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Habitat use of the Rio Grande silvery minnow (*Hybognathus amarus*) during a long-term flood pulse in the Middle Rio Grande, New Mexico

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Abstract The Middle Rio Grande (MRG) of New Mexico has been influenced by man for over 500 years. Native Americans began diverting water to irrigate agricultural crops in the floodplain in the 14th century. The Spanish followed and increased agricultural irrigation to over 125 000 acres. Frequent flooding of the MRG valley in the 19th century led to many engineering projects in the early 20th century to control flooding. A series of impoundment dams, diversion dams, and levees were constructed. The loss of floodplain habitats throughout the MRG Valley has altered the riparian community and caused the demise of many fish species. A controlled flood pulse from Cochiti Reservoir, New Mexico was initiated in April 2005 to support the recovery of the endangered Rio Grande silvery minnow, *Hybognathus amarus*. This study documents habitat selection by larval fishes in a restored floodplain in the Rio Grande, NM. Larval fish light traps captured 394 larvae representing four cyprinid species (*Pimephales promelas*, *H. amarus*, *Cyprinella lutrensis* and *Cyprinus carpio*). Results for CCA indicate that *Hybognathus amarus* prefer shallow, low velocity habitats. Results from Chao-Jaccard similarity index indicated that relative contribution was highest in *P. promelas* at 64% followed by *H. amarus* 33%. Results from (dis)similarity analysis reveal that species composition between habitat orientation and date was highest in *H. amarus* at 42% followed by *P. promelas* 40%. *Cyprinella lutrensis* and *C. carpio* represented 9.5 and 8.5%, respectively. A general linear model indicated that only depth and velocity were significantly different (p=0.02 and p=0.03 respectively).

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Introduction

It has been said "understanding how fauna respond to flooding in floodplain rivers is the holy grail of river ecologists" (Humphries, P. pers. comm., 2011). The present study was intended to elucidate the response of Rio Grande ichthyofauna to a long-term flood pulse in the Middle Rio Grande (MRG) of New Mexico. Few large alluvial rivers of the southwestern U.S. have been studied and documented as well as the MRG of New Mexico (Richard 2001). However, little is known about floodplain habitat use by Rio Grande ichthyofauna during floods in the MRG. The MRG is defined as the reach from Cochiti Dam to Elephant Butte Dam in southern NM, a distance of 289 km.

For the past 5 million years, the Rio Grande has flowed south through its valley from its origins in the San Juan Mountains of southern Colorado to the Gulf of Mexico (Crawford et al. 1993). The Rio Grande is the fourth largest river in North America, totaling more than 1900 miles in length (USGS 2011). Unlike typical river valleys, the river did not create the valley it flows through. Instead, the Rio Grande flows through the Rio Grande rift at the lowest point of the trough (Scurlock 1998). For millions of years the river would freely migrate across the floodplain (Molles et al. 1998) which varied in width from less than 1.5 km to approximately 10 km and bound on the east and west by raised landforms and mountains of varying geological origin (Crawford et al. 1993). The typical hydrological pattern of the Rio Grande's bed would be to aggrade over time, and in response to a flood or series of floods, would leave its elevated channel to lower elevation in the valley and establish a new course through a process known as 'avulsion' (Crawford et al. 1993). The historical Rio Grande is unique among other rivers described in the literature because of the high frequency of channel migration and avulsion (Mack and Leeder 1998). Richard (2001) used more than 74 years of hydraulic, topographic, sediment, and photographic data to quantify lateral migration of the Middle Rio Grande in the Cochiti reach. Since 1918, the channel moved toward a more stable state as peak discharges decreased prior to and following construction of Cochiti Dam, and shifting from a multi-thread to a more single-thread pattern (Richard 2001). This pattern has led to an incised channel, which rarely overtops its banks except in the lower sections leading to Elephant Butte Reservoir (Crawford et al. 1993).

The severity and frequency of major flooding along the MRG began in the late 19th and early 20th centuries (Wozniak 1987). Between 1849 and 1942, a total of 50 moderate to severe floods were recorded along the MRG reach with an average occurrence of approximately every 1.9 years (Scurlock 1998). The demand for water in this highly restricted and physically altered river led to the enactment of International, Federal and state laws to allocate water to the states of Colorado, New Mexico, Texas, and the Republic of Mexico (Crawford et al. 1993). Continued flooding led to the formation of the Middle Rio Grande Conservancy District (MRGCD) in 1925, whose emphasis was to increase the efficient use of river water (Scurlock 1998). By 1935 the MRGCD had constructed 555 km of drainage canals, 290 km of river levees, 400 km of main irrigation ditches, and almost 640 km of old irrigation ditches (Crawford et al. 1993).

The most significant ecological effect of Cochiti Dam was to diminish the river's historic flood regime (Crawford et al. 1996; Dahm et al. 2003). As a result of dam operations, the MRG no longer has a predictable flood regime; rather it has a 'naturalized flood regime' (Bayley 1995) in the form of annual hypolimnetic releases from Cochiti Reservoir. Flow in the MRG is confined to the area between levees (Crawford et al. 1996; Molles et al. 1998; Massong and Slaugh 2002), where much of the floodplain has become disconnected and abandoned through degradation and aggradation of the channel bed (Valett et al. 2005; Massong et al. 2006). Most floodplains in the MRG remain isolated from flooding while few are still regularly inundated by the flood pulse (Valett et al. 2005). Loss of connectivity between the river and floodplains in the MRG is due to flow regulation and has shifted the flood regime to longer inter-flood intervals (Valett et al. 2005). Presently, the riverbanks along the MRG are generally 1.2 to 1.5 m high and the incision of the river channel makes it very unlikely that controlled discharges from Cochiti Dam will overtop the riverbanks under present reservoir management practices (Crawford et al. 1993).

Floodplain inundation in rivers is thought to enhance fish recruitment by providing a suitable environment and abundant food and habitat for larvae (King et al. 2003). Existing literature indicates that fish yields are higher in river-floodplains, including individual temperate floodplain lakes that are connected to the river (Bayley 1995), particularly those with predictable annual flood pulse (Balcombe et al. 2007). The MRG lacks flood pulses of sufficient duration to provide adequate time for spawning, nursery, and recruitment of native ichthyofauna.

Virtually the entire endemic native fish fauna in the southwestern U.S. is listed as threatened or endangered under the Endangered Species Act, largely as a consequence of water withdrawal, flow stabilization, and exotic species proliferation (Poff et al. 1997).

The target species of this study, the Rio Grande silvery minnow (*Hybognathus amarus*) was at one time the most abundant fish in the Rio Grande and Pecos River occupying approximately 3800 river km (2400 mi) in New Mexico and Texas to the Gulf of Mexico (Bestgen and Platania 1991), but was listed as endangered by the U.S. Fish and Wildlife Service in 1994 (USFWS 1994). Officially, *H. amarus* only occurs in the Middle Rio Grande of New Mexico, a

280 km (174 mi) stretch of river that runs from Cochiti Dam to the headwaters of Elephant Butte Reservoir or approximately seven percent (7%) of its former range. However, *H. amarus* is confined to an even smaller reach between Angostura diversion dam and south of San Acacia dam, a distance of 141 km, or approximately 3.7% of *H. amarus* former range.

Studies of contemporary habitat use by *H. amarus* are very limited (Dudley and Platania 1997; Pease et al. 2006) therefore, the present study is important to understanding habitat use by *H. amarus* and associated ichthyofauna in a restored floodplain especially since it occurred during prolonged flood pulse. *Hybognathus amarus* uses only a small portion of the available aquatic habitat since channelization of the MRG has reduced or eliminated most backwaters, edge areas, and slow-water refugia which are typical habitat (Bestgen and Platania 1991; Dudley and Platania 1997). The present study was the first investigation of habitat use by Rio Grande ichthyofauna during a prolonged flood pulse in the MRG. In general, *H. amarus* most often uses silt substrates in areas of low or moderate water velocity (e.g., eddies formed by debris piles, pools, and backwaters) (Dudley and Platania 1997; Pease et al. 2006). *Hybognathus amarus* is rarely found in habitats with high water velocities, such as main channel runs, which are often deep and swift (Dudley and Platania 1997; USFWS 2001). The objectives of this study were; 1) Assess patterns of habitat utilization of restored floodplain by *H. amarus*, and Rio Grande ichthyofauna, and 2) Measure physical and chemical parameters as they relate larval fish diversity to habitat conditions.

Methods

The Los Lunas, NM, Habitat Restoration Project is located at approximately river kilometer 252, on the west bank of the Rio Grande adjacent to Mid Valley Airpark, Los Lunas, NM (Fig. 1). The restored overbank area is approximately 1800 x 100 m along the existing riverbank, encompassing an area of approximately 16 hectares that is bounded on the west by a two meter high earthen and rootwad berm. In 2001, the U.S. Fish and Wildlife Service (USFWS 2001) concluded that current management practices in the MRG would likely jeopardize the continued existence of *H. amarus*. Funded through an interagency collaborative program, the Middle Rio Grande Endangered Species Act Collaborative Program, the Los Lunas, New Mexico Habitat Restoration Project was initiated in 2002 to improve habitat conditions for *H. amarus* (Slaugh 2003). The project was designed to mechanically widen the active river channel and improve adjacent riparian habitats by moving over 53 518 m^3 of material within the former floodplain to produce a heterogeneous topography with goals to produce inundation of the floodplain at flows of greater than or equal to 70 m^3 s^{-1} and to ensure some inundation at a wide range of flows less than 70 m^3 s^{-1} (Slaugh 2003). Specific areas within the site were revegetated by the USCOE using seed, potted shrubs, or cottonwood (*Populus deltoids*) and willow poles (*Salix exigua* Nutt). Other features of floodplain modification included a network of variable depth side and transverse channels designed to aid in minnow egg retention and provide shallow water/low velocity rearing habitat (USBOR 2007). These alterations within the historic floodplain were intended to produce a variety of additional shallow water/low velocity egg-retention and nursery habitats for *H. amarus* during spring spawning flows. Spawning habits of *H. amarus* are unknown but are believed to occur in spring and summer in still waters over sandy-silt substrates (Sublette et al. 1990; Dudley and Platania 1997). Substrate at the Los Lunas Restoration site consisted mainly of sand and silt.

This study took place during a "wet" year in New Mexico where snowpack in northern New Mexico mountains was higher than normal levels (NOAA 2007) indicating a higher than normal spring runoff. Discharge data for this study was taken from U.S. Geological Survey (USGS) (Gage station 08330000) at Central Bridge in Albuquerque, NM.

Bayley (1995) stated that annual primary and secondary production in many in temperate systems may depend more on mechanisms occurring during drawdown than those occurring when the water is rising, therefore, this study was initiated at peak discharge (198 m^3 s^{-1}) on 24 May 2005 during a prolonged hypolimnetic release from Cochiti Reservoir (8 April-17 July 2005) and continued during the 44 days of the descending limb of the hydrograph.

At peak flow (24 May 2005), six larval fish light traps (Aquatic Research Instruments Inc., ARII 2007) illuminated with chemical light sticks (Cyalume, Omniglow Corp) were deployed at six sampling sites representing three habitat orientations; perpendicular to flow (LT1 and LT4), parallel to flow (LT2 and LT5), and

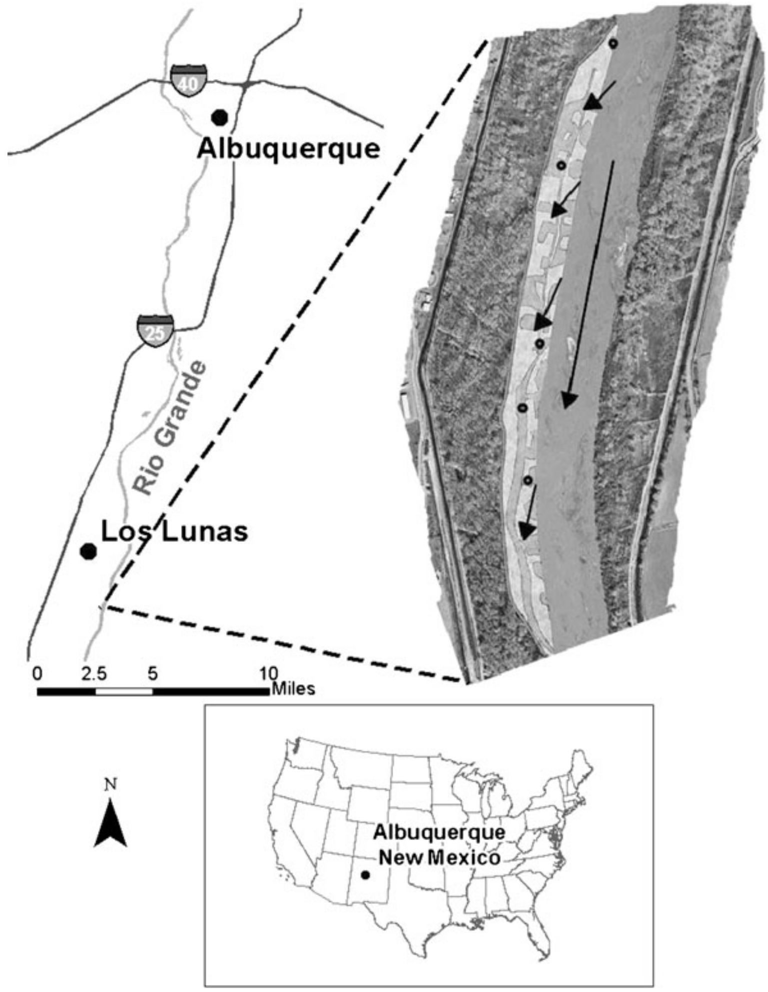


Fig. 1 Middle Rio Grande, NM. Inset: Los Lunas Habitat Restoration Project. White area (center-left) is the restored floodplain showing area of inundation at >71 $m^3 s^{-1}$. Gray areas indicate areas of inundation at <71 $m^3 s^{-1}$. Center of picture is the Rio Grande (flowing south). Dots indicate locations of light traps on the floodplain numbered 1-6 north to south

leeward side of islands (LT3 and LT6). No light trap controls were used in the main channel margin since *H. amarus* is rarely collected in this most abundant habitat (Dudley and Platania 1997). All habitat orientations had varying degrees of water velocity throughout the study. The water velocities at sites perpendicular to river flow where the river entered the floodplain (6.0 cm s^{-1} vs. main channel 80 cm s^{-1}), parallel to river (~11.0 cm s^{-1}) flow, or leeward side of islands (~1.0 cm s^{-1}). Light traps were deployed weekly at dusk and retrieved at dawn on 24 May, 1 June, 8, 14, 21, and 28 at six permanent habitat locations. On each sampling date, light traps were deployed and anchored to a metal post in water less than 1 m deep (39 cm±1.9 SE). Upon retrieval, larval fish were removed from cod-end of light trap and placed into 250 ml polycarbonate bottles of ice water and Alka-Seltzer® tablets were added to euthanize fish via CO_2 narcosis (Wall 1993). Euthanized fish were placed in 5% buffered formalin for 48 h, transferred to 35% ETOH for 7 days, and transferred to 70% ETOH for long-term preservation (Wall 1993, Pease et al. 2006).

Water samples (60 ml) were collected during light trap deployments, placed on ice, and delivered to the lab for analysis. Water samples were analyzed for dissolved nitrate (NO_3-N), soluble reactive phosphorus (PO_4-P) and ammonium (NH_4-N) (Magaña 2009). A YSI 556 multi-probe meter (Yellow Springs Inc.) was used at light trap deployment to measure water quality parameters (temperature (°C), conductivity (μSiemens cm^{-1}), dissolved oxygen (mg L^{-1}), percent saturation dissolved oxygen (%DO), and pH adjacent to the light traps. Depth was measured to the nearest tenth of a meter using a stadia rod (Crain Enterprises Inc. model #

Table 1 Los Lunas environmental parameters measured during 24 May to 28 June 2005

Variable	Mean (±SD)	Range
Temp (C°)	22.6 (1.95)	20.72–27.45
Conductivity (μS cm^{-1})	231.1 (80.9)	201–356
DO (mg/L)	6.9 (1.0)	2.35–9.29
DO (% saturation)	79.5 (13.6)	27.9–117.8
pH	8.1 (0.3)	6.69–8.76
Depth (cm)	39.1 (10.9)	17–69
Velocity (cm/s)	6.3 (13.1)	0–77
NO_3-N (μg/L)	138.9 (60.1)	5–298
PO_4-P (μg/L)	59.2 (41.5)	0–150
NH_4-N (μg/L)	67.5 (95.2)	0–430

90370). Water velocity was measured at six-tenths total depth using a flow pressure sensor (Marsh-McBirney Model 2000). Light quanta were measured using a Li-Cor quantum meter (Li-Cor Biosciences model Li-1000 and a 4π quantum sensor model Li-193SA).

A Canonical Correspondence Analysis (CCA) was used to provide visual representation of the data for physical and chemical characteristics of habitats occupied by fish across temporal and spatial scales. The CCA is a multivariate analysis technique that directly relates community composition to known variation in the environment (ter Braak 1986). Two data sets are used, one on the occurrence or abundance of a number of species at a series of sites, and data on a number of environmental variables measured at the same sites (ter Braak 1986). The technique generates an ordination diagram, where species and light trap orientation are represented by points and numbers, respectively, and environmental variables are represented by arrows (ter Braak 1986). The CCA analysis allows for a quick appraisal of how community composition varies with the environment (ter Braak 1986). By looking at the signs and relative magnitude of the intraset correlations we may infer the relative importance of each environmental variable for predicting the community composition (ter Braak 1986). For example, the arrow referring to "pH" on a CCA diagram allows us to infer which species largely occur at sites with highest and lowest pH. Two separate CCA triplots were produced for the data obtained. One triplot represents data for chemical site characteristics (e.g. NO_3-N, NH_4-N, PO_4-P, pH, and DO) while the other triplot represents data for physical site characteristics (e.g. Depth, velocity, temperature, and light quanta). Since DO and %DO were highly correlated (0.9799) only DO was used in the analyses ($p<0.0001$).

Two similarity indices were used to quantitatively compare fish species composition and trap light orientation. The two indices employed were the Chao-Jaccard index, a Jaccard coefficient weighted by abundance (Chao et al. 2005) used for assessing compositional similarity of assemblages based on the presence/absence of species in paired assemblages, and the (dis) similarity index (Dyer 1978) designed for data sets which involve both multiple species and multiple environmental variables. The total species dissimilarity is divided into

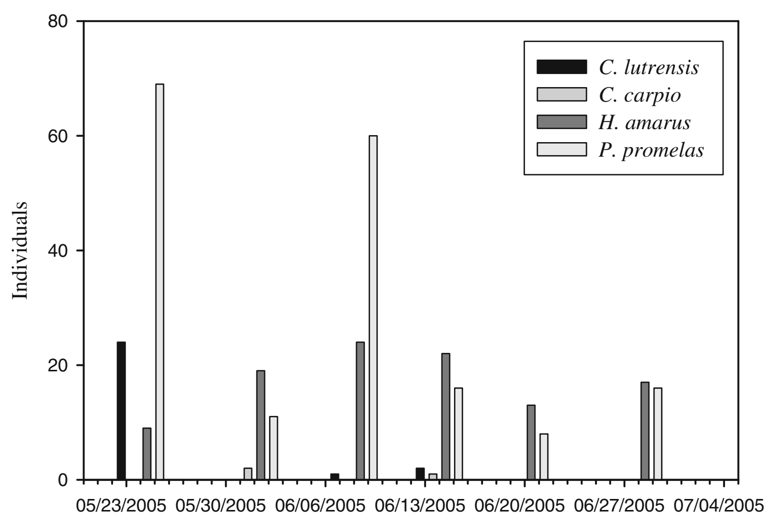


Fig. 2 Larval fish captures at Los Lunas Restoration site during sampling period

components with one (1) component being assigned to each environmental variable or interaction of environmental variables. This similarity index provides a versatile and convenient tool for quantitatively comparing the species composition of one (1) multispecies sample with another (Dyer 1978).

A generalized linear mixed model (SAS ver. 9.3, GLIMMIX procedure, SAS Institute Inc. Cary, NC) was used to determine the relationship between fish, environmental variables, and light trap orientation. A scatterplot was generated for habitat orientation versus each candidate explanatory variable. Then a linear regression between habitat orientations versus each explanatory variable was computed with fish species included as a class variable and as an interaction with the explanatory variable.

Results

During the descending limb of the hydrograph (May-June, 2005) deployed larval fish light traps captured 394 individuals representing four fish species from the Family Cyprinidae (*Pimephales promelas* (n=228, 59%), *Hybognathus amarus* (n=123, 32%), *Cyprinella lutrensis* (n=27, 7%) and *Cyprinus carpio* (n= 16, 2%) (Table 1 and Fig. 2). The highest captures were obtained in leeward habitats (46%) followed by perpendicular habitats (33%) and parallel habitats (21%). While larval fish light traps only captured four cyprinid species during the flood pulse a total of nine (9) species were captured with seines during drawdown. The larval fish light trap may be biased towards Cyprinidae species, but may be due to color of the light source (Kissick 1993; Marchetti et al. 2004).

Results from the chemical site characteristics CCA (Table 1 and Fig. 3) showed that PO_4-P, DO, and NH_4-N were positively correlated and NO_3-N was negatively correlated. *Cyprinella lutrensis* was positively associated with DO, PO_4-P, NH_4-N, and LT3. *Pimephales promelas*, *C. lutrensis*, LT1 and LT3 were positively associated with pH. *Pimephales promelas*, LT6, LT1, LT4, and LT2 were positively associated with NO_3-N. Results from the

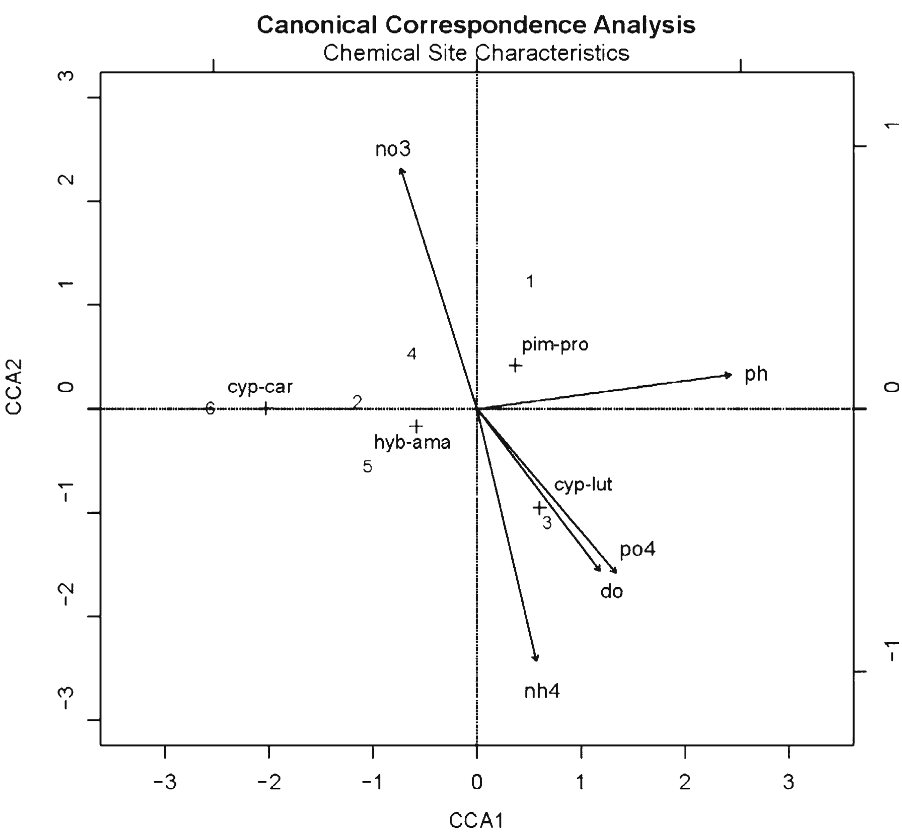


Fig. 3 The distribution of four Cyprinidae species captured in larval fish light traps as they relate to chemical site characteristics. Definitions as follows; cyp-car = *Cyprinus carpio*, hyb-ama = *Hybognathus amarus*, pim-pro = *Pimephales promelas*, and cyp-lut = *Cyprinella lutrensis*. The labels po4 = phosphate, do = dissolved oxygen, nh4 = ammonium. Numbers 1–6 relate to light trap and location

physical site characteristics CCA (Fig. 4) showed that I100 and I170 (light quanta) were positively correlated. *Cyprinella lutrensis*, *H. amarus*, LT3 and LT5 were positively associated with light.

Comparison of depth among LT locations showed that LT4 was significantly different from LT2 (p=0.005), LT5 (p=0.02), and LT6 (p=0.001) (Fig. 5). Results from the general linear mixed model indicated that only depth and velocity were significantly different among the environmental variables. Comparisons of velocity among LT locations showed that LT5 was significantly different from LT1 (p=0.03) and LT3 (p=0.03). *Pimephales promelas*, *C. lutrensis*, LT1 and LT3 were positively associated with depth. *Cyprinus carpio*, *H. amarus*, LT2, LT4-LT6 were positively associated with velocity. *Cyprinella lutrensis* and LT3 were positively associated with temperature.

Results from Chao-Jaccard similarity index (Chao et al. 2005) indicate that compositional similarity, weighted on abundance, was highest in *P. promelas* at 64% followed by *H. amarus* 33% C. *lutrensis* and *C. carpio* played a lesser role at 2.6 and 0.1% respectively. Results from (dis)similarity analysis (Dyer 1978) reveal that species composition between habitat orientation and date was highest in *H. amarus* at 42% followed by *P. promelas* 40% *C. lutrensis* and *C. carpio* represented 9.5 and 8.5% respectively (Table 2).

Nutrient concentrations at the Los Lunas study site varied considerably during the flood pulse (Table 2 and Fig. 5) and increased noticeably during final stages of dewatering of the floodplain. These results are similar to those reported by Valett et al. (2005) who found that NO_3-N and PO_4-P concentrations increased dramatically during the initial stages of flooding. Dissolved inorganic nitrate increased throughout the study ranging from 63 to 178 μg L^{-1}; however, no significant differences were observed. Mean ammonium concentration ranged from 39 to 190 μg L^{-1}, but no significant differences were observed. Results only indicate significant differences in PO_4-P concentrations between LT3 and LT6 (p=0.05).

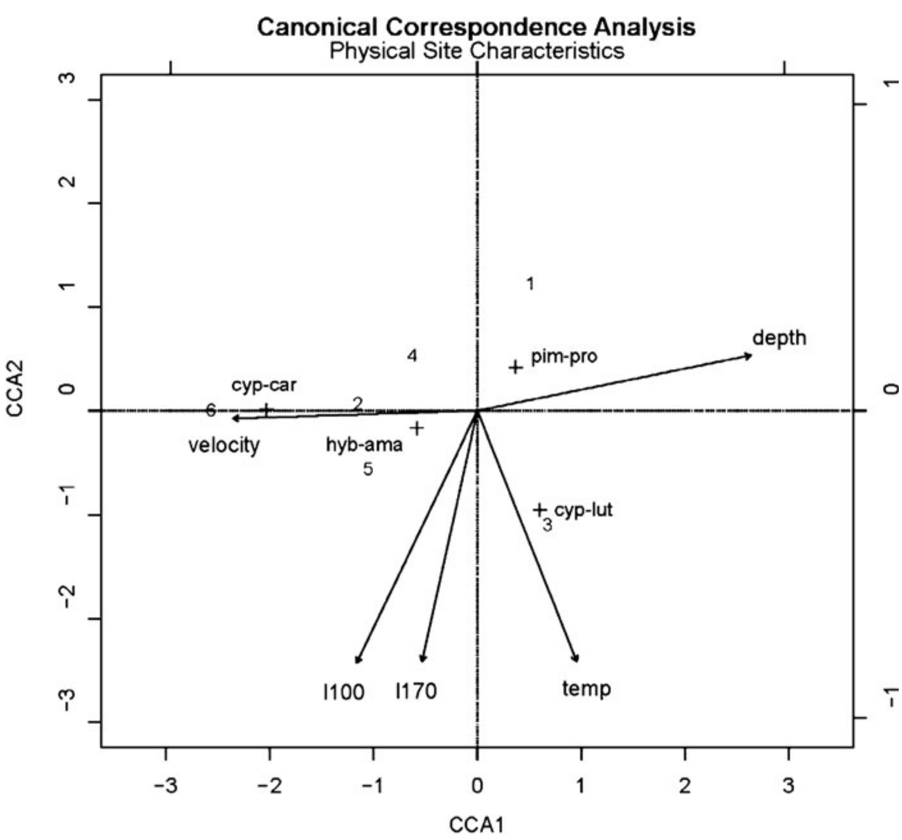


Fig. 4 The distribution of four Cyprinidae species captured in larval fish light traps as they relate to physical site characteristics. Definitions as follows; cyp-car = *Cyprinus carpio*, hyb-ama = *Hybognathus amarus*, pim-pro = *Pimephales promelas*, and cyp-lut = *Cyprinella lutrensis*. The labels I100 and I170 represent light quanta at depths of 100 mm and 170 mm respectively. Numbers 1–6 relate to light trap and location

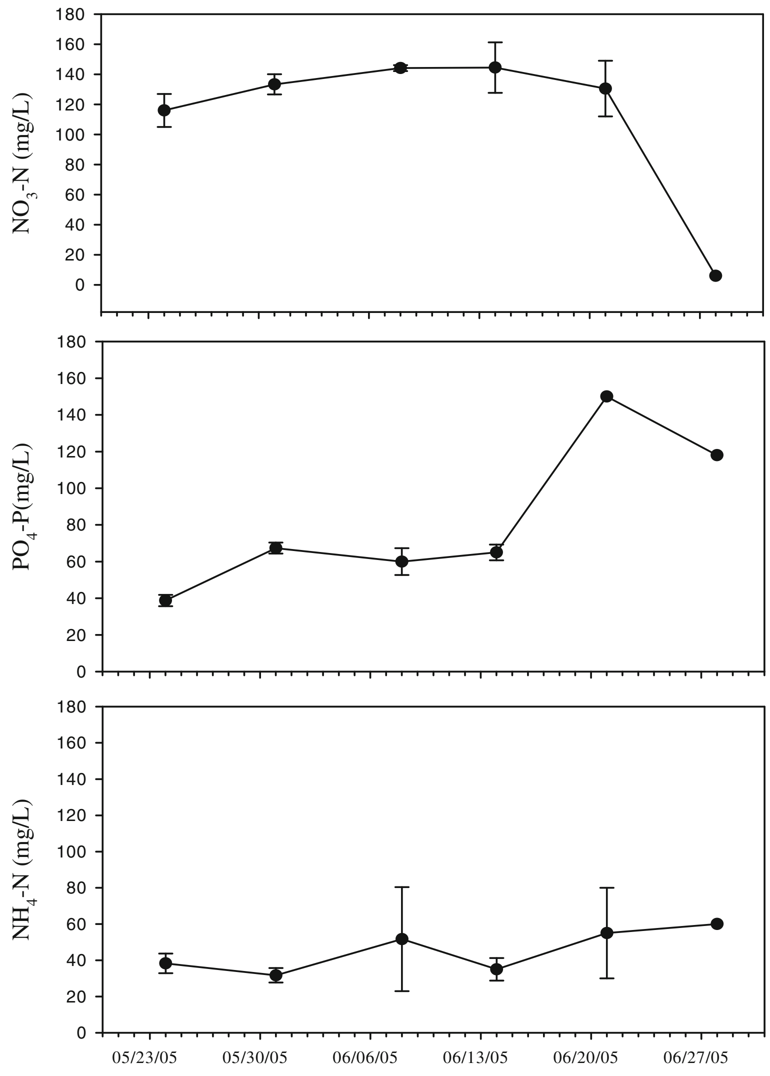


Fig. 5 Los Lunas floodplain nutrient concentrations during sampling period

Discussion

King et al. (2003) reported that few studies have recorded larvae or juveniles using temporary floodplain habitats. However, results from the Los Lunas site provide evidence that *Hybognathus amarus* as well as other ichthyofauna in the MRG do make use of temporary floodplains where habitats are shallow with lower water velocities. Since flood pulses in the MRG are too short lived (5–10 days) (M. Porter, pers. comm., 2009) and the naturalized flood pulses are probably not favorable for successful spawning for

Table 2 Captured cyprinid fish at the restored Los Lunas floodplain. Genus, species, quantity, and similarity indices for larval fish collected during sampling period (24 May- 28 June, 2005)

Species	n	%	(%) Chao-Jaccard contribution	(%) Similarity contribution
P. promelas	228	59	64	40.7
H. amarus	123	32	33.3	42.1
C.lutrensis	27	7	3.6	6.4
C. carpio	16	2	0.1	7.4
	394	100		

temperature sensitive species (Bayley 1995) combined, may be the leading causes for the decline in recruitment of ichthyofauna in the MRG (Thorp et al. 1998). In semiarid and arid-zone rivers, hydrological connectivity, unpredictable flooding combined with low flows governs the "boom and bust" ecology of these systems (Bunn et al. 2006) which ultimately influences food availability for fish and other consumers (Balcombe et al. 2007). The importance of the timing and duration of floods on the floodplain may modulate water temperatures appropriate for spawning of native fish species and may dictate the strength of biotic responses to the flood (King et al. 2003).

Controlled flooding has occurred previously in the MRG, and floods of similar magnitude and duration have occurred prior to 2005 (e.g. 1993). However, yearly total surface area inundated and yearly overbank surface area inundated in 2005 exceeded that of 1993 (USCOE 2010). While there have been 18 major floods of similar duration and magnitude to that of 2005 between 1942 and 2009 at the USGS station 08330000 these floods were unable to access the floodplain due to channelization and incision of the channel even at high flows throughout the MRG (Figs. 6, 7 and 8).

The U.S. Fish and Wildlife Service (USFWS) initiated rescue and salvage operations beginning in 2001

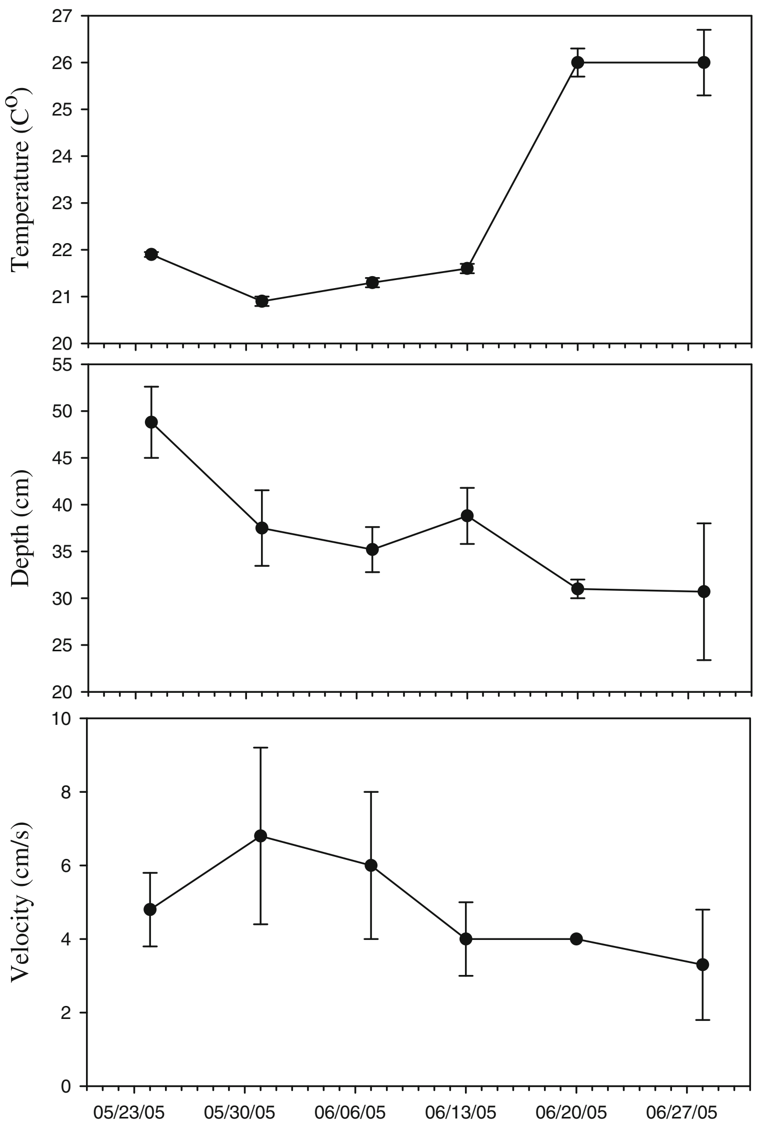


Fig. 6 Los Lunas, NM environmental variables during sampling period

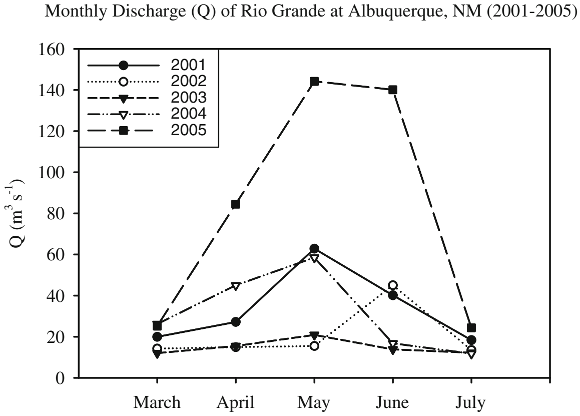


Fig. 7 Monthly discharge during flood pulse releases on MRG. The year 2005 shows a much longer duration and magnitude of flood pulse on floodplain compared to other recent years

to help the plight of *H. amarus* stranded in pools in the river and on limited floodplains when water receded after the flood pulse. The 1st and 3rd year of rescue and salvage operations USFWS rescued 380 and 713 *H. amarus* respectively. The 2nd and 4th year of salvage operations rescued 3662 and 12 865 *H. amarus* respectively. In 2005, the extended flood pulse yielded 626 444 *H. amarus* rescues with 67% being captured on the floodplain (USFWS 2006).

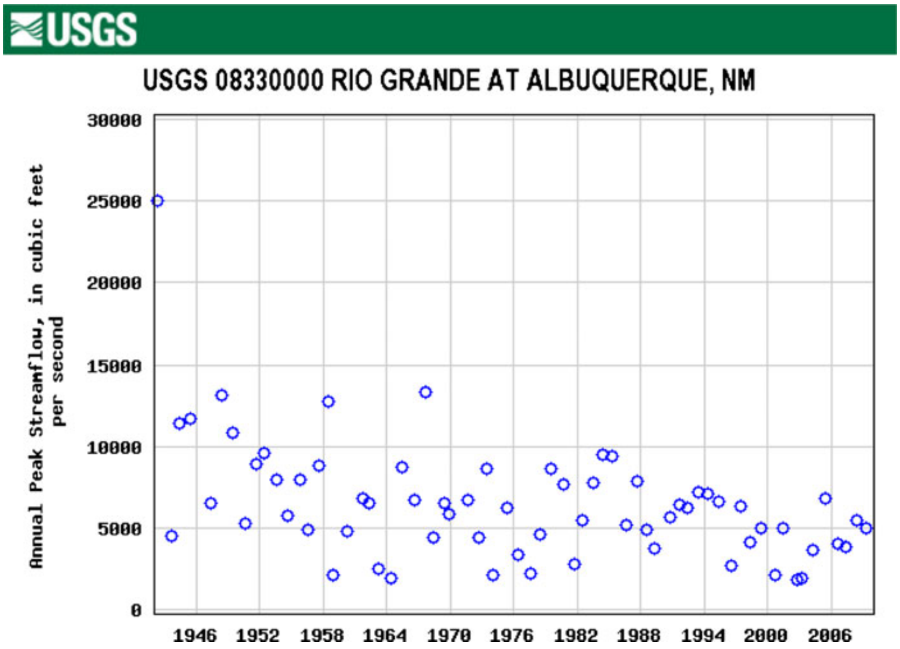
Previous studies have questioned whether fish in arid-zone rivers are adapted to take advantage of irregular flooding, and whether such floods promote fish production and floodplain energy subsidies (Bayley 1995; Balcombe et al. 2007). The reproductive strategy of *H. amarus* is well adapted for the flashy spring-summer hydrograph (Plantania and Altenbach 1998). Results from the present study and USFWS Rescue and Salvage operations (Smith 2001; Smith and Munoz 2002; Smith and Basham 2003; USFWS 2006) provide sufficient evidence that *H. amarus* has evolved a life-history strategy that enables the species to quickly colonize and spawn in recently inundated areas (*sensu* Bayley 1995).

Conclusions

The loss of floodplain habitats for Rio Grande ichthyofauna has led to the slow, but eventual demise of Rio Grande fishes. Plans to restore floodplain habitats should be undertaken as soon as possible to help prevent the extirpation of *H. amarus* from its last strong hold, the MRG.

Vertical banks should be graded to provide access to floodplain habitats during flooding. Prolonged flooding is likely the key to restoring the ichthyofauna community of the MRG and the flood pulse of 2005 provided the first opportunity to investigate habitat use

Fig. 8 Declining trend for peak discharge in MRG for the years 1942–2010



by Rio Grande fishes over many river kilometers. The findings of the present study have revealed the importance of floodplains in the MRG and provide adequate proof that flood pulse releases of longer duration in the MRG provide more nursery habitat for riverine fauna which translated to a significant increase in animal biomass.

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