Devils River Minnow Comprehensive Report from Pinto Creek and San Felipe Creek 2011-2014

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Executive Summary

The Texas Fish and Wildlife Conservation Office (TXFWCO) began monitoring the Devils River minnows (DRM) in 2011. The TXFWCO at that time was monitoring the entire range of the DRM. After discussing the work with the Texas Parks and Wildlife Department (TPWD) it became evident that the populations of DRM that needed to be monitored were the Pinto and San Felipe populations. A TPWD study was concluding on Pinto and no additional work was scheduled in the critical habitat. San Felipe creek continues to face many stressors including groundwater pumping (industrial/agriculture), the sale of water to municipalities, invasive species, and urbanization. Due to the pressures present it was apparent that the population at Pinto and San Felipe creek needed to be monitored and specific questions about abundance and distribution needed to be asked of that population.

Pinto Creek has always been an intermittent creek, however, the persistence and magnitude of the current drought has strained the aquatic organisms present within the watershed. The main springs within and adjacent to Pinto Creek have not flowed since 2009. The lack of longitudinal connectivity in Pinto Creek began somewhere around 2009 or 2010. Certain pools have persisted since the drought began, although the succession of these pools has been ongoing. The succession of these pools shifted from stream channel with a diverse fish community and submersed vegetation to a pool filled by predators with lily pads covering the surface.

The TXFWCO has been maintaining contact with local residents and has gained access to most of the critical habitat available above highway 90 (7.5 miles of 11). Prior to 2014 the TXFWCO had been monitoring a lower pool where DRM had been consistently found since 2010. In summer of 2014 an additional pool was added to the sampling within Pinto. Minnows were found in May at the downstream pool and in July of 2014 in both pools. In December of 2014, no minnows were found at either location. Sampling will continue on Pinto as part of the TXFWCO monitoring program indefinitely.

Data collected from San Felipe creek shows that the minnows are only present in the lower 2.6 kilometers of the connected designated critical habitat. In addition, DRM were found upstream of the connected critical habitat in what is considered spring number 6 by Brune (1981) each visit from 2011. Data shows that DRM within San Felipe Creek are associated with pools having flows around 0.02 m/s and silt substrates with aquatic vegetation cover. At this time the San Felipe population seems stable, although restricted within its critical habitat.

With growing regional needs for more water allocated to municipalities, the threat to San Felipe springs and other springs in Val Verde County have become a viable and imminent threat. Recently, attempts to sell the water from Val Verde County to San Antonio and San Angelo have failed. These attempts to sell the groundwater in Val Verde County will continue and due to Texas water law there may be no way to stop the sale of this water for municipalities. For these reasons, monitoring and gathering of data along San Felipe creek is imperative to provide the best science available for local managers and the Fish and Wildlife Service to make decisions about Devils River minnows and other listed taxa within San Felipe springs.

Introduction

The threatened Devils River minnow (*Dionda diaboli*, DRM) historically range throughout several creeks in Val Verde County and Kinney County in west Texas. This area is a prime target for groundwater pumping, which influence water quality and quantity, due to the lack of regulation in this area of the aquifer. The jurisdiction of the Edwards Aquifer Authority ends at the Uvalde county line, although the aquifer bleeds into Kinney County. Due to the lack of regulation, excessive amounts of water from the area may be taken to larger municipalities which require the water for urban consumption. Agriculture also puts a strain on the already limited water resource in the area (Urbanczyk 2003). Other threats include dams, introduction of invasive species, stream channelization (Garrett et al 1992, Lopez-Fernandez and Winemiller 2004) and industrial needs.

Groundwater is essential in the western desert systems due to the ephemeral nature of the streams in the area. If San Felipe springs were to be pumped dry, the amount of water within the creek would be negligible. These systems in west Texas are supported by groundwater inputs. The loss of DRM from historical sites in Texas and Mexico, the needs addressed by the recovery plan (USFWS 2005) particularly sections 1.1.1; 1.1.3; 1.4.4 of the recovery plan status (http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=E03V#crithab), and the imminent threats impress a need for consistent monitoring of this species over time in order to determine recovery status and take action if necessary.

The San Felipe population of DRM has been irregularly monitored since their discovery in 1979. Due to the sporadic sampling of the system, the TXFWCO seeks to answer specific questions about the population of DRM within San Felipe Creek.

- What is the current status of the DRM within San Felipe Creek?
- What is the distribution and abundance of DRM within the designated critical habitat of San Felipe Creek?
- What are the mechanisms that drive the distribution of DRM within San Felipe Creek?
- What are the relationship between DRM and native fishes and other non-native fishes within the community?
- What types of habitat does the San Felipe population associate with?
- What is the overall status of San Felipe Creek?

Sampling Design

Pinto Creek

Sampling within the Pinto Creek has been conducted opportunistically within the critical habitat due to varying levels of land owner cooperation and the continued dewatering of the creek due to drought and water use. Due to the current pressure that this population is under, more rigorous sampling would place an unnecessary stress on the remaining individuals in the isolated pools of Pinto Creek.

San Felipe Creek

2011 to 2013

Existing data, provided by partners from Texas Parks and Wildlife (pers comm. Gary Garrett) and UT Pan American University (pers comm. Bob Edwards), were used to determine naïve site occupancy (Ψ) and create an estimate of detection probability (p) based upon methods established by MacKenzie *et al*. (2006) using the program Presence. Naïve site occupancy is very similar to frequency of occurrence data. The model changes the naïve site occupancy score to an occupancy score by taking into account the probability of detection to provide a more robust estimate of occupancy for that site. A single season model was used to determine the probability of detection ($p = 0.64$). The naïve site occupancy for San Felipe Creek was $\Psi = 0.42$. These calculations were used to determine the number of samples that needed to be taken in San Felipe Creek (n = 5) with a variance of 0.075 and optimal number of surveys at each site (K) = 2 (see below for equation).

$$s = \frac{\Psi}{Var(\Psi)}\left[(1-\Psi) + \frac{(1-p^*)}{p^* - Kp(1-p)^{K-1}}\right]$$

From MacKenzie et. al 2006 equation 6.3

The creek was divided into the headwaters, middle, and the lower sections. From these sections, five 200 m reaches were selected to provide a longitudinal sampling of the creek and ease of access (Figure 1A). The main sites include the Golf Course, Memos, Canal, Barron, and Guyler (Figure 1B). Each reach was divided into two 100 m sections, and two sampling teams each seining a section. Each team started at the downstream end of their section. Fish were captured, identified, and recorded from six to eight seine hauls per section using a 10' seine. For each seine haul the habitat type (run, riffle, pool, etc) and substrate were recorded. Water chemistry was taken at the beginning, the middle, and at the end of the reach. Values were summed over the reach and an average was taken for each site. All species captured were recorded, while lengths were taken on the DRM.

For the TXFWCO data presented here, two different occupancy models for each site were run with the Presence program. The first model was a default single season model with probability of detection constant. The second was single season model that allowed the probability of detection to vary between sites. Typically the model with the lowest Akaike's Information Criterion (AIC) score is chosen. The AIC is a way of ranking models using parsimony. Each model was run separately for each site which included the Golf Course, Memos, and Canal sites as the data is consistent for five sampling events and minnows were only found at these sites. The data from each site visit was entered into Presence and was treated as a transect with 12 observations each for that transect. Therefore, for each site, each model was a 5 X 12.

A population estimate using repeated count data (Royle biometrics) within the Presence program was done using the Golf Course and the Memos sites. Canal was not included, since the DRM captured there were not consistent enough to use the model correctly. The data input for this analysis consisted of data from September 2012 to December of 2014 for each site constituting a 5 X 12 matrix. It is important to understand that during this analysis the closure assumption of the model was violated. Since this model incorporates different seasons it is safe to assume that the population was not the same at each event across the time of the sampling.

2014

Beginning in March of 2014 the sites sampled along San Felipe Creek were modified in order to collect habitat suitability data on the minnow within the occupied range. The new sites include the three main sites, Golf Course, Memos, and Canal, along with a site at highway 90 and at Johnson street crossing.

Aquatic Invertebrates

Aquatic invertebrate collections were added to the monitoring regime in October of 2012. Three aquatic invertebrate samples were collected with a Hess sampler at each section. . All collections were preserved with isopropyl alcohol in the field. Samples were sorted, and identified to the lowest practical taxonomic level in the lab. Once samples were identified they were combined for analysis. Standard methods from the Texas Commission on Environmental Quality Surface Water Quality Manual Volume II surber sample methods were used to create metrics for the data. Sampling of aquatic invertebrates will be permanently integrated into the regular monitoring in San Felipe Creek as a tool for examining system health over time.

Results

Pinto Creek

When the TXFWCO began monitoring Pinto Creek in 2010, the population of DRM was dwindling. Connectivity was being lost longitudinally in the creek and the pools where the minnows were once present were shifting ecologically. Pinto Creek is experiencing an ecological succession from riverine type habitats with submerged vegetation to the standing pools covered in emergent lily pads covering the surface (Figure 2). As this occurs, the fish community shifts from a balanced community to a predator dominated system. In September of 2011 DRM were captured in only one pool. In July of 2012, a total of 150 DRM were collected from the remaining pool and transferred to the San Marcos Aquatic Resources Center (SMARC) to supplement the refugia population In September 24, 2012, the water level had dropped about two feet at the remaining pool. A total of 27 DRM were captured and returned to the pool.

In 2013, the wetted area had decreased to a small pool with limited connectivity to a larger deeper pool downstream. In March of 2013, DRM were captured in the remaining small pool. However, in October two teams sampled the area for around 45 minutes without capturing any DRM. In addition, no Texas shiner (*Notropis amabilis*), *Gambusia* sp. or any other small non piscivorous species were captured. The remaining fish captured during the October visit were predators of all size classes. Water quality data is presented in Table 1.

In 2014, sampling of the pool was conducted in March and December. Devils River minnows were found in March, while no minnows were collected in December. In July of 2014, the TXFWCO was able to gain access to another site on Pinto Creek upstream of highway 2804. On 1 July 2014, Mike Montagne (TXFWCO) and Ken Ostrand of the SMARC conducted sampling activities on a section of Pinto Creek that had not been previously sampled by the TXFWCO for DRM. The team collected 68 DRM in two seine hauls in the upper of the two pools sampled, but did not collect any from the lower, more stagnant pool. The DRM were small and looked to be of the same year class (likely 2013). This pool was resampled in December of 2014 but no DRM were captured at the new location or the other downstream pool.

San Felipe Creek

Population Dynamics – Occupancy Data 2012-2014

Critical habitat was designated to nine kilometers of San Felipe Creek, beginning at the head springs, about one kilometer upstream from the Jap Lowe crossing, and ends about 0.8 kilometers downstream of the Academy Street bridge. The TXFWCO has determined the current distribution of DRM to be in only 2.6 kilometers of the nine kilometers of available critical habitat.

The TXFWCO data showed an overall naïve site occupancy score of 0.24. This naïve site occupancy score is lower than what was calculated from the partners data. However, the TXFWCO data included more surface area of the creek, including sites that were not historically sampled by the partners. Overall naïve site occupancy scores were calculated for each of the TXFWCO monitoring sites with their respective data (Table 2). Based upon these overall naïve site occupancy scores, a decrease in DRM density from the Golf Course down to Guyler (Figure 3) is observed. The data suggests there is a mechanism driving a decrease in the DRM density around the Canal site. Naïve site occupancy scores examining changes over time are shown for all of the monitoring locations in Figure 4. Pooled probabilities of detection were calculated for each site where DRM were detected during monitoring in September 2012, March 2013, and October 2013, May 2014, and December 2014 (Figure 5).

Heavy rains in October of 2013 flash flooded the system, and may be responsible for the declining occupancy trend in the Memos and Canal sites. The Golf Course site is the farthest upstream site and may be buffered from flash events due to the juxtaposition of the site in relation to the mainstem of the creek which passes by on the east side of the Golf Course. In addition, the sites below the Golf Course are channelized by concrete on the banks and River Cane (*Arundo donax*) on others potentially amplifying the scouring.

An additional site, spring #6 (Brune 1981), on a cooperative landowner's property has been opportunistically sampled and still contains DRM; however, due to its lack of connectivity it is not included in any analysis. Spring #6 is upstream of the Golf Course and consists of one pool approximately 30 feet in diameter, and has not been connected with other parts of the system, except during flash events, for at least three years. This is the most upstream site, to which the TXFWCO has access and that DRM have been found by the TXFWCO. The pool is seined to determine presence/absence of DRM and they have been consistently captured there since September of 2011. In addition there have been visual observations of DRM from different size classes within the pool. Water quality data is presented in Table 4. There is an additional pool thought to contain DRM upstream of this site, however we have not attained access to this site at the present time.

Population Estimate 2012-2013

The Canal site is the downstream limit for the population estimate due to the decrease in site occupancy figures. Data from all five sampling events was used for the population estimate (September 2012 to December 2014). Data was entered into the Presence program as a 5 X12 matrix for the Golf Course and for the Memos site. The two models selected for the Golf Course and Memos sites were the full identity models in the Royle Biometrics program. Each of these models scored the lower of the two AIC values. For each model the calculated occupancy score was 1. For the Golf Course site, the derived abundance total was 176 DRM with a standard error of 43.29 and confidence intervals of 109 to 285. For Memos the derived abundance total was 128 DRM with a standard error of 44.52 and confidence intervals of 65 to 253.

Size Classes 2012-2014

All captured DRM were measured for total length and the data was used to divide them into size classes. Data from 278 DRM were used to create the composite graph (Figure 6A) and the seasonal graph (Figure 6B) depicting size classes plotted against time. The composite graph shows in spring, the relative abundance of DRM peaking near 30 mm, while, in winter, the relative abundance peaks near 40 mm. These results are corroborated by the seasonal graph using data from individual sampling events. In December of 2014 the trend is shifted towards a semi-bimodal graph.

Relative Abundance of DRM and Fishes in San Felipe Creek

Relative abundance of DRM and the fish community of San Felipe creek are presented from sampling events starting in September 2012 and ending in December 2014: a total of 5,902 fish, from five events, were used to determine the relative abundance averages. Devils River minnows had their highest relative abundance at the Golf Course site, followed by Memos (Table 3). The most abundant fishes within San Felipe creek were *Gambusia sp*., followed by *N. amabilis* which in summation consist of 77% of the total fishes captured. The most diverse site was Memos with an average of nine species over the course of sampling events. The data collected by the TXFWCO shows that the relative abundance of armored catfish increases longitudinally moving downstream. This increase in the relative abundance of the armored catfish is negatively correlated with DRM occupancy scores (Pearson correlation coefficient = -0.89; $p = 0.04$; Figure 7). Although, seining is not the best method for capturing the faster swimming armored catfish, the data collected has been done consistently. In addition, aquatic life use scores have been calculated for the data using methods from Linam et al (2002) and are presented within Table 3.

Habitat Suitability Indices and Associations

Habitat Suitability Indices (HSI) were calculated with data from two sampling events in 2014; including 45 seine hauls and 128 observations of DRM. Additional data will be added to these curves as it becomes available. Relationships were calculated for DRM from data collected on flow (Figure 8), substrate (Figure 9), and macrophytes (Figure 10). Water quality measurements are presented in Table 5.

Data for all five sites from 2012 to 2014, shows that DRM are being found primarily in pool habitats (Figure 11). The data shows that 294 DRM were captured in pool habitat, 0 in riffle habitat, and 17 in run habitat. This data reflects the habitat availability within San Felipe Creek at the sites sampled. For example, the Golf Course site is mainly homogenous with pool habitat.

Aquatic Invertebrates

Invertebrate samples were collected from the five regular monitoring sites on December of 2014; a total of 33 families and 55 genra were recorded. An aquatic life use score was calculated for all sites (Table 6) with all sites rating as high except for the exceptional rating of the Guyler site. Canal Street had the highest diversity with 47 genra. The karst associated caddisfly, *Austrotinoides texensis*, was captured at the Canal and the Guyler sites. The most abundant genra collected across all sites were the riffle beetle *Macrelmis* sp. followed by the amphipod *Hyalella* sp.

Conservation Implications

Pinto Creek

Although this population has evolved within Pinto Creek for hundreds or thousands of years, and may have evolutionary defenses able to deal with issues of drought or other naturally stochastic events, the additive effect of anthropogenic stressors could drive this population to extinction. For example, it could be hypothesized that since geologically constant spring systems like San Felipe Creek and the Devils River have populations of *D. argentosa*, and Pinto does not, it could be said that Pinto may have gone dry over the geologic record and that spring assocciated species like *D. argentosa* (Kollaus and Bonner 2012) were not able to adapt to these conditions due to their dependent habitat associations with spring systems. However, the added pressures of over pumping and removing water from the area in conjunction with projected climate change predicted in the area could provide the perfect scenario for local extirpation. The threats to these minnows have reached a point that may not have been seen previously within the geologic record due the exacerbation by anthropogenic activities providing stronger magnitudes and durations of drought.

In addition to the other stressors, recent discovery of a parasite (Dr. D. Huffman 2015, pers. comm.) within Pinto may be causing unusual neurological behavior (swimming in circles). This parasite has been identified as *Macorderoides* sp and was found encysted in the neurocranial and splanchnocranial bones of Pinto Creek DRM (unpublished Dr. D. Huffman 2015). The genus of this parasite has been shown to be mainly distributed within North America, so the issue of an invasive parasite may not be the case. The effects of this parasite, that may have always been present within the system, just undetected, could be intensified due to the lack of flowing water and amount of water causing longer retention time and the congregation of parasites and snails (needed to complete the parasites life cycle) within the areas inhabited by DRM. Monitoring of the Pinto population will continue.

San Felipe Creek

There is a large restriction (2.6 of the nine km) within the critical habitat of San Felipe Creek where the DRM have been found. In addition, sampling events in December 2014 found no DRM below the Golf Course site at HWY 90 or at Johnson street site, indicating an even smaller restriction (at least seasonally) within the known bounds of their distribution in San Felipe Creek. The decreasing probability of detection and naïve occupancy longitudinally downstream elucidate the attenuation of the DRM population in San Felipe Creek.

Although the inverse correlation between the armored catfish and DRM show a decrease in DRM abundance along with an increase in the relative abundance of armored catfish, the hypothesis would not be that the armored catfish are outcompeting the DRM for resources or habitat, but are an indicator of habitat change longitudinally within San Felipe Creek from the headwaters to the confluence.

Foley and Garrett (2009) showed that the armored catfish was primarily consuming Rhodophyta algae. From 120 armored catfish the Rhodophyta algae consisted of 87% of the gut contents. Although the sample size is low for Dionda (2 for *D. diaboli*, and 5 for *D. argentosa*) the report stated that *D. diaboli* is consuming Bacillariophyta, which made up 55% of the stomach contents, while Cyanophyta (39%) and Rhodophyta (40%) were the main algae genera consumed by *D. argentosa.* There is some overlap between *D. argentosa* and the armored catfish, there is no overlap from this data with *D. diabolic*. Competition for food resources could be eliminated as a factor for the decrease of DRM longitudinally by examining a few more *D. diaboli* for gut contents.

Another potential cause for the decrease in DRM downstream could be the return of diverted water reentering the system. For example, at Johnson street, the water is diverted off and sent through neighborhoods and then reenters the system just below Canal street. Basic water chemistry from our monitoring sites shows no errant spikes in any of the parameters collected. The use of a semipermeable membrane device (SPMD) deployed for a period of up to 60 days may provide more insight to the chemical properties of the water reentering the system.

Analysis of the data shows these fishes are limited in their distribution and exhibit specific habitat associations, thereby decreasing the potential available area within the known longitudinal distribution. Future work using this data for population estimates will use models that allow for the assumption of a closed system to be violated. Some of these models will provide the trend analysis (Kéry et al. 2009) used to monitor the DRM population and variability needed to compensate for that loosening of the assumption (Dali and Madsen 2010).

Data collection for the habitat suitability indices will continue to provide consistent and reliable data for comparisons over time. However, even at this stage of the analysis with the smaller sample size, the current velocity data is corroborated with Kollaus and Bonner (2011) stating that the DRM within the Devils River are associated with flows around 0.025 m/s and silt substrates. Our data is similar with associated peak relative abundance around 0.02 (m/s) and substrates dominated by silt.

Aquatic invertebrates have been shown to be an important tool to determine aquatic health of a system consistently overtime, and may show response to perturbation or disturbance without the lag time accompanied by fishes and other vertebrates. For these reasons sampling of the aquatic invertebrate community will continue.

Table 1. Water quality data collected from critical habitat on Pinto Creek from 2011 to 2014.

	September 2011 Upper Pool			September 2011 Lower Pool			October 2013 Lower Pool		May 2014 Lower Pool			December 2014 Lower Pool		
	Upper	Middle	Lower	Upper	Middle	Lower	Upper	Lower	Upper	Middle	Lower	Upper	Middle	Lower
Temperature (C°)	26.6	26.9	27	25.6	25.6	26	22.73	22.72	22.4	21.88	21.89	22.4	21.8	21.89
DO (mg/L)	4.46	3.42	4.07	2.94	NA	2.95	4.6	5.73	9.05	10.21	11.72	9.05	10.21	11.72
Conductivity (µs)	519	576	590	561	532	444.7	NA	NA	741.6	737.1	728.3	741.6	737.1	728.3
pH	7.85	7.62	7.81	7.63	7.38	7.81	7.15	7.17	7.11	7.17	7.2	7.11	7.17	7.2
Nitrates (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	0.98	0.92	0.81	0.98	0.92	0.81

Table 2. Overall site occupancy scores for the five sites sampled on San Felipe Creek for 2012-2014.

Site	Site Occupancy
Entire Creek	0.20
Golf Course	0.55
Memos	0.42
Canal	0.05
Barron	0.02

Table 3. Count data from San Felipe monitoring sites from September 2012 to December 2014.

Golf Course	9_2012	3_2013	10_2013	5_2014	12_2014	SUMS	AVERAGE
Cyprinella proserpina	0	0	0	0	0	0	0
Cyprinella venusta	0	0	0	0	0	0	0
Dionda Juv	0	0	0	0	0	0	0
Dionda argentosa	6	3	1	68	14	92	18.4
Dionda diaboli	16	43	18	91	12	180	36
Notropis amabilis	20	0	0	8	12	40	8
Astyanax mexicanus	13	58	11	39	96	217	43.4
Hypostomus sp	4	5	2	1	0	12	2.4
Gambusia sp	33	258	64	309	253	917	183.4
Lepomis sp	0	0	0	0	0	0	0
Micropterus salmoides	1	1	0	0	0	2	0.4
Ethostoma grahami	16	26	8	77	13	140	28
Maxostoma sp	0	0	0	0	0	0	0
Lepisosteus osseus	0	0	1	0	0	1	0.2
Cichlasoma cyanoguttatum	1	0	0	2	0	3	0.6
TOTALS	110	394	105	595	400	1604	
SP RICH	10	8	8	9	7	8.4	
Aquatic Life Use Score	37	33	33	37	31		34
Designation	High	Intermediate	Intermediate	High	Intermediate		

MEMOS	9_2012	3_2013	10_2013	5_2014	12_2014	SUMS	AVERAGE
Cyprinella proserpina	0	0	0	0	0	0	0
Cyprinella venusta	0	0	0	0	0	0	0
Dionda Juv	0	3	0	0	0	3	0.6
Dionda argentosa	45	3	2	6	0	56	11.2
Dionda diaboli	22	8	7	56	25	118	23.6
Notropis amabilis	90	42	0	52	0	184	36.8
Astyanax mexicanus	3	0	0	29	0	32	6.4

Hypostomus sp	3	1	5	4	1	14	2.8
Gambusia sp	27	30	26	131	120	334	66.8
Lepomis sp	57	4	5	14	21	101	20.2
Micropterus salmoides	0	1	0	7	3	11	2.2
Ethostoma grahami	2	52	11	27	4	96	19.2
Maxostoma sp	0	0	0	0	0	0	0
Lepisosteus osseus	0	0	0	0	0	0	0
Cichlasoma cyanoguttatum	5	0	0	2	2	9	1.8
TOTALS	254	144	56	328	176	958	
SP RICH	10	10	7	11	8	9.2	
Aquatic Life Use Score	37	35	33	37	33		35
Designation	High	Intermediate	Intermediate	High	Intermediate		
CANAL	9_2012	3_2013	10_2013	5_2014	12_2014	SUMS	AVERAGE
Cyprinella proserpina	0	5	0	0	0	5	1
Cyprinella venusta	0	0	0	0	0	0	0
Dionda Juv	0	0	0	0	0	0	0
Dionda argentosa	0	0	0	0	0	0	0
Dionda diaboli	2	9	0	0	0	11	2.2
Notropis amabilis	413	12	149	92	6	672	134.4
Astyanax mexicanus	0	0	0	0	0	0	0
Hypostomus sp	28	0	6	63	2	99	19.8
Gambusia sp	13	31	146	226	336	752	150.4
Lepomis sp	1	0	0	0	2	3	0.6
Micropterus salmoides	0	0	0	0	0	0	0
Ethostoma grahami	0	0	0	0	0	0	0
Maxostoma sp	0	0	0	0	0	0	0
Lepisosteus osseus	0	0	0	0	0	0	0
Cichlasoma cyanoguttatum	0	0	0	0	0	0	0
TOTALS	457	57	301	381	346	1542	

SP RICH	6	5	4	4	5	4.8	
Aquatic Life Use Score	33	35	31	31	31		32
Designation	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate		
BARRON	9_2012	3_2013	10_2013	5_2014	12_2014	SUMS	AVERAGE
Cyprinella proserpina		4	0	0		4	1.333333
Cyprinella venusta		0	0	0		0	0
Dionda Juv		0	0	0		0	0
Dionda argentosa		0	0	0		0	0
Dionda diaboli		1	0	0		1	0.333333
Notropis amabilis		65	319	413		797	265.6667
Astyanax mexicanus		0	0	0		0	0
Hypostomus sp		7	44	0		51	17
Gambusia sp		78	350	306		734	244.6667
Lepomis sp		2	4	4		10	3.333333
Micropterus salmoides		0	0	0		0	0
Ethostoma grahami		0	0	0		0	0
Maxostoma sp		0	0	0		0	0
Lepisosteus osseus		0	0	0		0	0
Cichlasoma cyanoguttatum		0	0	0		0	0
TOTALS		157	717	723		1597	
SP RICH		7	5	4		5.333333	
Aquatic Life Use Score		33	31	31			31
Designation		Intermediate	Intermediate	Intermediate			
GUYLER	9_2012	3_2013	10_2013	5_2014	12_2014	SUMS	AVERAGE
Cyprinella proserpina		4		2		6	3
Cyprinella venusta		5		3		8	4
Dionda Juv		0		0		0	0
Dionda argentosa		0		0		0	0

Dionda diaboli	[redacted]	0	[redacted]	0	[redacted]	0	0
Notropis amabilis	[redacted]	3	[redacted]	19	[redacted]	22	11
Astyanax mexicanus	[redacted]	16	[redacted]	5	[redacted]	21	10.5
Hypostomus sp	[redacted]	1	[redacted]	7	[redacted]	8	4
Gambusia sp	[redacted]	104	[redacted]	28	[redacted]	132	66
Lepomis sp	[redacted]	0	[redacted]	0	[redacted]	0	0
Micropterus salmoides	[redacted]	0	[redacted]	0	[redacted]	0	0
Ethostoma grahami	[redacted]	0	[redacted]	0	[redacted]	0	0
Maxostoma sp	[redacted]	4	[redacted]	0	[redacted]	4	2
Lepisosteus osseus	[redacted]	0	[redacted]	0	[redacted]	0	0
Cichlasoma cyanoguttatum	[redacted]	0	[redacted]	0	[redacted]	0	0
TOTALS	[redacted]	137	[redacted]	64	[redacted]	201	
SP RICH	[redacted]	8	[redacted]	7	[redacted]	7.5	
Aquatic Life Use Score	[redacted]	35	[redacted]	35	[redacted]		35
Designation	[redacted]	Intermediate	[redacted]	Intermediate	[redacted]		
	[redacted]	HWY 90 12_ 2014	[redacted]	Johnson 12_2014	[redacted]		
Cyprinella proserpina	[redacted]	0	[redacted]	0	[redacted]		
Cyprinella venusta	[redacted]	0	[redacted]	0	[redacted]		
Dionda Juv	[redacted]	0	[redacted]	0	[redacted]		
Dionda argentosa	[redacted]	5	[redacted]	0	[redacted]		
Dionda diaboli	[redacted]	0	[redacted]	0	[redacted]		
Notropis amabilis	[redacted]	57	[redacted]	29	[redacted]		
Astyanax mexicanus	[redacted]	5	[redacted]	0	[redacted]		
Hypostomus sp	[redacted]	1	[redacted]	33	[redacted]		
Gambusia sp	[redacted]	290	[redacted]	1159	[redacted]		
Lepomis sp	[redacted]	7	[redacted]	0	[redacted]		
Micropterus salmoides	[redacted]	2	[redacted]	0	[redacted]		
Ethostoma grahami	[redacted]	4	[redacted]	0	[redacted]		
Maxostoma sp	[redacted]	0	[redacted]	0	[redacted]		

Lepisosteus osseus		0		0			
Cichlasoma cyanoguttatum		1		0			
TOTALS		372		1221			
SP RICH		9		3			
Aquatic Life Use Score		35		31			
Designation		Intermediate		Intermediate			

Table 4. Averaged water quality data collected from Spring #6 upstream of San Felipe Creek critical habitat.

	Aug-11	Sep-12	Mar-13	Oct-13	May-14	Dec-14
Temperature (C°)	26.10	25.50	NA	23.52	32.01	21.54
DO (mg/L)	6.44	3.83	NA	7.86	13.89	7.65
Conductivity (µs)	438.43	350.90	345.20	NA	281.73	522.53
pH	7.69	7.94	7.14	8.20	8.39	7.64
Nitrates (mg/L)	NA	NA	NA	NA	NA	2.68

Table 5. Averaged water quality data collected from critical habitat on San Felipe Creek from 2011 to 2014. The lowest row is longitudinal order from the headwaters to just above the confluence with the Rio Grande. Data in bold is only from one year.

	Golf Couse	SH 90	Memos	Johnson	Canal	Barron	Guyler
Temperature (C°)	23.80	**22.72**	23.74	**21.54**	23.36	24.64	25.08
DO (mg/L)	6.86	**7.06**	8.65	**7.65**	7.98	8.97	8.01
Conductivity (µs)	532.26	**518.85**	498.37	**522.53**	476.67	463.19	475.92
pH	7.29	**7.36**	7.70	**7.64**	7.86	7.98	7.97
Nitrates (mg/L)	3.59	**2.86**	3.45	**2.51**	3.13	**3.51**	**3.08**
Longitudinal Order	1	2	3	4	5	6	7

Table 6. Calculated metrics and associated aquatic life use score for monitoring sites in San Felipe Creek from October 2013.

	Golf Course	Canal	Barron	Guyler
Total Taxa	19	47	33	40
Diptera Taxa	4	14	13	12
Ephemeroptera Taxa	2	2	1	3
Intolerant Taxa	4	15	10	11
% EPT	22.95	7.43	11.78	25.47
% Chironomidae	6.56	9.20	31.99	27.72
% Tolerant	0	0	0	0
% Grazers	13.12	28.77	17.51	26.10
% Gatherers	17.48	36.08	36.03	31.31
% Filterers	1.64	7.77	13.13	6.40
% Dominance (3 taxa)	60.66	61.31	46.46	39.70
Total	33	39	39	41
Aquatic Life Use Determination	HIGH	HIGH	HIGH	EXCEPTIONAL

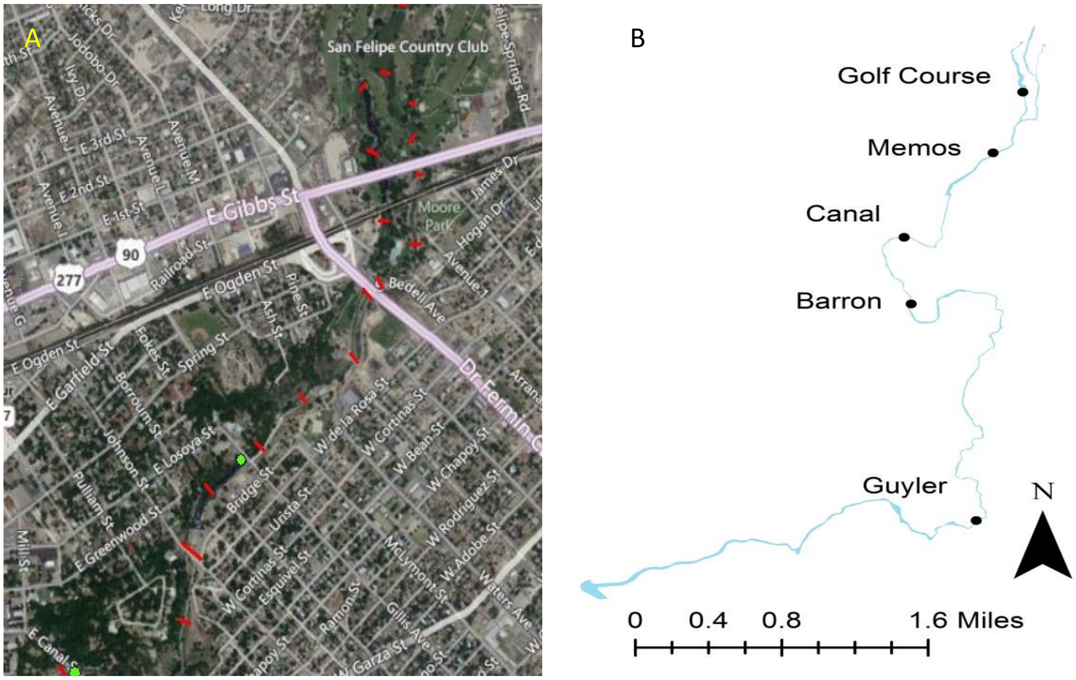

Figure 1. Maps of sampling locations along San Felipe Creek. Figure 1A shows potential monitoring sites in 200 meter increments. Figure 1B shows the distribution of selected sites for monitoring from 2012 to 2013.

Figure 2. Succession of Devils River minnow habitat in Pinto Creek. Image on the left taken by Warren Schlechte of TPWD.

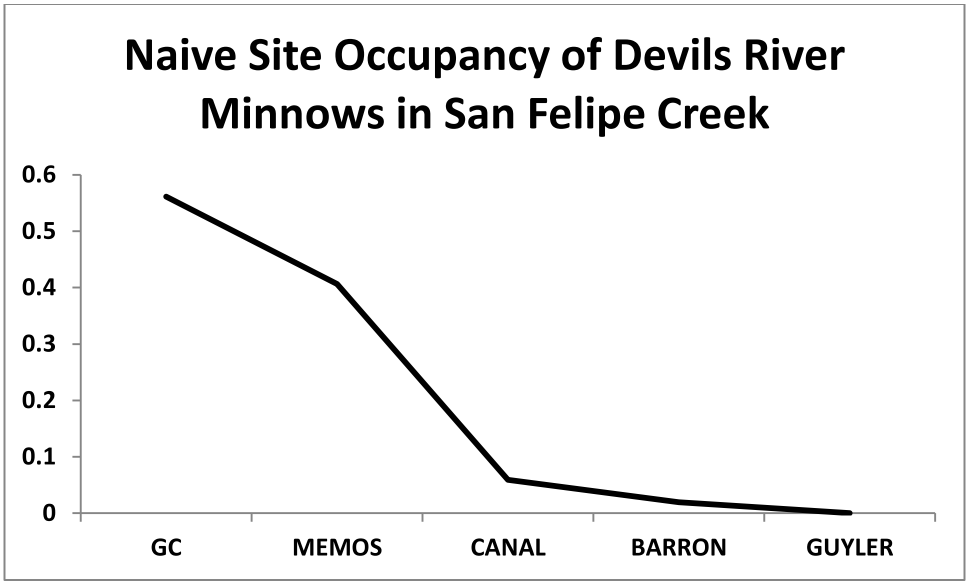

Figure 3. Linear depiction of naïve site occupancy scores for Devils River minnows on the five sites within San Felipe creek.

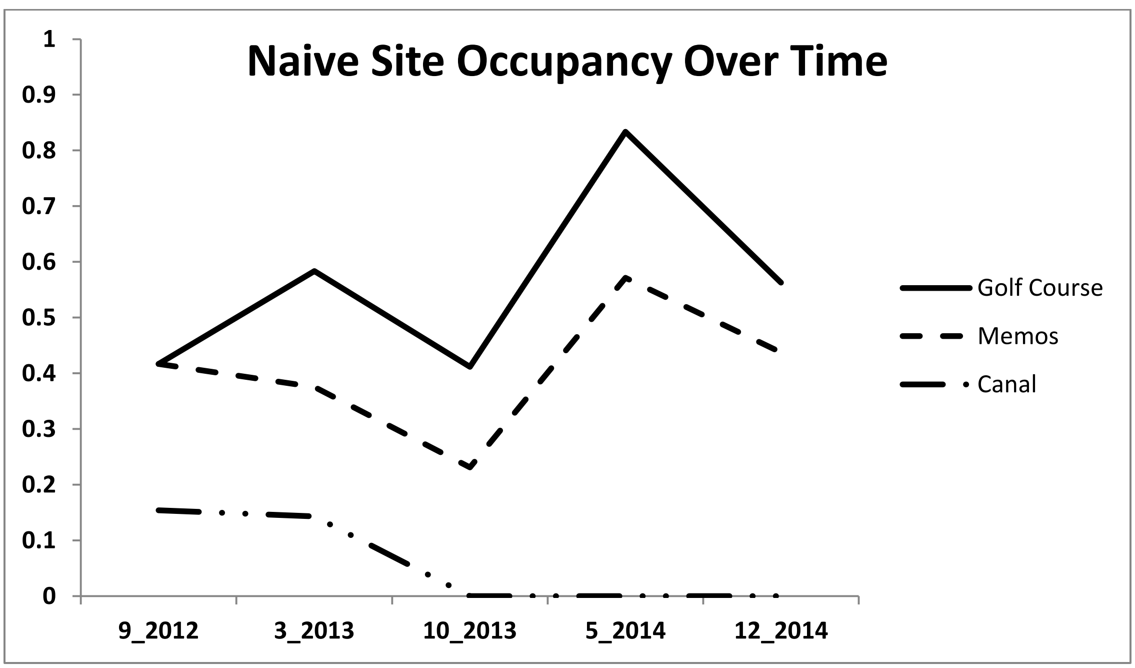

Figure 4. Naïve site occupancy scores for Devils River minnows at regular sampling locations on San Felipe Creek from 2012 to 2014.

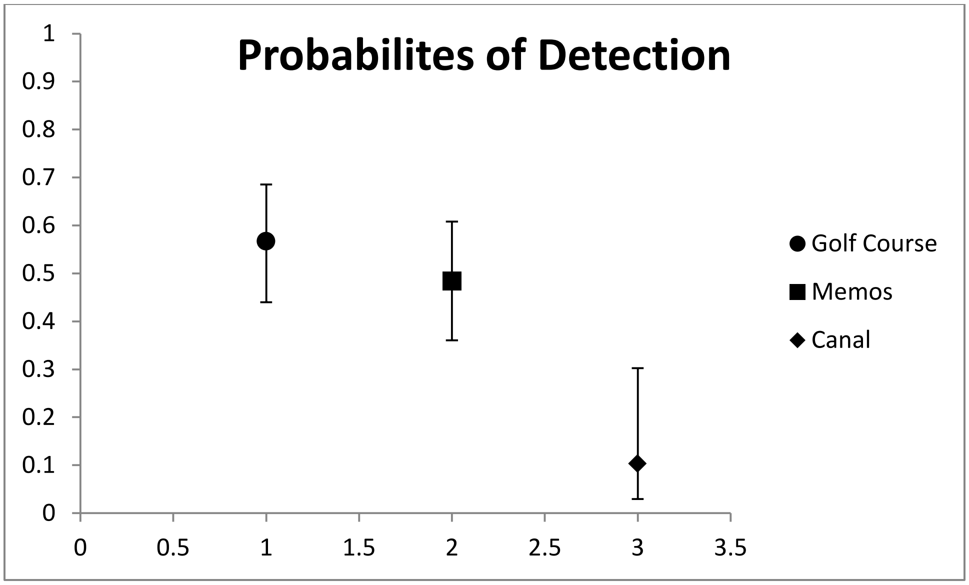

Figure 5. Overall probability of detection for monitoring sites of Devils River minnows in San Felipe Creek from 2012 and 2014. Error bars represent 95% confidence intervals.

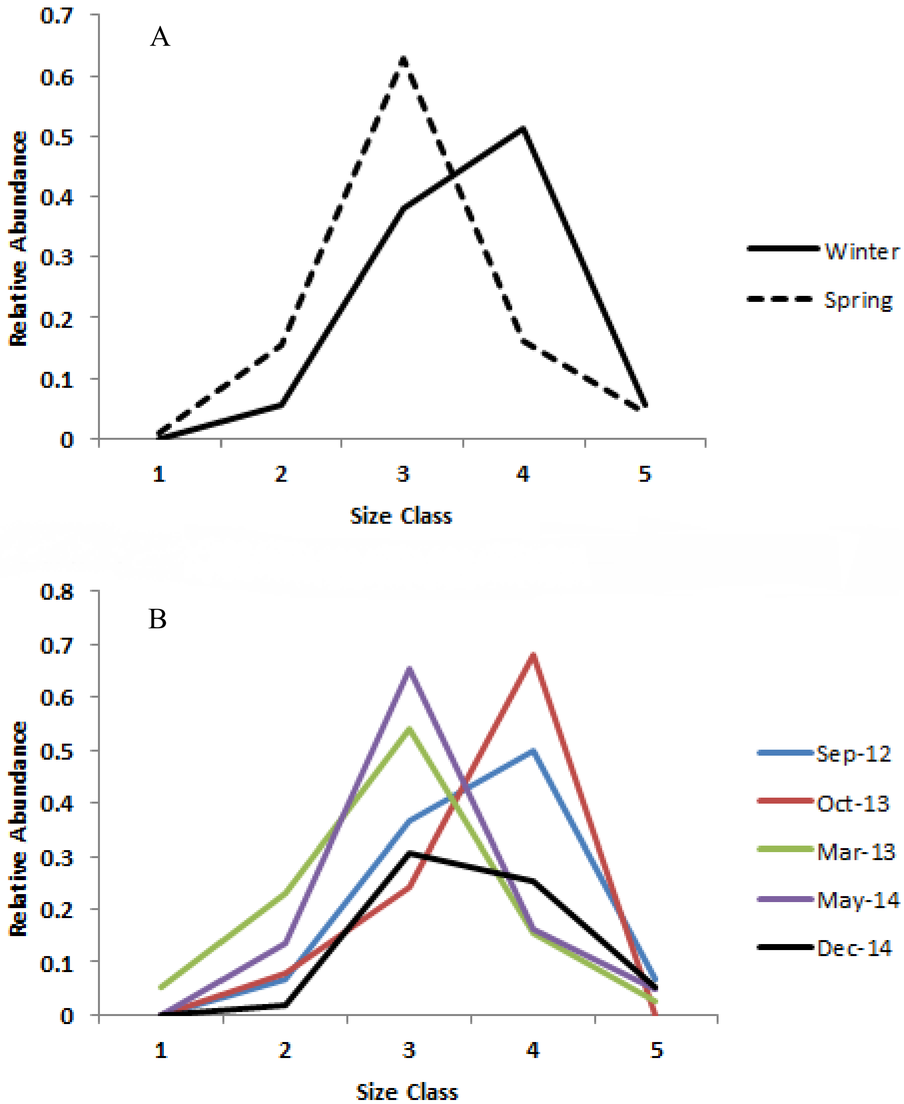

Figure 6. Seasonal changes in the population structure of Devils River minnows in San Felipe Creek.

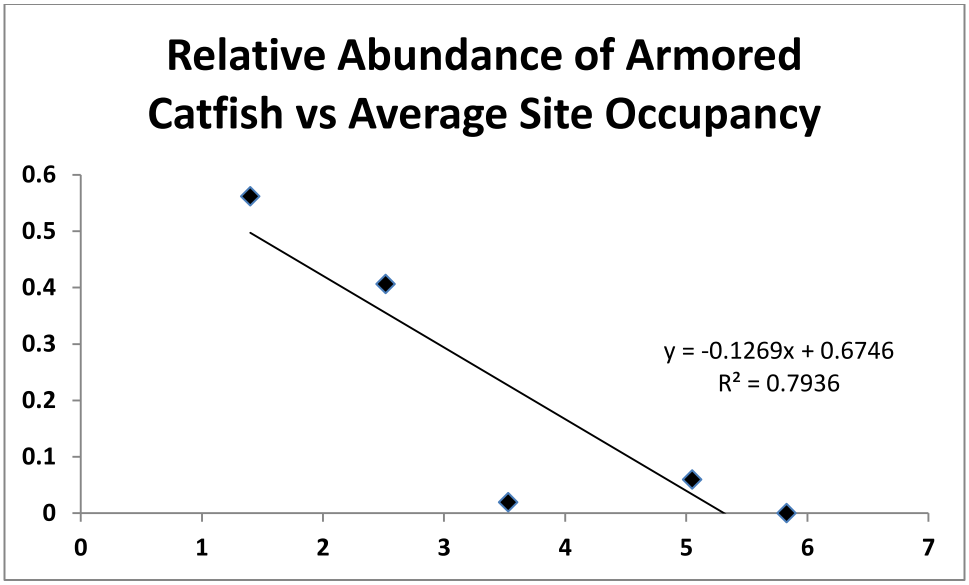

Figure 7. Relationship between the abundance of armored catfish and average site occupancy of Devils River minnows in San Felipe Creek.

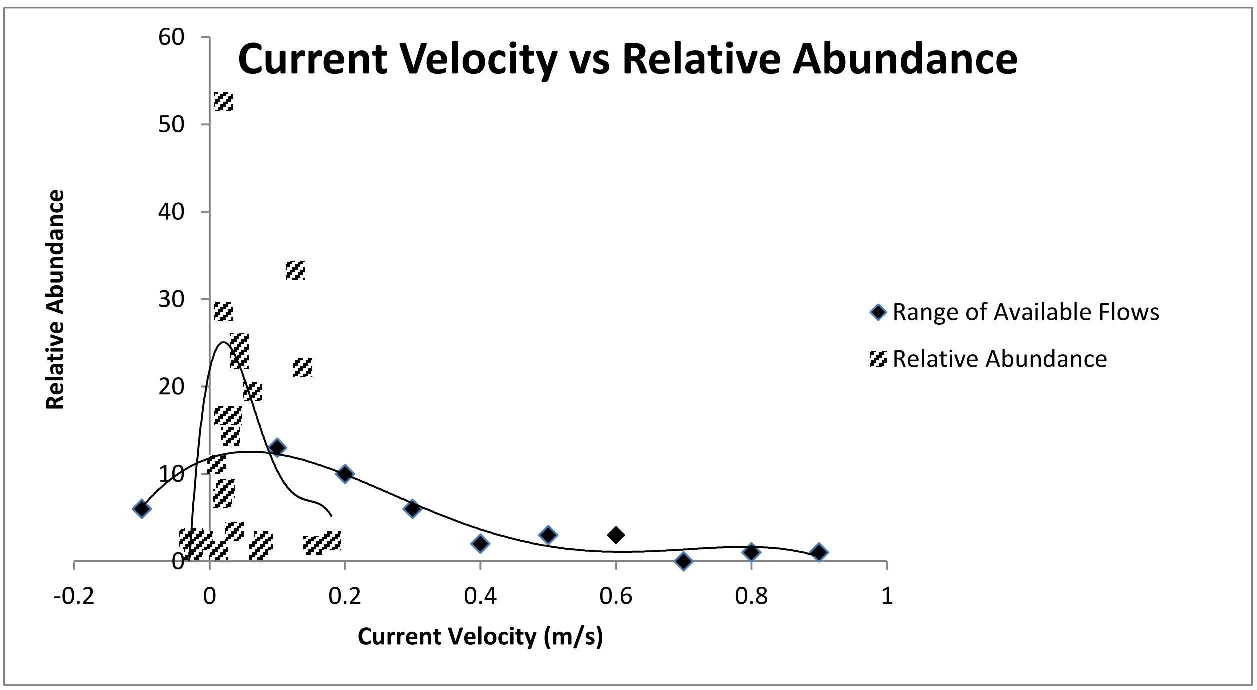

Figure 8. Univariate relationship for the Devils River minnow and associated flows (X-axis) with relative abundance on the Y-axis. Relationships were made from 45 seine hauls and 128 observations of Devils River minnows from 2014.

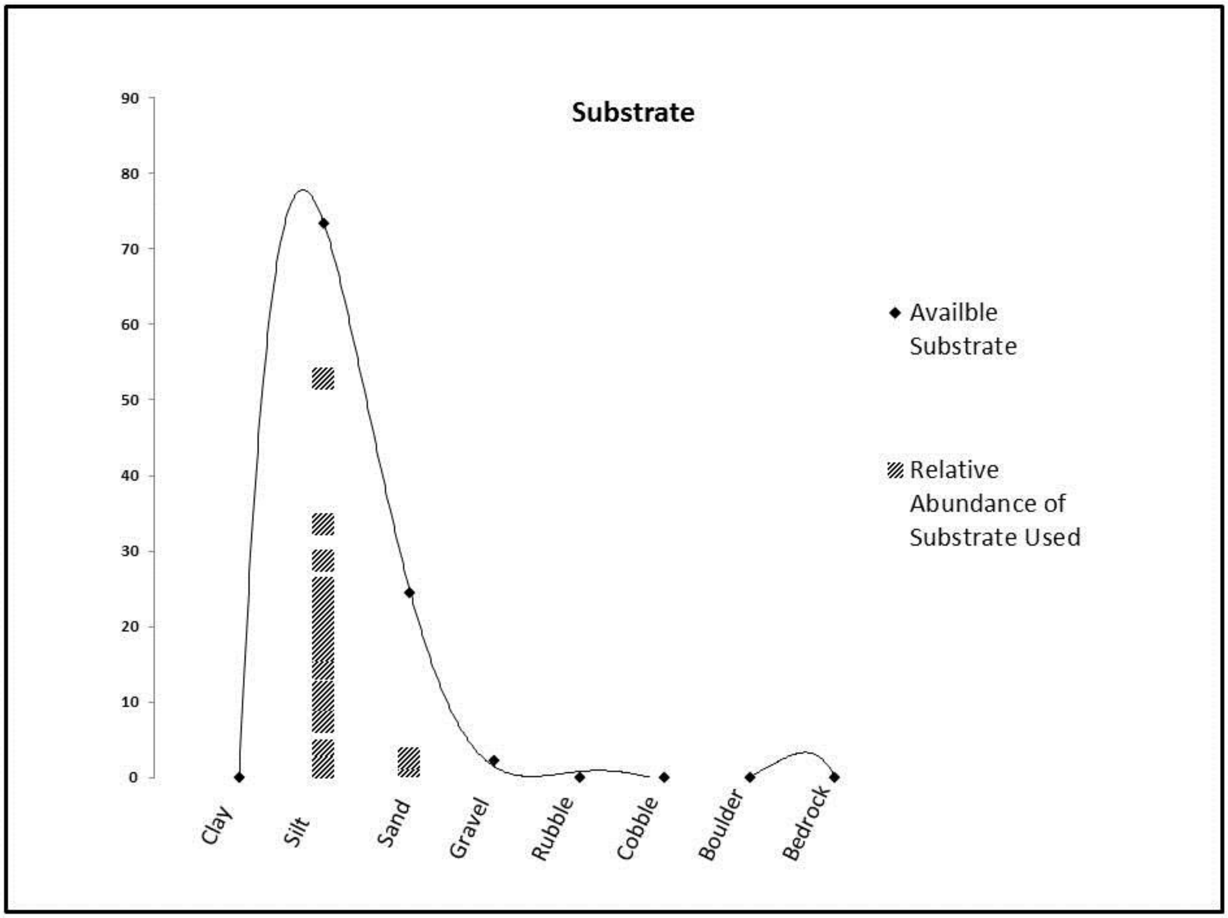

Figure 9. Univariate relationship for the Devils River minnow and associated dominant substrates with relative abundance on the Y-axis. Relationships were made from 45 seine hauls and 128 observations of Devils River minnows from 2014.

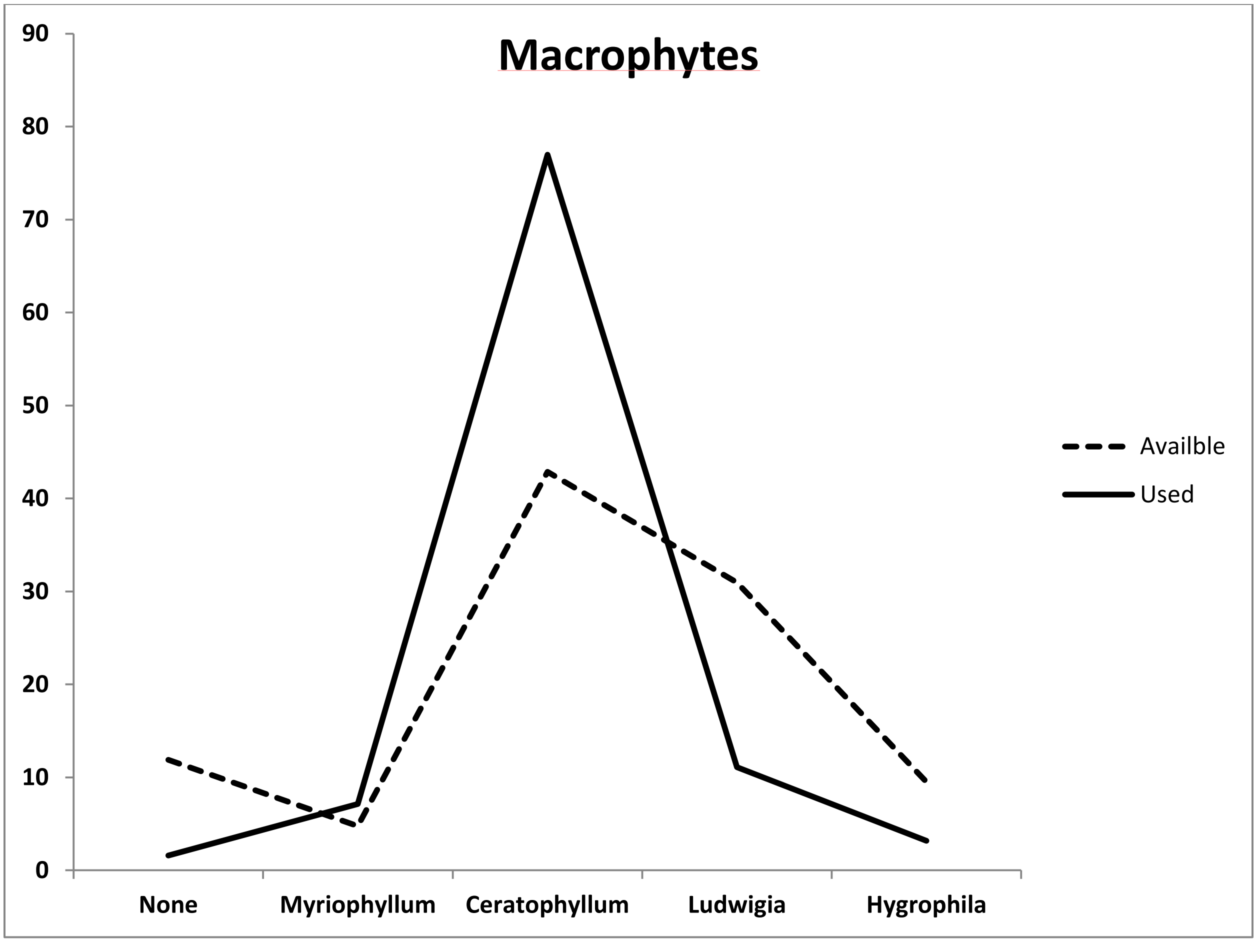

Figure 10. Univariate relationship for the Devils River minnow and associated macrophtes. Shown are percentages of available and the percentage of Devils River minnows using that type of macrophytes. Relationships were made from 45 seine hauls and 128 observations of Devils River minnows from 2014.

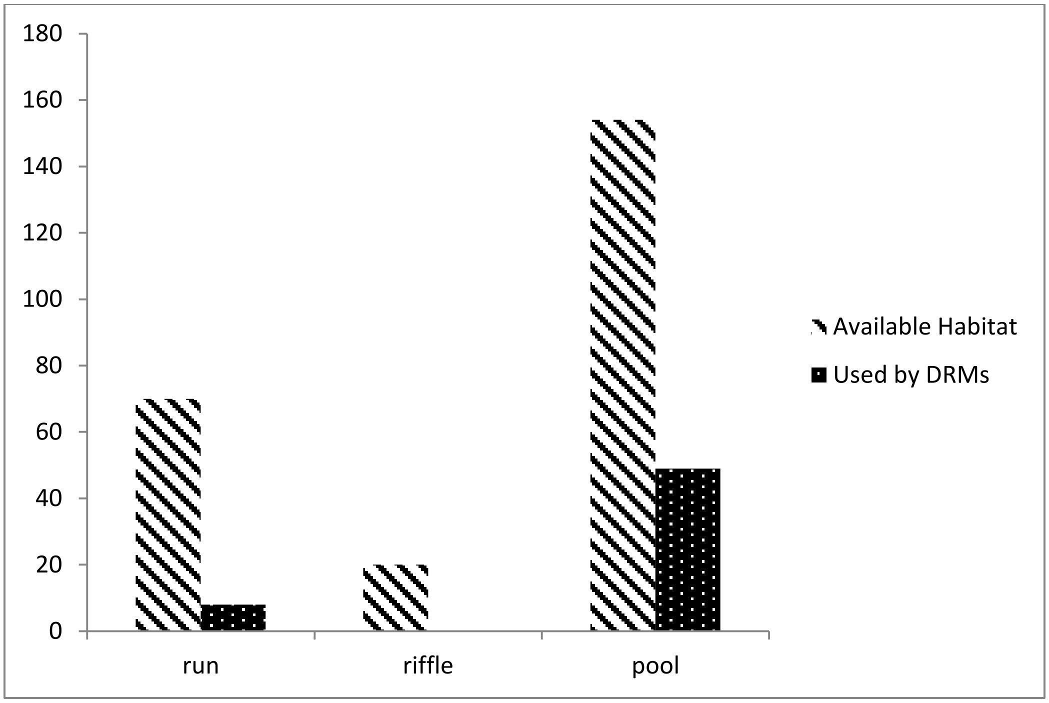

Figure 11. The stripped bars show habitat sampled. The black dotted bars show the use of that habitat by Devils River minnows. There were a total of 256 Devils River minnows using pool type habitat and 17 using the run habitat.

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Appendix

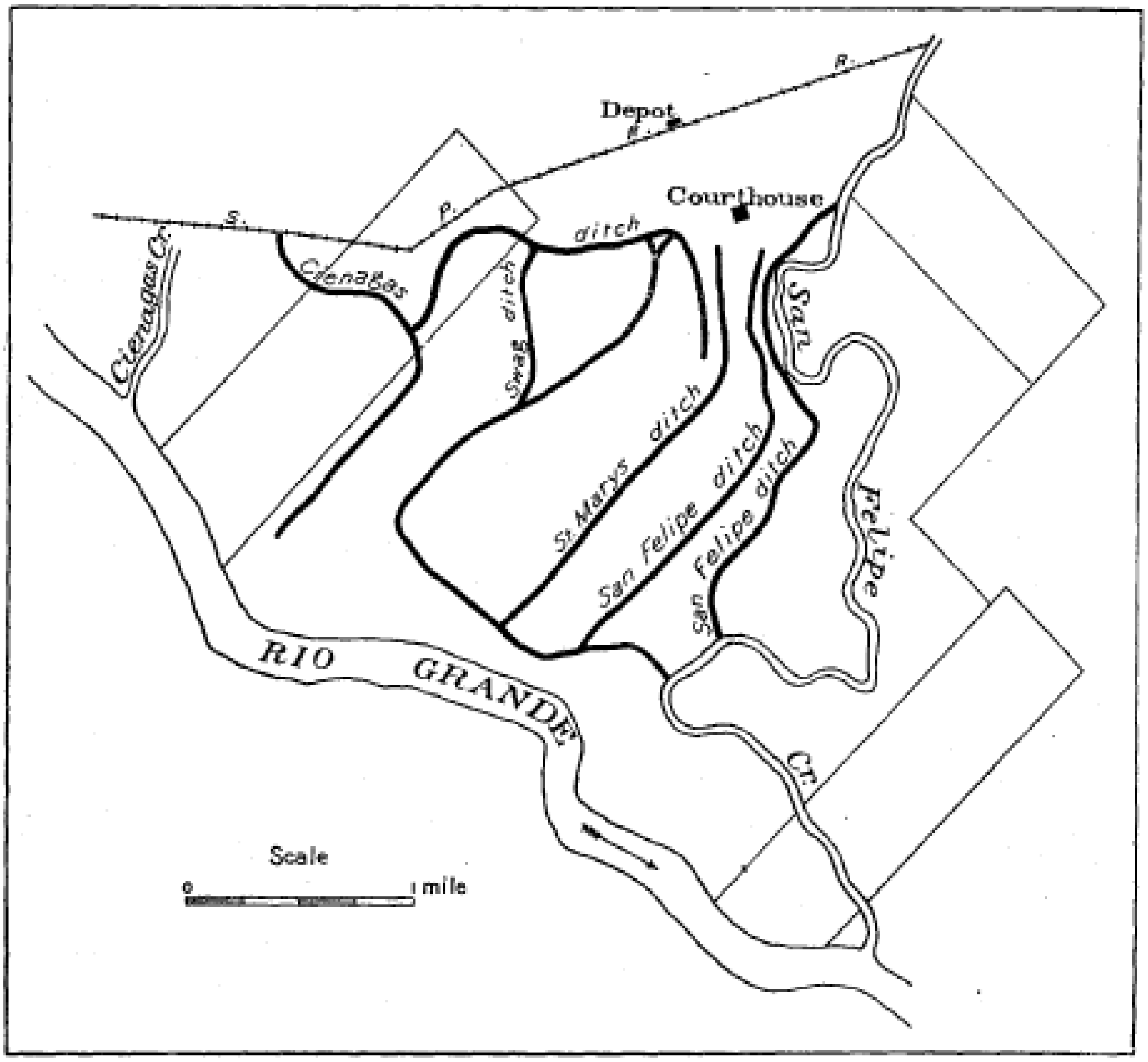

FIG. 6.—Map of Del Rio irrigation system.

A1. Map of aqueducts within the San Felipe system. Image taken from Taylor (1902) Irrigation Systems of Texas.