain darter	*Etheostoma fonticola*	Native	340	2717
Gambusia	*Gambusia sp.*	Native	2403	20816
Suckermouth catfish	*Hypostomus plecostomus*	Exotic	2	28
Redbreast sunfish	*Lepomis auritus*	Introduced	4	44
Green sunfish	*Lepomis cyanellus*	Native	1	6
Warmouth	*Lepomis gulosus*	Native	0	22
Bluegill	*Lepomis macrochirus*	Native	1	77
Longear sunfish	*Lepomis megalotis*	Native	0	3
Redspotted sunfish	*Lepomis miniatus*	Native	50	648
Sunfish	*Lepomis sp.*	Native/Introduced	7	133
Largemouth bass	*Micropterus salmoides*	Native	0	38
Gray redhorse	*Moxostoma congestum*	Native	0	3
Blacktail shiner	*Cyprinella venusta*	Native	0	6
Texas shiner	*Notropis amabilis*	Native	0	17
Ironcolor shiner	*Notropis chalybaeus*	Native	0	54
Unknown shiner	*Notropis sp.*	Native	0	4
Tadpole madtom	*Noturus gyrinus*	Native	0	4
Blue tilapia	*Oreochromis aurea*	Exotic	0	2
Texas logperch	*Percina carbonaria*	Native	0	14
Dusky darter	*Percina sciera*	Native	0	92
Sailfin molly	*Poecilia latipinna*	Introduced	0	30
Unknown molly	*Poecilia sp.*	Introduced	0	4
TOTAL			2864	25309

Among exotic species, the giant ramshorn snail also elicits concern because of its recent impacts (early 1990s) on aquatic vegetation in the Comal River. In the fall 2000 sample, 19 giant ramshorn snails were captured in the San Marcos Springs/River ecosystem, but none were collected during 2001-2003. In 2004-2006, there were a total of 15 giant ramshorn snails collected in drop net sampling. Although the occasional empty shell is found, no live ramshorns were collected in 2007 or 2008. Data suggests that giant ramshorn snail numbers are extremely low, but close monitoring should continue because of the impact that this exotic species can have on the vegetation community under heavier densities.

Dip Netting

The boundary for each section where dip net collections were conducted is depicted on Figure 10. Section numbers are included to be consistent with the USFWS classification system for the San Marcos River. Data gathered from the Hotel Reach at Spring Lake are presented in Figure 11, 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 nets is much greater than that found in the other two reaches. Filamentous algae present in this area provide the highest quality habitat found in the San Marcos Springs/River ecosystem. The majority of 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 <58 days old (Brandt et al. 1993) and their presence in all seasons indicate year-round reproduction. However, at the City Park and I-35 sites fountain darters in the smallest size class are usually only collected in the spring months, confirming the spring reproductive peak observed in length frequency data from these locations.

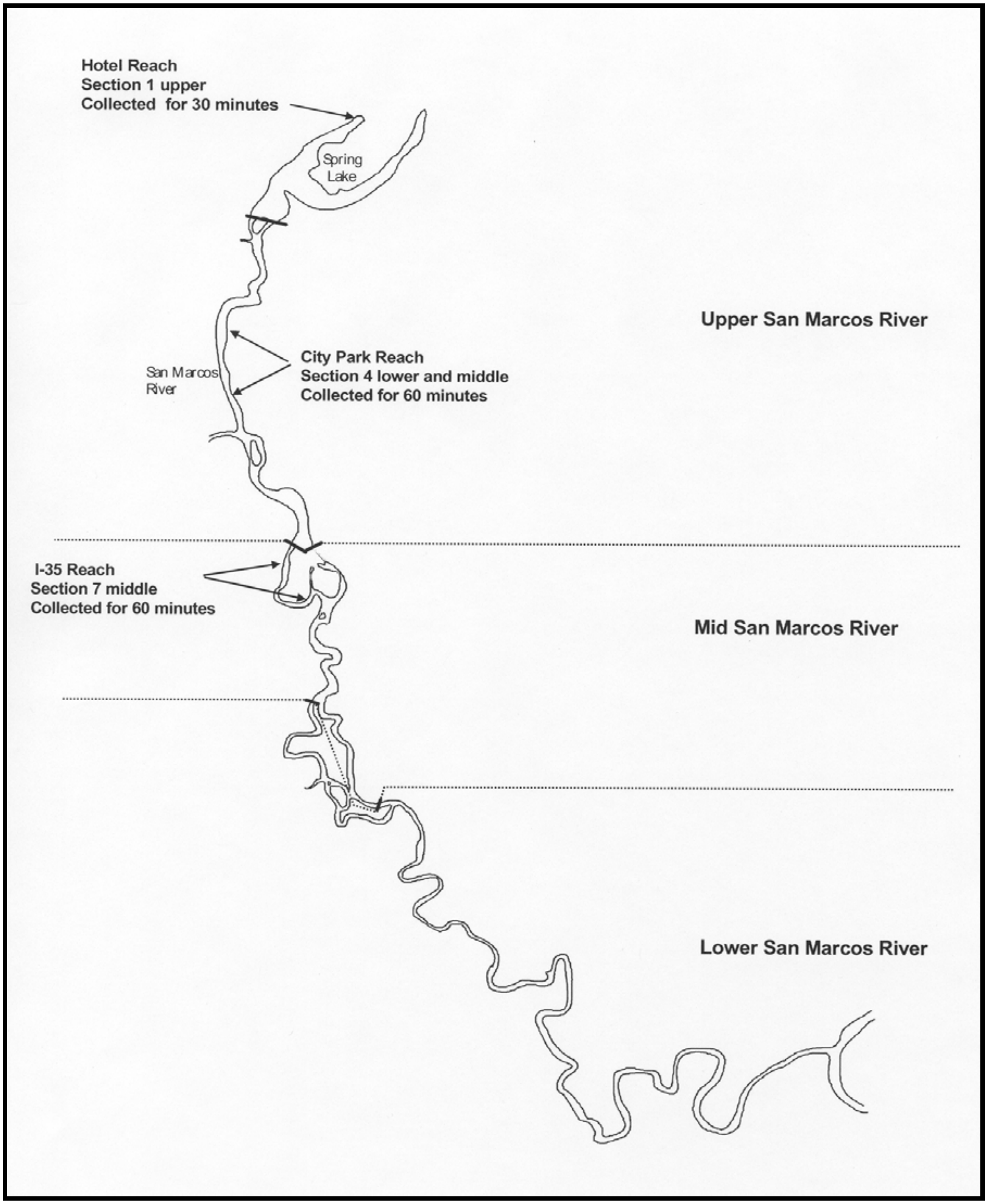

Figure 10. Map of the areas where fountain darters were collected with dip nets, then measured and released in the San Marcos River.

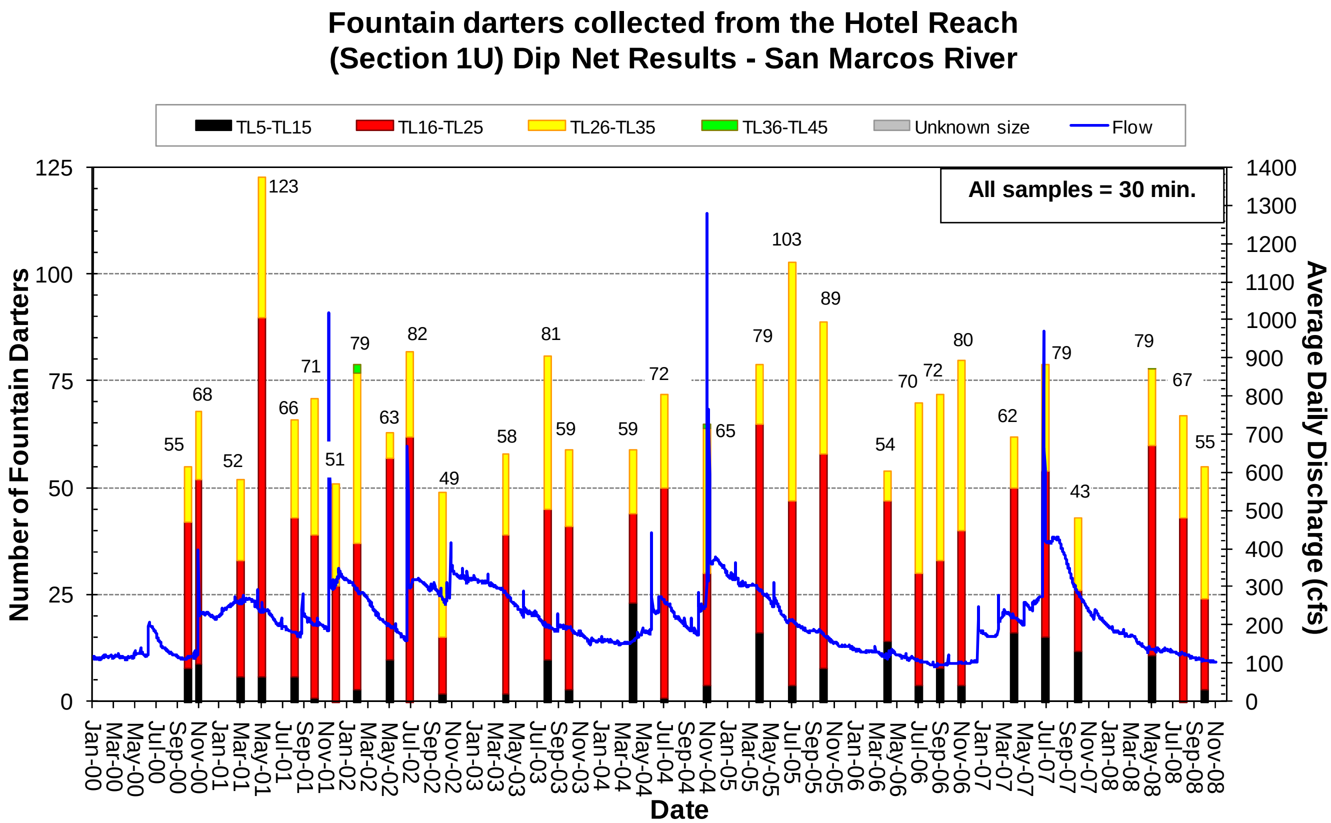

Figure 11. Number of fountain daters collected from the Hotel Reach (Section 1 Upper) of the San Marcos Springs / River ecosystem using dip nets.

Presence/Absence Dipnetting

The overall percentage of sites and percentage of dips in which fountain darters were present has varied little since initiation of this sampling technique on the San Marcos River in spring 2006 (Figure 12). The percentage of sites (n = 50) containing darters has varied from 40-58% across eight sample periods, and the percentage of dips (n = 4 @ each site = 50*4 = 200 total) containing darters has varied from 17-28%. These numbers are typically lower than those from the Comal River, demonstrating the importance of high quality habitats such as those found in the upper Comal near Landa Lake (Figure 13).

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. Therefore, data collected thus far provides a good baseline for comparison in future critical period events.

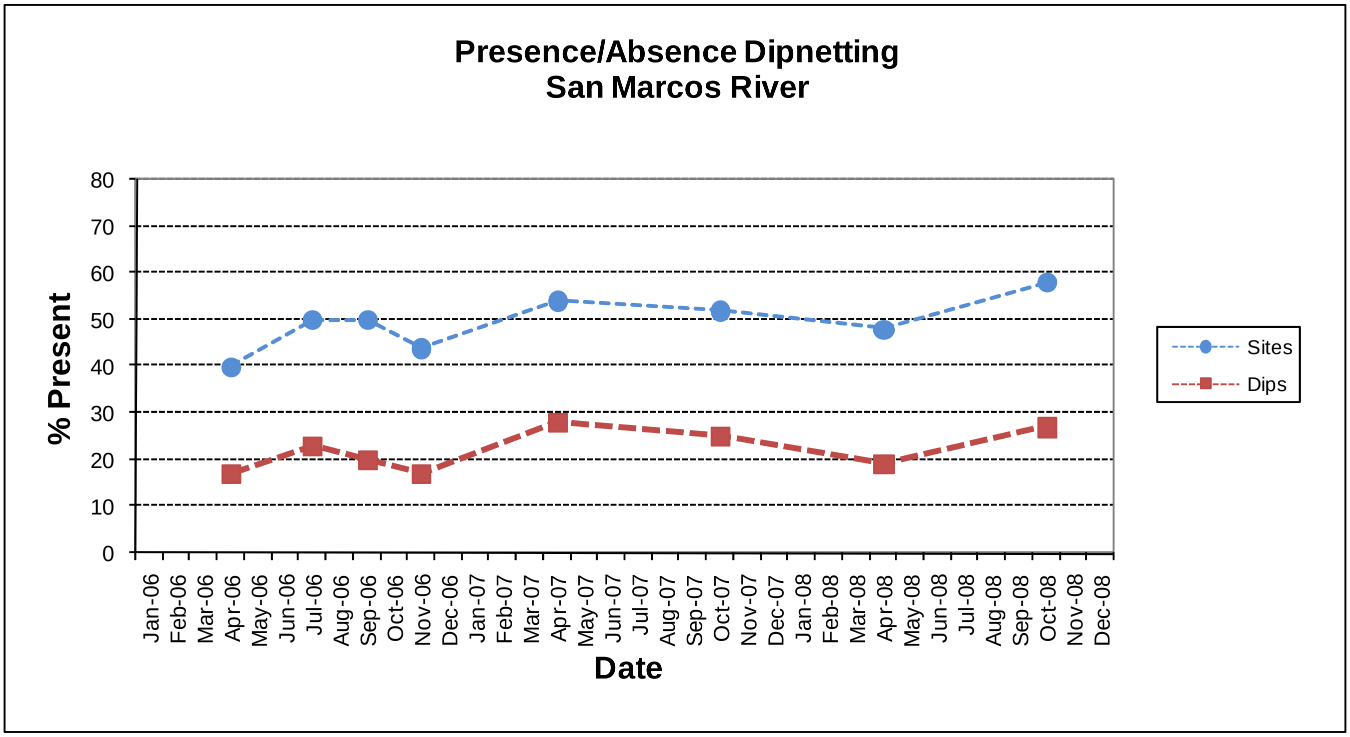

Figure 12. The percentage of sites (n = 50) and percentage of dips (n = 20) in which fountain darters were present during spring and fall sampling events in the San Marcos River (2005-2008).

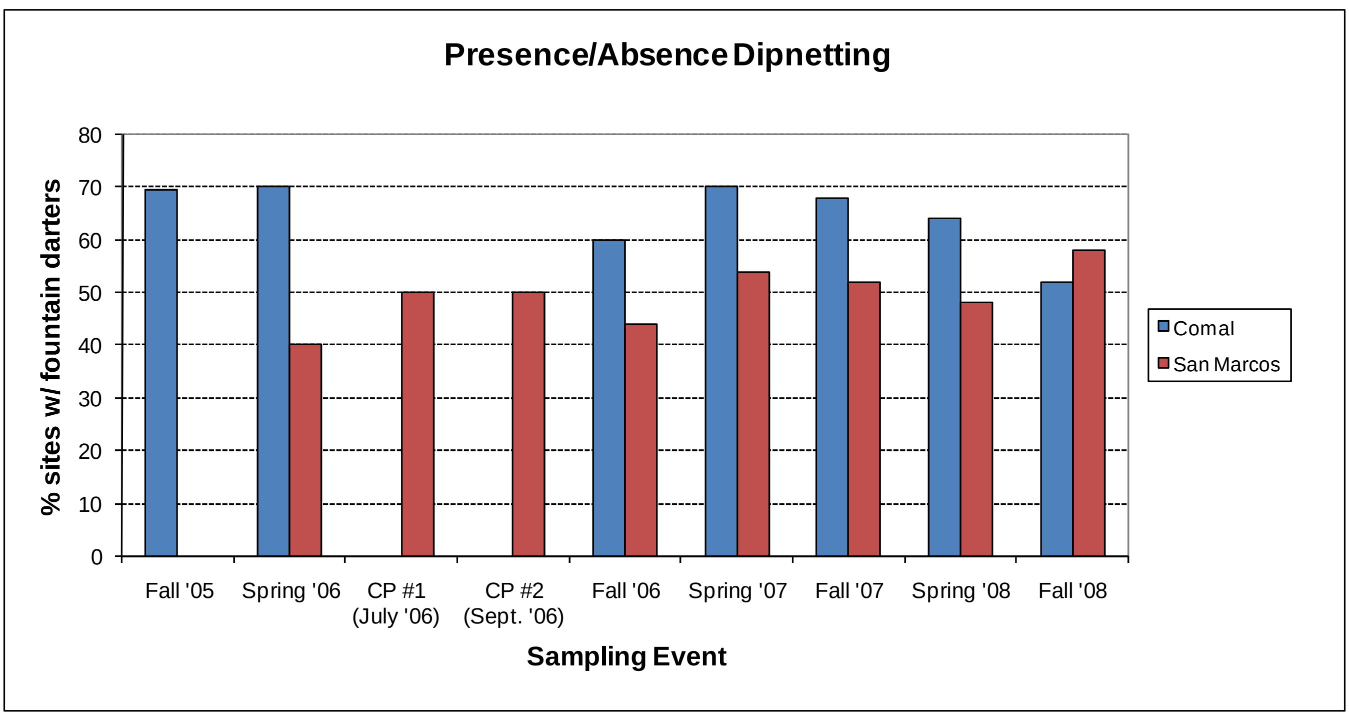

Figure 13. The percentage of sites (n = 50) in which fountain darters were present during spring and fall sampling events in the Comal and San Marcos Rivers (2005-2008).

San Marcos Salamander Visual Observations

As in previous years, filamentous algae covered sample sites 2 (Hotel Reach) and 14 with thick mats and coverage was relatively consistent throughout 2008. The abundance of algae potentially affected density estimates of San Marcos salamanders in these habitats because the area had to be cleared prior to sampling activities (i.e., disturbance may have startled salamanders and caused them to move). It is also possible that a significant portion of the San Marcos salamander population that would have been found under rocks was instead occupying the algae over top of the rocks during these times. Many salamanders were observed when clearing the area. In addition, the disturbance associated with cleaning the area may have alerted the San Marcos salamanders to the presence of the divers and impelled some individuals to retreat into deeper cavities within the rocks. Although this methodology reflects some uncertainty, it is consistent each year and allows valid comparisons among sites and seasons.

Similar densities of salamanders to previous years were observed during the lower than average flows of 2008. Nearly 17 salamanders were found per square meter in sample area 2 in the spring, and only decreased slightly by fall (Table 8). Salamander density also increased at sample area 14 in spring 2008, but fell slightly by fall. The only decrease in density from fall 2007 occurred at sample area 21, but by fall 2008 (approximately 8 salamanders/m^2), numbers were similar to 2007 levels. The decrease might be a result of manipulation of rocks that salamanders use as habitat. Several had been moved around to form rock structures in this area (see picture below). All salamander densities measured in 2008 were within the variability observed since study inception.

Example of a man-made rock structure in the Spring Lake Dam Reach

Table 8. San Marcos salamander density per square meter (m^2) during the study period.

SAMPLING PERIOD	SAMPLE AREA 2	SAMPLE AREA 14	SAMPLE AREA 21
Fall 2000	19.4	3.4	5.2
Winter 2001	8.7	Omitted	2.6
Spring 2001	9.4	13.9	0.4
Summer 2001	16.6	11.1	1.5
Fall 2001	10.0	6.7	3.2
High-flow 2001	9.7	8.6	1.0
Winter 2002	6.1	6.5	0.9
Spring 2002	20.2	8.5	0.6
Summer/High Flow 2002	17.7	4.2	0.7
Fall 2002	16.8	8.7	3.0
Spring 2003	7.9	11.9	1.0
Summer 2003	20.1	6.8	2.0
Fall 2003	11.3	9.5	2.7
Spring 2004	14.6	9.9	7.1
Summer 2004	10.9	9.2	7.0
Fall 2004	11.7	13.7	4.5
Spring 2005	18.2	7.8	3.5
Fall 2005	11.6	12.6	12.1
Spring 2006	15.5	7.7	7.1
Critical Period 1 2006	17.4	8.4	7.9
Critical Period 2 2006	16.1	19.2	7.5
Spring 2007	8.99	13.68	2.82
Fall 2007	9.19	8.11	9.07
Spring 2008	16.8	12.3	6.00
Fall 2008	15.1	11.7	8.55

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BIO-WEST. 2008. Comprehensive and Critical Period Monitoring Program to Evaluate the Effects of Variable Flow on Biological Resources in the Comal River Aquatic Ecosystem. Final 2007 Annual Report. Edwards Aquifer Authority. 35 pp.

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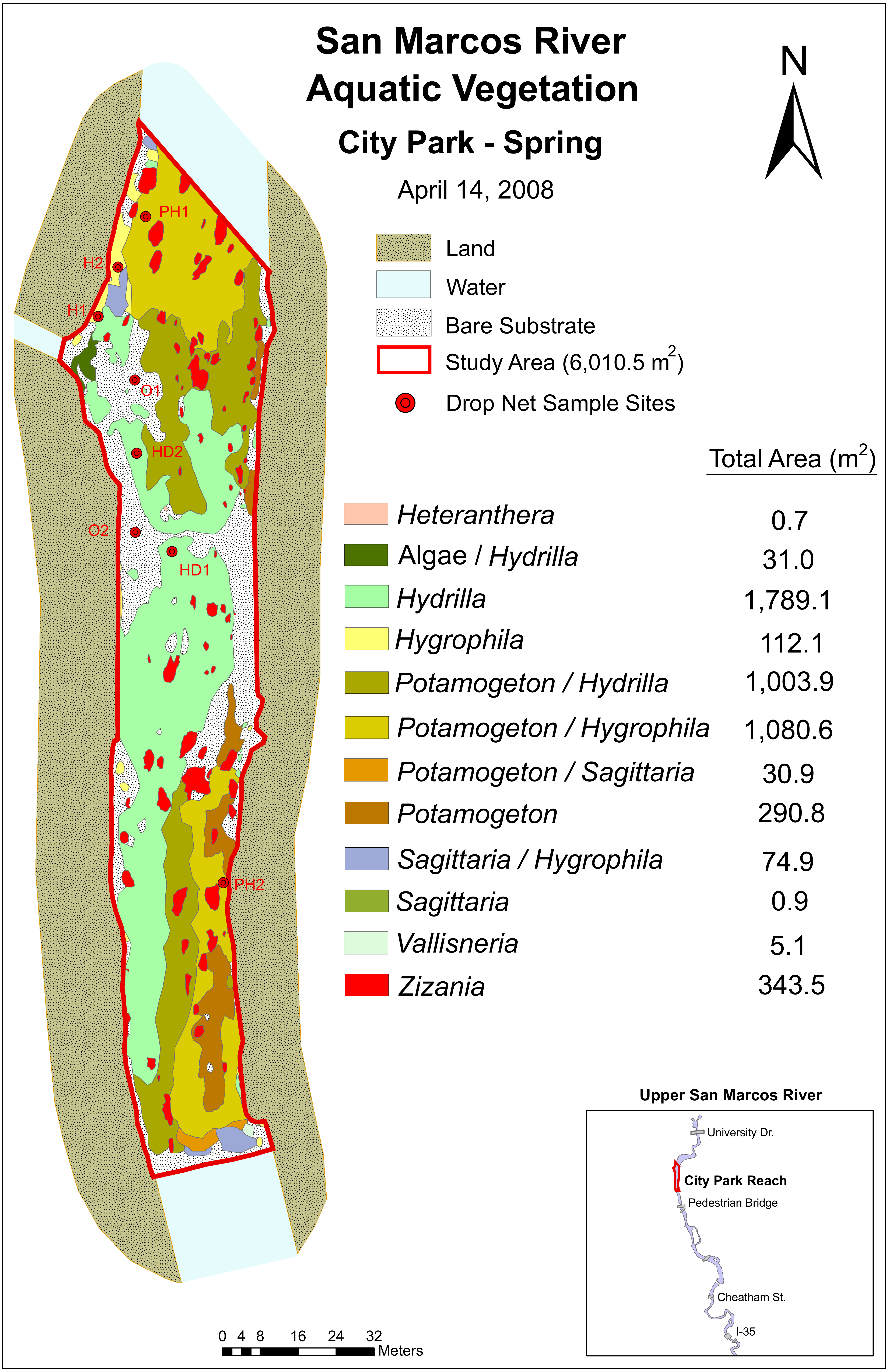
APPENDIX A:
AQUATIC VEGETATION MAPS

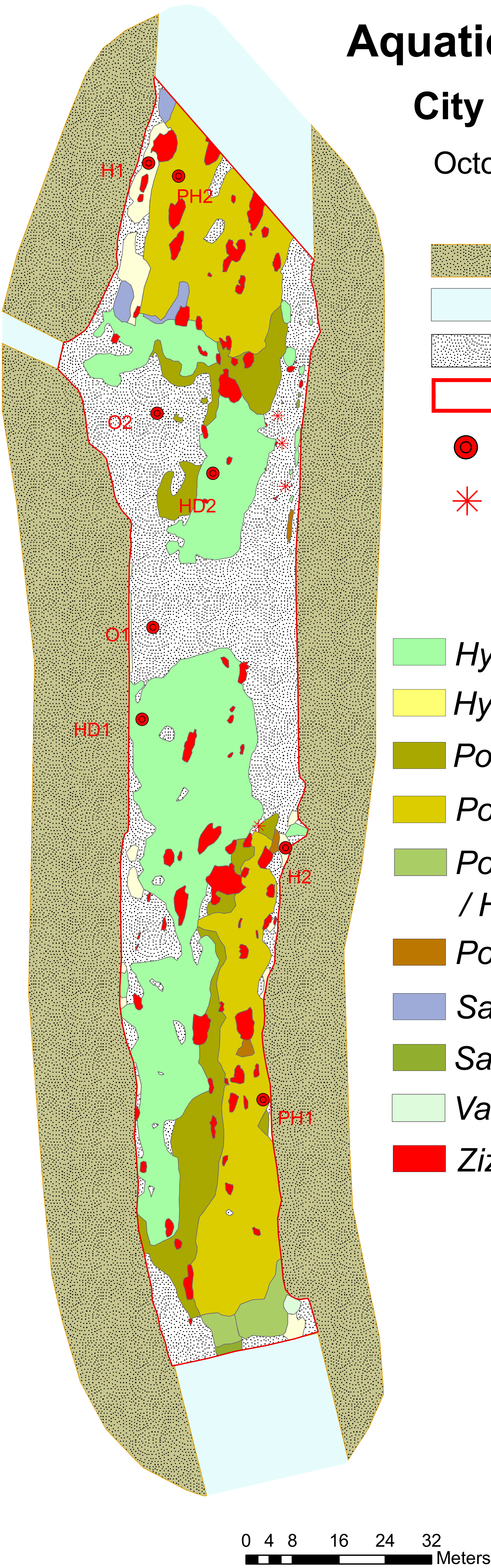
City Park Reach


San Marcos River
Aquatic Vegetation
City Park - Spring
April 14, 2008
N
Land
Water
Bare Substrate
Study Area (6,010.5 m2)
Drop Net Sample Sites
Total Area (m2)
Heteranthera 0.7
Algae / Hydrilla 31.0
Hydrilla 1,789.1
Hygrophila 112.1
Potamogeton / Hydrilla 1,003.9
Potamogeton / Hygrophila 1,080.6
Potamogeton / Sagittaria 30.9
Potamogeton 290.8
Sagittaria / Hygrophila 74.9
Sagittaria 0.9
Vallisneria 5.1
Zizania 343.5
PH1
H2
H1
O1
HD2
O2
HD1
PH2
0 4 8 16 24 32
Meters
Upper San Marcos River
University Dr.
City Park Reach
Pedestrian Bridge
Cheatham St.
I-35

San Marcos River Aquatic Vegetation

City Park - Fall

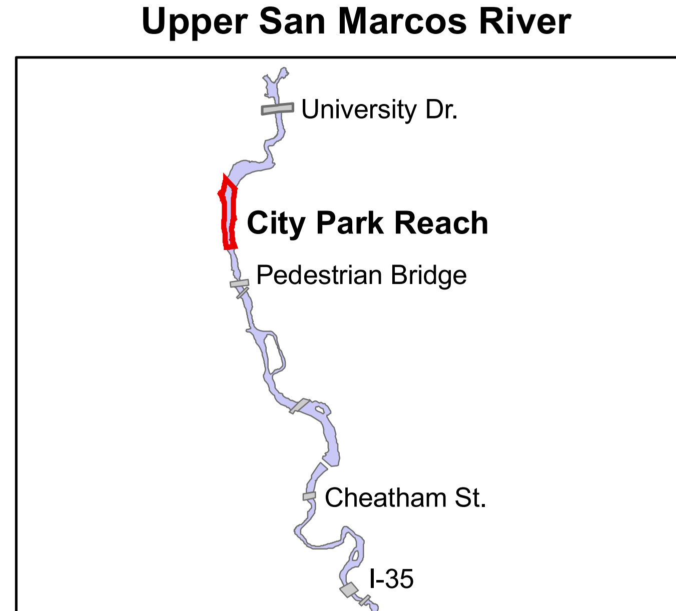
October 20, 2008



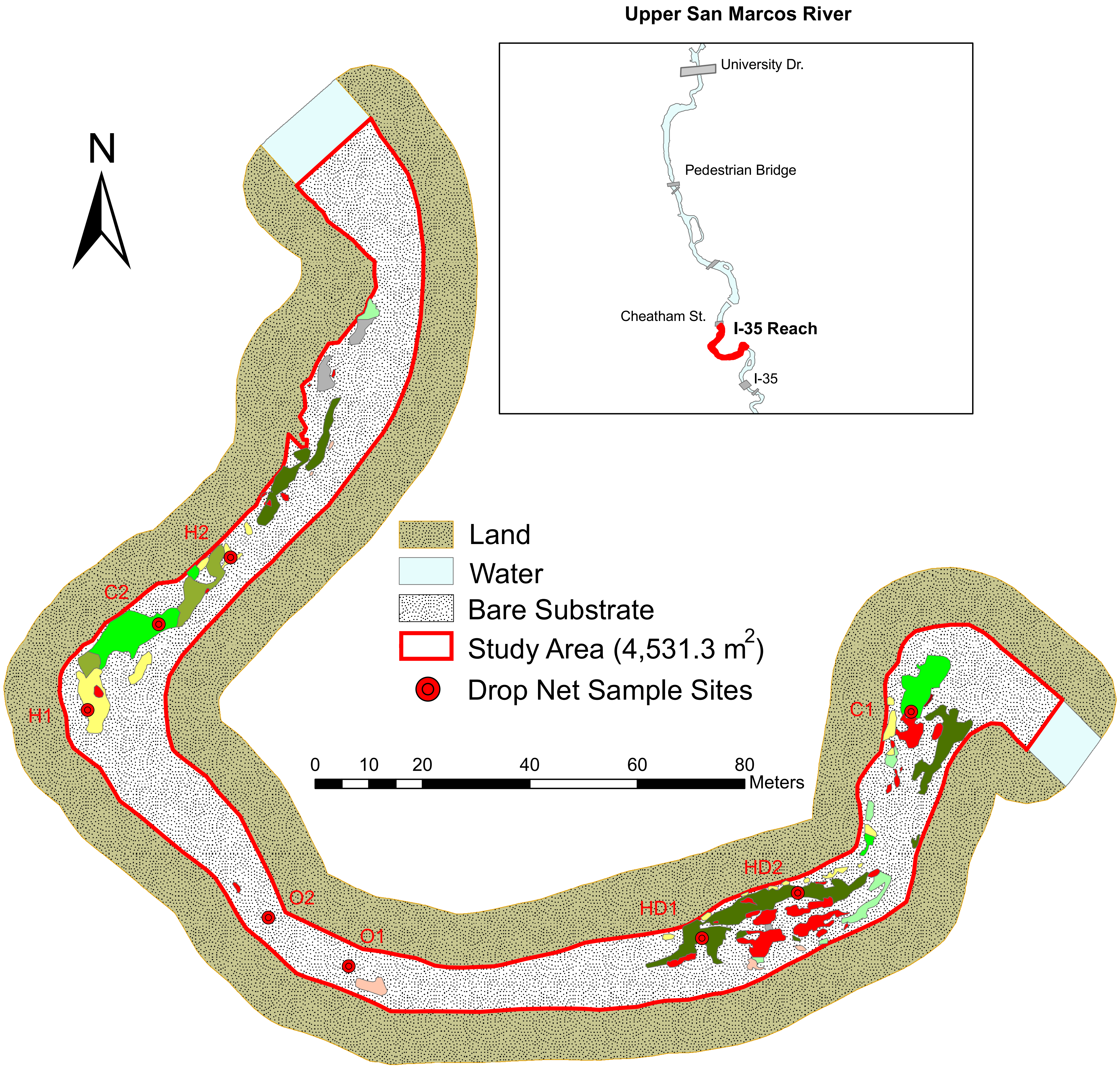
- Land
- Water
- Bare Substrate
- Study Area (6,010.5 m^2)
- Drop Net Sample Sites
- Small *Zizania* Plants

	Total Area (m^2)
Hydrilla	1,618.5
Hygrophila	142.2
Potamogeton / Hydrilla	503.2
Potamogeton / Hygrophila	1,272.4
Potamogeton / Sagittaria / Hygrophila	92.9
Potamogeton	14.3
Sagittaria / Hygrophila	44.5
Sagittaria	8.0
Vallisneria	7.2
Zizania	288.6

Upper San Marcos River



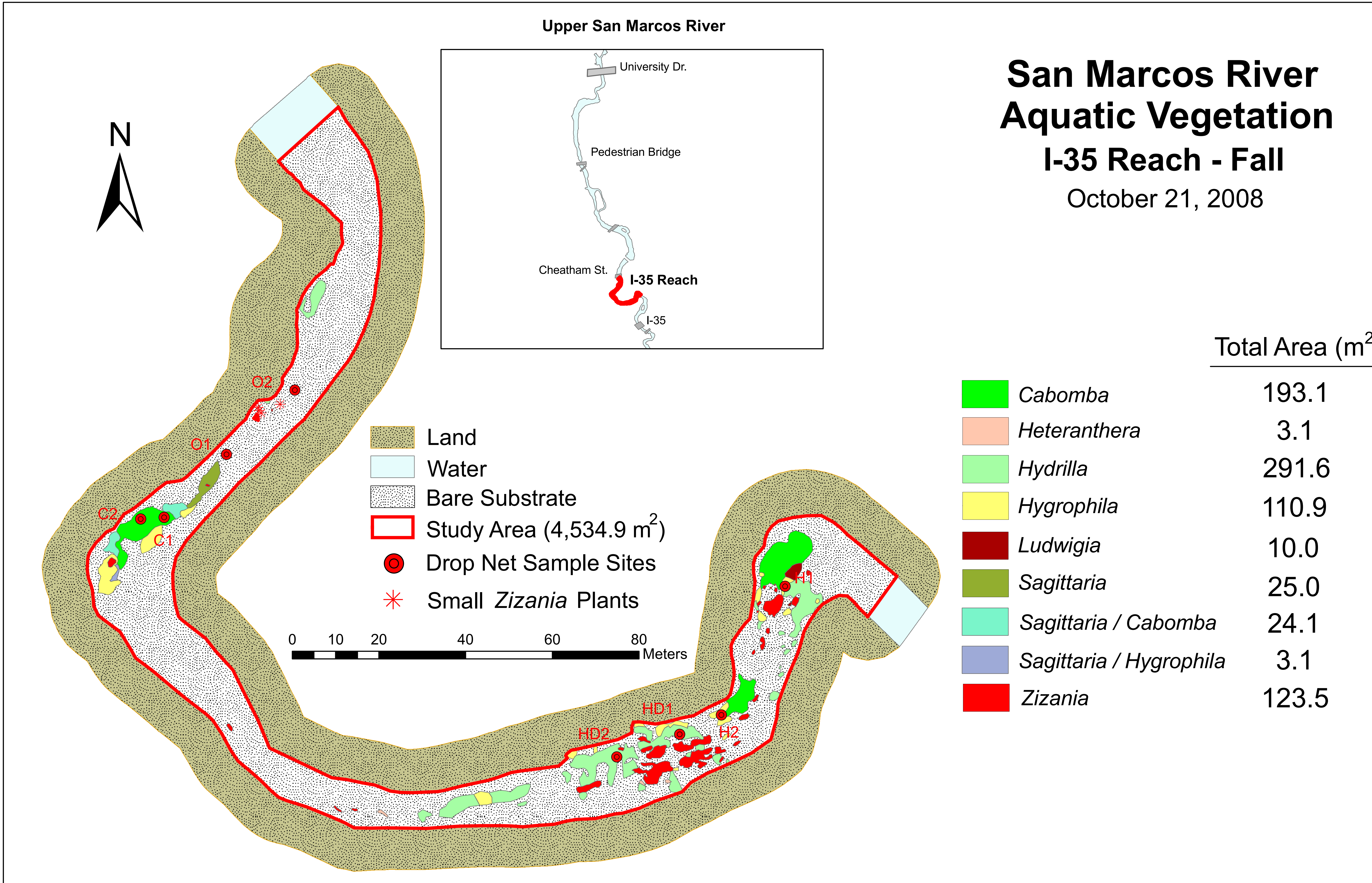
IH-35 Reach



San Marcos River Aquatic Vegetation
I-35 Reach - Spring

April 17, 2008

	Total Area (m^2)
Cabomba	150.6
Heteranthera	18.8
Hydrilla	42.2
Hygrophila	96.4
Algae	25.4
Ludwigia	1.3
Sagittaria	55.9
Zizania	119.4
Hydrilla / Algae	246.9



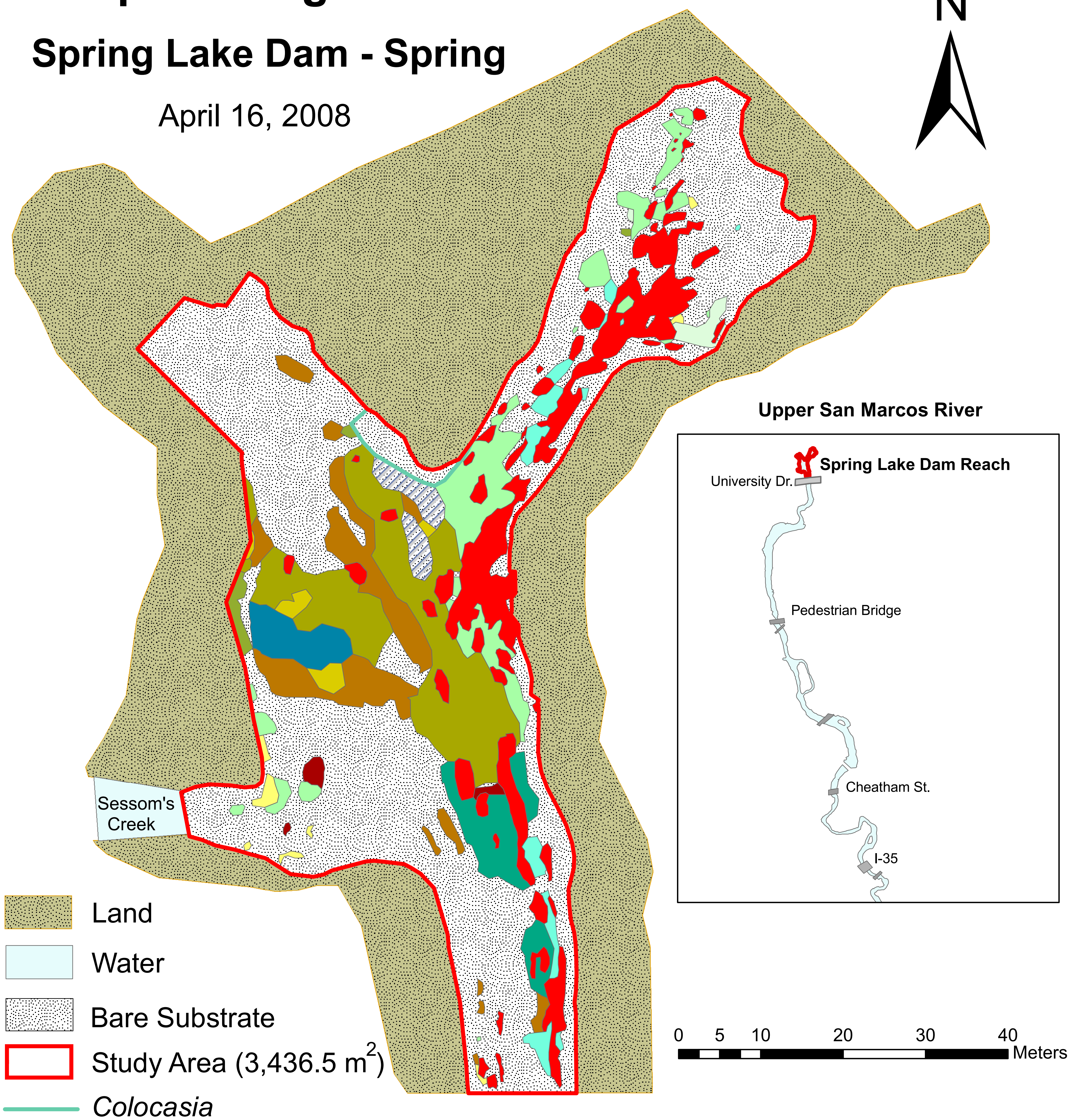
San Marcos River
Aquatic Vegetation
I-35 Reach - Fall
October 21, 2008
Upper San Marcos River
University Dr.
Pedestrian Bridge
Cheatham St.
I-35 Reach
I-35
N
Land
Water
Bare Substrate
Study Area (4,534.9 m2)
Drop Net Sample Sites
Small Zizania Plants
0 10 20 40 60 80 Meters
O2
O1
C2
C1
HD1
HD2
H1
H2
Total Area (m2)
Cabomba 193.1
Heteranthera 3.1
Hydrilla 291.6
Hygrophila 110.9
Ludwigia 10.0
Sagittaria 25.0
Sagittaria / Cabomba 24.1
Sagittaria / Hygrophila 3.1
Zizania 123.5

Spring Lake Dam Reach

San Marcos River Aquatic Vegetation

Spring Lake Dam - Spring

April 16, 2008

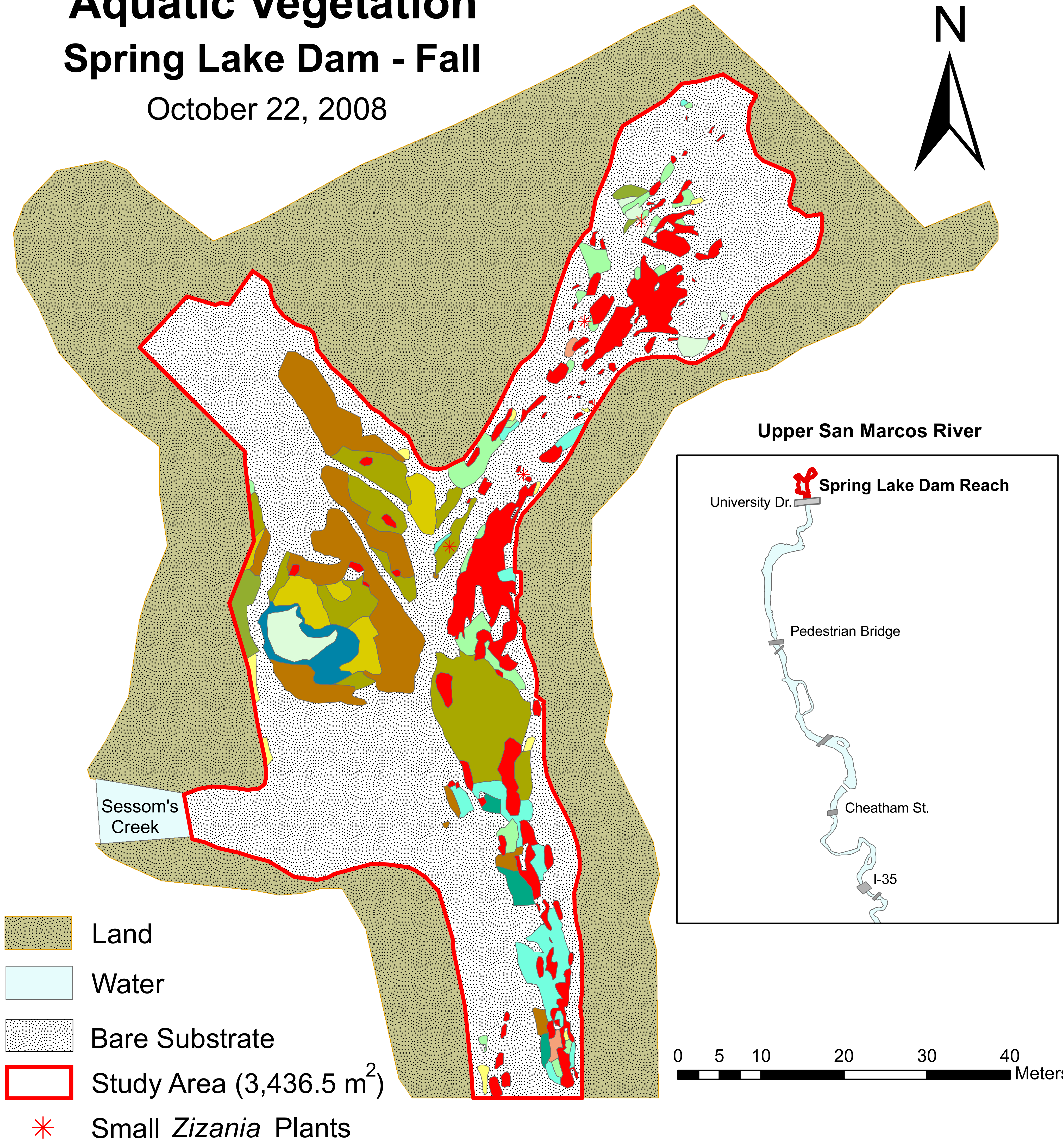


	Total Area (m^2)		Total Area (m^2)
Hydrilla	186.9	*Vallisneria*	18.9
Hydrocotyle	55.9	*Potamogeton / Hydrilla*	355.4
Hygrophila	16.8	*Potamogeton / Hydrocotyle*	96.2
Ludwigia	12.2	*Potamogeton / Hygrophila*	23.8
Potamogeton	732.8	*Potamogeton / Vallisneria*	59.9
Sagittaria	17.7	Floating Vegetation Mat	48.3
Zizania	384.8		

San Marcos River Aquatic Vegetation

Spring Lake Dam - Fall

October 22, 2008



	Total Area (m^2)		Total Area (m^2)
Hydrilla	75.8	*Vallisneria*	43.6
Hydrocotyle	82.0	*Potamogeton / Hydrilla*	248.3
Hygrophila	16.4	*Potamogeton / Hydrocotyle*	18.1
Potamogeton	258.5	*Potamogeton / Hygrophila*	70.5
Sagittaria	27.2	*Potamogeton / Vallisneria*	40.0
Zizania	295.7	*Hydrilla / Hydrocotyle*	5.9

Texas Wild-Rice

San Marcos River

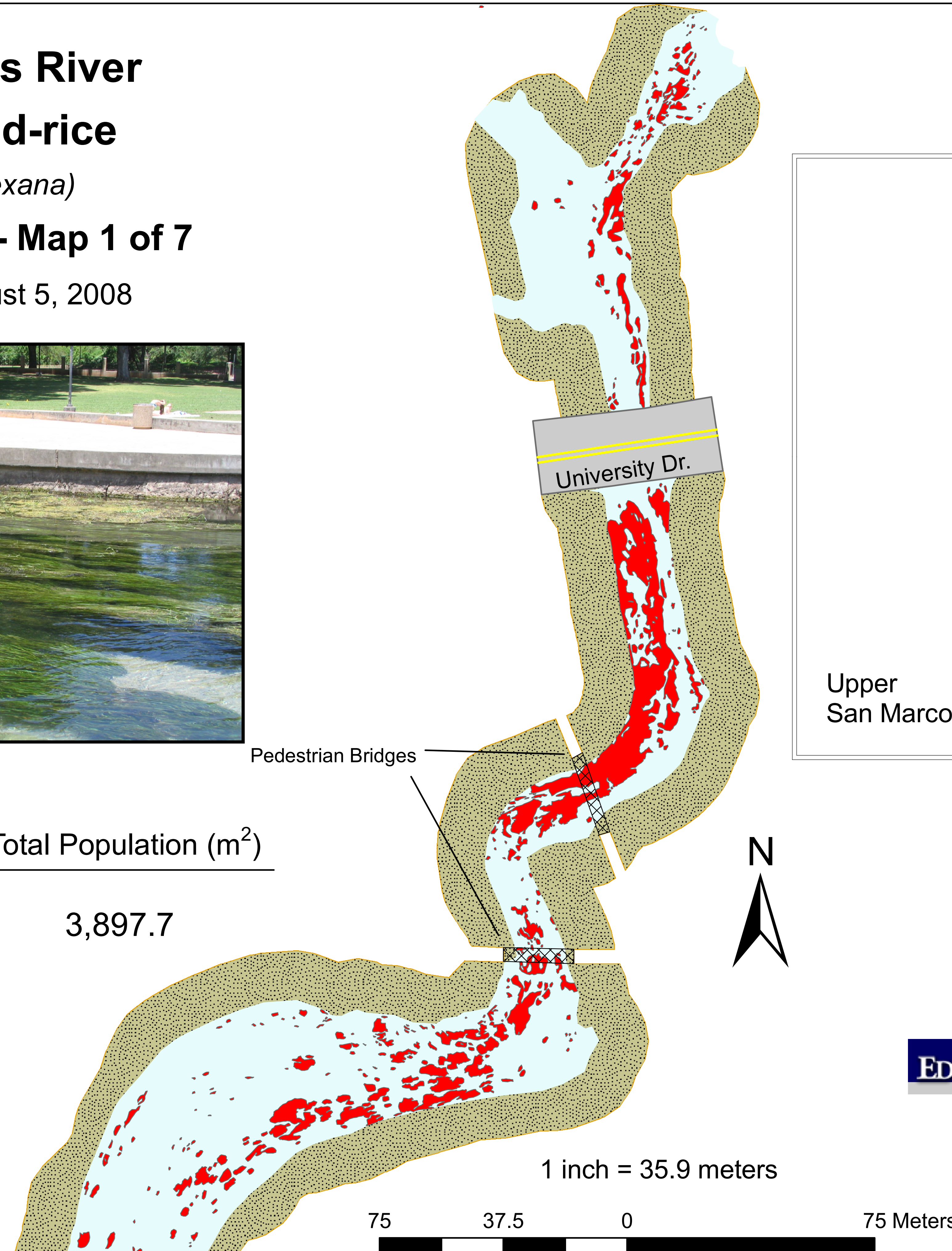
Texas wild-rice

(Zizania texana)

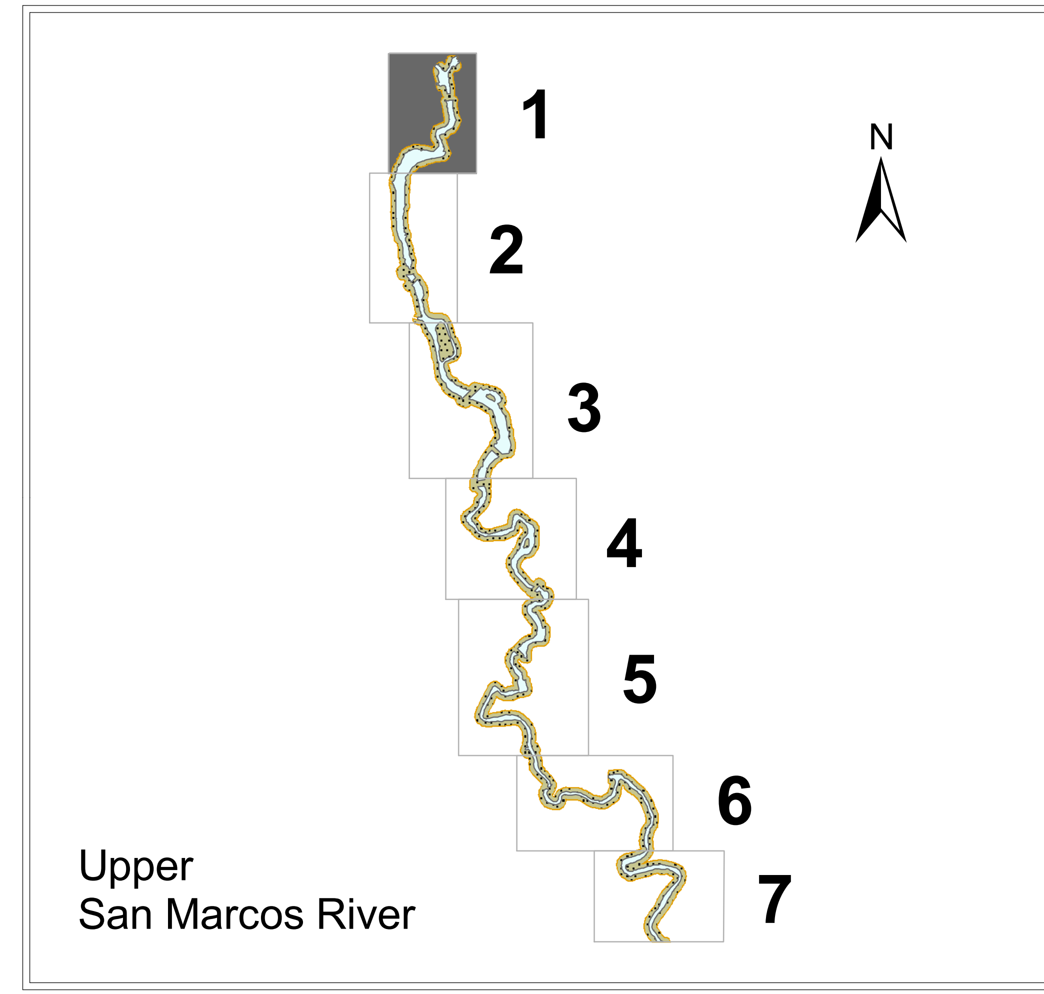
Summer 2008 - Map 1 of 7

July 28 - August 5, 2008

	Map 1 (m^2)	Total Population (m^2)
Zizania	2,462.1	3,897.7



Project Location



BIO-WEST, Inc.

EDWARDS AQUIFER AUTHORITY

San Marcos River

Texas wild-rice

(Zizania texana)

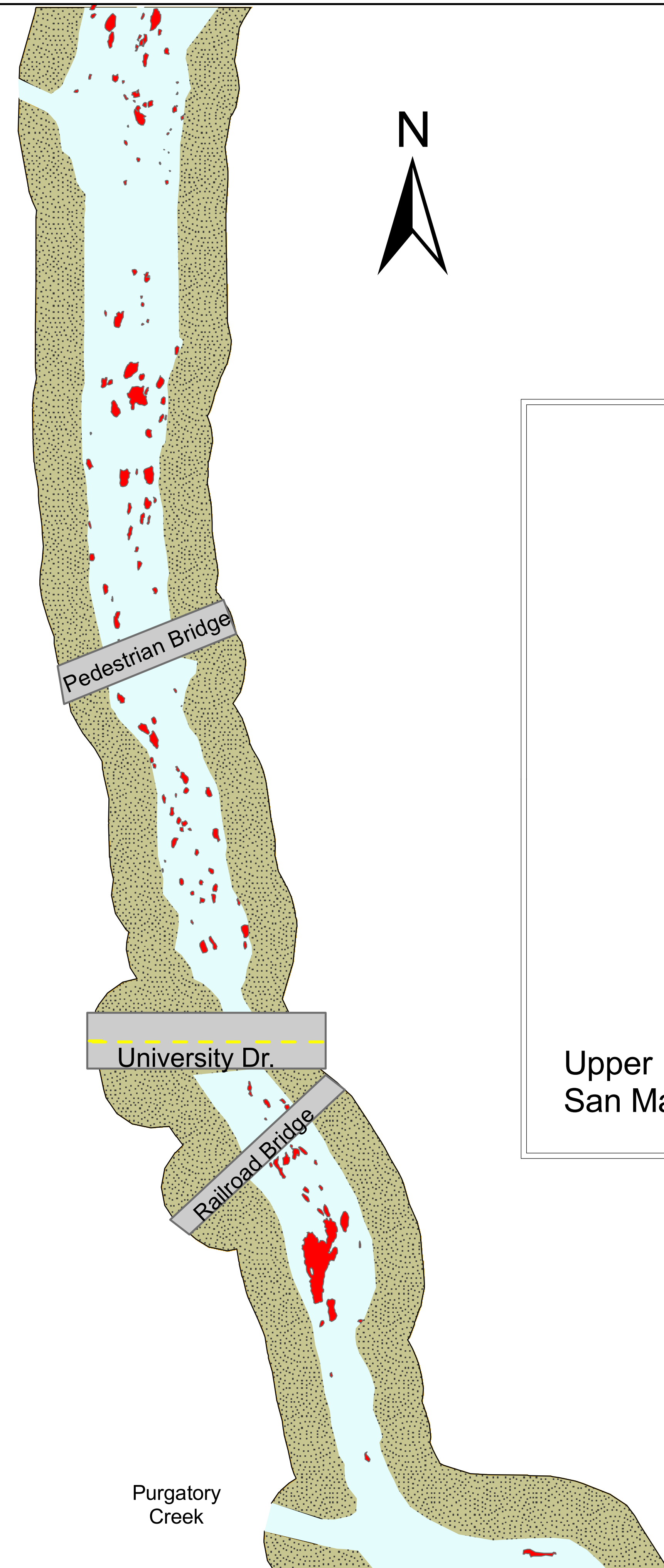
Summer 2008 - Map 2 of 7

July 28 - August 5, 2008

	Map 2 (m^2)	Total Population (m^2)
Zizania	566.3	3,646.4

1 inch = 45.8 meters

120 60 0 120 Meters



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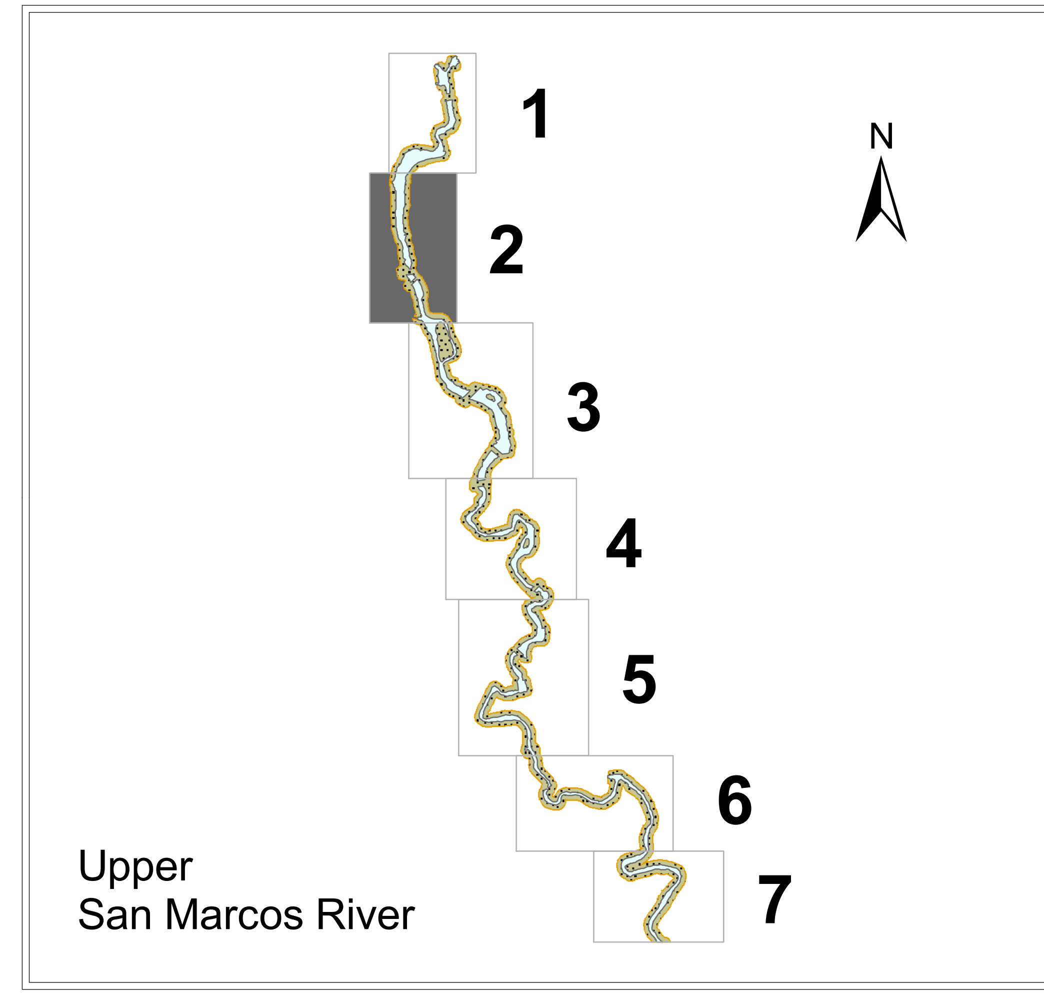


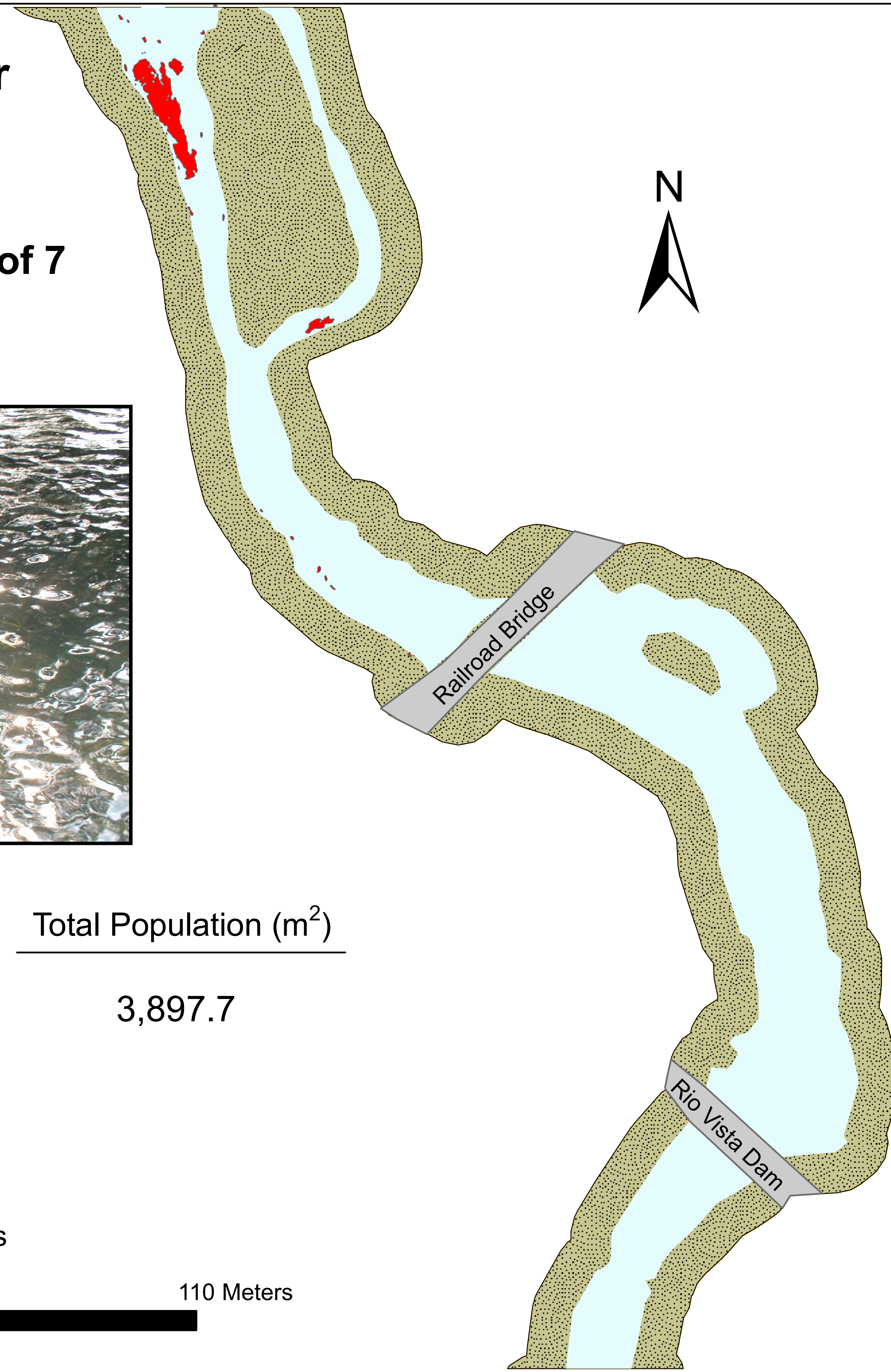
BIO-WEST, Inc.

EDWARDS AQUIFER AUTHORITY

San Marcos River
Texas wild-rice
(Zizania texana)

Summer 2008 - Map 3 of 7

July 28 - August 5, 2008

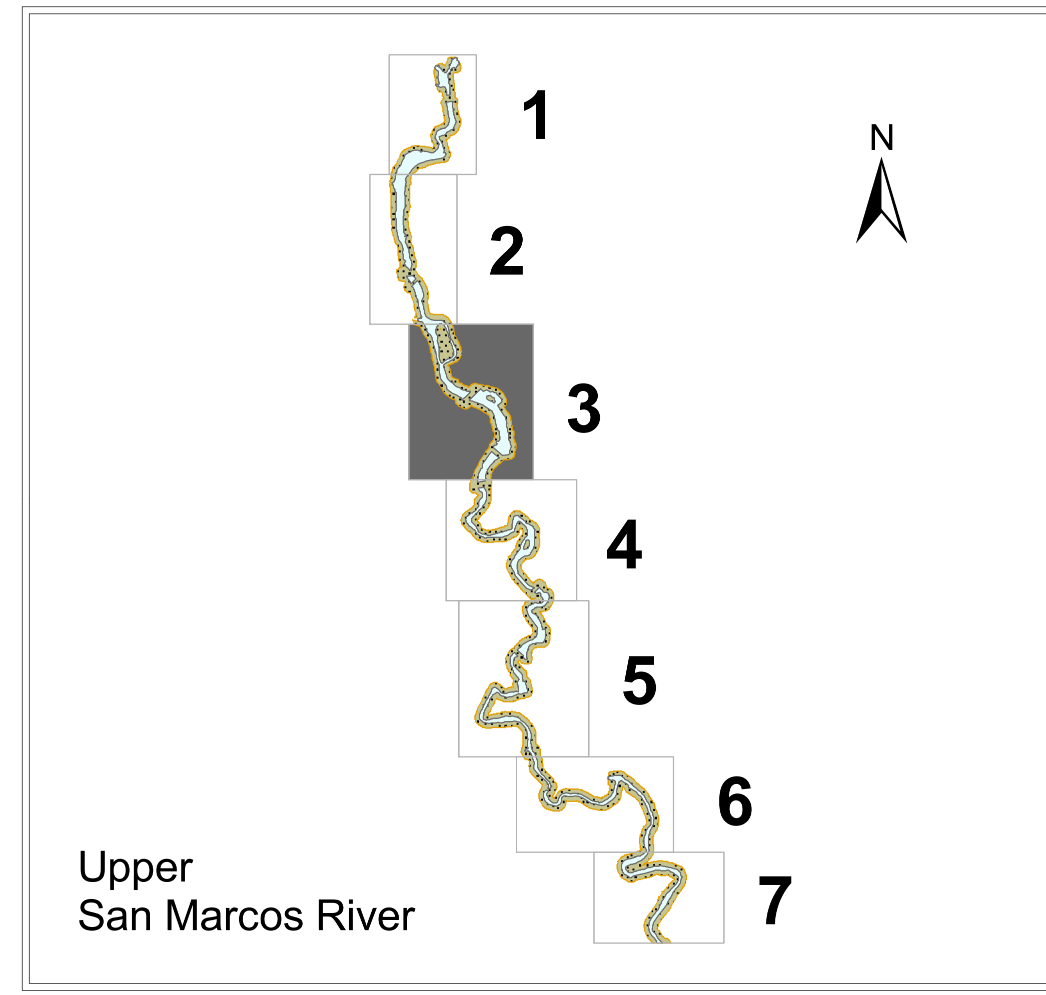


	Map 3 (m^2)	Total Population (m^2)
Zizania	376.7	3,897.7

1 inch = 48 meters

110 55 0 110 Meters

Project Location



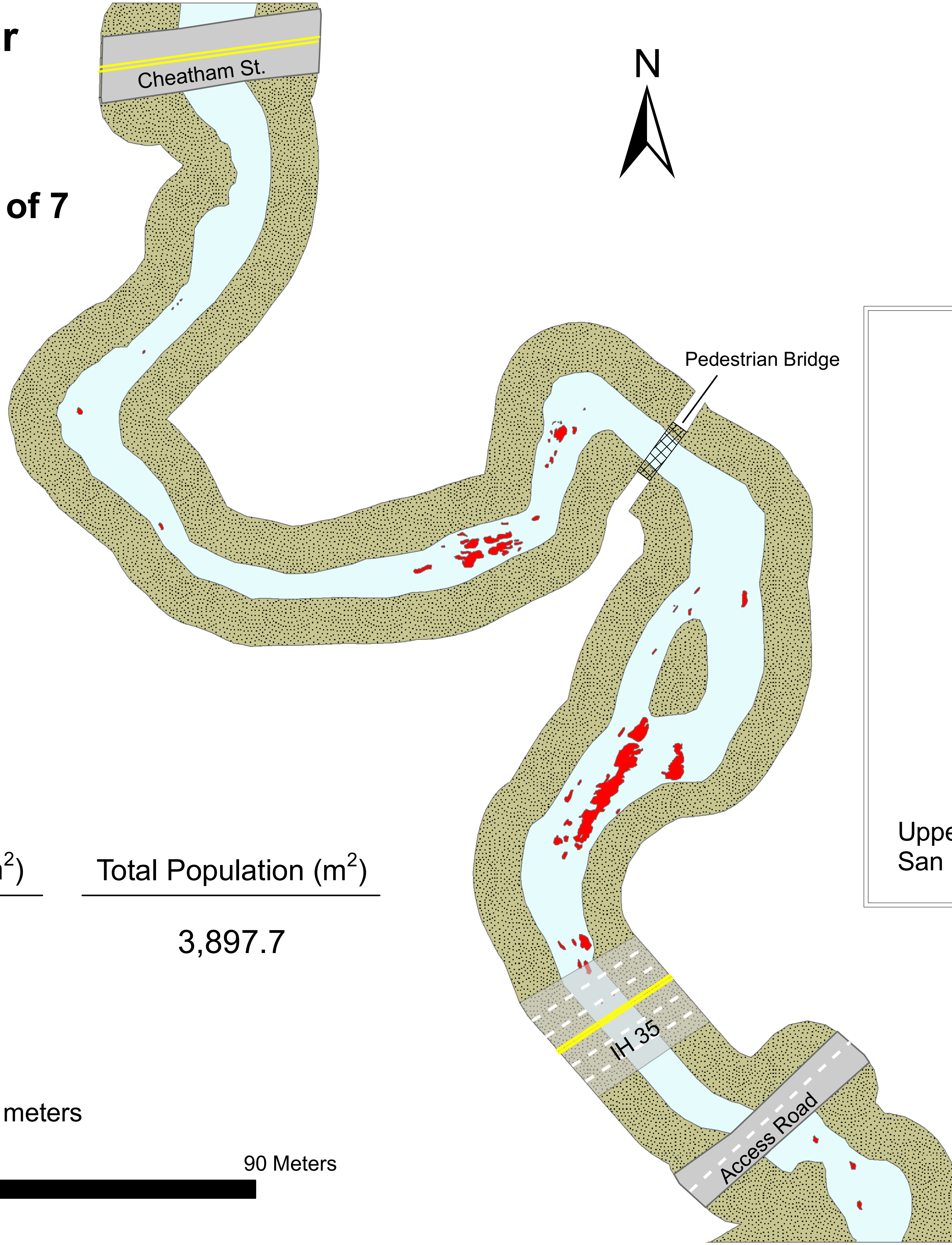
BIO-WEST, Inc.

EDWARDS AQUIFER AUTHORITY

San Marcos River
Texas wild-rice
(Zizania texana)

Summer 2008 - Map 4 of 7

July 28 - August 5, 2008

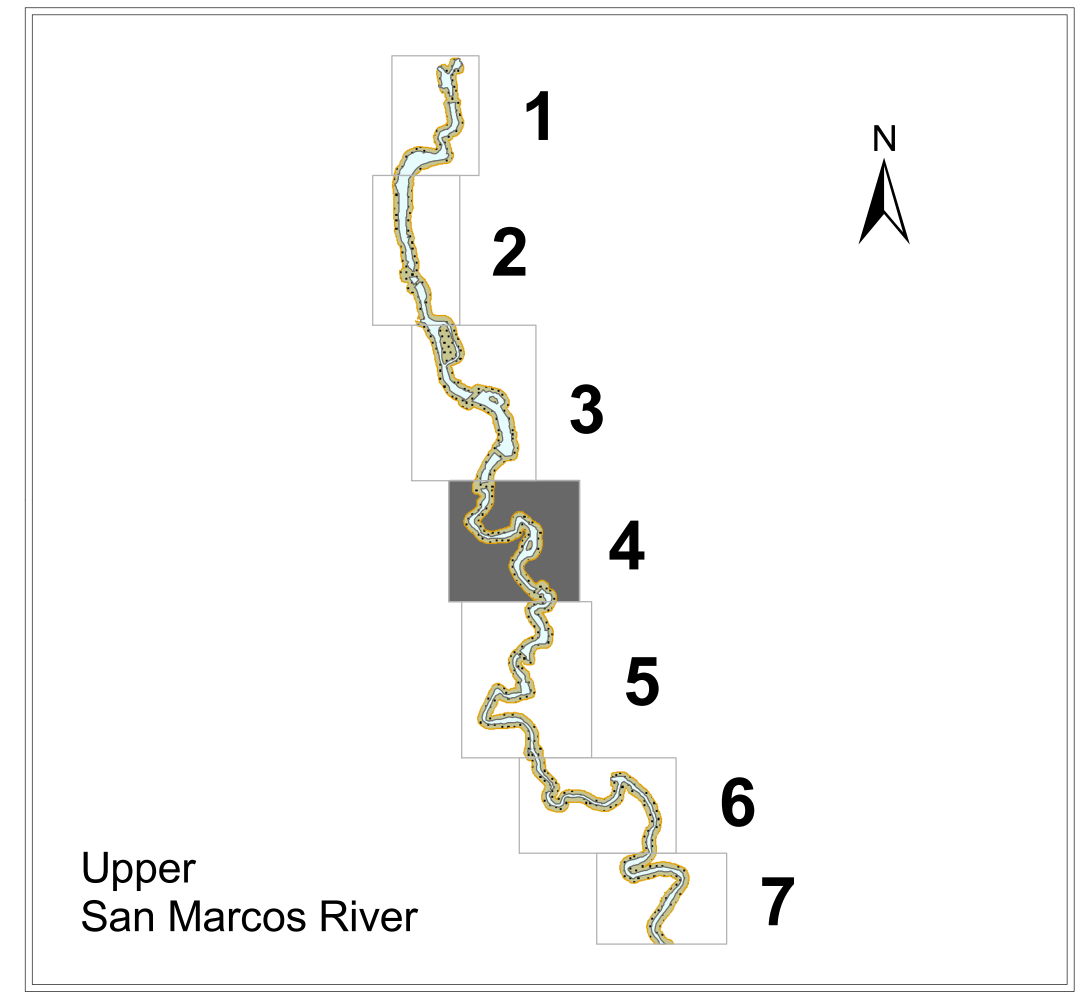


	Map 4 (m^2)	Total Population (m^2)
Zizania	403.7	3,897.7

1 inch = 37.2 meters

90 45 0 90 Meters

Project Location



BIO-WEST, Inc.

EDWARDS AQUIFER AUTHORITY

San Marcos River

Texas wild-rice

(Zizania texana)

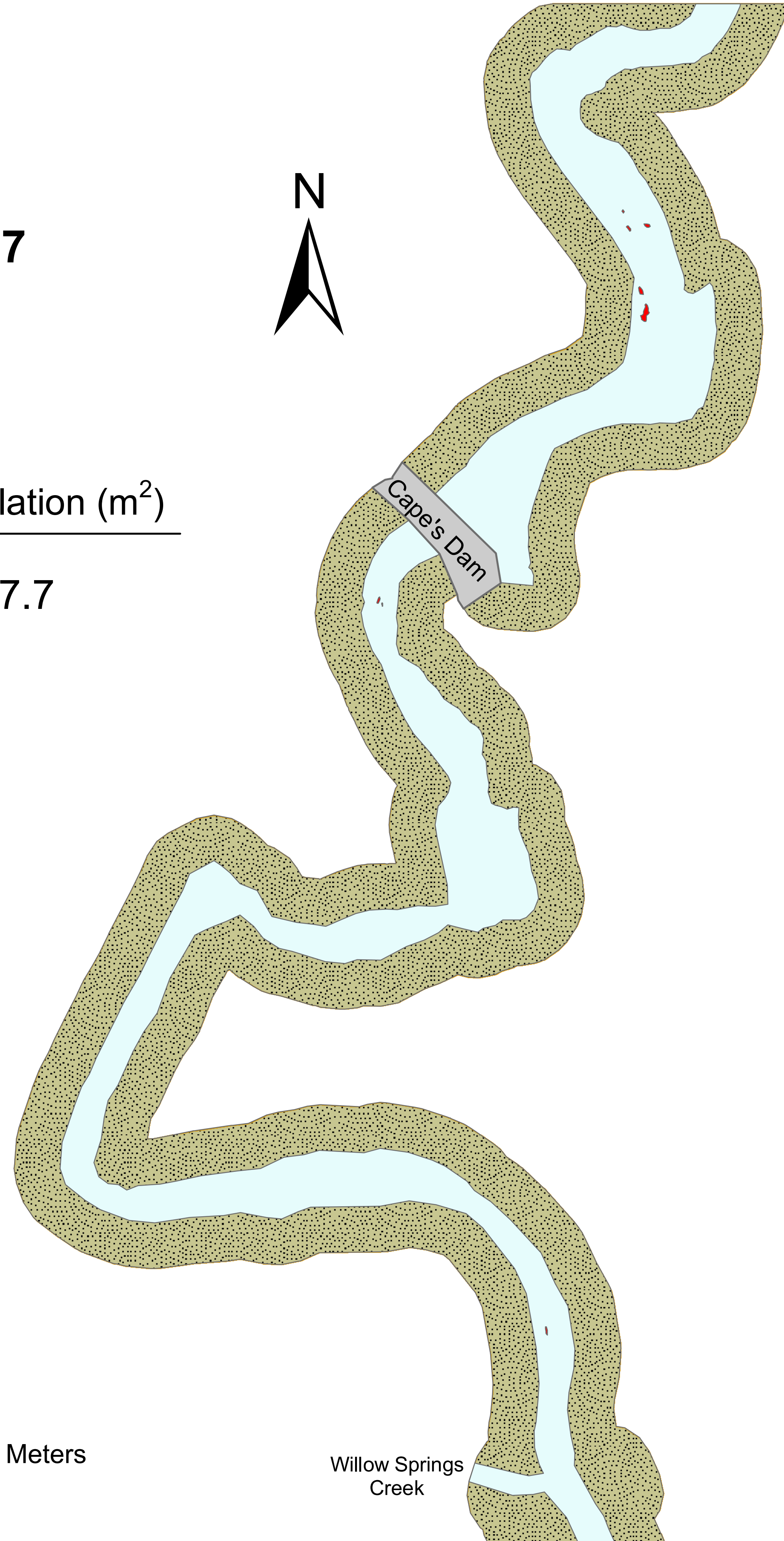
Summer 2008 - Map 5 of 7

July 28 - August 5, 2008

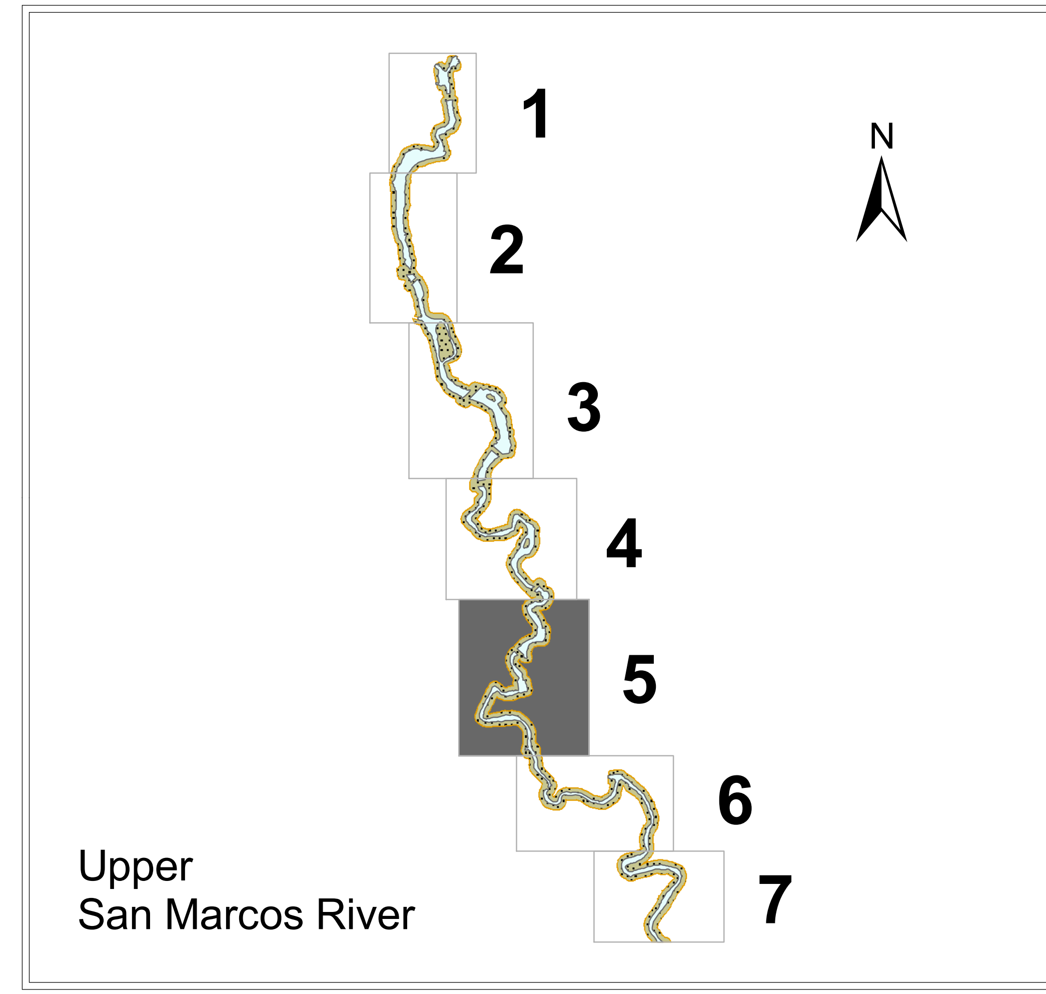
	Map 5 (m^2)	Total Population (m^2)
Zizania	16.2	3,897.7

1 inch = 48.1 meters

120 60 0 120 Meters



Project Location



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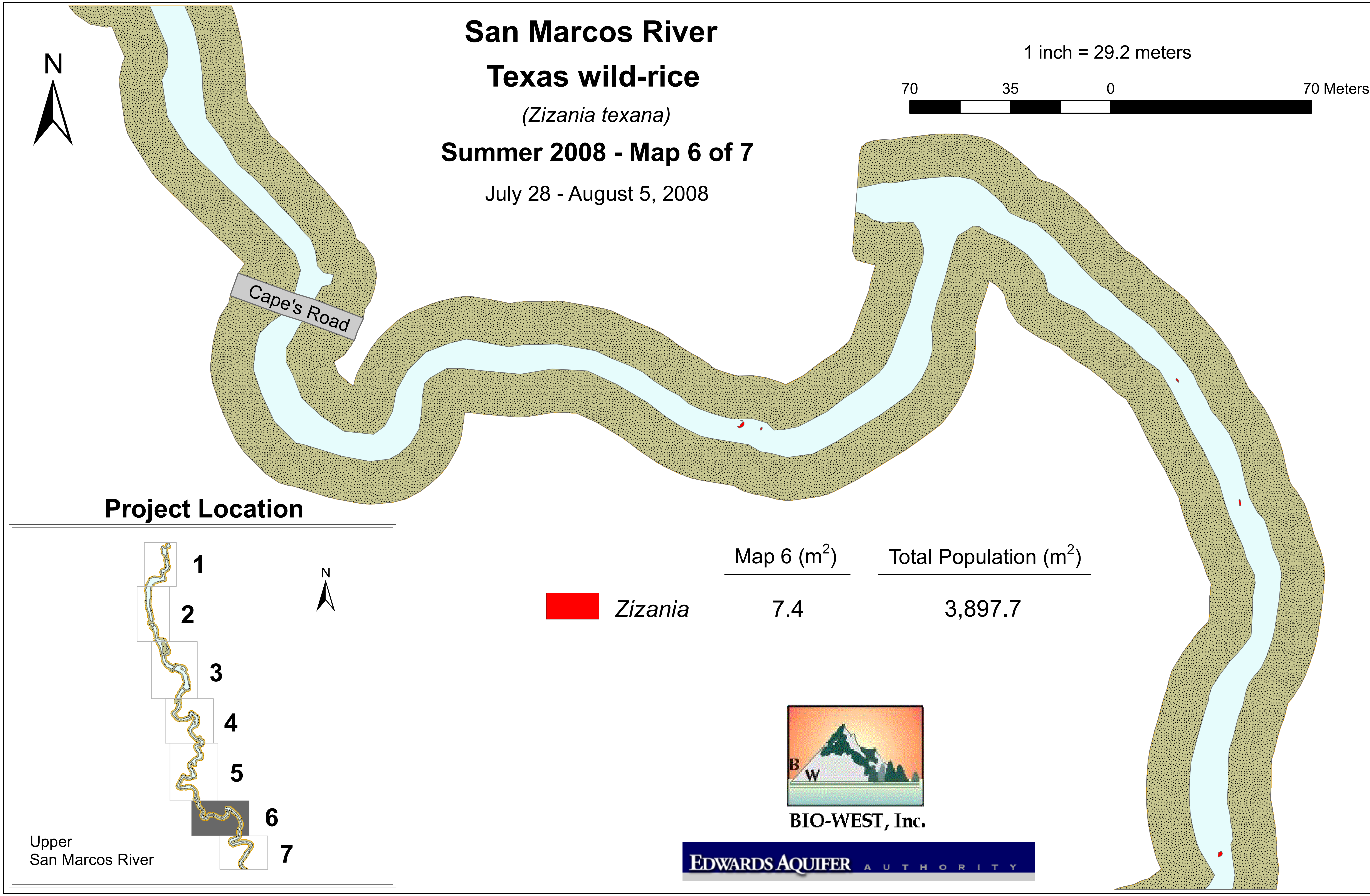
EDWARDS AQUIFER AUTHORITY


San Marcos River
Texas wild-rice
(Zizania texana)
Summer 2008 - Map 6 of 7
July 28 - August 5, 2008
N
1 inch = 29.2 meters
70
35
0
70 Meters
Cape's Road
Project Location
1
2
3
4
5
6
7
N
Upper
San Marcos River
Map 6 (m2)
Total Population (m2)
Zizania
7.4
3,897.7
BIO-WEST, Inc.
EDWARDS AQUIFER AUTHORITY

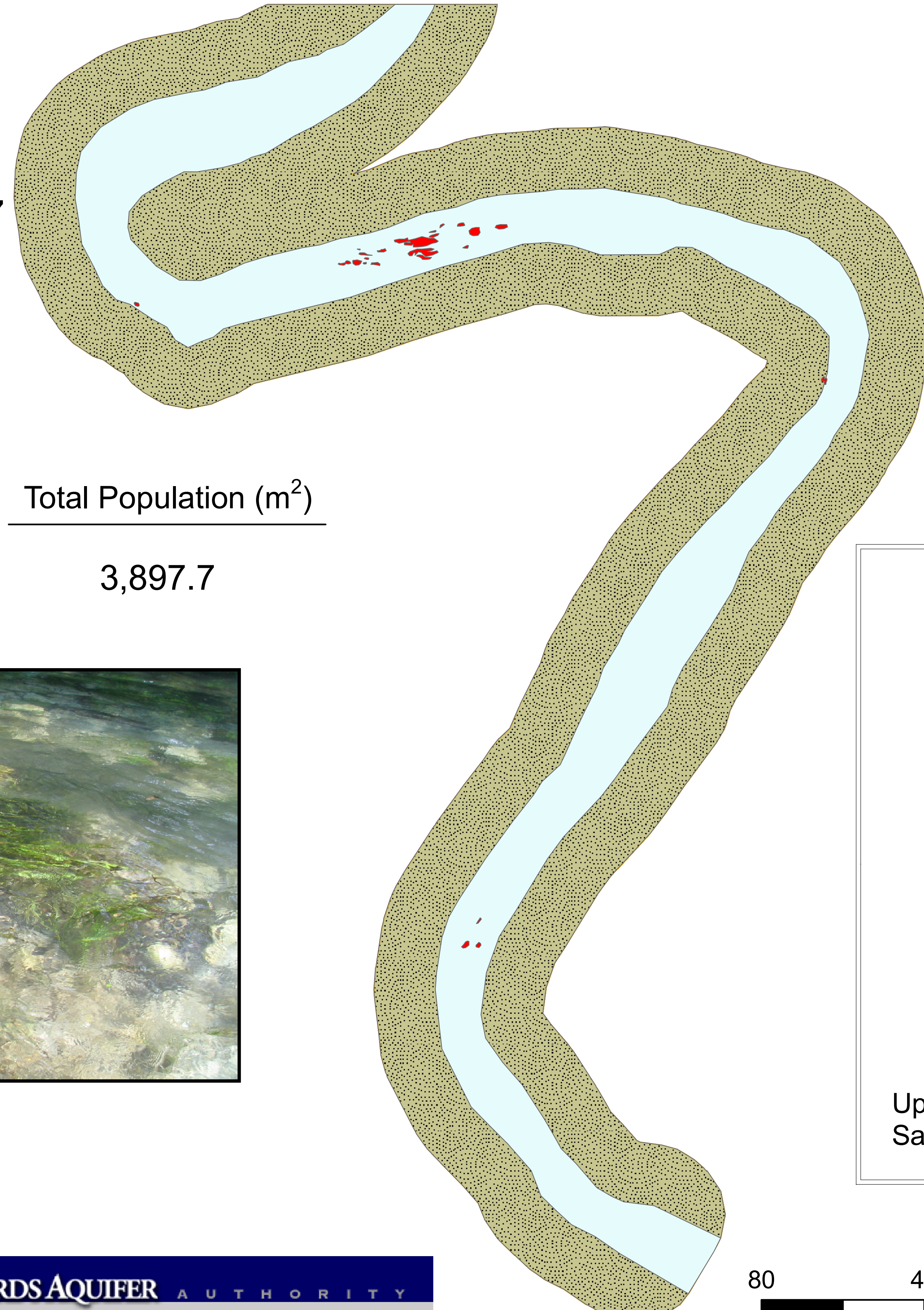
San Marcos River

Texas wild-rice

(Zizania texana)

Summer 2008 - Map 7 of 7

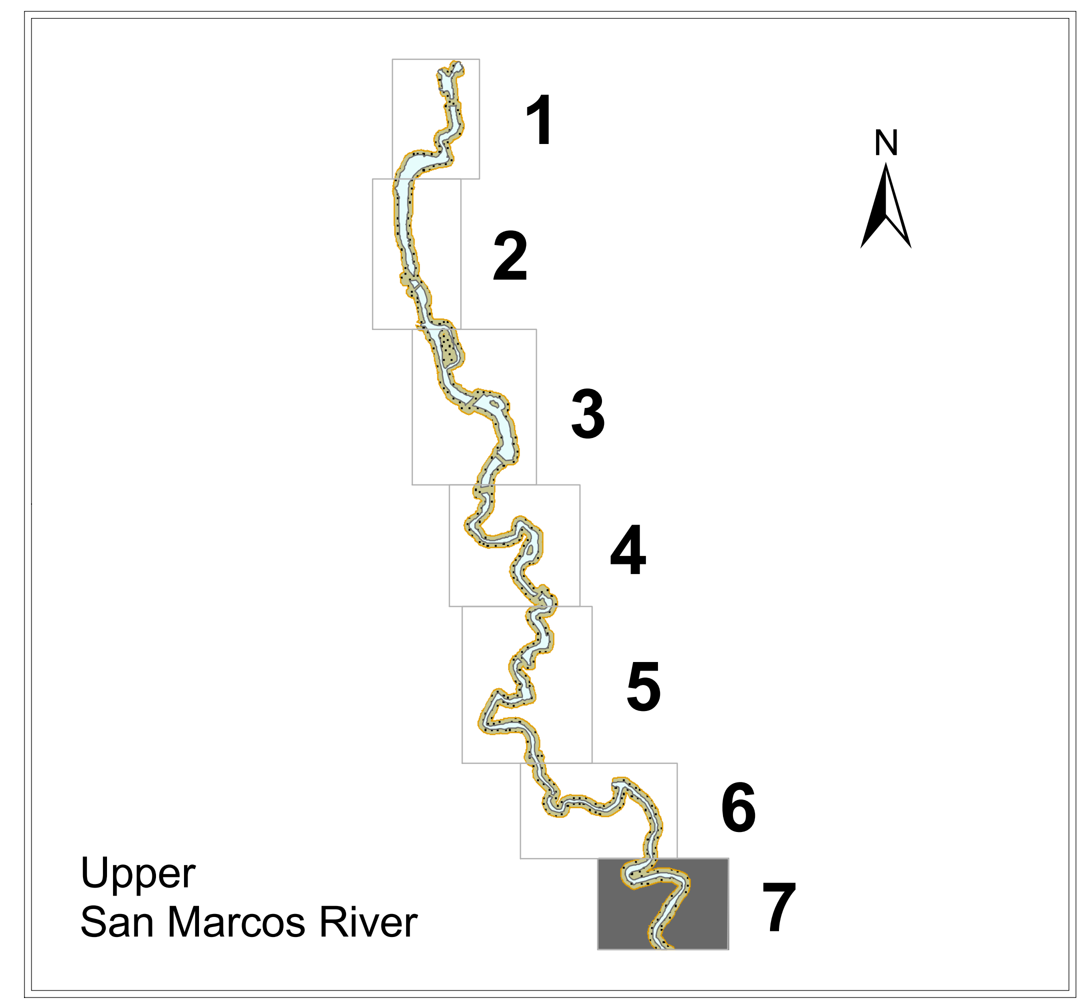
July 28 - August 5, 2008



	Map 7 (m^2)	Total Population (m^2)
Zizania	48.5	3,897.7

N

Project Location



1 inch = 30.6 meters

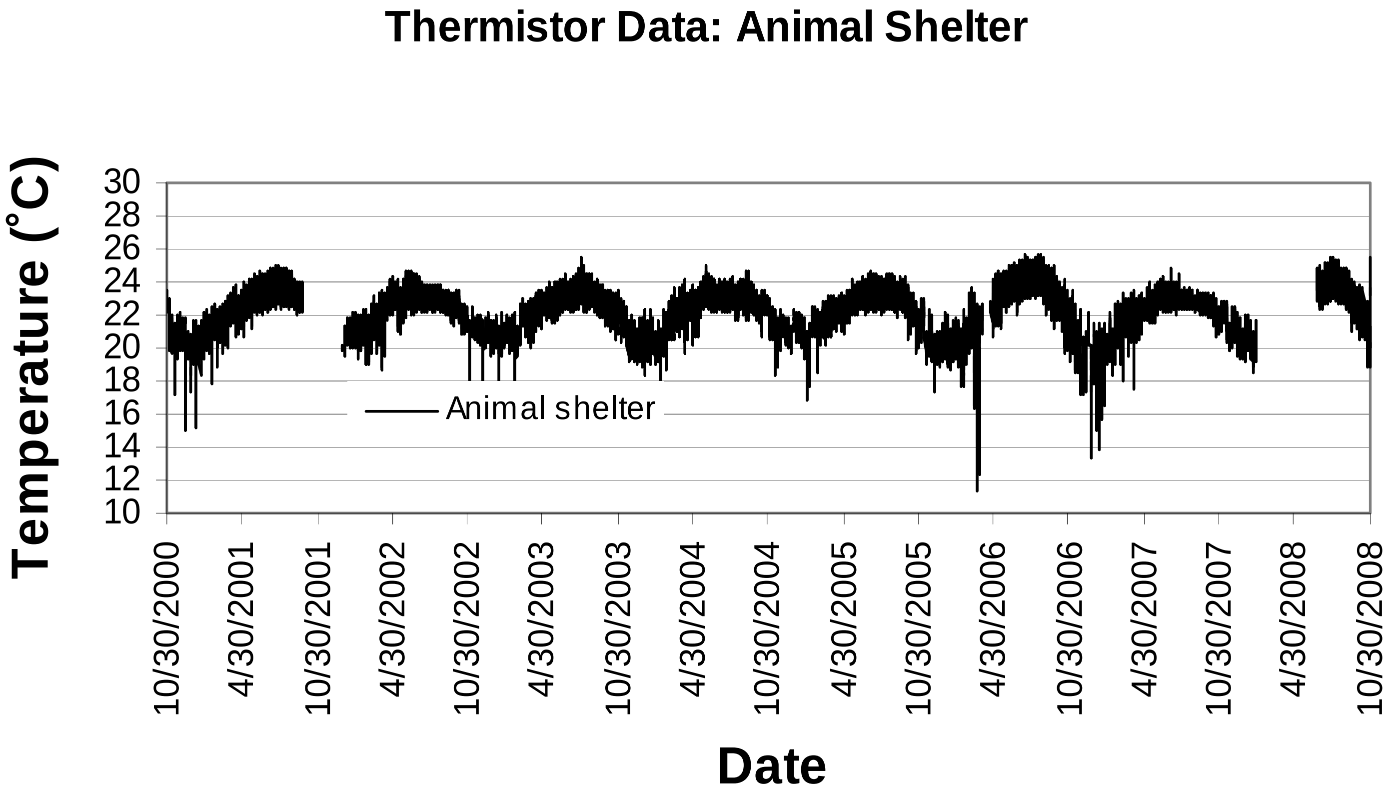
80 40 0 80 Meters

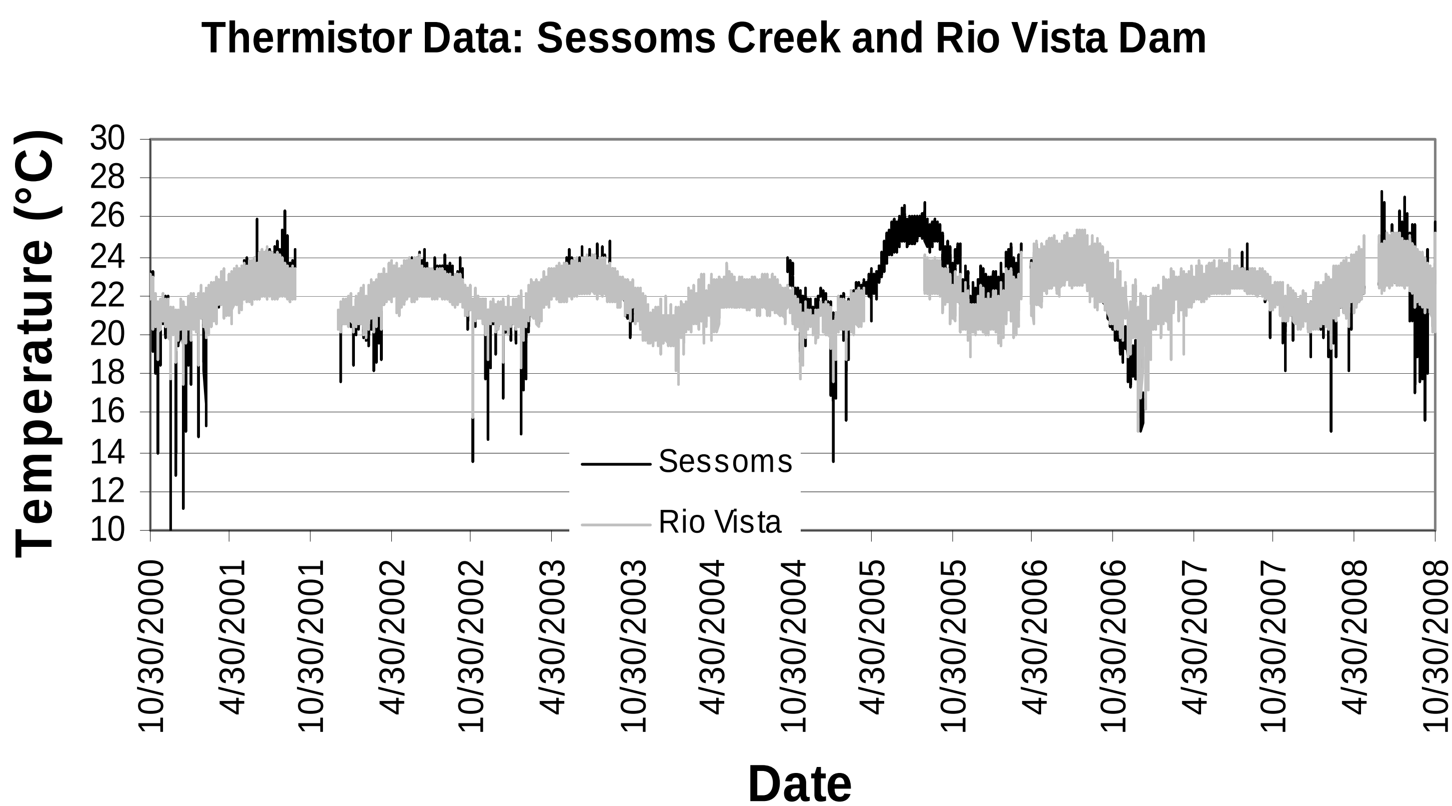
BIO-WEST, Inc.

EDWARDS AQUIFER AUTHORITY

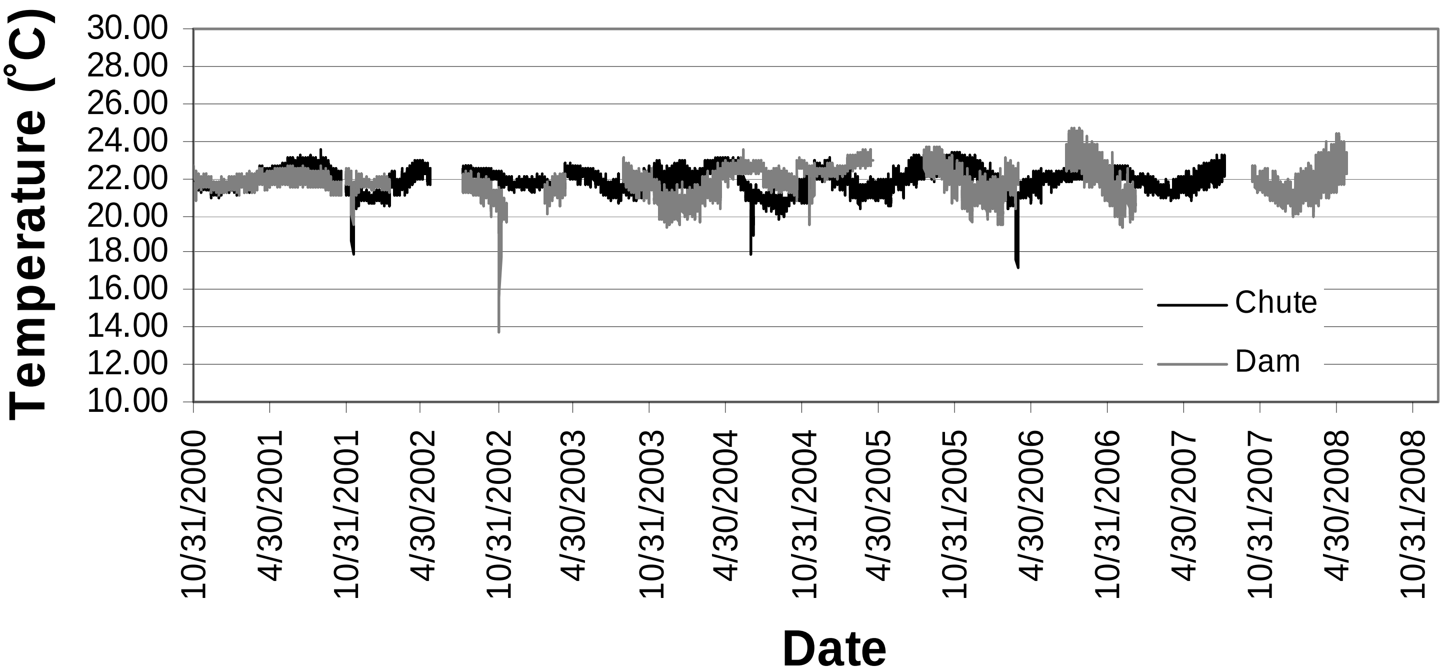
APPENDIX B:
DATA AND GRAPHS

Water Quality Data
and
Thermistor Graphs

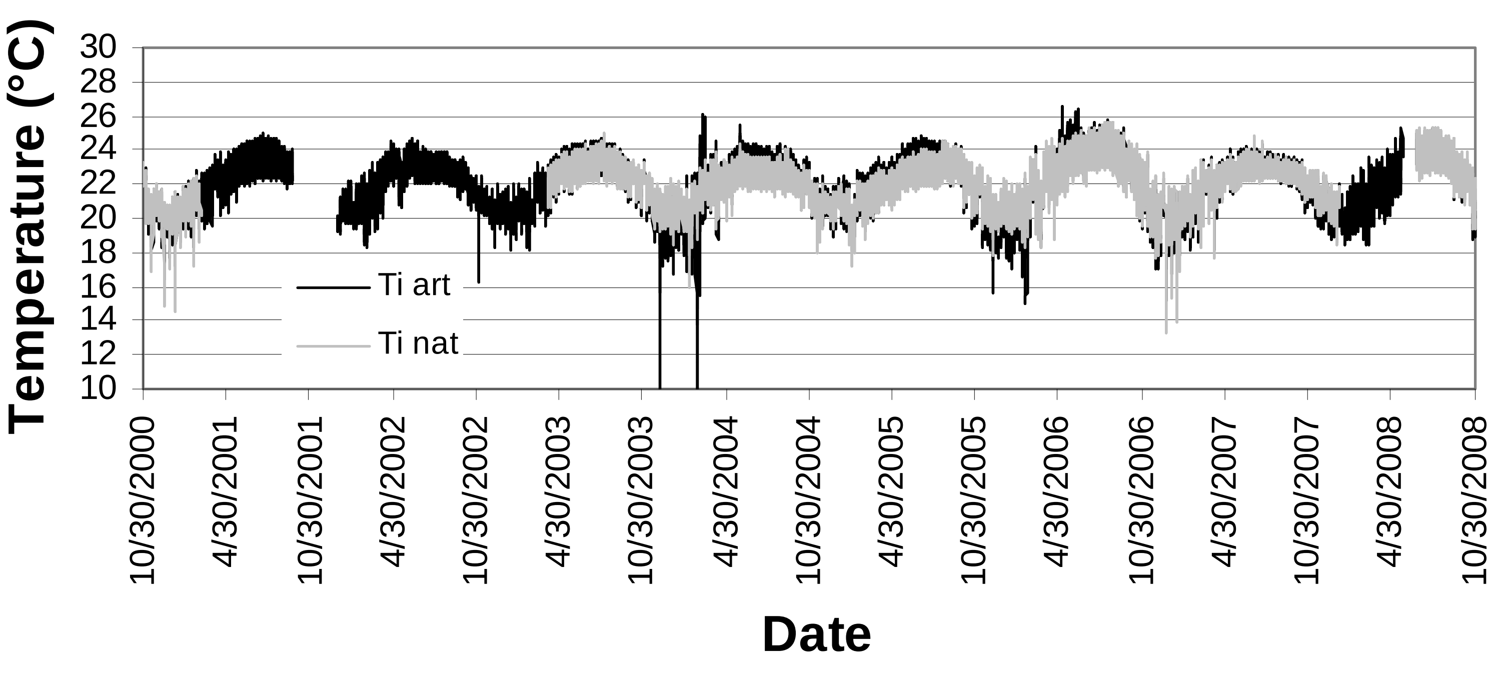

Thermistor Data: Animal Shelter
Temperature (°C)
30
28
26
24
22
20
18
16
14
12
10
Animal shelter
10/30/2000
4/30/2001
10/30/2001
4/30/2002
10/30/2002
4/30/2003
10/30/2003
4/30/2004
10/30/2004
4/30/2005
10/30/2005
4/30/2006
10/30/2006
4/30/2007
10/30/2007
4/30/2008
10/30/2008
Date

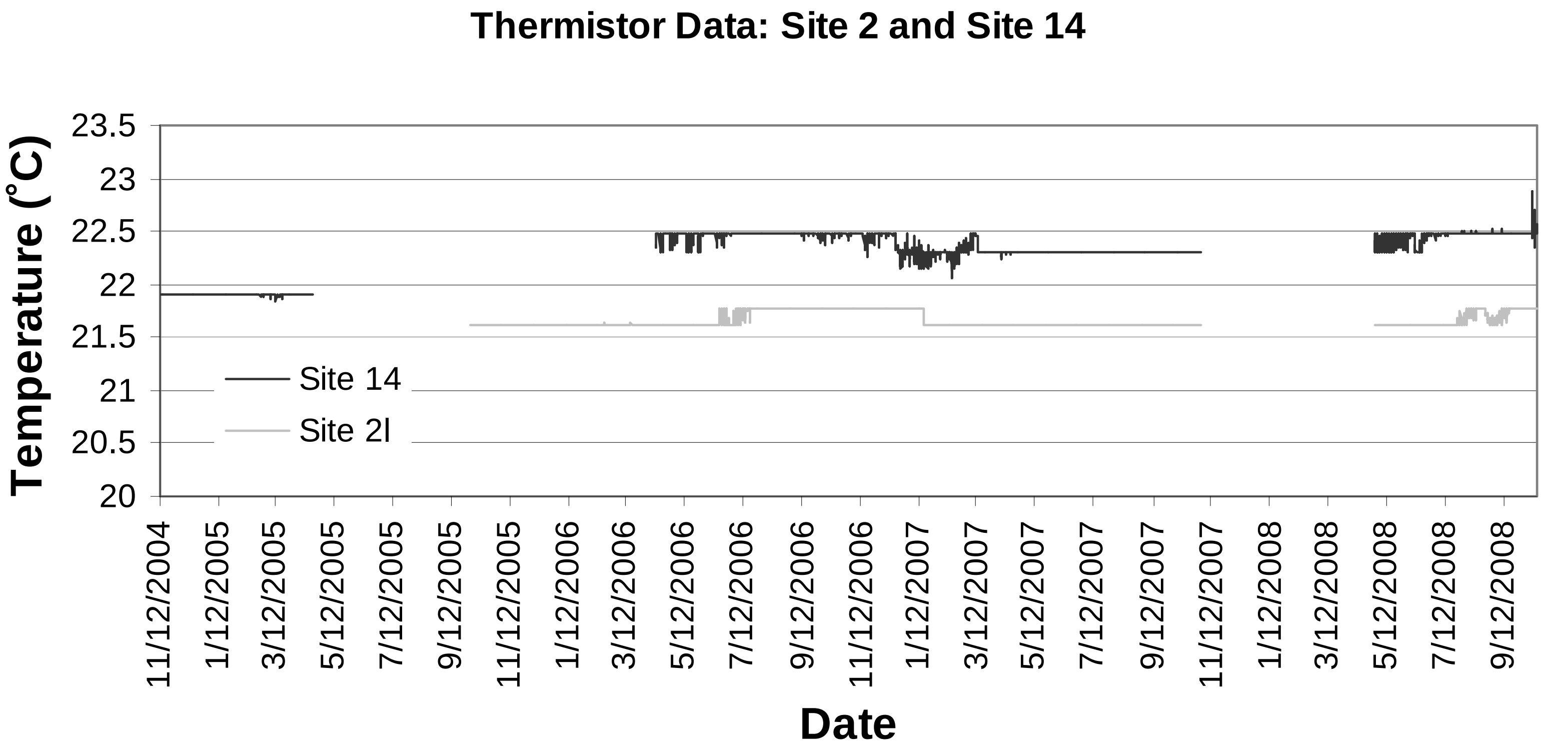

Thermistor Data: Sessoms Creek and Rio Vista Dam
Temperature (°C)
30
28
26
24
22
20
18
16
14
12
10
Sessoms
Rio Vista
10/30/2000
4/30/2001
10/30/2001
4/30/2002
10/30/2002
4/30/2003
10/30/2003
4/30/2004
10/30/2004
4/30/2005
10/30/2005
4/30/2006
10/30/2006
4/30/2007
10/30/2007
4/30/2008
10/30/2008
Date

Thermistor Data: Chute and Dam Tailrace



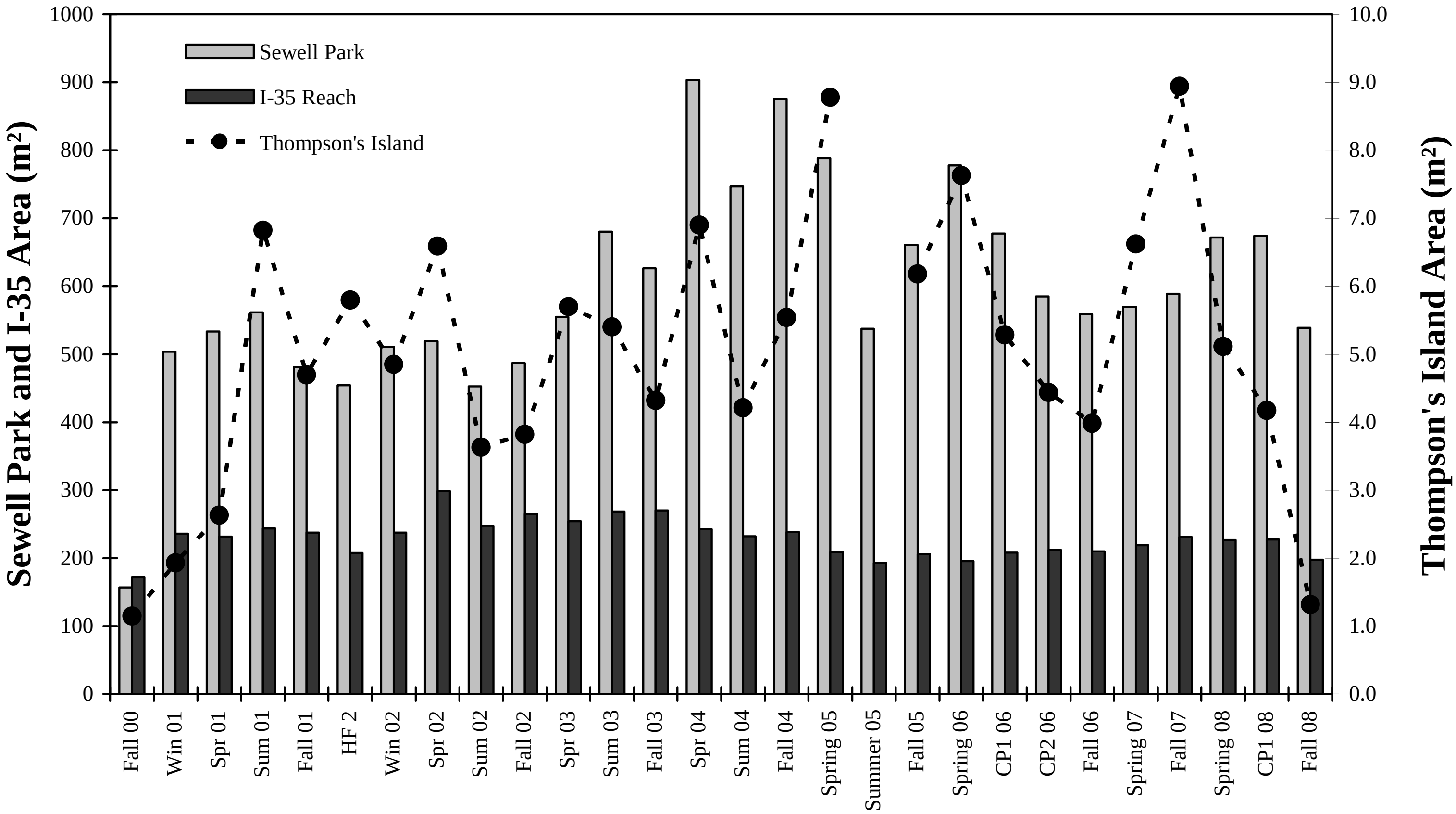
Thermistor Data:Thompsons Island Artificial and Natural



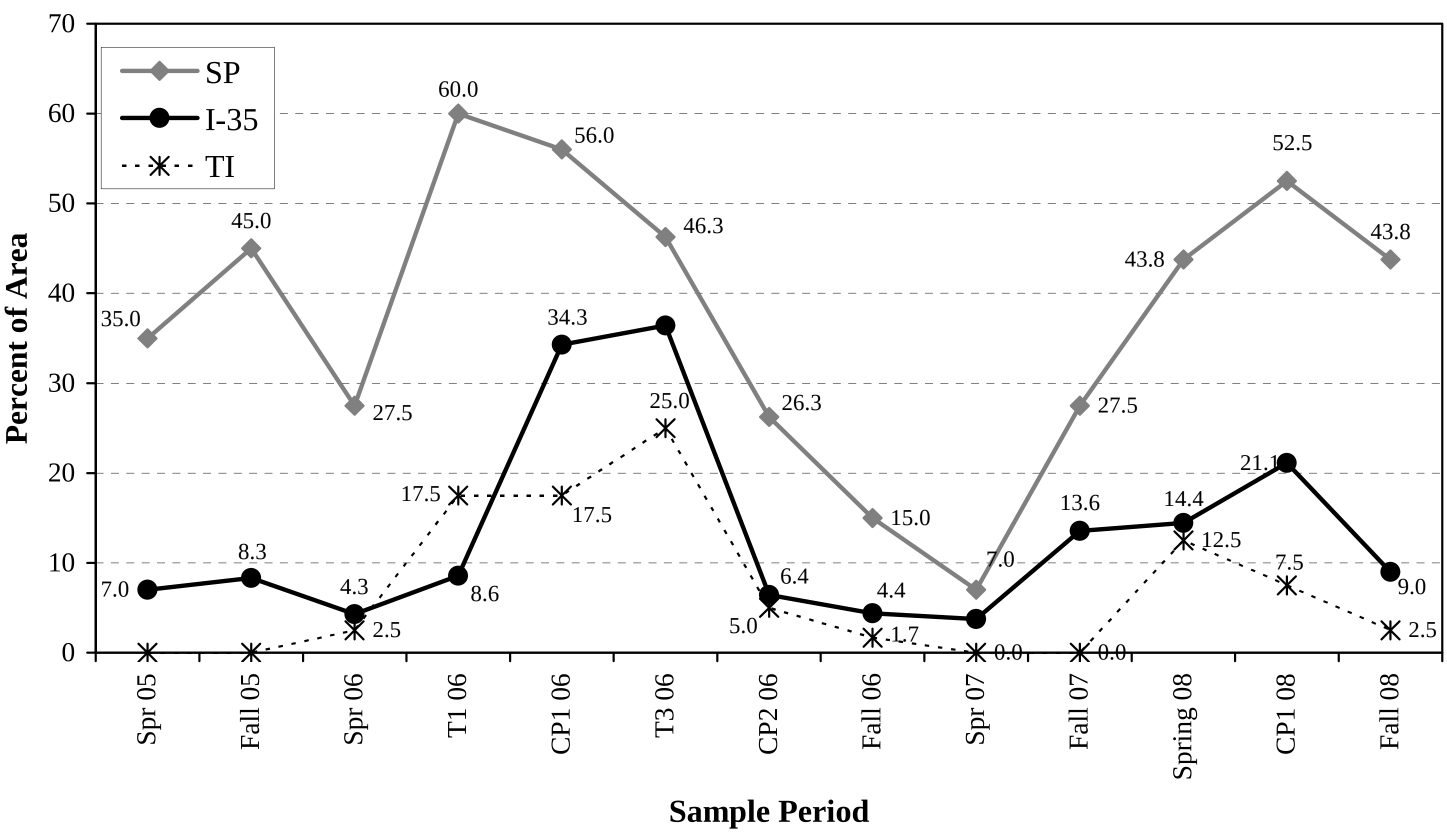

Thermistor Data: Site 2 and Site 14
Temperature (°C)
23.5
23
22.5
22
21.5
21
20.5
20
Site 14
Site 2I
11/12/2004
1/12/2005
3/12/2005
5/12/2005
7/12/2005
9/12/2005
11/12/2005
1/12/2006
3/12/2006
5/12/2006
7/12/2006
9/12/2006
11/12/2006
1/12/2007
3/12/2007
5/12/2007
7/12/2007
9/12/2007
11/12/2007
1/12/2008
3/12/2008
5/12/2008
7/12/2008
9/12/2008
Date

Texas Wild-Rice Observation Data

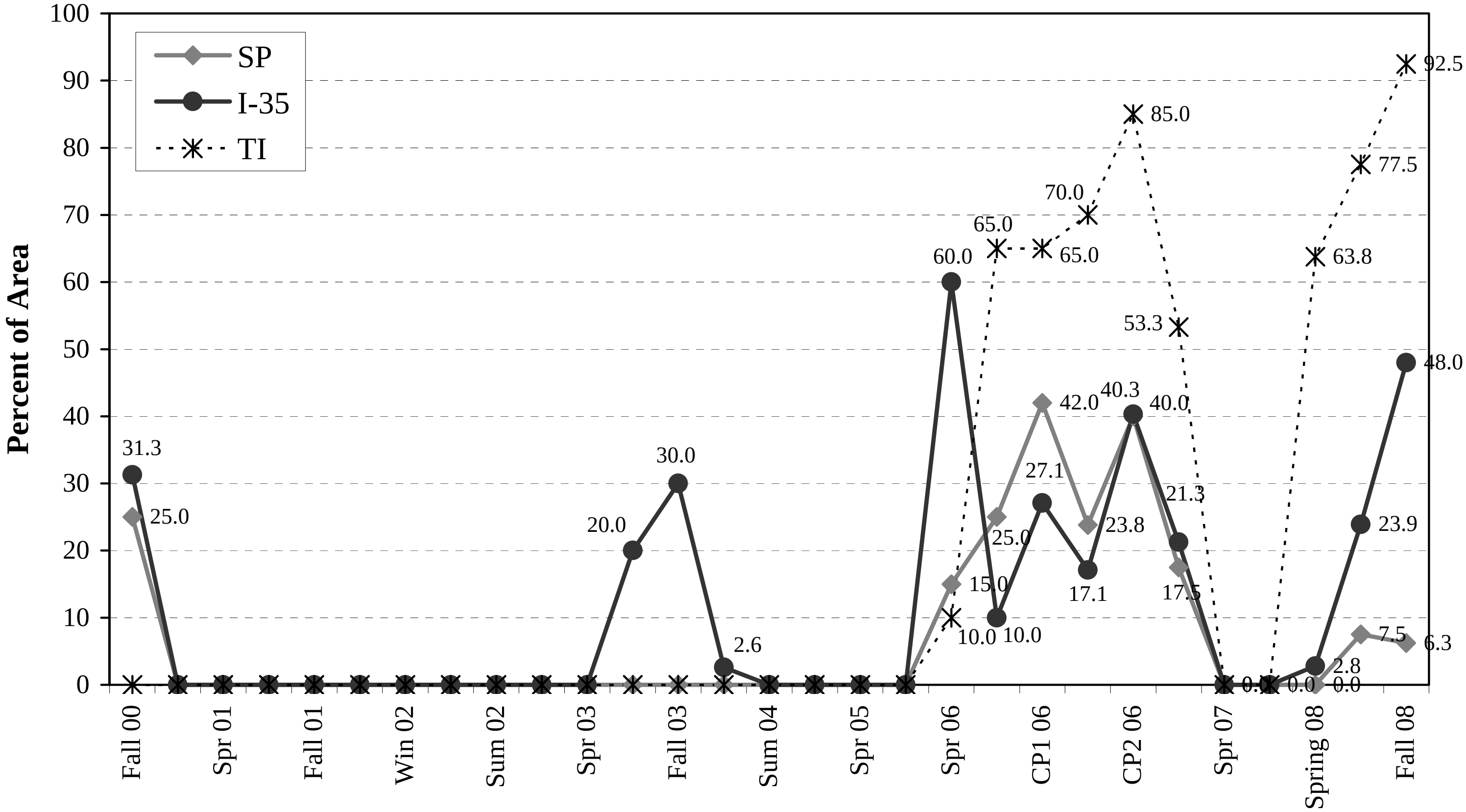
TWR Area by Season



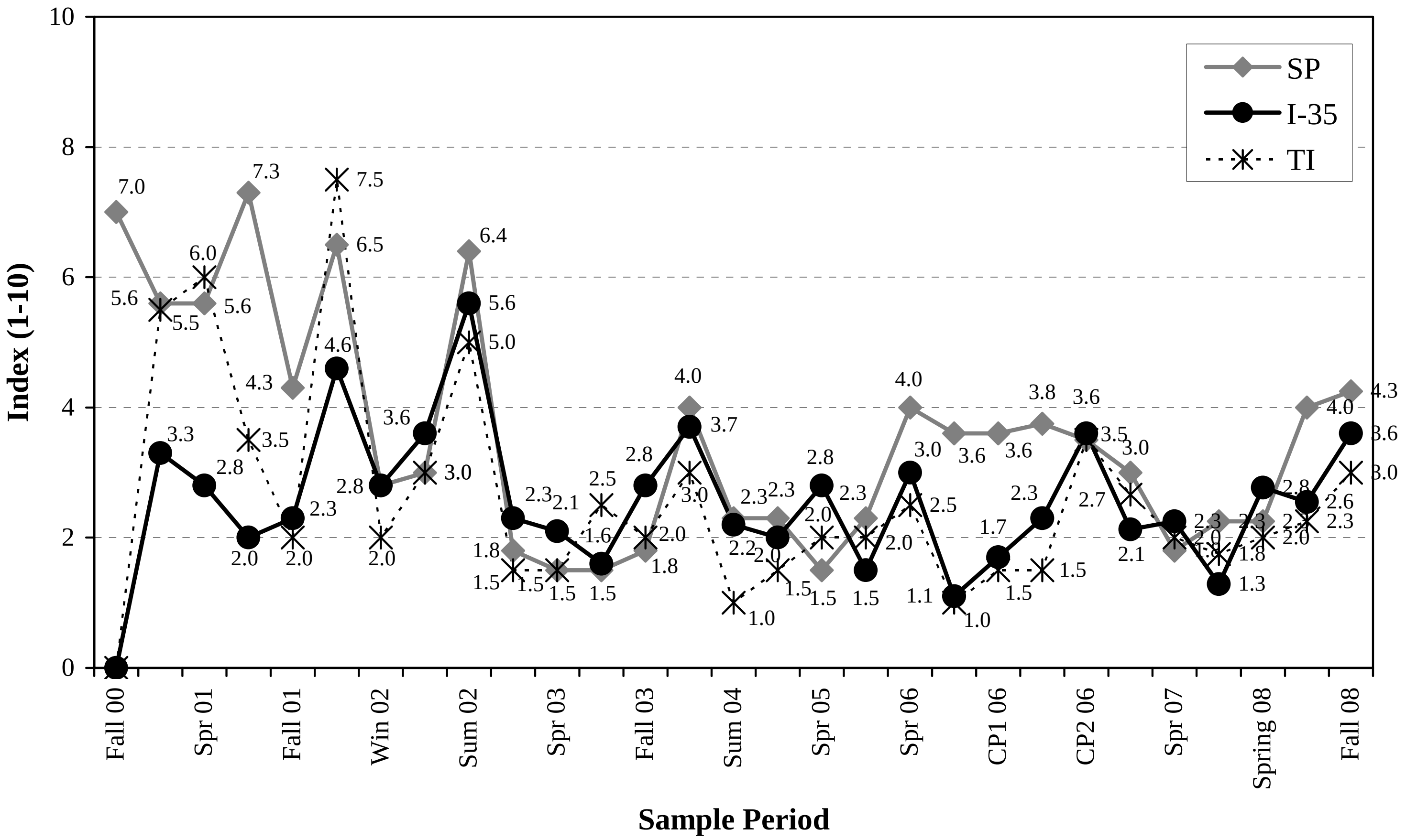
Percent of TWR Covered by Vegetation Mats



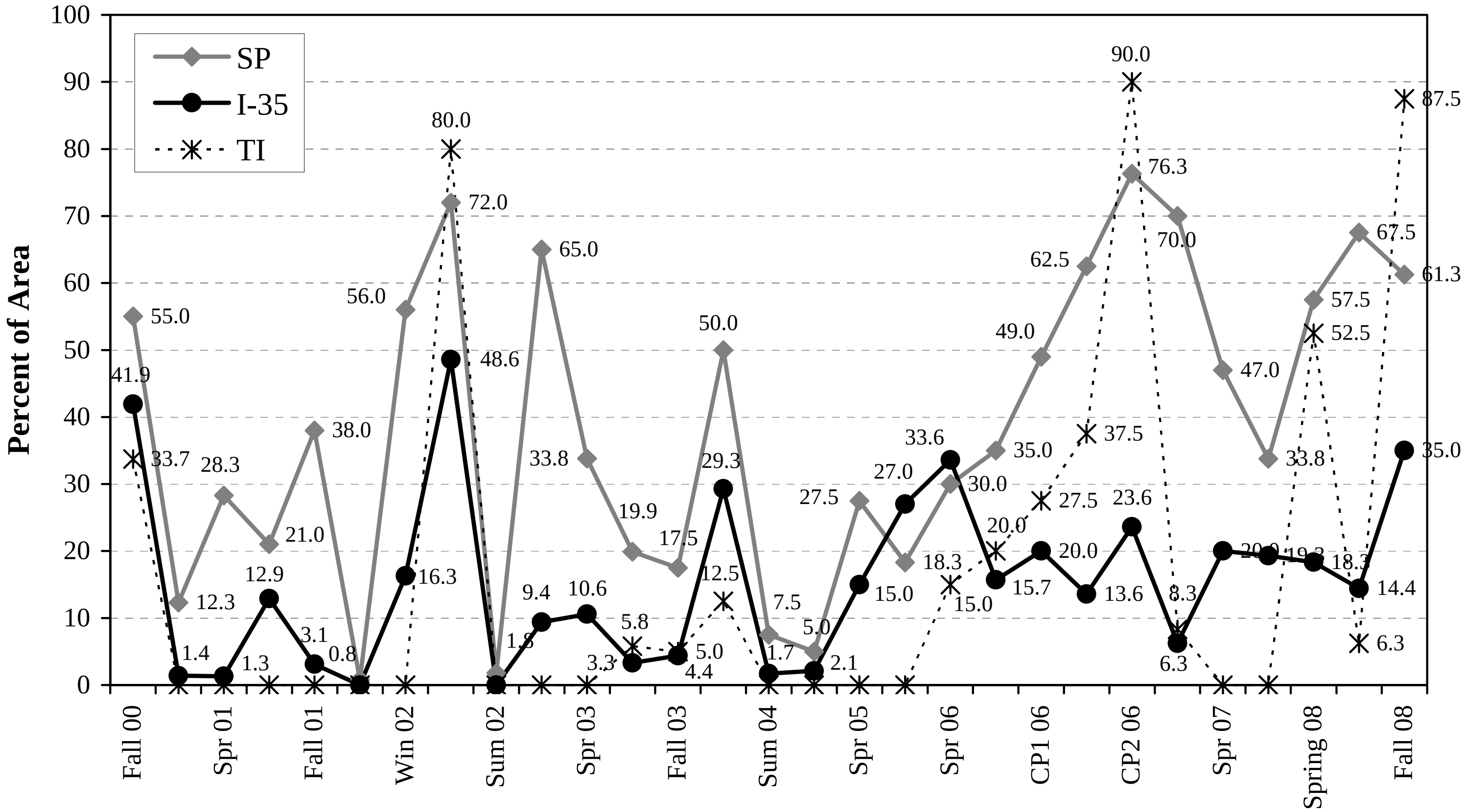
Percent of TWR Stands < 0.5 Feet



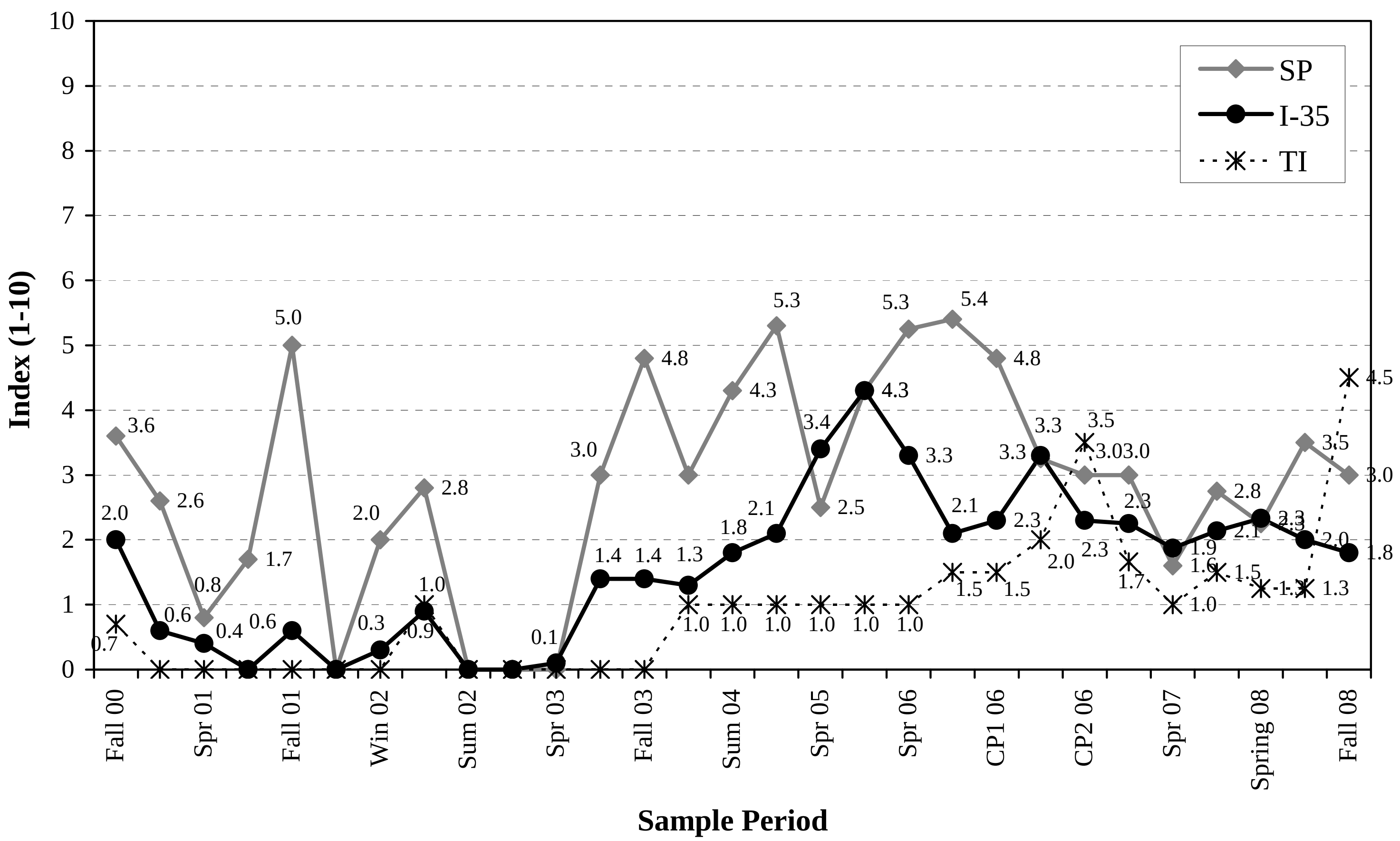
Index of Root Exposure for TWR Stands



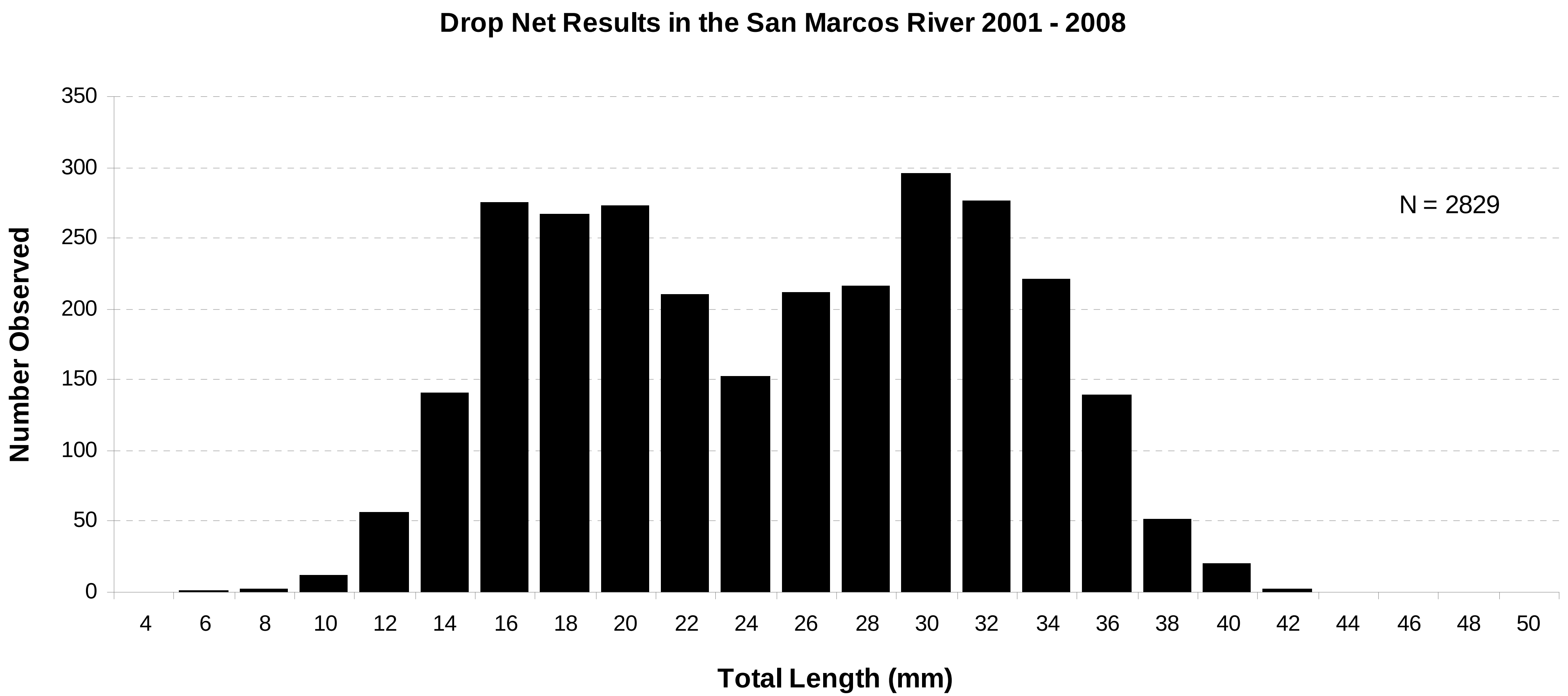
Percent Emergent TWR



Index of Herbivory for TWR Stands



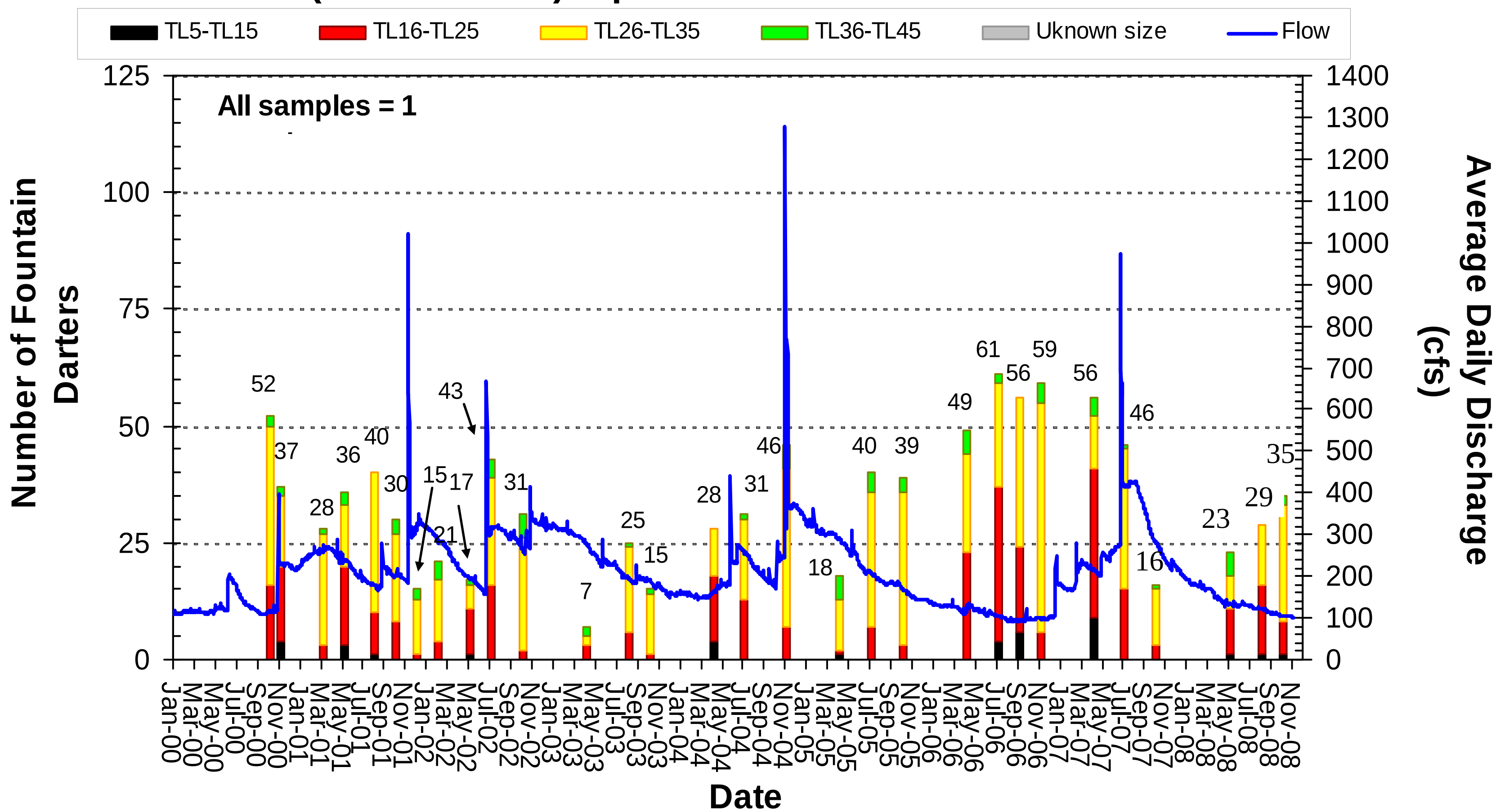
Drop Net Graph



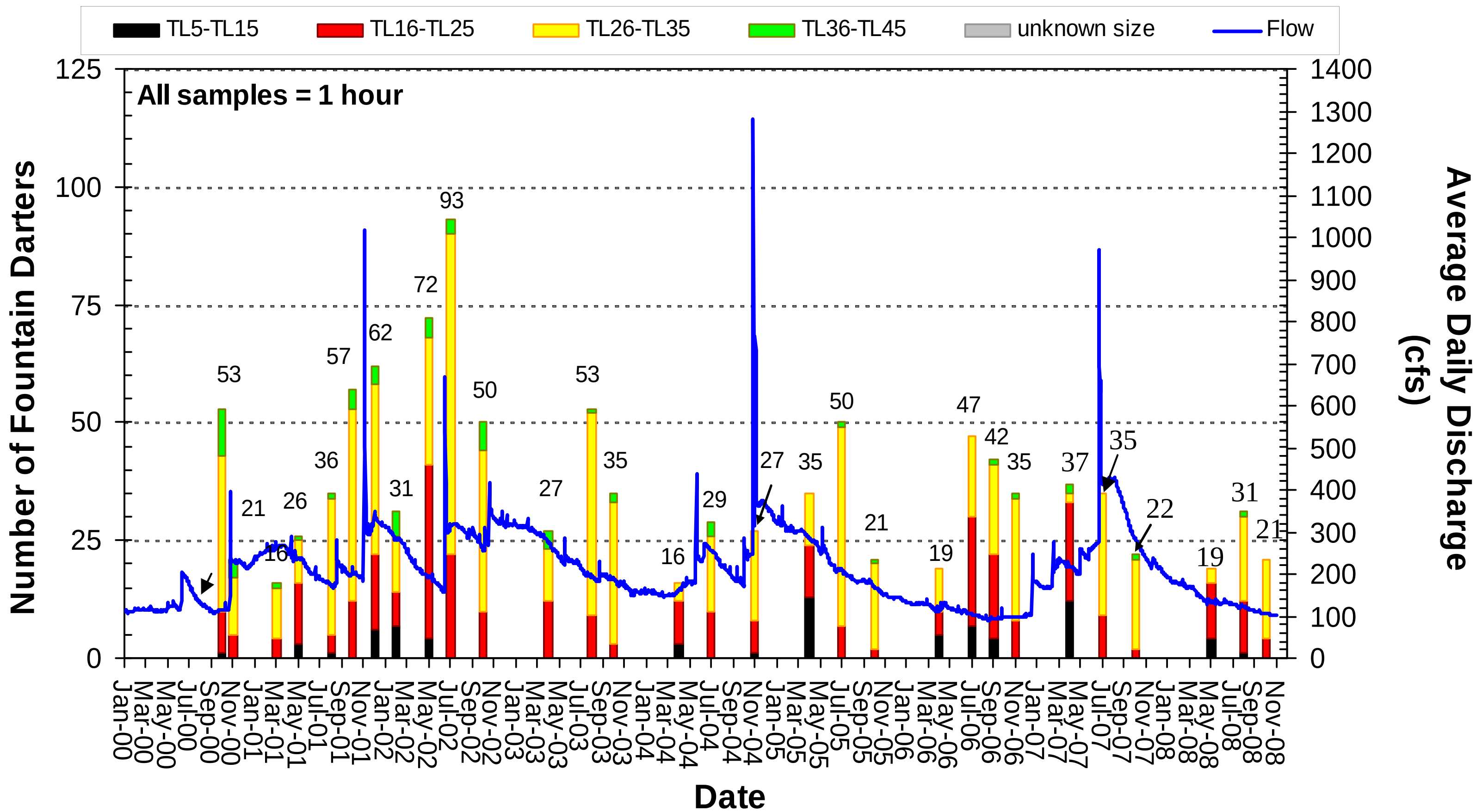
Drop Net Results in the San Marcos River 2001 - 2008
Number Observed
0
50
100
150
200
250
300
350
N = 2829
4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Total Length (mm)

Dip Net Graphs

Fountain Darters Collected from the City Park Reach (Section 4L-M) Dip Net Results - San Marcos River



Fountain Darters Collected from the I-35 Reach (Section 7-M) Dip Net Results - San Marcos River



APPENDIX C:
DROP NET RAW DATA

(not available digitally)