Middle Rio Grande
Riverine Habitat Restoration Fisheries Monitoring
Spring 2011 Final Report

Prepared for

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EXECUTIVE SUMMARY

SWCA Environmental Consultants, under contract to the New Mexico Interstate Stream Commission (NMISC), presents fisheries monitoring results for selected Interstate 40 (I-40) Subreach habitat restoration sites for 2011. The NMISC has applied a number of habitat restoration techniques within the Albuquerque Reach of the Middle Rio Grande to create and improve habitat for the Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow). The project is primarily funded by the State of New Mexico and the Middle Rio Grande Endangered Species Collaborative Program through grants with the U.S. Bureau of Reclamation.

This report provides the results of fisheries monitoring activities conducted during spring 2011. Results from monitoring allow for inferences to be made regarding restoration treatments and suitability of improved habitats for various life stages of the silvery minnow. Some of the key results from the 2011 fisheries monitoring include:

- 39 silvery minnow were collected at NMISC I-40 Subreach habitat restoration sites in spring 2010;
- three silvery minnow were collected with beach seines, while 36 were collected with fyke nets;
- at least one silvery minnow was collected from each of the sampled habitat restoration sites;
- the greatest single day collections of adult silvery minnow, bar and side channel collections, and main channel egg collections all occurred during the ascending limb of the hydrograph leading to peak flow (1,336 cubic feet per second) for spring 2011;
- 3,279 silvery minnow eggs were collected from main channel habitats with Moore egg collectors, while 3,269 were collected from vegetated margins of habitat restoration sites with D-frame kick nets; and
- silvery minnow eggs collected from the vegetated margins of habitat restoration sites with D-frame kick nets required less effort to collect than those collected from main channel habitats with Moore egg collectors.

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Photo of gravid Rio Grande silvery minnow (*Hybognathus amarus*) by Eric Gonzales, SWCA.

1.0 INTRODUCTION

The New Mexico Interstate Stream Commission (NMISC) has employed a number of habitat restoration techniques in the Middle Rio Grande (MRG) to reconnect portions of the floodplain with the main channel during periods of moderate and high flows to benefit the Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow). The restoration work has been conducted to satisfy federal requirements under Biological Opinion Reasonable Prudent Alternative Element S that, in coordination with the U.S. Fish and Wildlife Service (USFWS), agencies "shall…conduct habitat/ecosystem restoration projects in the Middle Rio Grande to increase backwaters and oxbows, widen the river channel, and/or lower river banks to produce shallow water habitats, overbank flooding, and regeneration of stands of willows and cottonwood to benefit the silvery minnow, the flycatcher, or their habitats" (USFWS 2003:95–96).

Fisheries information collected by SWCA Environmental Consultants (SWCA) on behalf of the NMISC indicates that silvery minnow occupy these habitats and may spawn at these areas during spring runoff (SWCA 2008a, 2008b, 2010, 2011; Gonzales and Hatch 2009). Multiple life stages of silvery minnow have been found on inundated habitat restoration sites created by the NMISC during spring runoff (SWCA 2008a, 2008b, 2010; 2011, Gonzales and Hatch 2009). In 2011 spring fisheries monitoring was conducted to document silvery minnow presence at a variety of habitat restoration treatment types, including bar and channel modifications. Information collected during this monitoring effort documents the occupancy of reproductively mature silvery minnow and the presence of their eggs on habitat restoration sites.

1.1 PROJECT GOALS AND OBJECTIVES

Fisheries monitoring was conducted in spring 2011 to determine if constructed habitat restoration sites are being utilized by the silvery minnow during runoff. Beach seine and fyke nets were used to sample for the species and the MRG fish community. Adult silvery minnow, their eggs, and larval fish were collected to assess the species utilization of these habitats during spawning. Spring runoff during 2011 was below average and provided an opportunity to survey restoration sites constructed to inundate at below average discharges.

2.0 HABITAT RESTORATION SITE MONITORING

2.1 SITE SELECTION

Five NMISC habitat restoration sites from the Interstate 40 (I-40) Subreach were selected for fisheries monitoring from the Albuquerque Reach of the MRG (Figure 2.1). Sites selected represented a diversity of habitat restoration techniques and were expected to be inundated during the anticipated peak flow of spring runoff. Prior to peak discharge, seine samples were collected from habitat restoration sites that were not sufficiently inundated to survey with fyke nets. Table 2.1 lists NMISC habitat restoration subreaches, site names, seine sampling locations, fyke net identification numbers, and the number of days and dates each seine sampling and fyke net locations were fished. Appendix A contains detailed maps of each site with seine sampling, fyke net, and water quality locations.

Table 2.1. Albuquerque Reach Sites Selected for NMISC 2011 Fisheries Monitoring

Sub-reach	Site	Seine Locations and Fyke Net Identification Number	Number of Days Sampled	Sample Dates
I-40	I-40-6b	Site A	3	5/13, 5/20, 5/31
		Site B	1	5/13
		1	10	5/10, 6/1, 6/2, 6/4, 6/5, 6/6, 6/7, 6/9, 6/10, 6/13
		2	10	5/10, 6/1, 6/2, 6/4, 6/5, 6/6, 6/7, 6/9, 6/10, 6/13
I-40	I-40-2b	Site A	4	5/10, 5/13, 5/20, 5/31
		Site B	3	5/13, 5/20, 5/31
		1	10	5/10, 6/1, 6/2, 6/4, 6/5, 6/6, 6/7, 6/9, 6/10, 6/13
		2	10	5/10, 6/1, 6/2, 6/4, 6/5, 6/6, 6/7, 6/9, 6/10, 6/13
I-40	Atrisco	Site A	3	5/10, 6/1, 6/2
		1	7	6/4, 6/5, 6/6, 6/7, 6/9, 6/10, 6/13
I-40	I-40-4b	Site A	3	5/13, 5/20, 5/31
		Site B	1	5/31
		1	9	6/1, 6/2, 6/4, 6/5, 6/6, 6/7, 6/9, 6/10, 6/13
		2	9	6/1, 6/2, 6/4, 6/5, 6/6, 6/7, 6/9, 6/10, 6/13
I-40	I-40-1i	Site A	3	5/13, 5/20, 6/2
		Site B	3	5/13, 5/20, 5/31
		1	6	6/4, 6/5, 6/6, 6/7, 6/10, 6/13

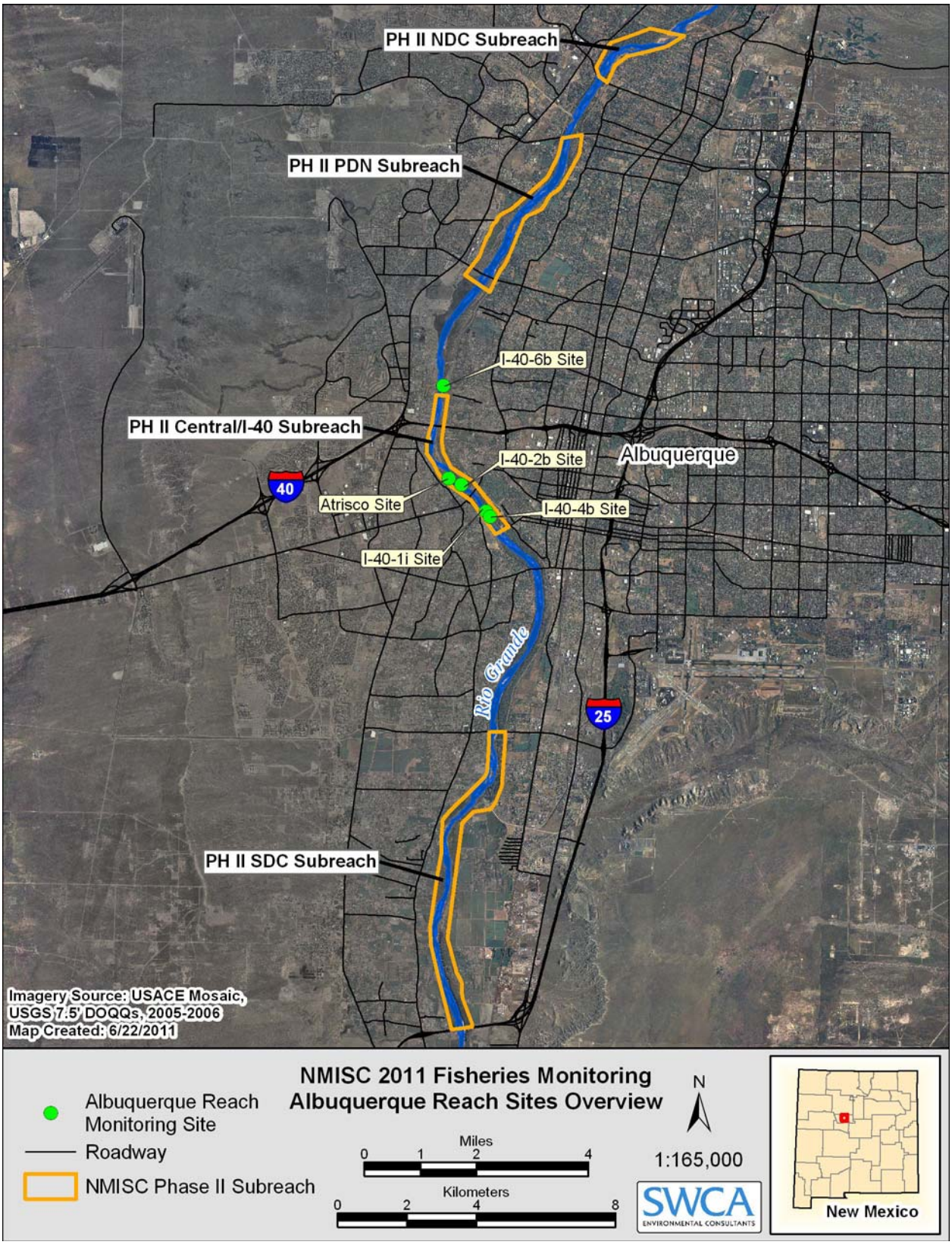

Figure 2.1. Overview map of Albuquerque Reach sites selected for spring 2011 monitoring.

2.2 METHODS

The sampling methods described in this document provide a general overview of field techniques used during monitoring. A sampling and analysis plan that details the project methodologies was prepared prior to the onset of monitoring and can be referred to for additional information related to site selection, fyke net setup, egg and larval fish collections, and the daily sampling approach used by monitoring crews (SWCA 2011b).

2.2.1 FISHERIES MONITORING

Fisheries monitoring was conducted from May 10 to June 13, 2011. Beach seines were used to survey habitat restoration sites that were not sufficiently inundated during the onset of monitoring. When sites were sufficiently inundated, individual fyke nets were deployed singly to capture silvery minnow within the inundated restoration sites. Appendix A shows locations of seine sampling locations, fyke net locations, water quality collection locations, and egg collection locations at each monitored restoration site.

Seine net samples were collected with a small beach seine (3.1 × 1.8 m [10 × 6 feet] with 3-mm mesh) from each seine sampling location on the indicated survey dates. A minimum of four and maximum of 10 seine hauls were collected from each seine sampling location. Depth (feet) and velocity (feet per second [ft/s]) of the seine sampling locations were characterized by sampling a longitudinal cross section of each sampling location on each survey date. The length of each seine haul (m) was recorded and collected fish were identified to species and counted after each seine haul. Standard length (mm) and observations of sex and reproductive condition (i.e., gravid female, male with milt, spent female, and unknown) were collected for silvery minnow. Fish were released back to the seine sampling location where they were captured after all seine hauls within an area were complete.

Fish were also collected at habitat restoration sites with D-frame double wing fyke nets (2.1 m length × 1.0 m width × 0.60 m height [6.9 × 3.3 × 2.0 feet]; wings 4.6 m length × 0.6 m height [15.9 × 2.0 feet]; 3.1-mm delta mesh, 5-cm-diameter [2-inch-diameter] throat) that were attached to metal posts (1.8-m [6-foot] t-posts). Fyke net locations were selected based on the presence of sufficient inundation for effective use of this gear type. On each sampling date fyke nets were set for 3.25 to 5.0 hours when conditions were conducive to sampling (i.e., sufficient inundation present at each site). Depth (feet) and velocity (ft/s) at each fyke net location and the time (hours) that each fyke net was fished were recorded on each sampling date. All post-larval fish collected were identified to species in the field, using taxonomic keys from Sublette et al. (1990); phylogenetic classification followed Nelson et al. (2004). Standard length (mm) and observations of sex and reproductive condition (i.e., gravid female, male with milt, spent female, and unknown) were collected for silvery minnow. Species counts were maintained for all collections, and all live fish were released back to the site of capture.

A Trimble GeoXT handheld global positioning system (GPS) unit with sub-meter accuracy was used to record spatial characteristics of seine and fyke net sampling locations. Data from the U.S. Geological Survey (USGS) stage gage at the Central Avenue Bridge (#08330000) was used as a record of river discharge over the sampling period (Figure 2.2). A digital camera was used for all photo documentation (Appendix B). A relational database (Microsoft Access) and a

spreadsheet database (Microsoft Excel) were developed for the storage, analysis, and retrieval of fish survey data.

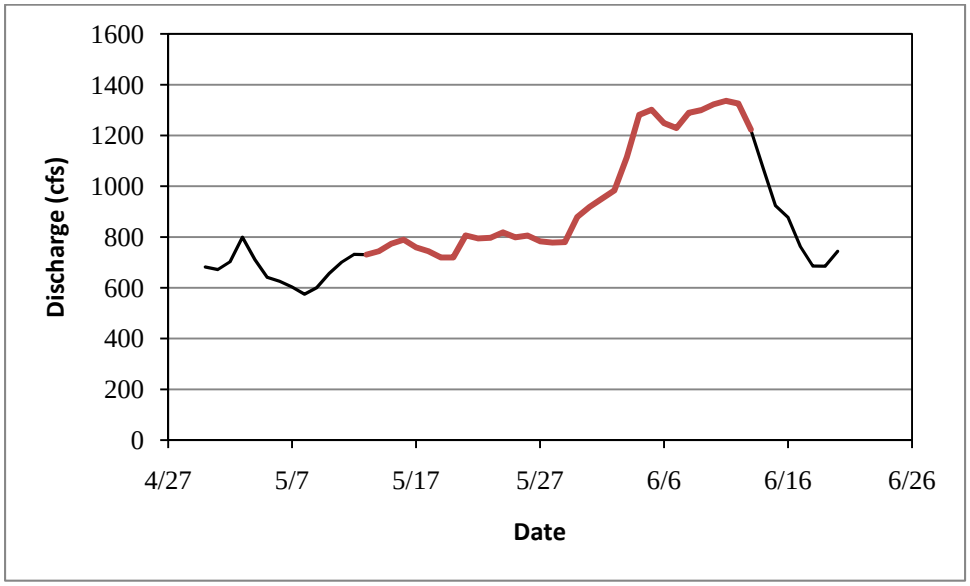

Figure 2.2. Average daily discharge in the Rio Grande at the USGS Central Avenue Bridge Gage (#08330000); the spring 2011 monitoring period is highlighted red.

2.2.2 Data Analysis

Beach seine effort was calculated by multiplying seine width (2.5 m [8.2 feet]) by the length of each seine haul. Catch per unit effort (CPUE) was calculated for each species as the total area sampled divided by the total number collected. Beach seine data are presented as percent composition and the total number of fish collected from each seine sampling location.

Silvery minnow CPUE was calculated for fyke net samples by dividing the total number of fish captured by the total number of hours each fyke net was fished on each day (Quinn and Deriso 1999; Hubert and Fabrizio 2007). Standardization of fyke net captures (assumes no periodic effect on captures) is expressed as fish per hour and is the index used to assess variation in species abundance among sites throughout the monitoring period.

Non-parametric statistical tests were conducted to assess if CPUE varied among sites and sampling dates. A Kruskal-Wallis single-factor analysis of variance by rank was used to test for CPUE differences among restoration sites and among sampling dates (Zar 1999). Non-parametric statistical analysis assumes random assignment of net locations and was chosen because the presence of zero values for individual net sites prevented normalization of the CPUE data through transformation.

2.3 RESULTS

2.3.1 SILVERY MINNOW OCCUPANCY OF NMISC HABITAT RESTORATION SITES

In total, three silvery minnow were collected from habitat restoration sites with beach seines during monitoring. Catches at individual seine sampling locations ranged from zero to two silvery minnow per sampling event, and the highest catch occurred at I-40-4b (two silvery minnow) immediately after site inundation. No silvery minnow were collected from I-40-6b, Atrisco, or I-40-2b with the beach seine (Table 2.2).

Table 2.2. Total Number of Silvery Minnow, Velocity and Depth Values Collected from Habitat Restoration Sites with Beach Seines

Restoration Site	Number of Silvery Minnow	Mean Velocity* (ft/s)	Mean Depth* (feet)
I-40-6b	0	1.14 (0.08)	1.37 (0.09)
Atrisco	0	0.39 (0.08)	1.44 (0.07)
I-40-2b	0	1.21 (0.08)	1.17 (0.06)
I-40-4b	2	0.79 (0.05)	0.80 (0.06)
I-40-1i	1	0.77 (0.09)	0.98 (0.05)

*Standard errors of CPUE, velocity, and depth values are given in parenthesis.

In total, 36 silvery minnow were collected with fyke nets from habitat restoration sites during monitoring. Catches at individual fyke net locations ranged from 0 to 15 silvery minnow per fyke net set, and the highest cumulative catches occurred at I-40-4b (25 silvery minnow) and I-40-6b (eight silvery minnow). Silvery minnow CPUE did not differ among I-40-6b, Atrisco, I-40-2b, I-40-4b and I-40-6b habitat restoration sites (Kruskal-Wallis single-factor analysis of variance $P = 0.12$). Qualitatively silvery minnow CPUE was greatest at I-40-4b (0.33 fish/hour) and lowest at I-40-1i (0.00 fish/hour) (Table 2.3).

Table 2.3. Total Number of Silvery Minnow, Mean CPUE, Velocity, and Depth Values Collected from Habitat Restoration Sites with Fyke Nets

Restoration Site	Number of Silvery Minnow	Mean CPUE* (fish/hour)	Mean Velocity* (ft/s)	Mean Depth* (feet)
I-40-6b	8	0.11 (0.07)	0.94 (0.07)	2.04 (0.10)
Atrisco	1	0.03 (0.03)	0.11 (0.03)	1.24 (0.05)
I-40-2b	2	0.02 (0.02)	1.35 (0.10)	1.56 (0.09)
I-40-4b	25	0.33 (0.19)	1.28 (0.09)	1.34 (0.07)
I-40-1i	0	0.00 (n/a)	1.23 (0.07)	1.18 (0.10)

*Standard errors of CPUE, velocity, and depth values are given in parenthesis.

Silvery minnow CPUE was relatively stable throughout monitoring and did not differ among May 10 to June 13 sampling dates (Kruskal-Wallis single-factor analysis of variance $P = 0.21$) (Figure 2.3). Qualitatively, CPUE was highest on June 2 (0.58 fish/hour), which was the first day of the ascending limb of the hydrograph to peak flow (1,300 cubic feet per second [cfs]).

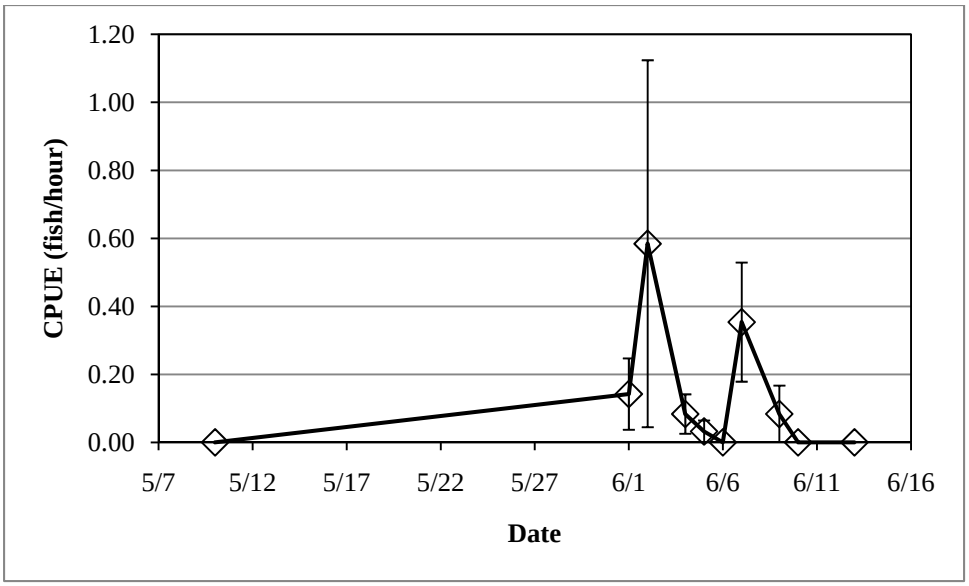

Figure 2.3. Arithmetic mean CPUE (fish/hour) values for silvery minnow collected from I-40-6b, Atrisco, I-40-2b, I-40-4b, and I-40-1i, May 10–June 13, 2011. Error bars denote one standard error.

2.3.2 COMMUNITY COMPOSITION

Daily community collections for beach seine collections are tabulated in Appendix C. Fish totaling 1,377 from 10 species were collected during monitoring with beach seines (Table 2.4). Red shiner (*Cyprinella lutrensis*), unknown larval fish, white sucker (*Catostomus commersonii*), and flathead chub (*Platygobi gracilis*) were the most commonly collected species, comprising 50%, 39%, 6%, and 3% of the total beach seine catch, respectively. All other fish species collectively comprised less than 2% of the total beach seine catch. Silvery minnow only comprised 0.22% of the total beach seine catch.

Table 2.4. Total Number Captured, Percent Composition, and Overall Density for Fish Community Collections at I-40 Subreach Sites with Beach Seines

Common Name	Scientific Name	Number Collected	Percent Composition*	CPUE (fish/100m^3)
Red shiner	*Cyprinella lutrensis*	692	50.25	25.48
Unknown	Unknown larval fish	540	39.22	19.88
White sucker	*Catostomus commersonii*	83	6.03	3.06
Flathead chub	*Platygobi gracilis*	40	2.90	1.47
Channel catfish	*Ictaluras punctatus*	9	0.65	0.33
Fathead minnow	*Pimephales promelas*	4	0.29	0.15
Rio Grande silvery minnow	*Hybognathus amarus*	3	0.22	0.11
River carpsucker	*Carpiodes carpio*	2	0.15	0.07
Green sunfish	*Lepomis cyanellus*	2	0.15	0.07

Common carp	*Cyprinus carpio*	1	0.07	0.04
Western mosquito fish	*Gambusia affinis*	1	0.07	0.04
Total		**1,377**	**100**	**4.61**

*Percentage total may not sum exactly due to rounding.

Daily community collections for fyke net collections are tabulated in Appendix C. Fish totaling 621 from nine species were collected during monitoring with fyke nets (Table 2.5). Red shiner, flathead chub, Rio Grande silvery minnow, and white sucker were the most commonly collected species, comprising 79%, 7%, 6% and 4% of the total fyke net catch, respectively. All other fish species collectively comprised less than 4% of the total fyke net catch.

Table 2.5. Total Number Captured and Percent Composition for Fish Community Collections at I-40 Subreach Sites with Fyke Nets

Common Name	Scientific Name	Number Collected	Percent Composition*
Red shiner	*Cyprinella lutrensis*	492	79.23
Flathead chub	*Platygobio gracilis*	44	7.09
Rio Grande silvery minnow	*Hybognathus amarus*	36	5.80
White sucker	*Catostomus commersonii*	26	4.19
Yellow bullhead	*Ameiurus natalis*	6	0.97
Unknown larval fish	Larval sp.	6	0.97
Fathead minnow	*Pimephales promelas*	6	0.97
Common carp	*Cyprinus carpio*	2	0.32
Channel catfish	*Ictalurus punctatus*	2	0.32
Western mosquitofish	*Gambusia affinis*	1	0.16
Total		**621**	**100**

*Percentage total may not sum exactly due to rounding.

3.0 SILVERY MINNOW SPAWNING INDICES

During monitoring, efforts were made at all sites to collect silvery minnow eggs. In addition, collected silvery minnow were visibly inspected for signs of reproductive maturity. Relative changes in proportions of visibly mature silvery minnow, peaks in main channel and floodplain silvery minnow egg collections, observations of silvery minnow collected from floodplain sites issuing gametes, and the presence of larval fish were all documented during monitoring.

3.1 METHODS

3.1.1 INDICES OF SILVERY MINNOW MATURITY

On each sampling date, silvery minnow were observed for signs of reproductive status and were classified as gravid female, male issuing milt, spent female, and unknown. Reproductive status (for each classification group) is expressed as a percentage of the total number of silvery minnow inspected during monitoring.

3.1.2 MAIN CHANNEL EGG COLLECTIONS

Main channel flow was sampled for silvery minnow eggs using Moore egg collectors (MECs) (Altenbach et al. 2000) set for 45 to 120 minutes each day from April 18 to June 15, 2011. The number of silvery minnow eggs, velocity of water (m/s) flowing through the MEC, and duration were recorded for each sample. Main channel egg collections were conducted near the Central Avenue Bridge and South Diversion Channel sites when this could be safely accomplished. MEC collections were standardized by dividing the number of drifting eggs and larval fish collected by the volume of water filtered (m^3) by the MEC times 100. The resultant standardization is expressed as silvery minnow eggs or larval fish/100 m^3.

3.1.3 MONITORING SITES EGG AND LARVAL FISH COLLECTIONS

Beginning on June 6, 2011, silvery minnow eggs were sampled with D-frame kick nets (0.0428-m^2 opening fitted with 0.2-mm mesh nytex) with multiple grab samples over heavily matted vegetation and along the margins of each of the surveyed habitat restoration sites. All collected eggs were identified (when possible), enumerated, and released back to the site of collection. Egg collections were standardized as the number of eggs collected per grab sample and plotted for two sites where exceptionally high densities of silvery minnow eggs were found.

3.2 RESULTS

3.2.1 INDICES OF SILVERY MINNOW MATURITY

Mature silvery minnow were first collected on May 13 near I-40-1i Site B with a beach seine. Mature silvery minnow were collected throughout monitoring. Silvery minnow were observed issuing eggs during processing on June 2 and June 4. Overall males with milt and gravid females, including those issuing eggs, represented 64% and 31% of the total catch, respectively (Figure 3.1).

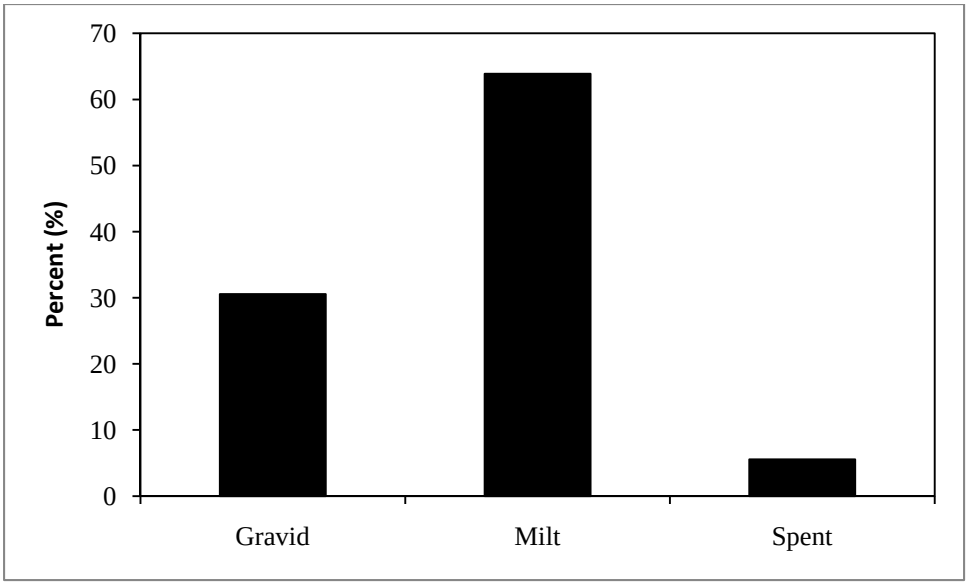

Figure 3.1. Percent of silvery minnow by reproductive classification observed during monitoring.

3.2.2 MAIN CHANNEL EGG COLLECTIONS

In total, 3,279 silvery minnow eggs were collected from the main channel using MECs during spring 2011 monitoring. Silvery minnow eggs were first collected on April 22 from the main channel immediately upstream of the Central Avenue Bridge (Figure 3.2). The highest egg density was observed during monitoring on June 4 and was coincidental with the ascending limb of peak discharge for spring 2011 (see Figure 3.2). The highest standardized values (silvery minnow eggs/100 m^3) were estimated in the main channel upstream of Central Avenue Bridge on June 4 (1,483 eggs/100 m^3).

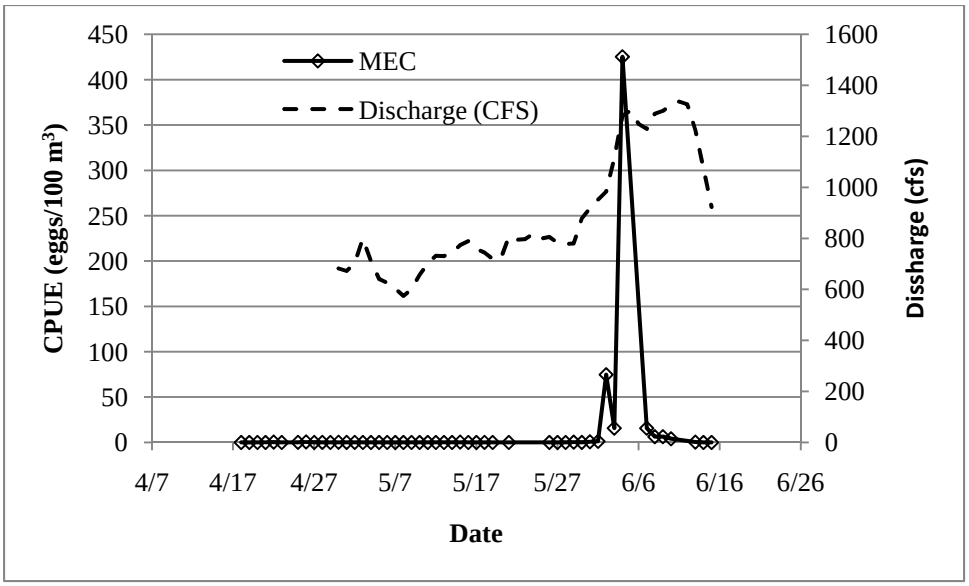

Figure 3.2. Average daily discharge (cfs) and average silvery minnow egg density estimated with MECs from main channel habitats during monitoring. Individual Y-axes are provided for both egg and discharge.

3.2.3 Monitoring Sites Egg and Larval Fish Collections

In total, 3,269 silvery minnow eggs were collected from vegetated river margins at habitat restoration sites with kick nets. Silvery minnow eggs were found at all monitoring sites except for the Atrisco refugia. The greatest single day collection of eggs with a dip nets occurred at I-40-6b. An additional 40 silvery minnow eggs were collected from the cod end of fyke nets on June 1 (four eggs) and June 4 (36 eggs).

Table 3.1. Number of Silvery Minnow Eggs Collected from Vegetated River Margins by Date and Habitat Restoration Site

Date	I-40-6b	Atrisco	I-40-2b	I-40-4b	I-40-1i	Combined
6/4/2011	666	0	7	165	637	1,475
6/5/2011	980	0	8	77	149	1,214
6/6/2011	324	0	-	61	0	385
6/7/2011	79	-	-	-	4	83
6/9/2011	72	0	-	4	0	76
6/10/2011	36	0	-	0	0	36
Total	**2,157**	**0**	**15**	**307**	**790**	**3,269**

Note: Dash indicates not sampled.

Two vegetated areas along the margins at I-40-6b and I-40-1i were repeatedly sampled with D-frame kick nets from June 4 through June 10 to determine if the number of eggs increased, decreased, or remained the same throughout monitoring. The mean number of silvery minnow eggs decreased as monitoring progressed at both sites (Figure 3.3). The rate of decrease was

greater at I-40-1i than at I-40-6b. Both areas where eggs were high densities of silvery minnow eggs were found contained matted vegetation comprised primarily of grasses (Figure 3.4). In addition, densities were greatest against the channel margins where velocities were lowest and depths were shallowest.

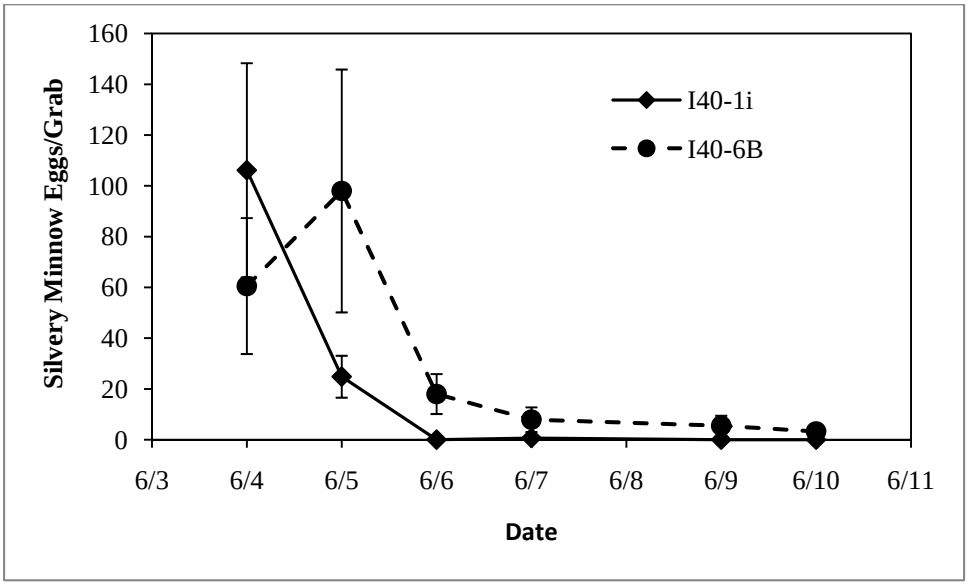

Figure 3.3. Number of silvery minnow eggs collected by dip net grab from vegetated margin areas at I-40-6b and I-40-4i.

Figure 3.4. Vegetated area at I-40-6b where substantial numbers of silvery minnow eggs were collected on June 4–6.

4.0 SILVERY MINNOW LENGTH

Monitoring included the collection of length data from silvery minnow; no weight data were collected. Size information for wild silvery minnow is limited—such information may be useful for understanding variations in a species life history. General comparisons were made between male and female silvery minnow to describe sexual dimorphism for the species.

4.1 METHODS

4.1.1 LENGTH

During monitoring, standard length was measured to the nearest millimeter (mm) with a handheld ruler from captured silvery minnow when this could be accomplished without stressing the fish.

4.1.2 DATA ANALYSIS

Length frequency was used to assess the age composition of silvery minnow. Histogram bin sizes were set at 2 mm. Mean standard length and 95% confidence intervals are presented for silvery minnow by reproductive group.

4.2 RESULTS

4.2.1 LENGTH

Silvery minnow ranged in length from 55 to 87 mm. Spent and gravid females were larger than mature male silvery minnow and no silvery minnow were documented as unknown (Table 4.1). Silvery minnow length frequency indicates the presence of one age group (Figure 4.1); however, fish collected during spring 2011 were notably larger than silvery minnow collected during springs 2008, 2009, and 2010.

Table 4.1. Mean Standard Length by Reproductive Group of Silvery Minnow Collected

Reproductive Group	Standard length (mm)
Gravid female	77 (+/-5.6)
Spent female	74 (+/-n/a)
Mature male	71 (+/-1.4)

Note: 95% confidence intervals are given in parenthesis.

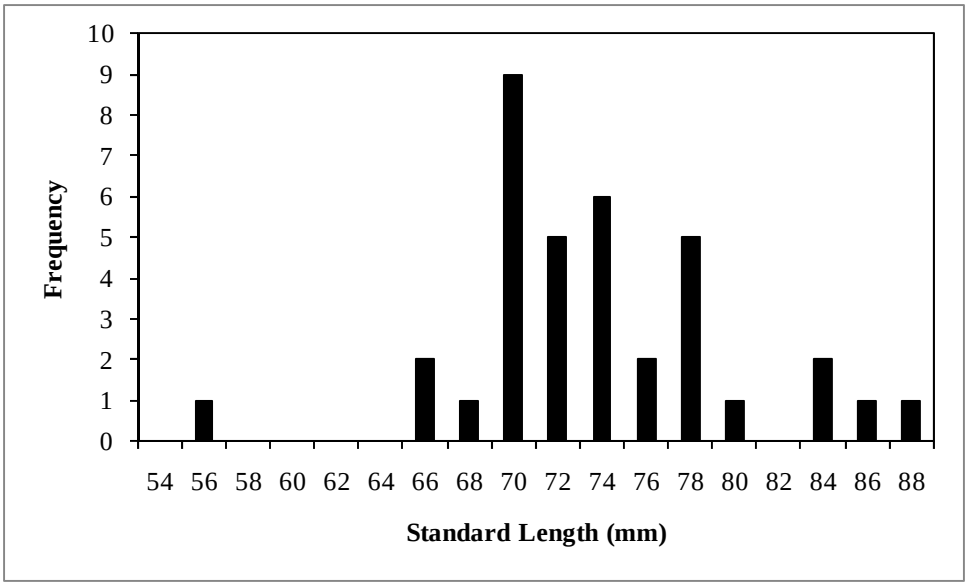

Figure 4.1. Length frequency histograms for silvery minnow collected during monitoring. Size groups are 2 mm.

5.0 WATER QUALITY

5.1 METHODS

Water quality parameters were monitored concurrent with fish sampling events from the main channel and at floodplain sites. Water quality parameters were measured using a YSI 556 multi-parameter handheld meter, including temperature (°C), dissolved oxygen (mg/L and %), corrected conductivity (µS/cm^{c}), salinity (parts per thousand), pH, and turbidity (Formazin turbidity units). Water depth (feet) and flow velocity (m/s) were measured using a USGS top-setting wading rod fitted with a Marsh-McBirney Flo-Mate portable flowmeter. Hobo event loggers were used to obtain hourly records of water temperature (°C) at each floodplain fish sample location and at one main channel location.

5.2 RESULTS

Water quality data for main channel and floodplain monitoring sites are illustrated in Appendix D. Values for all water quality parameters were within the provisional LC_{50} (concentration that results in 50% mortality of the test animals) provided for the silvery minnow by Buhl (2006). In general, temperature was not different at floodplain and main channel sites (Appendix E). The below average runoff during spring 2011 was not sufficient to inundate backwater and floodplain areas; therefore, water quality parameters were similar among bar, side, and main channel water quality locations.

6.0 DISCUSSION

Occupancy of NMISC habitat restoration sites by the silvery minnow has been documented since surveys began in 2007. Monitoring during 2011 provided a unique opportunity to observe silvery minnow use of habitat restoration sites intended to inundate at below average spring runoffs. Silvery minnow were found in low abundance during 2011 relative to 2008, 2009, and 2010. Despite poor captures of adult silvery minnow during 2011, collections of silvery minnow eggs from the main channel and vegetated margins of habitat restoration sites were seven times greater (6,548 total eggs) than collections made during 2008, 2009, and 2010 (898 total eggs) combined.

During the spring 2011 monitoring season, eggs were found within the main channel, within matted vegetation on the margins of habitat restoration sites, and in the cod end of fyke nets. The question still remains where eggs collected originate. Few adult silvery minnow were collected from habitat restoration sites; however, egg collections for both main channel and habitat restoration sites peaked during the ascending limb of the hydrograph, supporting the hypothesis that pelagic spawning cyprinids time their spawn to coincide with the arrival of a flood wave to minimize downstream displacement and promote entrainment of eggs and larvae in low-velocity habitats (Medley et al. 2007). In addition, egg counts steadily declined throughout monitoring at the two high egg density locations that were repeatedly sampled at I-40-1i and I-40-6b, indicating that many of the eggs retained in the vegetated margins of habitat restoration sites were either pushed onto or spawned over the site during the ascending limb of the hydrograph. Regardless of where silvery minnow eggs originate, floodplain habitats slow the rate of downstream transport of drifting eggs and larval fish, which in turn provides increased opportunity for the retention of reproduction effort within shorter segments of the river (Widmer et al. 2010).

Standard length of silvery minnow has been collected since 2008 and was significantly greater in 2011 than past monitoring years. The overall the mean standard length of silvery minnow during 2011 was 73 mm (for males and females combined), which is about 20 mm greater than the mean standard lengths obtained during 2008, 2009, and 2010. Presumably the majority of spawning silvery minnow during 2011 were age-2 and older, indicating a failed year class for fish spawned during spring 2010.

Population monitoring for silvery minnow over the past decade has documented order of magnitude increases and decreases in abundance, which appear to be related to changing environmental conditions (Dudley and Platania 2008; Dudley et al. 2008). Evidence suggests that recruitment success for the species is dependent on the magnitude and duration of spring runoff (USFWS 2007; Dudley and Platania 2008; Dudley et al. 2008) and less dependent on river drying during irrigation season (Dudley et al. 2008). Despite this evidence, a mechanistic explanation describing the use and function of the river channel and its remaining floodplain by the silvery minnow during spawning is lacking. Information collected from habitat restoration and naturally occurring floodplain sites during spring runoff 2007 to 2010 suggests that when these habitats are available silvery minnow may spawn there. Conversely, when these habitats are not available, data collected during 2011 indicates that the silvery minnow will still spawn and habitat restoration sites with design thresholds for below average spring runoff provide

retention and habitat for silvery minnow eggs and larval fish. Recruitment for the species is expected to be below average for 2011 (Dudley and Platania 2008) and any positive deviation from the expected value for fall CPUE in the Albuquerque Reach may be attributable to the extensive amount of habitat restoration that has occurred in the reach since 2005.

Spawning on floodplain type habitats would benefit silvery minnow recruitment through the increased availability of low-velocity floodplain and backwater habitats that reduce downstream displacement of eggs and larvae (Fluder et al. 2007; Hatch and Gonzales 2008; Gonzales and Hatch 2009), reduced hatching and rearing time for eggs and larvae retained in warmer floodplain and backwater habitats (Jobling 1995; Pease et al. 2006; Hatch and Gonzales 2008), increased production of newly inundated habitats (Junk et al. 1989; Valett et al. 2005), and increased nursery habitat area (Pease et al. 2006). Conversely, spawning on floodplain habitats could result in loss of reproductive effort if the descending limb of the hydrograph is not moderated such that individuals or eggs are stranded on floodplain habitats or forced into less suitable main channel habitats before sufficient size has been obtained by the newly hatched fish.

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APPENDIX A
SPRING 2009 FISHERIES MONITORING SITES

Figure A.1. Map depicting fyke net, water quality, and seine sampling location Site A at I-40-6b.

Figure A.2. Map depicting Site B seine sampling location at I-40-6b.

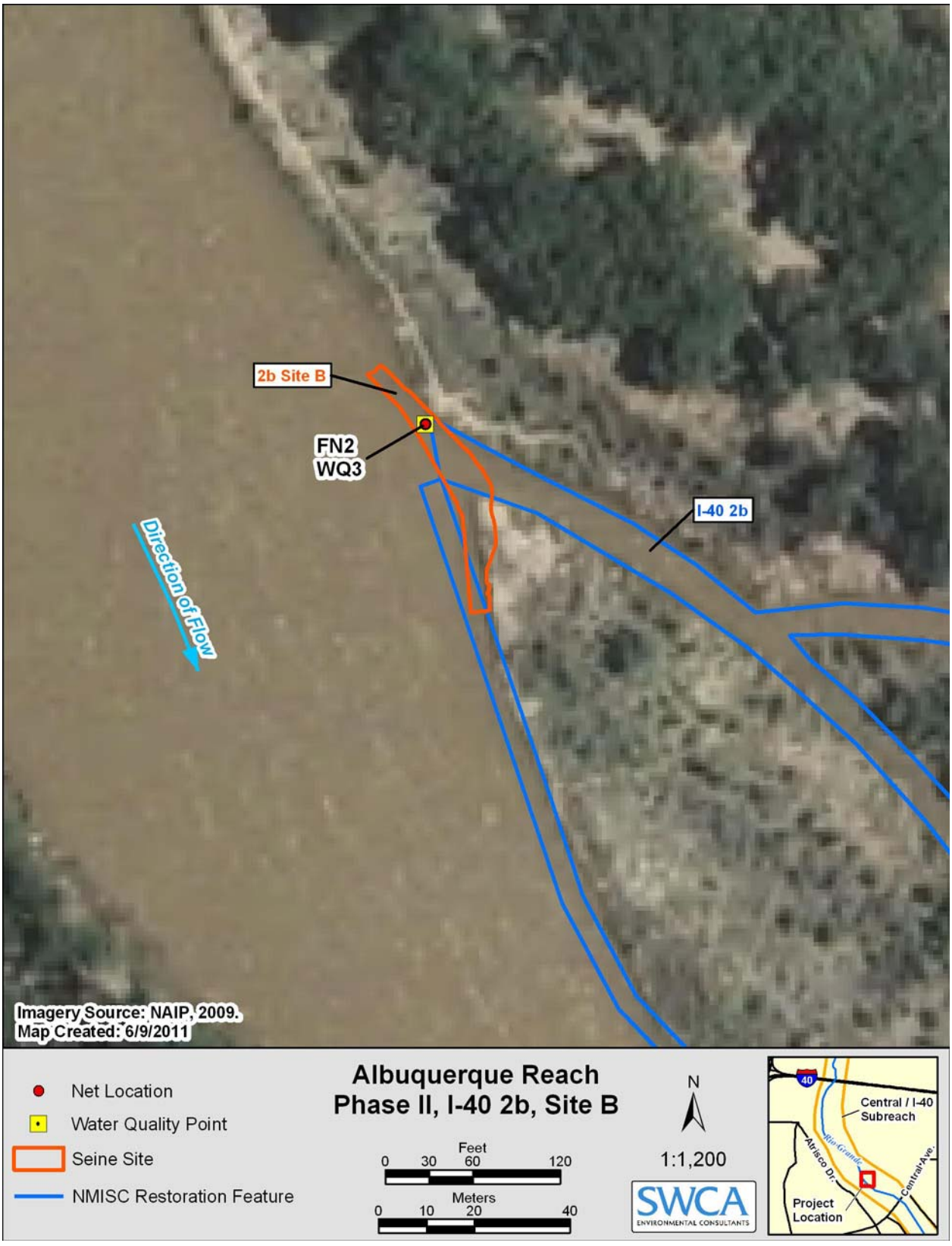

Figure A.3. Map depicting fyke net, water quality, and seine sampling location Site B at I-40-2b.

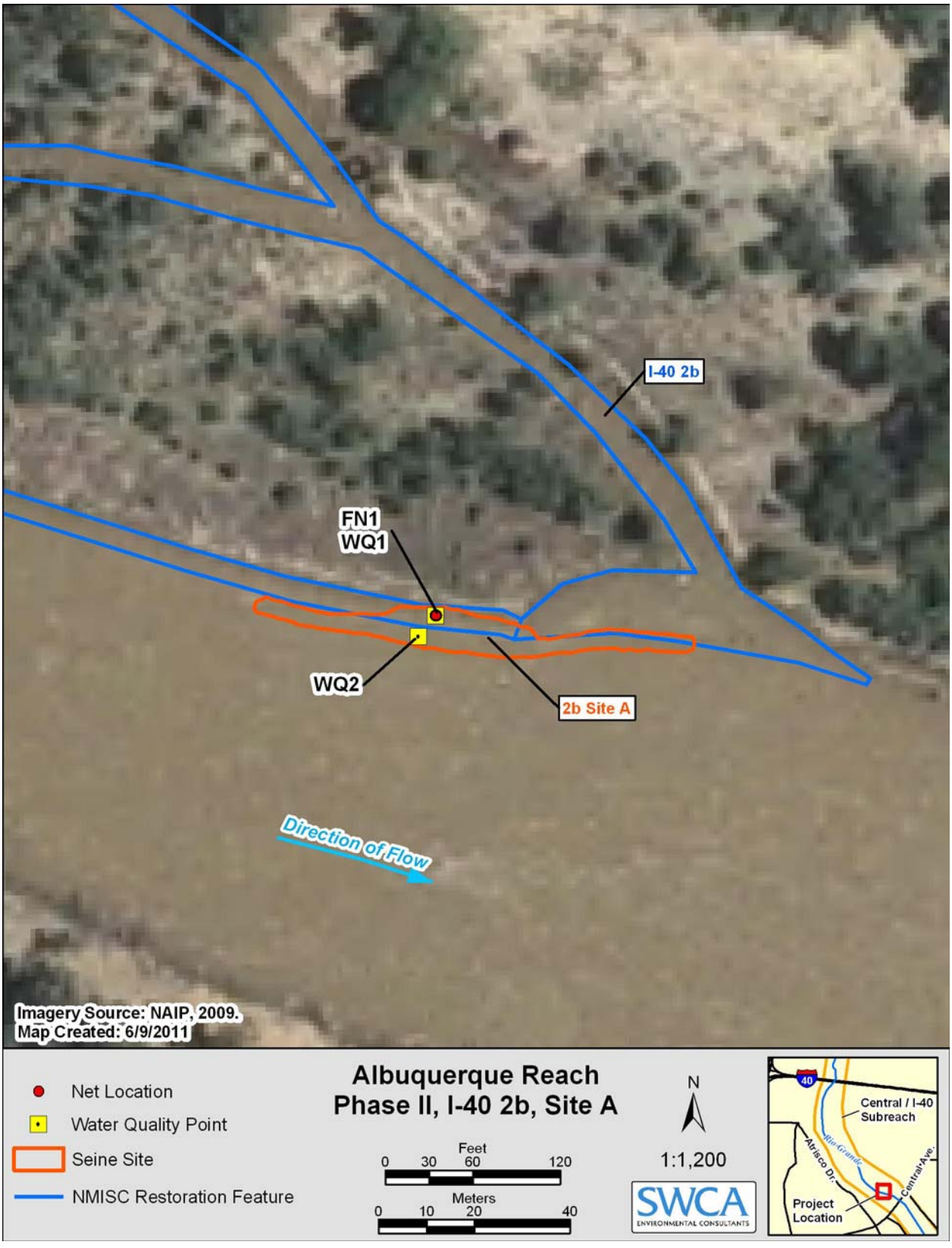

Figure A.4. Map depicting fyke net, water quality, and seine sampling location Site A at I-40-2b.

Figure A.5. Map depicting fyke net, water quality, and seine sampling location Site A at the Atrisco Refugia site.

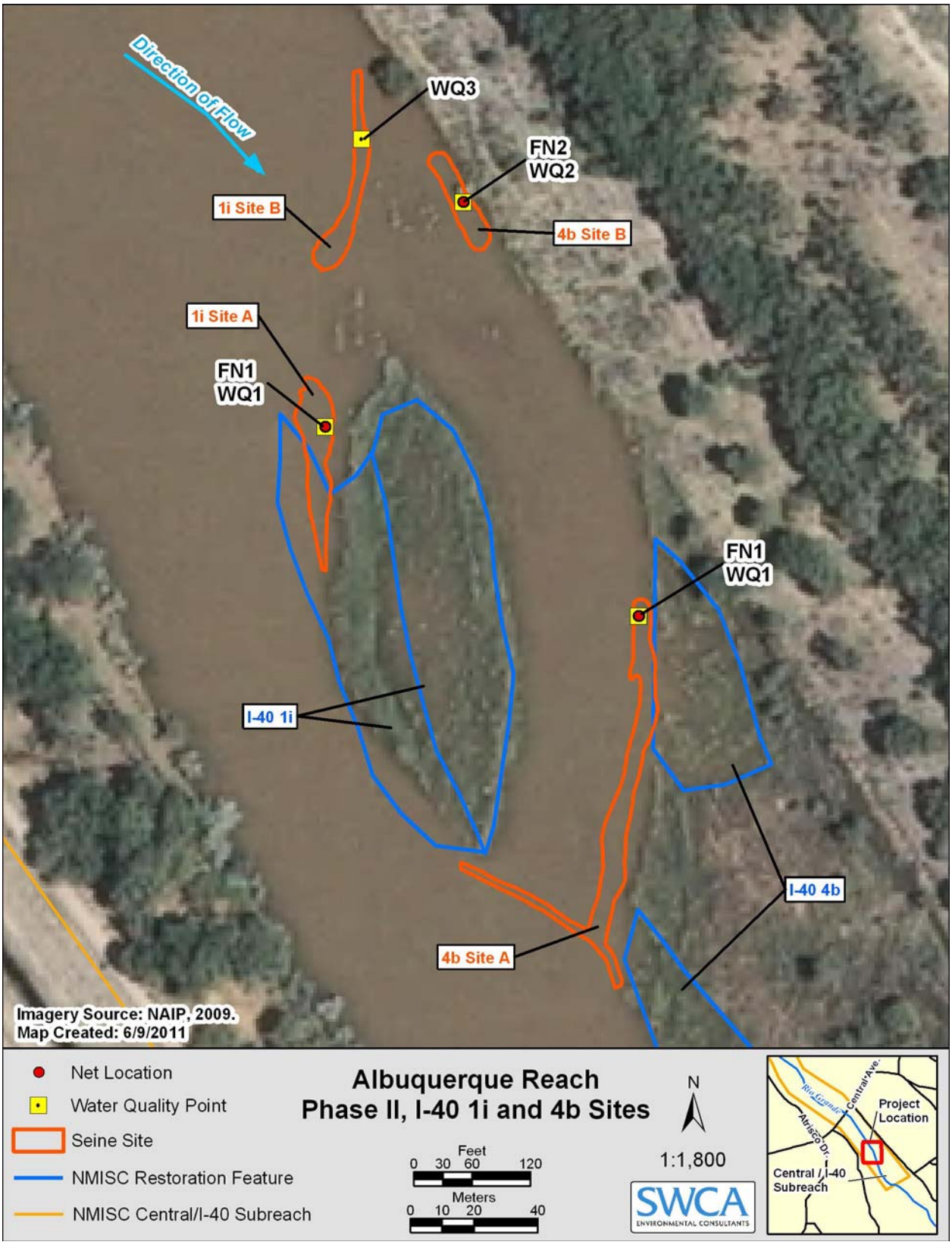

Figure A.6. Map depicting fyke net, water quality, and seine sampling locations at the I-40-1i and I-40-4b sites.

APPENDIX B
PROJECT PHOTOGRAPHS

Figure B.1. Facing southwest at I-40-6b fyke net locations 1 (top) and 2 (bottom) and seine sampling location A.

Figure. B.2. Facing southwest at crew seining I-40-6b.

Figure B.3. Gravid 80-mm standard length silvery minnow.

Figure B.4. Facing northeast at Atrisco seine sampling location A.

Appendix B.5. Facing southwest at Atrisco fyke net 1 and Atrisco seine sampling location A.

Figure B.6. Looking northwest at I-40-2b fyke net 1 and I-40-2b seine sample location A.

Figure B.7. Looking south at I-40-2b fyke net location 1 and I-40-2b seine sampling location B.

Figure B.8. Facing north at I-40-4b fyke net 1.

Figure B.9. Facing south at I-40-2b fyke net 2 and I-40-4b seine sampling location B.

Figure B.10. Facing north at I-40-1i fyke net 1 and I-40-1i seine sampling location A.

Figure B.11. Silvery minnow eggs collected from I-40-1i with a D-frame kick net.

Figure B.12. Silvery minnow eggs collected from I-40-6b with D-frame kick net.

Figure B.13. Matted vegetation where substantial numbers of silvery minnow eggs were found at I-40-1i.

Figure B.14. Gravid silvery minnow collected during monitoring.

APPENDIX C
FISH COMMUNITY COLLECTIONS BY SITE AND GEAR TYPE

Table C.1. Beach Seine Fish Community Collections by Site for 2011

Date	Seine Location	Species	Number
5/10/2011	Atrisco Site A		
		red shiner (*Cyprinella lutrensis*)	103
		western mosquitofish (*Gambusia affin*is)	1
		green sunfish (*Lepomis cyanellus*)	1
		flathead chub (*Platygobio gracilis*)	1
	I-40-2b Site A		
		red shiner (*Cyprinella lutrensis*)	9
5/13/2011	I-40-1i Site A		
		red shiner (*Cyprinella lutrensis*)	62
	I-40-1i Site B		
		red shiner (*Cyprinella lutrensis*)	44
		Rio Grande silvery minnow (*Hybognathus amarus*)	1
		channel catfish (*Ictalurus punctatus*)	1
	I-40-2b Site A		
		red shiner (*Cyprinella lutrensis*)	19
		channel catfish (*Ictalurus punctatus*)	2
		flathead chub (*Platygobio gracilis*)	1
	I-40-2b Site B		
		white sucker (*Catostomus commersonii*)	1
		red shiner (*Cyprinella lutrensis*)	22
		larval sp.	7
		flathead chub (*Platygobio gracilis*)	10
	I-40-4b Site A		
		red shiner (*Cyprinella lutrensis*)	14
		flathead chub (*Platygobio gracilis*)	2
	I-40-6b Site A		
		red shiner (*Cyprinella lutrensis*)	58
		channel catfish (*Ictalurus punctatus*)	2
		larval sp.	188
		flathead chub (*Platygobio gracilis*)	3
	I-40-6b Site B		
		red shiner (*Cyprinella lutrensis*)	35
		flathead chub (*Platygobio gracilis*)	1
5/20/2011	I-40-1i Site A		
		red shiner (*Cyprinella lutrensis*)	6
		larval sp.	15
	I-40-1i Site B		
		red shiner (*Cyprinella lutrensis*)	49
		larval sp.	1
	I-40-2b Site A		

		red shiner (*Cyprinella lutrensis*)	21
		larval sp.	45
		flathead chub (*Platygobio gracilis*)	2
	I-40-2b Site B		
		red shiner (*Cyprinella lutrensis*)	36
		larval sp.	8
		fathead minnow (*Pimephales promelas*)	1
	I-40-4b Site A		
		red shiner (*Cyprinella lutrensis*)	4
	I-40-6b Site A		
		red shiner (*Cyprinella lutrensis*)	52
		larval sp.	145
		flathead chub (*Platygobio gracilis*)	6
5/31/2011	I-40-1i Site B		
		white sucker (*Catostomus commersonii*)	17
		red shiner (*Cyprinella lutrensis*)	70
		fathead minnow (*Pimephales promelas*)	1
		flathead chub (*Platygobio gracilis*)	2
	I-40-2b Site A		
		red shiner (*Cyprinella lutrensis*)	3
		flathead chub (*Platygobio gracilis*)	4
	I-40-2b Site B		
		white sucker (*Catostomus commersonii*)	19
		red shiner (*Cyprinella lutrensis*)	21
		larval sp.	58
		fathead minnow (*Pimephales promelas*)	1
		flathead chub (*Platygobio gracilis*)	2
	I-40-4b Site A		
		white sucker (*Catostomus commersonii*)	1
		red shiner (*Cyprinella lutrensis*)	2
		larval sp.	1
	I-40-4b Site B		
		river carpsucker (*Carpiodes carpio*)	2
		white sucker (*Catostomus commersonii*)	3
		common carp (*Cyprinus carpio*)	1
		red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	2
		larval sp.	1
	I-40-6b Site A		
		white sucker (*Catostomus commersonii*)	26
		red shiner (*Cyprinella lutrensis*)	33
		channel catfish (*Ictalurus punctatus*)	2
		flathead chub (*Platygobio gracilis*)	5

	Atrisco Site A		
		white sucker (*Catostomus commersonii*)	4
		red shiner (*Cyprinella lutrensis*)	4
		channel catfish (*Ictalurus punctatus*)	1
		larval sp.	30
		green sunfish (*Lepomis cyanellus*)	1
6/2/2011	Atrisco Site A		
		white sucker (*Catostomus commersonii*)	1
		red shiner (*Cyprinella lutrensis*)	11
		channel catfish (*Ictalurus punctatus*)	1
		larval sp.	21
	I-40-1i Site A		
		white sucker (*Catostomus commersonii*)	11
		red shiner (*Cyprinella lutrensis*)	13
		larval sp.	20
		fathead minnow (*Pimephales promelas*)	1
		flathead chub (*Platygobio gracilis*)	1
Total			**1,377**

Table C.2. Fyke Net Fish Community Collections by Site for 2011

Date	Site	Species	Number
5/10/2011			
	I-40-2b		
		red shiner (*Cyprinella lutrensis*)	6
		channel catfish (*Ictalurus punctatus*)	1
	I-40-6b		
		red shiner (*Cyprinella lutrensis*)	2
6/1/2011			
	I-40-2b		
		red shiner (*Cyprinella lutrensis*)	2
		flathead chub (*Platygobio gracilis*)	5
	I-40-4b		
		white sucker (*Catostomus commersonii*)	2
		red shiner (*Cyprinella lutrensis*)	2
		western mosquitofish (*Gambusia affinis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	4
	I-40-6b		
		red shiner (*Cyprinella lutrensis*)	43
		larval sp.	1
		flathead chub (*Platygobio gracilis*)	1
6/2/2011			
	I-40-2b		
		red shiner (*Cyprinella lutrensis*)	1
		fathead minnow (*Pimephales promelas*)	1
		flathead chub (*Platygobio gracilis*)	7
	I-40-4b		
		white sucker (*Catostomus commersonii*)	2
		red shiner (*Cyprinella lutrensis*)	21
		Rio Grande silvery minnow (*Hybognathus amarus*)	15
	I-40-6b		
		yellow bullhead (*Ameiurus natalis*)	1
		red shiner (*Cyprinella lutrensis*)	29
		common carp (*Cyprinus carpio*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	1
		larval sp.	1
6/4/2011			
	Atrisco		
		yellow bullhead (*Ameiurus natalis*)	1
		red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	1
	I-40-2b		

		white sucker (*Catostomus commersonii*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	2
	I-40-4i		
		red shiner (*Cyprinella lutrensis*)	8
	I-40-6b		
		red shiner (*Cyprinella lutrensis*)	2
6/5/2011			
	Atrisco		
		white sucker (*Catostomus commersonii*)	1
		red shiner (*Cyprinella lutrensis*)	22
	I-40-2b		
		red shiner (*Cyprinella lutrensis*)	1
		fathead minnow (*Pimephales promelas*)	1
		flathead chub (*Platygobio gracilis*)	1
	I-40-4b		
		red shiner (*Cyprinella lutrensis*)	19
		Rio Grande silvery minnow (*Hybognathus amarus*)	1
		flathead chub (*Platygobio gracilis*)	1
	I-40-4i		
		red shiner (*Cyprinella lutrensis*)	14
	I-40-6b		
		yellow bullhead (*Ameiurus natalis*)	1
		red shiner (*Cyprinella lutrensis*)	18
6/6/2011			
	Atrisco		
		red shiner (*Cyprinella lutrensis*)	37
		larval sp.	3
	I-40-2b		
		yellow bullhead (*Ameiurus natalis*)	1
		red shiner (*Cyprinella lutrensis*)	7
		fathead minnow (*Pimephales promelas*)	1
		flathead chub (*Platygobio gracilis*)	1
	I-40-4b		
		red shiner (*Cyprinella lutrensis*)	5
	I-40-4i		
		red shiner (*Cyprinella lutrensis*)	2
		flathead chub (*Platygobio gracilis*)	1
	I-40-6b		
		yellow bullhead (*Ameiurus natalis*)	1
		red shiner (*Cyprinella lutrensis*)	21
		larval sp.	1
6/7/2011			
	Atrisco		

		red shiner (*Cyprinella lutrensis*)	1
	I-40-2b		
		red shiner (*Cyprinella lutrensis*)	1
		fathead minnow (*Pimephales promelas*)	1
		flathead chub (*Platygobio gracilis*)	2
	I-40-4b		
		red shiner (*Cyprinella lutrensis*)	3
		Rio Grande silvery minnow (*Hybognathus amarus*)	3
		flathead chub (*Platygobio gracilis*)	1
	I-40-6b		
		red shiner (*Cyprinella lutrensis*)	15
		Rio Grande silvery minnow (*Hybognathus amarus*)	7
6/9/2011			
	I-40-2b		
		white sucker (*Catostomus commersonii*)	1
		red shiner (*Cyprinella lutrensis*)	1
		fathead minnow (*Pimephales promelas*)	1
		flathead chub (*Platygobio gracilis*)	5
	I-40-4b		
		red shiner (*Cyprinella lutrensis*)	4
		Rio Grande silvery minnow (*Hybognathus amarus*)	2
	I-40-6b		
		white sucker (*Catostomus commersonii*)	5
		red shiner (*Cyprinella lutrensis*)	13
6/10/2011			
	Atrisco		
		white sucker (*Catostomus commersonii*)	2
		red shiner (*Cyprinella lutrensis*)	68
	I-40-2b		
		flathead chub (*Platygobio gracilis*)	8
	I-40-4b		
		red shiner (*Cyprinella lutrensis*)	5
		flathead chub (*Platygobio gracilis*)	1
	I-40-4i		
		flathead chub (*Platygobio gracilis*)	6
	I-40-6b		
		yellow bullhead (*Ameiurus natalis*)	1
		white sucker (*Catostomus commersonii*)	1
		red shiner (*Cyprinella lutrensis*)	27
6/13/2011			
	Atrisco		
		white sucker (*Catostomus commersonii*)	2
		red shiner (*Cyprinella lutrensis*)	5

		channel catfish (*Ictalurus punctatus*)	1
	I-40-2b		
		white sucker (*Catostomus commersonii*)	5
		red shiner (*Cyprinella lutrensis*)	7
		fathead minnow (*Pimephales promelas*)	1
		flathead chub (*Platygobio gracilis*)	2
	I-40-4b		
		red shiner (*Cyprinella lutrensis*)	49
		common carp (*Cyprinus carpio*)	1
		flathead chub (*Platygobio gracilis*)	2
	I-40-4i		
		white sucker (*Catostomus commersonii*)	1
	I-40-6b		
		white sucker (*Catostomus commersonii*)	3
		red shiner (*Cyprinella lutrensis*)	30
Total			**621**

APPENDIX D
WATER QUALITY DATA

Water Quality - Basic Report

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
ATR											
	10-May-2011										
		1:24 PM	1.00	0.36	18.87	9.21	99.10	8.26	0.15	271.00	59.00
	01-Jun-2011										
		1:46 PM	1.40	0.77	22.54	7.92	91.40	8.28	0.15	308.00	59.00
	02-Jun-2011										
		11:25 AM	1.40	0.26	19.45	7.84	85.10	8.27	0.15	286.00	72.00
	04-Jun-2011										
		10:12 AM	1.10	0.24	18.34	7.90	84.10	8.23	0.15	316.00	102.00
	05-Jun-2011										
		9:34 AM	1.40	0.11	19.14	6.67	72.10	8.37	0.15	317.00	86.00
	06-Jun-2011										
		10:51 AM	1.30	0.17	20.01	6.16	68.70	8.33	0.15	285.00	59.00
	07-Jun-2011										
		9:45 AM	1.10	0.06	18.45	7.33	78.20	8.33	0.15	310.00	88.00
	09-Jun-2011										
		10:08 AM	1.10	-0.04	18.17	7.25	78.00	8.44	0.15	312.00	86.00
	10-Jun-2011										
		9:47 AM	1.20	0.12	18.15	7.00	74.30	8.45	0.15	268.00	68.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
	13-Jun-2011										
		2:43 PM	1.20	0.09	23.59	6.86	81.00	8.42	0.14	299.00	55.00
	Summary Statistics for ATR (10 records):										
		Avg.	1.22	0.21	19.67	7.41	81.20	8.34	0.15	297.20	73.40
		St. Dev.	0.15	0.23	1.90	0.85	9.15	0.08	0.00	18.44	16.13
		Max.	1.40	0.77	23.59	9.21	99.10	8.45	0.15	317.00	102.00
		Min.	1.00	-0.04	18.15	6.16	68.70	8.23	0.14	268.00	55.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
I-40-2b											
	05-May-2011										
		3:00 PM	0.74	1.25	21.50	7.38	83.70	8.30	0.15	303.00	55.00
		3:30 PM	0.12	1.13	22.20	7.02	80.80	8.30	0.16	313.00	52.00
	10-May-2011										
		2:35 PM	1.00	0.15	19.47	9.10	99.20	8.33	0.14	270.00	53.00
		2:40 PM	0.72	0.20	19.47	8.73	95.20	8.35	0.14	269.00	52.00
		3:00 PM	1.26	0.74	19.72	8.76	96.10	8.46	0.14	271.00	53.00
	20-May-2011										
		2:08 PM	1.50	0.59	16.02	8.81	89.40	8.35	0.16	269.00	39.04
		3:50 PM	1.30	0.87	16.79	8.66	89.40	8.36	0.16	273.00	37.53
	31-May-2011										
		1:45 PM	1.40	1.16	20.09	8.16	90.00	8.40	0.15	292.00	54.00
		2:45 PM	1.40	2.04	20.85	8.40	93.00	8.42	0.15	295.00	57.00
	01-Jun-2011										
		2:16 PM	1.43	0.90	22.16	7.69	88.20	8.30	0.15	302.00	65.00
		2:19 PM	1.40	1.83	22.16	7.57	86.80	8.28	0.15	301.00	57.00
		2:30 PM	1.50	1.80	22.25	7.68	88.10	8.34	0.15	302.00	63.00
	02-Jun-2011										
		9:20 AM	1.20	1.46	17.28	7.91	82.20	8.26	0.16	326.00	63.00
		9:22 AM	1.60	1.26	17.29	7.64	79.60	8.19	0.16	326.00	65.00
		9:33 AM	1.30	1.51	17.34	7.70	80.20	8.17	0.16	326.00	65.00
	04-Jun-2011										
		9:11 AM	1.40	1.20	17.35	8.29	86.30	8.20	0.14	303.00	89.00
		9:15 AM	2.00	1.00	17.37	7.95	83.00	8.12	0.15	312.00	93.00
		9:20 AM	1.60	1.30	17.51	7.94	83.10	8.13	0.15	263.00	91.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
	05-Jun-2011										
		8:56 AM	1.50	1.40	18.25	7.29	77.50	8.27	0.15	315.00	107.00
		8:58 AM	2.40	1.71	18.26	7.14	75.90	8.24	0.15	315.00	96.00
		9:09 AM	2.20	1.35	18.35	7.28	77.40	8.24	0.15	315.00	93.00
	06-Jun-2011										
		10:05 AM	1.60	1.54	19.02	6.36	68.70	8.22	0.13	243.00	74.00
		10:10 AM	2.50	1.54	19.06	6.42	69.30	8.26	0.15	280.00	68.00
		10:23 AM	1.70	0.93	19.20	6.65	72.00	8.28	0.15	281.00	85.00
	07-Jun-2011										
		9:10 AM	2.00	0.90	17.75	7.75	81.50	8.35	0.15	313.00	90.00
		9:12 AM	2.50	1.60	17.76	7.69	80.90	8.20	0.15	312.00	77.00
		9:22 AM	1.50	1.50	17.88	7.71	81.20	8.41	0.15	312.00	78.00
	09-Jun-2011										
		9:30 AM	2.10	0.92	17.59	7.74	81.20	8.27	0.15	311.00	90.00
		9:36 AM	2.20	2.04	17.66	7.64	80.20	8.32	0.15	310.00	85.00
		9:45 AM	1.50	1.79	17.81	7.62	80.20	8.37	0.14	293.00	86.00
	10-Jun-2011										
		9:12 AM	2.10	1.62	17.50	7.45	78.10	8.51	0.15	264.00	88.00
		9:13 AM	2.20	2.04	17.53	7.36	77.10	8.44	0.15	263.00	97.00
		9:24 AM	1.50	2.11	17.65	7.48	78.60	8.34	0.15	265.00	81.00
	13-Jun-2011										
		1:45 PM	1.10	1.81	22.41	7.55	87.10	8.38	0.12	255.00	65.00
		1:58 PM	1.30	1.70	22.76	7.42	85.90	8.36	0.13	289.00	73.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
	Summary Statistics for I-40-2b (35 records):										
		Avg.	1.56	1.34	18.95	7.71	83.06	8.31	0.15	292.91	72.47
		St. Dev.	0.52	0.49	1.92	0.63	7.02	0.09	0.01	22.95	17.80
		Max.	2.50	2.11	22.76	9.10	99.20	8.51	0.16	326.00	107.00
		Min.	0.12	0.15	16.02	6.36	68.70	8.12	0.12	243.00	37.53

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
I-40-4b											
	05-May-2011										
		9:52 AM	0.72	0.92	14.04	7.76	75.40	8.83	0.16	269.00	58.00
		11:30 AM	1.20	1.43	16.22	8.33	85.00	8.32	0.16	284.00	47.38
	20-May-2011										
		9:12 AM	1.10	0.95	11.39	9.21	84.40	8.26	0.16	244.00	42.06
		10:40 AM	2.00	1.05	12.14	9.24	86.30	8.29	0.16	249.00	36.36
	31-May-2011										
		9:08 AM	0.80	0.52	15.73	9.17	92.90	8.43	0.16	276.00	34.31
		10:05 AM	0.60	0.38	15.43	8.57	85.90	8.31	0.15	261.00	44.07
		10:50 AM	1.50	1.94	16.17	8.60	87.30	8.34	0.16	274.00	51.00
	01-Jun-2011										
		3:50 PM	1.10	0.59	22.80	7.76	90.80	8.39	0.15	305.00	0.00
		4:15 PM	1.00	0.53	22.67	7.53	86.30	8.38	0.15	305.00	0.00
		4:23 PM	1.40	1.30	22.72	7.78	90.00	8.37	0.15	304.00	0.00
	02-Jun-2011										
		10:10 AM	1.30	0.85	18.19	8.54	90.40	8.34	0.15	324.00	53.00
		10:22 AM	0.80	0.95	17.99	7.70	81.10	8.23	0.14	299.00	50.00
		10:26 AM	1.40	1.29	18.06	7.68	81.20	8.20	0.16	224.00	62.00
	04-Jun-2011										
		10:40 AM	1.50	1.22	18.85	8.01	86.10	8.29	0.15	313.00	94.00
		10:54 AM	1.10	1.30	18.78	8.19	87.90	8.30	0.15	313.00	93.00
		11:00 AM	1.70	1.52	18.93	8.03	86.50	8.25	0.15	314.00	100.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
	05-Jun-2011										
		10:02 AM	1.60	1.02	19.24	7.57	81.90	8.36	0.15	314.00	72.00
		10:15 AM	1.00	1.54	19.16	7.14	77.30	8.29	0.15	315.00	90.00
		10:23 AM	1.70	2.06	19.37	7.27	79.00	8.26	0.15	314.00	91.00
	06-Jun-2011										
		11:05 AM	1.60	1.86	20.22	6.62	73.20	8.30	0.15	286.00	84.00
		11:24 AM	1.20	1.27	20.26	6.17	68.20	8.35	0.15	284.00	84.00
		11:30 AM	1.80	2.01	20.40	6.21	68.90	8.31	0.15	287.00	78.00
	07-Jun-2011										
		10:13 AM	1.60	1.67	18.55	7.80	83.40	8.37	0.15	312.00	87.00
		10:22 AM	1.10	1.33	18.59	7.67	82.00	8.34	0.15	311.00	83.00
		10:27 AM	1.80	1.71	18.74	7.71	82.80	8.34	0.15	312.00	72.00
	09-Jun-2011										
		10:48 AM	1.70	1.69	18.73	7.70	82.60	8.28	0.15	310.00	81.00
		10:55 AM	1.40	1.49	18.80	7.69	82.80	8.40	0.15	310.00	90.00
		11:01 AM	1.40	1.98	18.91	7.69	82.90	8.37	0.15	310.00	84.00
	10-Jun-2011										
		10:17 AM	1.80	1.83	18.37	7.52	80.20	8.40	0.13	236.00	81.00
		10:24 AM	1.40	1.37	18.42	7.38	78.80	8.38	0.15	208.00	83.00
		10:30 AM	1.90	1.95	18.53	7.42	79.40	8.38	0.15	307.00	84.00
	13-Jun-2011										
		3:11 PM	1.60	1.40	23.77	7.45	88.20	8.40	0.14	298.00	61.00
		3:22 PM	1.30	1.21	23.71	7.35	86.80	8.40	0.14	296.00	65.00
		3:34 PM	1.80	1.20	23.69	7.35	86.90	8.40	0.14	299.00	66.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
	Summary Statistics for I-40-4b (34 records):										
		Avg.	1.38	1.33	18.75	7.76	83.02	8.35	0.15	290.21	64.74
		St. Dev.	0.36	0.46	2.94	0.71	5.74	0.10	0.01	29.13	27.24
		Max.	2.00	2.06	23.77	9.24	92.90	8.83	0.16	324.00	100.00
		Min.	0.60	0.38	11.39	6.17	68.20	8.20	0.13	208.00	0.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
I-40-4i											
	05-May-2011										
		10:30 AM	0.90	0.20	15.09	7.82	77.60	8.33	0.16	276.00	58.00
	20-May-2011										
		9:58 AM	0.90	0.18	11.94	9.04	83.00	8.27	0.16	247.00	51.00
	02-Jun-2011										
		12:30 PM	0.60	0.42	19.54	7.50	81.80	8.21	0.15	288.00	62.00
	04-Jun-2011										
		11:10 AM	1.00	1.08	19.13	7.79	84.20	8.20	0.15	315.00	112.00
	05-Jun-2011										
		10:28 AM	1.00	1.03	19.49	7.19	78.30	8.30	0.15	314.00	86.00
	06-Jun-2011										
		11:35 AM	1.60	1.30	20.49	6.22	69.20	8.31	0.15	288.00	81.00
	07-Jun-2011										
		10:32 AM	1.00	1.16	18.81	7.67	82.50	8.26	0.15	311.00	83.00
	10-Jun-2011										
		10:32 AM	1.40	1.51	18.65	7.28	78.00	8.37	0.12	214.00	85.00
	13-Jun-2011										
		3:41 PM	1.10	1.27	23.72	7.19	85.00	8.40	0.14	293.00	66.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
	Summary Statistics for I-40-4i (9 records):										
		Avg.	1.06	0.91	18.54	7.52	79.96	8.29	0.15	282.89	76.00
		St. Dev.	0.29	0.50	3.32	0.75	4.88	0.07	0.01	33.59	18.69
		Max.	1.60	1.51	23.72	9.04	85.00	8.40	0.16	315.00	112.00
		Min.	0.60	0.18	11.94	6.22	69.20	8.20	0.12	214.00	51.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
I-40-6b											
	05-May-2011										
		12:50 PM	1.54	1.22	19.44	7.57	82.30	8.30	0.16	295.00	60.00
		1:55 PM	0.00	0.00	21.19	82.40	82.40	8.33	0.16	305.00	64.00
	10-May-2011										
		3:45 PM	1.70	0.54	19.99	8.87	97.70	8.49	0.14	268.00	49.34
		3:50 PM	1.10	0.48	19.87	8.75	96.40	8.46	0.14	267.00	48.00
	20-May-2011										
		12:39 PM	1.20	1.23	14.93	8.81	87.30	8.39	0.16	262.00	42.51
	31-May-2011										
		12:20 PM	1.90	1.26	19.51	8.13	88.60	8.40	0.15	282.00	61.00
	01-Jun-2011										
		3:10 PM	2.30	1.60	22.18	7.80	89.50	8.32	0.15	298.00	78.00
		3:20 PM	1.50	0.43	22.16	7.21	82.50	8.06	0.15	299.00	65.00
	02-Jun-2011										
		8:50 AM	2.20	1.00	17.61	7.53	78.80	8.38	0.15	315.00	77.00
		8:55 AM	1.50	0.79	17.70	7.89	82.30	8.19	0.15	315.00	63.00
	04-Jun-2011										
		8:39 AM	2.30	0.94	17.34	8.12	84.60	8.28	0.15	310.00	99.00
		8:44 AM	1.70	0.67	17.39	7.82	81.60	8.21	0.15	311.00	98.00
	05-Jun-2011										
		8:30 AM	2.30	1.30	18.42	6.88	73.30	8.37	0.15	368.00	99.00
		8:34 AM	1.70	0.70	18.48	6.91	73.70	8.27	0.15	311.00	87.00

Geographic Area	Date	Time	Depth	Current	Water Temp	DO (ppm)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
	06-Jun-2011										
		9:35 AM	2.40	0.63	19.00	6.42	69.20	8.24	0.14	260.00	88.00
		9:38 AM	2.10	0.88	19.04	6.34	68.40	8.29	0.15	275.00	71.00
	07-Jun-2011										
		8:43 AM	2.60	1.35	17.82	7.69	81.00	8.25	0.15	310.00	88.00
		8:48 AM	1.80	0.80	17.86	7.67	80.90	8.29	0.15	310.00	80.00
	09-Jun-2011										
		9:00 AM	2.60	1.21	17.80	7.58	79.70	8.28	0.15	306.00	81.00
		9:10 AM	2.10	0.77	17.88	7.62	80.40	8.36	0.15	306.00	77.00
	10-Jun-2011										
		8:41 AM	2.70	1.18	17.62	7.47	78.50	8.56	0.15	261.00	84.00
		8:46 AM	1.90	0.73	17.68	7.33	77.00	8.34	0.15	262.00	83.00
	13-Jun-2011										
		1:11 PM	2.50	1.33	22.05	7.61	87.20	8.36	0.14	294.00	62.00
		1:17 PM	1.50	0.95	22.18	7.44	85.50	8.35	0.14	295.00	73.00
	Summary Statistics for I-40-6b (24 records):										
		Avg.	1.88	0.92	18.96	10.74	82.03	8.32	0.15	295.21	74.08
		St. Dev.	0.60	0.37	1.88	15.28	7.16	0.10	0.01	24.96	15.86
		Max.	2.70	1.60	22.18	82.40	97.70	8.56	0.16	368.00	99.00
		Min.	0.00	0.00	14.93	6.34	68.40	8.06	0.14	260.00	42.51

APPENDIX E
TEMPERATURE DATA PLOTS

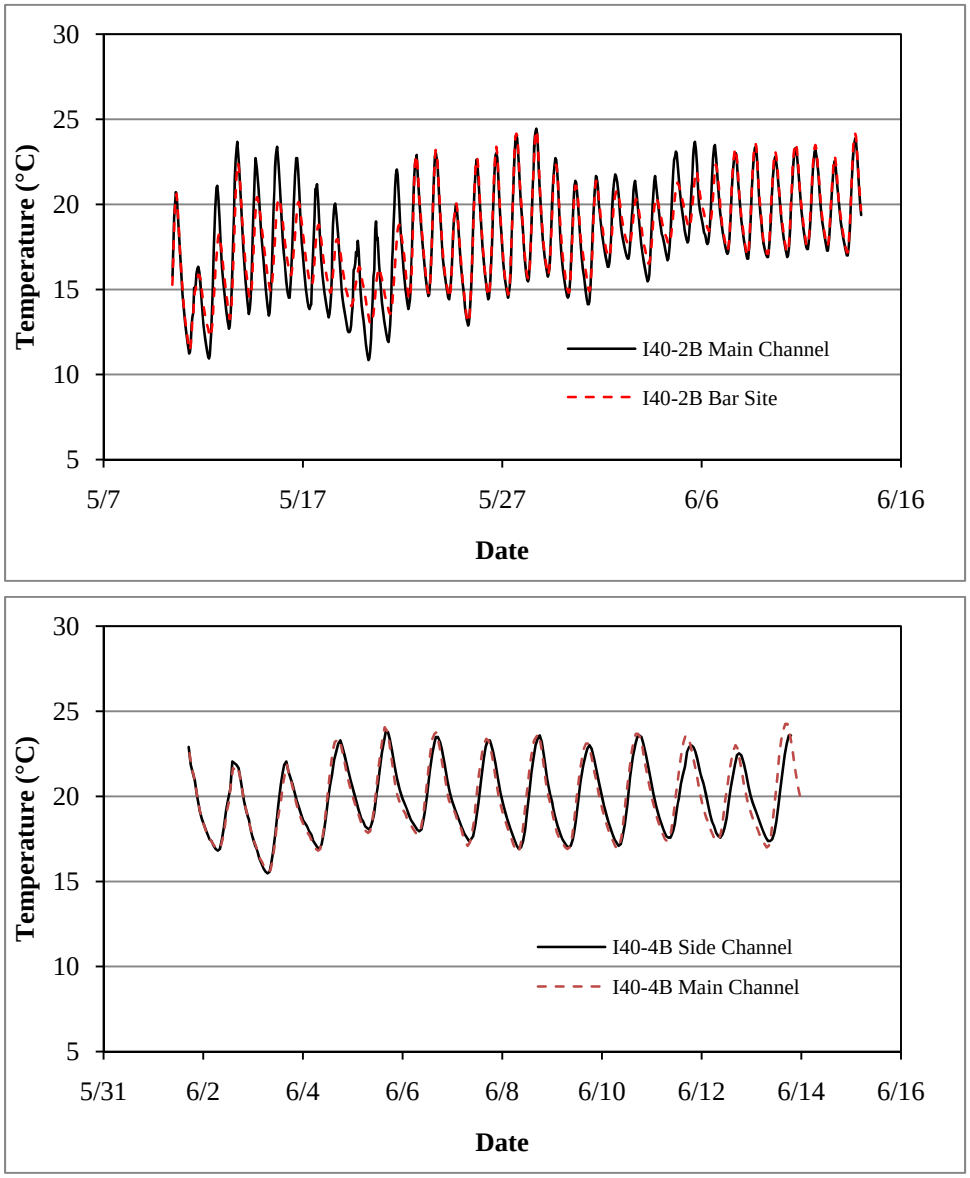

Figure E.1. Temperature profiles (°C) collected from I-40 Subreach sites during monitoring.