Los Lunas Habitat Restoration Fisheries Monitoring

Prepared for

U.S. BUREAU OF RECLAMATION, ALBUQUERQUE AREA OFFICE
555 Broadway N.E., Suite 100
Albuquerque, New Mexico 87102
Telephone: (505) 462-3540

Prepared by

SWCA ENVIRONMENTAL CONSULTANTS
5647 Jefferson Street N.E.
Albuquerque, NM 87109
Telephone: (505) 254-1115, Fax: (505) 254-1116
www.swca.com

Michael D. Hatch, M.S.
and
Eric Gonzales, M.S.

SWCA Project No. 13199

October 16, 2008

EXECUTIVE SUMMARY

The Los Lunas Habitat Restoration Project was designed in part to recouple a portion of the Middle Rio Grande with its floodplain to enhance Rio Grande silvery minnow (silvery minnow; *Hybognathus amarus*) reproduction and recruitment. The Los Lunas Habitat Restoration Project site is located approximately 5.0 km (3.1 miles) south of Los Lunas along the west bank of the Rio Grande. The Los Lunas Habitat Restoration Project site and the river adjacent to the restoration site are only intermittently inundated.

Results of synoptic fish surveys of river and floodplain habitats and environmental characteristics of these habitats are examined to elucidate how faunal assemblages at this site are structured by underlying physical, chemical, and hydrologic features of the environment. This study documents the occupancy of the Los Lunas Habitat Restoration Project site and the adjacent segment of the main channel by reproductively mature silvery minnow. This information is used to support inferences about silvery minnow reproductive biology and processes such as dispersal and habitat selection.

Occupancy of the floodplain at the Los Lunas Habitat Restoration Project site by reproductively mature silvery minnow was documented over the duration of sampling (May 20 to June 6, 2008). Reproductively mature males and females were most commonly found at sample sites where low velocity flows predominated. A heightened level of floodplain occupation by reproductively mature males and females occurred with a rise in river flow over the period of May 21 to May 23, 2008. Spent females, i.e., females that had obviously spawned, were not observed until calendar week 22 (May 25–May 31).

Mean silvery minnow catch per unit effort (CPUE) was positively correlated to mean 24-hour change in main channel flow. A linear model fit the data relatively well for the 24-hour increases in discharge and CPUE ($R^2 = 0.85$), while a polynomial fit best described the relationship between 24-hour decreases in discharge and CPUE ($R^2 = 0.54$).

Rate of silvery minnow capture was generally highest at all sample sites during week 21 (May 20–May 24). During this time, flow in the river was generally less than 4,300 cubic feet per second (cfs) and low velocity conditions prevailed at half of the floodplain sample sites where the rate of silvery minnow capture was highest. Rate of silvery minnow capture generally declined progressively over time at most sample sites.

Average weekly water temperatures were consistently higher at floodplain sites compared to average weekly water temperatures in the main channel. Low velocity sample sites exhibited the highest mean weekly water temperatures of the floodplain habitat types sampled. The highest deviation in mean weekly water temperature occurred during week 21 when water temperatures of low velocity floodplain habitats ranged 1.39–2.16°C higher than temperatures of the adjacent main channel. Coincidentally, the rate of silvery minnow capture was highest during this week. During week 21 when flow was generally less than 4,300 cfs, maximum water temperatures of low velocity floodplain sample sites deviated from main channel maximum water temperatures by 8.26°C to 9.78°C.

Patterns of fish community composition indicate that floodplain habitats of the Los Lunas Habitat Restoration Project site support a greater diversity of species and a greater number of reproductive guilds than the adjacent portion of the main channel of the Middle Rio Grande. Patterns of community composition indicate that fauna-environment interactions of the floodplain favor colonizing species, including silvery minnow, common carp (*Cyprinus carpio*), and red shiner (*Cyprinella lutrensis*). Together these three species numerically comprise nearly 97.0 percent of the floodplain fauna. The absence of five species from main channel collections accounts for the low similarity between the fauna of these adjacent habitat types. Many of the higher rank species (i.e., species of low relative abundance) and species that are absent from adjacent aquatic habitats generally represent peripheral or adventitious occurrences at Los Lunas—their presence or absence is not likely to have a significant ecological consequence given their low relative abundance. The exception to this is the common carp, which was absent from main channel collections. The presence of this species in the floodplain is undoubtedly ecologically significant given its high fecundity. It is expected that high discharge that inundates floodplain habitats will lead to positive population trajectories of silvery minnow and common carp, but through different modes of reproduction. Ecologically, floods and drought represent disturbance factors in the Middle Rio Grande that serve to differentially advantage or disadvantage species, thereby regulating species diversity and species abundance across varying spatial and temporal scales. Significantly, the contemporary disturbance flow regime of the Middle Rio Grande disadvantages nest-guarding lithophils, which serves to reduce the diversity and abundance of predatory fish species.

Monthly samples in the segment of the Rio Grande adjacent to the Los Lunas Habitat Restoration Project site document an initial occupancy of this river segment by a core of colonizing species including silvery minnow, red shiner, and river carpsucker (*Carpiodes carpio*). Although species composition of collections varied over time, monthly diversity quickly reached a plateau at six species after rewetting. This relatively low proportion of the regional species pool suggests a delayed influence of regional diversity on local diversity, governed to some extent by local conditions, notably including lingering effects of recent channel drying.

The fish faunal assemblage of the Los Lunas Habitat Restoration Project site comprised a greater portion of the pooled faunal assemblage of the Isleta Reach compared to the adjacent segment of river. The relative species saturation of the floodplain appears to depend significantly on annual species-specific reproduction cycles and high flows that serve to facilitate dispersal of advanced life stage fish. Whereas the high flows are disruptive and serve to disperse fish, lateral habitats offer velocity refuges that can operate to moderate this effect.

Estimates of floodplain species richness differed by sampling method. Thirteen species were represented in fyke net samples, while only eight species were represented in seine samples. We used Jaccard's index as an index of similarity among estimates of species richness from floodplain seine and fyke net samples. The index value for fyke net samples (0.62) was 1.63 times higher that the index value for seine net samples (0.38), indicating that species richness in floodplain habitats is underestimated by seining relative to sampling with fyke nets.

Rank abundance of silvery minnow in floodplain habitats differed by sampling method. Silvery minnow was the most abundant species in fyke net samples. In contrast, silvery minnow was the third most abundant species in seine samples. Linear regression reveals a general agreement in daily indices of silvery minnow abundance derived from fyke net and seine samples. Despite this, average fyke net capture of silvery minnow was 70 times higher than seine net captures. The calculated fishing power coefficient indicates that the fyke net CPUE index (silvery minnow per hour) was on average nine times higher (average 9.0, SE = 1.5) than comparable seine net CPUE (silvery minnow per 100 m^2) values.

Table of Contents

Executive Summary iii

Introduction 1

Project Background 3

Methods 7
- Fish and Environmental Quality Surveys 7
- Data Analysis 9

Results 11
- Silvery Minnow Floodplain Occupancy 11
  - Silvery Minnow Demographic Characteristics 12
  - Silvery Minnow Habitat Selection 14
    - Water Discharge / Velocity 14
    - Water Temperature 16
    - Water Chemistry 17
  - Silvery Minnow Reproductive Condition and the Appearance of Early Life Stage Fish 17
- Community Composition 19
  - Species Richness / Relative Abundance 19
- Habitat Patch Occupation 21
- Sampling Adequacy and Sampling Bias 22

Discussion 25
- Channel-floodplain Coupling 25
- Assessment of Habitat Restoration Projects 27

Literature Cited 29

Appendix A Fish Collections by Fyke Net Site and Date 33

Appendix B Collections by Gender and Reproductive Condition 45

Appendix C Fish Species Catch per Fyke Net Hour Fished 49

Appendix D Water Quality by Date 53

Appendix E Rio Grande Silvery Minnow Collections by Water Velocity Category 61

Appendix F Hobo Plots/Data 65

Appendix G Bivariate Plots 69

Appendix H Bootstrap Analysis of Main Channel Seine Samples Adjacent to the Los Lunas Habitat Restoration Project Site 73

Appendix I Photographs 77

List of Figures

1. Los Lunas Habitat Restoration Project site at approximately River Mile 158.. 5
2. Developing Rio Grande silvery minnow embryo 7
3. Spring 2008 hydrograph as measured at the USGS Bosque Farms gauge. 8
4. Geometric mean CPUE values observed during the monitoring period. 11
5. Box plots of CPUE for fyke net sites sampled May 20 through June 6, 2008.. 12
6. Length frequency of reproductively mature Rio Grande silvery minnow collected at the Los Lunas Habitat Restoration Project site. 13
7. Rate of silvery minnow capture in floodplain habitats at the Los Lunas Habitat Restoration Project site as a lognormal function of increasing flow over a 24-hour period. 14
8. Rate of silvery minnow capture in floodplain habitats at the Los Lunas Habitat Restoration Project site as a polynomial function of declining flow over a 24-hour period. 15
9. Number of reproductively mature silvery minnow observed at floodplain sample sites of the Los Lunas Habitat Restoration Project site. 18
10. Number of unidentified fish larvae observed at floodplain sample sites of the Los Lunas Habitat Restoration Project site. 19
11. Levels of faunal similarity expressed as Jaccard's coefficient of similarity between pooled species ranks for the Isleta Reach and species ranks for more localized and habitat specific assemblages. 22
12. Relationship between the two indices of abundance calculated from fyke net sampling and seine net sampling during floodplain monitoring.......................................24

List of Tables

1. Rank Abundance of Fish Species of the Isleta Reach of the Middle Rio Grande 6
2. Weekly Average Water Velocities at Sample Sites of Floodplain Habitats of the Los Lunas Habitat Restoration Project. 8
3. Average Silvery Minnow Catch per Fyke Net Trap Hour in Floodplain Habitats of the Los Lunas Habitat Restoration Project Site. 15
4. Water Temperatures at Floodplain Sample Sites of the Los Lunas Habitat Restoration Project Site..16
5. Fish Species Collected from Floodplain Habitats at the Los Lunas Habitat Restoration Project Site and Adjacent Main Channel Habitats 20
6. Monthly Species Abundance Ranks for Main Channel Samples Adjacent to the Los Lunas Habitat Restoration Project Site 21
7. Species Rank Abundance in Floodplain Habitats of the Los Lunas Habitat Restoration Project Site by Sampling Method..23

Cover Photo

Photo of gravid 87mm SL Rio Grande silvery minnow (*Hybognathus amarus*) by Michael Hatch, SWCA.

INTRODUCTION

New Mexico is the third most arid state in the United States, receiving less than 50.8 cm of precipitation annually over 90 percent of its 195,685-km² (75,554-square-mile) area. Most (97%) of the water entering the state annually, either as precipitation or inflow, is lost through evaporation (Harris 1984). Perennial streams of the Rio Grande are concentrated in mountainous regions above about 1,675 m (5,495 feet) in elevation. Within the bounds of the Middle Rio Grande and below 1,675 m (5,495 feet) of elevation, arid and semiarid conditions prevail and no perennial tributary streams are present.

Humans have modified components of the hydrology of the Middle Rio Grande (MRG) for at least 400 years (Shurlock 1998) in attempts to overcome the limitations of drought and other problems that accompany variations in water supply. Modifications to reduce variation in water supply have been elaborate and extensive with profound consequences to the region's native ichthyofauna. Over the course of history, 13 native fish taxa, representing eight families (48 percent of the region's native fish fauna), have been extirpated from the Rio Grande of New Mexico or have become extinct (Sublette et al. 1990). Although extant in the MRG, the Rio Grande silvery minnow (silvery minnow; *Hybognathus amarus*) is listed as endangered by state and federal governments. The State of New Mexico first listed the silvery minnow on May 25, 1979, as an endangered endemic population of the Mississippi silvery minnow (*Hybognathus nuchalis*). On July 20, 1994, the U.S. Fish and Wildlife Service published a final rule to list the silvery minnow as a federal endangered species with proposed critical habitat (Federal Register 1994).

Traditional river engineering activities within the MRG have served to confine the river to its channel and isolate it from the adjacent floodplain for the purposes of preventing flooding and to remove water from catchments as soon as possible primarily to reduce depletions of water and drain water-saturated lands. Unaltered, the flow regime of the MRG would seasonally inundate floodplains of the river and provide heightened heterogeneity of habitat and structural refugia for developing stages of fish relative to the active channel. Many fish species native to low-gradient rivers of the Mississippi Basin are known to spawn on inundated floodplains, and the heightened productivity of these areas has been demonstrated to be important as nursery habitats (Copp 1989; Junk et al. 1989; Junk and Welcomme 1990; Robinson et al. 2002; Galat et al. 2004; Valett et al. 2005; Pease et al. 2006).

Following the recession of snowmelt floodwaters in 2005, surveys for fish in floodplain pools in the Isleta Reach of the MRG produced large (i.e., tens of thousands), nearly monotypic collections of young-of-year silvery minnow (U.S. Fish and Wildlife Service [USFWS] 2006). In some instances, these collections were made within approximately 65 to 75 km (40–47 miles) of the upstream limits of the species' contemporary range, implying that the eggs or larvae could not have drifted downstream farther than that distance. Clearly, silvery minnow egg and larvae retention in these floodplain habitats can be biologically significant, dramatically affecting the trajectory of local population growth.

Hatch et al. (2008) speculated that the 2005 floodplain collections of young-of-year silvery minnow was attributable to the species adaptively and preferentially spawning in low water exchange lateral habitats, including most importantly backwater and other hydrologic retentive floodplain habitats, resulting in reduced downstream displacement of eggs and larvae. The collection of large numbers of reproductively mature silvery minnow and their embryos in fyke nets set in low-water exchange floodplain habitats during May and June 2008 is evidence of this working hypothesis (Hatch and Gonzales in prep).

The Los Lunas Habitat Restoration Project is designed in part to recouple a portion of the Middle Rio Grande[1] with its floodplain to enhance silvery minnow reproduction and recruitment. This study documents the occupancy of this seasonably inundated floodplain by reproductively mature silvery minnow. Results of synoptic fish surveys of river and floodplain habitats and environmental characteristics of these habitats are examined to elucidate how faunal assemblages at this site are structured by underlying physical, chemical, and hydrologic features of the environment. This information is also used to support inferences about silvery minnow reproductive biology and processes such as dispersal and habitat selection. Knowledge of how silvery minnow and other fish species use inundated floodplain habitats and other habitats lateral to the active river channel is essential to guide habitat restoration efforts.

[1] For reference in this document, the "Middle Rio Grande" is defined as the Rio Grande downstream from Cochiti Dam to the headwaters of Elephant Butte Reservoir. The MRG below Cochiti Dam is further designated by four reaches defined by locations of mainstream irrigation diversion dams. The Cochiti Reach extends from Cochiti Dam to Angostura Diversion Dam. The reach from Angostura Diversion Dam to Isleta Diversion Dam is called the Albuquerque Reach. The Isleta Reach is bounded upstream by Isleta Diversion Dam and downstream by San Acacia Diversion Dam. The reach downstream of San Acacia Diversion Dam to the headwaters of Elephant Butte Reservoir is the San Acacia Reach.

PROJECT BACKGROUND

The June 2001 Biological Opinion (2001 BO) issued by the USFWS (2001) mandates the restoration of habitat in eight subreaches of the MRG in accordance with Reasonable and Prudent Alternative Element J. The Los Lunas Habitat Restoration Project is intended in part to fulfill the restoration requirement in one of these subreaches. The Los Lunas Habitat Restoration Project site is located approximately 5.0 km (3.1 miles) south of Los Lunas along the west bank of the Rio Grande.

The U.S. Bureau of Reclamation, Albuquerque Area Office (Reclamation) and the U.S. Army Corps of Engineers, Albuquerque District (Corps) have acted as joint lead federal agencies on this project, and the Middle Rio Grande Conservancy District (MRGCD) is the primary non-federal cooperator. Section J of the 2001 BO requires that each restoration site be monitored for 15 years following project completion in order to assess whether native riparian habitats are self-sustaining and successfully regenerating, and whether the habitats are suitable for the listed species.

In 2003, the USFWS released biological and conference opinions on the effects of actions associated with the *Programmatic Biological Assessment of Bureau of Reclamation's Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operation, and Related Non-Federal Actions on the Middle Rio Grande, New Mexico* (2003 BO; USFWS 2003). This biological opinion requires habitat restoration projects that would improve survival of all life stages of the silvery minnow and other endangered species. The 2003 BO identified the need for increased availability of low velocity habitat and silt and sand substrates to provide food, shelter, and sites for reproduction for silvery minnow and thereby alleviate jeopardy to the continued existence of the species in the MRG.

Coincidentally, a wildfire in April 2000 consumed much of the vegetation over the areal extent of the Los Lunas Habitat Restoration Project site (Figure 1). Restoration of the area began in April 2002 with the removal 1,400 Kellner jetty jacks. Following jetty jack removal, the elevation of approximately 40 acres (16.19 hectares) of floodplain on the west bank of the channel was mechanically lowered and reseeded or planted with potted shrubs, cottonwood, and willow poles (Siegle 2006).

The Los Lunas Habitat Restoration Project site and the river adjacent to the restoration site are only intermittently inundated. Flow diminished sufficiently during the latter part of the 2007 irrigation season to dry a segment of the river in the Isleta Reach that included the study site. Flow was generally discontinuous over a 14-km (9-mile) segment of river upstream of Peralta Wasteway to Los Lunas beginning August 12, 2007 and continuing through the remainder of the irrigation season. Following the irrigation season, with reduced consumptive use of water and reduced seasonal effects from evaporation and transpiration, flow in the river increased sufficiently to become a through-flowing system. Monthly surveys for fish in the main channel, beginning in November 2007, chronicle the reoccupation of this empty habitat patch by fish from outlying areas. Flows greater than 2,500 cubic feet per second (cfs), which typically occur during May and June, are sufficient to inundate floodplain habitats over the areal extent of the Los Lunas Habitat Restoration Project site. Varied topography, including secondary channels, inlets, and backwater design features allows for partial inundation of these habitat features at lower flows.

Percent cover of all vegetation in the habitat restoration area ranged from 32.1% (17.8% native) in 2003 to 67.5% (40.3% native) in 2004 to 60.9% (44.6% native) in 2005 (Siegle 2006). The most common forb species shifted from sunflowers (native, *Helianthus annuus*), lambsquarters (introduced, *Chenopodium album*), and white clover (introduced, *Melilotus* albus) in 2003 to devil's beggarstick (native, *Bidens frondosa*), kochia (introduced, *Kochia scoparia*), and common cocklebur (native, *Xanthium strumarium*) in 2005 (Siegle 2006). Survival of mixed shrub plantings was 65 percent. No wolfberry (*Lycium torreyii*) or cottonwood *(Populus deltoides*) survived; New Mexico olive (*Forestiera neomexicana*) had the highest survival rate, at 92.6% (Siegle 2006).

Reclamation monitored the fish community at the Los Lunas Habitat Restoration Project site from 2004 to 2006. Silvery minnow were absent from samples obtained by seining and electrofishing in 2004 (Porter et al. 2004). In 2005, the species comprised 95% of the fish community in seine samples and 58% of the sample obtained by electrofishing (Porter and Dean 2005). In 2006, silvery minnows constituted 5% of fish captured in fyke nets (Beck and Fluder 2006) and 37% of fish captured via electrofishing (Porter and Dean 2006).

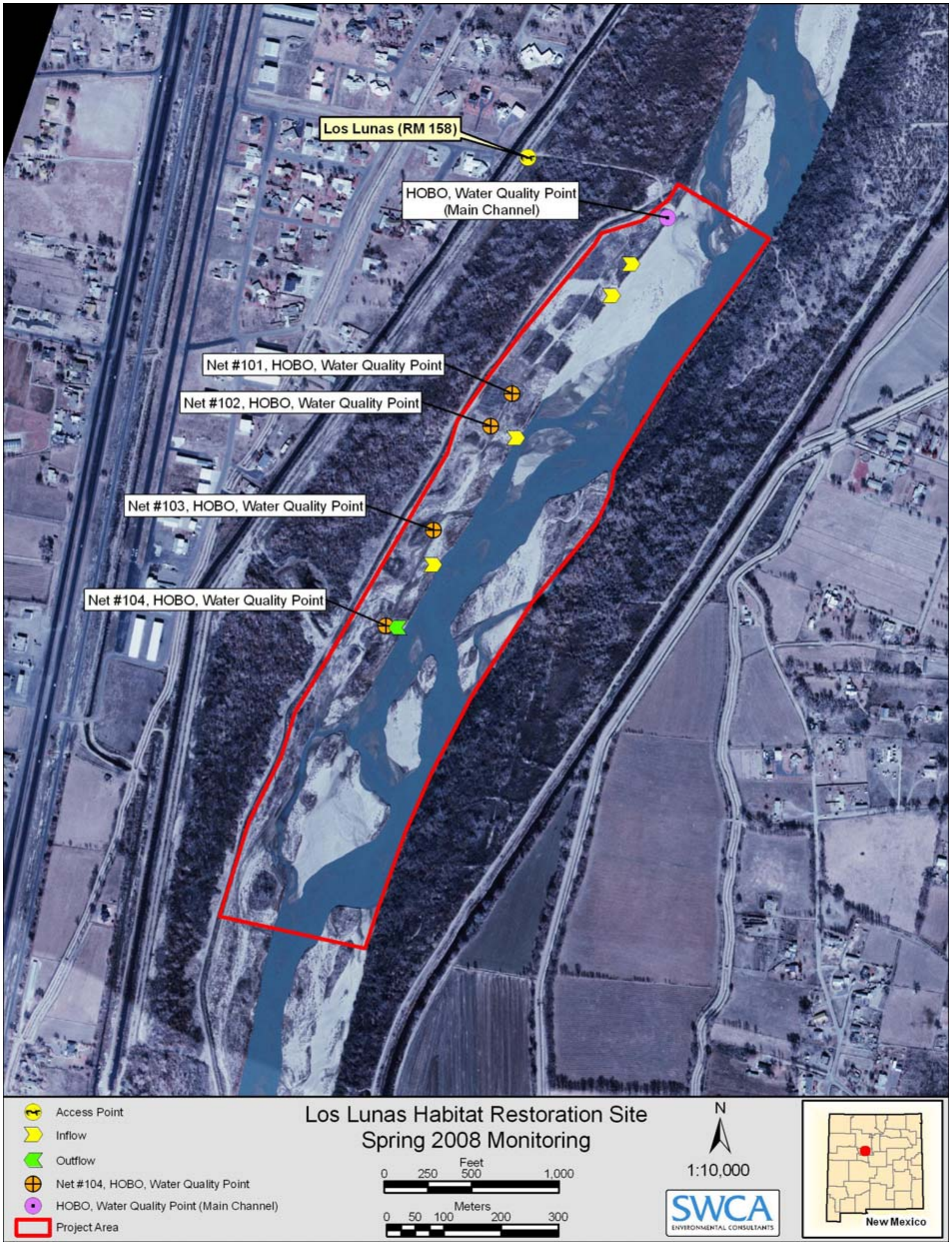


Figure 1. Los Lunas Habitat Restoration Project site at approximately River Mile 158. Aerial photo taken January 2006 by U. S. Army Corps of Engineers.

Pooled samples from recent fish surveys, aggregated over multiple sampling methods, suggest that the contemporary ichthyofauna of the Isleta Reach of the MRG consists of 21 species, representing eight families. Table 1 presents the rank abundance of species from these pooled samples.

Table 1. Rank Abundance of Fish Species of the Isleta Reach of the Middle Rio Grande

Family	Species	Common Name	Rank
Catostomidae	*Carpiodes carpio (n)*	river carpsucker	5
	Catostomus commersonii (e)	white sucker	9
Centrarchidae	*Lepomis cyanellus (e)*	green sunfish	17
	Lepomis macrochirus (n)	bluegill	16
	Micropterus salmoides (n)	largemouth bass	15
	Pomoxis annularis (e)	white crappie	11
	Pomoxis nigromaculatus (e)	black crappie	21
Clupeidae	*Dorosoma cepedianum (n)*	gizzard shad	13
Cyprinidae	*Cyprinella lutrensis (n)*	red shiner	1
	Cyprinus carpio (e)	common carp	6
	Hybognathus amarus (n)	Rio Grande silvery minnow	3
	Pimephales promelas (n)	fathead minnow	4
	Platygobio gracilis (n)	flathead chub	8
	Rhinichthys cataractae (n)	longnose dace	10
Ictaluridae	*Ameiurus melas (e)*	black bullhead	18
	Ameiurus natalis (e)	yellow bullhead	12
	Ictalurus punctatus (e)	channel catfish	7
Percichthyidae	*Morone chrysops (e)*	white bass	14
Percidae	*Perca flavescens (e)*	yellow perch	19
	Sander vitreum (e)	walleye	20
Poeciliidae	*Gambusia affinis (e)*	western mosquitofish	2

Note: Data represents pooled results from recent surveys comprised variously of data sets provided by personnel of the Division of Fishes, Museum of Southwestern Biology, University of New Mexico, and the American Southwest Ichthyological Research Foundation, Hatch et al. (2008), and Hatch and Gonzales (in prep). Native (*n*) and nonnative (*e*) determinations follow Sublette et al. (1990). The most abundant species was assigned a rank of 1 and increased with decreasing abundance.

METHODS

FISH AND ENVIRONMENTAL QUALITY SURVEYS

Sampling for fish was conducted in the main channel on one day each month from November 2007 to February 2008. Fish were collected with a 3.7 × 1.2–m seine (0.476-cm delta mesh). Seine hauls were conducted in all accessible mesohabitat types in the channel. Increased water depth and discharge on February 20, 2008, precluded sampling some of the deeper runs of the main channel that were otherwise accessible during all other sampling trials. Sampling effort was recorded in terms of the number of seine hauls and the approximate area seined (100 m^2).

Fish were collected at floodplain sites with a 3.7 × 1.2–m seine (0.476-cm delta mesh) and rectangular fyke nets (0.5 × 0.5 m, 6.44 mm mesh size). Sampling effort was recorded in terms of the number of seine hauls (standardized to ten seine hauls, representing areas ranging from 135 m^2 to 420 m^2) and the approximate area seined (100 m^2) or the time that a fyke net was fishing. Silvery minnow eggs and post larval fish were sampled with a kick net of standard size with multiple grab samples over transects of approximately 100 meters in length. Silvery minnow eggs were positively identified by a suite of characters, including egg diameter (2.9 – 3.7 mm; mean 3.2 mm) high transparency and the lack of obvious (yellow) yolk (Figure 2). A Trimble GeoXT handheld global positioning system (GPS) unit with sub-meter accuracy was used to record spatial characteristics of fyke net sampling locations.

Figure 2. Developing Rio Grande silvery minnow embryo
(photo by Michael Hatch).

Four floodplain sites at the Los Lunas Habitat Restoration Project site were sampled for sixteen out of eighteen days from May 20 to June 6, 2008. Two of the sample sites (101 and 102) were distinguished as low velocity sites at flows less than approximately 4,300 cfs, as measured at the U.S. Geological Survey (USGS) Bosque Farms gauge (Table 2). The other two sample sites (103 and 104) were characterized as high velocity sites. Over the period of floodplain sampling, flow in the main channel varied radically, ranging from a low of 2,110 cfs on May 21 to a high of 5,230 cfs on May 25 as measured at the Bosque Farms USGS gauge (Figure 3).

Table 2. Weekly Average Water Velocities (m/s) at Sample Sites of Floodplain Habitats of the Los Lunas Habitat Restoration Project.

	Floodplain Sample Sites			
	Low Velocity Sites		High Velocity Sites	
Week	**101**	**102**	**103**	**104**
21 (May 20–May 24)	0.03	0.01	0.26	0.12
22 (May 25–May 30)	0.15	0.07	0.22	0.24
23 (June 1–June 6)	0.08	0.08	0.37	0.10
Overall Averages	0.09	0.05	0.28	0.15

To assess the adequacy of high and low velocity site designations, a Wilcoxon two-sample test was used to determine if differences in velocity between combined high and low velocity sites exist (Zar 1999). Velocity varied significantly between high and low velocity sites (Wilcoxon rank sum test, $W_{0.05(2),32,32}$ = 173, two-sided p = <0.001), which indicates that high and low velocity site designations are appropriate.

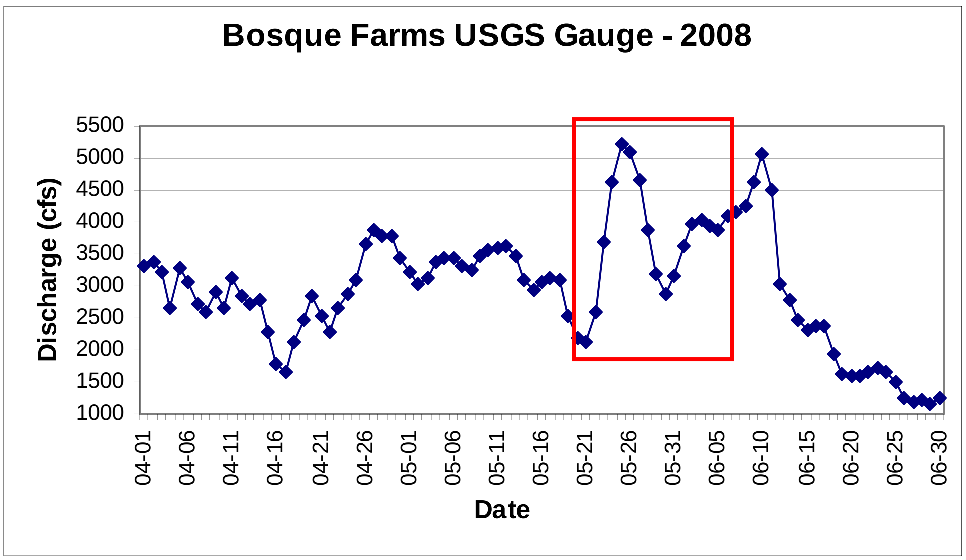


Figure 3. Spring 2008 hydrograph as measured at the USGS Bosque Farms gauge. The period of floodplain sampling for fish is indicated by the red rectangle. Flows greater than 2,500 cfs are sufficient to inundate the entire Los Lunas Habitat Restoration Project site. Varied topography, including secondary channels, inlets, and backwater design features, allows for partial inundation of these habitat features at lower flows.

All post larval fish collected were identified to species in the field utilizing taxonomic keys provided in Sublette et al. (1990); phylogenetic classification followed Nelson et al. (2004).

Species counts were maintained for all collections. Standard length[2] (mm) and reproductive condition (e.g., gravid female or reproductively mature male) were recorded for silvery minnow specimens when such could be accomplished without stressing the fish. Silvery minnow mortality was quantified and preserved for eventual museum accession. All live fish were released back to the site of capture.

Water quality parameters were monitored concurrent with fish sampling events for main channel and floodplain samples. Water quality parameters were measured using a YSI 556 multiparameter handheld meter, including temperature (degrees Celsius [°C]), dissolved oxygen (parts per million [ppm]), conductivity (microsiemens per centimeter [µS/cm]), salinity (ppt), and hydrogen ion concentration (pH). Water depth (m) and flow velocity (meters per second [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 at each floodplain fish sample location and at one main channel location (Figure 1).

A digital camera was employed for all photo documentation. A relational database (Microsoft Access) and a spreadsheet database (Microsoft Excel) were developed for the storage, analysis, and retrieval of fish survey data.

DATA ANALYSIS

Fish assemblage composition is expressed in terms of species relative abundance and percent composition. Presence/absence data were used to compute pair-wise similarity coefficients between pooled samples from the floodplain of the Los Lunas Habitat Restoration Project site, pooled samples from the adjacent segment of the main channel, and pooled samples from the pool of extant fish species in the Isleta Reach. Jaccard's coefficient of similarity is the fraction of species at two sites that are common to both (Sneath and Sokal 1973; Bridge 1993).

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). Standardization of fyke net captures is expressed as fish per hour and is the index used to assess variation in species abundance between sites throughout the study period. Catch per unit effort was calculated for seine samples by dividing the total number of fish captured by the total area sampled (expressed as fish per 100 m^2).

Statistical analysis was conducted to assess if CPUE varied between fyke net sample sites and dates. A single factor analysis of variance (ANOVA) was used to test for differences between fyke net sample sites (Zar 1999), while a repeated measures ANOVA was used to test for differences between sampling dates (Zar 1999; Hubert and Fabrizio 2007). CPUE data was normalized by natural log transformation prior to analysis (Hubert and Fabrizio 2007). Assumptions of normality (examination of cumulative frequency plots) and heteroscedasticity (examination of residuals and Bartlett's test) were tested for all analyses (Zar 1999).

---

[2] Standard length is defined as the distance from the anteriormost projection of the head to the hypural notch; the hypural notch is the point between the end of the body vertebrae and the beginning of the caudal fin, generally denoted as the crease in the caudal peduncle made by bending the caudal fin to one side or the other.

Comparisons between capture efficiency of the dichotomous sampling methods were made by plotting CPUE data by date and by using linear regression to assess the relative agreement of the two indices of abundance. Lastly, a fishing power coefficient was calculated by dividing the daily mean fyke net CPUE by the daily seine net CPUE (the standard sampling method used in this area) (Quinn and Deriso 1999). The fishing power coefficient allows for standardization of effort and direct comparison of CPUE values collected with different gear types (Quinn and Deriso 1999). The fishing power coefficient is being used in this study to assess the relative magnitude in difference between the two indices.

Records of contemporary fish collections, including collections from the Los Lunas Habitat Restoration Project site, are used from the Isleta Reach to assess how the regional species pool responds to hydrologic variability to produce local fish assemblages. Levels of faunal similarity are expressed as Jaccard's coefficient of similarity between pooled species assemblages for the Isleta Reach and for more localized and habitat specific assemblages that vary temporally by site. A reach and site-specific rank of species relative abundance facilitates this analysis. Rank abundance avoids many problems associated with heterogeneity in sampling methods, effort, and scale differences in size of habitats sampled (Schluter and Rickleffs 1993). It also reduces bias in over-representation of abundant species and under-representation of rare species (Cowley et al. 2007). Each species is assigned a rank abundance value based on its relative abundance. The most abundant species was assigned a value of "1." Tied scores were assigned the mean of the ranks that would be available to them. Comparisons among similarity coefficients provides insight into the relative dependence of the fish assemblage composition of the floodplain at the Los Lunas Habitat Restoration Project site on the recently colonized adjacent segment of river and more distal outlying areas.

Nonparametric bootstrap analysis was employed as an objective evaluator of sampling bias and precision[3] in estimating species richness from seine samples in main channel habitats. The nonparametric bootstrap requires fewer assumptions about the population compared to a parametric bootstrap, as it assumes only that the observed sample is representative of the population, which is generally a reasonable assumption except in instances involving very small samples (Davison and Hinkley 1997). The approach to bootstrap analysis involved standardizing the sample to 1,000 total fish, taking random samples of data (with replacement), calculating species richness, repeating the process 1,000 times for a reasonable array of prospective sample sizes (e.g., 20, 50, 75, 100, 125, 150, 175, and 200 seine hauls), and then estimating the mean and standard deviation of species richness for the replicate bootstrap estimates.

We used Jaccard's index as an objective index of similarity among estimates of species richness derived from different sampling methods. The Jaccard's index was also used to assess similarity between various fish species assemblages. It is important to recognize the biases inherent in the alternative measures of system state to discriminate properly among plausible hypotheses regarding system behavior.

[3] Bias and precision are separate components of accuracy (Zar 1999). *Bias* refers to the difference between the population value and the average of the sampling distribution. *Precision* depends on the variability in the sampling distribution.

RESULTS

SILVERY MINNOW FLOODPLAIN OCCUPANCY

A total of 12,531 silvery minnows were captured during monitoring, of which 12,378 were captured with fyke nets, while 153 were captured using seine nets. Silvery minnow CPUE varied throughout the monitoring period and between fyke net sites (Figure 4). Significant differences in CPUE were not found between dates despite the observed temporal variability in CPUE (repeated measures ANOVA, $F_{15, 45} = 1.381$, P = 0.198). However, significant differences in CPUE were found between sites (one-way ANOVA, $F_{3,60}$ P<0.001). CPUE values were highest and more variable at the low water exchange sites (sites 101 and 102; Figure 5).

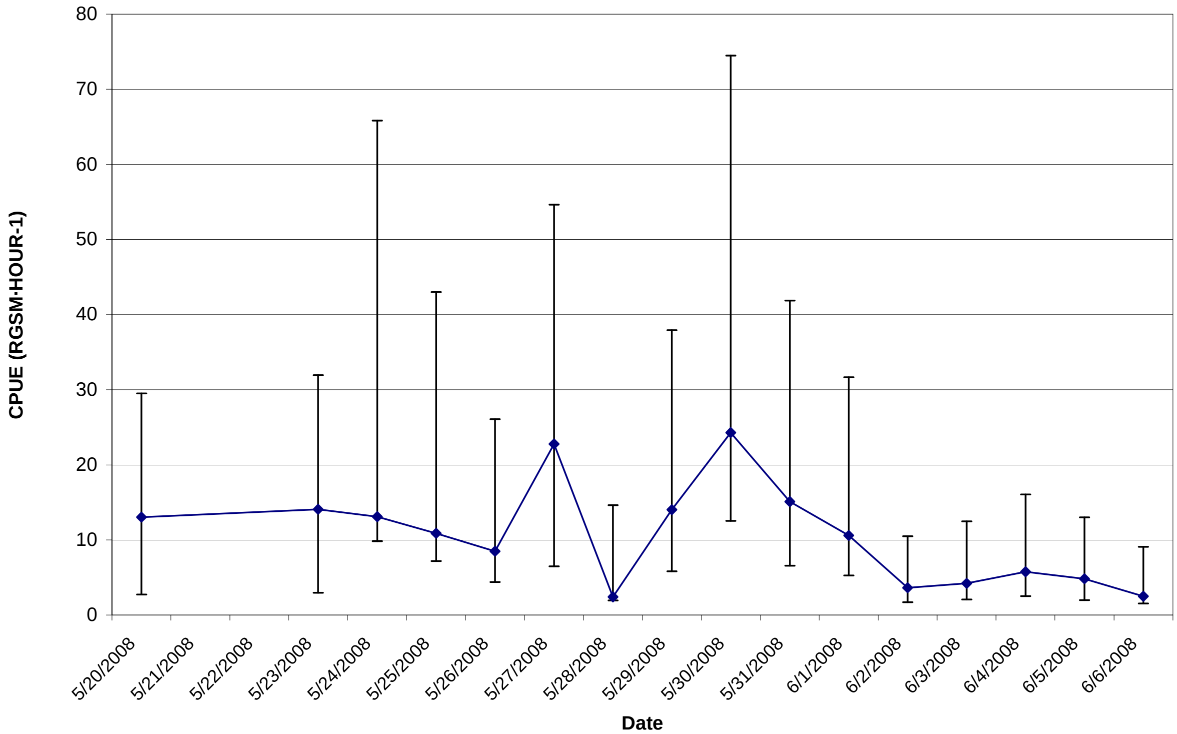


Figure 4. Geometric mean CPUE values (silvery minnow per hour) observed during the monitoring period. Error bars represent one standard error.

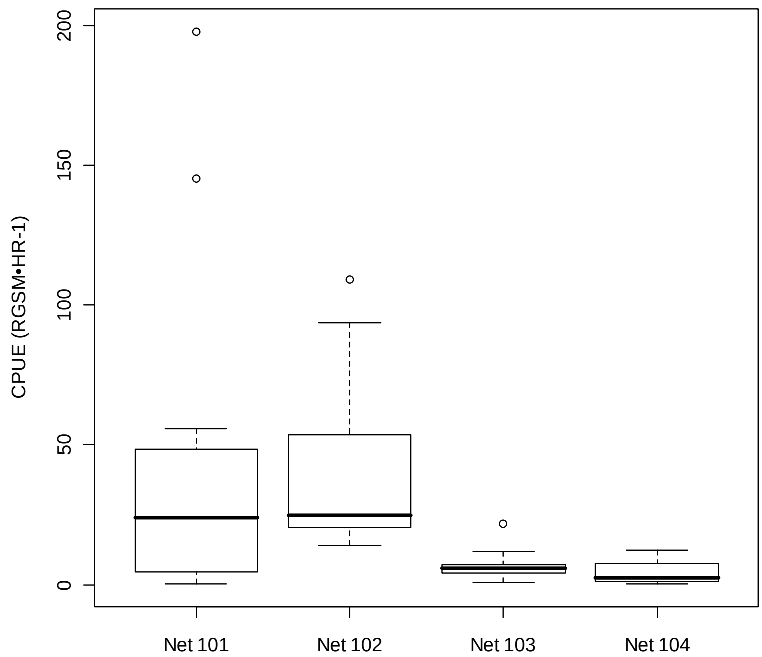


Figure 5. Box plots of CPUE (silvery minnow per hour) for fyke net sites sampled May 20 through June 6, 2008. Sites 101 and 102 represent low velocity sites; sites 103 and 104 represent high velocity sites.

SILVERY MINNOW DEMOGRAPHIC CHARACTERISTICS

Standard length was obtained for 1,614 silvery minnows of known gender and 854 silvery minnows of unknown gender at the Los Lunas Habitat Restoration Project site (Figure 6). Standard length (SL) of reproductively mature males ranged from 38 to 68 mm. Standard length of sexually mature females ranged from 41 to 85 mm.

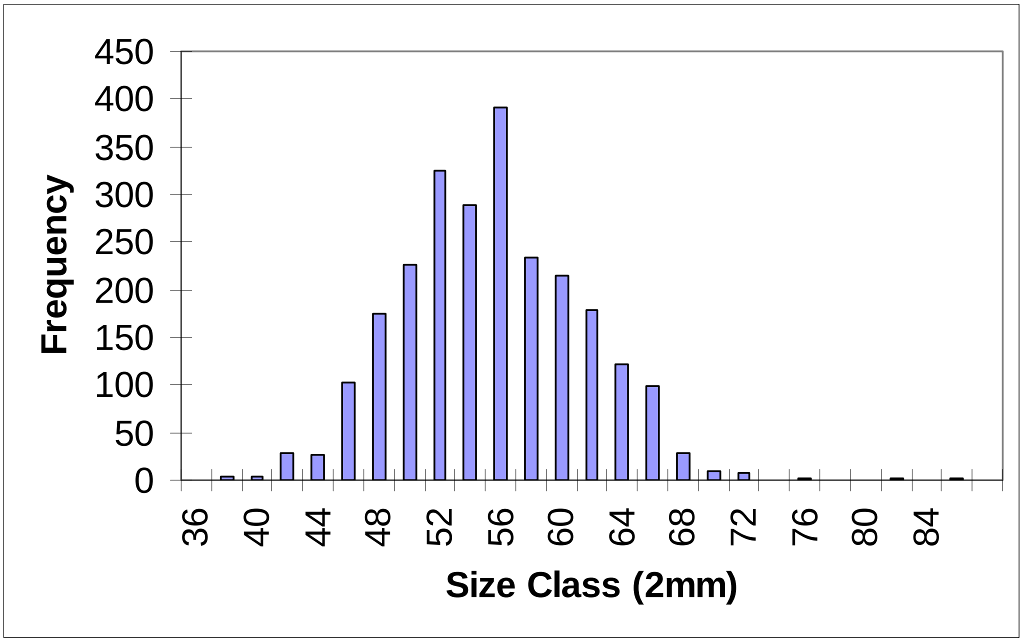


Figure 6. Length frequency of reproductively mature Rio Grande silvery minnow (males and females) collected at the Los Lunas Habitat Restoration Project site (n = 2,468).

Reproductively mature silvery minnow were documented to occupy the floodplain at the Los Lunas Habitat Restoration Project site over the duration of sampling (May 20 to June 6, 2008). The floodplain at the Los Lunas Habitat Restoration Project site had been inundated before this study was initiated so we cannot determine when silvery minnow began to occupy the site. Given that the initiation of sampling approximately coincided with the onset of silvery minnow spawning (Hatch and Gonzales, in prep), it is clear that the range of observed fish lengths represent Age I and older fish. Based on a size-at-age relationship reported for the species by Cowley et al. (2006) as a rough guide for a size-based interpretation of silvery minnow age, it is speculated that multiple age classes older than Age 0 were represented in the samples. However, length alone is an imperfect index of silvery minnow age because the species' extended spawning season does not provide for a clear demarcation of age by size without validation of age founded on known-age individuals or from evidence of annual growth that is often discernable on scales and otoliths. Furthermore, sexual size dimorphism further complicates size-based interpretation of silvery minnow age.

Reproductively mature males and females were most commonly found at sites where low velocity flows predominate — primarily sample sites 101 and 102 (Appendix B). This pattern of distribution became obscured only when flows were rapidly rising or falling. A heightened level of floodplain occupation by reproductively mature males and females was noticeable with a rapid rise in discharge over the period of May 21 to May 23, 2008. Spent females, i.e., females that had obviously spawned, were not observed until week 22 (May 25–May 31).

SILVERY MINNOW HABITAT SELECTION

Water Discharge / Velocity

A heightened level of floodplain occupancy by reproductively mature male and female silvery minnow was observed with a rapid rise in flow over the period of May 21 to May 23, 2008. Mean silvery minnow CPUE was positively correlated to mean 24-hour increase in main channel flow (Figure 7 and Figure 8). A linear model fit the data relatively well for the 24-hour increases in discharge and natural log CPUE (R^2 = 0.85), while a polynomial fit best described the relationship between 24-hour decreases in discharge and CPUE (R^2 = 0.54).

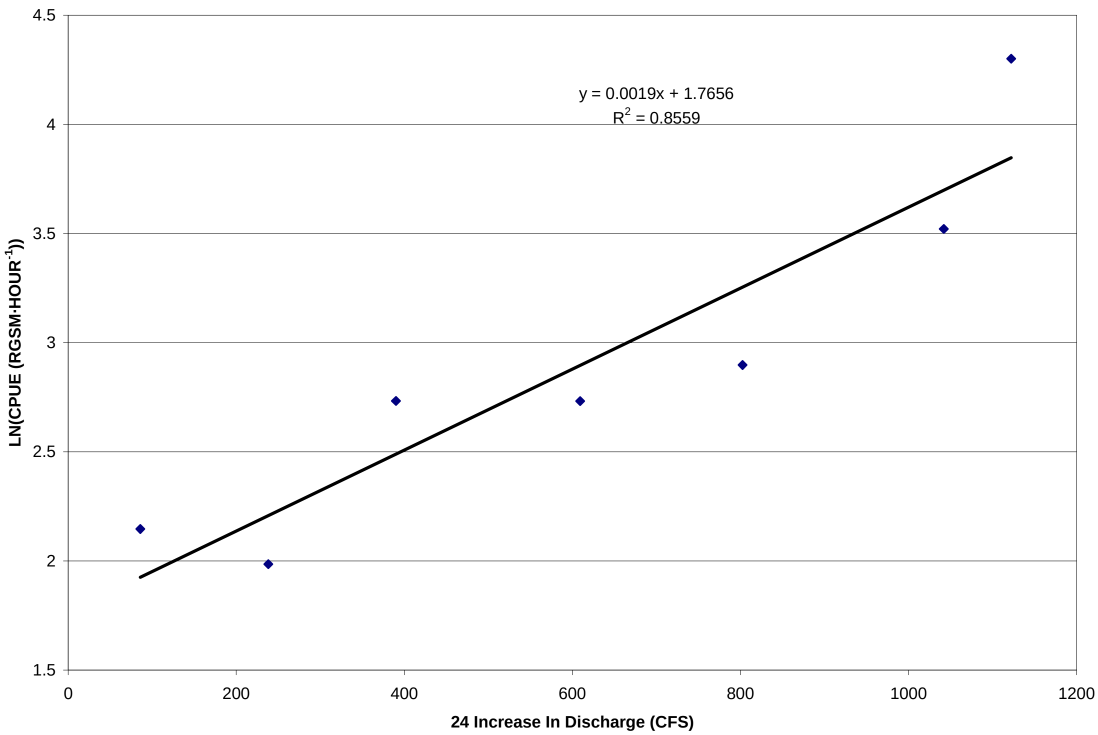


Figure 7. Rate of silvery minnow capture in floodplain habitats at the Los Lunas Habitat Restoration Project site as a lognormal function of increasing flow over a 24-hour period.

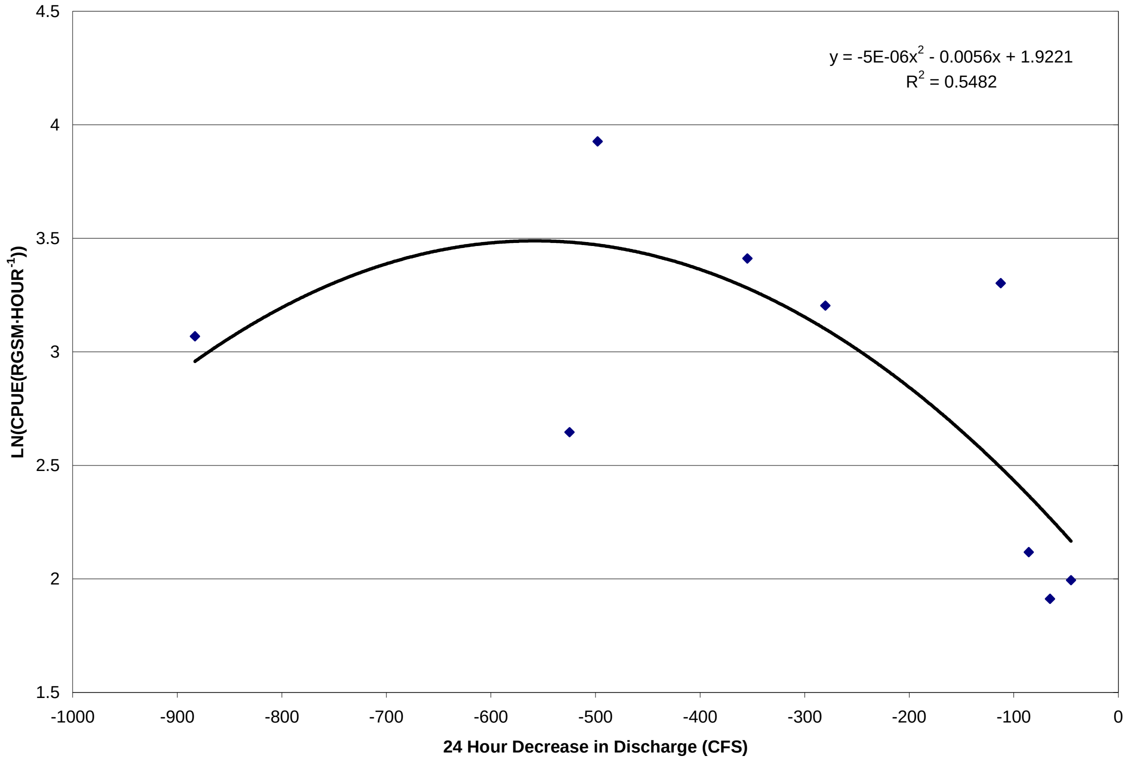


Figure 8. Rate of silvery minnow capture in floodplain habitats at the Los Lunas Habitat Restoration Project site as a polynomial function of declining flow over a 24-hour period.

Rate of silvery minnow capture was generally highest at all sample sites during week 21 (May 20–May 24). During this time, flow in the river was generally less than 4,300 cfs and low velocity conditions prevailed at sample sites 101 and 102 where the rate of silvery minnow capture was highest. Rate of silvery minnow capture generally declined progressively over sample weeks 22 and 23 at most sample sites (Table 3).

Table 3. Average Silvery Minnow Catch per Fyke Net Trap Hour in Floodplain Habitats of the Los Lunas Habitat Restoration Project Site (standard error given parenthetically).

	Low Velocity Sites		High Velocity Sites	
Week	**101**	**102**	**103**	**104**
21 (May 20–May 24)	78.93 (29.81)	44.59 (12.34)	6.32 (0.94)	7.85 (1.82)
22 (May 25–May 30)	43.25 (9.16)	40.44 (4.87)	8.15 (1.28)	5.55 (0.73)
23 (June 1–June 6)	9.50 (2.83)	21.60 (1.08)	4.92 (0.32)	1.59 (0.12)

Note: Data are aggregated by calendar week.

Water Temperature

Average weekly water temperatures were consistently higher at floodplain sites compared to average weekly water temperatures in the main channel (Table 4). Sample sites 101 and 102, both low velocity sample sites at flows less than approximately 4,300 cfs, exhibited the highest deviation in mean weekly water temperature from main channel water temperatures during week 21 (+ 2.16°C and + 1.39°C, respectively). Coincidentally, rate of silvery minnow capture was highest during this week and at these sample sites (Table 3). During week 21 when flow was generally less than 4,300 cfs, maximum water temperatures at low velocity floodplain sample sites deviated from main channel maximum water temperatures by 8.26°C to 9.78 C.

Rate of silvery minnow capture generally declined progressively over sample weeks 22 and 23 at most sample sites. The onset of this decline in catch rates coincided with higher discharges (flow in excess of 4,300 cfs) over the period from May 24 through May 27, 2008. The decline in catch rates (Table 3) also coincided with average and maximum floodplain temperatures approaching main channel water temperatures (Table 4). The single exception to this generalization is the low and relatively consistent rate of silvery minnow capture over time at sample site 103 (a high velocity site).

Table 4. Water Temperatures (°C) at Floodplain Sample Sites of the Los Lunas Habitat Restoration Project Site.

Note: Data are aggregated by calendar week.

Week		Floodplain Collection Sites				Main Channel
		Low Velocity		High Velocity		
		101	102	103	104	
21 (May 20–May 24)	Avg.	19.53	18.76	18.12	18.03	17.37
	St. Dev.	4.19	4.2	3.45	2.74	2.07
	Min.	13.31	13.28	14.05	14.23	14.36
	Max.	30.32	31.84	28.72	23.68	22.06
22 (May 25–May 31)	Avg.	19.24	18.89	18.69	19.56	18.25
	St. Dev.	2.57	2.1	1.78	2.66	1.55
	Min.	15.13	15.13	15.46	15.38	15.46
	Max.	26.38	23.28	22.61	25.9	21.63
23 (June 1–June 6)	Avg.	19.96	19.77	19.48	19.59	19.07
	St. Dev.	2.72	2.38	1.57	1.61	1.57
	Min.	15.96	15.96	16.44	16.52	16.15
	Max.	26.55	24.53	22.73	23	22.23
All Weeks	Avg.	19.54	19.11	18.75	19.16	18.23
	St. Dev.	3.18	2.97	2.41	2.48	1.84
	Min.	13.31	13.28	14.05	14.23	14.36
	Max.	30.32	31.84	28.72	25.9	22.23

Water Chemistry

Water quality data for main channel and floodplain monitoring sites are tabulated in Appendix D. Bivariate plots of water quality parameters collected from main channel and floodplain sites appear in Appendix G. Values for all parameters measured were within normal limits for low elevation potamon[4] systems. The values of several parameters varied positively with water velocity and are therefore autocorrelated with silvery minnow catch rates. However, such relationships are considered spurious and should not be interpreted to indicate necessary or sufficient causation for silvery minnow spawning or for floodplain occupation by the species.

The values of several water quality parameters are known to vary over diel cycles, notably dissolved oxygen and alkalinity. The observed temporal shifts in dissolved oxygen and alkalinity are logically associated with the effects of photosynthesis. Although a fine-scale temporal record of these variables is not available, they likely exhibit diel cycles, with extreme values most likely in low velocity recesses of the floodplain. Mortality-causing conditions of low dissolved oxygen are possible in floodplain habitats of the MRG under conditions of high water temperatures and extended periods of low light (e.g., a series of cloudy days and shade from dense canopy of riparian vegetation).

Silvery Minnow Reproductive Condition and the Appearance of Early Life Stage Fish

Over the period of monitoring, 3,344 reproductively mature silvery minnow were observed in floodplain habitats of the Los Lunas Habitat Restoration Project site (Figure 9). The highest number of gravid females and males issuing milt were observed during the first seven days of monitoring. Spent females were not observed over the first three days of monitoring. The number of gravid females and males issuing milt decreased slightly, while the number of spent females increased slightly after the seventh day of the monitoring period.

[4] *Potamon* refers to the warmer and lower gradient river of the lowlands. Unaltered, the potomon is characterized by slower currents, finer substrate materials, and variety of size, depth and flow of the river channel, including large river channels, oxbows, sloughs, and habitats of the floodplain. Autochthonous inputs of organic materials support a preponderance of detritivores, herbivores, and planktivores.

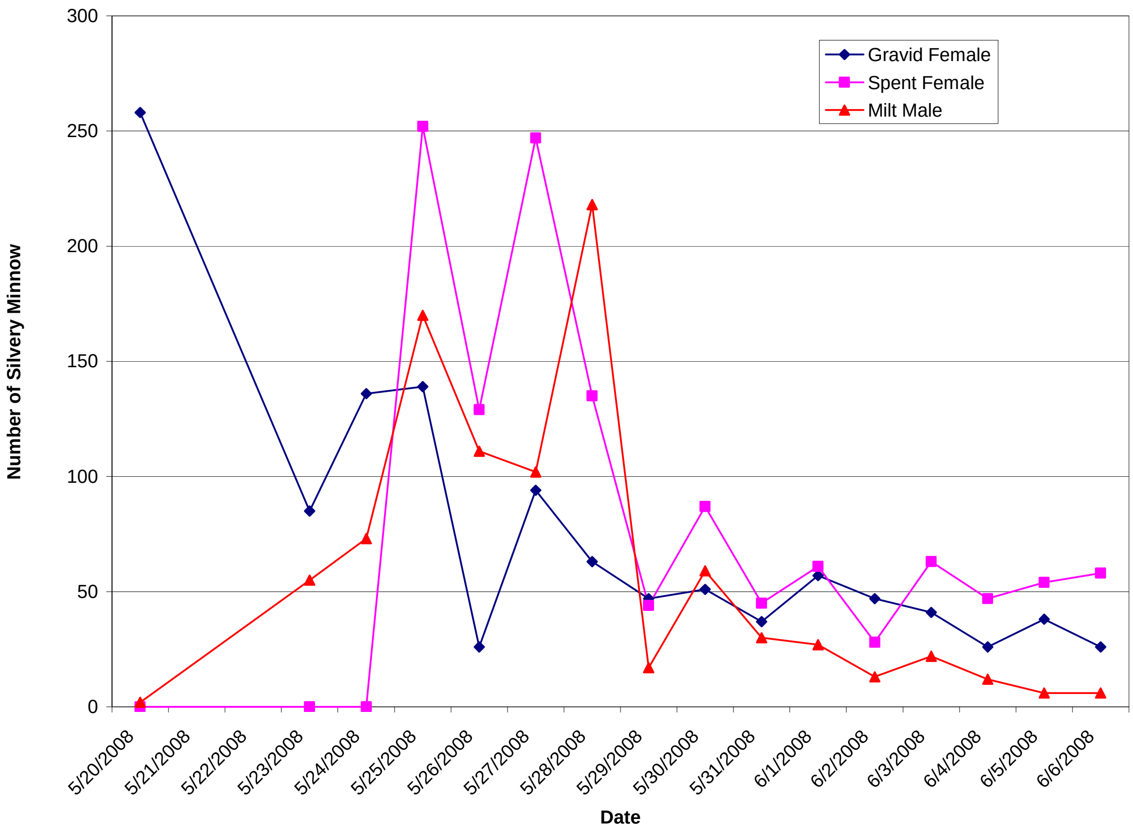


Figure 9. Number of reproductively mature silvery minnow observed at floodplain sample sites of the Los Lunas Habitat Restoration Project site.

Over the period of monitoring, 1,621 unidentified larval and early post larval fish were observed in floodplain habitats of the Los Lunas Habitat Restoration Project site (Figure 10). Fish larvae were first observed on May 25, 2008, coincidental with the first silvery minnow egg observed on the floodplain. Larval and early post larval fish were observed on all subsequent days of sampling. The number of fish larvae observed increased dramatically on June 2 and 3, 2008. The observed number of fish larvae declined sharply over the period June 4 through June 6, 2008 (Figure 10).

Very few silvery minnow eggs were collected in kick net samples of floodplain habitats perhaps due to the properties of the species' semi-buoyant egg in such habitats. *Semi-buoyant* implies that the eggs are subject to displacement in running water habitats; such eggs may settle to the substrate in low velocity habitats. It is possible that the sampling method was poorly suited to the sampling situation.

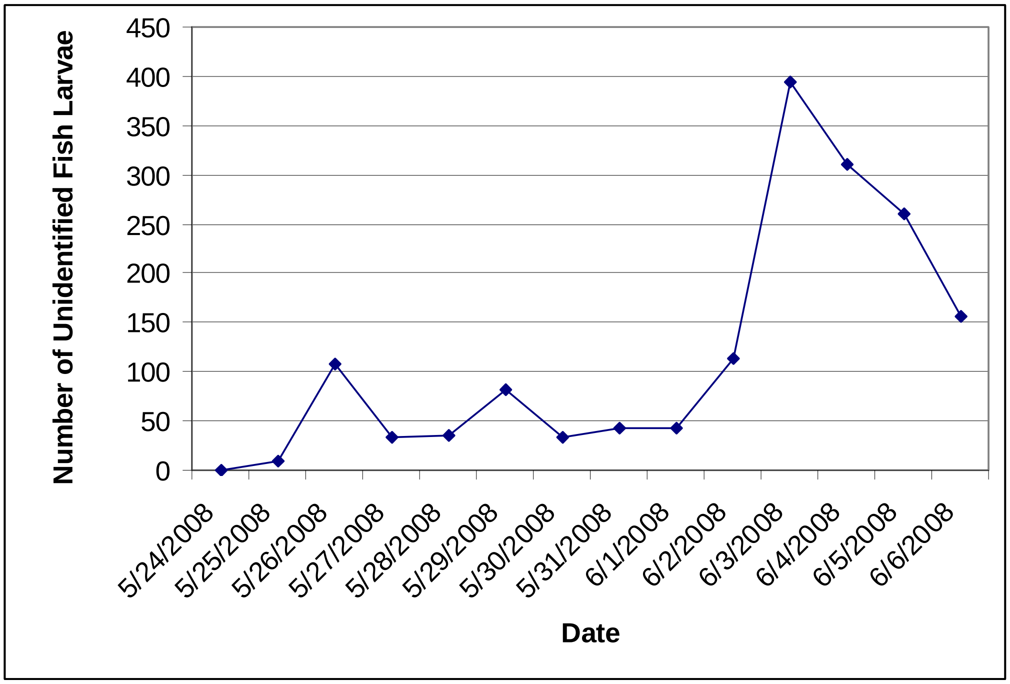


Figure 10. Number of unidentified fish larvae observed at floodplain sample sites of the Los Lunas Habitat Restoration Project site.

COMMUNITY COMPOSITION

SPECIES RICHNESS / RELATIVE ABUNDANCE

Patterns of fish community composition indicate that floodplain habitats of the Los Lunas Habitat Restoration Project site support a greater diversity of species and a greater number of reproductive guilds than the adjacent portion of the main channel of the MRG (Table 5). Patterns of community composition indicate that fauna-environment interactions of the floodplain favor colonizing species[5] including silvery minnow, common carp, and red shiner. Together these three species numerically comprise nearly 97.0 percent of the floodplain fauna. Pelagophils (represented solely by silvery minnow) was the most abundant reproductive guild. Non-guarding phytophils and nest-guarding phytophils are also numerically significant components of the floodplain fauna (Table 5).

[5] Colonist species are distinguished as fast growing opportunists. There is no parental care of eggs and other early development life stages. Species quickly take advantage of intervals of more favorable growth and are generally tolerant of high-frequency disturbance.

Table 5. Fish Species Collected from Floodplain Habitats at the Los Lunas Habitat Restoration Project Site and Adjacent Main Channel Habitats

	Floodplain Collections			River Collections		
Species (reproductive guild)	**Number Collected**	**Percent Abundance**	**Rank Abundance**	**Number Collected**	**Percent Abundance**	**Rank Abundance**
Hybognathus amarus (1)	12531	69.80	1	359	49.79	1.0
Cyprinus carpio (5)	3721	20.73	2	--	--	--
Cyprinella lutrensis (8)	1092	6.08	3	320	44.38	2.0
Gambusia affinis (12)	508	2.83	4	4	0.55	4.5
Pimephales promelas (11)	29	0.16	5	4	0.55	4.5
Carpiodes carpio (6)	22	0.12	6	28	3.88	3.0
Platygobio gracilis (3)	14	0.08	7	3	0.42	6.0
Ictalurus punctatus (11)	10	0.06	8	1	0.14	8.0
Lepomis cyanellus (9)	9	0.05	9	1	0.14	8.0
Catostomus commersonii (3)	8	0.04	10	--	--	--
Ameiurus natalis (11)	6	0.03	11	--	--	--
Lepomis macrochirus (9)	2	0.01	12	--	--	--
Perca flavescens (4)	1	0.01	13	--	--	--
Pomoxis annularis (9)	--	--	--	1	0.14	8.0

Note: Floodplain collections enumerated in this table include fish from fyke net and seine samples. Main channel collections are from seine samples. Number collected, percent abundance, and rank abundance are indicated for each species by main channel and floodplain habitats. The parenthetic numbers following species names pertain to reproductive guilds. Reproductive guild assignments generally follow Balon (1975, 1987). Reproductive guild codes are assigned as follows:

NON-GUARDERS: 1 - Pelagophils; 2 - Litho-pelagophils; 3 – Non-guarding Lithophils; 4 - Phyto-lithophils; 5 - Non-guarding Phytophils; 6 - Psammophils; 7 - Brood Hider Lithophils;

NEST GUARDERS: 8 – Nest-guarding Phytophils; 9 – Nest-guarding Lithophils; 10 - Phyto-epipilophils; 11 - Spelenophils; 12 - Livebearers.

Faunal patterns of the Los Lunas Habitat Restoration Project site deviate from those of the adjacent segment of the main channel of the Middle Rio Grande. The Jaccard similarity coefficient between these adjacent aquatic habitats is surprisingly low (0.54) considering that there were no barriers to fish movement at the time of sampling. The absence of five species from main channel collections accounts for the low similarity among the fauna of these adjacent habitats. Many of the higher rank species (i.e., low relative abundance) and species that are absent from the adjacent aquatic habitats generally represent peripheral or adventitious occurrences—their presence or absence is not likely to have a significant ecological consequence given their low relative abundance. The exception to this is the common carp, which was absent from main channel collections. The presence of this species in the floodplain is undoubtedly ecologically significant given its high fecundity.

It is expected that high discharge that inundates floodplain habitats will lead to positive population trajectories of silvery minnow and common carp, but through different modes of reproduction. Ecologically, floods and drought represent disturbance factors in the MRG that serve to differentially advantage or disadvantage species, thereby regulating species diversity and species abundance across a range of spatial and temporal scales. Significantly, the contemporary hydrologic disturbance regime of the MRG disadvantages nest-guarding lithophils, which serves to reduce the diversity and abundance of predatory fish species. However, these generalizations will not apply if the fundamental aspects of the hydrologic disturbance regime are radically altered.

HABITAT PATCH OCCUPATION

The occupation of the seasonally inundated floodplain at the Los Lunas Habitat Restoration Project site is logically dependent in part on the faunal composition of the adjacent portion of the river. In this regard, it is significant that flow diminished sufficiently during the latter part of the 2007 irrigation season to dry a segment of the river in the Isleta Reach that included the study site. Beginning August 12, 2007, and continuing through the remainder of the irrigation season, flow was generally discontinuous over a 14-km (9-mile) segment of river upstream of Peralta Wasteway to Los Lunas.

Following the irrigation season, with the reduction of consumptive use of water and reduced effects of evaporation and transpiration, flow in the river increased sufficiently to become a through-flowing system. Monthly surveys for fish beginning in November 2007 chronicle the reoccupation of this empty habitat patch by fish from outlying areas (Table 6).

Monthly and pooled abundance ranks for species in the segment of the Rio Grande adjacent to the Los Lunas Habitat Restoration Project site document an initial occupancy of this river segment by a core of colonizing species including silvery minnow, red shiner, and river carpsucker (Table 6). Although species composition of collections varied over sample events, monthly diversity quickly reached a plateau of six species soon after rewetting. This relatively low proportion of the regional species pool suggests a delayed influence of regional diversity on local diversity, governed to some extent by local conditions, notably including lingering effects of recent channel drying. The delayed influence of the regional faunal pool suggests that the extent and duration of stream drying might play a critical role in the rate of reoccupation.

Table 6. Monthly Species Abundance Ranks for Main Channel Samples Adjacent to the Los Lunas Habitat Restoration Project Site

	Date				Pooled Rank
Species	**29-Nov-2007**	**20-Dec-2007**	**23-Jan-2008**	**20-Feb-2008**	
Carpiodes carpio	3.0	3.0	3.0	2.0	3.0
Cyprinella lutrensis	2.0	2.0	1.0	4.0	2.0
Gambusia affinis	--	4.0	5.0	--	4.5
Hybognathus amarus	1.0	1.0	2.0	1.0	1.0
Ictalurus punctatus	5.0	--	--	--	7.0
Lepomis cyanellus	5.0	--	--	--	7.0
Pimephales promelas	--	5.0	5.0	4.0	4.5
Platygobio gracilis	5.0	--	5.0	4.0	5.0
Pomoxis annularis	--	6.0	--	--	7.0
Species Counts	**6**	**6**	**6**	**5**	**9**

Jaccard's coefficient of similarity between pooled species assemblages for the Isleta Reach (see Table 1) and more localized and habitat specific assemblages associated with the Los Lunas Habitat Restoration Project site help to elucidate the relative importance of large-scale processes involved in species dispersal and habitat patch occupation. While floodplain and main channel sites associated with the Los Lunas Habitat Restoration Project area were both recently occupied, similarity coefficients reveal that the faunal assemblage of floodplain habitats is more similar to the pooled species assemblage for the Isleta Reach than the adjacent segment of river (Figure

11). The higher similarity coefficient coupled with the prevailing flow regime at the time of floodplain collections suggests that the relative species saturation of the floodplain depends significantly on annual species-specific reproduction cycles and high flows that serve to facilitate dispersal of advanced life stage fish. Whereas the high flows are disruptive and serve to disperse fish of various life stages, the lateral habitats offer velocity refuges that can operate to moderate the effect of dispersal by passive drift.

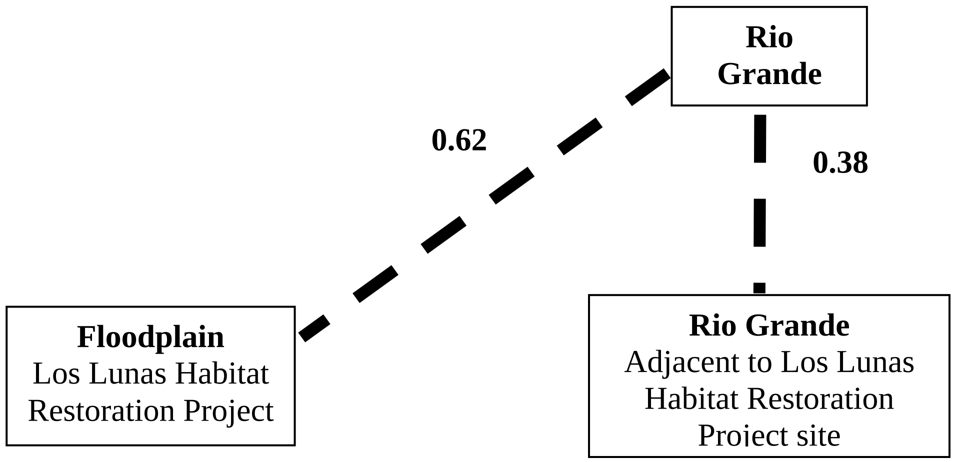


Figure 11. Levels of faunal similarity expressed as Jaccard's coefficient of similarity (shown adjacent to dashed lines) between pooled species ranks for the Isleta Reach and species ranks for more localized and habitat specific assemblages.

SAMPLING ADEQUACY AND SAMPLING BIAS

Results of the bootstrap analysis of monthly seine samples from main channel habitats adjacent to the Los Lunas Habitat Restoration Project site are presented in Appendix H. Results indicate that these samples yielded unbiased estimates of species richness. Actual species richness was often greater than predicted by the bootstrap estimator. This was likely the result of purposeful efforts to thoroughly sample the array of available mesohabitats for a given sample effort. The exception to this may have occurred with the February 20, 2008 sample when species richness may have been underestimated by approximately one species. Analysis indicates that sampling effort and representation of mesohabitats was adequate to yield an unbiased estimator of species richness given the community composition observed at low flow conditions. At higher discharges, sampling efficiency decreases, suggesting more seine hauls would be required to yield an unbiased estimator of site-specific species richness by seining. It would be instructive to compare the relative efficiency of seining and electrofishing to represent species richness over a variety of flow conditions.

Estimates of floodplain species richness differed by sampling method. Thirteen species were represented in fyke net samples, while only eight species were represented in seine samples (Table 7). We used Jaccard's index as an index of similarity among estimates of species richness from floodplain seine and fyke net samples. The index value for fyke net samples (0.62) was 1.63 times higher that the index value for seine net samples (0.38), indicating that species richness in floodplain habitats is underestimated by seining relative to sampling with fyke nets.

Rank abundance of silvery minnow in floodplain habitats differed by sampling method. Silvery minnow was the most abundant species in fyke net samples. In contrast, silvery minnow was the third most abundant species in seine samples (see Table 7).

Table 7. Species Rank Abundance in Floodplain Habitats of the Los Lunas Habitat Restoration Project Site by Sampling Method

Species	Fyke Net Samples	Seine Samples
Hybognathus amarus	1	3
Cyprinus carpio	2	1
Cyprinella lutrensis	3	2
Gambusia affinis	4	8
Pimephales promelas	5	6
Carpiodes carpio	6	5
Platygobio gracilis	7	–
Lepomis cyanellus	8	–
Catostomus commersonii	9.5	7
Ameiurus natalis	9.5	–
Ictalurus punctatus	11	4
Lepomis macrochirus	12	–
Perca flavescens	13	–
Species Counts	**13**	**8**

Linear regression of the two indices of silvery minnow abundance indicates a general agreement in absolute trends of daily fluctuations in abundance (Figure 12). Despite the general daily agreement, average rate of silvery minnow catch in fyke net was 70 times higher than rate of catch with seine nets. The calculated fishing power coefficient indicates that the fyke net CPUE index (silvery minnow per hour) was on average nine times higher (average 9.0, SE = 1.5) than comparable seine net CPUE (silvery minnow per 100 m^2) values.

The noted disparity of sampling efficiency between fyke nets and seining is probably a consequence of the heightened existence of hazards in floodplain habitats, such as uneven ground, emergent plants, and organic debris. Relative to seining, fyke nets are less affected by these limitations because they operate passively. However, fyke nets and other sampling methods have their own set of limitations that govern their utility in gathering samples that would allow researchers/managers to discriminate among competing hypotheses about system behavior. Tangentially related, an obvious but unquantified difference in representation of silvery minnow size class frequency exists between sampling methods. Fyke net samples generally have a greater frequency of larger silvery minnows.

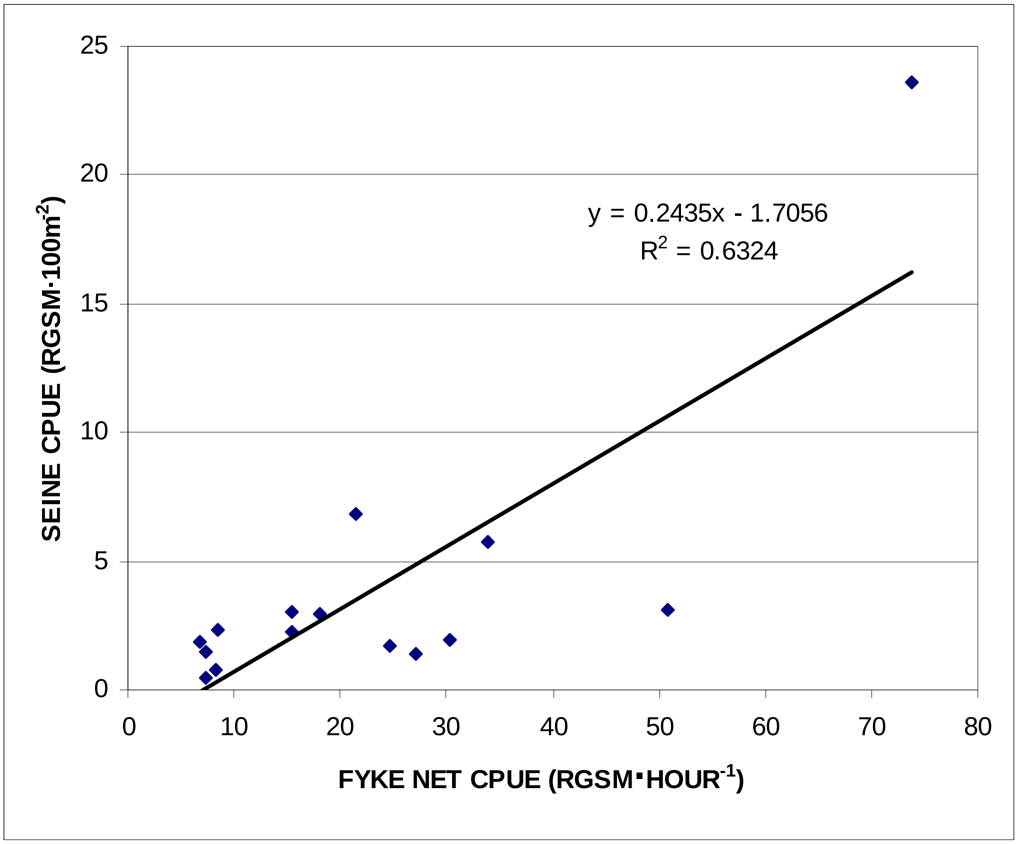


Figure 12. **Relationship between the two indices of abundance calculated from fyke net sampling (silvery minnow per hour^{-1}) and seine net sampling (silvery minnow per 100 m^2) during floodplain monitoring.**

DISCUSSION

CHANNEL-FLOODPLAIN COUPLING

River channel-floodplain coupling represents a plausible and attractive strategy to accommodate silvery minnow spawning and enhance retention and survival of eggs and larvae in upstream river segments. This study documents the occupancy of seasonably inundated floodplain habitats at the Los Lunas Habitat Restoration Project site by reproductively mature silvery minnow. Results of synoptic fish surveys of river and floodplain habitats are examined along with site-specific environmental characteristics to elucidate how faunal assemblages are structured by underlying physical, chemical, and hydrologic features. This information is also used to support inferences about silvery minnow reproductive biology and processes such as dispersal and habitat selection. Knowledge of how silvery minnow and other fish species use inundated floodplain habitats and other habitats lateral to the active river channel is essential to guide habitat restoration efforts. Although understanding remains provisional, the association of silvery minnow spawning with lateral habitats, including the floodplain, is generally consistent with observations by Raney (1939) of eastern silvery minnow (*Hybognathus regius*) spawning and observations by Copes (1975) of brassy minnow (*Hybognathus hankinsoni*) spawning. However, the challenge remains to specify the elements of "sufficient causation" that lead to silvery minnow spawning and strong recruitment—the antecedent conditions, consequent effects, and rules of correspondence for their conjoint occurrence.

Flows that inundate the floodplain of the MRG during the spring (primarily during May and June) invariably contribute to increasing trajectories of silvery minnow populations so long as sustained duration of river channel-floodplain coupling is maintained above minimal threshold standards that provide the parental stock time to occupy the floodplain and spawn, to allow time for embryo development and hatching, and finally to allow sufficient time for young-of-year silvery minnow development to at least the juvenile stage to effectively enable fish to evacuate draining floodplain habitats. Logically, silvery minnow reproduction and recruitment to juvenile stages in floodplain habitats of the MRG is dependent on the timing, duration, and magnitude of channel-floodplain coupling in relation to the species' physiological reproductive state.

Silvery minnow occupancy of the floodplain represents a behavioral adaptation that involves synchronization with long-term flow dynamics. The timing and duration of silvery minnow spawning is strategically aligned with an opportunistic approach to reproduction—spanning a range of relatively abundant hydrologic conditions that correspond with variable probabilities for species recruitment. It is important to note that this adaptation, like most behavioral adaptations, is not obligatory, which serves to minimize fitness costs that would otherwise be associated with an adaptation under suboptimal conditions.

Hatch and Gonzales (in prep), in agreement with Platania and Altenbach (1996), have found generally that Age-I and older silvery minnows are reproductively mature. In our study, reproductively mature males ranged in length from 38 to 68 mm SL, and reproductively mature females ranged in length from 41 to 85 mm SL. Hatch and Gonzales (in prep) report that reproductively mature males range in length from 39 to 69 mm SL, and sexually mature females range in length from 40 to 92 mm SL. The greater maximum length of sexually mature females compared to males may be attributable to a longer life span for females or to inherent sexual size dimorphism. Females ranging in size from approximately 36 to 48 mm SL in the spring may have developing oocytes and spawn for the first time later in the season (Hatch and Gonzales in prep).

Our findings support a working hypothesis that silvery minnow adaptively and preferentially spawns in low water exchange lateral habitats, including most importantly backwater and other hydrologic retentive floodplain habitats when possible to reduce downstream displacement of eggs and larvae. It is believed that inundated floodplain habitats factor prominently in the survival and growth of larval and older silvery minnows due in part to the existence of highly productive food chains founded on the bacterial conditioning of retained fine and course particulate organic material and newly inundated terrestrial vegetation. Heightened floodplain productivity is further enhanced by the lower water exchange rates, heightened subsidy of allochthonous energy inputs at the aquatic-land interface, and heightened temperatures characteristic of such areas (Schlosser 1991; Valett et al. 2005). Additionally, reduced water velocity habitats that typify the margins of rivers, especially flood terraces, are conducive to energy conservation—a general life strategy shared by many lotic fish species (Facey and Grossman 1992). It is speculated that deeper and more expansive habitats are vital to silvery minnow survival in the floodplain due to enhanced temporal environmental stability intrinsic to such habitats. Additionally, it is more likely that deeper floodplain habitats offer greater protection against avian and other predators compared to shallow areas.

The degree to which incubating silvery minnow embryos are retained in upstream habitats appears to vary with discharge. Although silvery minnow embryos are known to drift considerable distances when flow is confined to the active channel (Dudley and Platania 2007), downstream drift of embryos appears to be negatively related to flow as it increases sufficiently for water to escape the active river channel and flood adjacent terraces. Reduction in egg and larvae drift and retention in upstream river reaches serves to reduce impacts of habitat fragmentation that would otherwise restrict movement between subpopulations and source-sink exchanges. Under the "drift paradox" concept advanced by Hershey et al. (1993), extinction is inevitable when downstream drift is the only transport process (Speirs and Gurney 2001).

Much of the contemporary inference about the linkage of water temperature and silvery minnow spawning is founded on the misperception that the silvery minnow is an obligate main channel spawner. An alternative explanation of the mechanical role of water temperature in silvery minnow reproductive biology will likely be found less equivocally linked to the effects of temperature dynamics of low water exchange habitats of the inundated floodplain on the survival of larval silvery minnows (e.g., following the investigations of Mapula et al. in prep). Our study documents higher and more variable water temperatures in floodplain habitats compared to water temperatures in main channel habitats during primary periods of silvery minnow spawning.

Thermal variability may be an especially important consideration in the design of floodplain habitats intended to enhance species' reproduction and recruitment considering the apparent link of silvery minnow larval survival to water temperature reported by Mapula et al. (in prep). Baker and Ross (1981), Gorman (1988a, 1988b), and Labbe and Fausch (2000) all reported heightened environmental stability with increasing water depth. We have generally found that backwater habitats with persistent linkages to perennial flowing river segments are characterized by a heightened degree of environmental stability. Likewise, backwater habitats that are proximal to perennial running water habitats have a heightened potential for rapid faunal exchanges with running water habitats, especially by the silvery minnow given its high vagility (Hatch et al. 2008). Floodplain habitats that naturally drain to the active channel would aid in the evacuation of young-of-year silvery minnow from floodplain habitats as flows recede.

The timing and magnitude of silvery minnow spawning in the MRG, as traditionally indicated by rates of capture of reproductively mature silvery minnow, varies with the abundance of parental stock and typically coincides with high-discharge runoff events during the growing season, notably including those that result in significant inundation of lands adjacent to the active river channel. From experience, moderate to high levels of silvery minnow recruitment to the juvenile stage are expected when flows that inundate floodplain habitats are sustained for a minimum of seven to ten consecutive days. Higher levels of recruitment are expected with longer consecutive days of floodplain inundation. Minimal sustained duration of river channel-floodplain coupling is essential to allow adults a chance to occupy the floodplain and spawn, to allow time for embryo development and hatching, and finally to allow sufficient time for young-of-year silvery minnow development to at least the juvenile stage to effectively enable fish to evacuate draining floodplain habitats. Although Hatch and Gonzales (in prep) found that adult silvery minnow will actively evacuate floodplain habitats as flows recede, significant numbers of silvery minnow eggs and larvae can be stranded if the river channel-floodplain becomes uncoupled prematurely (i.e., before eggs hatch and fish mature to advanced post larval stages) or if flows are abruptly reduced (USFWS 2006).

From a population ecology perspective, the provision of flows conducive to strong recruitment are most important when silvery minnow populations are decreasing, which is to say, the value of each offspring increases when the population is decreasing (i.e., when the finite rate of population increase is less than one).[6] Prospects of species survival are enhanced to the extent that population densities can be maintained above levels subject to depensatory deterministic effects. Minimum population size needed to achieve some standard of viability will occur at the highest survival rate of young-of-year and no population-wide year class failures. Viable population size increases as the failure rate for the younger age classes increases. Therefore, it is prudent to maximize survival and manage for larger population sizes to accommodate temporal variation in demography and habitat quality (Cowley 2007).

ASSESSMENT OF HABITAT RESTORATION PROJECTS

In situ conservation of rare species often requires habitat modification to enhance species' reproduction and recruitment. Assessments of such projects typically rely on detectable change in select variables. An important component of the experimental protocol for assessing the effect of habitat modification projects is the provision of adequate concurrent controls. Such studies require that samples or observations be taken before and after habitat modification and from impact and control locations, following the before—after, control—impact (BACI) design by Green (1979), and represent the key underlying elements of rigorous impact assessment monitoring designs. However, in the absence of such controls, the data derived from experimental field studies are often difficult to interpret because an explicit means of estimating

[6] Collectively, *birth + immigration – death – emigration* represents the geometric rate of natural increase (*R*). The parameter *R* represents the per capita rate of change in the size of the population. The quantity (1 + *R*), traditionally represented by the symbol λ (lambda), is referred to as the finite rate of increase.

the baseline may not be available and because non-treatment effects may lead to errors in causal inference. Causal inference may be difficult to establish because compared sites or times usually differ in a variety of ways so it is unclear which factors are responsible for any perceived patterns, and two variables may be correlated because both are related to a third, perhaps unmeasured and incidental, variable. Relationships between environmental and response variables may only be valid over the range of values of the environmental conditions found in the surveyed sites. If this range of values is small, sampling variation may preclude detection of a relationship between environmental and response variables. More importantly, it is not clear whether the survey results can be applied to sites or times with environmental values lying outside the surveyed range. Significantly, correlation analyses rely on static measures and are, therefore, poor at elucidating dynamic relationships between factors (e.g., those involving feedbacks and time lags). Finally, because surveys often are based on measurements taken over a limited period of time, they may miss important extreme events.

Beyond the problematic issues of causal inference outlined above, BACI studies may be inappropriate for assessing the effects of many habitat restoration projects because the fundamental question of impact assessment does not concern detectable change; rather, the logical test of success involves no difference between modified habitats and a properly functioning reference site or state. This approach to impact assessment deviates from traditional falsification-based statistical inference and is reliant on the existence of a reference state or a defensible definition of such.

LITERATURE CITED

Baker, J.A., and S. T. Ross. 1981. Spatial and temporal resource utilization by southeastern Cyprinids. Copeia 1981:178–179.

Balon, E.K. 1975. Reproductive guilds of fishes: a proposal and definition. Journal of the Fisheries Research Board of Canada 32:821–864.

———. 1987. On decisive events in the early life history of fishes and the pertinence of such events to the functional grouping of fishes according to their susceptibility to impact. In Mechanisms of Compensatory Response of Fish Populations: Workshop Proceedings, pp. 5-1–5-34. Electric Power Research Institute, Inc.

Beck, S.E., and J.J. Fluder. 2006. Silvery Minnow Egg and Larval Fish Monitoring in Nursery Habitats: Summary of Findings Report. Report prepared for U.S. Department of the Interior, Bureau of Reclamation. SWCA Environmental Consultants, Albuquerque. 26 pgs.

Bridge, P.D. 1993. Classification. In Biological Data Analysis: A Practical Approach, edited by J.C. Fry, pp. 220–242. New York: Oxford University Press.

Copes, F.A. 1975. Ecology of the brassy minnow, *Hybognathus hankinsoni* (Cyprinidae). University of Wisconsin Stevens Point Museum of Natural History Reports on the Fauna and Flora of Wisconsin 10. Contributions to Ichthyology: 47–72.

Copp, G.H. 1989. The habitat diversity and fish reproductive function of floodplain ecosystems. Environmental Biology of Fishes. 26:1–27.

Cowley, D. E. 2007. Estimating required habitat size for fish conservation in streams. Aquatic Conservation: Marine and Freshwater Ecosystems. Wiley InterScience. 10.1002/aqc.845.

Cowley, D.E., P.D. Shirey, and M.D. Hatch. 2006. Ecology of the Rio Grande silvery minnow (Cyprinidae: *Hybognathus amarus*) inferred from specimens collected in 1874. Reviews in Fisheries Science 14:111–125.

Cowley, D.E., R.C. Wissmar, and R. Sallenave. 2007. Fish assemblages and seasonal movements of fish in irrigation canals and river reaches of the Middle Rio Grande, New Mexico (USA). Ecology of Freshwater Fish. Doi: 10.1111/j.1600–0633.2007.00250.x.

Davison, A. C., and D. V. Hinkley. 1997. Bootstrap methods and their application. Cambridge University Press, Cambridge.

Dudley, R.K., and S.P. Platania. 2007. Flow regulation and fragmentation imperil pelagic spawning riverine fishes. Ecological Applications 17(7), 2007, 2074–2086.

Facey, D.E., and G.D. Grossman. 1992. The relationship between water velocity, energetic costs, and microhabitat in four North American stream fishes. Hydrobiologica 239:1–6.

Federal Register. 1994. Endangered and threatened wildlife and plants: final rule to list the Rio Grande silvery minnow as an endangered species. 50 CFR Part 17, RIN 1018-AB88. July 20, 1994. 59 (138): 36988-36995.

Galat, D.L., G.W. Whitledge, L.D. Tatton, and J. Hooker. 2004. Larval fish use of lower Missouri River scour basins in relation to connectivity. Final report to Missouri Department of Conservation. Columbia, Missouri.

Gorman, O.T. 1988a. An experimental study of habitat use in a guild of Ozark minnows. Ecology 69:1239–1250.

———. 1988b. The dynamics of habitat use in a guild of Ozark minnows. Ecological Monographs 58:1–18.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. New York: John Wiley.

Harris, L. G. 1984. New Mexico water rights. New Mexico Water Resources Research Institute. Misc. Report No. 15. Las Cruces, New Mexico.

Hatch, M.D., and E. Gonzales. In prep. Habitat Restoration Monitoring. Santa Fe: New Mexico Interstate Stream Commission.

Hatch, M.D., E. Gonzales, J.J. Fluder, and J. Welch. 2008. 2007 Bureau of Reclamation Experimental Activities on the Middle Rio Grande. Project Summary Report. Albuquerque: U.S. Bureau of Reclamation.

Hershey, A.E., J. Pastor, B.J. Peterson, and G.W. Kling. 1993. Stable isotopes resolve the drift paradox for *Baetis* mayflies in an arctic river. Ecology 74:2315–2325.

Hubert W.A., and M.C. Fabrizio 2007. Relative abundance and catch per unit effort. In Analysis and Interpretation of Freshwater Fisheries Data, edited by C.S. Guy and M.L. Brown, pp 279–326. Bethesda, Maryland: American Fisheries Society.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. In Proceedings of the International Large River Symposium, edited by D.P. Dodge, pp. 110–127. Canadian Special Publication of Fisheries and Aquatic Science 106.

Junk, W.J., and R.L. Welcomme. 1990. Floodplains. In Wetlands and Shallow Continental Water Bodies, edited by B.C. Patten et al., pp. 491–524. The Hague, Netherlands: SPB Academic Publishing.

Labbe, T.R., and K.D. Fausch. 2000. Dynamics of intermittent stream habitat regulate persistence of a threatened fish at multiple scales. Ecological Applications 10(6): 1774–1791.

Lytle, D.A., and N.L. Poff. 2004. Adaptation to natural flow regimes. Trends in Ecology and Evolution 9(2):94–100.

Mapula, J.A., W.J. Boeing and D.E. Cowley. In prep. Temperature and Salinity Influence Egg Hatching and Larval Survival of Rio Grande Silvery Minnow. Las Cruces, New Mexico: New Mexico State University.

Nelson, J. S., E. J. Crossman, H. Espinosa-Perez, L. T. Findley, C. R. Gilbert, R. N. Lea, and J. D. Williams. 2004. Common and scientific names of fishes from the United States, Canada and Mexico. Sixth edition. Bethesda, Maryland: American Fisheries Society Special Publication 29.

Pease, A.A., J.J. Davis, M.S. Edwards, and T.F. Turner. 2006. Habitat and resource use by larval and juvenile fishes in an arid-land river (Rio Grande, New Mexico). Freshwater Biology: 1–12.

Platania, S. P. and C. S. Altenbach 1996. Reproductive ecology of Rio Grande silvery minnow Hybognathus amarus: clutch and batch production and fecundity estimates. U.S. Army Corps of Engineers. Albuquerque, NM.

Porter, M.D., and G. Dean. 2005. Annual Report - 2005, Rio Grande Fish Community Surveys. Albuquerque: U.S. Department of the Interior, Bureau of Reclamation. 14 pp.

———. 2006. Annual Report - 2006, Rio Grande Fish Community Surveys. Albuquerque: U.S. Department of the Interior, Bureau of Reclamation. 12 pp.

Porter, M.D., G. Dean, and T.M. Massong. 2004. Annual Report 2004: Rio Grande Fish Community Surveys. Albuquerque: U.S. Department of the Interior, Bureau of Reclamation. 12 pp.

Quinn, T.J. II, and R.B. Deriso. 1999. Quantitative Fish Dynamics. New York: Oxford University Press.

Raney, E.C. 1939. The breeding habits of the silvery minnow, *Hybognathus regius*. American Midland Naturalist 21:674–680.

Robinson, C. T., K. Tockner, and J. V. Ward. 2002. The fauna of dynamic riverine landscapes. Freshwater Biology 47: 661-677.

Schlosser, I. J. 1991. Stream fish ecology: a landscape perspective. Bioscience 41:704–712.

Schluter, D., and R.E. Rickleffs 1993. Species diversity: an introduction to the problem. In Species Diversity in Ecological Communities: Historical and Geographical Perspectives, edited by R.E. Rickleffs and D. Schluter, pp. 1–10. Chicago: University of Chicago Press.

Scurlock, D. 1998. From the Rio to the Sierra: an environmental history of the Middle Rio Grande Basin. General Technical Report RMRS-GTR-5. Fort Collins, Colorado: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 440p.

Siegle, R. 2006. 2005 Monitoring report for the Los Lunas habitat restoration site. USDI, Bureau of Reclamation, Albuquerque. 61 pp.

Sneath, P.H., and R.R. Sokal. 1973. Numerical taxonomy. San Francisco: W.H. Freeman and Co.

Speirs, D.C., and W.C. Gurney. 2001. Population persistence in rivers and estuaries. Ecology 82(5):1219–1237.

Sublette, J.E., M.D. Hatch, and M. Sublette. 1990. The Fishes of New Mexico. Albuquerque: University of New Mexico Press.

U.S. Fish and Wildlife Service (USFWS). 2001. Programmatic Biological Opinion on the Effects of the U.S. Bureau of Reclamation's, U.S. Army Corps of Engineers', and Non-Federal Entities' Discretionary Actions Related to Water Management on the Middle Rio Grand, Albuquerque. June 29.

———. 2003. Biological and Conference Opinions on the Effects of Actions Associated with the Programmatic Biological Assessment of Bureau of Reclamation's Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operation, and Related Non-Federal Actions on the Middle Rio Grande, Albuquerque. Consultation Number 2-22-03-F-0129. March 17.

———. 2006. Rio Grande Silvery Minnow Rescue and Salvage – Fiscal Year 2005. Interagency Agreement 02-AA-40-8190. Albuquerque: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

———. 2007. Rio Grande Silvery Minnow Rescue and Salvage – Fiscal Year 2006. Interagency Agreement 02-AA-40-8190. Albuquerque: U. S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

Valett, H.M., M.A. Baker, J.A. Morrice, C.S. Crawford, M.C. Molles, Jr., C.N. Dahm, D.L. Moyer, J.R. Thibault, and L.M. Ellis. 2005. Biological and metabolic responses to the flood pulse in a semiarid floodplain. Ecology 86(1):220–234.

Zar, J.H. 1999. Biostatistical analysis, 4th ed. New Jersey: Prentice Hall.

APPENDIX A
FISH COLLECTIONS BY FYKE NET SITE AND DATE

Fish Collections by Fyke Net Site and Date

Net ID	Date	Species	Rank Order by Date	Number Collected	Daily Percent Abundance
101					
	20-May-2008				
		Cyprinus carpio	1	300	39.84
		Hybognathus amarus	2	283	37.58
		Gambusia affinis	3	100	13.28
		Cyprinella lutrensis	4	70	9.30
	23-May-2008				
		Hybognathus amarus	1	77	81.91
		Cyprinus carpio	2	17	18.09
	24-May-2008				
		Hybognathus amarus	1	3514	98.16
		Cyprinus carpio	2	48	1.34
		Pimephales promelas	3	10	0.28
		Cyprinella lutrensis	4	5	0.14
		Ictalurus punctatus	5	2	0.06
		Lepomis cyanellus	6	1	0.03
	25-May-2008				
		Hybognathus amarus	1	282	98.95
		Cyprinella lutrensis	2	3	1.05
	26-May-2008				
		Hybognathus amarus	1	128	99.22
		Cyprinella lutrensis	2	1	0.78
	27-May-2008				
		Hybognathus amarus	1	279	84.29
		Cyprinella lutrensis	2	42	12.69
		Cyprinus carpio	3	5	1.51
		Pimephales promelas	4	4	1.21
		Catostomus commersonii	5	1	0.30
	28-May-2008				
		Hybognathus amarus	1	3	100.00
	29-May-2008				
		Cyprinus carpio	1	479	58.63
		Hybognathus amarus	2	296	36.23
		Cyprinella lutrensis	3	41	5.02
		Pimephales promelas	4	1	0.12

Net ID	Date	Species	Rank Order by Date	Number Collected	Daily Percent Abundance
	30-May-2008				
		Hybognathus amarus	1	726	90.75
		Cyprinus carpio	2	72	9.00
		Cyprinella lutrensis	3	2	0.25
	31-May-2008				
		Cyprinus carpio	1	523	79.24
		Hybognathus amarus	2	111	16.82
		Cyprinella lutrensis	3	22	3.33
		Lepomis cyanellus	4	2	0.30
		Pimephales promelas	5	1	0.15
		Carpiodes carpio	6	1	0.15
	01-Jun-2008				
		Hybognathus amarus	1	193	90.61
		Cyprinus carpio	2	15	7.04
		Cyprinella lutrensis	3	5	2.35
	02-Jun-2008				
		Hybognathus amarus	1	8	50.00
		Cyprinus carpio	2	7	43.75
		Cyprinella lutrensis	3	1	6.25
	03-Jun-2008				
		Cyprinus carpio	1	13	50.00
		Hybognathus amarus	2	8	30.77
		Cyprinella lutrensis	3	5	19.23
	04-Jun-2008				
		Hybognathus amarus	1	44	57.14
		Cyprinus carpio	2	24	31.17
		Cyprinella lutrensis	3	9	11.69
	05-Jun-2008				
		Hybognathus amarus	1	33	62.26
		Cyprinus carpio	2	20	37.74
	06-Jun-2008				
		Hybognathus amarus	1	1	100.00

Net ID	Date	Species	Rank Order by Date	Number Collected	Daily Percent Abundance
102					
	20-May-2008				
		Cyprinus carpio	1	600	41.24
		Hybognathus amarus	2	564	38.76
		Gambusia affinis	3	250	17.18
		Cyprinella lutrensis	4	40	2.75
		Carpiodes carpio	5	1	0.07
	23-May-2008				
		Hybognathus amarus	1	46	63.89
		Cyprinus carpio	2	26	36.11
	24-May-2008				
		Hybognathus amarus	1	2000	99.01
		Cyprinus carpio	2	16	0.79
		Cyprinella lutrensis	3	4	0.20
	25-May-2008				
		Hybognathus amarus	1	473	97.73
		Cyprinella lutrensis	2	8	1.65
		Cyprinus carpio	3	3	0.62
	26-May-2008				
		Hybognathus amarus	1	144	94.12
		Cyprinella lutrensis	2	6	3.92
		Cyprinus carpio	3	2	1.31
		Lepomis cyanellus	4	1	0.65
	27-May-2008				
		Hybognathus amarus	1	91	97.85
		Cyprinus carpio	2	2	2.15
	28-May-2008				
		Hybognathus amarus	1	491	67.45
		Cyprinella lutrensis	2	225	30.91
		Ameiurus natalis	3	5	0.69
		Pimephales promelas	4	3	0.41
		Cyprinus carpio	5	3	0.41
		Perca flavescens	6	1	0.14
	29-May-2008				
		Hybognathus amarus	1	122	71.76
		Cyprinella lutrensis	2	30	17.65
		Cyprinus carpio	3	18	10.59

Net ID	Date	Species	Rank Order by Date	Number Collected	Daily Percent Abundance
	30-May-2008				
		Hybognathus amarus	1	181	70.70
		Cyprinus carpio	2	70	27.34
		Gambusia affinis	3	4	1.56
		Cyprinella lutrensis	4	1	0.39
	31-May-2008				
		Cyprinus carpio	1	466	61.07
		Hybognathus amarus	2	289	37.88
		Cyprinella lutrensis	3	7	0.92
		Pimephales promelas	4	1	0.13
	01-Jun-2008				
		Cyprinus carpio	1	182	58.90
		Hybognathus amarus	2	122	39.48
		Cyprinella lutrensis	3	5	1.62
	02-Jun-2008				
		Hybognathus amarus	1	97	57.74
		Cyprinus carpio	2	42	25.00
		Cyprinella lutrensis	3	29	17.26
	03-Jun-2008				
		Hybognathus amarus	1	123	70.29
		Cyprinella lutrensis	2	26	14.86
		Cyprinus carpio	3	25	14.29
		Lepomis macrochirus	4	1	0.57
	04-Jun-2008				
		Hybognathus amarus	1	68	79.07
		Cyprinella lutrensis	2	11	12.79
		Cyprinus carpio	3	5	5.81
		Pimephales promelas	4	1	1.16
		Ameiurus natalis	5	1	1.16
	05-Jun-2008				
		Hybognathus amarus	1	64	83.12
		Cyprinus carpio	2	11	14.29
		Cyprinella lutrensis	3	1	1.30
		Gambusia affinis	4	1	1.30

Net ID	Date	Species	Rank Order by Date	Number Collected	Daily Percent Abundance
	06-Jun-2008				
		Hybognathus amarus	1	100	72.46
		Cyprinus carpio	2	33	23.91
		Cyprinella lutrensis	3	2	1.45
		Gambusia affinis	4	2	1.45
		Lepomis macrochirus	5	1	0.72

Net ID	Date	Species	Rank Order by Date	Number Collected	Daily Percent Abundance
103					
	20-May-2008				
		Hybognathus amarus	1	181	54.52
		Cyprinus carpio	2	100	30.12
		Gambusia affinis	3	50	15.06
		Catostomus commersonii	4	1	0.30
	23-May-2008				
		Hybognathus amarus	1	22	95.65
		Cyprinus carpio	2	1	4.35
	24-May-2008				
		Hybognathus amarus	1	58	96.67
		Cyprinus carpio	2	2	3.33
	25-May-2008				
		Hybognathus amarus	1	4	66.67
		Cyprinus carpio	2	2	33.33
	26-May-2008				
		Hybognathus amarus	1	90	100.00
	27-May-2008				
		Hybognathus amarus	1	108	99.08
		Cyprinus carpio	2	1	0.92
	28-May-2008				
		Hybognathus amarus	1	67	97.10
		Carpiodes carpio	2	1	1.45
		Cyprinella lutrensis	3	1	1.45
	29-May-2008				
		Hybognathus amarus	1	33	86.84
		Cyprinus carpio	2	5	13.16
	30-May-2008				
		Hybognathus amarus	1	35	94.59
		Cyprinella lutrensis	2	2	5.41
	31-May-2008				
		Hybognathus amarus	1	33	80.49
		Cyprinella lutrensis	2	4	9.76
		Cyprinus carpio	3	3	7.32
		Lepomis cyanellus	4	1	2.44

Net ID	Date	Species	Rank Order by Date	Number Collected	Daily Percent Abundance
	01-Jun-2008				
		Hybognathus amarus	1	41	93.18
		Cyprinella lutrensis	2	3	6.82
	02-Jun-2008				
		Hybognathus amarus	1	16	59.26
		Cyprinella lutrensis	2	11	40.74
	03-Jun-2008				
		Hybognathus amarus	1	29	96.67
		Cyprinella lutrensis	2	1	3.33
	04-Jun-2008				
		Hybognathus amarus	1	32	76.19
		Cyprinella lutrensis	2	10	23.81
	05-Jun-2008				
		Hybognathus amarus	1	25	86.21
		Cyprinella lutrensis	2	4	13.79
	06-Jun-2008				
		Hybognathus amarus	1	16	100.00

Net ID	Date	Species	Rank Order by Date	Number Collected	Daily Percent Abundance
104					
	20-May-2008				
		Hybognathus amarus	1	287	50.00
		Cyprinus carpio	2	150	26.13
		Gambusia affinis	3	100	17.42
		Platygobio gracilis	4	14	2.44
		Carpiodes carpio	5	11	1.92
		Cyprinella lutrensis	6	4	0.70
		Catostomus commersonii	7	4	0.70
		Lepomis cyanellus	8	3	0.52
		Ictalurus punctatus	9	1	0.17
	23-May-2008				
		Hybognathus amarus	1	25	100.00
	24-May-2008				
		Hybognathus amarus	1	14	66.67
		Cyprinus carpio	2	3	14.29
		Carpiodes carpio	3	3	14.29
		Cyprinella lutrensis	4	1	4.76
	25-May-2008				
		Hybognathus amarus	1	31	100.00
	26-May-2008				
		Hybognathus amarus	1	27	93.10
		Ictalurus punctatus	2	1	3.45
		Pimephales promelas	3	1	3.45
	27-May-2008				
		Hybognathus amarus	1	59	95.16
		Cyprinus carpio	2	2	3.23
		Cyprinella lutrensis	3	1	1.61
	28-May-2008				
		Lepomis cyanellus	1	1	50.00
		Hybognathus amarus	2	1	50.00
	29-May-2008				
		Hybognathus amarus	1	28	58.33
		Cyprinella lutrensis	2	19	39.58
		Cyprinus carpio	3	1	2.08

Net ID	Date	Species	Rank Order by Date	Number Collected	Daily Percent Abundance
	30-May-2008				
		Hybognathus amarus	1	53	89.83
		Cyprinella lutrensis	2	5	8.47
		Cyprinus carpio	3	1	1.69
	31-May-2008				
		Cyprinella lutrensis	1	64	55.17
		Hybognathus amarus	2	48	41.38
		Carpiodes carpio	3	1	0.86
		Cyprinus carpio	4	1	0.86
		Ictalurus punctatus	5	1	0.86
		Pimephales promelas	6	1	0.86
	01-Jun-2008				
		Cyprinella lutrensis	1	45	78.95
		Hybognathus amarus	2	12	21.05
	02-Jun-2008				
		Cyprinella lutrensis	1	21	75.00
		Hybognathus amarus	2	7	25.00
	03-Jun-2008				
		Cyprinella lutrensis	1	18	64.29
		Hybognathus amarus	2	8	28.57
		Pimephales promelas	3	2	7.14
	04-Jun-2008				
		Hybognathus amarus	1	6	54.55
		Cyprinella lutrensis	2	4	36.36
		Pimephales promelas	3	1	9.09
	05-Jun-2008				
		Hybognathus amarus	1	6	85.71
		Cyprinella lutrensis	2	1	14.29
	06-Jun-2008				
		Hybognathus amarus	1	15	93.75
		Cyprinella lutrensis	2	1	6.25

APPENDIX B
COLLECTIONS BY GENDER AND REPRODUCTIVE CONDITION

Chronological Record of Rio Grande Silvery Minnow Collections by Gender and Reproductive Condition

Composition Date	Gender/Reproductive Condition	Number Collected	Percent by Date
20-May-2008			
	Female - Gravid	258	19.62
	Male - Milt expressed	2	0.15
	Unknown Gender - Reproductive Condition Unknown / Not Checked	1055	80.23
23-May-2008			
	Female - Gravid	85	49.13
	Male - Milt expressed	55	31.79
	Unknown Gender - Reproductive Condition Unknown / Not Checked	33	19.08
24-May-2008			
	Female - Gravid	136	2.41
	Male - Milt expressed	73	1.29
	Unknown Gender - Reproductive Condition Unknown / Not Checked	5439	96.30
25-May-2008			
	Female - Gravid	139	17.27
	Female - Spent	252	31.30
	Male - Milt expressed	170	21.12
	Unknown Gender - Reproductive Condition Unknown / Not Checked	244	30.31
26-May-2008			
	Female - Spent	129	32.66
	Female - Gravid	26	6.58
	Male - Milt expressed	111	28.10
	Unknown Gender - Reproductive Condition Unknown / Not Checked	129	32.66
27-May-2008			
	Female - Gravid	94	17.41
	Female - Spent	247	45.74
	Male - Milt expressed	102	18.89
	Unknown Gender - Reproductive Condition Unknown / Not Checked	97	17.96
28-May-2008			
	Female - Gravid	63	11.09
	Female - Spent	135	23.77
	Male - Milt expressed	218	38.38
	Unknown Gender - Reproductive Condition Unknown / Not Checked	152	26.76
29-May-2008			
	Female - Gravid	47	9.48
	Female - Spent	44	8.87
	Male - Milt expressed	17	3.43
	Unknown Gender - Reproductive Condition Unknown / Not Checked	388	78.23

Composition Date	Gender/Reproductive Condition	Number Collected	Percent by Date
30-May-2008			
	Female - Spent	87	8.67
	Female - Gravid	51	5.08
	Male - Milt expressed	59	5.88
	Unknown Gender - Reproductive Condition Unknown / Not Checked	807	80.38
31-May-2008			
	Female - Gravid	37	7.60
	Female - Spent	45	9.24
	Male - Milt expressed	30	6.16
	Unknown Gender - Reproductive Condition Unknown / Not Checked	375	77.00
01-Jun-2008			
	Female - Gravid	57	15.16
	Female - Spent	61	16.22
	Male - Milt expressed	27	7.18
	Unknown Gender - Reproductive Condition Unknown / Not Checked	231	61.44
02-Jun-2008			
	Female - Gravid	47	36.15
	Female - Spent	28	21.54
	Male - Milt expressed	13	10.00
	Unknown Gender - Reproductive Condition Unknown / Not Checked	42	32.31
03-Jun-2008			
	Female - Spent	63	36.42
	Female - Gravid	41	23.70
	Male - Milt expressed	22	12.72
	Unknown Gender - Reproductive Condition Unknown / Not Checked	47	27.17
04-Jun-2008			
	Female - Gravid	26	17.11
	Female - Spent	47	30.92
	Male - Milt expressed	12	7.89
	Unknown Gender - Reproductive Condition Unknown / Not Checked	67	44.08
05-Jun-2008			
	Female - Gravid	38	28.57
	Female - Spent	54	40.60
	Male - Milt expressed	6	4.51
	Unknown Gender - Reproductive Condition Unknown / Not Checked	35	26.32
06-Jun-2008			
	Female - Gravid	26	19.12
	Female - Spent	58	42.65
	Male - Milt expressed	6	4.41
	Unknown Gender - Reproductive Condition Unknown / Not Checked	46	33.82

APPENDIX C
FISH SPECIES CATCH PER FYKE NET HOUR FISHED

Fish Species Catch per Fyke Net Hour Fished

Los Lunas Habitat Restoration Project Site - 2008

Species	20-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May	01-Jun	02-Jun	03-Jun	04-Jun	05-Jun	06-Jun
Ameiurus natalis	---	---	---	---	---	---	0.09	---	---	---	---	---	---	0.05	---	---
Carpiodes carpio	0.13	---	0.04	---	---	---	0.02	---	---	0.09	0.13	0.05	---	---	---	---
Catostomus commersonii	0.05	---	---	---	---	0.03	---	0.05	---	---	---	---	---	---	0.05	---
Cyprinella lutrensis	1.23	0.66	0.42	0.72	0.19	1.58	4.87	4.69	1.69	4.35	3.01	4.11	4.05	3.53	1.67	0.90
Cyprinus carpio	12.40	8.35	1.07	0.64	0.17	1.30	0.31	25.79	7.86	48.26	9.57	3.00	2.80	2.18	2.53	2.95
Gambusia affinis	5.39	---	---	---	---	---	---	---	0.19	---	---	---	---	0.05	0.05	0.10
Hybognathus amarus	14.18	16.23	66.97	34.26	8.32	13.79	10.48	22.80	48.39	21.41	16.90	6.84	8.34	7.90	6.73	6.80
Ictalurus punctatus	0.01	---	0.02	---	0.02	0.03	---	---	---	0.04	---	0.16	---	0.05	---	---
Lepomis cyanellus	0.03	---	0.01	---	0.02	---	0.02	---	---	0.13	---	---	---	---	---	---
Lepomis macrochirus	---	---	---	---	---	---	---	---	---	---	---	---	0.05	---	---	0.05
Perca flavescens	---	---	---	---	---	---	0.02	---	---	---	---	---	---	---	---	---
Pimephales promelas	---	---	0.13	---	0.02	0.10	0.06	0.05	---	0.13	---	---	0.10	0.16	0.05	---
Platygobio gracilis	0.15	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

APPENDIX D
WATER QUALITY BY DATE

Main Channel Water Quality by Date

Date	Time	Water Temp (C)	O^2 (% sat.)	Spec. Con. (uS/cm)	Salinity (ppt)	pH	Cloud Cover	Substrate	Wind Speed	Notes
5/20/2008	8:20:00 AM	17.50	78.30	265.40	0.10	8.03	25.00	SI	5	
5/23/2008	9:17:00 AM	14.60	73.50	261.60	0.10	8.33	100.00	SA	20-30	
5/24/2008	7:33:00 AM	14.30	72.80	257.70	0.10	8.41	10.00	SA	0-15	
5/25/2008	7:32:00 AM	15.60	69.50	266.10	0.10	8.31	0.00	SA	0-10	
5/25/2008	12:50:00 PM	18.00	90.20	266.80	0.10	8.45	0.00	SA	0-10	
5/26/2008	7:24:00 AM	16.30	66.70	258.90	0.10	8.54	0.00	SA	0-10	
5/26/2008	1:45:00 PM	19.00	69.40	257.60	0.10	8.40	0.00	SA	0-10	
5/27/2008	7:07:00 AM	15.85	71.20	241.00	0.11	7.86	0.00	SA	0-10	used different water qual meter
5/27/2008	2:30:00 PM	18.86	84.10	242.00	0.12	8.14	0.00	SA	0-10	used different water qual meter
5/28/2008	7:23:00 AM	16.70	72.40	255.00	0.10	8.72	0.00	SA	0-10	
5/29/2008	7:14:00 AM	17.60	63.80	255.70	0.10	8.56	0.00	SA	0-10	
5/29/2008	2:30:00 PM	20.90	87.70	258.30	0.10	8.45	0.00	SA	0-10	
5/30/2008	2:10:00 PM	20.60	79.90	252.40	0.10	8.89	0.00	SA	0-10	
5/30/2008	7:19:00 AM	17.40	70.10	259.00	0.10	8.61	0.00	SA	0-10	
5/31/2008	2:53:00 PM	21.20	81.50	259.50	0.10	8.54	10.00	SA	0	
5/31/2008	7:15:00 AM	17.50	71.20	259.70	0.10	8.70	10.00	SA	0	
6/1/2008	7:30:00 AM	17.80	83.50	259.50	0.10	8.71	0.00	SA	0-10	
6/1/2008	2:53:00 PM	21.70	103.80	260.50	0.10	8.90	0.00	SA	0-10	
6/2/2008	7:21:00 AM	18.40	83.60	258.40	0.10	8.87	0.00	SA	0-10	
6/2/2008	1:45:00 PM	21.10	77.20	260.80	0.10	8.80	0.00	SA	0-10	
6/3/2008	7:32:00 AM	17.90	67.50	260.30	0.10	8.90	0.00	SA	0-10	
6/3/2008	2:10:00 PM	20.90	91.90	260.10	0.10	8.98	0.00	SA	0-10	
6/4/2008	7:30:00 AM	17.80	72.30	258.30	0.10	8.92	0.00	SA	0-10	
6/4/2008	1:55:00 PM	20.20	94.10	257.10	0.10	8.94	0.00	SA	0-10	
6/5/2008	7:26:00 AM	16.60	70.60	256.30	0.10	9.08	95.00	SA	10-15 from SW	
6/5/2008	1:37:00 PM	18.40	88.50	255.40	0.10	9.20	95.00	SA	30-40 from west	increased oxygen saturation possibly occurring because of wind-induced aeration
6/6/2008	2:24:00 PM	19.60	111.90	251.20	0.10	9.04	0.00	SA	0	
6/6/2008	7:44:00 AM	15.90	70.40	251.60	0.10	9.27	0.00	SA	0	

Summary for 28 detail records

	Water Temp (C)	O^2 (% sat.)	Spec. Con. (uS/cm)	Salinity (ppt)	pH	Cloud Cover
Avg	*18.15*	*79.20*	*257.36*	*0.10*	*8.66*	*12.32*
Min	*14.30*	*63.80*	*241.00*	*0.10*	*7.86*	*0.00*
Max	*21.70*	*111.90*	*266.80*	*0.12*	*9.27*	*100.00*

Floodplain Water Quality by Net Site

Net	Date	Time	Depth (ft)	Velocity (m/sec)	Water Temp (C)	O² (% sat.)	Spec. Con. (uS/cm)	Salinity (ppt)	pH	Cloud Cover	Substrate	Wind Speed	Notes
101													
	5/20/2008	8:40:00 AM	1.20	0.00	19.00	31.20	312.70	0.20	8.07	25.00	SI	5	
	5/23/2008	1:20:00 PM	1.80	0.00	16.30	62.30	268.30	0.10	8.51	100.00	SI	20-30	
	5/24/2008	7:47:00 AM	2.30	0.09	13.60	62.80	284.50	0.10	8.56	10.00	SI	0-15	
	5/25/2008	2:00:00 PM	2.80	0.20	21.30	82.80	284.90	0.10	8.25	0.00	SI	0-10	
	5/26/2008	12:30:00 PM	2.60	0.29	19.90	75.10	266.00	0.10	8.41	0.00	SI	0-10	
	5/27/2008	1:40:00 PM	2.60	0.22	20.60	92.10	251.00	0.12	8.17	0.00	SI-CL	0-10	used different water qual meter
	5/27/2008	8:21:00 AM	2.70	0.22	15.64	67.80	247.00	0.12	7.88	0.00	SI-CL	0-10	used different water qual meter
	5/28/2008	7:36:00 AM	2.40	0.21	16.30	78.10	262.20	0.10	8.49	0.00	SI-CL	0-10	
	5/29/2008	1:26:00 PM	2.00	0.04	24.90	110.40	263.90	0.10	8.86	0.00	CL	0-10	
	5/30/2008	12:09:00 PM	1.70	0.00	20.50	50.20	285.00	0.10	8.79	0.00	CL	0-10	
	5/31/2008	12:25:00 PM	2.00	0.00	21.40	68.20	298.00	0.10	8.90	10.00	CL	0	
	6/1/2008	12:28:00 PM	2.10	0.03	21.00	109.90	263.80	0.10	8.77	0.00	CL	0-10	
	6/2/2008	12:02:00 PM	2.40	0.09	23.30	87.30	266.00	0.10	8.97	0.00	CL	0-10	
	6/3/2008	12:40:00 PM	2.20	0.08	22.70	106.50	264.30	0.10	9.06	0.00	CL	0-10	
	6/4/2008	12:19:00 PM	2.20	0.07	22.30	114.30	261.50	0.10	9.07	0.00	CL	0-10	
	6/5/2008	12:24:00 PM	2.10	0.06	19.50	125.90	258.50	0.10	9.48	95.00	CL	30-40 from west	increased oxygen saturation possibly occurring because of wind-induced aeration
	6/6/2008	12:29:00 PM	2.10	0.14	20.00	142.30	249.60	0.10	9.50	0.00	CL	0	
	Summary for 'Net' = 101 (17 detail records)												
		Avg	*2.19*	*0.10*	*19.90*	*86.31*	*269.84*	*0.11*	*8.69*	*14.12*			
		Min	*1.20*	*0.00*	*13.60*	*31.20*	*247.00*	*0.10*	*7.88*	*0.00*			
		Max	*2.80*	*0.29*	*24.90*	*142.30*	*312.70*	*0.20*	*9.50*	*100.00*			

Net	Date	Time	Depth (ft)	Velocity (m/sec)	Water Temp (C)	O² (% sat.)	Spec. Con. (uS/cm)	Salinity (ppt)	pH	Cloud Cover	Substrate	Wind Speed	Notes
102													
	5/20/2008	11:15:00 AM	0.70	0.01	24.80	84.20	279.20	0.10	8.29	25.00	SI	5	
	5/23/2008	12:50:00 PM	1.40	0.00	15.80	79.60	261.60	0.10	8.48	100.00	SI-CL	20-30	
	5/24/2008	10:19:00 AM	1.80	0.02	15.80	74.60	335.70	0.20	8.50	10.00	SI	0-15	
	5/25/2008	1:55:00 PM	2.30	0.03	20.60	84.30	286.40	0.10	8.43	0.00	SI	0-10	
	5/26/2008	1:05:00 PM	2.20	0.08	20.50	65.40	267.90	0.10	8.38	0.00	SI	0-10	
	5/27/2008	12:00:00 PM	2.00	0.04	19.30	85.40	255.00	0.12	7.95	0.00	SI-CL	0-10	used different water qual meter
	5/28/2008	7:36:00 AM	2.40	0.21	16.30	78.10	262.20	0.10	8.49	0.00	SI-CL	0-10	
	5/28/2008	12:30:00 PM	2.40	0.13	21.00	85.60	243.20	0.10	8.56	0.00	SI-CL	0-10	
	5/29/2008	1:26:00 PM	2.00	0.04	24.90	110.40	263.90	0.10	8.86	0.00	CL	0-10	
	5/30/2008	12:09:00 PM	1.70	0.00	20.50	50.20	285.00	0.10	8.79	0.00	CL	0-10	
	5/31/2008	12:25:00 PM	2.00	0.00	21.40	68.20	298.00	0.10	8.90	10.00	CL	0	
	6/1/2008	12:28:00 PM	2.10	0.03	21.00	109.90	263.80	0.10	8.77	0.00	CL	0-10	
	6/2/2008	12:02:00 PM	2.40	0.09	23.30	87.30	266.00	0.10	8.97	0.00	CL	0-10	
	6/3/2008	12:40:00 PM	2.20	0.08	22.70	106.50	264.30	0.10	9.06	0.00	CL	0-10	
	6/4/2008	12:19:00 PM	2.20	0.07	22.30	114.30	261.50	0.10	9.07	0.00	CL	0-10	
	6/5/2008	12:24:00 PM	2.10	0.06	19.50	125.90	258.50	0.10	9.48	95.00	CL	30-40 from west	increased oxygen saturation possibly occurring because of wind-induced aeration
	6/6/2008	12:29:00 PM	2.10	0.14	20.00	142.30	249.60	0.10	9.50	0.00	CL	0	

Summary for 'Net' = 102 (17 detail records)

	Depth (ft)	Velocity (m/sec)	Water Temp (C)	O² (% sat.)	Spec. Con. (uS/cm)	Salinity (ppt)	pH	Cloud Cover
Avg	*2.00*	*0.06*	*20.57*	*91.31*	*270.69*	*0.11*	*8.73*	*14.12*
Min	*0.70*	*0.00*	*15.80*	*50.20*	*243.20*	*0.10*	*7.95*	*0.00*
Max	*2.40*	*0.21*	*24.90*	*142.30*	*335.70*	*0.20*	*9.50*	*100.00*

Net	Date	Time	Depth (ft)	Velocity (m/sec)	Water Temp (C)	O^2 (% sat.)	Spec. Con. (uS/cm)	Salinity (ppt)	pH	Cloud Cover	Substrate	Wind Speed	Notes
103													
	5/20/2008	1:15:00 PM	1.10	0.00	26.90	75.80	273.80	0.10	8.32	25.00	SI	5	
	5/23/2008	12:25:00 PM	1.20	0.40	16.00	78.40	261.50	0.10	8.47	100.00	SI	20-30	
	5/24/2008	10:35:00 AM	1.80	0.37	15.70	78.40	253.00	0.10	8.45	10.00	SI	0-15	
	5/25/2008	1:30:00 PM	0.80	0.17	18.70	83.80	268.20	0.10	8.42	0.00	SI	0-10	
	5/26/2008	8:35:00 AM	0.90	0.23	16.40	63.60	262.00	0.10	8.35	0.00	SI	0-10	
	5/27/2008	12:40:00 PM	0.80	0.11	18.37	87.10	244.00	0.12	8.13	0.00	SI-CL	0-10	used different water qual meter
	5/28/2008	1:15:00 PM	0.80	0.15	19.90	89.50	255.50	0.10	8.55	0.00	SI-CL	0-10	
	5/29/2008	1:00:00 PM	1.60	0.26	21.20	92.30	259.60	0.10	8.64	0.00	CL	0-10	
	5/30/2008	1:20:00 PM	0.90	0.25	21.50	86.90	261.10	0.10	8.68	0.00	CL	0-10	
	5/31/2008	1:46:00 PM	1.50	0.34	22.00	90.30	262.40	0.10	8.74	10.00	CL	0	
	6/1/2008	1:50:00 PM	1.60	0.26	22.00	119.90	261.40	0.10	8.71	0.00	CL	0-10	
	6/2/2008	12:50:00 PM	1.70	0.34	20.90	83.30	262.00	0.10	8.71	0.00	CL	0-10	
	6/3/2008	1:20:00 PM	1.60	0.34	21.20	101.90	262.30	0.10	9.10	0.00	CL	0-10	
	6/4/2008	1:07:00 PM	1.70	0.35	20.80	99.80	255.70	0.10	8.90	0.00	CL	0-10	
	6/5/2008	12:57:00 PM	1.60	0.42	19.30	102.10	255.80	0.10	9.05	95.00	CL	30-40 from west	increased oxygen saturation possibly occurring because of wind-induced aeration
	6/6/2008	1:15:00 PM	1.70	0.50	19.80	116.10	252.80	0.10	9.29	0.00	CL	0	
	Summary for 'Net' = 103 (16 detail records)												
		Avg	*1.33*	*0.28*	*20.04*	*90.58*	*259.44*	*0.10*	*8.66*	*15.00*			
		Min	*0.80*	*0.00*	*15.70*	*63.60*	*244.00*	*0.10*	*8.13*	*0.00*			
		Max	*1.80*	*0.50*	*26.90*	*119.90*	*273.80*	*0.12*	*9.29*	*100.00*			

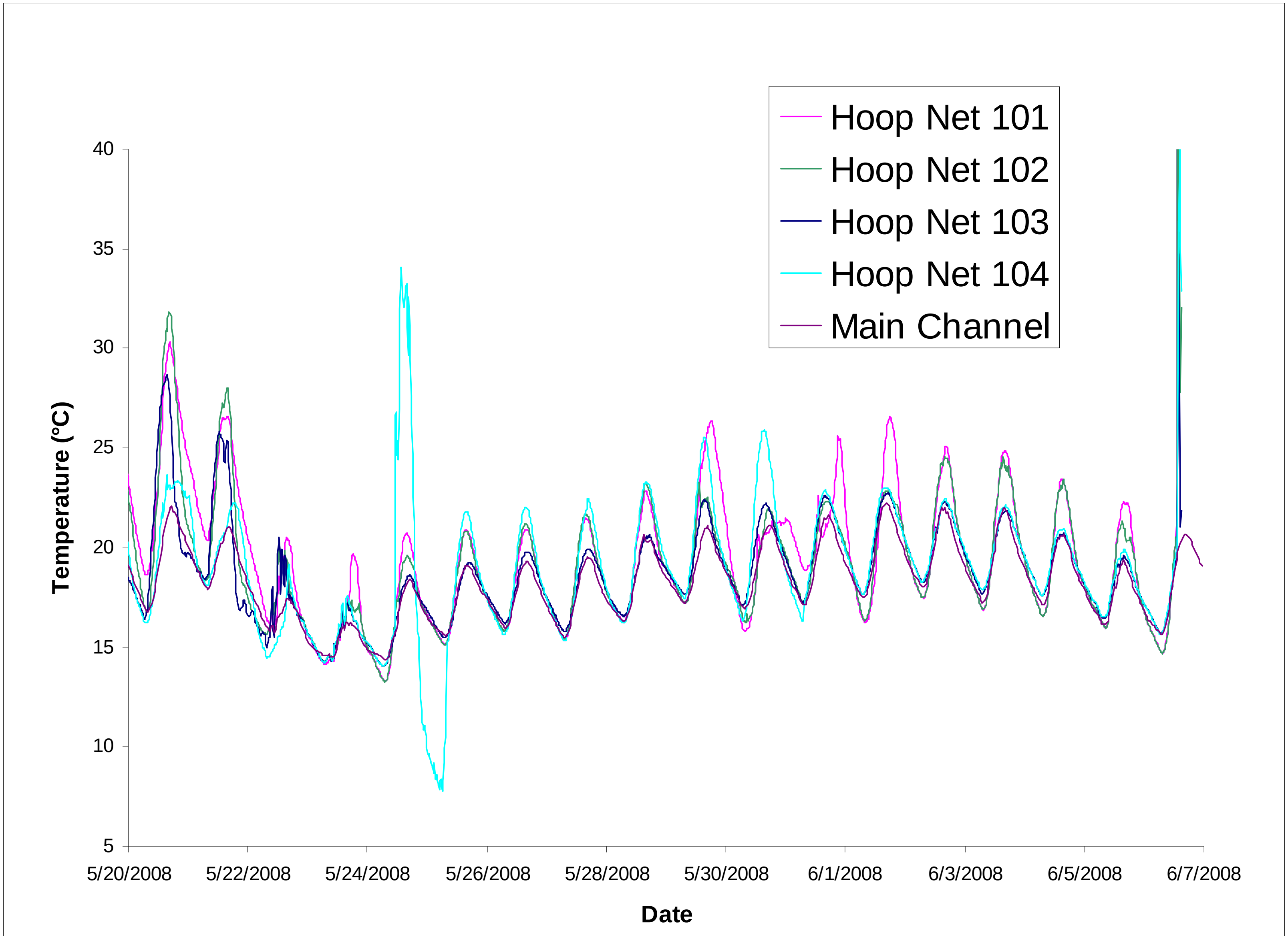
Net	Date	Time	Depth (ft)	Velocity (m/sec)	Water Temp (C)	O^2 (% sat.)	Spec. Con. (uS/cm)	Salinity (ppt)	pH	Cloud Cover	Substrate	Wind Speed	Notes
104													
	5/20/2008	1:35:00 PM	1.70	0.00	23.90	100.50	268.30	0.10	8.65	25.00	SI	5	
	5/23/2008	11:55:00 AM	2.30	0.07	15.50	76.00	262.00	0.10	8.63	100.00	SI	20-30	
	5/24/2008	11:15:00 AM	2.60	0.29	16.10	77.10	260.50	0.10	8.40	10.00	SI	0-15	
	5/25/2008	1:10:00 PM	2.40	0.33	20.40	91.50	289.10	0.10	8.38	0.00	TV	0-10	
	5/26/2008	8:00:00 AM	2.30	0.28	15.70	58.00	274.50	0.10	8.55	0.00	TV	0-10	
	5/27/2008	1:11:00 PM	1.90	0.40	20.51	95.20	252.00	0.12	8.27	0.00	SI-CL	0-10	used different water qual meter
	5/28/2008	1:50:00 PM	2.10	0.27	22.40	121.50	263.20	0.10	8.74	0.00	SI-CL	0-10	
	5/29/2008	12:26:00 PM	1.80	0.21	22.50	129.90	261.20	0.10	8.89	0.00	CL	0-10	
	5/30/2008	1:40:00 PM	1.40	0.08	25.00	133.00	260.60	0.10	9.28	0.00	CL	0-10	
	5/31/2008	2:17:00 PM	1.70	0.08	22.50	87.40	262.70	0.10	8.78	10.00	CL	0	
	6/1/2008	2:20:00 PM	2.20	0.14	22.50	116.40	261.50	0.10	8.70	0.00	CL	0-10	
	6/2/2008	1:13:00 PM	2.50	0.07	21.30	83.10	262.80	0.10	8.82	0.00	CL	0-10	
	6/3/2008	1:42:00 PM	2.50	0.09	21.70	92.30	262.30	0.10	9.08	0.00	CL	0-10	
	6/4/2008	1:20:00 PM	2.40	0.10	20.80	98.30	258.50	0.10	8.92	0.00	CL	0-10	
	6/5/2008	1:15:00 PM	2.50	0.09	19.50	99.10	257.60	0.10	9.23	95.00	CL	30-40 from west	increased oxygen saturation possibly occurring because of wind-induced aeration
	6/6/2008	1:35:00 PM	2.60	0.09	20.20	116.30	252.20	0.10	9.25	0.00	CL	0	
	Summary for 'Net' = 104 (16 detail records)												
		Avg	*2.18*	*0.16*	*20.66*	*98.48*	*263.06*	*0.10*	*8.79*	*15.00*			
		Min	*1.40*	*0.00*	*15.50*	*58.00*	*252.00*	*0.10*	*8.27*	*0.00*			
		Max	*2.60*	*0.40*	*25.00*	*133.00*	*289.10*	*0.12*	*9.28*	*100.00*			

APPENDIX E
RIO GRANDE SILVERY MINNOW COLLECTIONS BY WATER VELOCITY CATEGORY

Chronological Record of Rio Grande Silvery Minnow Collections by Water Velocity Category

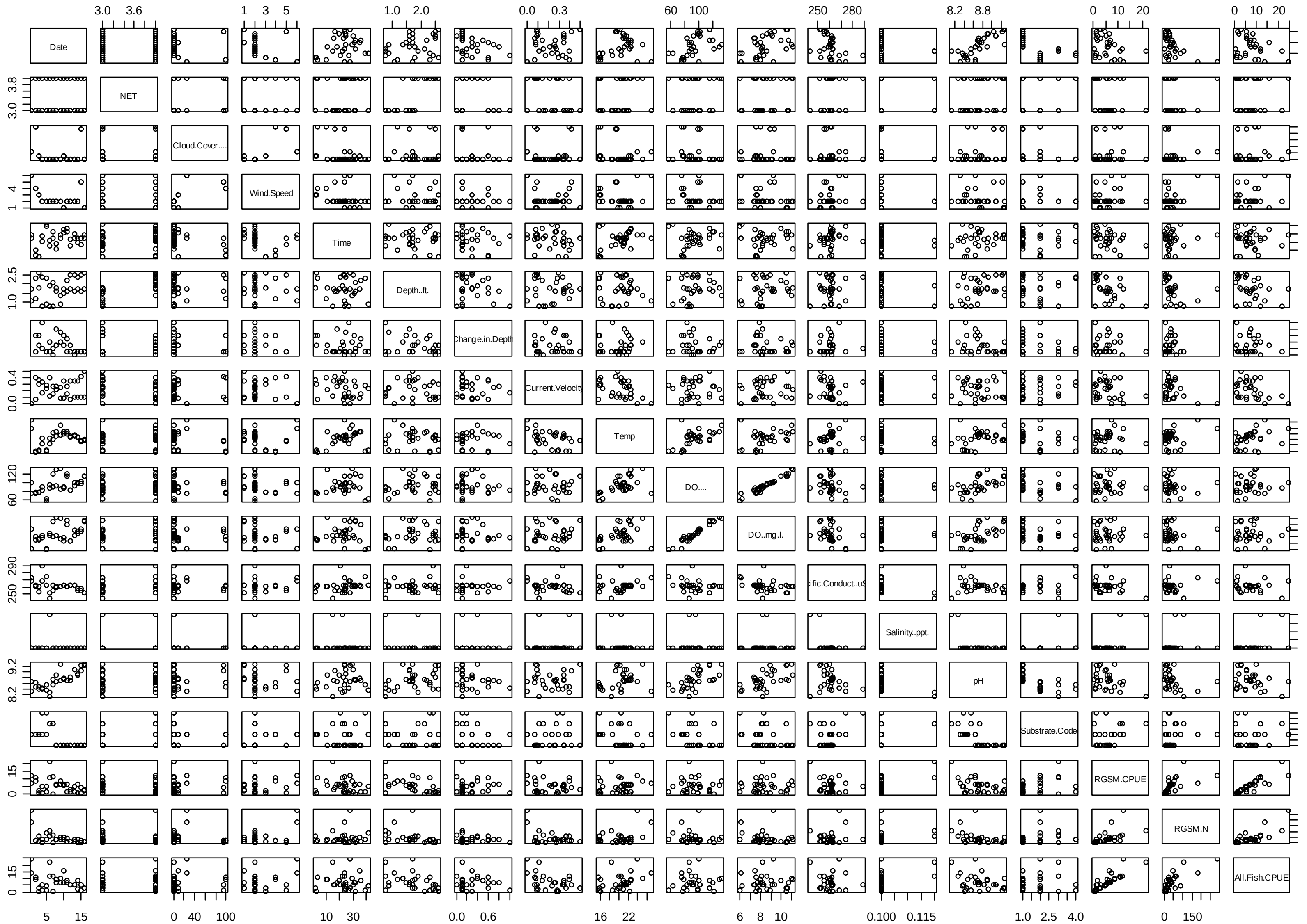
Velocity Type	Date	Female (gravid)	Female (spent)	Male (milt)	Not Checked	Unknown
High Velocity						
	5/20/2008	91	0	0	0	377
	5/23/2008	24	0	10	0	13
	5/24/2008	34	0	29	0	9
	5/25/2008	5	7	5	0	18
	5/26/2008	7	31	35	0	44
	5/27/2008	46	66	32	0	23
	5/28/2008	11	14	20	0	23
	5/29/2008	15	9	9	0	28
	5/30/2008	23	19	12	5	29
	5/31/2008	10	26	16	0	29
	6/1/2008	15	18	8	0	12
	6/2/2008	13	3	2	0	5
	6/3/2008	10	15	4	0	8
	6/4/2008	9	15	4	0	10
	6/5/2008	9	13	0	0	9
	6/6/2008	7	16	0	0	8
	Summary for 'Velocity Type' = High Velocity (16 detail records)					
	Avg	*20.56*	*15.75*	*11.63*	*0.31*	*40.31*
Low Velocity						
	5/20/2008	167	0	2	95	583
	5/23/2008	59	0	45	0	19
	5/24/2008	62	0	26	3464	1962
	5/25/2008	129	243	160	0	223
	5/26/2008	16	98	75	0	83
	5/27/2008	45	181	70	0	74
	5/28/2008	49	120	198	0	127
	5/29/2008	20	35	8	318	37
	5/30/2008	25	68	43	692	79
	5/31/2008	23	19	14	299	45
	6/1/2008	36	42	19	190	28
	6/2/2008	32	25	11	0	37
	6/3/2008	28	48	17	0	38
	6/4/2008	16	32	8	0	56
	6/5/2008	24	41	6	0	26
	6/6/2008	17	42	6	0	36
	Summary for 'Velocity Type' = Low Velocity (16 detail records)					
	Avg	*46.75*	*62.13*	*44.25*	*316.13*	*215.81*

APPENDIX F
HOBO PLOTS/DATA


Hoop Net 101
Hoop Net 102
Hoop Net 103
Hoop Net 104
Main Channel
Temperature (°C)
40
35
30
25
20
15
10
5
5/20/2008
5/22/2008
5/24/2008
5/26/2008
5/28/2008
5/30/2008
6/1/2008
6/3/2008
6/5/2008
6/7/2008
Date

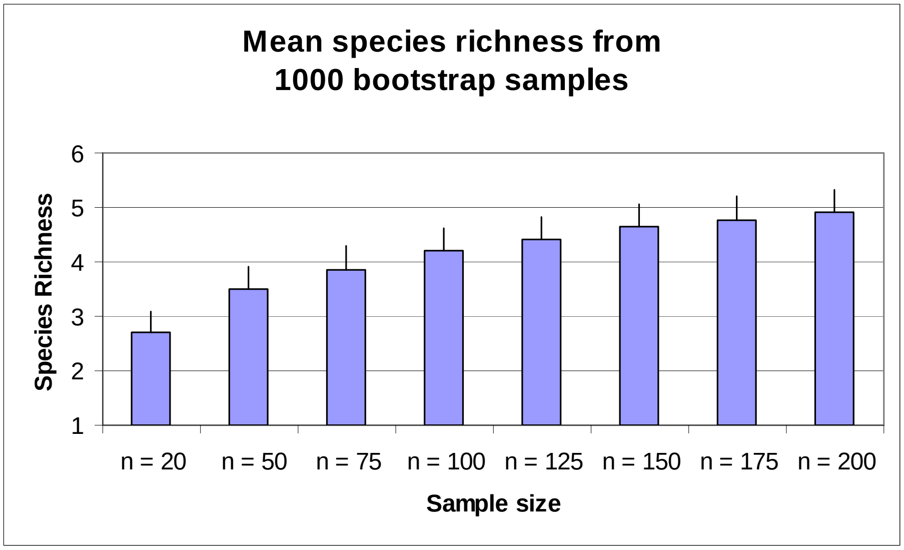
APPENDIX G
BIVARIATE PLOTS

Pairs plot of environmental variables for sample sites 101 and 102. Plots are arranged in a matrix with plot scales constant over the rows and columns of the matrix.

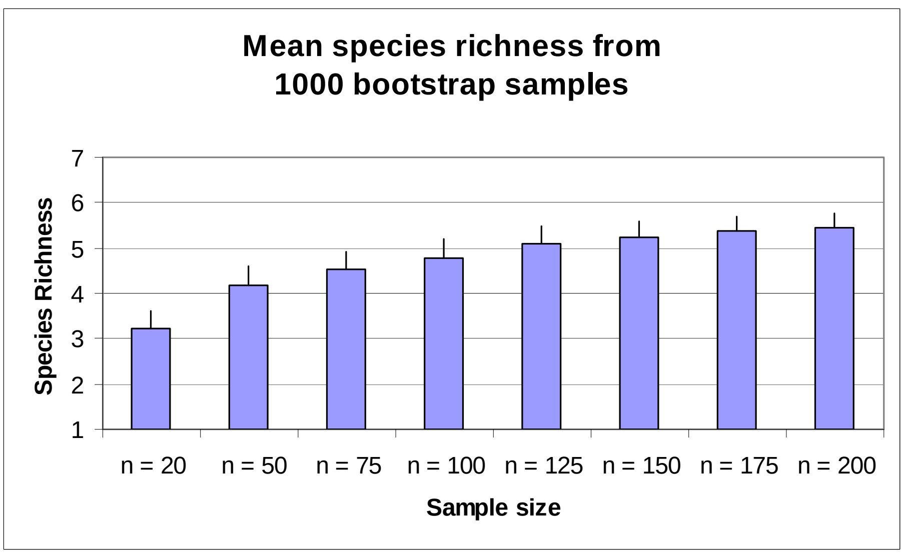


Pairs plot of environmental variables for sample sites 103 and 104. Plots are arranged in a matrix with plot scales constant over the rows and columns of the matrix.

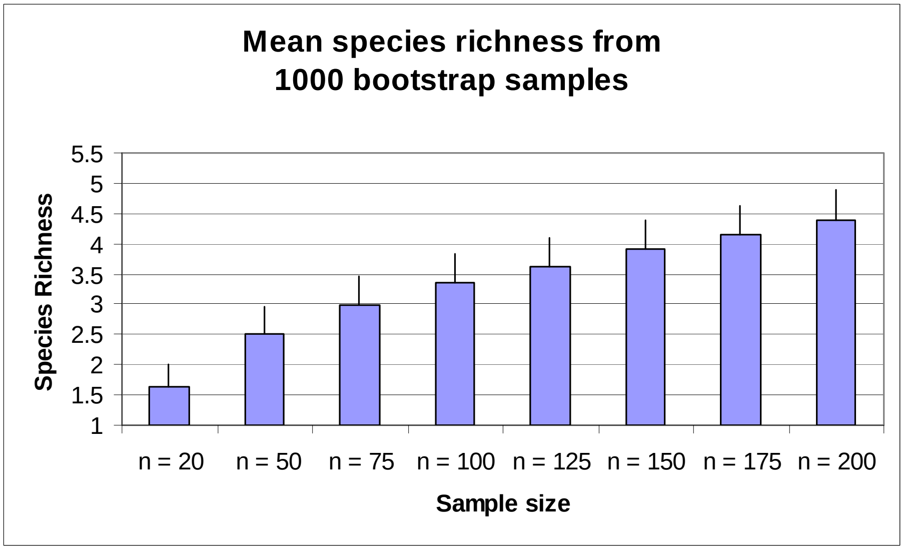
APPENDIX H
BOOTSTRAP ANALYSIS OF MAIN CHANNEL SEINE SAMPLES ADJACENT TO THE LOS LUNAS HABITAT RESTORATION PROJECT SITE



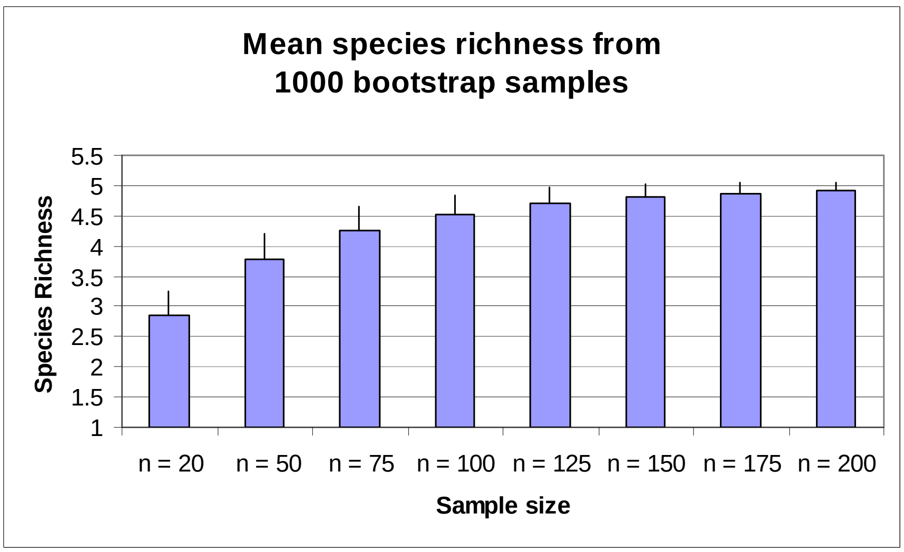
29-Nov-2007 (actual n = 52)



20-Dec-2007 (actual n = 61)



23-Jan-2008 (actual n = 35)



20-Feb-2008 (actual n = 39)

APPENDIX I
PHOTOGRAPHS

Photos I.1 and I.2. Main channel monitoring conducted adjacent to the Los Lunas Habitat Restoration Project site on November 29, 2007.

Photos I.3 and I.4. Main channel monitoring conducted adjacent to the Los Lunas Habitat Restoration Project site on January 23, 2008.

Photo I.5. Silvery minnow captured during main channel monitoring on January 23, 2008.

Photo I.6. Main channel monitoring conducted adjacent to the Los Lunas Habitat Restoration Project site on February 20, 2008.

Photo I.7 and I.8. View of the Los Lunas Habitat Restoration Project site prior to inundation on March 11, 2008.

Photo I.9. Crew member collecting water quality data from fyke net site 101 on May 20, 2008.

Photo I.10. Fyke net site 102 on May 20, 2008.

Photo I.11. Fyke net site 103 on May 20, 2008.

Photo I.12. Fyke net site 104 on May 23, 2008.

Photo I.13. Gravid silvery minnow collected on May 23, 2008.