Endangered Fish Monitoring and Nonnative Fish Control in the Lower San Juan River 2012

Annual Report

Submitted to
San Juan River Recovery
Implementation Program

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EXECUTIVE SUMMARY

The eleventh consecutive year of nonnative fish control in the lower San Juan River was conducted in 2012. This project was initiated to remove large-bodied nonnative fish species and to identify factors involved in movement of striped bass (*Morone saxatilis*) into the lower San Juan River from Lake Powell. Since 2003 the nonnative removal project has focused on reducing channel catfish (*Ictalurus punctatus*) and other large-bodied nonnative fishes that occur within the San Juan River.

In 2012, eight nonnative fish removal passes were made, beginning in early-March and continuing through August. Raft mounted electrofishing was conducted from Mexican Hat to Clay Hills, UT between river miles (RM) 52.8-2.9. Mean daily river flow ranged from 563-1,123 cubic feet per second (cfs) during sampling trips in 2012.

Channel catfish made up the the majority of large-bodied nonnative fish collected in 2012. Mean catch per unit effort was 29.5 fish per hour. Considerable variability in catch rates was occurred between passes, but the mean catch rate of channel catfish in 2012 was the highest observed since 2009. Overall catfish populations have remained relatively stable since removal efforts began, and common carp catches remained low in 2012 with just 5 individuals being captured and removed.

In 2012 sampling, 344 Colorado pikeminnow and 111 razorback sucker were collected in the lower San Juan River. All pikeminnow captured are likely of hatchery origin stocked within the San Juan River from 2003 through 2011 at upstream locations near Farmington, NM. Population estimates based on capture-recapture data for Colorado pikeminnow indicated that 365 to 965 fish are utilizing the lower San Juan River. This was the first year that population estimates were odtained for razorback sucker, giving an estimate of 265 individuals in our study area.

INTRODUCTION

Native fishes in the Southwestern United States have been negatively impacted by the proliferation of nonnative fishes, extensive water development and anthropogenic alteration of habitats (Minckley and Marsh 2009). The establishment of nonnative species occurred via the intentional planting of desired sport fishes and through illegal stockings or bait bucket transfers. The widespread distribution of nonnative species has led to the homogenization of fish communities throughout the Southwest, and elsewhere and potentially effects the survival and persistence of native fish communities (Rahel 2003). Within the Upper Colorado River Basin (i.e. Colorado River, Green River, San Juan River), increases in the abundance of nonnative fishes coupled with habitat changes have led to reductions in abundance and range contractions of many native fishes. Subsequently, four native species including the Colorado pikeminnow, razorback sucker, humpback chub and bonytail chub have been Federally listed and are fully protected under the Endangered Species Act. Competitive and predatory interactions between native and nonnative fishes have been identified by management agencies as a potential factor limiting recovery of these species and managers within the Upper Colorado River Recovery Program and the San Juan River Recovery Implementation Program have established removal projects to control nonnative fish species (Mueller 2005).

The lower San Juan River in southeastern Utah contains a remnant population of Colorado pikeminnow and razorback sucker (Ryden 2000, Davis et al. 2010). These populations are recruitment limited and augmentation activities have been established since 1994 to promote population persistence (Ryden 2003). Since the threat of nonnative fishes exists and there was concern that striped bass and other Lake Powell resident fish may colonize and establish reproducing populations within the Lower San Juan River (Gustaveson et al. 1984), the Utah Division of Wildlife Resources Moab Field Office initiated the mechanical removal of nonnative fish in the lower San Juan River from Mexican Hat, UT to the Clay Hills Crossing beginning in 2002.

The objectives of this study include: 1) mechanical removal of large-bodied nonnative species in the lower portion of the San Juan River from Mexican Hat to Clay Hills; 2) estimate population size and exploitation rate of channel catfish from mark-recapture data; 3) and determine the abundance and distribution of Colorado pikeminnow and razorback suckers in the lower San Juan River. These objectives are identified in the San Juan Recovery Implementation Program Draft Long Range Plan under Element 3 and goal 3.1.

METHODS

Study Area

The study area includes the San Juan River from Mexican Hat (RM 52.8) to Clay Hills (RM 2.9), Utah (Figure 1). The river from Mexican Hat to RM 16 is primarily bedrock confined and dominated by riffle and run habitats. The river is canyon bound with an active alluvial bed from RM 16 to Clay Hills (RM 2.9). Habitats within this section exhibit considerable heterogeneity and river geomorphology is significantly influenced by spring freshets, monsoonal floods, and changing reservoir elevations. This section of river has been identified as nursery habitat for native and endangered fishes (Archer et al. 2000).

Sampling

Two raft mounted electrofishing boats were used to sample fish populations in the Lower San Juan during eight five day sampling trips in 2012. Trips occurred between March and mid-August. Each electrofishing boat was outfitted with a Smith-Root electrofishing system (5.0 GPP) to sample fish populations. Amperage for the GPP system was typically set at 4 to 6 depending on specific conductivity measurements and sampling occurred on each side of the river. Individual sampling units consisted of approximately 3-mile segments of shoreline fished by each electrofishing raft. Data are collected for approximately 30 sample units per trip. When conditions allowed, a chase boat was used to net fishes not captured by the electrofishing boats. Beginning in 2007, a 6 foot by 30 foot 1-inch mesh seine was also used for removing nonnative fishes. The seine was extended into the river and held in place for several minutes after the electrofishing raft had passed downstream. The use of a seine and chase boat for nonnative removal was discontinued in 2010.

All nonnative and endangered species were netted (Table 1). Total length (mm) was measured for all nonnative and endangered fishes and a sub-sample of nonnative fishes were also measured for standard length (mm) and weight (g). Standard length and weight were measured for all endangered fishes. All endangered fishes $\geq$ 150 mm TL were assessed for the presence of a PIT tag and tagged if not previously marked. The location of captured endangered fishes was determined to the nearest tenth of a river mile. All endangered fishes were released at or near the location of capture. From 2003-2006 and 2008-2011, all channel catfish $\geq$ 200 mm TL collected during the first pass (trip) were marked in various ways and released. Channel catfish collected in 2009 to 2012 were uniquely marked with individually numbered T-bar floy tag. Prior to 2009, channel catfish were tagged with colored tags only and were not uniquely marked. Since 2010, channel catfish $\geq$ 200 mm TL were tagged and received an adipose fin clip. Channel catfish and all other large-bodied nonnative fishes collected on subsequent passes were removed. Turbidity, using a Secchi disk, river temperature, conductivity, and salinity were measured at least twice during each pass. River discharge was determined from the USGS gage # 09379500 near Mexican Hat, UT. Lake Powell elevations and temperatures were taken from the Lake Powell water database website (http://lakepowell.water-data.com/).

Data Analysis

Catch-per-unit-effort (CPUE) was calculated as the number of fish caught per hour of electrofishing effort for a given sampling section. For each sampling trip approximately 30, three-mile sections were sampled. CPUE was calculated for channel catfish, common carp, Colorado pikeminnow, and razorback sucker and summarized by trip and year. CPUE effort data for all species were highly non-normal (failed a Kolmogorov-Smirnov test; $p<0.05$) and the non-parametric Kruskal-Wallis test was used to assess for differences in species-specific CPUE by year and trip. The Dunn's Method was selected for post hoc multiple comparisons.

During trips one and two of 2012, we estimated the abundance of channel catfish greater than 200 mm TL using a Lincoln-Petersen estimator with Chapman's correction (Equation 1).

Equation 1: $$\mathbf{N = \frac{(M+1)*(C+1)}{(R+1)}}$$

In Equation 1, M is the number of channel catfish marked during trip 1, C is the total number of channel catfish greater than 200 mm TL captured during trip 2, R is the number of channel catfish marked in trip 1 that were recaptured during trip 2, and N is estimated channel catfish abundance. Lincoln-Petersen population estimates have been used to assess early season channel catfish abundance since 2003 with the exception of 2007.

Tag return data were also used to calculate exploitation rates for tagged catfish and upstream movement rates for channel catfish (Equation 2). Exploitation rates, μ, were estimated as the proportion of recaptured marked fish (R) to the total number marked fish (M) (Deroba et al. 2005),

Equation 2: $$\boldsymbol{\mu} = \mathbf{R/M}$$

Tag return studies can be biased by immigration, emigration, tag loss, mortality and changing capture probabilities between trips. However, when they are used with other trend data they are effective in assessing our removal effectiveness.

Population size was estimated for age-2+ Colorado pikeminnow (>150 mm) and Razorback sucker in the lower San Juan River using closed population models within program MARK (Otis et al. 1978, White et al. 1982, Rexstad and Burnham 1991). Capture histories for Colorado pikeminnow and razorback sucker were generated in Microsoft Excel and converted to a file for Program MARK to read. Closed population estimators generate estimates of population size, capture probability, and recapture probability by using a multinomial maximum likelihood function based on the matrix of capture information. For Colorado pikeminnow and razorback sucker, three different models were specific and run in Program MARK. The first model was a Mo model which estimates two parameters: a single capture probability for all trips and one abundance estimate. Recapture probability was set equal to capture probability. The second model was an Mb model which estimates three parameters: a single capture probability, a single recapture probability and a one abundance estimate. The third model was an Mt model which estimated 9 parameters: a trip specific capture probability and a year specific abundance. Recapture probability was set equal to capture probability for this model. More complex models such as an Mtb model which estimates a trip specific recapture and capture probability could not be fit due to the sparseness of the data. Model fit was assessed using Akaike's Information Criteria (AIC). The top model ranked by AIC was used to interpret the current population status of Colorado pikeminnow and razorback sucker in the Lower San Juan River.

RESULTS

Eight sampling passes were conducted on the San Juan River between Mexican Hat and Clay Hills, UT in 2012 (Figure 1). Sampling dates were: March 6-8, March 16-19, March 26-29, April 5-9, April 18-18, August 3-7, August 14-17, and August 27-30. Nine large-bodied fish species were encountered including Colorado pikeminnoww, razorback sucker, and six nonnative species (Table 1). We also collected four suspected razorback-flannelmouth sucker hybrids. Native bluehead and flannelmouth suckers were present during all passes but not netted during nonnative control efforts because of their large population sizes. Electrofishing effort totaled 250 hours and resulted in the capture of 8,165 fish (Table 1). Similar to past years, channel catfish were numerically dominant in the catch; no striped bass or walleye were encountered.

Nonnative Species

Channel catfish

In 2012, channel catfish comprised 94% of the total catch during nonnative removal passes in the lower San Juan River. The mean catch rate of all sizes of channel catfish was 29.5 fish per hour; catch rates varied significantly between passes and ranged from 12.8 to 45.1 fish per hour ($p < 0.001$; Table 2, Figure 2). Catch rates showed a 50% increase from 2011 to 2012. In 2012, catch rates were statistically higher than 2003, 2008 and 2011, but statistically similar to all other years (Figure 3). The mean catch rate of adult (>300 mm TL) channel catfish in 2012 was 2.68 fish per hour and significantly lower than in 2002, 2008 and 2009 (Figure 4). As observed in previous years, the juvenile channel catfish catch drives CPUE trends in the lower San Juan River.

The mean total length of channel catfish collected in the lower San Juan River in 2012 was 192 mm. In general, the mean size of channel catfish has declined since removal programs began (Appendix C). Analysis of length-frequency histograms showed that the majority of catfish collected during 2012 were fish under 300 mm with a large proportion of juvenile catfish under 200 mm (Figure 5). Visual observation of length frequency histograms indicates four distinct modes which likely represent YOY to Age 3 fish. The percentage of adult ($\geq$300 mm TL) channel catfish in the total catch was similar to previous years except 2008 (Figure 6). The catch of adults significantly increased in 2008 was attributed to immigration of channel catfish from the

Middle San Juan River in response to a period of high flow from Navajo Dam. Large-bodied adult channel catfish greater than 400 mm continue to represent a small proportion of the overall catch. Channel catfish $\geq$ 400mm TL have declined from 9.4% in 2002 to 1% in 2012 of the total channel catfish catch.

In 2012, the channel catfish population greater than 200 mm was assessed (Figure 7). For the population estimate, 535 channel catfish were tagged during the first sampling trip; 994 catfish were captured during second sampling trip with only 14 recaptures. In 2012, 35,555 individuals (95% CI = 17,911-53,197) were estimated within the lower San Juan River. The 2012 estimate is significantly higher than the 2004, 2009, and 2011 estimates but statistically similar to all other years. Capture probability changed drastically between the marking trip (trip one) and the recapture trip (trip two) contributing to the large amount of variation in the estimate.

In 2012, the exploitation rate of channel catfish was assessed using tag return data. Exploitation rates increased with size class (Table 2) and ranged from 7.1% for channel catfish between 200-299 mm TL to 28.6% for channel catfish between 400-499 mm TL (Table 2). Exploitation rates were considerably higher on nonnative removal trips 1-4 conducted prior to spring runoff when compared to the exploitation rate on trips after runoff (Table 2). The overall exploitation rate was lower than in previous years and may have been affected by changing capture probabilities, a relatively small tagged population, and environmental conditions such as discharge.

Upstream movement of channel catfish from the lower San Juan to the middle San Juan was observed in 2012. Seventeen channel catfish tagged in 2012 within the lower reach were recaptured in 2012 by Fish and Wildlife Service collaborators in the middle river reach. Additionally, 107 channel catfish originally tagged between 2010 and 2011 in the lower river were recaptured in the middle reach of the San Juan in 2012. Movements between tagging and recapture locations of channel catfish varied from 5 to 150 miles. In 2012, only three fish that had been originally tagged in the middle San Juan were recaptured in the lower river. The lack of recaptures suggests that movement of channel catfish is largely directed upstream and that channel catfish habitat needs change between juvenile and adult fish.

Common carp

In 2012, only five common carp were captured and mean catch rates of common carp were 0.02 fish per hour. Catch rates precipitously declined between 2002 -2004 and catch rates since 2005 have not exceeded 0.2 fish per hour (Figure 8).

Endangered Species

Colorado pikeminnow

A total of 344 Colorado pikeminnow were collected in 2012 during nonnative control efforts in lower San Juan River. Catch rates in 2012 are statistically similar to 2011 and greater than catch rates from 2003-2008 (Figure 9). Catch rates in 2012 were significantly higher than catch rates from 2003 to 2008 ($p<0.05$), but were significantly lower than 2009 and 2010 catch rates. Catch rates in 2012 ranged from 0.75 to 1.8 fish per hour and varied minimally between trips (Figure 10). Analysis of length frequency histograms indicated three distinct modes of cohorts presumed to represent age-0, age-1 and age-2 fish (Figure 11). The small mode centered around 75 mm are thought to be small fish that were stocked during the fall of 2011 and subsequently captured during early trips in 2012 (Figure 11). These fish are from the 2010 (Age 2) and 2011 (Age 1) fish stocking program. Colorado pikeminnow captures were widely distributed throughout the study reach in 2012 (Figure 12). Catches of Colorado pikeminnow were lowest for river miles 3 to 15 and generally highest between river miles 53 to 35. Colorado pikeminnow capture locations were consistent with distributional patterns observed in previous years (Figure 12).

Population estimates of Colorado pikeminnow have been generated for the lower San Juan River since 2004 (Table 3). In 2012, the top model ranked by AIC was the Mt model which estimated a trip specific capture probability and a year specific abundance estimate. The model estimated 666 Colorado pikeminnow in the lower San Juan River with a confidence interval of 480 to 965 individuals. Capture probabilities were low and ranged from 0.025 to 0.07. Population estimates for Colorado pikeminnow in the lower San Juan River indicated that abundance increased from 2004 to 2009 and stabilized around 1100 individuals from 2009 to 2011. The population experienced a nearly 50% reduction from 2011 to 2012. Increases and decreases in Colorado pikeminnow populations in the lower San Juan River are likely affected by changes in stocking numbers, movement, and overwinter mortality rather than variable recruitment.

Captures of adult (>450 mm TL) Colorado pikeminnow have been low since this project began in 2002. In 2012, one adult Colorado pikeminnow (480 mm TL) was captured and from 2004-2011 only three adult pikeminnow were captured. During 2002, five adult Colorado pikeminnow ranging from 460 to 539 TL were captured. Three Colorado pikeminnow adults were captured in 2003; their sizes ranged from 530 mm to 590 mm TL. In 2004, one adult Colorado pikeminnow was collected (547 mm TL) at RM 16.4 on March 25. This fish was originally captured and marked in 2002 at RM 19.8 and measured 460 mm TL.

Razorback sucker

One hundred and eleven razorback suckers were collected in the lower San Juan River in 2011 during nonnative fish removal trips (Table 1). Mean catch rate of razorback suckers were significantly higher in 2012 when compared to all other years with the exception of 2007 (Figure 13). Catch rates varied between passes from 0.22 to 0.69 fish captured per hour. Catch rates were generally higher during the early season trips when compared to the late season trips (Figure 14). The mean size of razorback sucker captured in the lower San Juan River was 404 mm and ranged from 250 to 560 mm total length. Razorback sucker catches were widely distributed throughout the lower Canyon but the greatest frequency of captures occurred between river mile 45 to 40 and river mile 25 to 20. Recaptures of razorback sucker were sufficient to run three closed mark-recapture models. The top model, ranked by AIC, estimated a unique capture probability for each sampling trip and an annual abundance estimate (Table 4). The model estimated 256 razorback suckers in the Lower San Juan River with a confidence between 166 to 428 individuals. Capture probabilities ranged from 0.02 to 0.08. During the early season many of the razorback captures were aggregated in groups near cobble bars. No fish captured were actively expressing gametes however fish did exhibit spawning colors and tubercles. Four suspected razorback-flannelmouth sucker hybrids were collected in 2012 in the lower San Juan River.

DISCUSSION

In general, catch rates in 2012 were higher than those observed in 2002-2011. Overall, CPUE trends from 2002 to 2012 exhibit considerable yearly variation, but overall have remained relatively stable. Many factors may have contributed to the higher catch rates in 2012 such as the time of year, river discharge, water temperature, turbidity, netter and raft operator experience, and pass number. The increasing trend in CPUE between passes in 2012 may also be a result of recruitment, emigration, changing capture probability between passes and behavioral responses to electrofishing gear. The use of CPUE as an index of population abundance is a popular way to assess fish populations (Fabrizio and Richards 1996; Hubert 1996; Ney 1999). Future analysis of channel catfish CPUE in the lower San Juan River should consider comparing CPUE from similar times of year such as pre-runoff trips and mid-summer trips in order to minimize some of the fluctuations in capture probability that may be obscuring overall population trends and the utility of CPUE as a population index.

Population estimates of channel catfish $\geq$ 200 mm TL have been conducted in the lower San Juan River since 2003. The 2012 population estimate was significantly higher than the 2004, 2009, and 2011 estimate and within the confidence limits of the 2003, 2005, 2006, 2008 and 2010 estimates. In general, population sizes have been relatively stable since 2003 but large declines in the channel catfish population greater than 400 mm have also been observed. The large margin of uncertainty around the 2012 estimate is likely driven by changes in capture probability between the marking and recapture pass, significant tagging mortality, or fish movement. The increases in adult catfish in 2008 were likely a result of immigration of fish from the middle reaches in response to high spring discharges from Navajo Dam. When considering both CPUE and the abundance estimate, channel catfish populations in the San Juan seem relatively stable.

Exploitation rate for channel catfish was estimated using tag return data from individually marked fish. Exploitation rates varied depending on fish length and increased with increasing total length. Electrofishing gear is biased toward collecting larger individuals. This bias occurs because larger individuals have more surface area for the electrical field to come into contact with (Reynolds 1996). Exploitation was also higher during sampling trips conducted prior to runoff. Increased exploitation rates were also observed for larger size classes and prior to spring runoff in 2009 through 2011 (Gerig 2012). The reduced exploitation rate of channel catfish post runoff may be the result of numerous factors such as capture probability between pre and post runoff periods. In addition, channel catfish tagged in the lower San Juan move outside of the study reach. This movement may indicate a more widespread upstream dispersal of catfish during the summer and result in a markedly reduced tagged population within our study reach. Movements in excess of 100 km have been observed in other channel catfish populations (Dames et al. 1989, Hale et al. 1986). Lastly, retention of floy tags can be poor over longer time periods and loss could have increased during the high discharge runoff period that the lower San Juan River experienced during the summer of 2011.

The large number of juvenile channel catfish in the lower San Juan River could be the result of numerous factors. The lower San Juan may be a rearing habitat for juvenile catfish and as they grow they migrate and reside in the middle and upper reaches of the San Juan river. The removal of large adult channel catfish from the population may be causing a compensatory improvement in juvenile channel catfish survival rates which would account for the increase in fish from 200-299 mm (Walters and Martell 2004). This pattern of a compensatory increase in juvenile survival rates has been noted in numerous fish populations throughout North America (Rose et al. 2001). The mechanism for improved juvenile survival can be caused by reduction in predator abundances, increases in food availability, improved growth (caused by reduced predation or improved food) or a reduction in cannibalistic behavior (Walters and Martell 2004). Past research within the Powder River drainage in Wyoming indicated that population structure and abundance of channel catfish changed considerably as adult exploitation rates increased (Gerhardt and Hubert 1991). Gerhardt and Hubert (1991) reported that an annual exploitation rate of 22% would result in a 75% reduction in overall abundance of catfish $\geq$ 300 mm TL, and cause a substantial shift towards smaller individuals. Similar shifts in yield and population structure have been observed in sport and commercial fisheries as the rate of exploitation increased (Bennett 1971, McHugh 1984, Pitlo 1997). In the San Juan River, shifts in size structure of channel catfish were observed upstream (Davis 2005) and on a river-wide scale (Ryden 2005) after the initiation of nonnative removal. Continuing population estimates for channel catfish will allow for evaluation of removal effectiveness and exploitation rate of the channel catfish population.

Since 2002, a significant decline in catch rates of common carp has been observed. During the first year of removal, 1052 common carp were removed from the lower San Juan River. In 2012, only five common carp were captured in the same river section. It is unclear if this decline is directly related to removal efforts, the presence of the waterfall, limited habitat availability, or the water conditions that have been present over the period of this project. All or some of these factors are likely responsible for the reduction in common carp. Nonnative removal efforts in the upper San Juan River have also documented a significant decline in the CPUE of common carp (Davis 2010). River-wide adult and sub-adult monitoring has also shown a significant decline in CPUE of common carp (Ryden 2010).

Population estimates generated for stocked juvenile Colorado pikeminnow indicate that pikeminnow abundance has increased from 2002 to 2010 and have declined from 2010 to 2012. The estimated abundance for 2012 was between 485 to 965 individuals. The strong support for trip specific estimates illustrates the importance of estimating unique capture probabilities. The preciseness of the estimate is dependent on the estimate of capture probability. Years (2006 in particular) which have a low estimate of capture probability (less than 5%) estimate abundance poorly, whereas years with higher capture probability (greater than 10%) provide relatively precise estimates of abundance. Movement of pikeminnow outside of the study reaches may reduce capture probability within the study reach which would reduce the precision of the estimate causing increased uncertainty in population estimates. A river-wide sampling trip which minimized the length between passes may be a sufficient way to achieve precise estimates of abundance. The use of open population models and passive PIT tag antennas may be useful in understanding pikeminnow movements and mortality patterns in the Lower San Juan.

The catch of adult Colorado pikeminnow has been low and declined slightly over the period of this study (2002-2012). The reasons for this decline are unknown but might be explained by several factors: 1) avoidance of the electrofishing field; 2) emigration below the waterfall outside of the study area; 3) emigration upstream of the study reach; 4) or mortality. Past radio telemetry studies of adult Colorado pikeminnow within the San Juan River indicated fish were able to detect electrofishing rafts and actively moved to avoid the electrical field (Ryden 2000). Colorado pikeminnow that avoided the electrofishing boats ranged from 521 to 948 mm TL. Their avoidance of rafts has been documented by other researchers as well (Bestgen et. al 2004). In contrast to channel catfish, capture probabilities for pikeminnow declined with increasing fish size. Thus, adult fish had lower capture probabilities than younger smaller fish. We are uncertain whether adult fish are present and can avoid electrofishing gear or generally absent from the lower San Juan reach. Alternatively, the deep pools used for foraging and resting by are scarce in the lower river and may contribute to the lack of adults in this region.

The total number of razorback suckers captured in the lower San Juan River in 2012 was the second highest since monitoring began and CPUE of razorback sucker is significantly higher than all other years with the exception of 2007. This corresponds with a river wide trend of increasing razorback numbers throughout the entire San Juan River (Ryden 2012). Additionally, 2012 was the first year in which a population was estimated for Razorback suckers. This effort should continue if recaptures are sufficient.

CONCLUSIONS AND RECOMMENDATIONS

• Population estimates of channel catfish in the lower San Juan River have been relatively stable since removal began in 2002. There is considerable variation around yearly estimates. Estimates of channel catfish populations were relatively imprecise (indicated by large confidence intervals) from 2003 to 2006 but have improved in recent years with the notable exception of 2012. The proportion of the channel catfish $\geq$ 400 mm TL in the total catch has continued to decrease. Channel catfish should continue to be marked with numbered tags during the first pass in order to determine population size at the beginning of each removal year. Along with population estimates, mark/recapture using individually numbered tags allows for determination of exploitation rate by size class, and monitoring of channel catfish growth rates and movement throughout the river.

• The CPUE and mean TL of channel catfish in 2012 are similar to most of the previous years. Length-frequency histograms from fish captured in 2009-2011 indicate large numbers of juvenile fish in the catch. It is unknown if the increase in juvenile channel catfish is the result of removal efforts or favorable environmental conditions.

• Catch rates of common carp decreased significantly from 2002 to 2012. The cause of the decreasing trend in catch rate for these fish is unknown. Several factors may be acting together including: continued nonnative removal, the presence of the waterfall which prevents upstream colonization of carp from Lake Powell and low water conditions present during the first three years of removal which may have limited recruitment. Common carp should continue to be removed from the lower San Juan River to reduce competition with native and endangered fishes.

• Population estimates of juvenile Colorado pikeminnow increased from 2003 through 2009 and have declined from 2010 to 2012. From 2004 to 2012, the majority of captures were age-1 and age-2 fish. Age-0 stocked fish are likely more abundant, but electrofishing sampling effectiveness increases with fish size. Ongoing monitoring and population estimates for Colorado pikeminnow should be continued in future monitoring programs.

- This year was the first a population estimate was made for razorback sucker in the lower San Juan River. If recaptures are sufficient enough, population estimates for razorback sucker should continue.

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Table 1. Total counts of fish species collected during electrofishing sampling in the lower San Juan River in 2012.

	3/6-3/9	3/16-3/19	3/26-3/29	4/5-4/9	4/15-4/18	8/3-8/7	8/14-8/17	8/27-8/30	Total
Black Bullhead	0	3	3	5	0	1	9	6	27
Brown Trout	0	0	1	1	0	0	0	0	2
Channel Catfish	588	994	1009	1437	1073	434	1610	518	7663
Common Carp	0	0	1	0	0	0	3	1	5
Colorado Pikeminnow	29	46	36	66	44	35	54	34	344
Green Sunfish	0	0	0	0	0	0	0	1	1
Razorback Sucker	19	22	17	22	6	8	10	7	111
RZ x FM	0	3	0	0	0	0	1	0	4
Yellow Bullhead	0	0	0	2	0	4	2	0	8

Table 2. Percentage of total catch, number of channel catfish tagged by size class and exploitation rate of channel catfish by size class in 2012 in the lower San Juan River. Numbers below percentages are the actual number caught.

	200-299	300-399	400-499	500-599	600+	Total
Number Tagged	366	152	7	0	0	525
3/16-3/19	7	12	0	0	0	19
3/26-3/29	8	6	0	0	0	14
4/5-4/9	8	5	1	0	0	14
4/15-4/18	3	3	0	0	0	6
8/3-8/7	0	0	0	0	0	0
8/14-8/17	0	0	0	0	0	0
8/27-8/30	0	0	1	0	0	1
UDWR Total	26	26	2	0	0	54
Trips 2-5	26	26	1	0	0	53
Trips 6-8	0	0	1	0	0	1
UDWR Exploitation	7.1%	17.1%	28.6%	0.0%	0.0%	
Middle San Juan	13	3	1	0	0	17
Total of All Efforts	39	29	3	0	0	71
Exploitation by size class	10.7%	19.1%	42.9%	0.0%	0.0%	

Table 3. AICc ranking of three closed mark-recapture models used to estimate Colorado pikeminnow abundance and capture probability in the Lower San Juan River.

Model	AICc	Δ AICc	AICc Weights	K	Deviance
Mt	-598.1891	0	1	9	36.2822
Mb	-542.3193	55.8698	0	2	106.2709
Mo	-539.9863	58.2028	0	2	108.6038

Table 4. AICc ranking of three closed mark-recapture models used to estimate razorback sucker abundance and capture probability in the Lower San Juan River.

Model	AICc	Δ AICc	AICc Weights	K	Deviance
Mt	-128.172	0	1	9	34.8467
Mo	-96.3449	31.8271	0	2	80.9476
Mb	-95.7739	32.3981	0	3	79.4992

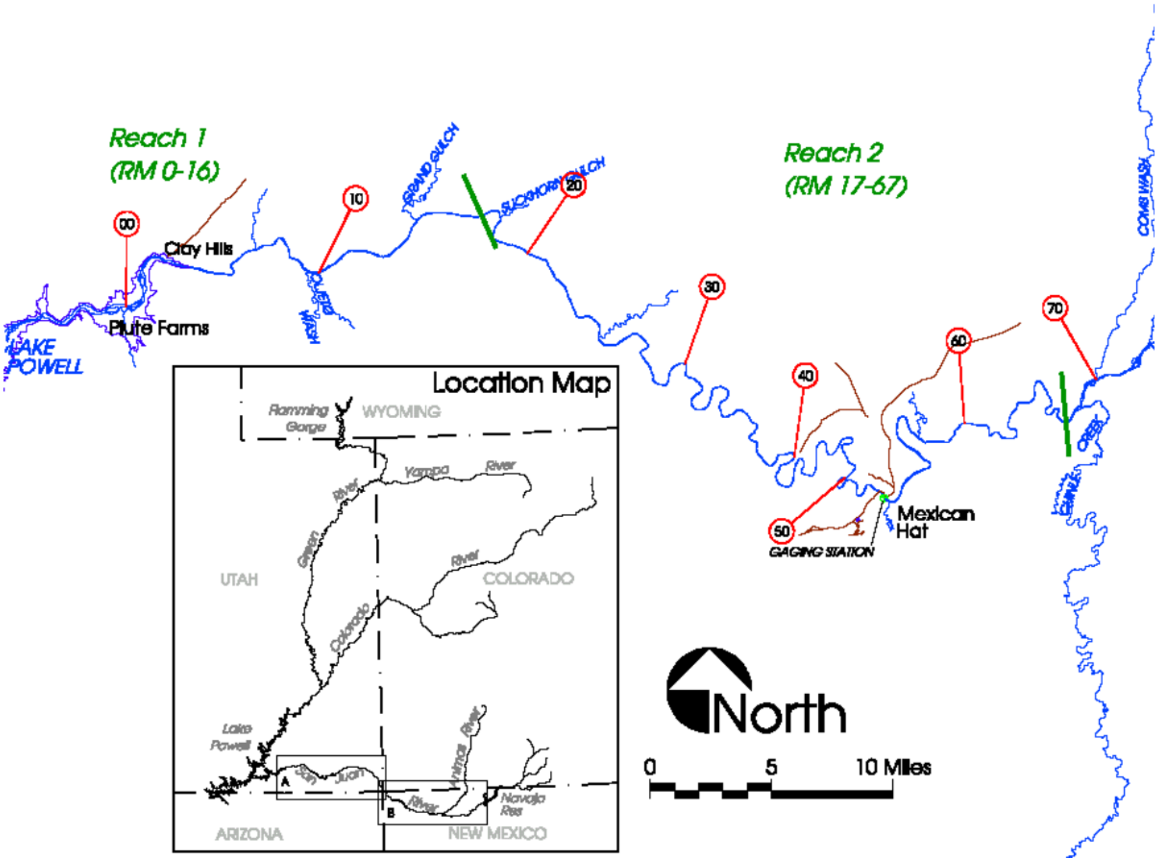


Figure 1. Map of the study area for nonnative fish control in the lower San Juan River. Sampling area extends from Mexican Hat to Clay Hills.

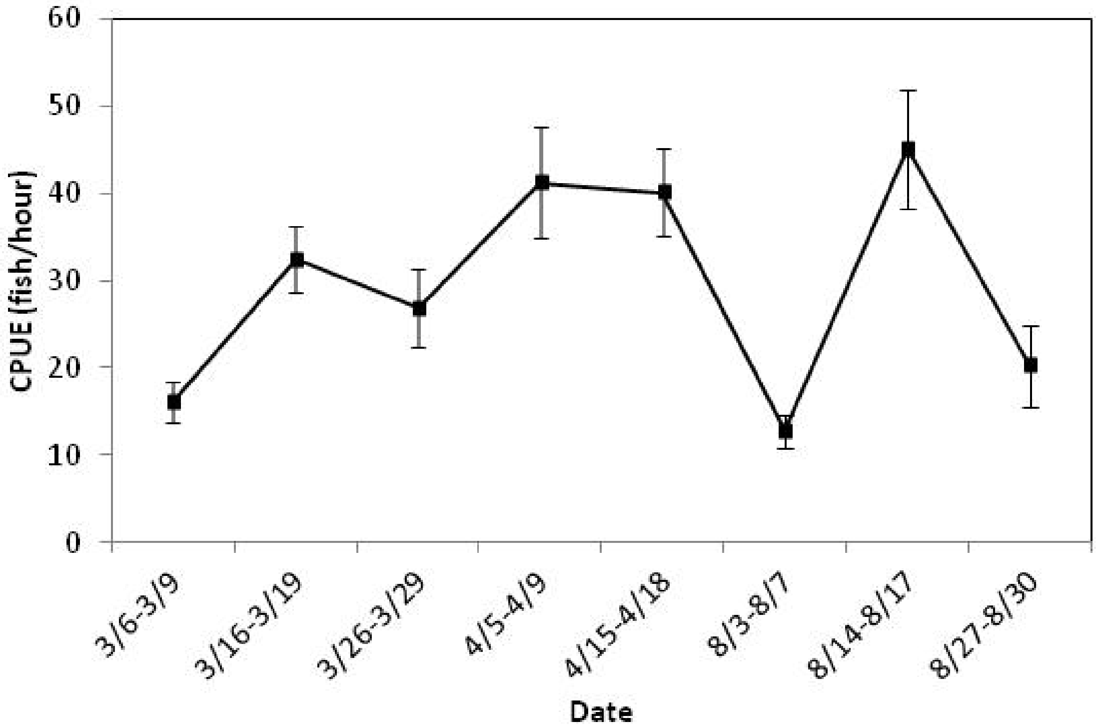


Figure 2. Mean electrofishing catch-per-unit-effort of channel catfish in the lower San Juan River by pass in 2012. Error bars represent ± 1 standard error.

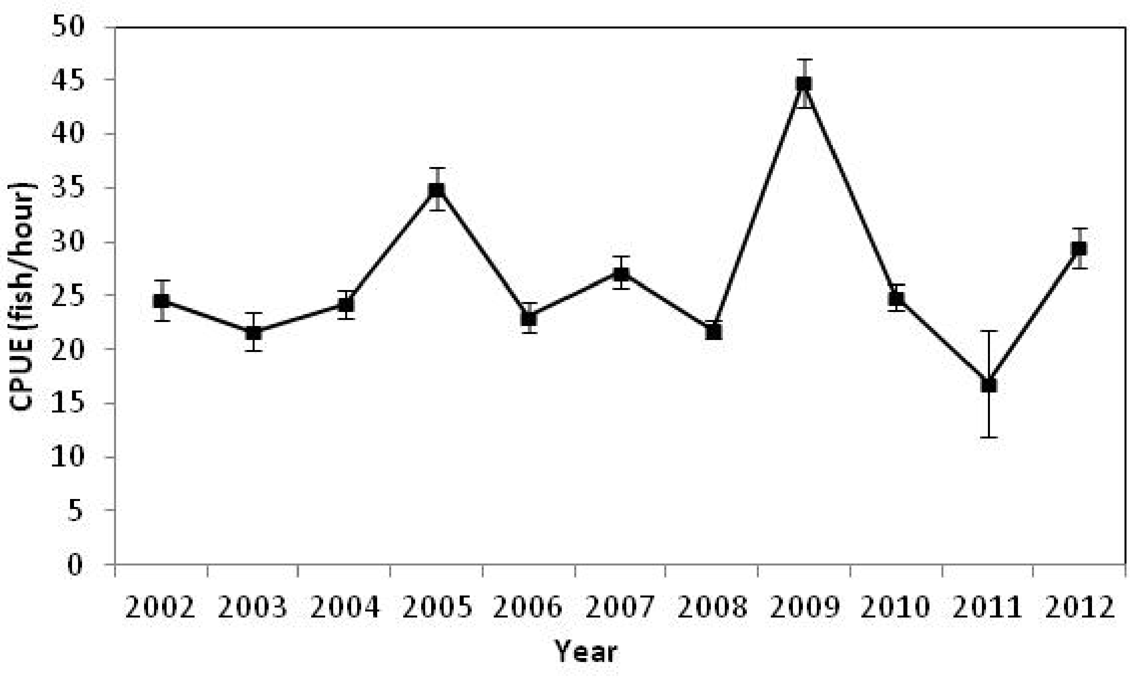


Figure 3. Mean electrofishing catch-per-unit-effort of channel catfish in the lower San Juan River from 2002 to 2012. Error bars represent ± 1 standard error.

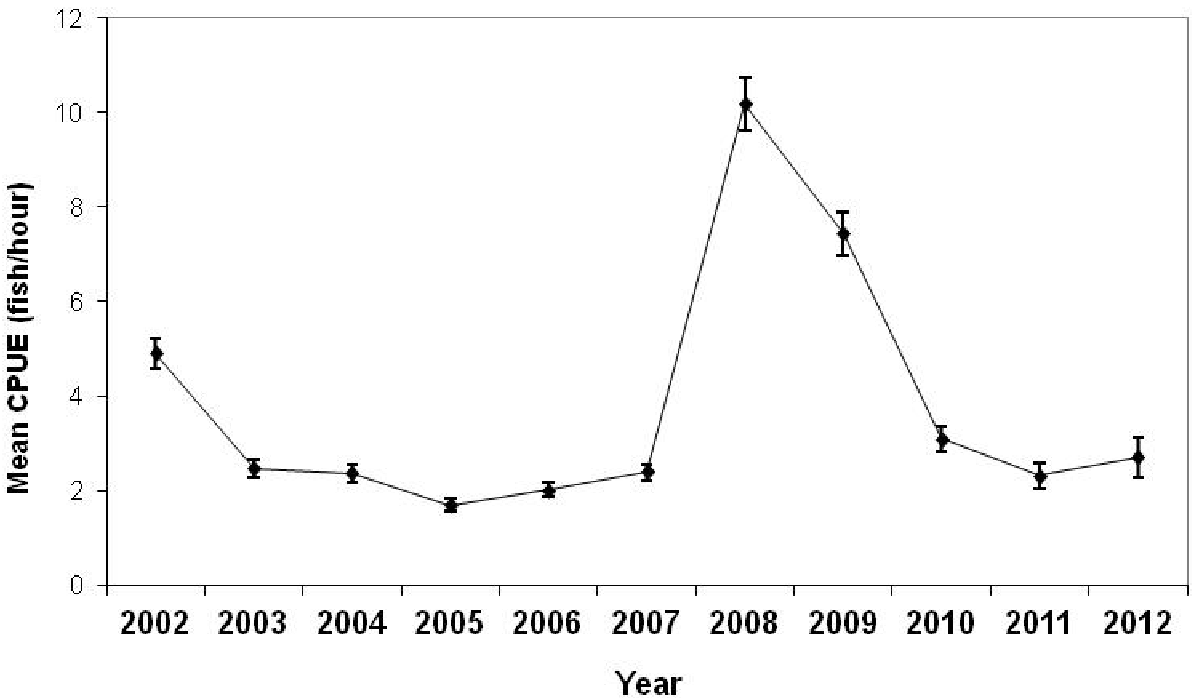


Figure 4. Mean electrofishing catch per unit effort of adult (>300 mm TL) channel catfish in the lower San Juan River from 2002 to 2011. Error bars represent + 1 standard error.

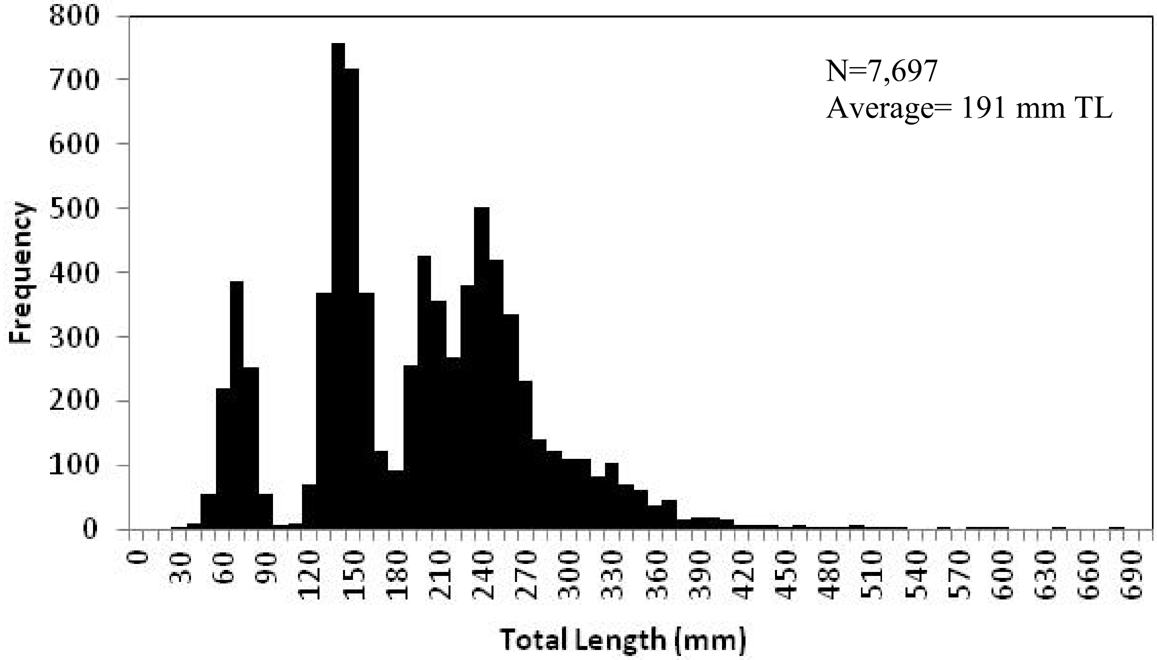


Figure 5. Length-frequency histograms of channel catfish in the lower San Juan River in 2012.

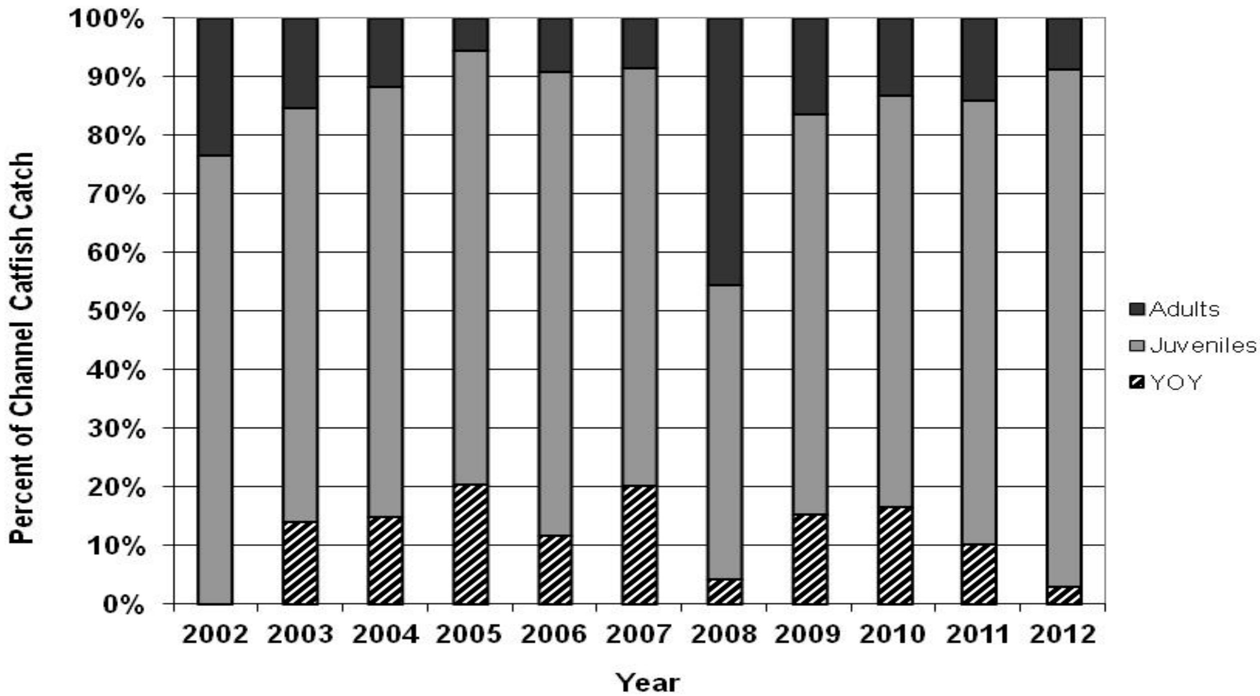


Figure 6. Percent of each life stage of channel catfish in the total channel catfish catch from 2002 to 2012. Note: YOY and juveniles life stages were not differentiated in 2002.

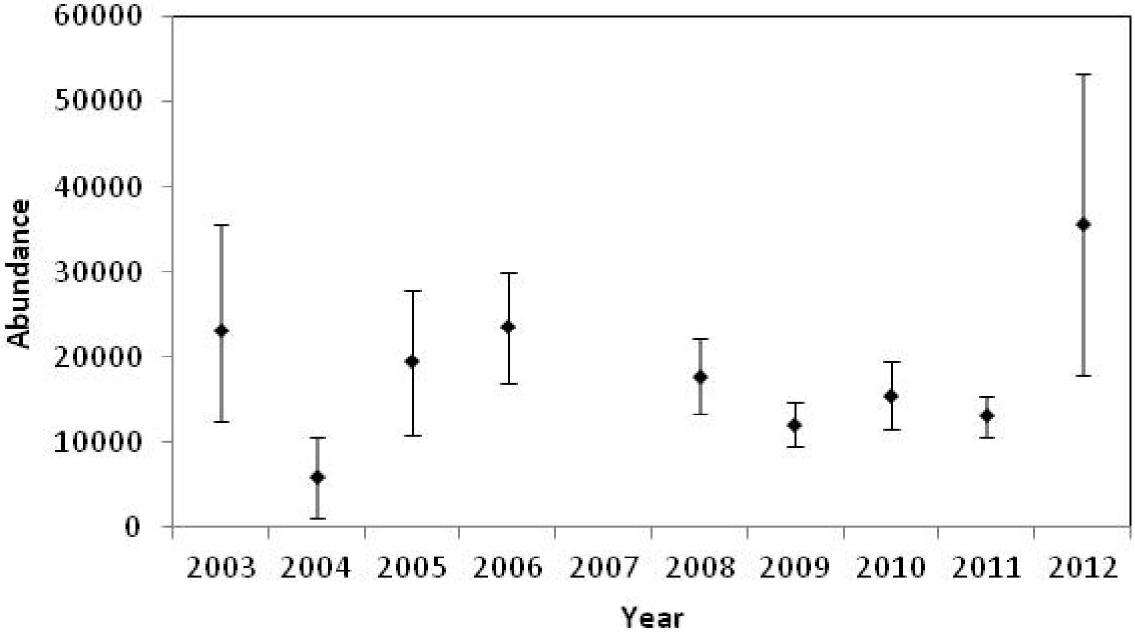


Figure 7. Abundance estimates for channel catfish from 2003 to 2012 in the lower San Juan River. Error bars represent 95% confidence intervals. Abundance estimates were calculated using the Lincoln-Peterson estimator with Chapman's correction.

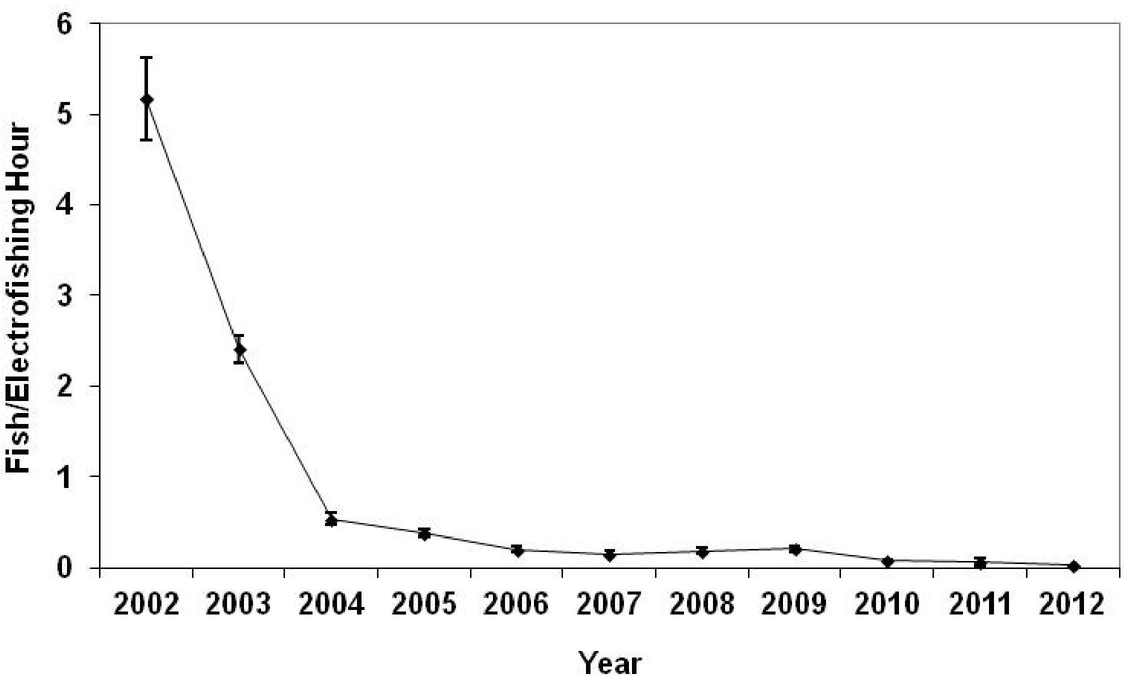


Figure 8. Mean electrofishing catch-per-unit-effort of common carp from 2002 to 2012 in the lower San Juan River. Error bars represent $\pm$ 1 standard error.

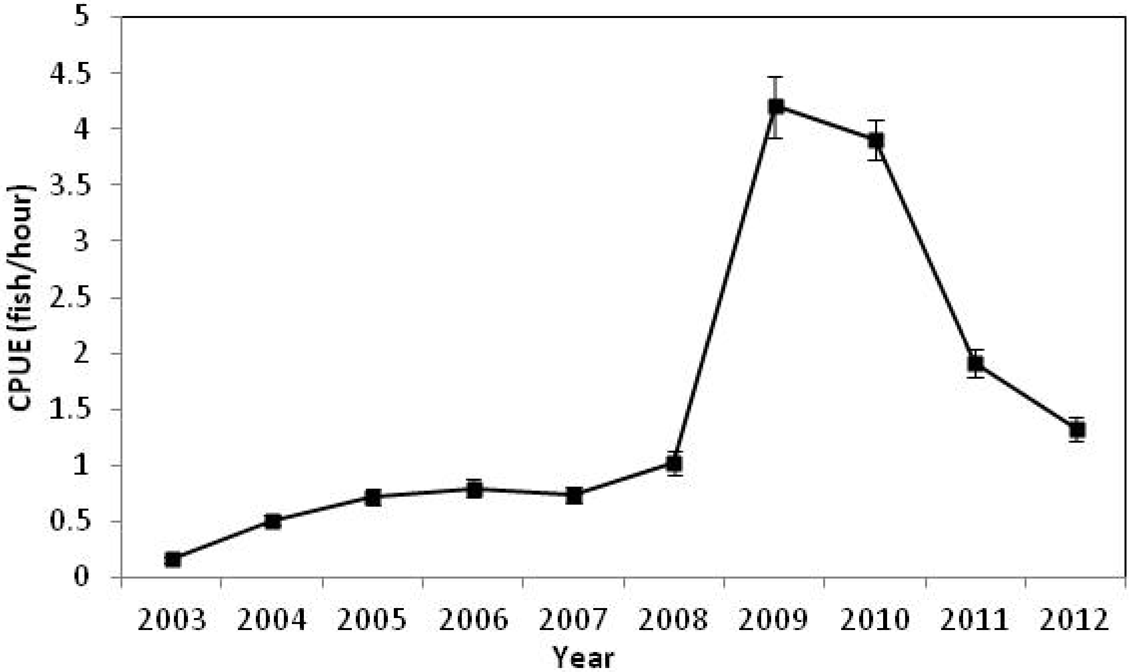


Figure 9. Mean electrofishing catch-per-unit-effort of Colorado pikeminnow in the lower San Juan River from 2003 to 2012. Error bars represent + 1 standard error.

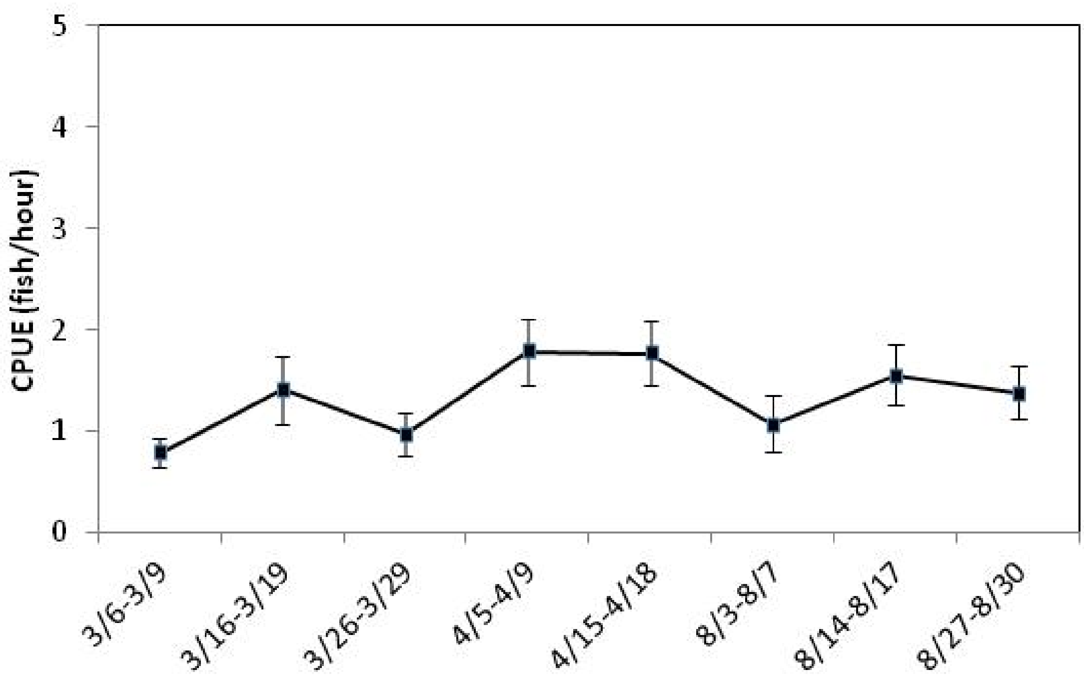


Figure 10. Mean electrofishing catch-per-unit-effort of Colorado pikeminnow by pass in the lower San Juan River during 2012. Error bars represent + 1 standard error.

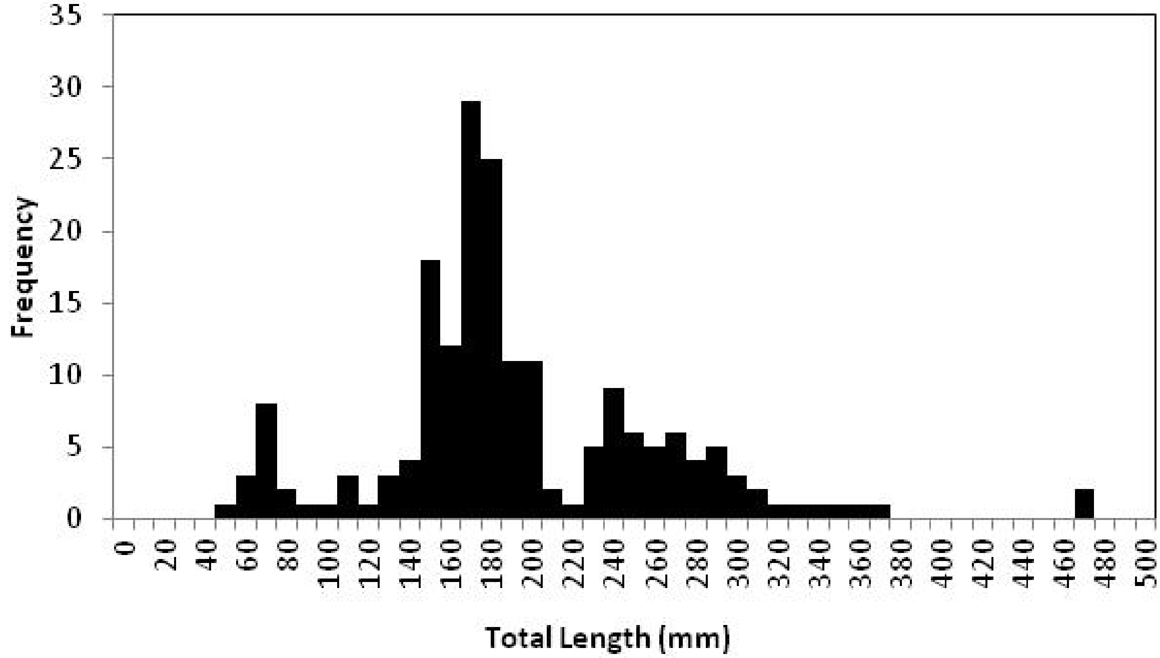


Figure 11. Length-frequency histogram of Colorado pikeminnow in the lower San Juan River during 2012.

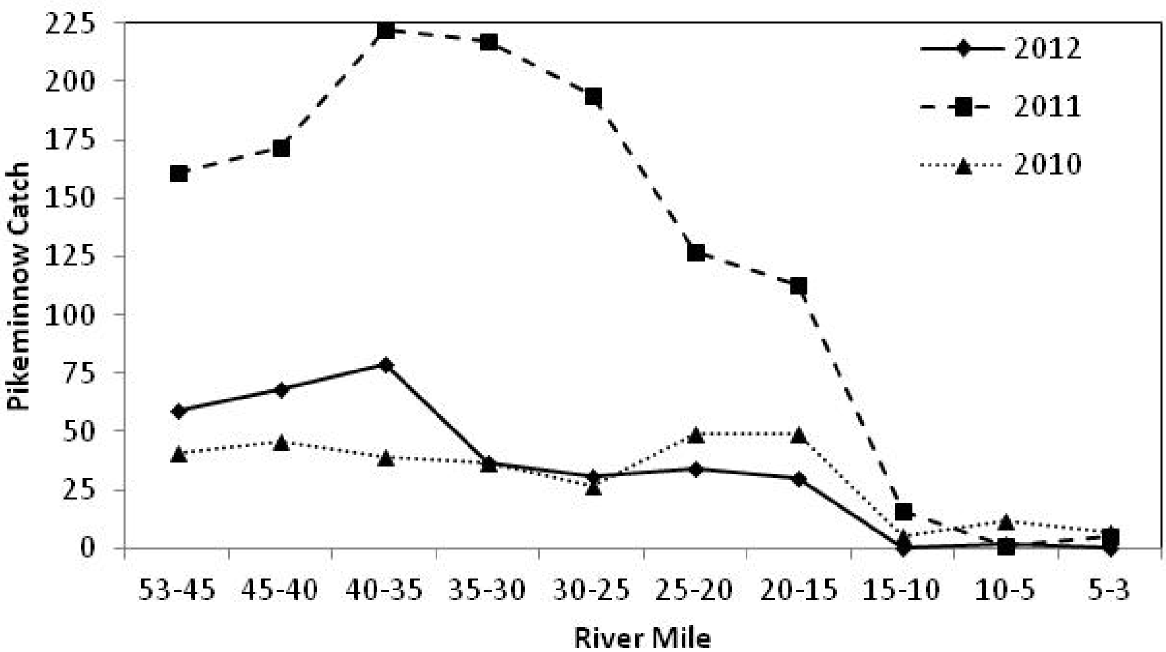


Figure 12. Distribution of Colorado pikeminnow captures by river mile from 2010 to 2012 in the lower San Juan River.

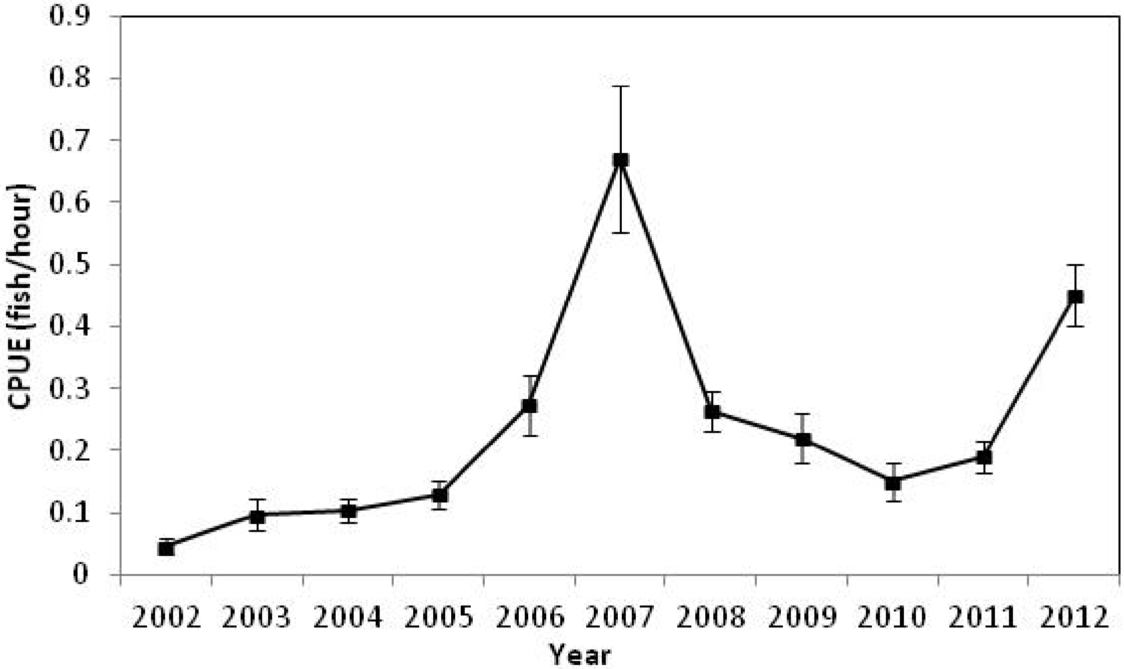


Figure 13. Mean electrofishing catch per unit effort of razorback sucker in the lower San Juan River from 2002 to 2012. Error bars represent ± 1 standard error.

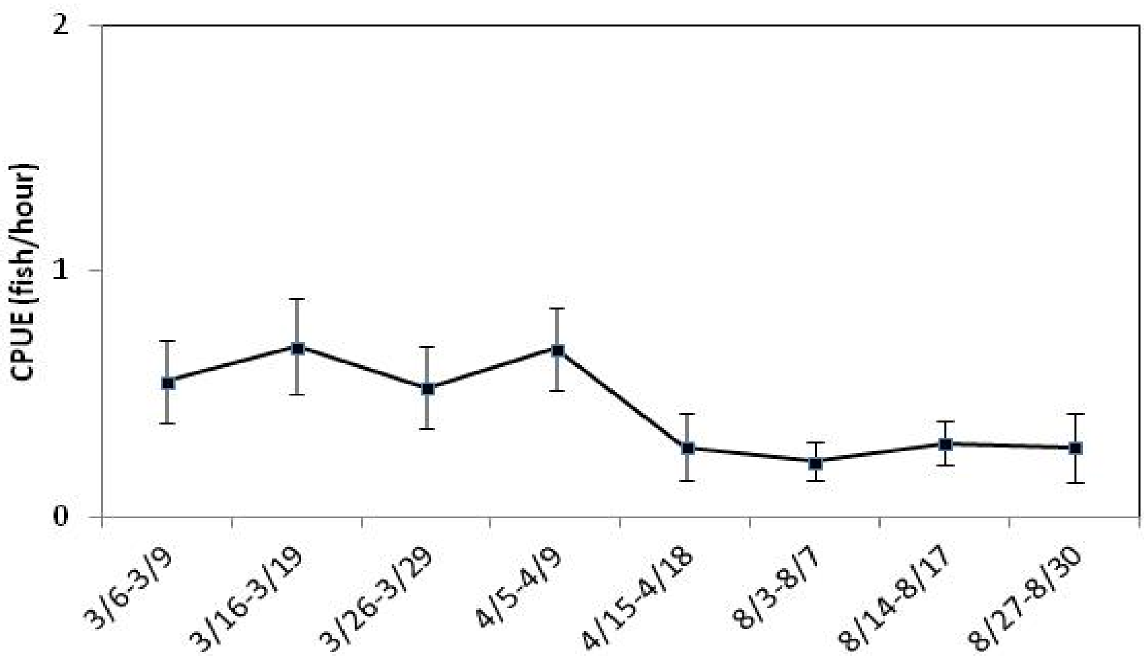
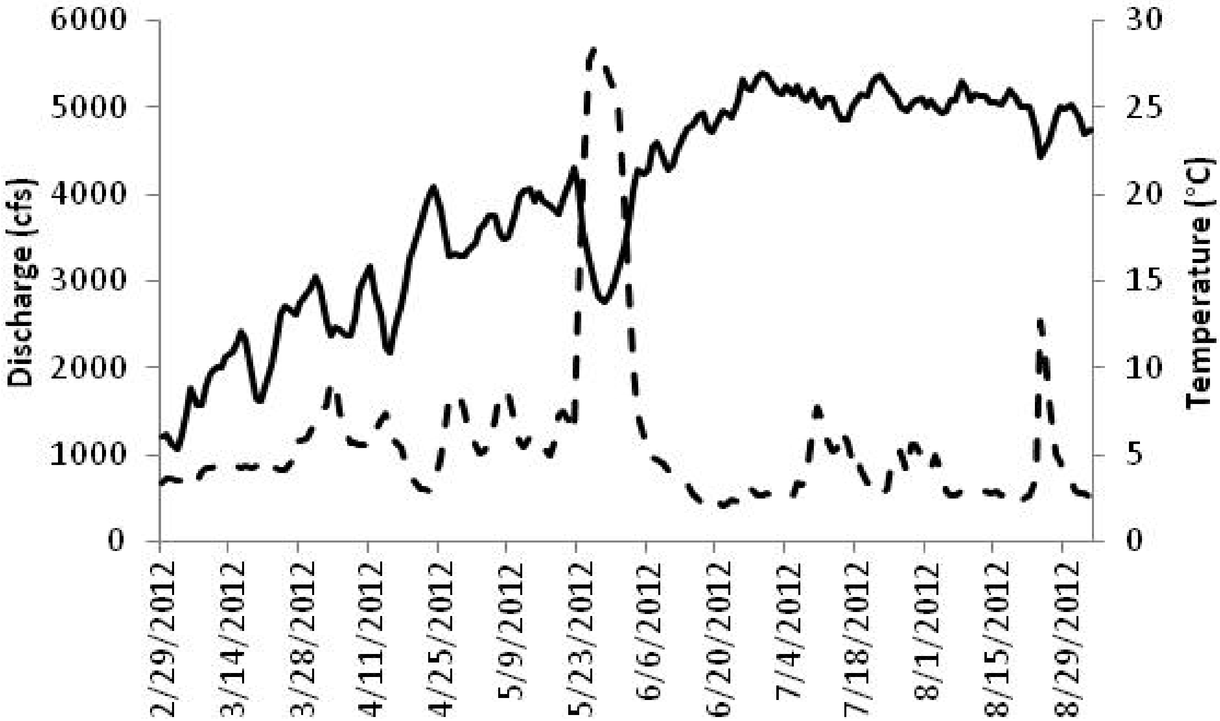


Figure 14. Mean electrofishing catch per unit effort of razorback sucker by pass in the lower San Juan River in 2012.

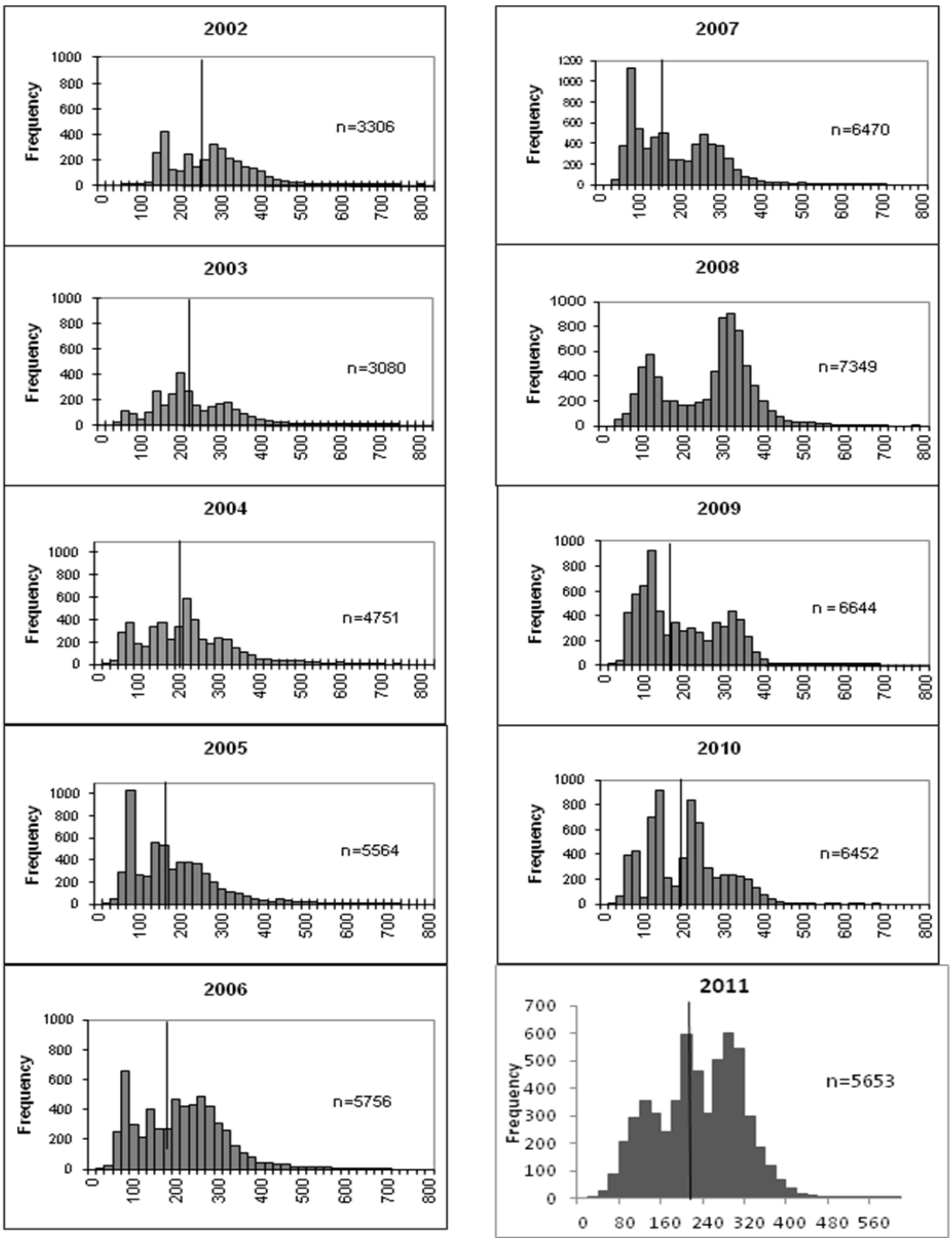
Appendix A. Average daily flow (USGS gage 09379500 near Mexican Hat, Utah), average water temperature and average turbidity (mm to Secchi disk disappearance) during sampling trips on the lower San Juan River in 2012.

Date	Temp	Discharge	Spec C	Turbidity (mm)
3/6-3/9	8.375	747.5	777	310
3/16-3/19	10.375	864	688	253
3/26-3/29	13.625	1111.75	595.25	171
4/5-4/9	12.66	1234	451.2	135
4/15-4/18	12.85	1123.25	445.75	162
8/3-8/7	24.975	684.8	715.5	3
8/14-8/17	25.325	563.75	562	7
8/27-8/30	24.9	856	579.5	13

Appendix B. Average daily flow (USGS gage 09379500 near Mexican Hat, Utah) during the 2012 field season on the lower San Juan River.



Appendix C. Length-frequency histograms of channel catfish in the lower San Juan River from 2002 to 2011. Vertical lines indicate mean TL by year.



Appendix D. Population estimates for juvenile Colorado pikeminnow ≥ 150 mm TL in the lower San Juan River from 2004 to 2011. Models used include the null model (Mo) and the time variable model (Mt) from Program Capture. CI represents the likelihood profile. CV indicates the coefficient of variation, and p-hat represents capture probability.

Year	Passes	Model	Estimate	CI	CV	p-hat
2004	1-2	Lincoln-Peterson	160	17-303	-	-
	1-3	Mo	315	218-545	0.22	0.07
	1-5	Mo	183	99-469	0.38	0.09
	4-6	Mo	195	124-372	0.27	0.13
	5-8	Mt	157	100-297	0.26	0.1
2005	1-3	Mo	536	288-1,283	0.37	0.06
	1-4	Mt	537	321-1064	0.3	0.06
	1-6	Mt	696	454-1189	0.24	0.03
	3-6	Mt	582	293-1556	0.41	0.04
	7-9	Mo	681	241-3950	0.67	0.03
2006	1-3	Mo	202	112-2,135	0.94	0.03
	4-6	Mo	124	78-237	0.3	0.14
	7-9	Mt	976	237-4,775	0.94	0.02
	7-10	Mt	1267	417-4,296	0.67	0.02
	1-10	Mt	455	340-640	0.16	0.04
2007	1-3	Mt	238	148-436	0.29	0.1
	4-6	No Estimate				
	7-9	Mo	68	36-180	0.31	0.13
	1-9	Mt	296	233-399	0.14	0.06
	1-10	Mt	326	257-433	0.13	0.05
2008	1-5	Mt	470	358-652	0.15	0.09
	6-9	Mt	270	149-636	0.36	0.07
	1-9	Mt	572	450-715	0.12	0.05
2009	1-4	Mo	1078	965-1222	0.06	0.16
	6-9	Mt	1221	678-2335	0.33	0.03
	1-4 and 6-9	Mt	1452	1306-1633	0.06	0.07
2010	1-7	Mo	1100	1022-1193	0.04	0.13
	1-9	Mo	1273	1185-1377	0.04	0.1
2011	1-5	Mt	1010	863-1207	0.09	0.1
	1-9	Mt	1160	1014-1348	0.07	0.06