Los Lunas Habitat Restoration Fisheries Monitoring – 2009

Prepared for

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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 (*Hybognathus amarus*; silvery minnow) reproduction and recruitment. The Los Lunas Habitat Restoration Project area is located approximately 5.0 km (3.1 miles) south of Los Lunas along the west bank of the Rio Grande.

A temporal change in rank abundance is used to chronicle changes in species diversity in running water habitats of the main channel adjacent to the Los Lunas Habitat Restoration Project area. Pool and backwater mesohabitat features were absent from the sample area as flow increased. This reduced habitat complexity accounts in part for the lower species richness observed in January and February 2009 samples. The species that were absent from these collections were, with the exception of flathead chub (*Platygobio gracilis*), species with strong affinities for pool and backwater mesohabitats.

Results of synoptic fish surveys in floodplain habitats were examined to elucidate how faunal assemblages at the Los Lunas Habitat Restoration Project area are structured by underlying physical, chemical, and hydrologic features of the environment. Occupancy of the floodplain by reproductively mature silvery minnow was documented over the duration of sampling (May 9–29, 2009). Reproductively mature males and females were most commonly found at sample sites where low-velocity flows predominated.

Median silvery minnow catch per unit effort (CPUE) was significantly higher from May 9 to 18, 2009, during the ascending hydrograph as compared to the median CPUE from May 19 to 29, 2009, a period where mixed hydrologic conditions prevailed (i.e., rapidly descending and ascending hydrograph). The decline in catch rates also coincided with reduced differences in average and maximum water temperatures in main channel and floodplain habitats. Mean weekly silvery minnow CPUE was highest at floodplain sample sites that were farthest removed from the main channel thalweg.

Patterns of community composition indicate that fauna-environment interactions of the floodplain favor colonizing species, including silvery minnow, red shiner (*Cyprinella lutrensis*), and common carp (*Cyprinus carpio*). Together these three species numerically comprise approximately 98.0% of the floodplain fauna. Classification of species by reproductive guild provides an ecological classification of species that represent a synthesis of adult spawning behavior and embryonic development—multiple aspects of life history fundamental to species survival. Non-guarding, open substrate spawning lithopelagophils, represented in floodplain collections by silvery minnow and river carpsucker (*Carpiodes carpio*), was the most abundant reproductive guild. Non-guarding, brood hiding speleophils (represented by red shiner) was the second most abundant reproductive guild. Non-guarding, open substrate spawning phytolithophils (represented solely by common carp) was also a numerically prominent component of the floodplain fauna.

The relatively low faunal similarity of the main channel and floodplain habitats associated with the Los Lunas Habitat Restoration Project to the larger faunal assemblage of the Isleta Reach suggests a localized monotony of main channel habitat features that may limit overall localized

community diversity. The relatively low faunal similarity also suggests that the species saturation of the area depends significantly on annual species-specific reproduction cycles and high flows that serve to facilitate dispersal of advanced life stage fish. Whereas higher flows (i.e., those in which floodplain and main channel habits become confluent) can be regarded as 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.

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 a range of spatial and temporal scales. Significantly, the contemporary hydrologic disturbance regime of the Middle Rio Grande, which also serves to reduce the diversity and abundance of predatory fish species, disadvantages nest-guarding lithophils. However, these generalizations will not apply if the fundamental aspects of the hydrologic disturbance regime are radically altered.

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Cover Photo

Photo of gravid Rio Grande silvery minnow (*Hybognathus amarus*; 45 mm).

INTRODUCTION

New Mexico is the third most arid state in the United States, receiving less than 50.8 cm (20 inches) of precipitation annually over 90% 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[1] (MRG) 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 the hydrologic regime of the MRG for at least 400 years (Scurlock 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 fishes. Over the course of history, 13 native fish taxa, representing eight families (48% 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 (*Hybognathus amarus*: silvery minnow) 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 (USFWS) published a final rule to list the silvery minnow as a federal endangered species with proposed critical habitat (Federal Register 1994).

River engineering of the MRG has confined the river, isolating it from the adjacent floodplain. Unaltered, the flow regime of the MRG would seasonally inundate adjacent floodplains and provide a diversity of habitats and refuge for developing stages of fish relative to the main channel.

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 (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 significant and may affect the trajectory of local population growth.

The Los Lunas Habitat Restoration Project is designed in part to recouple a portion of the MRG with its floodplain to enhance silvery minnow reproduction and recruitment. This project replicates important aspects of the study conducted in 2008 by Hatch and Gonzales (2008). Results of main channel and floodplain habitat fish surveys are examined to determine how the fish community in the project area is structured by physical, chemical, and hydrologic features of

[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.

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.

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 (RPA) Element J. The Los Lunas Habitat Restoration Project is intended in part to fulfill the restoration requirement in one of these subreaches. The project area 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. RPA Element 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 mandates habitat restoration projects that would improve survival of all life stages of the silvery minnow and other endangered species. The 2003 BO identifies the need for increased availability of low-velocity habitat and silt and sand substrates to provide food, shelter, and sites for silvery minnow reproduction to 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 area. Restoration of the area began in April 2002 with the removal 1,400 Kellner jetty jacks. Following jetty jack removal, approximately 40 acres (16.19 hectares) of the west bank floodplain was mechanically lowered and reseeded or planted with potted shrubs, cottonwood (*Populus deltoides* ssp. *wislizeni*), and willow (*Salix* sp.) poles (Siegle 2006).

The Los Lunas Habitat Restoration Project area is only intermittently inundated, usually during high runoff. Likewise, flow in the river adjacent to the restoration area is known to diminish sufficiently during the latter part of an irrigation season to dry a segment of the river in the Isleta Reach that includes the study area (e.g., 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 October 31, 2007). The flow regime for the Isleta Reach is relatively predictable, characterized by a large spring runoff from snowmelt that tapers after several months to summer base flow conditions. Following the irrigation season, with reduced consumptive use of water and reduced seasonal effects from evaporation and transpiration, flow in the river increases, typically in November, to a winter-spring base flow, which even in a dry year is predictably sufficient to maintain through-flowing conditions. 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 area. Varied topography, including secondary channels, inlets, and backwater design features, allows for partial inundation of these habitat features at lower flows.

Fisheries monitoring was conducted by Reclamation at the Los Lunas Habitat Restoration Project area from 2004 to 2006. During 2004 silvery minnow were absent from samples obtained by seining and electrofishing (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 minnow constituted 5% of fish captured in fyke nets (Beck and Fluder 2006) and 37% of fish captured via electrofishing (Porter and Dean 2006). In 2008, silvery minnow comprised 69.8% of fish species captured in spring (May 20–June 6) fyke net samples in inundated floodplain habitats of the project area (Hatch and Gonzales 2008).

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 MRG

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

Data in Table 1 represent pooled results from recent surveys composed 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), Hatch and Gonzales (2008), and Gonzales and Hatch (2009). Native (*n*) and non-native (*e*) determinations follow Sublette et al. (1990). Each species is assigned a rank abundance value based on its relative abundance. The most abundant species was assigned a value of “1.” Subsequent ascending rank assignments are assigned in descending order of relative abundance.

SAMPLING CHRONOLOGY AND HYDROLOGIC SETTING

Sampling for fish was conducted monthly in the Rio Grande adjacent to the Los Lunas Habitat Restoration Project area on five occasions between the 2008 and 2009 irrigation seasons (i.e., 31-Oct-2008, 21-Nov-2008, 19-Dec-2008, 27-Jan-2009, and 19-Feb-2009; Figure 1). Over the period of sampling, water discharge increased abruptly from a low of 210 cfs on October 31, 2008, to a plateau ranging generally from 700 to 830 cfs over the latter half of December 2008 through most of February 2009 (see Figure 1).

Figure 1. Bosque Farms hydrograph (U.S. Geological Survey data) during the approximate period of sampling in main channel of the MRG adjacent to the Los Lunas Habitat Restoration Project area.

Main channel sampling dates are indicated by red triangles (i.e., 31-Oct-2008, 21-Nov-2008, 19-Dec-2008, 27-Jan-2009, and 19-Feb-2009). Over this period of record, flow remained well below the 2,500-cfs threshold level necessary to couple the river with floodplain habitats of the Los Lunas Habitat Restoration Project area. This gauge is not maintained at flows > 800 cfs; however, the data from this site are used as a relative assessment of flow variability throughout monitoring.

Three floodplain sites (FN1, FN3, and FN4; Figure 2) at the Los Lunas Habitat Restoration Project area were sampled for silvery minnow eggs, fish larvae, and post-larval silvery minnow for 15 out of 21 days over the period of May 9 to 29, 2009. One floodplain site (FN2; see Figure 2) was sampled for 14 out of 21 days over this same period. Flow in the main channel varied from a low of 3,950 cfs on May 9, 2009, to a high of 5,060 cfs on May 17, 2009, as measured at the U.S. Geological Survey (USGS) Bosque Farms gage (Figure 3).

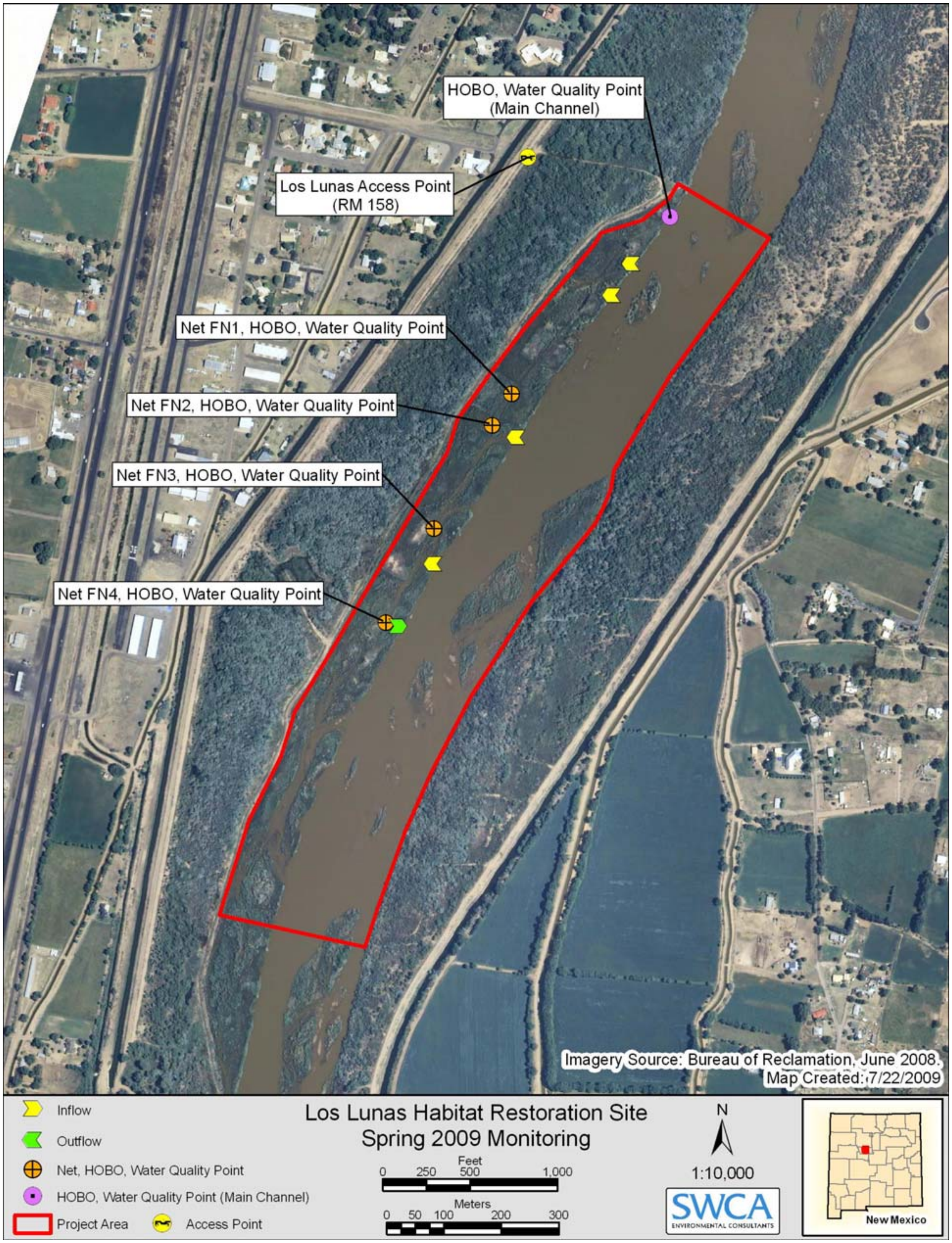

Figure 2. Los Lunas Habitat Restoration Project area at approximately River Mile 158. Aerial photo taken June 2008 by Reclamation.

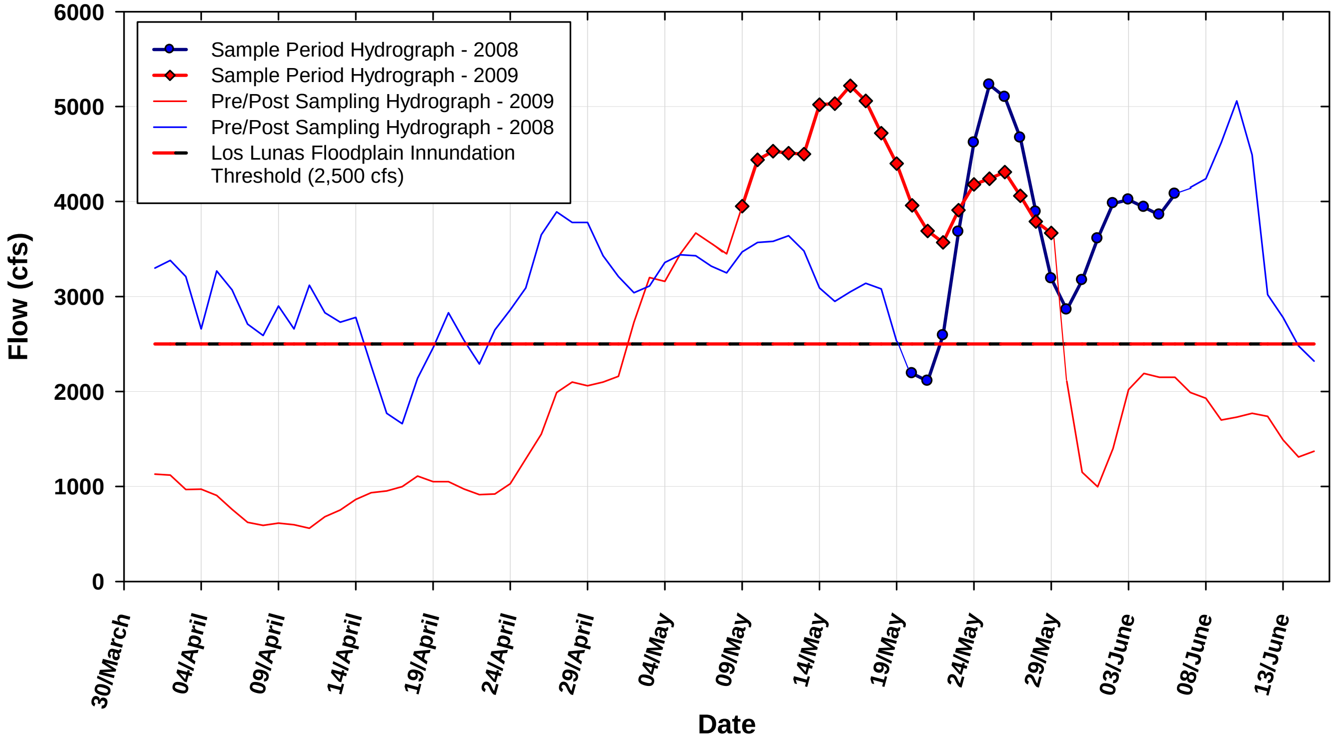

Figure 3. Bosque Farms hydrographs (USGS Data) for the spring of 2008 (blue line) and 2009 (red line).

Floodplain sampling for fish occurred on 16 out of 18 days over the period from May 20 to June 6, 2008 (blue circle line segment). Floodplain sampling for fish occurred on 15 out of 21 days over the period May 9 to May 29, 2009 (red diamond line segment). Note: Flows greater than 2,500 cfs (red-black dashed line) are sufficient to inundate floodplain habitats over the areal extent of the Los Lunas Habitat Restoration Project area. Because one long-term focus of study is to learn how the system behaves under the contrasting hydrological conditions, such as those in 2008 and 2009, it is important to note that mean flow for the 2008 and 2009 sample periods are statistically different ($t = -2.518$ with 38 degrees of freedom; $P = 0.016$). Mean flow for the 2009 sample period was 571.72 cfs higher than the mean flow for the 2008 sample period (95% confidence interval for difference of means: 1,031.286–112.148).

Three of the sample sites (FN1, FN2, and FN4) were distinguished by low-velocity flows (velocities generally < 0.05 m/s) (Table 2, Figure 4). At the remaining site, FN3, moderate-velocity flow (i.e., water velocities > 0.05 m/s and < 0.30 m/s) generally prevailed over the sample period (see Table 2, Figure 4).

Sampling effort within floodplain habitats was allotted over weekly strata. Week intervals extended from Sunday to Saturday. Some weekly strata did not include an equal number of sample days due to abbreviated sampling during a specific calendar week. Weekly floodplain sample sizes were: May 3–9 (week 19; N = 1), May 10–16 (week 20; N= 4), May 17–23 (week 21; N = 5), and May 24–29 (week 22, N = 5).

Table 2. Weekly Average Water Velocities (m/s) at Floodplain Sample Sites of the Los Lunas Habitat Restoration Project, May 2009

	Floodplain Sample Sites			
	Low-velocity Sites			Moderate-velocity Site
Week* (sample size)	**FN1**	**FN2**	**FN4**	**FN3**
19 (1)	0.02	–	0.03	0.02
20 (4)	0.04	0.01	0.04	0.28
21 (5)	0.01	0.00	0.02	0.18
22 (5)	0.01	0.02	0.03	0.19
Overall Averages	0.02	0.01	0.03	0.17

*Week strata: May 3–9 (week 19), May 10–16 (week 20), May 17–23 (week 21), and May 24–29 (week 22). Low-velocity sites were distinguished by velocities generally < 0.05 m/s. The moderate-velocity site was distinguished by water velocities generally > 0.05 m/s and < 0.30 m/s.

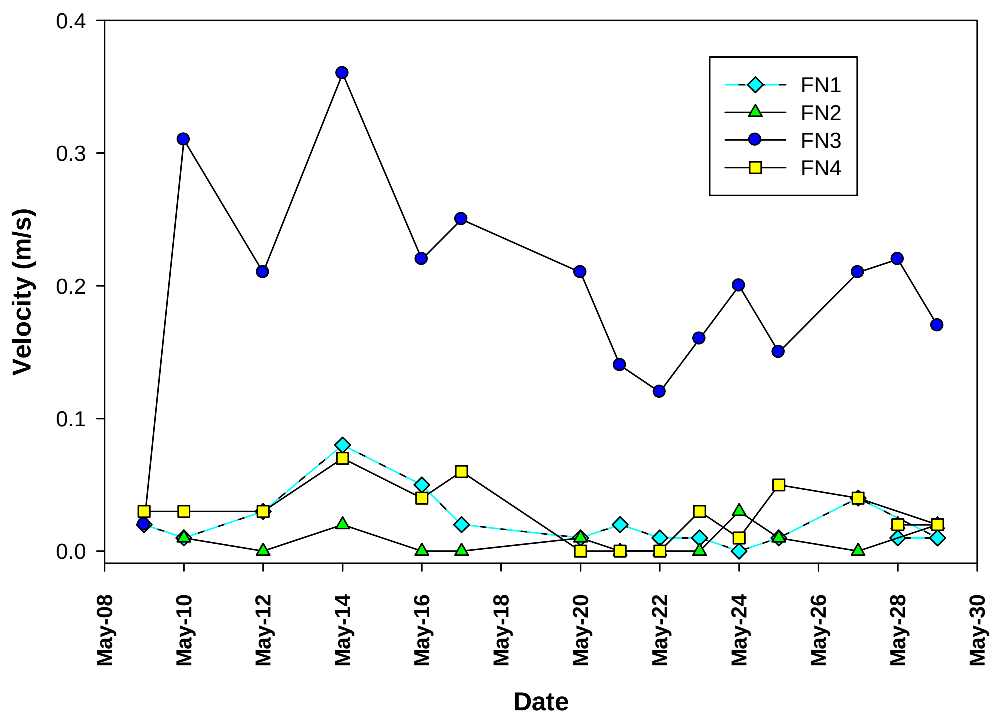

Figure 4. Daily water velocities (m/s) at floodplain sample sites of the Los Lunas Habitat Restoration Project, 2009.

METHODS

FISH AND ENVIRONMENTAL QUALITY SURVEYS

Fish were collected from main channel habitats with a 3.7 × 1.2–m, 0.476-cm delta mesh seine. Mesohabitats were defined by the field lead on each sampling day as riffle/shallow run, main channel run, pool, or eddy. Seine hauls were conducted in all accessible mesohabitat types within the channel. Sampling effort was recorded in terms of the number of seine hauls and the approximate area seined (100 m^2) within each of the accessible mesohabitat types.

Fish were collected at floodplain sites with rectangular fyke nets (0.5 × 0.5 m, 6.44 mm mesh size). Sampling effort was recorded in terms of the number of hours a fyke was employed to sample fish. Water depth (m) and water velocity (m/s) was recorded for each sample site, on each sampling date. A Trimble GeoXT handheld global positioning system (GPS) unit with sub-meter accuracy was used to record spatial characteristics of fyke net sampling locations. A map depicting features at sample site locations was created using ArcGIS 9.x (see Figure 2). A digital camera was employed for all photo documentation (Appendix A). A relational database (Microsoft Access) and a spreadsheet database (Microsoft Excel) were developed for the storage, analysis, and retrieval of fish and environmental data. The databases incorporated a hierarchical structure that allowed aggregations of data over multiple scales of time and space and ordering by phylogenetic and ecologic divisions.

Collected fish were identified to species in the field using taxonomic keys provided in Sublette et al. (1990); phylogenetic classification followed Nelson et al. (2004). Species counts were maintained for all collections. Standard length (mm), weight (g), 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.

Silvery minnow eggs were collected from the main channel upstream of the northernmost inflow point (see Figure 2) using Moore egg collectors (MECs) set for 15 to 60 minutes on each sampling date (Altenbach et al. 2000). Number of eggs collected, velocity of water (m/s) flowing through the MEC, and the sample duration were recorded for each sample.

Silvery minnow eggs and larval fish were collected at floodplain sample sites with a D-frame kick net (0.0428-m^2 opening) fitted with 0.2-mm mesh Nytex netting. Sampling effort with the D-frame kick net was standardized to a 10-m transect, ideally including shallow inundated stands of fine-stemmed, low-growing vegetation. The wings of each fyke net defined an additional transect that was sampled with a with the D-frame kick net for silvery minnow eggs and larval fish. All collected eggs and larval fish were identified (when possible), enumerated, and released back to the site of collection.

Fish species were classified into eight reproductive guilds,[2] which define the ecological and ethological characters of fish species that are necessary for successful reproduction. These

[2] A guild is defined as a group of species that exploits a resource in a similar fashion and can take over each other's functional roles in an ecosystem.

reproductive guilds form a hierarchy of specializations in reproductive patterns, beginning with three major categories regarding the degree of parental care: 1) non-guarders, 2) guarders, and 3) livebearers. Each of these is subdivided according to aspects of spawning location, preferred or required substrate, and egg development. Non-guarders include fish that abandon eggs that are scattered over open substratum or buried in redds. Guarders provide parental care to incubating eggs and larvae and either choose some natural substratum on which to deposit eggs or construct some artificial substratum or redd. Reproduction in livebearers is substrate independent. Reproductive guild assignments generally follow Simon (1999). Placement of fish species in the reproductive guild framework is as follows:

- Non-guarding, open substrate spawners: Phytolithophils – common carp (*Cyprinus carpio*);
  Lithopelagophils – silvery minnow, river carpsucker (*Carpiodes carpio*), flathead chub (*Platygobio gracilis*); and
  Phytophils – yellow perch (*Perca flavescens*).
- Non-guarding, brood hiders: Speleophils – red shiner (*Cyprinella lutrensis*).
- Guarding, nest spawners: Speleophils – fathead minnow (*Pimephalas promelas*), channel catfish (*Ictalurus punctatus*);
  Polyphils – green sunfish (*Lepomis cyanellus*); and
  Phytophils – white crappie (*Pomoxis annularis*).
- Bearers; internal bearers: western mosquitofish (*Gambusia affinis*).

Water quality parameters were monitored concurrent with fish sampling events and measured using a YSI 556 multi-parameter 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). Turbidity (Formazin Turbidity Unit [FTU]) was collected with a Hanna portable microprocessor turbidity meter. Water depth (m) and flow velocity (m/s) were measured using a USGS top-setting wading rod fitted with a Marsh-McBirney Flo-Mate portable flow meter. HOBO event loggers were used to obtain hourly records of water temperature at two floodplain locations and at one main channel location (see Figure 2).

DATA ANALYSIS

Catch per unit effort (CPUE) was calculated for main channel collections by dividing the total number of fish collected from each mesohabitat type by the total area sampled on each day. The resultant standardization is expressed as fish/m^2 and is used to assess trends in main channel abundance of silvery minnow occupying each mesohabitat type.

Main channel collections of silvery minnow were analyzed to assess if differences in silvery minnow abundance existed among sampling dates and among mesohabitat types that were present over the duration of sampling. We used a Kruskal-Wallis single factor analysis of variance (ANOVA) by rank to test for differences among sampling dates and among sufficiently replicated mesohabitat types (i.e., shallow run/riffle, main channel run, and eddy mesohabitats). The numeric composition and spatial arrangement of mesohabitat features varied with discharge. Although backwater and pool mesohabitats were present in the sample area at flows between 200 and 500 cfs (i.e., during October and November 2008 sampling), these mesohabitats were absent as flows increased above 700 cfs (i.e., they did not exist for sampling on December 2008 and January and February 2009). As such, it was impossible to achieve adequate replication in backwater and pool mesohabitats to assess if differences in silvery minnow abundance existed among sampling dates for these habitats.

Silvery minnow CPUE was calculated for fyke net samples by dividing the total number of fish captured by the total number of hours each fyke net was fished on each day (Quinn and Deriso 1999; Hubert and Fabrizio 2007). This method of standardizing silvery minnow catches (CPUE) assumes that absolute numbers of silvery minnow will continue to increase as sample time increases. The management utility of CPUE as an index of abundance depends on the proportional relationship between the numbers of fish captured and the amount of effort expended (Hubert and Fabrizio 2007). To test for this relationship, we used regression analysis to determine the effect of sample time on absolute numbers of silvery minnow captured. Since floodplain collections of silvery minnow vary by date (Gonzales and Hatch 2009) and site (Hatch and Gonzales 2008; Gonzales and Hatch 2009), we used a multiple regression model that incorporates both factors. The resulting model used to assess the effect of sample time on the absolute number of captured silvery minnow is denoted as:

$$\text{Number of silvery minnow} = \alpha + \beta_1 \text{ sample time} + \beta_2 \text{ site} + \beta_3 \text{ date} + \epsilon$$

where α is the Y intercept, β_i are the partial regression coefficients, and ϵ_j is the residual standard error. In this model sample time is a quantitative variable, while site and date are considered “dummy” or “indicator” variables (Zar 1999:Chapter 20). To better meet model assumptions, number of silvery minnow was normalized by natural log transformation ($Y = \log_e[X + 1]$) prior to analysis (Zar 1999:Chapter 13).

A Kruskal-Wallis single factor ANOVA by rank was conducted to assess if median CPUE varied among floodplain sample sites and among sampling dates. Non-parametric analysis was selected due to non-normality of the CPUE data (i.e., Shapiro-Wilk test of normality failed; $P < 0.050$). Pairwise multiple comparisons with a Mann-Whitney Rank Sum test (Dunn’s p-value adjustment method) were conducted between floodplain sampling sites to assess the relative differences between median CPUE values.

An ascending hydrograph prevailed over the sample period from May 9 to 17, 2009, while mixed hydrologic conditions prevailed after that date, beginning with a period of sharply decreasing flow and followed by short alternating periods of moderate amplitude increases and decreases in flow (see Figure 3). A Mann-Whitney Rank Sum test was used to verify differences between median silvery minnow CPUE values collected during ascending (May 9–17, 2009) and descending (May 18–29, 2009) portions of the hydrograph.

Main channel MEC collections were standardized by dividing the number of eggs collected by the volume of water filtered (m^3) multiplied by 100. The resultant standardization is expressed as silvery minnow eggs/100 m^3. Eggs collected from fyke net wings and transects established at each site were not standardized and are simply expressed as the total number of eggs collected from the floodplain site on each sampling date.

We used logistic regression to determine if increased floodplain abundance of silvery minnow is related to the presence of silvery minnow eggs on fyke net wings and transects established within the project area. The absence or presence of eggs on fyke net wings and transects was binomially coded as 0 (absent) or 1 (present) on each sampling day. The presence or absence of eggs was used as the binomial response variable, while mean daily CPUE was used as the continuous predictor variable (Hastie et al. 2001; Dalgaard 2002). Model fit of the logistic response function was assessed with a drop in deviance test (Dalgaard 2002).

Records of contemporary fish collections, including collections from the Los Lunas Habitat Restoration Project area, were 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 were expressed as Jaccard's coefficient of similarity between pooled species assemblages for the Isleta Reach and for more localized and habitat specific assemblages that varied temporally by site. A reach- and site-specific rank of species relative abundance facilitated this analysis. Rank abundance avoids many problems associated with heterogeneity in sampling methods, sampling effort, and 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 was 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 provided insight into the relative dependence of the fish assemblage composition of the floodplain at the Los Lunas Habitat Restoration Project area on the adjacent segment of river and more distal outlying areas.

We used Jaccard's index to assess similarity between various fish species assemblages. Jaccard's coefficient of similarity is the fraction of species at two sites that are common to both (Sneath and Sokal 1973; Bridge 1993). Objective assessment of similarity and dissimilarity of faunal assemblages over time and space is important in assessing the effectiveness of management strategies and the response of species to environmental stressors. The Jaccard index provides an objective assessment of faunal changes that might occur in response to a host of environmental stressors, including climatic changes and changes in the long-term average hydrologic regime (and related anthropogenic changes).

Non-parametric 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 non-parametric 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.

[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

MAIN CHANNEL FISH COLLECTIONS AND SILVERY MINNOW MESOHABITAT ASSOCIATIONS

A total of 1,672 fish, representing 10 species was collected in main channel surveys (Table 3, Appendix B). Red shiner and silvery minnow were most abundant, comprising 67% and 15% of the total catch, respectively. Common carp, channel catfish, flathead chub, river carpsucker, white crappie, and yellow perch each comprised less than 1% of the total catch.

Table 3. Summary of Main Channel Fish Collections – 2009

Common Name	Scientific Name	Number Sampled	Percent Composition
Red shiner	*Cyprinella lutrensis*	1,120	66.99
Rio Grande silvery minnow	*Hybognathus amarus*	259	15.49
Western mosquitofish	*Gambusia affinis*	139	8.31
Fathead minnow	*Pimephales promelas*	106	6.34
Common carp	*Cyprinus carpio*	16	0.96
Channel catfish	*Ictalurus punctatus*	13	0.78
Flathead chub	*Platygobio gracilis*	9	0.54
River carpsucker	*Carpiodes carpio*	8	0.48
White crappie	*Pomoxis annularis*	1	0.06
Yellow perch	*Perca flavescens*	1	0.06

During main channel surveys, a total area of 17,681 m^2 (190,327 square feet) was sampled from accessible mesohabitats (Table 4). Main channel runs were the most abundant mesohabitat, while pools, backwaters, and eddies were the least abundant mesohabitats.

Table 4. Amount of Area (m^2) Seined by Mesohabitat and Date during Main Channel Fish Surveys

Date	Backwater	Eddy	Main Channel Run	Pool	Shallow Run/Riffle	Total
10/31/08	2,573	990	2,470	NA	1,450	7,483
11/21/08	NA	555	750	363	1,600	3,268
12/19/08	NA	860	313	NA	363	1,535
1/27/09	NA	900	575	NA	1,325	2,800
2/19/09	NA	220	400	NA	1,975	2,595
Total	**2,573**	**3,525**	**4,508**	**363**	**6,713**	17,681

A total of 259 silvery minnows was collected from main channel habitats (Table 5). Of this total, 170 (65%) were collected on November 21, 2008, and the majority of were found in eddy habitats. Silvery minnow CPUE did not differ among sampling dates (Kruskal-Wallis one-way ANOVA; P = 0.7346) but did differ among main channel, shallow run/riffle, and eddy mesohabitats (Kruskal-Wallis one-way ANOVA; P = 0.008). Mean silvery minnow CPUE ranged from 0.87 to 45.3 fish/m^2 among sampling dates and 0.31 to 36.09 fish/m^2 among mesohabitat types (Table 6). The highest single-day CPUE values were in eddy (168.5 fish/m^2), pool (11.03 fish/m^2), and backwater (10.07 fish/m^2) habitats, while the lowest CPUE values were observed in main channel run habitats (0.00 fish/m^2) on November 21, 2008.

Table 5. Number of Silvery Minnow Collected by Mesohabitat and Date during Main Channel Fish Surveys

Date	Backwater	Eddy	Main Channel Run	Pool	Shallow Run/Riffle	Total
10/31/08	37	3	1	NA	2	43
11/21/08	NA	156	2	8	4	170
12/19/08	NA	1	0	NA	9	10
1/27/09	NA	2	1	NA	9	12
2/19/09	NA	9	2	NA	13	24
Total	**37**	**171**	**6**	**8**	**37**	**259**

Table 6. Silvery Minnow CPUE (fish/100 m^2) by Mesohabitat and Date during Main Channel Fish Collection Surveys

Date	Back Water	Eddy	Main Channel Run	Pool	Shallow Run/Riffle	Mean
10/31/08	10.07	1.82	0.16	NA	0.55	3.15
11/21/08	NA	168.65	0.53	11.03	1.00	45.30
12/19/08	NA	0.93	0.00	NA	2.48	1.14
1/27/09	NA	0.89	0.35	NA	1.36	0.87
2/19/09	NA	8.18	0.50	NA	1.32	3.33
Mean	**10.07**	**36.09**	**0.31**	**11.03**	**1.34**	**10.76**
Standard Error	**NA**	**33.17**	**0.10**	**NA**	**0.32**	**8.65**

Silvery Minnow Floodplain Occupancy

A total of 2,507 silvery minnows was captured during May 2009 at four floodplain sample sites (Appendix C and Appendix D). Mean CPUE was greatest at FN1 (14.13) and lowest at FN2 (3.50). The highest observed CPUE occurred on May 10, 2009, at FN1 (47.82) and FN2 (39.78).

Multiple regression model results indicate that catches of silvery minnow increase as a function of sample time, site, and date (R^2 = 0.66, P = <0.001). ANOVA of the predictor variables indicates that all three have a significant influence on catches of silvery minnow (all P = <0.005) (Dalgaard 2002). From this analysis, standardization of silvery minnow catches by sample time (CPUE = fish/hour) appears to be a valid method for assessing trends in abundance of silvery minnow collected with fyke nets.

Silvery minnow CPUE varied over the course of monitoring between floodplain sample sites (Table 7–Table 9). Median CPUE values were different among dates (see Table 7) (Kruskal-Wallis one-way ANOVA by rank; $P = 0.022$) and sampling sites (Kruskal-Wallis one-way ANOVA by rank; $P = 0.016$).

Table 7. Descriptive Statistics for Silvery Minnow Median CPUE for Sample Dates

			Percentile	
Date	**N**	**Median**	**25%**	**75%**
09-May-2009	3	15.854	1.928	38.855
10-May-2009	4	28.180	5.306	45.806
12-May-2009	4	15.838	4.875	38.294
14-May-2009	4	10.997	3.139	21.569
16-May-2009	4	16.290	8.361	18.540
17-May-2009	4	20.088	7.965	33.029
20-May-2009	4	7.956	3.920	11.097
21-May-2009	4	1.798	0.821	8.357
22-May-2009	4	2.393	0.0731	6.157
23-May-2009	4	3.342	0.289	8.438
24-May-2009	4	1.401	0.750	7.450
25-May-2009	4	2.272	0.136	9.200
27-May-2009	4	1.420	0.665	7.165
28-May-2009	4	4.048	1.247	6.449
29-May-2009	4	1.946	0.715	4.668

Table 8. Median Silvery Minnow CPUE for Sample Strata before and after May 18, 2009

			Percentile	
Temporal Strata	**N**	**Median CPUE**	**25%**	**75%**
Before May 18, 2009 (ascending hydrograph)	23	15.947	5.833	25.818
After May 18, 2009 (mixed hydrograph)	36	2.280	0.640	6.589

Table 9. Descriptive Statistics for Silvery Minnow Median CPUE for Each Floodplain Sample Site

			Percentile Rank	
Floodplain Sample Site	**N**	**Median Silvery Minnow CPUE**	**25%**	**75%**
FN1	15	3.333	0.967	35.433
FN2	14	1.807	0.490	18.008
FN3	15	10.539	8.289	15.854
FN4	15	2.924	1.546	5.832

For all sites combined, mean and median CPUE was higher than 10 fish/hour from May 9 through May 17, and was less than 10 fish/hour after May 17, 2009 (Figure 5). Median silvery minnow CPUE was significantly higher concurrent with the ascending hydrograph that existed before May 18, 2009 (see Figure 3), compared to the median CPUE after May 17, 2009 (see Table 7 and Table 8), when mixed hydrologic conditions prevailed, beginning with a period of sharply decreasing flow and followed by short alternating periods of moderate increases and decreases in flow (Mann-Whitney Rank Sum test; P = < 0.001) (see Table 8, Figure 3 and Figure 5).

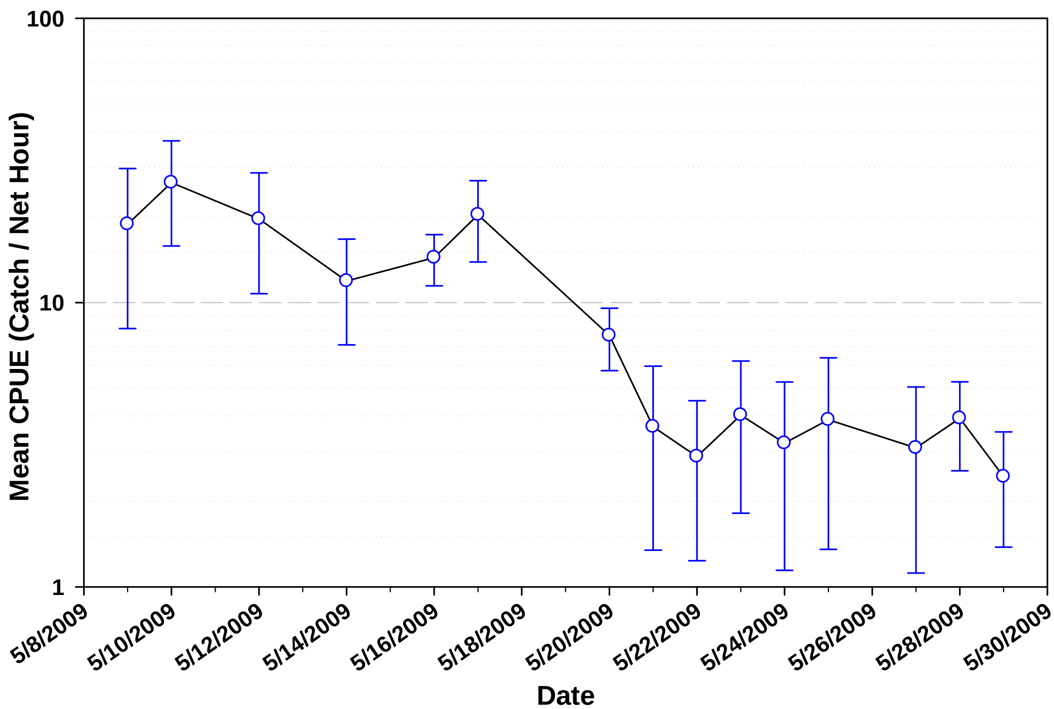

Figure 5. Mean CPUE values (fish/hour) observed during the 2009 monitoring period. CPUE is plotted on the $\log_{10}$ scale. Error bars represent one standard error.

Significant differences between site-specific median CPUE values were only found between FN3 and FN4 (Table 10, Figure 6and Figure 7). Median CPUE values for silvery minnow were highest at sites FN3 and FN1 (see Table 9, Figure 6–Figure 7). Mean and median weekly CPUE values for silvery minnow were highest prior to May 18, 2009—a period dominated by an ascending hydrograph (see Figure 3 and Figure 5).

Table 10. Site-specific Pairwise Comparisons of Silvery Minnow Median CPUE

Comparison	Diff of Ranks	P < 0.05
FN3 vs. FN4	18.467	Yes
FN3 vs. FN2	16.400	No
FN3 vs. FN1	11.067	No
FN1 vs. FN4	7.400	No
FN1 vs. FN2	5.333	No
FN2 vs. FN4	2.067	No

Multiple comparison results were used to determine which site-specific median CPUE values are different.

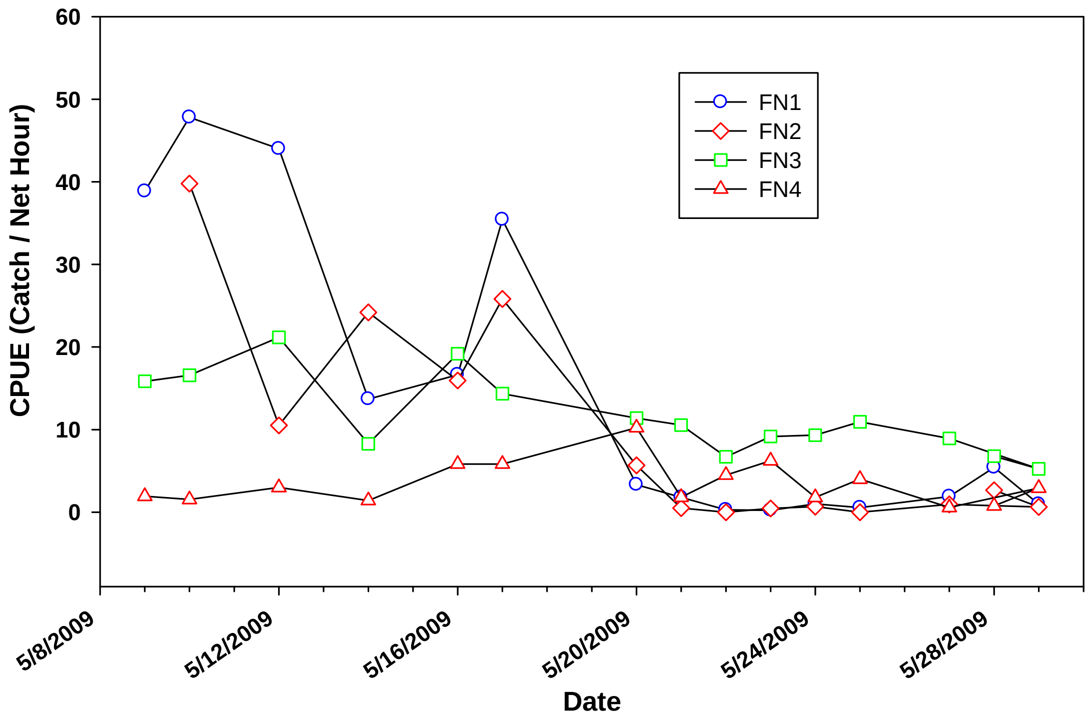

Figure 6. Silvery minnow CPUE for individual floodplain sample sites observed over the period of sampling period (May 9–29, 2009). Sites FN1, FN2, and FN4 represent low-velocity sites; site FN3 was the only moderate-velocity site represented in the sample set.

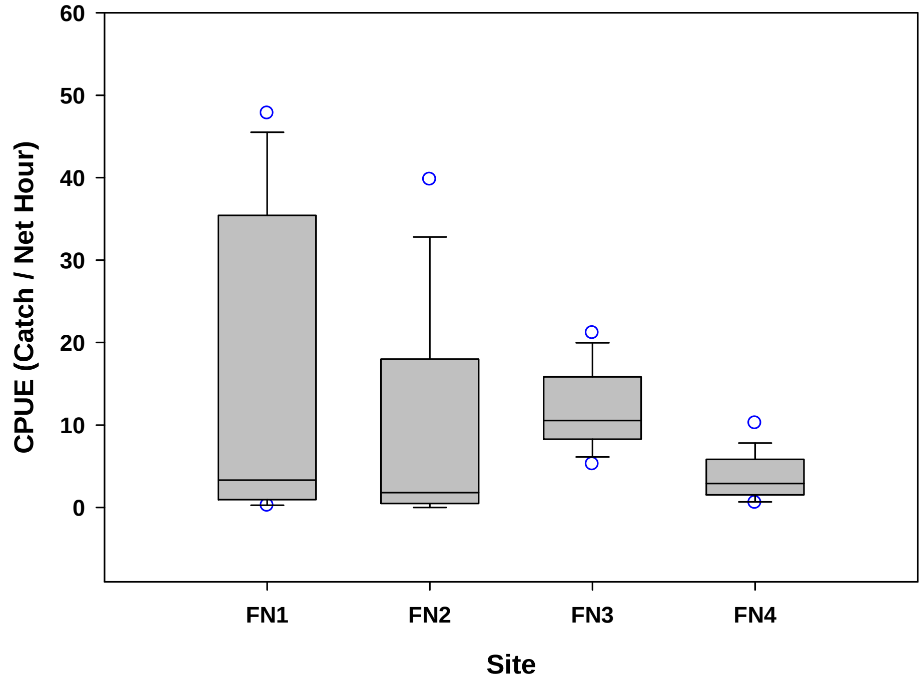

Figure 7. Box plots of silvery minnow CPUE sampled in fyke nets from floodplain sample sites over the period May 9–29, 2009.

Sites FN1, FN2, and FN4 represent low-velocity sites; site FN3 was the only moderate-velocity site represented in the sample set. The boundary of the box closest to zero indicates the 25th percentile. The line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Error bars above and below the box indicate the 90th and 10th percentiles, respectively. The blue circle symbols represent outlying points.

SILVERY MINNOW DEMOGRAPHIC CHARACTERISTICS

Standard length was obtained for 2,423 silvery minnows from floodplain habitats of the Los Lunas Habitat Restoration Project area. Of these, 1,300 silvery minnows were of known gender and 1,123 were of unknown gender (Figure 8). Standard length of silvery minnow ranged from 36 to 86 mm. Standard length of reproductively mature males ranged from 40 to 75 mm. Standard length of sexually mature females ranged from 42 to 79 mm.

Mature silvery minnow were documented to occupy the floodplain at the Los Lunas Habitat Restoration Project area on each sample date over the duration of sampling (May 9–28, 2009). The floodplain at the project area had been inundated approximately 10 days before the study was initiated. Because silvery minnow colonization of the floodplain at the Los Lunas Habitat Restoration Project area depends on the continuity of aquatic habitat in time and space, silvery minnow reoccupation of study site could only have occurred within this time period.

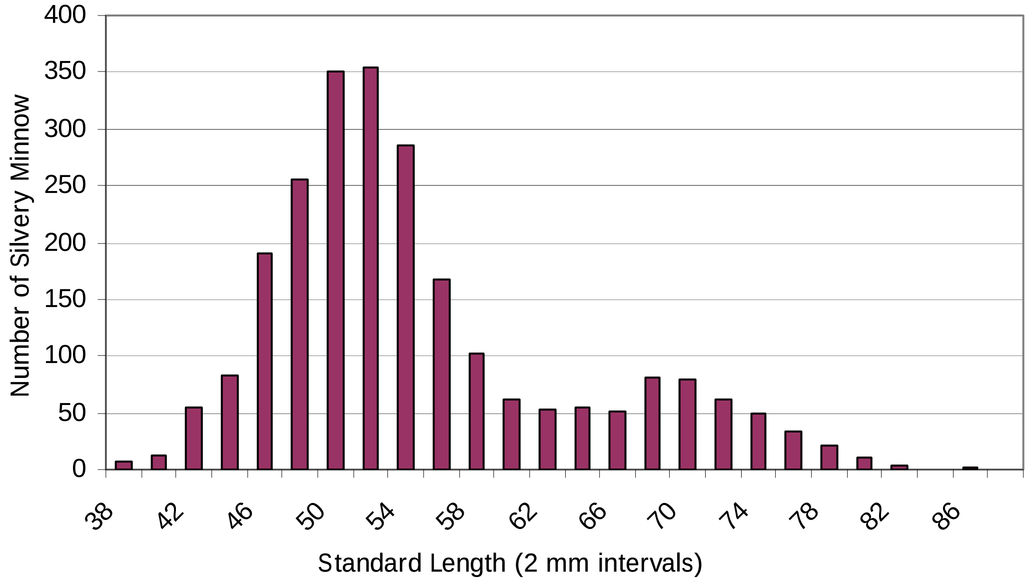

Figure 8. Length frequency of reproductively mature silvery minnow collected at the Los Lunas Habitat Restoration Project area (n = 2,423).

Given that the initiation of sampling approximately coincided with the onset of silvery minnow spawning, it is clear that the range of observed fish lengths represent age 1 and older fish. Based on discontinuities in the length frequency distribution of reproductively mature silvery minnow (males and females) collected at the Los Lunas Habitat Restoration Project area (n = 2,423; see Figure 8), it seems evident that age 1 and age 2 fish are represented in the samples. Older individuals may be present in the sample; however, it is difficult to discern if older age classes are represented in the collection based on length frequency alone. An extended spawning season and a decrease in annual growth as individual age may result in overlapping age-specific length distributions, which complicates assignment of age based on length. Additionally, sexual size dimorphism further complicates size-based interpretation of silvery minnow age (Gonzales and Hatch 2009). Clear demarcation of age by size is often difficult to discern for even the youngest age class fish without validation of age founded on known-age individuals or from evidence of annual growth that is often discernable on scales and otoliths.

SILVERY MINNOW HABITAT SELECTION

Water Discharge/Velocity

Mean weekly silvery minnow CPUE was highest at sites that were furthest from the main channel (sites FN1, FN2, and FN3) compared to the single site that was located immediately adjacent to the main channel (FN4) (Table 11). We did not detect a consistent pattern of mean CPUE with changes in velocity (Appendix E).

Table 11. Average Weekly Silvery Minnow Catch per Fyke Net Trap Hour in Floodplain Habitats of the Los Lunas Habitat Restoration Project Area, 2009

	Low-velocity Sites			Moderate-velocity Site
Week* (sample size)	**FN1**	**FN2**	**FN4**	**FN3**
19 (1)	38.86	–	1.93	15.85
20 (4)	28.80	23.45	3.01	15.98
21 (5)	10.08	9.65	5.53	10.65
22 (5)	1.89	1.23	1.96	8.13
Averages	19.91	11.44	3.11	12.65

* Week strata: May 3–9 (week 19), May 10–16 (week 20), May 17–23 (week 21), and May 24–29 (week 22).

Water Temperature

Highest average weekly silvery minnow CPUE in floodplain habitats coincided with the highest absolute floodplain water temperatures and occurred when average weekly water temperatures exceeded that of the main channel (Table 12, Appendix F) to the greatest extent. Before May 18, 2009, coincidental with the ascending hydrograph, floodplain site FP1 exhibited the greatest deviation in mean weekly water temperature from main channel water temperatures (+1.26°C–+1.25°C). During this same period, average weekly maximum floodplain water temperatures exceeded that of the main channel by as much as 3.27°C.

Rate of silvery minnow capture generally declined progressively over sample weeks 21 and 22 at most sample sites. The decline in catch rates (see Table 11, Figure 5) also coincided with reduced differences in weekly average and weekly average maximum water temperatures between main channel and floodplain habitats (Table 12).

Table 12. Water Temperatures (°C) at the Los Lunas Habitat Restoration Project Area, Including Two Floodplain Monitoring Locations and One Main Channel Monitoring Location

Week *		Floodplain Collection Locations		Main Channel
		FP1	FP2	
19 (May 3–9)	Avg.	20.38	19.96	19.13
	St. Dev.	1.66	2.00	1.24
	Min.	17.38	16.90	17.00
	Max.	22.72	23.39	20.71
20 (May 10–16)	Avg.	20.10	19.23	18.84
	St. Dev.	2.49	1.58	1.24
	Min.	16.14	16.90	16.81
	Max.	24.93	23.00	21.00
21 (May 17–23)	Avg.	19.91	19.17	18.90
	St. Dev.	2.13	1.62	1.34
	Min.	15.47	16.33	16.62
	Max.	24.45	23.20	21.66
22 (May 24–29)	Avg.	18.96	18.77	18.75
	St. Dev.	1.46	1.27	1.16
	Min.	16.33	16.90	16.81
	Max.	21.66	22.43	21.47
All Weeks	Avg.	19.76	19.14	18.86
	St. Dev.	2.14	1.58	1.25
	Min.	15.47	16.33	16.62
	Max.	24.93	23.39	21.66

Water Chemistry

Water quality data for main channel and floodplain monitoring sites are tabulated 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 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

[4] *Potamon* refers to the warmer and lower gradient river of the lowlands. Unaltered, the potamon 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.

water temperatures and extended periods of low light (e.g., a series of cloudy days and shade from dense canopy of riparian vegetation).

Evidence Linked to Silvery Minnow Spawning

Female silvery minnow that had already spawned (i.e., "spent" females) were observed on each sampling date throughout the period of monitoring. The proportion of gravid females and females issuing eggs decreased after May 17, 2009 (i.e., generally over the span of the latter two weeks of May) (Figure 9), when mixed hydrologic conditions prevailed, beginning with a period of sharply decreasing flow, followed by short alternating periods of moderate amplitude increases and decreases in flow (see Figure 3).

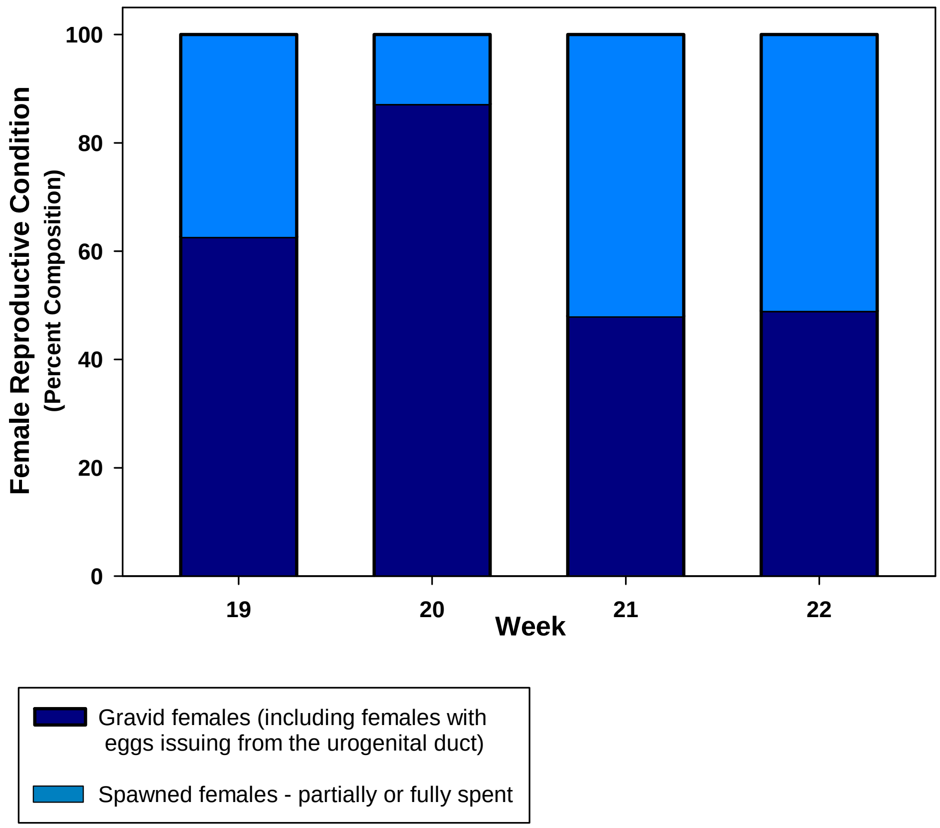

Figure 9. Condition of reproductively active female silvery minnow observed at floodplain sample sites of the Los Lunas Habitat Restoration Project area during 2009.

Stacked columns represent the fraction of reproductively active female silvery minnow that were judged to be gravid or to have spawned (i.e., partially or fully spent). Week strata: May 3–9 (week 19), May 10–16 (week 20), May 17–23 (week 21), and May 24–29 (week 22).

MECs were used in the main river channel to detect downstream drifting silvery minnow eggs. MEC samplers were deployed in the main channel for a total of 747 sampling minutes over 15 days of monitoring. A total of three silvery minnow eggs were collected in MEC main channel samples; two were collected on May 14, 2009, and one was collected on May 22, 2009.

Silvery minnow eggs first appeared in floodplain collections on May 9, 2009 (Figure 10). Relatively large collections of eggs were made at one floodplain site (FN1) on May 10 and 12, 2009. Only a few eggs were collected in subsequent floodplain sampling trials; no silvery minnow eggs were collected after May 14, 2009. Habitat attributes of sample site FN1 on May 10 and 12, 2009, include water depths less than 0.30 m (0.98 foot), velocities less than 0.05 m/s (0.16 foot/s), and expansive inundated stands of fine-stemmed, low-growing vegetation (e.g., grasses; Figure 11). This sample site exhibited the highest deviation in mean weekly water temperature from main channel water temperatures (+1.26°C) coincidental with the largest collections of eggs (i.e., during week 20). Week 20 also coincided with the highest weekly mean discharge rate (see Figure 3).

Over the period of monitoring, 2,632 unidentified larval and early post-larval fish were observed in floodplain habitats of the Los Lunas Habitat Restoration Project area (see Figure 10). Fish larvae were first observed on May 10, 2009, a day after the first silvery minnow egg was observed on the floodplain. Larval and early post-larval fish were observed on all but two of the subsequent days of sampling. The number of fish larvae observed increased dramatically after May 16, 2009 (see Figure 10).

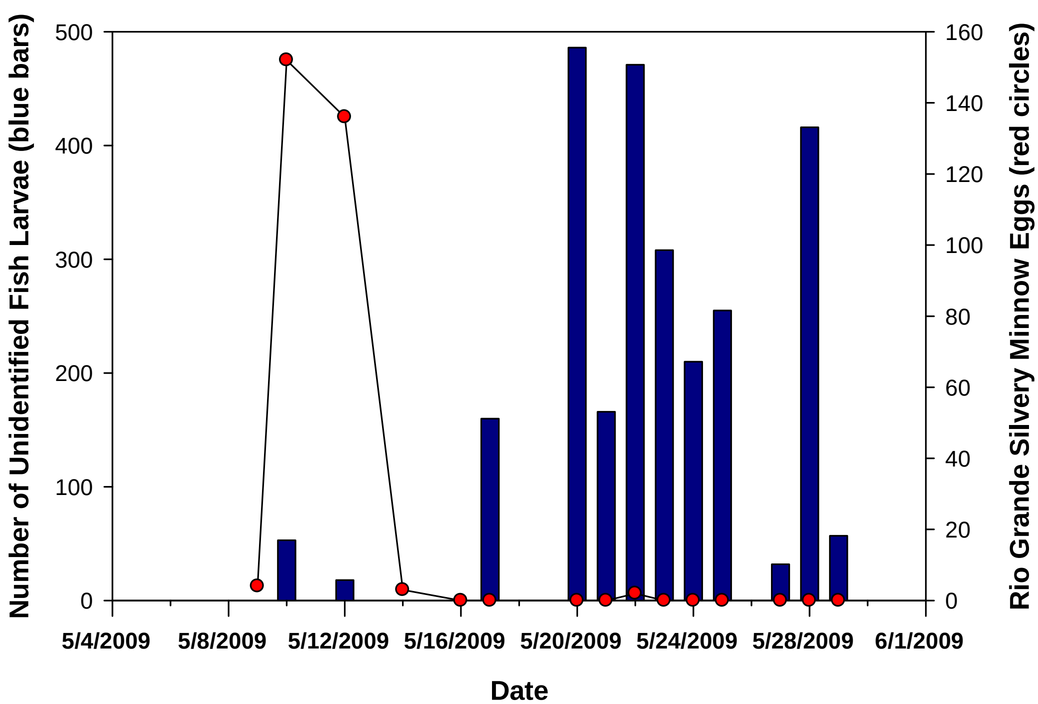

Figure 10. Number of unidentified fish larvae (blue bars) and silvery minnow eggs (red circles) observed at floodplain sample sites of the Los Lunas Habitat Restoration Project area, 2009.

Figure 11. A typical floodplain habitat patch in which higher concentrations of spawning silvery minnow and incubating embryos were observed.

The presence of silvery minnow eggs on floodplain habitats was associated with increased silvery minnow CPUE (Z_{13} = 2.043, p = 0.04). As silvery minnow floodplain abundance increased, the probability of collecting a silvery minnow egg on the floodplain also increased (Figure 12).

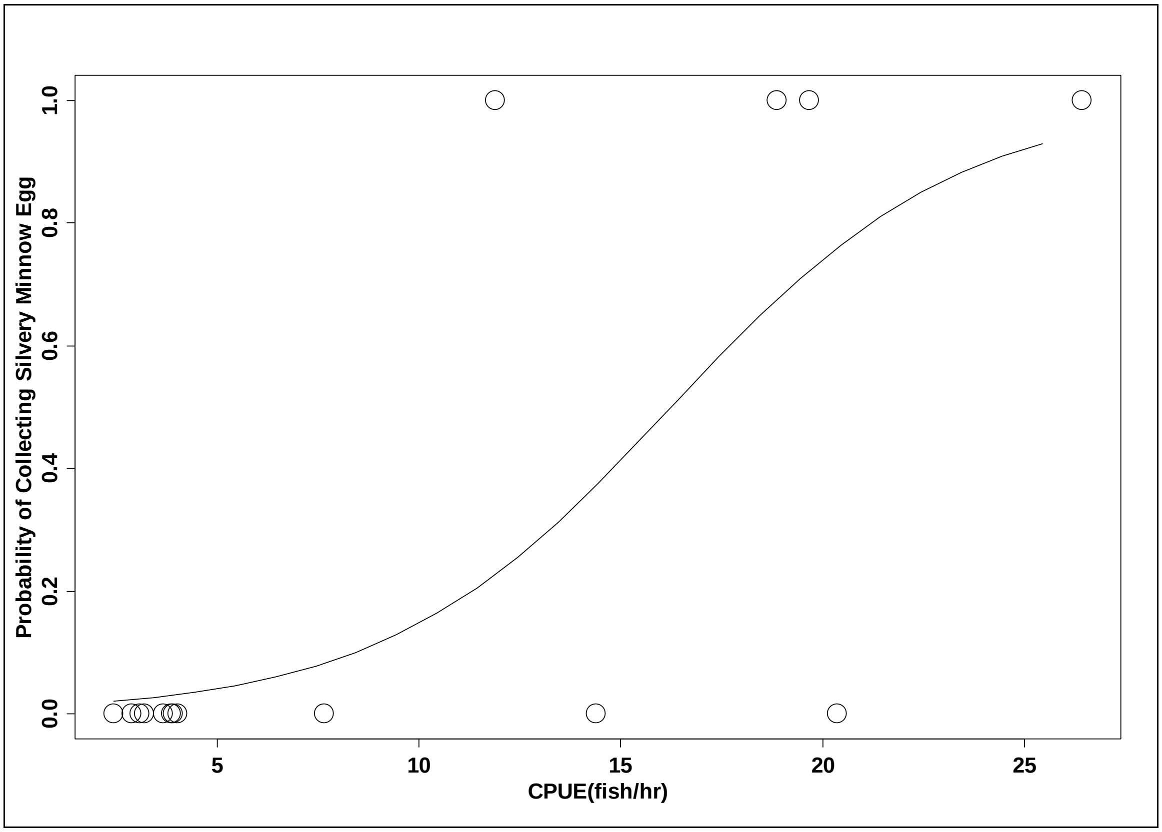

Figure 12. Relationship between silvery minnow CPUE (fish/hour) and the probability of collecting a silvery minnow egg for floodplain samples.

COMMUNITY COMPOSITION

PHYLOGENETIC AND ECOLOGIC INDICES OF FAUNAL RICHNESS

A temporal change in rank abundance is used to chronicle changes in species diversity in running water habitats of the main channel adjacent to the Los Lunas Habitat Restoration Project area (Table 13). Pool and backwater mesohabitat features were absent from the sample area as flow increased. This reduced habitat complexity accounts in part for the lower species richness observed in January and February 2009 samples. The species that were absent from these collections were, with the exception of flathead chub, species with strong affinities for pool and backwater mesohabitats.

Table 13. Monthly Species Abundance Ranks for Main Channel Samples Adjacent to the Los Lunas Habitat Restoration Project Area

	Date					Pooled Rank
Species	31-Oct-2008	21-Nov-2008	19-Dec-2008	27-Jan-2009	19-Feb-2009	
Carpiodes carpio	5.5	–	–	4.5	–	8.0
Cyprinella lutrensis	1.0	1.0	1.0	2.0	1.0	1.0
Cyprinus carpio	7.0	5.0	7.0	–	–	5.0
Gambusia affinis	2.0	4.0	3.0	–	–	3.0
Hybognathus amarus	4.0	2.0	2.0	1.0	2.0	2.0
Ictalurus punctatus	5.5	6.0	7.0	4.5	–	6.0
Perca flavescens	–	–	–	–	3.5	9.5
Pimephales promelas	3.0	3.0	4.5	4.5	3.5	4.0
Platygobio gracilis	8.0	7.0	4.5	4.5	–	7.0
Pomoxis annularis	–	–	7.0	–	–	9.5
Species Counts	**8**	**7**	**8**	**6**	**4**	**10**

Patterns of fish community composition indicate that floodplain habitats of the Los Lunas Habitat Restoration Project area support a relatively small subset of the species and reproductive guilds that were represented in the larger species assemblage of the Isleta Reach and in the portion of the main channel adjacent to the project area (Table 14–Table 16). Patterns of community composition indicate that fauna-environment interactions of the floodplain favor colonizing species,[5] including silvery minnow, red shiner, and common carp. Together these three species numerically comprise approximately 98.0% of the floodplain fauna (see Table 14). Non-guarding, open substrate spawning lithopelagophils (represented in floodplain collections by silvery minnow and river carpsucker) was the most abundant reproductive guild (see Table 15). Non-guarding, brood hiding speleophils (represented by red shiner) was the second most abundant reproductive guild. Non-guarding, open substrate spawning phytolithophils (represented solely by common carp) is also a numerically prominent component of the floodplain fauna (see Table 15).

Table 14. Fish Species Collected from Floodplain Habitats at the Los Lunas Habitat Restoration Project Area and Adjacent Main Channel Habitats, 2009

Species	Number Collected	Percent of Total
Hybognathus amarus	2,507	88.68
Cyprinella lutrensis	230	8.14
Cyprinus carpio	40	1.41
Pimephales promelas	36	1.27
Carpiodes carpio	10	0.35
Lepomis cyanellus	3	0.11
Ictalurus punctatus	1	0.04

[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 15. Reproductive Guild Classification and Relative Abundance of Fishes Collected in Inundated Floodplain Habitats of the Los Lunas Habitat Restoration Project Area, 2009

Parental Care	Spawning Location	Reproductive Guild	Count	Percent Composition
Non-guarders				
	Open Substrate Spawners			
		Phytolithophils	40	1.41
		Lithopelagophils	2,517	89.03
	Brood Hiders			
		Speleophils	230	8.14
Guarders				
	Nest Spawners			
		Speleophils	37	1.31
		Polyphils	3	0.11

Reproductive guild assignments generally follow Simon (1999; see "Methods" in this report).

Table 16. Fish Species Collected from Floodplain and Adjacent Main Channel Habitats at the Los Lunas Habitat Restoration Project Area, 2009

	Floodplain Collections			River Collections		
Species	Number Collected	Percent Abundance	Rank Abundance	Number Collected	Percent Abundance	Rank Abundance
Hybognathus amarus	2,507	88.68	1	259	15.51	2
Cyprinella lutrensis	230	8.14	2	1,120	67.07	1
Cyprinus carpio	40	1.41	3	16	0.96	5
Pimephales promelas	36	1.27	4	106	6.34	4
Carpiodes carpio	10	0.35	5	8	0.48	8
Lepomis cyanellus	3	0.11	6	–	–	–
Ictalurus punctatus	1	0.04	7	13	0.78	6
Platygobio gracilis	–	–	–	9	0.54	7
Gambusia affinis	–	–	–	139	8.32	3
Pomoxis annularis	–	–	–	1	0.06	9.5
Perca flavescens	–	–	–	1	0.06	9.5

Note: Floodplain collections enumerated in this table include fish from fyke net samples from inundated floodplain habitats and seine samples from main channel collections. Number collected, percent abundance, and rank abundance are indicated for each species by main channel and floodplain habitats. Percentages may not sum exactly to 100 due to rounding.

Faunal patterns of the floodplain component of the Los Lunas Habitat Restoration Project area deviate from those of the adjacent segment of the main channel of the MRG (see Table 16). The Jaccard similarity coefficient between these adjacent aquatic habitats is seemingly low (0.55) considering that there were no barriers to fish movement at the time of sampling. The absence of four species from floodplain collections largely accounts for the low similarity among the fauna of these adjacent habitats. This low faunal similarity may also be partially due to the short duration of coupling between floodplain and the running water habitats prior to the initiation of sampling, i.e., approximately eight days.

Although species composition of floodplain collections varied over time, species diversity quickly reached a plateau that varied between four to six species within 11 days of floodplain inundation. The absence of low relative abundance species of the main channel in floodplain habitats is likely due to chance. Conversely, the absence of some high relative abundance species in floodplain samples is possibly an artifact of fyke net sampling. This seems especially likely for small-bodied species like western mosquitofish that probably could swim through the fyke trap netting. Many of the higher rank species (i.e., low relative abundance) generally represent peripheral or adventitious occurrences in the vicinity of Los Lunas.

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

Jaccard's coefficient of similarity between pooled species assemblages for the Isleta Reach (see Table 1) and more localized main channel and floodplain species assemblages associated with the Los Lunas Habitat Restoration Project area (see Table 15 and Table 16) help to elucidate the relative importance of large-scale processes involved in species dispersal and habitat patch occupation.

Similarity coefficients reveal that the faunal assemblage of the river segment adjacent to the Los Lunas Habitat Restoration Project area is only marginally more similar to the pooled species assemblage for the Isleta Reach than the adjacent floodplain (Figure 13). The relatively low faunal similarity of the main channel and floodplain habitats associated with the Los Lunas Habitat Restoration Project area to the larger faunal assemblage of the Isleta Reach suggests a localized monotony of main channel habitat features that may limit overall localized community diversity. The relatively low faunal similarity also suggests that the species saturation of the area depends significantly on annual species-specific reproduction cycles and high flows that serve to facilitate dispersal of advanced life stage fish. Whereas higher flows (i.e., those in which floodplain and main channel habits become confluent) can be regarded as 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.

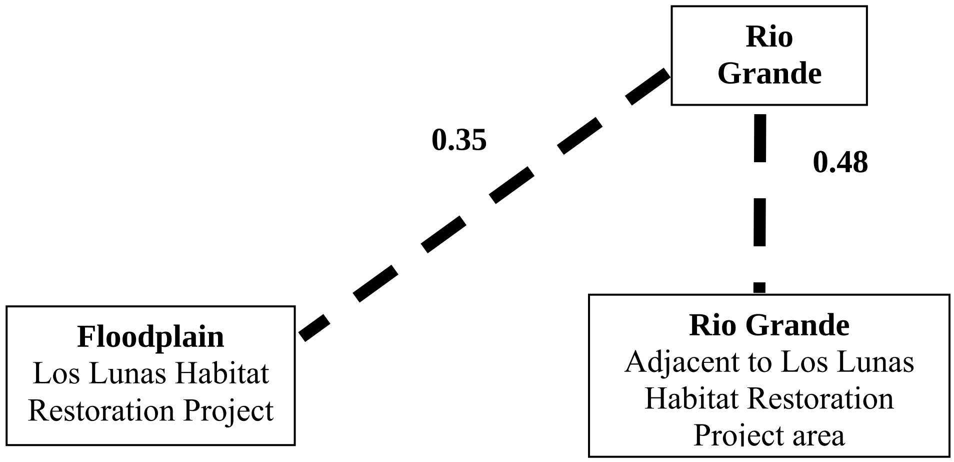

Figure 13. Levels of faunal similarity expressed as Jaccard's coefficient of similarity (shown adjacent to dashed lines) between pooled species ranks for the Isleta Reach and species ranks for more localized and habitat-specific assemblages.

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 area are presented in Appendix H. Results indicate that these samples generally yielded unbiased estimates of species richness. Observed species richness was often greater at the actual sample effort compared to predicted species richness. This was likely the result of purposeful efforts to sample the array of available mesohabitats thoroughly. 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 flow conditions that prevailed over the sample period. It would be instructive to compare the relative efficiency of seining and electrofishing to represent species richness over a variety of flow conditions.

DISCUSSION

During main channel sampling it was evident that the number and spatial arrangement of mesohabitat features was found to vary over changing hydrologic conditions, and species richness changed as a result. This suggests that contemporary field studies can only document habitat use relative to availability. Given the extensive and highly modified geomorphic and hydrologic conditions of the MRG, it is possible that preferred habitat conditions no longer exist. Not knowing the habitat conditions under which the silvery minnow might thrive greatly complicates efforts to improve habitat judged to be degraded. Nonetheless, evidence exists to suggest the silvery minnow is a habitat generalist of the sand bed dominated MRG.

The findings of this study support a working hypothesis that silvery minnow spawn in low water exchange lateral habitats, including most importantly backwater and other hydrologic retentive floodplain habitats when available 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 minnow 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. Floodplain productivity is further enhanced by the lower water exchange rates, increased subsidy of allochthonous energy inputs at the aquatic-land interface, and elevated 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).

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 the eastern silvery minnow (*Hybognathus regius*) spawning and observations by Copes (1975) of brassy minnow (*H. hankinsoni*) spawning. Occupancy of the floodplain is generally consistent with observations by Kilgore and Hoover (1992) and Robison and Buchanan (1988) for the Mississippi silvery minnow (*H. nuchalis*) and the cypress minnow (*H. hayi*). However, the challenge remains to specify the elements of "sufficient causation" that lead to silvery minnow spawning and strong annual recruitment.

Within the inundated floodplain, highest and most consistent concentrations of reproductively active silvery minnow and incubating eggs came from shallow, low-exchange habitats, often in association with fine-stemmed vegetation, notably grasses, which could increase egg retention rates. The more productive and expansive floodplain habitats utilized by the species for spawning and as a nursery for developing larvae are distinguished by a superimposed dendritic network of shallow, low-volume channels that carry low- to moderate-velocity currents (less than 0.3 m/s [0.98 foot/s]) that effectively serve to prevent stagnation and drain floodplain habitats as floodwaters recede.

The selection of inundated floodplain habitats by reproductively active silvery minnow for spawning could be in response to the dramatically warmer and more productive conditions found in inundated floodplain habitats compared to main channel habitats. Heightened productivity of inundated floodplain habitats has been demonstrated to be important as nursery habitats for many fish species native to low-gradient rivers of the Mississippi Basin (Copp 1989; Junk et al. 1989;

Junk and Welcomme 1990; Bayley and Li 1992; Galat et al. 2004; Pease et al. 2006). Thermal distinction of floodplain habitats of the MRG is most pronounced early in the spring—often in May—coinciding with the long-term modal pulse of high snowmelt runoff (see Figure 3). Warmer water temperatures are linked to shorter incubation periods for developing silvery minnow embryos (Platania and Altenbach 1998; Cowley et al. 2005), and the warmer temperatures of inundated floodplain habitats very likely contribute to enhanced survival of larvae. Mapula et al. (in prep) found that silvery minnow larval survival was highest at 20ºC in experimental trials involving water temperatures of 12 ºC, 20 ºC, and 28ºC.

Much of the contemporary inference about the linkage of water temperature and silvery minnow spawning is founded on the perception that the silvery minnow is an obligate main channel spawner. An alternative explanation of the role of water temperature in silvery minnow reproductive biology may be linked to the effects of temperature dynamics of low water exchange habitats of the inundated floodplain on the survival of larval silvery minnow (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 report greater environmental stability with increasing water depth. Hatch et al. (2008) find 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 greater potential for rapid faunal exchanges with running water habitats (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 degree to which incubating silvery minnow embryos are retained in upstream habitats varies with the magnitude of discharge and the modality of flow over the span of these early life stages. Although silvery minnow embryos are known to drift considerable distances when flow is confined to the active channel (Dudley and Platania 2007), evidence shows reduced downstream drift as flow increases sufficiently to flood adjacent floodplain terraces. During such events, inorganic and organic materials, including silvery minnow eggs and larvae, can be retained (or detained for significant periods of time) in lateral habitats (Widmer et al. 2007), either as a result of channel morphology that allows hydrologic energy to dissipate laterally, the flooding of low water exchange backwaters, or as a consequence of large lateral flow-deflecting objects in the floodplain along with the physical process of drifting material being strained by the vegetated and debris-laden riparian corridor. Multi-modal hydrographs, even if sufficient to escape the active river channel, may result in heightened downstream drift of incubating silvery minnow embryos with repeated spikes in discharge. Reduction in egg and larvae drift (emigration) and retention in upstream river reaches serves to reduce impacts of habitat fragmentation that would otherwise restrict movement between subpopulations and source-sink exchanges. Likewise, it is hypothesized that gradual reductions in flow (e.g., 50 cfs/day) following periods of high discharge would reduce impacts of stranding.

Population monitoring for silvery minnow over the past decade has documented order of magnitude increases and decreases in abundance, which appear to be related to changing environmental conditions (Dudley and Platania 2008; Dudley et al. 2008). Evidence suggests that recruitment success for the species appears highly dependent on the magnitude and duration of spring runoff (USFWS 2007; Dudley and Platania 2008; Dudley et al. 2008) and less dependent on river drying during irrigation season (Dudley et al. 2008). Flow management that maximizes silvery minnow recruitment and survival while meeting the demands of water users would provide a useful basis for management of the species.

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APPENDIX A
PHOTOGRAPHS

Figure A.1. View facing north at backwater habitat sampled on October 31, 2008.

Figure A.2. View facing south at the inlet of the backwater habitat sampled on October 31, 2008.

Figure A.3. Shallow run/riffle habitat sampled on October 31, 2008.

Figure A.4. Crew seining a main channel run on October 31, 2008.

Figure A.5. Silvery minnow collected from the main channel on October 31, 2008.

Figure A.6. Pool habitat sampled on November 21, 2008.

Figure A.7. Main channel run habitat on November 21, 2008.

Figure A.8. Eddy habitat on December 19, 2008.

Figure A.9. Crew collecting water quality data from a shallow run/riffle on December 12, 2008.

Figure A.10. Crew seining a main channel run on January 27, 2009.

Figure A.11. A 74-mm silvery minnow collected from the main channel on January 27, 2009.

Figure A.12. Eddy habitat on February 19, 2009.

Figure A.13. Eddy habitat on February 19, 2009.

Figure A.14. View facing south at FN1.

Figure A.15. Crew setting up FN2.

Figure A.16. View facing south at FN3.

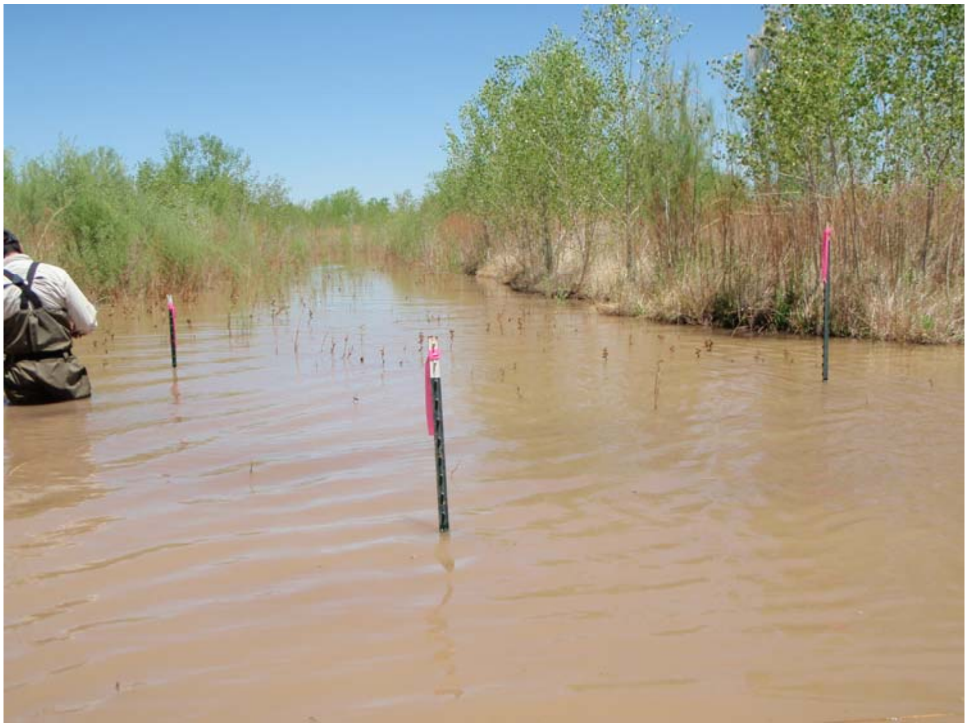


Figure A.17. View facing north at FN4.

Figure A.18. Crew looking for eggs along fyke net wings.

Figure A.19. Crew looking for eggs along established egg transects.

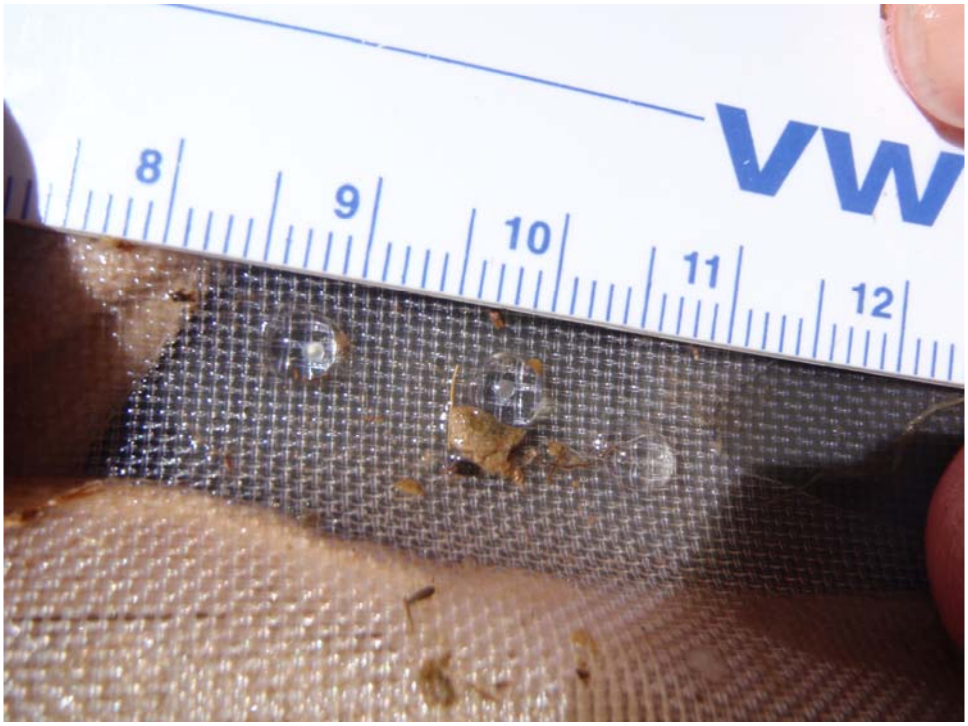


Figure A.20. Silvery minnow eggs collected from established egg transects.

Figure A.21. Silvery minnow eggs collected from established egg transects.

Figure A.22. Gravid silvery minnow collected during floodplain monitoring.

APPENDIX B
MAIN CHANNEL FISH SAMPLE RESULTS

Los Lunas Fish Sample Results - 2009

Date	Rank Order	Species	Number Collected	Percent Composition by Date
31-Oct-2008				
	1	*Cyprinella lutrensis*	497	70.40
	2	*Gambusia affinis*	94	13.31
	3	*Pimephales promelas*	49	6.94
	4	*Hybognathus amarus*	43	6.09
	5	*Ictalurus punctatus*	7	0.99
	6	*Carpiodes carpio*	7	0.99
	7	*Cyprinus carpio*	6	0.85
	8	*Platygobio gracilis*	3	0.42
21-Nov-2008				
	1	*Cyprinella lutrensis*	566	66.82
	2	*Hybognathus amarus*	170	20.07
	3	*Pimephales promelas*	53	6.26
	4	*Gambusia affinis*	42	4.96
	5	*Cyprinus carpio*	9	1.06
	6	*Ictalurus punctatus*	4	0.47
	7	*Platygobio gracilis*	3	0.35
19-Dec-2008				
	1	*Cyprinella lutrensis*	13	39.39
	2	*Hybognathus amarus*	10	30.30
	3	*Gambusia affinis*	3	9.09
	4	*Pimephales promelas*	2	6.06
	5	*Platygobio gracilis*	2	6.06
	6	*Cyprinus carpio*	1	3.03
	7	*Ictalurus punctatus*	1	3.03
	8	*Pomoxis annularis*	1	3.03
27-Jan-2009				
	1	*Hybognathus amarus*	12	50.00
	2	*Cyprinella lutrensis*	8	33.33
	3	*Carpiodes carpio*	1	4.17
	4	*Pimephales promelas*	1	4.17
	5	*Platygobio gracilis*	1	4.17
	6	*Ictalurus punctatus*	1	4.17
19-Feb-2009				
	1	*Cyprinella lutrensis*	36	58.06
	2	*Hybognathus amarus*	24	38.71
	3	*Pimephales promelas*	1	1.61
	4	*Perca flavescens*	1	1.61

Main Channel Fish Sample Results

Meso-habitat	Date	Area Seined (sq m)	Species	Number Observed	CPUE (Fish / 100 sq m)
Back Water					
	31-Oct-2008	**367.5**			
			Cyprinella lutrensis	419	114.01
			Gambusia affinis	94	25.58
			Pimephales promelas	47	12.79
			Hybognathus amarus	37	10.07
			Carpiodes carpio	5	1.36
			Cyprinus carpio	2	0.54
			Ictalurus punctatus	1	0.27
Eddy					
	31-Oct-2008	**165**			
			Cyprinella lutrensis	34	20.61
			Ictalurus punctatus	5	3.03
			Cyprinus carpio	4	2.42
			Hybognathus amarus	3	1.82
			Pimephales promelas	2	1.21
			Carpiodes carpio	1	0.61
	21-Nov-2008	**92.5**			
			Cyprinella lutrensis	506	547.03
			Hybognathus amarus	156	168.65
			Pimephales promelas	52	56.22
			Gambusia affinis	42	45.41
			Cyprinus carpio	5	5.41
			Ictalurus punctatus	1	1.08
	19-Dec-2008	**107.5**			
			Cyprinella lutrensis	13	12.09
			Gambusia affinis	3	2.79
			Platygobio gracilis	2	1.86
			Pimephales promelas	2	1.86
			Pomoxis annularis	1	0.93
			Cyprinus carpio	1	0.93
			Hybognathus amarus	1	0.93
			Ictalurus punctatus	1	0.93
	27-Jan-2009	**225**			
			Cyprinella lutrensis	8	3.56
			Hybognathus amarus	2	0.89
			Pimephales promelas	1	0.44
			Ictalurus punctatus	1	0.44
	19-Feb-2009	**110**			
			Cyprinella lutrensis	30	27.27
			Hybognathus amarus	9	8.18
			Perca flavescens	1	0.91
			Pimephales promelas	1	0.91

Meso-habitat	Date	Area Seined (sq m)	Species	Number Observed	CPUE (Fish / 100 sq m)
Main Channel Run					
	31-Oct-2008	**617.5**			
			Cyprinella lutrensis	28	4.53
			Ictalurus punctatus	1	0.16
			Platygobio gracilis	1	0.16
			Hybognathus amarus	1	0.16
	21-Nov-2008	**375**			
			Hybognathus amarus	2	0.53
			Platygobio gracilis	1	0.27
	27-Jan-2009	**287.5**			
			Carpiodes carpio	1	0.35
			Hybognathus amarus	1	0.35
	19-Feb-2009	**400**			
			Hybognathus amarus	2	0.50
Pool					
	21-Nov-2008	**72.5**			
			Cyprinella lutrensis	49	67.59
			Hybognathus amarus	8	11.03
			Cyprinus carpio	4	5.52
			Ictalurus punctatus	2	2.76
			Pimephales promelas	1	1.38

Meso-habitat	Date	Area Seined (sq m)	Species	Number Observed	CPUE (Fish / 100 sq m)
Shallow Run					
	31-Oct-2008	**362.5**			
			Cyprinella lutrensis	16	4.41
			Platygobio gracilis	2	0.55
			Hybognathus amarus	2	0.55
			Carpiodes carpio	1	0.28
	21-Nov-2008	**400**			
			Cyprinella lutrensis	11	2.75
			Hybognathus amarus	4	1.00
			Platygobio gracilis	2	0.50
			Ictalurus punctatus	1	0.25
	19-Dec-2008	**362.5**			
			Hybognathus amarus	9	2.48
	27-Jan-2009	**662.5**			
			Hybognathus amarus	9	1.36
			Platygobio gracilis	1	0.15
	19-Feb-2009	**987.5**			
			Hybognathus amarus	13	1.32
			Cyprinella lutrensis	6	0.61

APPENDIX C
FLOODPLAIN FISH COLLECTIONS BY SAMPLE SITE AND DATE

Fish Collections by Fyke Net Site and Date

Sample Site	Date	Species	Rank Order by Site and Date	Number Collected	Daily Percent Abundance by Site
Los Lunas FN1					
	09-May-2009				
		Hybognathus amarus	1	129	99.23
		Pimephales promelas	2	1	0.77
	10-May-2009				
		Hybognathus amarus	1	208	99.05
		Cyprinella lutrensis	2	1	0.48
		Pimephales promelas	3	1	0.48
	12-May-2009				
		Hybognathus amarus	1	132	98.51
		Cyprinella lutrensis	2	1	0.75
		Lepomis (Chaenobryttus) cyanellus	3	1	0.75
	14-May-2009				
		Hybognathus amarus	1	64	98.46
		Cyprinella lutrensis	2	1	1.54
	16-May-2009				
		Hybognathus amarus	1	79	96.34
		Cyprinella lutrensis	2	3	3.66
	17-May-2009				
		Hybognathus amarus	1	180	97.30
		Pimephales promelas	2	3	1.62
		Cyprinus carpio	3	2	1.08
	20-May-2009				
		Hybognathus amarus	1	10	71.43
		Cyprinella lutrensis	2	4	28.57
	21-May-2009				
		Hybognathus amarus	1	7	58.33
		Cyprinella lutrensis	2	4	33.33
		Pimephales promelas	3	1	8.33
	22-May-2009				
		Hybognathus amarus	1	1	50.00
		Cyprinus carpio	2	1	50.00
	23-May-2009				
		Pimephales promelas	1	1	33.33
		Hybognathus amarus	2	1	33.33
		Cyprinus carpio	3	1	33.33
	24-May-2009				
		Hybognathus amarus	1	3	50.00
		Pimephales promelas	2	1	16.67
		Cyprinella lutrensis	3	1	16.67
		Cyprinus carpio	4	1	16.67

Sample Site	Date	Species	Rank Order by Site and Date	Number Collected	Daily Percent Abundance by Site
	25-May-2009				
		Hybognathus amarus	1	2	40.00
		Cyprinella lutrensis	2	1	20.00
		Pimephales promelas	3	1	20.00
		Cyprinus carpio	4	1	20.00
	27-May-2009				
		Hybognathus amarus	1	6	60.00
		Cyprinus carpio	2	3	30.00
		Lepomis (Chaenobryttus) cyanellus	3	1	10.00
	28-May-2009				
		Hybognathus amarus	1	19	86.36
		Cyprinus carpio	2	2	9.09
		Lepomis (Chaenobryttus) cyanellus	3	1	4.55
	29-May-2009				
		Hybognathus amarus	1	5	100.00

Sample Site	Date	Species	Rank Order by Site and Date	Number Collected	Daily Percent Abundance by Site
Los Lunas FN 2					
	10-May-2009				
		Hybognathus amarus	1	214	99.07
		Pimephales promelas	2	1	0.46
		Cyprinella lutrensis	3	1	0.46
	12-May-2009				
		Hybognathus amarus	1	42	97.67
		Pimephales promelas	2	1	2.33
	14-May-2009				
		Hybognathus amarus	1	127	96.21
		Cyprinella lutrensis	2	5	3.79
	16-May-2009				
		Hybognathus amarus	1	85	95.51
		Cyprinella lutrensis	2	2	2.25
		Pimephales promelas	3	1	1.12
		Carpiodes carpio	4	1	1.12
	17-May-2009				
		Hybognathus amarus	1	142	98.61
		Pimephales promelas	2	1	0.69
		Cyprinella lutrensis	3	1	0.69
	20-May-2009				
		Hybognathus amarus	1	18	81.82
		Cyprinella lutrensis	2	4	18.18
	21-May-2009				
		Hybognathus amarus	1	2	50.00
		Cyprinella lutrensis	2	1	25.00
		Pimephales promelas	3	1	25.00
	22-May-2009				
		Pimephales promelas	1	1	100.00
	23-May-2009				
		Hybognathus amarus	1	2	50.00
		Cyprinus carpio	2	1	25.00
		Pimephales promelas	3	1	25.00
	24-May-2009				
		Cyprinus carpio	1	2	50.00
		Hybognathus amarus	2	2	50.00
	25-May-2009				
		Cyprinella lutrensis	1	1	100.00
	27-May-2009				
		Hybognathus amarus	1	3	100.00
	28-May-2009				
		Cyprinus carpio	1	11	52.38
		Hybognathus amarus	2	10	47.62
	29-May-2009				
		Cyprinus carpio	1	4	50.00
		Hybognathus amarus	2	3	37.50
		Pimephales promelas	3	1	12.50

Sample Site	Date	Species	Rank Order by Site and Date	Number Collected	Daily Percent Abundance by Site
Los Lunas FN3					
	09-May-2009				
		Hybognathus amarus	1	52	81.25
		Cyprinella lutrensis	2	11	17.19
		Pimephales promelas	3	1	1.56
	10-May-2009				
		Hybognathus amarus	1	99	83.90
		Cyprinella lutrensis	2	16	13.56
		Pimephales promelas	3	3	2.54
	12-May-2009				
		Hybognathus amarus	1	90	90.00
		Cyprinella lutrensis	2	10	10.00
	14-May-2009				
		Hybognathus amarus	1	47	58.75
		Cyprinella lutrensis	2	31	38.75
		Pimephales promelas	3	1	1.25
		Carpiodes carpio	4	1	1.25
	16-May-2009				
		Hybognathus amarus	1	107	95.54
		Cyprinella lutrensis	2	4	3.57
		Pimephales promelas	3	1	0.89
	17-May-2009				
		Hybognathus amarus	1	85	97.70
		Cyprinella lutrensis	2	2	2.30
	20-May-2009				
		Hybognathus amarus	1	37	88.10
		Cyprinella lutrensis	2	5	11.90
	21-May-2009				
		Hybognathus amarus	1	43	76.79
		Cyprinella lutrensis	2	11	19.64
		Pimephales promelas	3	2	3.57
	22-May-2009				
		Hybognathus amarus	1	30	100.00
	23-May-2009				
		Hybognathus amarus	1	39	90.70
		Pimephales promelas	2	3	6.98
		Cyprinella lutrensis	3	1	2.33
	24-May-2009				
		Hybognathus amarus	1	28	96.55
		Pimephales promelas	2	1	3.45
	25-May-2009				
		Hybognathus amarus	1	41	78.85
		Cyprinella lutrensis	2	11	21.15

Sample Site	Date	Species	Rank Order by Site and Date	Number Collected	Daily Percent Abundance by Site
	27-May-2009				
		Hybognathus amarus	1	29	85.29
		Cyprinus carpio	2	5	14.71
	28-May-2009				
		Hybognathus amarus	1	26	61.90
		Cyprinella lutrensis	2	14	33.33
		Pimephales promelas	3	2	4.76
	29-May-2009				
		Hybognathus amarus	1	21	77.78
		Cyprinus carpio	2	6	22.22

Sample Site	Date	Species	Rank Order by Site and Date	Number Collected	Daily Percent Abundance by Site
Los Lunas FN 4					
	09-May-2009				
		Hybognathus amarus	1	8	57.14
		Cyprinella lutrensis	2	6	42.86
	10-May-2009				
		Cyprinella lutrensis	1	13	56.52
		Hybognathus amarus	2	9	39.13
		Pimephales promelas	3	1	4.35
	12-May-2009				
		Cyprinella lutrensis	1	32	66.67
		Hybognathus amarus	2	15	31.25
		Pimephales promelas	3	1	2.08
	14-May-2009				
		Cyprinella lutrensis	1	15	65.22
		Hybognathus amarus	2	7	30.43
		Ictalurus punctatus	3	1	4.35
	16-May-2009				
		Hybognathus amarus	1	34	85.00
		Cyprinella lutrensis	2	5	12.50
		Pimephales promelas	3	1	2.50
	17-May-2009				
		Hybognathus amarus	1	35	72.92
		Cyprinella lutrensis	2	12	25.00
		Pimephales promelas	3	1	2.08
	20-May-2009				
		Hybognathus amarus	1	35	89.74
		Carpiodes carpio	2	3	7.69
		Pimephales promelas	3	1	2.56
	21-May-2009				
		Hybognathus amarus	1	8	100.00
	22-May-2009				
		Hybognathus amarus	1	20	95.24
		Carpiodes carpio	2	1	4.76
	23-May-2009				
		Hybognathus amarus	1	28	100.00
	24-May-2009				
		Hybognathus amarus	1	6	85.71
		Carpiodes carpio	2	1	14.29
	25-May-2009				
		Hybognathus amarus	1	16	100.00
	27-May-2009				
		Hybognathus amarus	1	2	66.67
		Carpiodes carpio	2	1	33.33

Sample Site	Date	Species	Rank Order by Site and Date	Number Collected	Daily Percent Abundance by Site
	28-May-2009				
		Hybognathus amarus	1	4	80.00
		Carpiodes carpio	2	1	20.00
	29-May-2009				
		Hybognathus amarus	1	10	90.91
		Carpiodes carpio	2	1	9.09

Fish Community Collection Report by Site and Week

Site	Species	Number Collected	Percent Abundance by Sample Site and Week
Los Lunas FN1			
Week: 19			
	Hybognathus amarus	129	99.23
	Pimephales promelas	1	0.77
Week: 20			
	Hybognathus amarus	483	98.37
	Cyprinella lutrensis	6	1.22
	Lepomis cyanellus	1	0.20
	Pimephales promelas	1	0.20
Week: 21			
	Hybognathus amarus	199	92.13
	Cyprinella lutrensis	8	3.70
	Pimephales promelas	5	2.31
	Cyprinus carpio	4	1.85
Week: 22			
	Hybognathus amarus	35	72.92
	Cyprinus carpio	7	14.58
	Pimephales promelas	2	4.17
	Cyprinella lutrensis	2	4.17
	Lepomis cyanellus	2	4.17
Los Lunas FN2			
Week: 20			
	Hybognathus amarus	468	97.50
	Cyprinella lutrensis	8	1.67
	Pimephales promelas	3	0.63
	Carpiodes carpio	1	0.21
Week: 21			
	Hybognathus amarus	164	93.71
	Cyprinella lutrensis	6	3.43
	Pimephales promelas	4	2.29
	Cyprinus carpio	1	0.57
Week: 22			
	Hybognathus amarus	18	48.65
	Cyprinus carpio	17	45.95
	Cyprinella lutrensis	1	2.70
	Pimephales promelas	1	2.70

Site	Species	Number Collected	Percent Abundance by Sample Site and Week
Los Lunas FN3			
Week: 19			
	Hybognathus amarus	52	81.25
	Cyprinella lutrensis	11	17.19
	Pimephales promelas	1	1.56
Week: 20			
	Hybognathus amarus	343	83.66
	Cyprinella lutrensis	61	14.88
	Pimephales promelas	5	1.22
	Carpiodes carpio	1	0.24
Week: 21			
	Hybognathus amarus	234	90.70
	Cyprinella lutrensis	19	7.36
	Pimephales promelas	5	1.94
Week: 22			
	Hybognathus amarus	145	78.80
	Cyprinella lutrensis	25	13.59
	Cyprinus carpio	11	5.98
	Pimephales promelas	3	1.63
Los Lunas FN4			
Week: 19			
	Hybognathus amarus	8	57.14
	Cyprinella lutrensis	6	42.86
Week: 20			
	Hybognathus amarus	65	48.51
	Cyprinella lutrensis	65	48.51
	Pimephales promelas	3	2.24
	Ictalurus punctatus	1	0.75
Week: 21			
	Hybognathus amarus	126	87.50
	Cyprinella lutrensis	12	8.33
	Carpiodes carpio	4	2.78
	Pimephales promelas	2	1.39
Week: 22			
	Hybognathus amarus	38	90.48
	Carpiodes carpio	4	9.52

Fish Species Collections by Sample Site

Sample Site	Species	Number Collected	Percent of Total by Site
Los Lunas FN_1			
	Hybognathus amarus	846	95.59
	Cyprinella lutrensis	16	1.81
	Cyprinus carpio	11	1.24
	Pimephales promelas	9	1.02
	Lepomis cyanellus	3	0.34
Los Lunas FN_2			
	Hybognathus amarus	650	93.93
	Cyprinus carpio	18	2.60
	Cyprinella lutrensis	15	2.17
	Pimephales promelas	8	1.16
	Carpiodes carpio	1	0.14
Los Lunas FN_3			
	Hybognathus amarus	774	84.50
	Cyprinella lutrensis	116	12.66
	Pimephales promelas	14	1.53
	Cyprinus carpio	11	1.20
	Carpiodes carpio	1	0.11
Los Lunas FN_4			
	Hybognathus amarus	237	70.96
	Cyprinella lutrensis	83	24.85
	Carpiodes carpio	8	2.40
	Pimephales promelas	5	1.50
	Ictalurus punctatus	1	0.30

APPENDIX D
FLOODPLAIN FISH SAMPLES

Fish Species Catch per Fyke Net Hour - Los Lunas, 2009

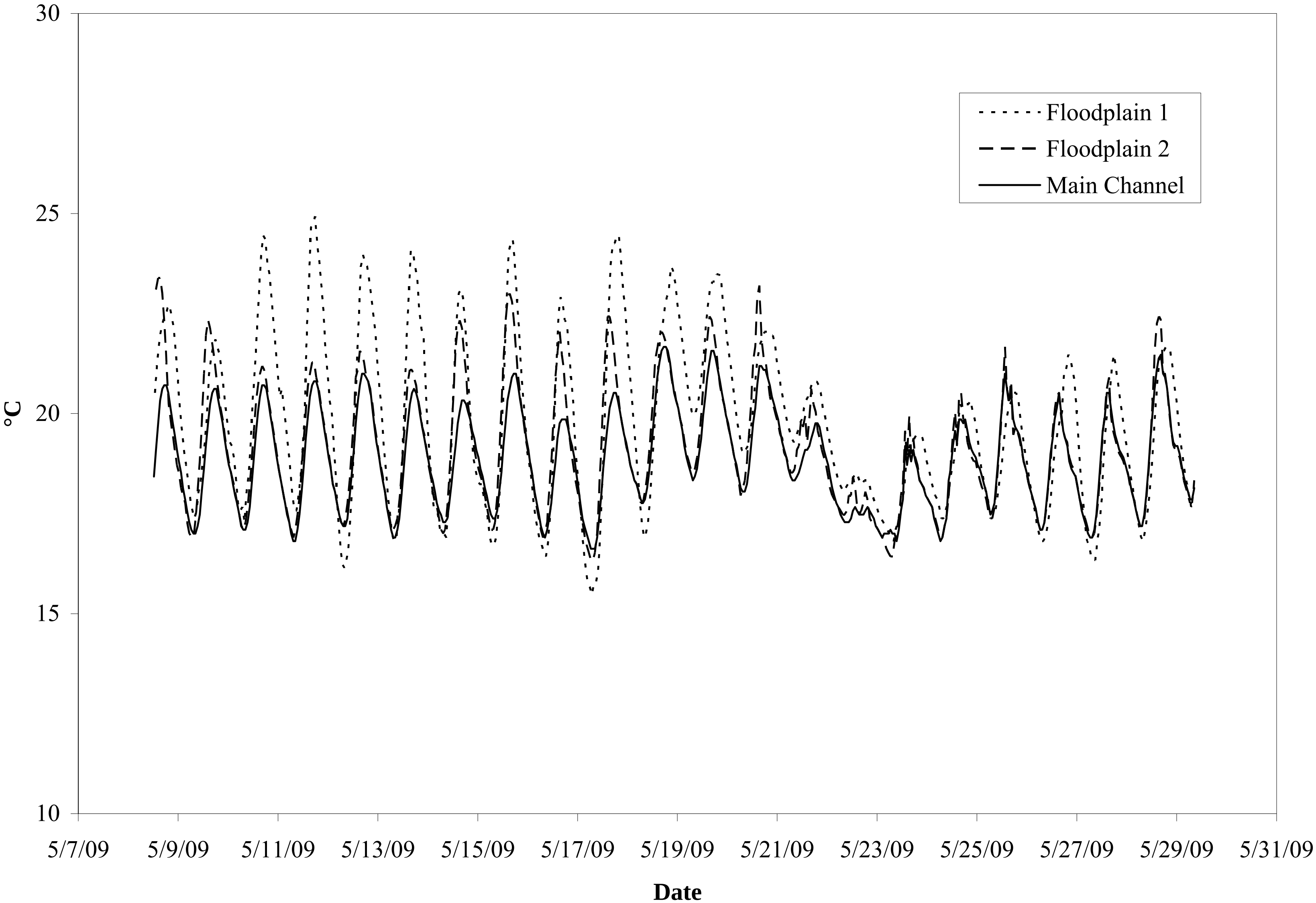
Net	Species	09-May	10-May	12-May	14-May	16-May	17-May	20-May	21-May	22-May	23-May	24-May	25-May	27-May	28-May	29-May
Los Lunas FN1																
	Cyprinella lutrensis	---	0.23	0.33	0.21	0.63	---	1.33	1.02	---	---	0.33	0.27	---	---	---
	Cyprinus carpio	---	---	---	---	---	0.39	---	---	0.29	0.23	0.33	0.27	0.95	0.57	---
	Hybognathus amarus	38.86	47.82	44.00	13.70	16.63	35.43	3.33	1.79	0.29	0.23	1.00	0.54	1.89	5.43	0.97
	Lepomis cyanellus	---	---	0.33	---	---	---	---	---	---	---	---	---	0.32	0.29	---
	Pimephales promelas	0.30	0.23	---	---	---	0.59	---	0.26	---	0.23	0.33	0.27	---	---	---
Los Lunas FN2																
	Carpiodes carpio	---	---	---	---	0.19	---	---	---	---	---	---	---	---	---	---
	Cyprinella lutrensis	---	0.19	---	0.95	0.38	0.18	1.26	0.25	---	---	---	0.27	---	---	---
	Cyprinus carpio	---	---	---	---	---	---	---	---	---	0.23	0.67	---	---	2.93	0.84
	Hybognathus amarus	---	39.78	10.50	24.19	15.95	25.82	5.68	0.50	---	0.46	0.67	---	0.95	2.67	0.63
	Pimephales promelas	---	0.19	0.25	---	0.19	0.18	---	0.25	0.30	0.23	---	---	---	---	0.21
Los Lunas FN3																
	Carpiodes carpio	---	---	---	0.18	---	---	---	---	---	---	---	---	---	---	---
	Cyprinella lutrensis	3.35	2.68	2.35	5.47	0.72	0.34	1.54	2.70	---	0.24	---	2.93	---	3.66	---
	Cyprinus carpio	---	---	---	---	---	---	---	---	---	---	---	---	1.54	---	1.50
	Hybognathus amarus	15.85	16.58	21.18	8.29	19.18	14.36	11.38	10.54	6.71	9.18	9.33	10.93	8.92	6.79	5.25
	Pimephales promelas	0.30	0.50	---	0.18	0.18	---	---	0.49	---	0.71	0.33	---	---	0.52	---
Los Lunas FN4																
	Carpiodes carpio	---	---	---	---	---	---	0.88	---	0.22	---	0.30	---	0.29	0.19	0.29
	Cyprinella lutrensis	1.45	2.23	6.40	3.05	0.86	2.00	---	---	---	---	---	---	---	---	---
	Hybognathus amarus	1.93	1.55	3.00	1.42	5.83	5.83	10.23	1.81	4.49	6.22	1.80	4.00	0.57	0.77	2.92
	Ictalurus punctatus	---	---	---	0.20	---	---	---	---	---	---	---	---	---	---	---
	Pimephales promelas	---	0.17	0.20	---	0.17	0.17	0.29	---	---	---	---	---	---	---	---

APPENDIX E
RIO GRANDE SILVERY MINNOW COLLECTIONS BY WATER VELOCITY CATEGORY

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

Velocity Type	Date	Observed Female Condition: Gravid	Eggs	Spent	Male: Milt	Unknown
High Velocity						
	09-May-2009	4	0	19	23	6
	10-May-2009	26	2	1	33	37
	12-May-2009	18	0	0	24	48
	14-May-2009	10	0	0	13	24
	16-May-2009	19	0	10	27	51
	17-May-2009	19	0	15	29	22
	20-May-2009	8	0	1	5	23
	21-May-2009	5	0	10	4	24
	22-May-2009	3	1	11	10	5
	23-May-2009	9	0	16	12	2
	24-May-2009	2	0	4	4	18
	25-May-2009	4	0	8	12	16
	27-May-2009	7	0	6	9	7
	28-May-2009	2	0	8	7	9
	29-May-2009	3	0	7	3	8
Summary for the Single High Velocity Site (15 detail records)						
	Averages:	*9.27*	*0.20*	*7.73*	*14.33*	*20.00*
Low Velocity						
	09-May-2009	48	0	12	7	28
	10-May-2009	75	7	3	104	242
	12-May-2009	8	0	4	33	146
	14-May-2009	21	0	7	57	113
	16-May-2009	25	0	6	35	132
	17-May-2009	59	0	84	92	122
	20-May-2009	15	0	3	5	40
	21-May-2009	6	0	2	3	6
	22-May-2009	8	0	9	1	3
	23-May-2009	13	0	7	6	5
	24-May-2009	2	0	3	0	6
	25-May-2009	4	0	5	2	7
	27-May-2009	4	0	1	1	5
	28-May-2009	13	0	3	11	6
	29-May-2009	7	0	5	2	4
Summary for Low Velocity Sites (15 detail records)						
	Averages:	*20.53*	*0.47*	*10.27*	*23.93*	*57.67*

APPENDIX F
HOBO TEMPERATURE PLOTS



30
25
20
15
10
°C
Floodplain 1
Floodplain 2
Main Channel
5/7/09
5/9/09
5/11/09
5/13/09
5/15/09
5/17/09
5/19/09
5/21/09
5/23/09
5/25/09
5/27/09
5/29/09
5/31/09
Date

APPENDIX G
WATER QUALITY DATA

Water Quality - Overview

Geographic Area	Date	Time	Depth(ft)	Current	Water Temp(C)	DO (PPM)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
Los Lunas WQ1											
	09-May-2009	11:15 AM	2.20	0.36	17.82	5.56	58.50	4.77	0.12	258.00	123.00
	10-May-2009	7:52 AM	2.40	0.52	16.98	5.85	60.50	8.08	0.12	250.00	---
	12-May-2009	7:48 AM	2.40	0.48	17.09	6.20	64.40	0.12	8.23	207.00	---
	14-May-2009	7:35 AM	2.10	0.55	17.22	6.60	68.90	8.21	0.12	206.00	---
	16-May-2009	7:35 AM	2.30	0.59	16.89	7.00	72.20	8.19	0.11	198.00	---
	17-May-2009	7:25 AM	2.30	0.05	16.55	7.08	72.80	8.21	0.11	198.00	---
	20-May-2009	7:35 AM	1.90	0.38	17.94	6.92	73.00	8.38	0.11	207.00	---
	21-May-2009	7:45 AM	1.90	0.33	18.25	6.88	73.10	8.22	0.12	212.00	---
	22-May-2009	7:24 AM	1.80	0.29	17.31	7.53	78.40	8.08	0.12	208.00	---
	23-May-2009	7:20 AM	0.80	0.54	16.27	7.56	77.10	8.19	0.12	206.00	84.00
	24-May-2009	9:00 AM	1.10	0.61	16.96	7.50	77.60	8.14	0.12	217.00	69.00
	25-May-2009	8:25 AM	1.10	0.49	17.38	7.14	71.40	8.08	0.12	218.00	71.00
	27-May-2009	8:05 AM	1.70	0.53	16.68	9.17	92.00	6.76	0.13	222.00	---
	29-May-2009	7:40 AM	1.90	0.38	17.59	8.65	90.70	8.36	0.13	230.00	---

Summary Statistics for Los Lunas WQ1 (14 records):

	Depth(ft)	Current	Water Temp(C)	DO (PPM)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
Avg.	1.85	0.44	17.21	7.12	73.61	7.27	0.70	216.93	86.75
St. Dev.	0.52	0.15	0.55	0.97	9.59	2.27	2.17	18.05	NA
Max.	2.40	0.61	18.25	9.17	92.00	8.38	8.23	258.00	NA
Min.	0.80	0.05	16.27	5.56	58.50	0.12	0.11	198.00	NA

Geographic Area	Date	Time	Depth(ft)	Current	Water Temp(C)	DO (PPM)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
Los Lunas WQ2											
	09-May-2009	9:40 AM	1.00	-0.02	17.19	2.57	26.70	5.62	0.13	274.00	83.00
	10-May-2009	8:29 AM	1.30	0.00	18.10	2.00	22.20	8.11	0.14	297.00	---
	12-May-2009	8:01 AM	1.40	0.01	16.05	2.17	22.30	8.20	0.13	224.00	---
	14-May-2009	7:50 AM	1.70	0.01	16.63	4.34	44.80	8.16	0.12	215.00	---
	16-May-2009	7:45 AM	1.60	0.00	16.27	3.51	36.20	8.06	0.12	204.00	---
	17-May-2009	7:40 AM	1.40	0.00	15.49	3.04	30.50	8.18	0.12	205.00	---
	20-May-2009	8:00 AM	1.60	0.01	18.80	3.15	33.60	8.11	0.13	239.00	---
	21-May-2009	8:00 AM	1.50	0.02	19.14	3.36	36.70	8.08	0.13	235.00	---
	23-May-2009	7:37 AM	1.20	0.01	16.71	2.90	29.90	8.20	0.13	226.00	59.00
	24-May-2009	9:15 AM	1.00	0.00	17.49	3.60	38.20	8.15	0.12	220.00	41.00
	25-May-2009	8:40 AM	1.00	0.00	17.31	4.37	45.70	8.15	0.13	228.00	38.25
	27-May-2009	7:15 AM	1.60	0.00	15.66	4.26	43.20	7.63	0.14	235.00	---
	27-May-2009	7:35 AM	0.80	0.06	14.43	8.60	88.40	7.89	0.13	220.00	---
	29-May-2009	7:50 AM	0.90	0.01	17.39	7.86	59.40	8.43	0.14	251.00	---

Summary Statistics for Los Lunas WQ2 (14 records):

	Depth(ft)	Current	Water Temp(C)	DO (PPM)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
Avg.	1.29	0.01	16.90	3.98	39.84	7.93	0.13	233.79	55.31
St. Dev.	0.30	0.02	1.29	1.95	17.22	0.69	0.01	25.69	NA
Max.	1.70	0.06	19.14	8.60	88.40	8.43	0.14	297.00	NA
Min.	0.80	-0.02	14.43	2.00	22.20	5.62	0.12	204.00	NA

Geographic Area	Date	Time	Depth(ft)	Current	Water Temp(C)	DO (PPM)	DO % Sat	pH	Salinity	Specific Cond	Turbidity
Los Lunas WQ3											
	09-May-2009	10:47 AM	0.65	-0.02	18.95	6.23	67.50	5.12	0.12	257.00	92.00
	10-May-2009	9:38 AM	1.00	0.02	17.68	5.02	52.30	8.13	0.12	256.00	---
	12-May-2009	8:43 AM	1.00	0.02	17.28	4.80	49.20	8.19	0.12	210.00	---
	14-May-2009	8:20 AM	1.20	0.18	17.09	6.11	63.40	8.15	0.12	209.00	---
	16-May-2009	8:05 AM	1.30	0.06	16.75	5.53	58.00	8.04	0.11	202.00	---
	17-May-2009	8:05 AM	1.10	0.03	16.18	5.20	52.60	8.02	0.12	206.00	---
	20-May-2009	8:25 AM	0.70	0.04	18.11	6.30	66.90	7.98	0.11	210.00	---
	21-May-2009	8:20 AM	0.80	0.01	18.41	6.17	66.10	8.02	0.12	214.00	---
	23-May-2009	8:01 AM	0.50	0.00	16.49	6.47	68.90	8.15	0.12	209.00	71.00
	24-May-2009	9:40 AM	0.70	0.02	17.37	6.00	64.40	8.05	0.12	219.00	79.00
	25-May-2009	9:00 AM	0.60	0.02	17.84	7.24	76.20	8.13	0.12	222.00	51.00
	29-May-2009	8:15 AM	0.60	0.02	17.75	8.65	89.80	8.37	0.13	232.00	---
Summary Statistics for Los Lunas WQ3 (12 records):											
		Avg.	0.85	0.03	17.49	6.14	64.61	7.86	0.12	220.50	73.25
		St. Dev.	0.26	0.05	0.80	1.04	11.21	0.87	0.01	18.61	NA
		Max.	1.30	0.18	18.95	8.65	89.80	8.37	0.13	257.00	NA
		Min.	0.50	-0.02	16.18	4.80	49.20	5.12	0.11	202.00	NA

APPENDIX H
BOOTSTRAP ANALYSIS OF MAIN CHANNEL SEINE SAMPLES

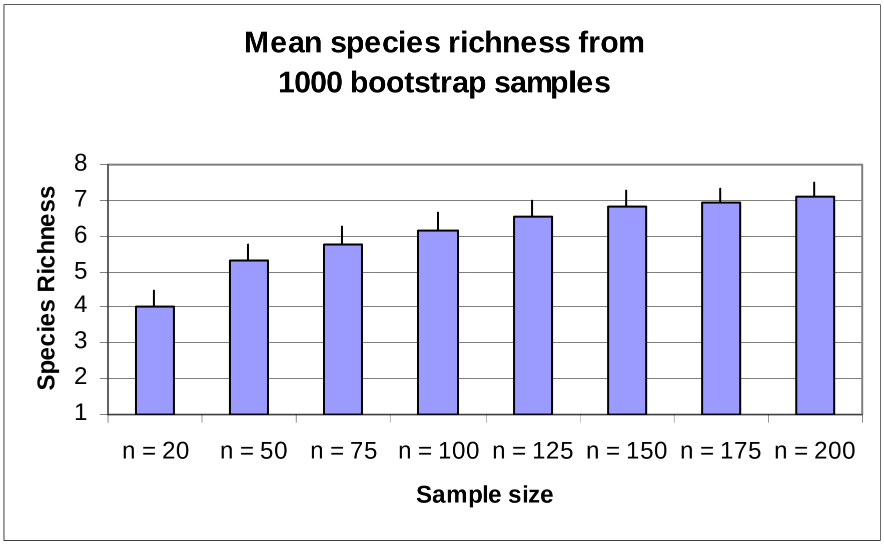


Figure H.1. 31-Oct-2008 (actual n = 42).

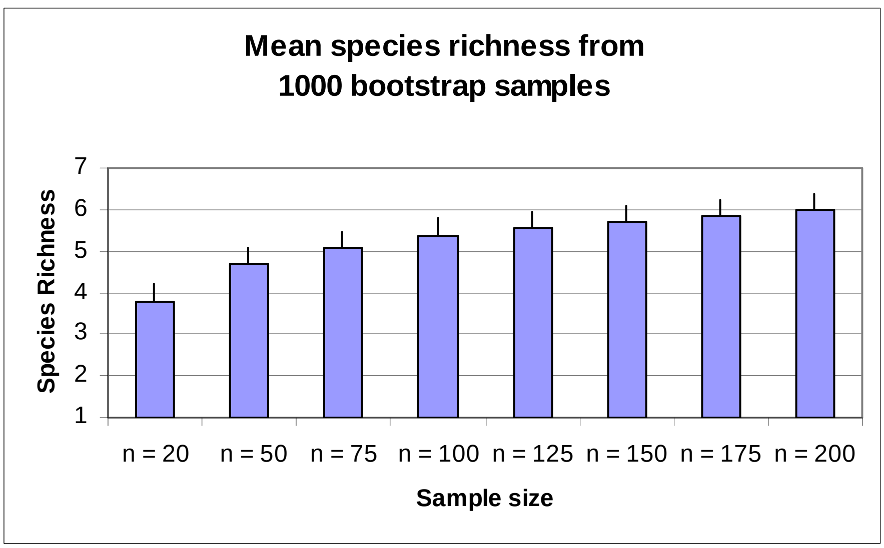


Figure H.2. 21-Nov-2008 (actual n = 29).

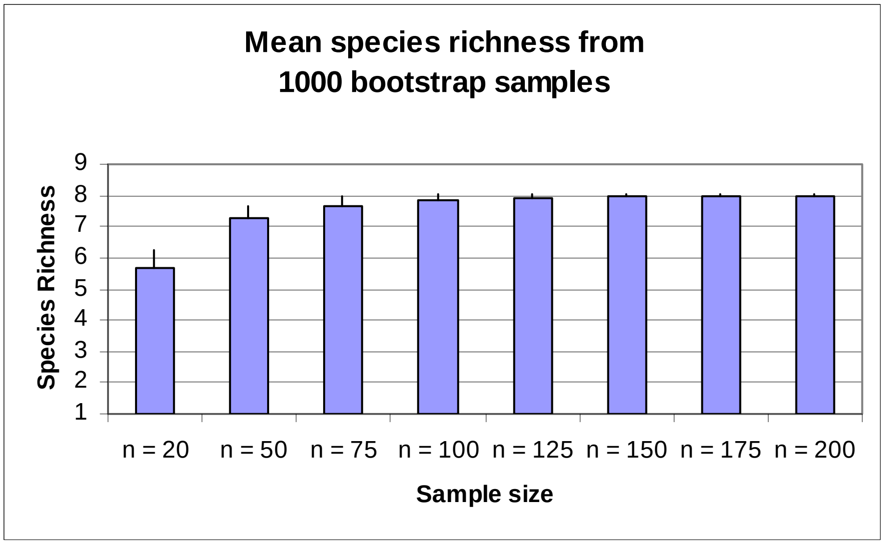


Figure H.3. 19-Dec-2008 (actual n = 19).

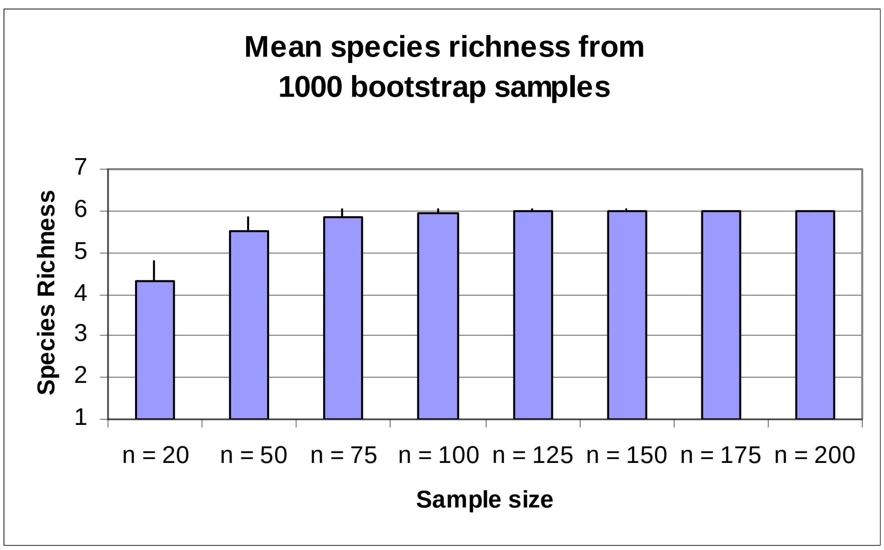


Figure H.4. 27-Jan-2009 (actual n = 30).

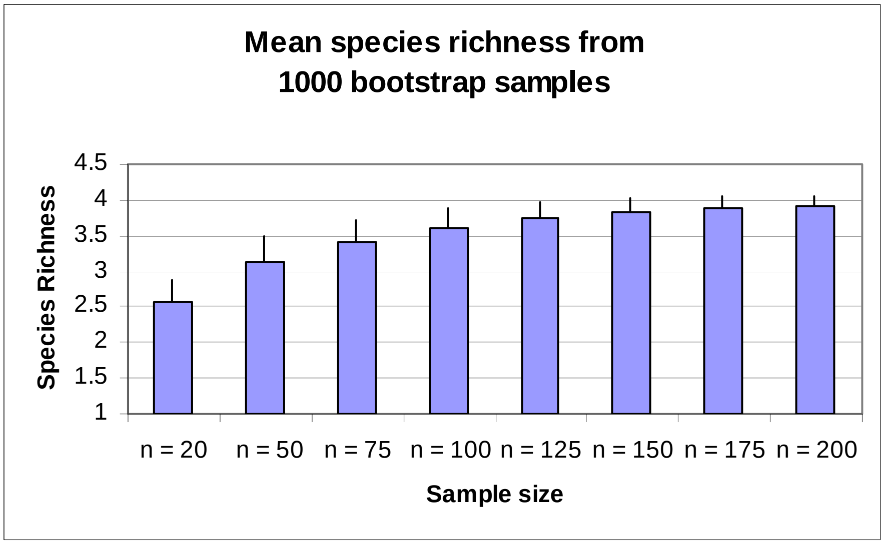


Figure H.5. 19-Feb-2009 (actual n = 37).