MIDDLE RIO GRANDE
SILVERY MINNOW HABITAT RESTORATION MONITORING
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Prepared for

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EXECUTIVE SUMMARY

SWCA Environmental Consultants, under contract to the U.S. Army Corps of Engineers (Corps) Albuquerque District, presents fisheries monitoring results for selected Bosque Restoration Project habitat treatments at Corrales and Route 66 habitat restoration sites for 2016. The Corps 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 Corps.

This report provides the results of fisheries monitoring activities conducted during spring 2016. Monitoring results 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 2016 fisheries monitoring include the following:

- 372 adult silvery minnow were collected with fyke nets—six tagged fish and 364 wild fish, and two unknown escaped;
- zero silvery minnow eggs were collected from dip netting on floodplain grids; however, three silvery minnow eggs were collected off the grid at the Nature Center site;
- mean daily temperatures among all the sites ranged from 12.3°C (54.1°F) to 26.7°C (80.1°F) from May 18 to June 20; the average temperate across all sites was 19.6°C (67.3°F); the mean daily temperature of the river at the Nature Center ranged from 18°C (64.4°F) to 23.2°C (73.8°F) from May 30 to June 20;
- of the 372 silvery minnow collected during spring 2016, there were 37 males expressing milt, one gravid female, and one spent female; the remaining 333 were of unknown reproductive condition; and
- unidentified larval fish were observed on every grid, except grid 6 at the Route 66 Middle site.

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1.0 INTRODUCTION

Habitat restoration is one of the four U.S. Fish and Wildlife Service (USFWS) primary conservation principles for recovery of endangered Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow) (USFWS 2010). Many habitat restoration efforts, including Bosque habitat restoration treatments, have been implemented in efforts to recover the imperiled species. The primary focus of habitat restoration treatments for the silvery minnow has included creating features that provide inundated floodplain habitat during spring runoff (USFWS 2003, 2011), such as bank terracing, high flow channels, and revegetation. Previous work suggests silvery minnow use inundated floodplain and riparian areas for spawning and nursery habitat, and occupy these areas in high abundance when such habitat is available (Gonzales et al. 2012, 2014).

To evaluate the effectiveness of specific restoration practices, monitoring of restored habitats is required (Bond and Lake 2003; Shirey et al 2016). In addition, quantifying specific habitat used by silvery minnows (adults and juveniles) provides information for better designing and managing habitat restoration features to increase silvery minnow spawning and recruitment. During spring 2016 we monitored silvery minnow presence by surveying for adult silvery minnow and eggs at habitat restoration sites. Our results document the occupancy of silvery minnow in these important restored sites and provide insight into habitat use during silvery minnow spring spawning. This information will inform and direct future monitoring efforts to further evaluate the effectiveness of restoration sites in providing floodplain habitat for silvery minnow during critical early life stages.

1.1 PROJECT GOALS AND OBJECTIVES

Sampling for silvery minnow adults and eggs within the inundated restoration features was conducted in spring 2016 to evaluate the effectiveness of the restoration treatments in providing habitat for the silvery minnow during spawning and early life stages. The specific objectives were to 1) document whether constructed habitat restoration sites are being utilized by the silvery minnow during runoff, 2) determine if silvery minnow relative abundance varies among habitat restoration sites (treatments) during spring runoff, and 3) document the presence of silvery minnow eggs on flooded habitat restoration sites during spawning/spring runoff. Fyke nets were used to sample for reproductive adults moving onto the floodplains in habitat restoration sites. Adult silvery minnow were collected to assess the species utilization of these habitats during spawning. Additionally, silvery minnow eggs were sampled on the floodplain using dip nets on a pre-determined 5 × 5–m grid to evaluate a more quantitative protocol. This summary report shows the presence, relative abundance, and percent community composition of silvery minnow at the habitat restoration sites sampled in 2016.

2.0 HABITAT RESTORATION SITE MONITORING

2.1 SITE SELECTION

Select U.S. Army Corps of Engineers (Corps) terrace lowering and high flow channel habitat restoration treatment sites from the Albuquerque Reach of the Middle Rio Grande were selected for floodplain monitoring during the spring of 2016. These sites were selected based on previous observations that these features provide spawning habitat for silvery minnow (Gonzalez et al. 2014). The selected sites include Corrales North, Corrales South, Nature Center, Route 66 North, and Route 66 Middle (Figure 2.1). Due to the size of the Route 66 North site, it was divided into two sites: site A and site B.

To better understand how silvery minnow are using the floodplain during the spawning period, a high intensity sampling effort was employed to the Corrales South site, where it was sampled approximately 6 days/week. The remaining sites were sampled with a low intensity effort 3 days/week. Sites were sampled from May 23 through June 16, 2016. All sites were sampled for eggs using a 5 × 5–m grid sampling design, while only three sites were sampled for adults using fyke nets (Table 2.1).

Table 2.1. Corps Albuquerque Reach Sites Where Fisheries Monitoring for Adult Fish and Eggs with Fyke Nets and Grid Surveys Were Conducted, 2016

Site	Restoration Treatment	Sampling Method	Number of Days Sampled
Corrales North	Terrace lowering	Grid and fyke net	9
Corrales South	Terrace lowering	Grid and fyke net	20
Nature Center	High flow channel	Grid only	9
Route 66 North A	High flow channel	Grid only	9
Route 66 North B	High flow channel	Grid and fyke net	10
Route 66 Middle	High flow channel	Grid only	9

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, grid design for egg sampling, and the daily sampling approach used by monitoring crews (SWCA Environmental Consultants [SWCA] 2016a).

Figure 2.1. Overview map of Albuquerque Reach sites where monitoring for adult fish and eggs were conducted with fyke nets and grids.

2.2.1 FISHERIES MONITORING

Fisheries monitoring, using fyke nets, was conducted from May 24 through June 16, 2016, at the Corrales North, Corrales South, and Route 66 North B sites. The Corrales South site was monitored 6 days per week, while Corrales North and Route 66 North B were monitored every other day. Appendix A shows fyke net and water quality collection locations at each monitored restoration site.

Fish were collected from the 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 1-m (3.3-foot) u-posts. Fyke net locations were selected based on the presence of sufficient inundation for effective use of this gear. On each sampling date fyke nets were set for 3 to 6 hours when conditions were conducive to sampling (i.e., sufficient inundation present at each site). 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 reproductive condition 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 grid and fyke net sampling locations. Data from the U.S. Geological Survey (USGS) stage gage at the Central Avenue Bridge (No. 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 spreadsheet database (Microsoft Excel) was developed for the storage, analysis, and retrieval of fish survey data.

2.2.2 DATA ANALYSIS

Silvery minnow catch per unit effort (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; Gonzales et al. 2012). Standardization of fyke net captures (assuming 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.

We performed a Kruskal-Wallis test to determine if relative abundance varied among restoration sites. The Kruskal-Wallis test, a non-parametric test, does not assume a normal distribution. It assigns a rank to each observation in the data-set, to test the null-hypothesis that the mean ranks of the groups are the same (McDonald 2014). In addition, a single-species, single-season occupancy model with no covariates was developed to determine the probability of detection and the probability a site is occupied for silvery minnow on the restoration sites. The occupancy analyses were performed in R statistical software version 3.0.3 (R Development Core Team 2014) in package unmarked 0.16-6. The model was backtransformed to obtain the estimate for detection and occupancy probabilities.

2.3 RESULTS

2.3.1 SPRING HYDROGRAPH

Water releases from the dams in spring 2016 resulted in one main peak in the hydrograph during the study period (see Figure 2.2). The flows increased from approximately 2,000 to 2,600 cubic feet per second (cfs) on May 25, then leveled out until June 4 where they increased to 3,500 cfs on June 7. The flow releases from the Cochiti Dam were higher and lasted longer than anticipated and resulted from significant rain and snow events that occurred in the early spring 2016.

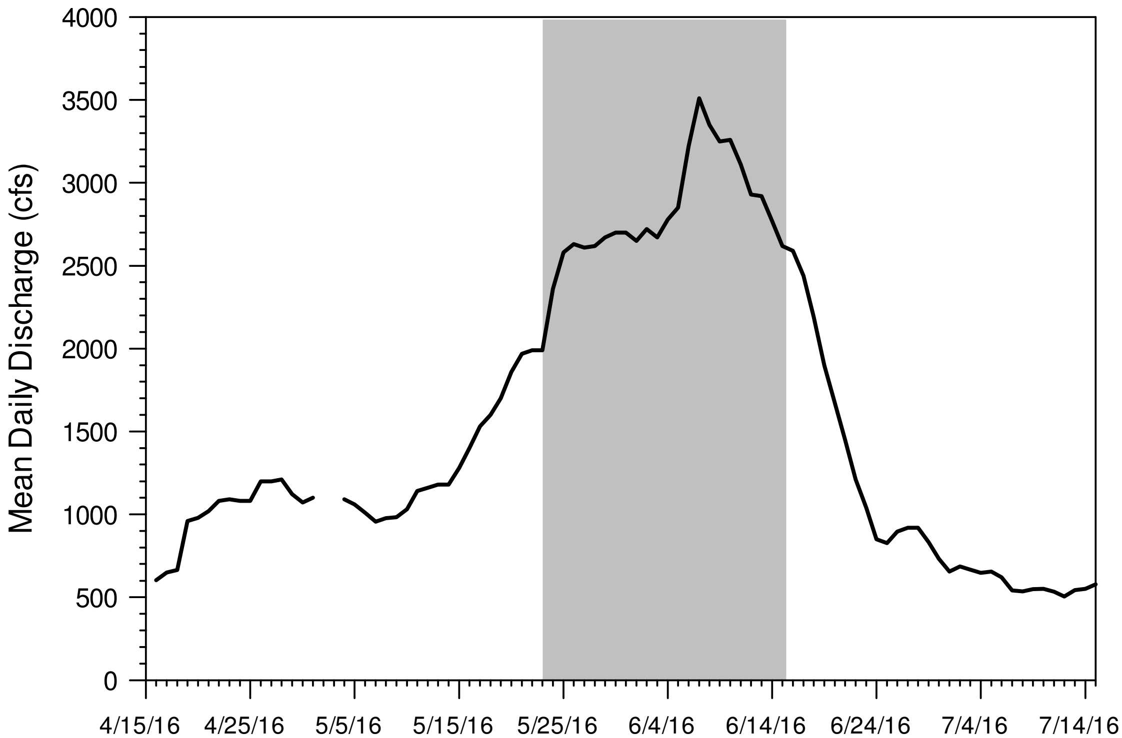

Figure 2.2. Mean daily discharge in the Rio Grande at the USGS Central Avenue Bridge Gage (No. 08330000) from April 15 to July 15, 2016; the shaded area denotes the spring monitoring period from May 23 to June 16, 2016.

2.3.2 SILVERY MINNOW OCCUPANCY OF CORPS HABITAT RESTORATION SITES

In total, 372 silvery minnow were collected with fyke nets from habitat restoration sites during the monitoring period (Table 2.2). Silvery minnow were collected on 16 of the 20 sampling dates at Corrales South, eight of the nine sampling dates for Corrales North, and four of the nine sampling dates for Route 66 North B (Figure 2.3). Silvery minnow relative abundance did not significantly vary among restoration sites during the sampling period (Kruskal Wallis: X^2 =3.74;

df=2; P-value=0.154). Corrales North had the highest average CPUE, followed by Corrales South and Route 66 North A. Corrales North and South are both terrace lowering treatments, and Route 66 North is a high flow channel. In total, 138 silvery minnow were collected at Corrales North. On May 24, 104 fish were caught resulting in a high CPUE for that day, which also explains the large standard error for that site (see Table 2.2). Additionally, silvery minnow were consistently caught at Corrales South, the high intensity sampling site. The most fish collected at Corrales South occurred on May 31, when 65 silvery minnow were caught. Route 66 North B had the fewest fish collected throughout the study period; no silvery minnow were collected at this site after June 3, 2016 (see Figure 2.3). The single-species, single-season backtransformed occupancy model estimated the probability of detection among the three restoration sites to be 0.737, with a standard error of 0.0714. The model estimated the probability of a site being occupied at 1.0 with a standard error of 0.0077.

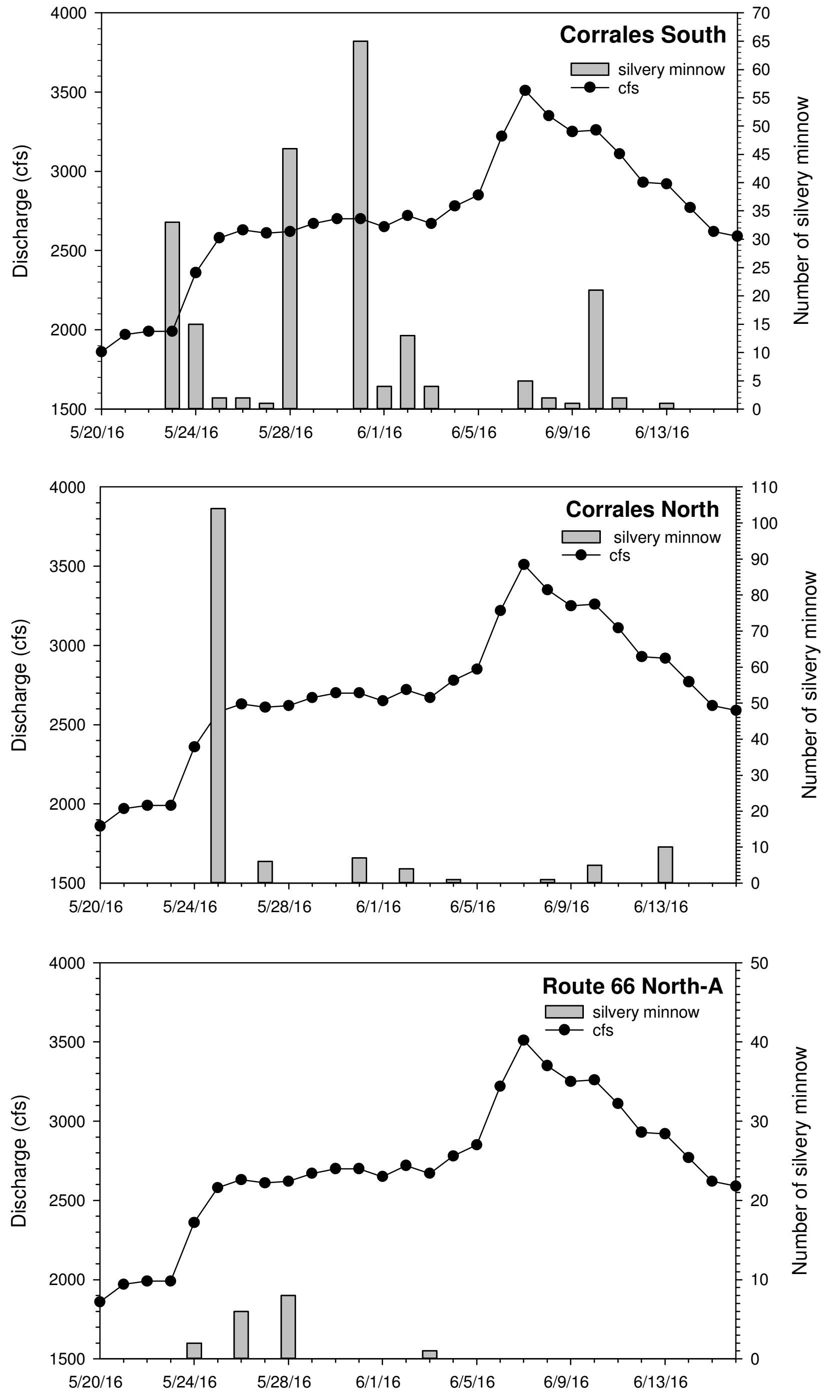

Figure 2.3. Number of silvery minnow collected throughout sites from May 23 to June 16, 2016, and the mean daily discharge at the USGS Central Avenue Bridge Gage (No. 08330000) from May 20 to June 16, 2016. Mean daily discharge is located on the left y-axis and is reported in cfs. The total number of silvery minnow caught on a sampling date is on the right y-axis. Note the days where no silvery minnow were captured are not represented on this figure.

Table 2.2. Total Number of Silvery Minnow and Mean CPUE Collected from Habitat Restoration Sites with Fyke Nets

Restoration Site	Number of Silvery Minnow	Mean CPUE* (fish/hour)
Corrales North	138	3.90 (8.78)
Corrales South	217	2.73 (0.96)
Route 66 North B	17	0.49 (0.26)
Total	**372**	---

*Standard errors of CPUE are given in parenthesis.

2.3.3 COMMUNITY COMPOSITION

Daily community collections for fyke net collections are tabulated in Appendix C. Fish totaling 562 from 11 species were collected during monitoring with fyke nets (Table 2.3). Silvery minnow were the most abundant species, comprising 66.2% of the total fyke net catch (Table 2.3). Red shiner (*Cyprinella lutrensis*) and common carp (*Cyprinus carpio*) were the second most abundant species, comprising of 13.9% and 12.1% of the total fyke net catch, respectively. All other fish species collectively comprised less than 5% of the total fyke net catch.

Table 2.3. Total Number Captured and Percent Composition for Fish Community Collections at Corrales North, Corrales South, and Route 66 North A Restoration Sites with Fyke Nets. Number of marked silvery minnow is in parentheses

Common Name	Scientific Name	Number Collected	Percent
Rio Grande silvery minnow	*Hybognathus amarus*	372 (6)	66.2
Red shiner	*Cyprinella lutrensis*	78	13.9
Common carp	*Cyprinus carpio*	68	12.1
White sucker	*Catostomus commersonii*	22	3.9
Fathead minnow	*Pimephales promelas*	9	1.6
Longnose dace	*Rhinichthys cataracate*	3	0.5
Flathead chub	*Platygobio gracilis*	2	0.4
Green sunfish	*Lepomis (Chaenobryttus) cyanellus*	2	0.4
Largemouth bass	*Micropterus salmoides salmoides*	2	0.4
Unknown young-of-year	–	2	0.4
Channel catfish	*Ictalurus punctatus*	1	0.2
Western mosquitofish	*Gambusia affinis*	1	0.2
Total	–	**562**	**100**

3.0 SILVERY MINNOW SPAWNING INDICES

During monitoring, collected silvery minnow were visibly inspected for signs of reproductive maturity and silvery minnow eggs were sampled on the floodplain in pre-determined 5 × 5–m grids using dip nets.

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.

3.1.2 FLOODPLAIN EGG MONITORING

A 5 × 5–m grid sampling design was used to sample floodplains for silvery minnow eggs. Each site had two to three stationary grids that were measured and marked prior to sampling dates. Grid locations were determined by substrate, vegetation, cover, and potential flow (Table 3.1). Grids were 5 × 5 m in area and were divided into 10 columns (A–J) and 10 rows (1–10), resulting in one hundred 0.5-m cells. Prior to each sampling event a random number generator was used to determine which row was sampled. Numbers were selected between 1 and 10 without replacement so every column was sampled once. Each grid cell that was randomly selected (e.g., cell A7, B3, C1) was swept with a dip net for eggs. If eggs were collected, they were counted and released near the collection location. After each dip net sweep, the vegetation and depth were recorded to calculate mean depth of grid and determine the dominant vegetation. Flow measurements were collected at each cornet of every grid using a Marsh-McBirney Flo-Mate portable flowmeter (Hach Company, Loveland, Colorado).

Table 3.1. Number of Girds at Each Site and Dominant Substrate and Vegetation for Each Grid

Site	Number of Grids	Dominant Substrate	Dominant Vegetation
Corrales North	3	Sand/Silt	Open
Corrales South	3	Vegetation/Silt	Grass/Aquatic vegetation
Nature Center	3	Leaf litter/Silt	Willow/Leaf litter
Route 66 North A	2	Sand/Silt	Willow/open
Route 66 North B	2	Vegetation/Silt	Willow
Route 66 Middle	2	Vegetation/Leaf litter	Willow/Leaf litter

3.2 RESULTS

3.2.1 INDICES OF SILVERY MINNOW MATURITY

Of the 372 silvery minnow collected with fyke nets from May 25 to June 16, 2016, one was documented as a spent female, one was a gravid female, and 37 were males issuing milt. The remaining 333 silvery minnow were documented as unknown; they were not visibly expressing signs of reproduction.

3.2.2 FLOODPLAIN EGG MONITORING

In total, zero silvery minnow eggs were collected from the floodplain using the grid sampling design during spring 2016 monitoring. However, three silvery minnow eggs were collected just above grid 15 along the shoreline at the Nature Center site on May 31, 2016. During the second half of the sampling period, unidentified larval fish were observed on every grid, at each site, except for grid 6 at Route 66 Middle.

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.

4.1 METHODS

4.1.1 LENGTH

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

4.2 RESULTS

4.2.1 LENGTH

Silvery minnow ranged in length from 31 to 97 mm (

Figure 4.1). The mean standard length of fish was 60.5 mm (standard error = 0.32). Of the 372 fish collected, only six were tagged hatchery fish, two escaped and were of unknown origin, and the remaining 364 silvery minnows were wild (unmarked fish).

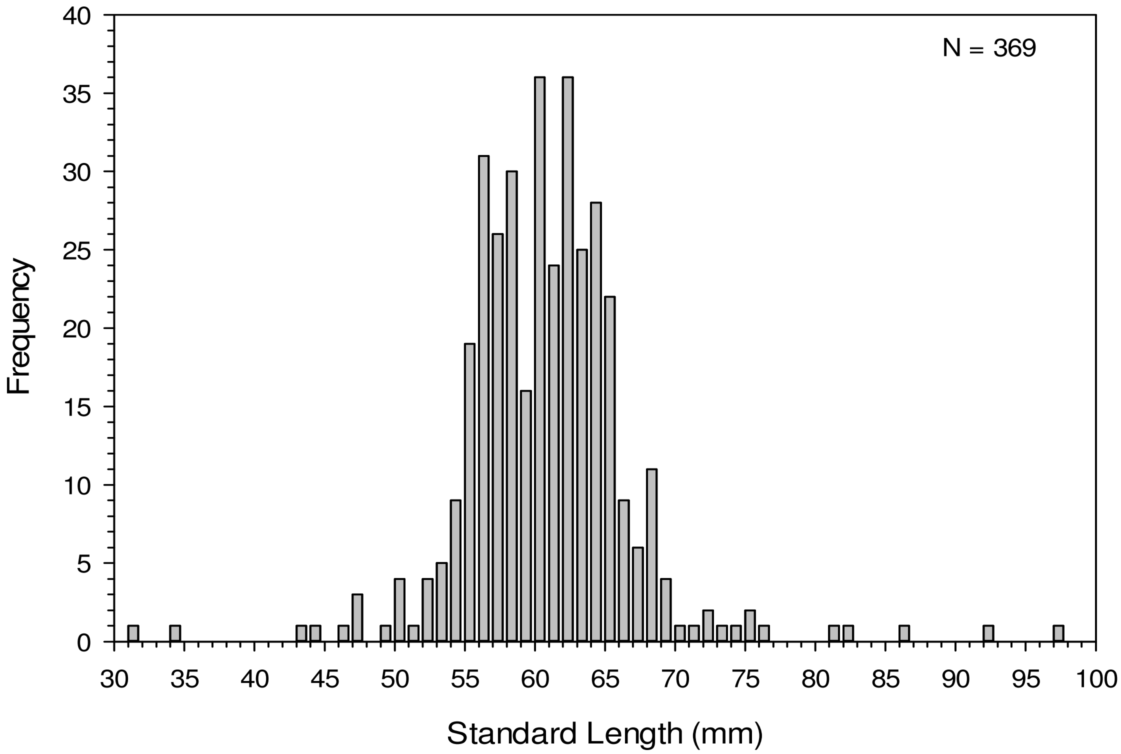

Figure 4.1. Standard length frequency histogram for silvery minnow collected from all sample sites from May 23 to June 16, 2016.

5.0 WATER QUALITY

5.1 METHODS

5.1.1 FLOODPLAIN PROFILE

Water quality parameters were monitored concurrent with fish and grid sampling events from each restoration site. Water quality measurements were collected at or near the same location each sampling date; however, the time of day the sample was collected varied among sampling dates. Water quality measurements included temperature (°C), dissolved oxygen (mg/L and percentage), conductivity (µS/cm [conductivity corrected to 25°C] and µS/cm [uncorrected]), salinity (parts per thousand), and pH. Turbidity (Formazin turbidity units) was measured using a Hanna HI93703 portable turbidity meter. In addition, two HOBO temperature loggers were deployed at each restoration site, one in the main channel of the river at the Nature Center. The temperature loggers remained at each site for the duration of the study period. The temperature loggers at Route 66 North A and Route 66 Middle at Grid 5, however, were lost. The average daily temperature was calculated for HOBO loggers placed in floodplain sites and the adjacent river temperature logger. Mean site depth and mean grid depth was also calculated for each restoration site.

5.2 RESULTS

5.2.1 FLOODPLAIN PROFILE

Water quality data for 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). Water quality was relatively similar among all restoration sites, except Grid 6 at the Route 66 Middle site (Figure 5.1). Route 66 Middle Grid 6 had had extremely low dissolved oxygen and high specific conductivity and salinity. This was different from other grids; it had no flow from the main channel, and the substrate was dense leaf litter. Mean daily temperature ranged from 12.3°C to 26.3°C and the mean daily temperature was 19.6°C across all sites (Figure 5.2). The mean daily temperature of the river at the Nature Center ranged from 18°C to 23.2°C from May 30 to June 20 and the mean daily temperature was 20.4°C. Mean grid depths ranged from 0.08 m at Grid 12 to 0.43 m at Grid 7, and the mean depth for all grids was 0.28 m (Figure 5.3). Mean site depth ranged from 0.104 to 0.4 m at Route 66 North B.

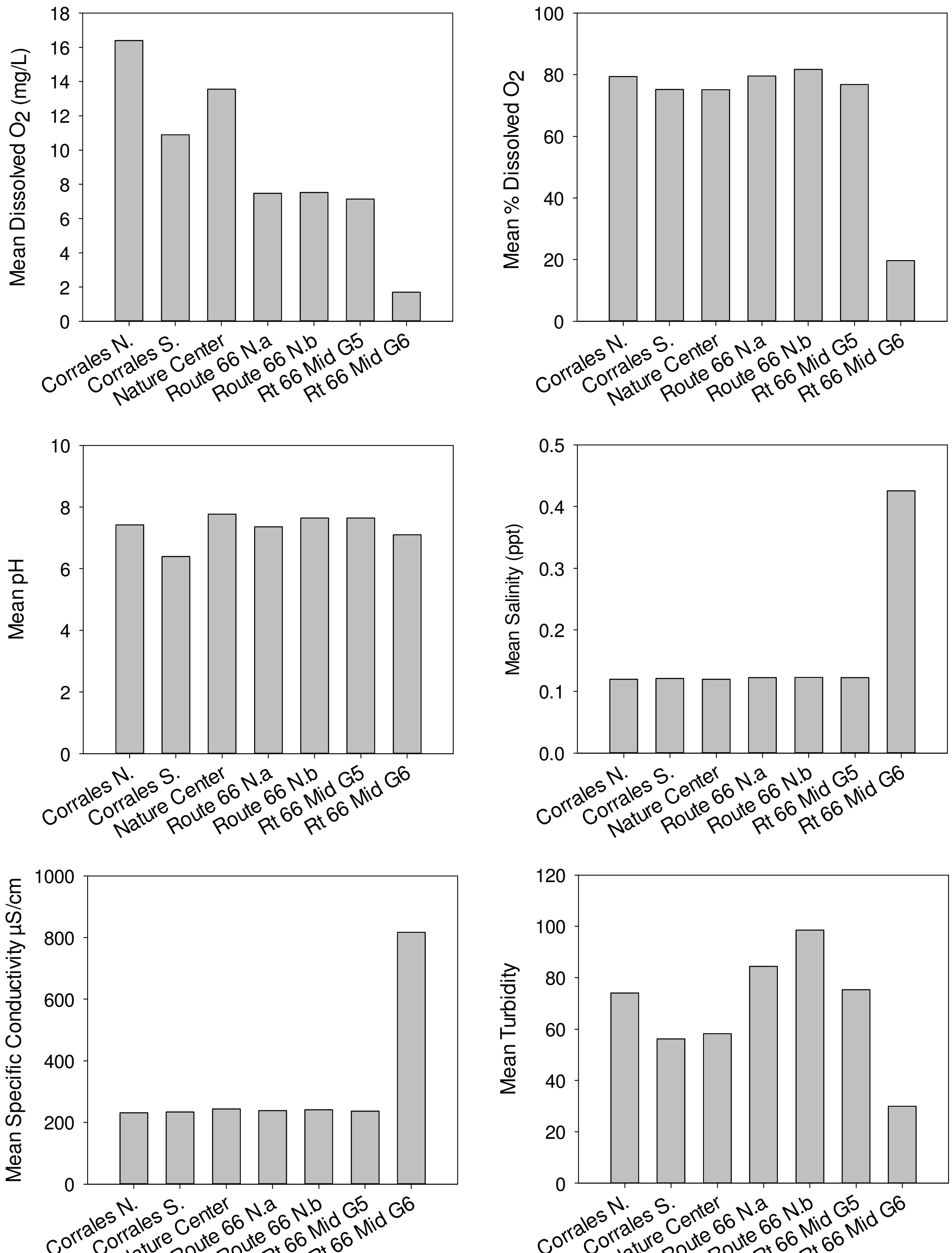

Figure 5.1. Mean water quality measurement for all sites, from May 23 to June 16, 2016. Values are an average of all water quality measurements taken from each sampling date.

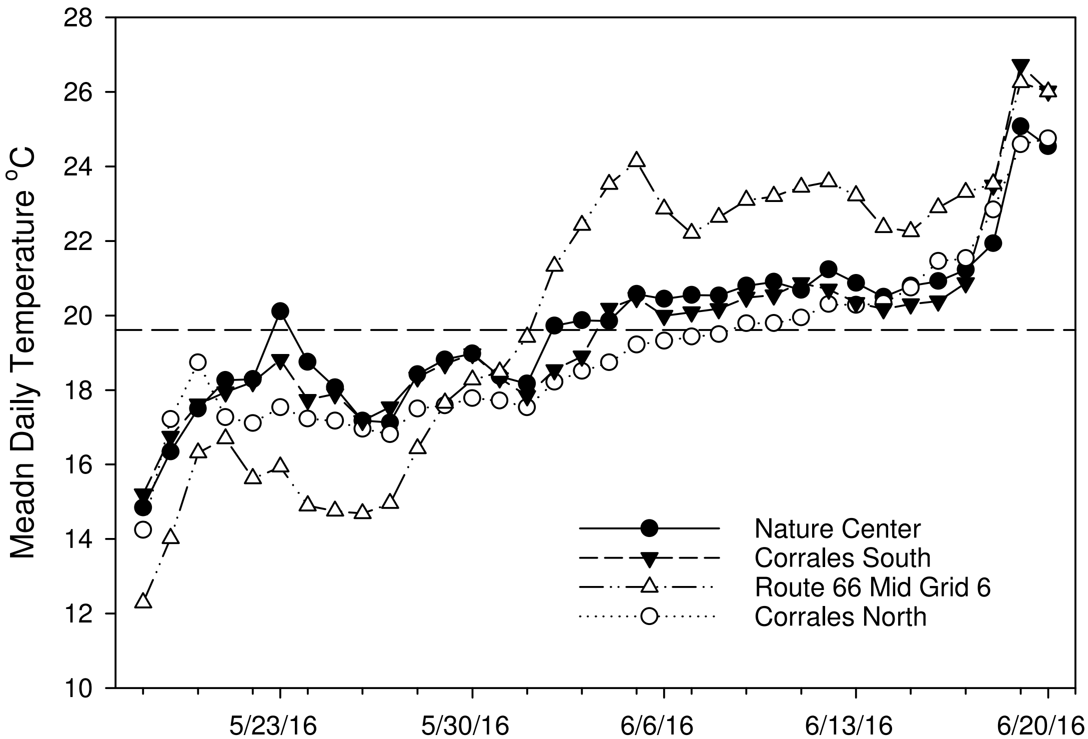

Figure 5.2. Mean daily temperature (°C) at Corrales North, Corrales South, Nature Center, and Route 66 Middle Grid 6 sites. The dashed line represents the mean temperature, 19.5°C, across all sites.

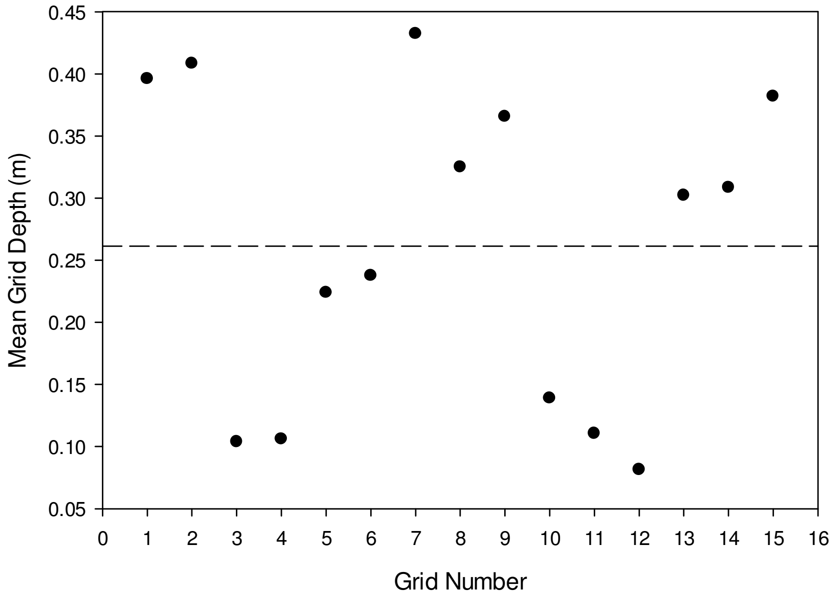

Figure 5.3. Mean grid depth for all restoration sites. The dashed line represents the mean depth across all girds (0.28 m). Grids 1 and 2 were located at Route 66 North B; Grids 3 and 4 were located Route 66 North A; Grids 5 and 6 were located at Route 66 Middle; Grids 7–9 were located at Corrales South; Grids 10–12 were located at Corrales North; and grids 13–15 were located at the Nature Center.

6.0 DISCUSSION

Monitoring of Corps habitat restoration sites during spring 2016 documents the presence of adult silvery minnow on all three sampled restoration sites (Corrales North, Corrales South, and Route 66 North B). One of the primary goals of this monitoring effort was to document whether constructed habitat restoration sites are being utilized by the silvery minnow during runoff, and whether relative abundance differed among sites. Our occupancy model indicated the probability a site was occupied by silvery minnow to be 100 %, with a 73% detection probability. In addition, the Kuskal-Wallis test suggests there were no significant differences in relative abundance among the restoration sites. These observations coincide with previous restoration monitoring efforts in the middle Rio Grande where reproductive silvery minnow were documented using floodplain restoration sites (SWCA Environmental Consulting 2008, 2009, 2010a, 2011; Gonzales 2014). Furthermore, approximately 97% of the fish caught were wild (unmarked), indicating natural recruitment was likely successful in previous years.

The absence of silvery minnow eggs on the sample grids is inconclusive for whether there was spawning on the sites. Previous dip net monitoring indicates that eggs occur in small patches on the floodplain. When a species is rare and/or the detection probability is low the species will not always be detected even when it is actually present (MacKenzie and Royle 2005). The negative dip net data document the very low impact of this sampling method on silvery minnow eggs and spawning habitat, and the need to increase sample effort to detect spawning areas. The data also provide contrast to previous dip net samples by documenting floodplain parameters (depth, water temperature) silvery minnows may avoid as possible spawning sites. Consequently, eggs were found at the Nature Center site outside of the grid resulting in a biased estimate of occupancy (MacKenzie and Royle 2005). Silvery minnow eggs likely have a low detection probability and may require more sampling units (i.e., grids) to be sampled less intensively (MacKenzie and Royle 2005). A stratified design where grids are selected based on likely spawning habitat features (e.g., substrate, depth, velocity, temperature) may be needed when sampling for silvery minnow eggs at restoration sites.

Unidentified larval fish were observed at all five restoration sites (North Corrales, South Corrales, Nature Center, Route 66 North, and Route 66 Middle). An additional monitoring effort during the same time period conducted by the SWCA on behalf of New Mexico Interstate Stream Commission, found > 50% of larvae collected at seven restoration sites were silvery minnow (SWCA 2016b). Therefore, it is likely that a portion of the larval fish observed were silvery minnow. These floodplain restoration sites are providing important nursery habitat for early life stages when fishes naturally experience the highest rates of mortality (Schiemer et al. 2002). Accordingly, the early developmental period for fishes can determine recruitment success (Flake et al. 2010)

Inundated floodplains provide complex habitat including; low velocity, warm temperatures, increased primary production, and structural refugia, for aquatic species (Schlosser 1991; Pease et al. 2006). Silvery minnow larvae are believed to actively seek out these low-velocity habitats (Platania and Altenbach 1998). Similarly, eggs and larvae from other species of *Hybognathus* have been documented in low-velocity, back water, and inundated floodplain habitats (Medley and Shirey 2013). For example, the brassy minnow (*Hybognathus hankinsoni*) spawn in shallow vegetated backwater habitats; and these habitats are critical for brassy minnow spawning and recruitment to occur (Falke et al. 2010). Dip net monitoring at the Nature Center (2014) sampled 612 eggs in shallow habitat (150-200 mm depth) over five days (Porter pers. comm). In addition, research by Medley and Shirey (2013) examining the reproductive ecology of silvery minnow eggs suggest the current interpretation of spawning ecology be refined. They explain, based on the historic geomorphology of the Middle Rio Grande, the ecology and physiological characteristics of silvery minnow eggs, the presence of reproductive silvery minnow on the flood plains, and the life history of other *Hybognathus*; silvery minnow likely move laterally onto inundated, low-velocity, floodplain habitats to spawn (Medley and Shirey 2013).

Riverine species have evolved life-history strategies that are synchronized with long term hydrologic patterns (Lytle and Poff 2004). Many fish species including the silvery minnow, respond to increasing flows associated with spring runoff as a cue to initiate spawning (Platania and Altenbach 1998, Medley and Shirey 2013, Lytle and Poff 2004). The contemporary Middle Rio Grande no longer has a "predictable" flow regime and is dictated by dam operations and water demands (Magaña 2012). The timing, magnitude and duration of spring runoff are determined by amount of snowpack, spring rains, and anthropogenic water demands (Tidwell et al. 2004, SWCA 2110b, Magaña 2012). The hydrograph for the Middle Rio Grande in spring 2016 began to increase after May 7th, and sampling did not occur until May 23rd. Silvery minnows were already present on the floodplain at all sites when sampling began, indicating we likely did not capture the timing when the minnows first move onto the floodplain. Future studies may provide insight to water managers by determining what flows cue the minnows begin to move onto floodplain.

Future monitoring efforts to determine floodplain habitat restoration use by adult silvery minnow may benefit from increasing the restoration treatment types and the number of sites sampled. This would allow for a better comparison of differences in relative abundance as a function of restoration treatment (i.e., high flow channel or terrace). Additionally, floodplain egg monitoring may benefit from modifying the grid method by increasing the number of grids, and decreasing the amount of visits to a grid. Alternatively, widespread point-sampling with a dip net to identify areas for locating 5 × 5–m sample grids may provide a more robust protocol for documenting floodplain spawning sites. Both approaches would support increased monitoring effort to sample more efficiently for patches of eggs with low detection probabilities. Targeting specific habitat features on the floodplain using a stratified sampling design may also increase chances of detecting eggs. Furthermore, sampling for larval silvery minnow would provide important information about critical early life history requirements and identify potential factors limiting successful recruitment.

It is imperative to gain a better understanding of the factors limiting silvery minnow spawning and recruitment. Designing monitoring studies that focus on these life stages will allow for better determination of what habitat features and water management strategies can be employed to maximize annual recruitment. This dataset contains observations of adult silvery minnow using restored floodplain habitat during spawning. These observations provide additional insights regarding the timing and duration of silvery minnow spawning on the floodplain. Data collected during spring 2016 runoff contribute additional information about silvery minnow use of off-channel floodplain habitat of the Middle Rio Grande. The negative egg data provides information on the extent of floodplain use for spawning, with inferences for better understanding floodplain habitat use and refining egg sampling protocols.

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APPENDIX A
SPRING 2015 MONITORING SITES

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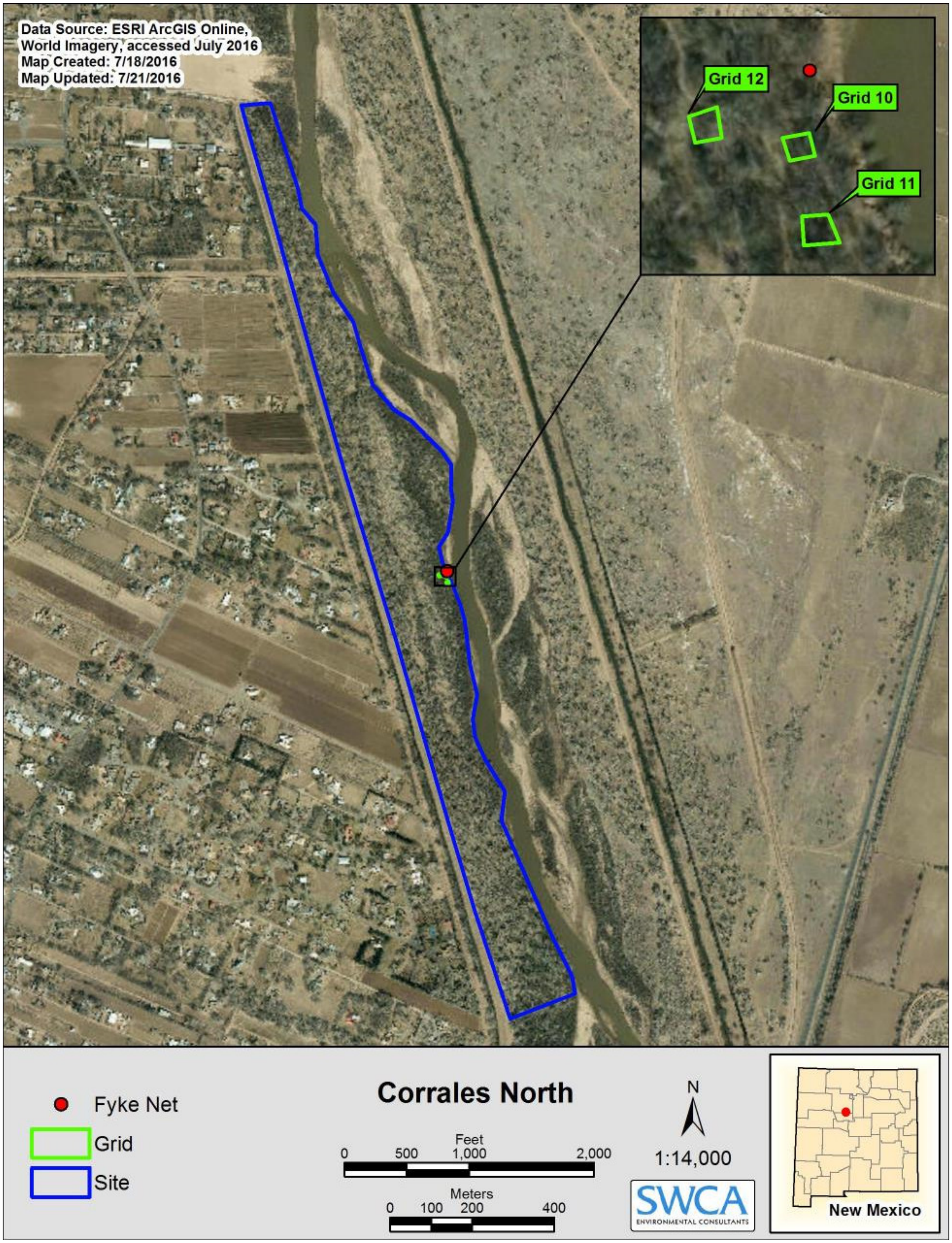

Figure A.1. Map depicting fyke net and grid locations at the Corrales North site.

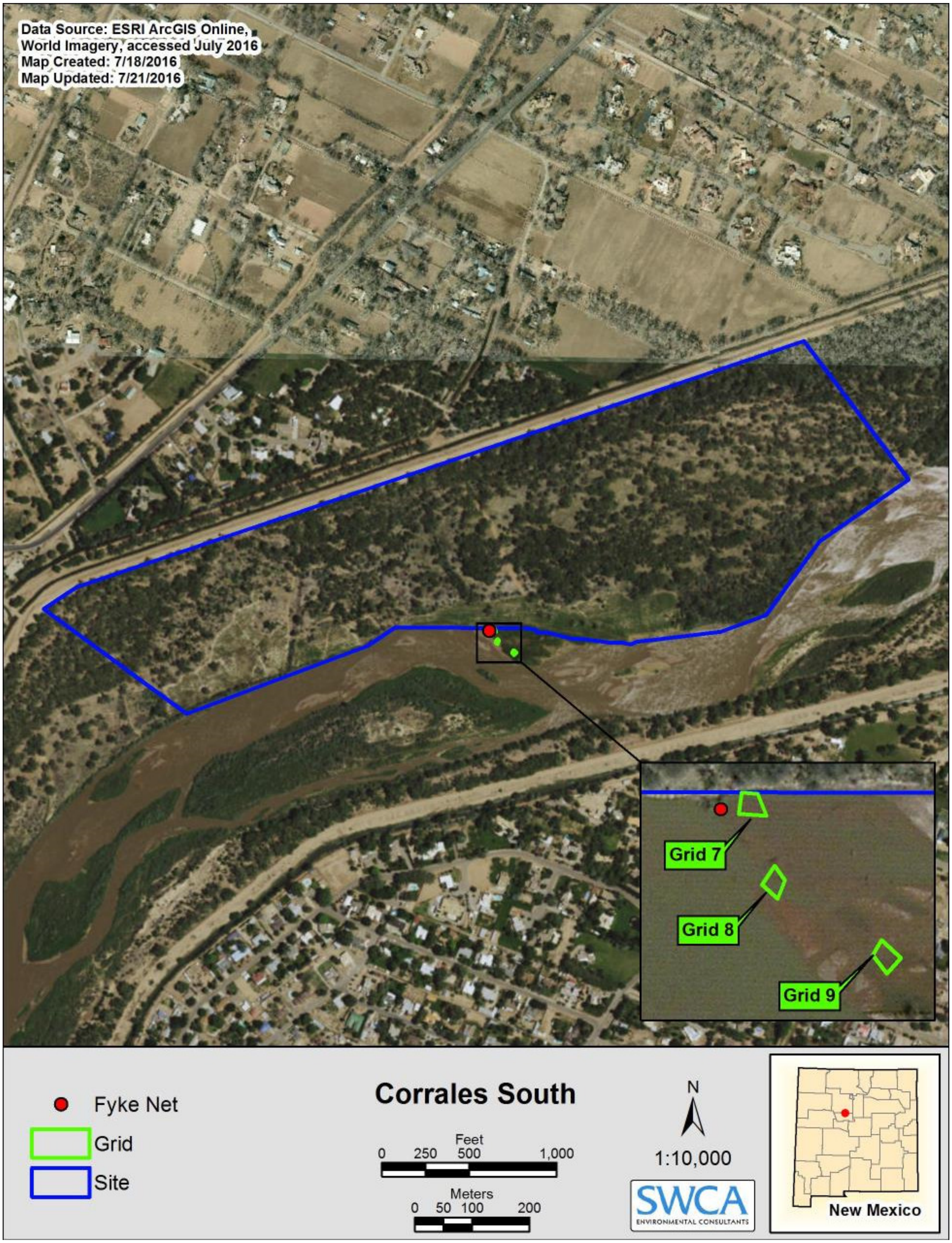

Figure A.2. Map depicting fyke net and grid locations at the Corrales South site.

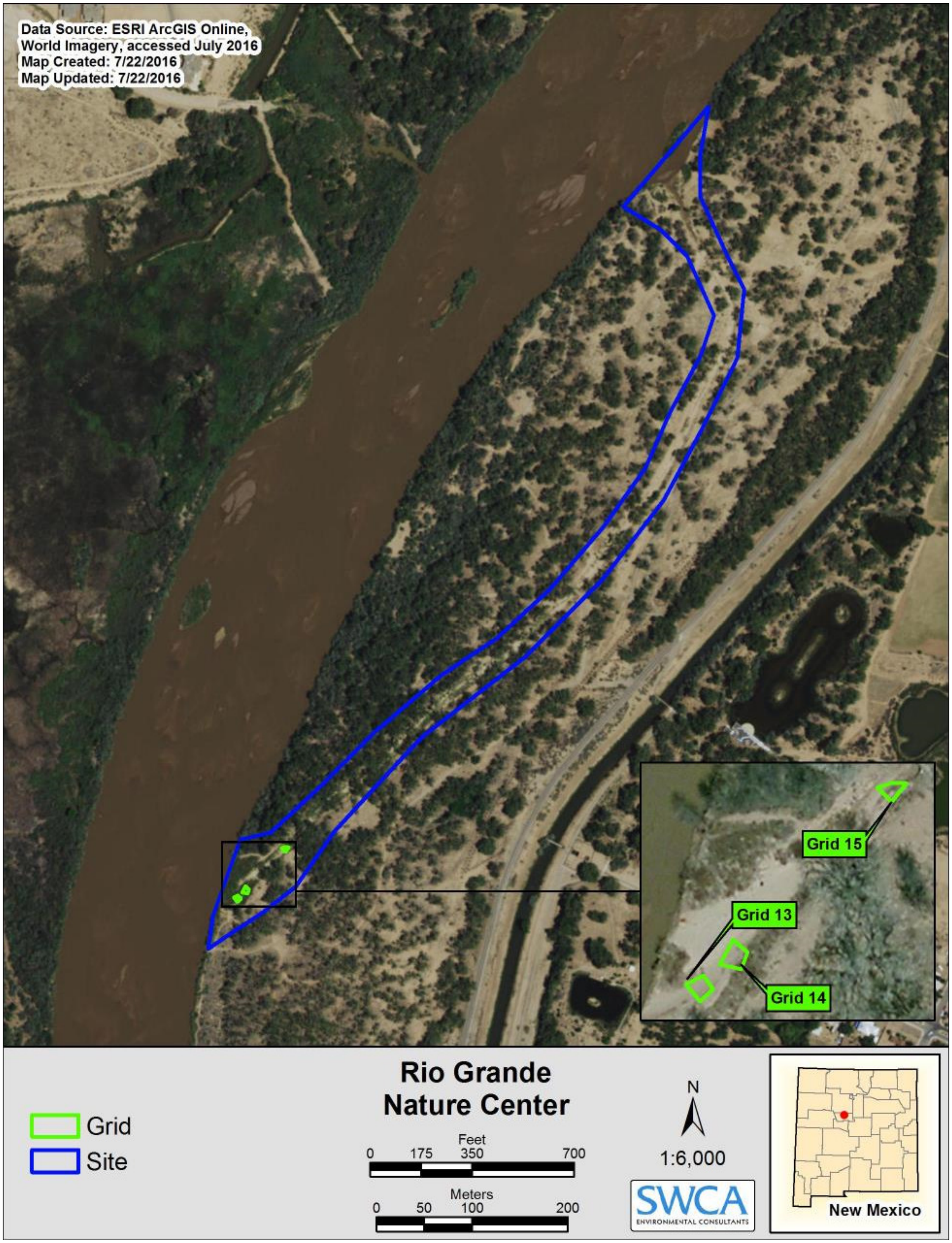

Figure A.3. Map depicting grid locations at the Nature Center site.

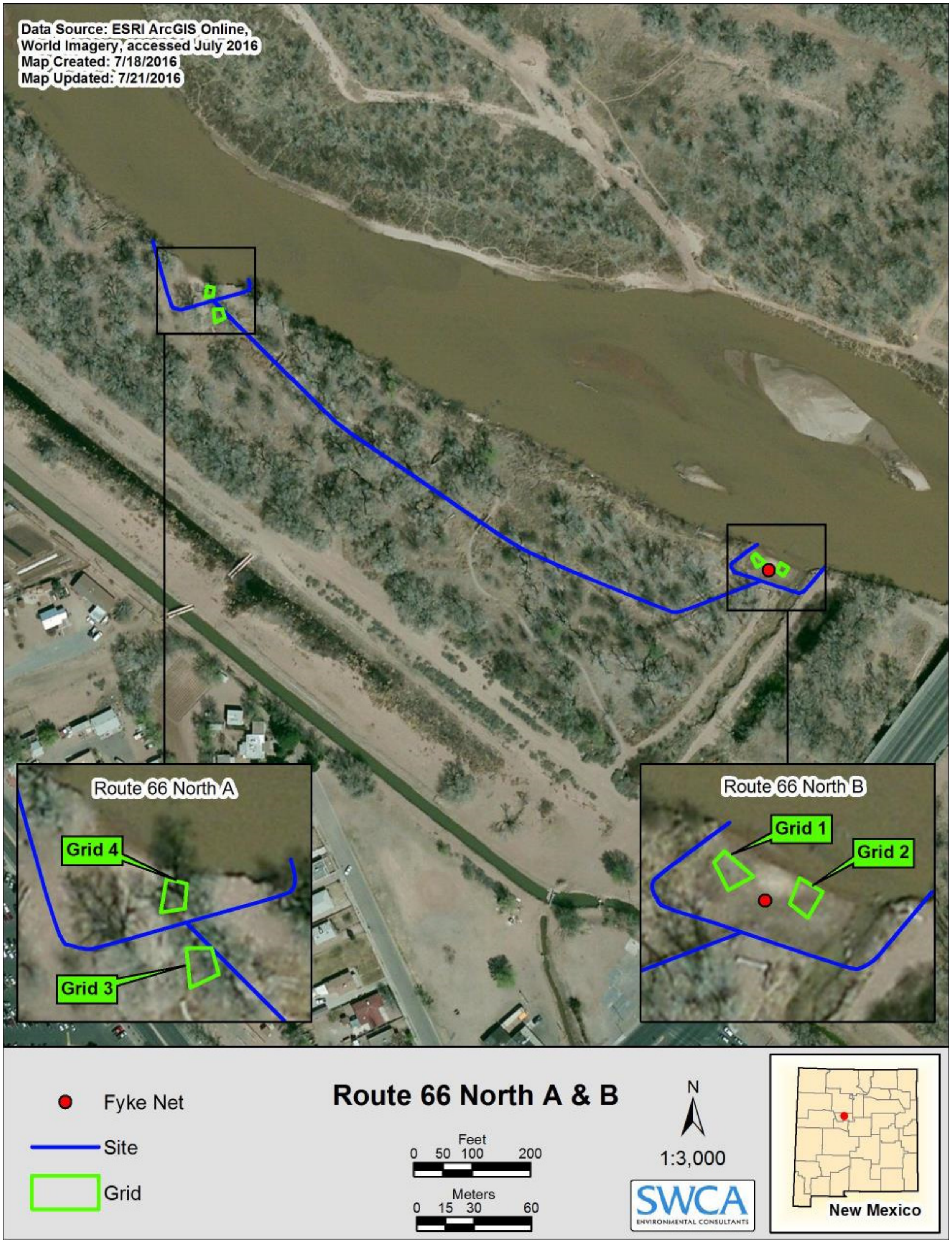

Figure A.4. Map depicting fyke net and grid locations at the Route 66 North A and B sites.

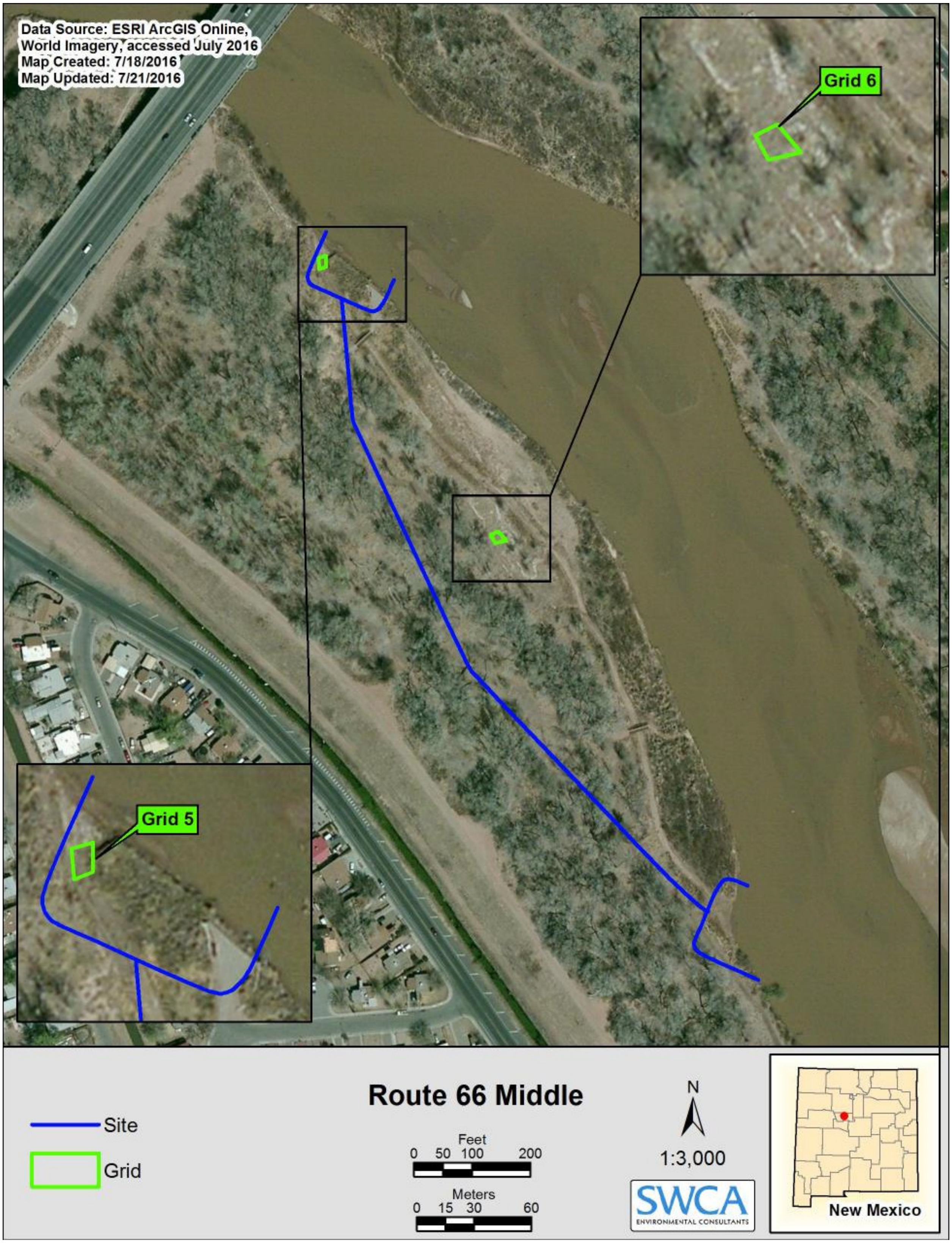

Figure A.5. Map depicting grid locations at the Route 66 Middle site.

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APPENDIX B
PROJECT PHOTOGRAPHS

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Figure B.1. Fyke net setup at the Corrales North site.

Figure B.2. Dip net sampling on Grid 10 at the Corrales North site.

Figure B.3. Fyke net setup at the Corrales South site.

Figure B.4. Overview of Grid 8 at the Corrales South site.

Figure B.5. Dip net sampling Grid 14 at the Nature Center site.

Figure B.6. Overview of Grid 4 at the Route 66 North A site.

Figure B.7. Fyke net setup at the Route 66 North B site.

Figure B.8. Overview of Grid 6 at the Route 66 Middle site.

Figure B.9. Overview of Grid 6 at the Route 66 Middle site.

Figure B.10. Silvery minnow caught in a fyke net at the Corrales South site.

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APPENDIX C
FISH COMMUNITY COLLECTIONS BY SITE AND GEAR TYPE

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Table C.1. Fyke Net Fish Community Collections by Date and Site for 2016

Date	Site	Species	Number
5/23/2016	Corrales South	Rio Grande silvery minnow (*Hybognathus amarus*)	33
5/24/2016	Corrales South	Red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	15
	Route 66 North B	Red shiner (*Cyprinella lutrensis*)	4
		Rio Grande silvery minnow (*Hybognathus amarus*)	2
5/25/2016	Corrales South	Rio Grande silvery minnow (*Hybognathus amarus*)	2
	Corrales North	Rio Grande silvery minnow (*Hybognathus amarus*)	104
5/26/2016	Corrales South	Rio Grande silvery minnow (*Hybognathus amarus*)	2
	Route 66 North B	Green sunfish (*Lepomis [Chaenobryttus] cyanellus*)	1
		Red shiner (*Cyprinella lutrensis*)	2
		Rio Grande silvery minnow (*Hybognathus amarus*)	6
		White sucker (*Catostomus commersonii)*	2
5/27/2016	Corrales South	Red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	1
	Corrales North	Rio Grande silvery minnow (*Hybognathus amarus*)	6
5/28/2016	Corrales South	Rio Grande silvery minnow (*Hybognathus amarus*)	46
	Route 66 North B	Fathead Minnow (*Pimephales promelas)*	3
		Red shiner (*Cyprinella lutrensis*)	12
		Rio Grande silvery minnow (*Hybognathus amarus*)	8
		White sucker (*Catostomus commersonii)*	1
5/31/2016	Corrales South	Largemouth bass (*Micropterus salmoides salmoides)*	1
		Red shiner (*Cyprinella lutrensis*)	4
		Rio Grande silvery minnow (*Hybognathus amarus*)	65
	Corrales North	Rio Grande silvery minnow (*Hybognathus amarus*)	7
6/1/2016	Corrales South	Rio Grande silvery minnow (*Hybognathus amarus*)	4
	Route 66 North B	Red shiner (*Cyprinella lutrensis*)	2
		Rio Grande silvery minnow (*Hybognathus amarus*)	0
6/2/2016	Corrales South	Fathead Minnow (*Pimephales promelas)*	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	13
		White sucker (*Catostomus commersonii)*	1
	Corrales North	Longnose dace (*Rhinichthys cataracate)*	2
		Red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	4
6/3/2016	Corrales South	Red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	4
		White sucker (*Catostomus commersonii)*	6
	Route 66 North B	Red shiner (*Cyprinella lutrensis*)	10
		Rio Grande silvery minnow (*Hybognathus amarus*)	1
		White sucker (*Catostomus commersonii)*	2

Date	Site	Species	Number
6/4/2016	Corrales South	Red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	0
	Corrales North	Longnose dace (*Rhinichthys cataracate)*	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	1
6/7/2016	Corrales South	Fathead minnow (*Pimephales promelas)*	1
		Red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	5
		White sucker (*Catostomus commersonii)*	1
	Route 66 North B	Rio Grande silvery minnow (*Hybognathus amarus*)	0
		White sucker (*Catostomus commersonii)*	1
6/8/2016	Corrales South	Red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	2
	Corrales North	Rio Grande silvery minnow (*Hybognathus amarus*)	1
6/9/2016	Corrales South	Common carp (*Cyprinus carpio)*	1
		Fathead Minnow (*Pimephales promelas)*	2
		Largemouth bass (*Micropterus salmoides salmoides)*	1
		Red shiner (*Cyprinella lutrensis*)	9
		Rio Grande silvery minnow (*Hybognathus amarus*)	1
	Route 66 North B	Flathead chub (*Platygobio gracilis)*	1
		Red shiner (*Cyprinella lutrensis*)	17
		Rio Grande silvery minnow (*Hybognathus amarus*)	0
6/10/2016	Corrales South	Common carp (*Cyprinus carpio)*	3
		Fathead minnow (*Pimephales promelas)*	1
		Green sunfish (*Lepomis Chaenobryttus cyanellus)*	1
		Red shiner (*Cyprinella lutrensis*)	6
		Rio Grande silvery minnow (*Hybognathus amarus*)	21
		Unknown young-of-year	2
		Western mosquitofish (*Gambusia affinis)*	1
		White sucker (*Catostomus commersonii)*	3
	Corrales North	Rio Grande silvery minnow (*Hybognathus amarus*)	5
6/11/2016	Corrales South	Common carp (*Cyprinus carpio)*	32
		Channel catfish (*Ictalurus punctatus)*	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	2
		White sucker (*Catostomus commersonii)*	1
	Route 66 North B	Fathead minnow (*Pimephales promelas)*	1
		Red shiner (*Cyprinella lutrensis*)	2
		Rio Grande silvery minnow (*Hybognathus amarus*)	0

Date	Site	Species	Number
6/13/2016	Corrales South	Rio Grande silvery minnow (*Hybognathus amarus*)	1
		White sucker (*Catostomus commersonii)*	1
	Corrales North	Flathead chub (*Platygobio gracilis)*	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	10
6/14/2016	Corrales South	Common carp (*Cyprinus carpio)*	2
		Rio Grande silvery minnow (*Hybognathus amarus*)	0
	Route 66 North B	Red shiner (*Cyprinella lutrensis*)	2
		Rio Grande silvery minnow (*Hybognathus amarus*)	0
		White sucker (*Catostomus commersonii)*	1
6/15/2016	Corrales South	Common carp (*Cyprinus carpio)*	28
		Rio Grande silvery minnow (*Hybognathus amarus*)	0
		White sucker (*Catostomus commersonii)*	1
	Corrales North	Red shiner (*Cyprinella lutrensis*)	1
		Rio Grande silvery minnow (*Hybognathus amarus*)	0
		White sucker (*Catostomus commersonii)*	1
6/16/2016	Corrales South	Common carp (*Cyprinus carpio)*	2
		Rio Grande silvery minnow (*Hybognathus amarus*)	0
	Route 66 North B	None	0
Total			**562**

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APPENDIX D
WATER QUALITY DATA

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Table D.1 Water Quality Data, Spring 2016

Site	Date	Time	Temperature C	Dissolved O_2 (mg/L)	Dissolved O_2 (%)	pH	Salinity	Specific Conductivity (µs/cm)	Turbidity (FTU)	Substrate
Corrales North	25-May-16	14:31	18.44	8.68	92.9	7.7	0.13	270	73	SI
Corrales North	27-May-16	9:50	15.75	8.5	89.8	7.77	0.13	266	63	SA
Corrales North	31-May-16	12:00	17.68	9.24	97.3	7	0.13	226	46.54	SI/SA
Corrales North	2-Jun-16	12:30	19.06	8.65	93.4	8.11	0.12	252	69	SA/SI
Corrales North	4-Jun-16	10:45	18.08	9.18	96.6	8.14	0.12	218	87	SI
Corrales North	8-Jun-16	12:57	20.05	6.71	74	6.72	0.12	225	115	SI
Corrales North	10-Jun-16	9:02	18.22	7.72	81.8	6.9	0.11	207	81	SI
Corrales North	13-Jun-16	10:53	19.18	7.45	80.6	6.9	0.11	211	69	SI
Corrales North	15-Jun-16	10:45	18.8	81.5	7.95	7.54	0.11	208	63	SI
Corrales South	23-May-16	10:23	16.02	8.09	82.1	7.68	0.12	257	88	SI
Corrales South	24-May-16	9:20	15.43	6.8	68.2	7.54	0.13	262	91	TV
Corrales South	25-May-16	13:51	20.96	6.09	70.1	7.33	0.14	287	50	SI
Corrales South	26-May-16	13:34	18.98	7.5	82.2	7.44	0.13	283	36.88	SI
Corrales South	27-May-16	8:50	15.29	7.5	75	7.73	0.1	217	41.31	TV
Corrales South	28-May-16	11:30	18.2	10.13	98.8	8.04	0.12	269	74	TV
Corrales South	31-May-16	10:35	18	10.21	107.2	6.86	0.12	226	19.28	SI
Corrales South	1-Jun-16	9:05	15.75	7.97	81	6.28	0.12	212	67	TV
Corrales South	2-Jun-16	11:11	17.47	6.75	70.5	7.78	0.12	257	65	SI
Corrales South	3-Jun-16	9:08	16.82	8.4	85.5	6.13	0.12	213	36.16	TV
Corrales South	4-Jun-16	9:37	18.19	5.48	58.3	6.14	0.13	229	41.51	SI
Corrales South	7-Jun-16	9:20	18.19	8.63	90	5.57	0.12	220	79	SI
Corrales South	8-Jun-16	10:08	18.43	6.76	72	6.7	0.12	219	53	SI
Corrales South	9-Jun-16	9:00	18.58	7.78	82.1	5.58	0.12	218	52	SI
Corrales South	10-Jun-16	8:07	18.21	7.23	77.2	5.28	0.12	215	44.46	SI
Corrales South	11-Jun-16	8:31	18.86	5.55	60	5.29	0.13	239	78	SI
Corrales South	13-Jun-16	10:00	19.17	8.35	90	5.78	0.11	209	66	SI
Corrales South	14-Jun-16	9:32	17.94	5.73	62.5	5.37	0.13	238	21.91	SI
Corrales South	15-Jun-16	9:00	18.05	75	7	4.65	0.11	202	52	SI
Corrales South	16-Jun-16	8:55	18.52	7.86	84.4	4.9	0.11	204	66	SI
Nature Center	23-May-16	11:46	20.02	5.83	64	7.32	0.13	267	33.58	SI
Nature Center	25-May-16	12:25	19.59	6.52	71.3	7.58	0.13	267	59	SI
Nature Center	27-May-16	11:27	17.14	9.13	94.9	8.12	0.13	271	51	TV
Nature Center	31-May-16	13:40	21.11	9.94	111.7	8.32	0.12	244	32.58	SI
Nature Center	2-Jun-16	9:22	17.14	7.25	75.3	7.01	0.12	257	64	SI
Nature Center	4-Jun-16	12:50	20.68	8.8	98.5	8.12	0.12	230	78	SI

Site	Date	Time	Temperature C	Dissolved O_2 (mg/L)	Dissolved O_2 (%)	pH	Salinity	Specific Conductivity (µs/cm)	Turbidity (FTU)	Substrate
Nature Center	10-Jun-16	10:33	19.32	7.1	77.3	7.92	0.11	218	95	SI
Nature Center	13-Jun-16	12:30	21.12	6.92	78.1	7.68	0.11	219	--	SI
Nature Center	15-Jun-16	12:30	21.56	60.5	5.32	7.89	0.11	220	53	SI
Route 66 North A	24-May-16	11:37	17.38	7.57	78.9	7.58	0.13	279	109	TV
Route 66 North A	26-May-16	11:50	16.91	7.83	80.7	7.79	0.13	270	111	SI
Route 66 North A	28-May-16	9:00	16.04	6.3	64.5	7.53	0.13	276	80	TV
Route 66 North A	1-Jun-16	11:05	16.69	8.07	83.5	7.03	0.13	222	62	SI
Route 66 North A	3-Jun-16	11:17	18.57	8.4	90.4	8.66	0.12	221	73	SA/SI
Route 66 North A	7-Jun-16	11:30	19.69	8.16	89.5	6.09	0.12	227	100	SI
Route 66 North A	9-Jun-16	11:15	19.97	7.1	78.2	7.76	0.12	222	71	SI
Route 66 North A	11-Jun-16	10:22	19.94	6.76	74.3	7.89	0.11	218	71	SI
Route 66 North A	14-Jun-16	11:20	19.23	7.02	76.5	5.91	0.11	210	83	SI
Route 66 North B	24-May-16	10:45	17.62	6.82	85.4	7.17	0.13	283	73	SI
Route 66 North B	26-May-16	11:00	16.73	6.15	62.7	7.22	0.13	279	48.29	SI
Route 66 North B	28-May-16	9:30	16.59	8.76	90.7	7.7	0.13	270	105	TV
Route 66 North B	1-Jun-16	10:20	16.9	7.26	74.5	7.79	0.13	229	45.83	SI
Route 66 North B	3-Jun-16	10:36	18.74	6.83	73.1	7.87	0.12	229	52	SI
Route 66 North B	7-Jun-16	10:49	19.49	7.93	86.7	7.89	0.12	229	113	SI
Route 66 North B	9-Jun-16	10:33	19.81	7.2	81	7.95	0.12	225	121	SI
Route 66 North B	11-Jun-16	9:40	19.7	6.91	75.4	7.77	0.12	222	313	SI
Route 66 North B	14-Jun-16	10:30	19.46	11.17	120.4	7.61	0.11	214	61	SI
Route 66 North B	16-Jun-16	10:20	19.9	6.2	68	7.49	0.12	233	53	SI
Route 66 Middle G-5	26-May-16	12:20	17.44	7.91	82.6	7.4	0.13	277	48.87	SI
Route 66 Middle G-5	28-May-16	10:00	17.33	7.76	80.8	7.81	0.13	274	68	TV
Route 66 Middle G-5	1-Jun-16	11:40	16.8	7.96	82.2	7.83	0.13	225	48.61	TV
Route 66 Middle G-5	3-Jun-16	12:15	19.44	7.73	84.3	7.99	0.12	229	65	TV
Route 66 Middle G-5	7-Jun-16	12:08	19.94	7.96	87.9	6.49	0.12	231	79	SI
Route 66 Middle G-5	9-Jun-16	12:01	20.01	6.19	68.1	7.71	0.12	222	159	SI
Route 66 Middle G-5	11-Jun-16	10:56	19.87	6.14	67.5	7.94	0.12	219	60	SI
Route 66 Middle G-5	14-Jun-16	12:10	19.85	5.48	61	8	0.11	214	74	SI
Route 66 Middle G-6	24-May-16	12:17	21.42	2.03	23.6	6.84	1.04	2029	13.84	TV
Route 66 Middle G-6	1-Jun-16	11:28	17.06	0.56	6.1	7.33	0.43	743	14.9	TV
Route 66 Middle G-6	3-Jun-16	12:07	19.6	1.34	15.2	7.15	0.46	836	7.37	TV
Route 66 Middle G-6	7-Jun-16	12:24	23.61	2.88	33.3	7.14	0.19	390	33.56	TV
Route 66 Middle G-6	9-Jun-16	12:15	22.3	1.36	15.6	6.92	0.31	654	41.14	SI
Route 66 Middle G-6	11-Jun-16	10:45	22.14	1.9	22	7.06	0.28	552	29.95	SI
Route 66 Middle G-6	14-Jun-16	11:52	22.3	1.86	22.02	7.29	0.27	514	69	SI