Endangered Fish Monitoring and Nonnative Fish Control in the Lower San Juan River 2011

Progress Report

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Implementation Program

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EXECUTIVE SUMMARY

The tenth consecutive year of nonnative fish control in the lower San Juan River was conducted in 2011. 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. However, in 2003 a waterfall formed near Piute Farms canyon in the lower San Juan River. This waterfall created an impassable upstream barrier to upstream fish movement between the San Juan River and 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 2011, nine nonnative fish removal passes were made, beginning in early-March and continuing through August. Electrofishing was conducted from Mexican Hat to Clay Hills, UT between river miles (RM) 52.8-2.9. Mean daily river flow ranged from 603-2,310 cubic feet per second (cfs) during sampling trips in 2011.

The majority of large-bodied nonnative fish collected in 2011 were channel catfish (N = 3,058 individuals). Mean catch per unit effort (fish caught per hour) was 37.91. Considerable variability in catch rates was observed between passes. Mean catch rate of channel catfish in 2011 was significantly higher than catch rates in 2010 but similar to 2009. Common carp catches remained low in 2011 with just 11 individuals being captured and removed.

In 2011 sampling, 346 endangered fishes were collected in the lower San Juan River. Of which, 317 were juvenile or sub-adult (< 450 mm TL) Colorado pikeminnow (*Ptychocheilus lucius*) and 29 were razorback sucker (*Xyrauchen texanus*). All pikeminnow captured are likely of hatchery origin stocked within the San Juan River from 2003 through 2010 at upstream locations near Farmington, NM. Population assessments from capture-recapture data for Colorado pikeminnow estimated that between 1000 to 1200 fish are utilizing the lower San Juan River.

INTRODUCTION

The lower San Juan River is essential to the recovery of the Colorado pikeminnow and razorback sucker in the San Juan River Basin. It contains nursery habitats comparable to those existing in the Green and Colorado rivers, where limited recruitment is occurring. Since 2000, collections of endangered fishes have been increasing in the lower San Juan River. Razorback sucker larvae were collected during several years with the largest collection of razorback sucker larvae occurring in 2002 (Brandenburg et al. 2003). The largest collections of razorback sucker larvae in 2003, 2006, and 2007 came from a backwater in Reach 1 at RM 8.1 (Brandenburg et al. 2004, Brandenburg and Farrington 2007, 2008). Additionally, adult razorback sucker were found congregated around Slickhorn Rapid (RM 17.7) in the spring of 2002, and around RM 23.5 in the spring of 2006 during Utah Division of Wildlife Resources (UDWR) studies. These congregations of adult razorback suckers were potentially spawning aggregations.

Collections of adult Colorado pikeminnow in the San Juan River have been extremely rare. No wild adults have been collected since 2000 (Ryden 2003). From 2002 to 2004, sampling conducted by UDWR revealed low numbers of Colorado pikeminnow adults, presumably from the 1996-1997 stocking efforts, using the lower San Juan River in the spring and summer. From 2003-2009, age-0 Colorado pikeminnow stocked in the fall of the previous year near Farmington, NM, were found using the lower portions of the San Juan River (Golden et al. 2006, Elverud 2009). In 2004, wild-spawned Colorado pikeminnow larvae were collected at RM 46.3 and RM 18.1 (Brandenburg et al. 2005), and were the only Colorado pikeminnow larvae collected from 2002 to 2006. In 2007, three wild-spawned Colorado pikeminnow larvae were collected in the San Juan River with one of these larvae being collected at RM 33.7 (Brandenburg and Farrington, 2008) and in 2009 the only Colorado pikeminnow larvae collected in the San Juan River was collected at RM 24.7 (Brandenburg and Farrington 2010).

The UDWR studies were originally initiated in an attempt to target striped bass and other nonnative predatory fishes such as walleye that move from Lake Powell into the San Juan River. Striped bass became a particular concern in 2000 when substantial numbers (approximately 270 individuals) and widespread distribution of these fish were observed in July during electrofishing surveys on the upper San Juan River (RM 147.9-129.0; Ryden 2001). United States Fish and Wildlife Service New Mexico Fish and Wildlife Conservation Office (NMFWCO) crews collected another 33 striped bass between RM 166.6 and 158.6, just below the PNM weir during September and October 2000 sampling (Davis 2002). Adult monitoring in October 2000 revealed approximately 100 striped bass still in the river. It was speculated that the absence of small native flannelmouth sucker (*Catostomus latipinnis*), native bluehead sucker (*Catostomus discobolus*), and nonnative common carp caught in summer 2000, was directly related to striped bass predation since they were abundant in striped bass stomachs (Ryden 2001). Further evidence of this relationship was found during the October 2000 sampling when higher numbers of flannelmouth sucker, bluehead sucker, and common carp were collected above the PNM weir where striped bass were not present.

Striped bass were first stocked into Lake Powell in 1974, and since 1979, a large self-sustaining population has persisted (Gustaveson 1984). Angler bag limits for striped bass were slowly raised and ultimately removed in Lake Powell to aid in control of the growing population. From

1988 to the summer of 1995, a waterfall at approximately RM 0 acted as a barrier between the San Juan River and the lake. Lake levels rose to full pool (3700 ft above sea level) during 1995 and inundated the waterfall allowing for the upstream movement of all species from Lake Powell. When lake levels receded in the winter of 1996, the river either cut a new channel or had not scoured the sediment enough to expose the rock and the waterfall did not reappear (Schaugaard and Gustaveson 1996). Striped bass, walleye, and threadfin shad (*Dorosoma petenense*), not previously documented in the San Juan River before waterfall inundation, were collected during large-bodied fish sampling in 1995 (Ryden 2001). Additionally, channel catfish and common carp catch rates had increased in the lower river, and these species were presumed to have invaded from the lake.

The life history of striped bass suggests that they move out of lakes and into lotic waters to spawn in the spring (Sigler and Sigler 1996). Striped bass usually spawn when temperatures are between 10°C and 21.1°C (Sigler and Sigler 1996). In the Sacramento-San Joaquin Delta, striped bass movement up river was positively related to high flows and turbidity (Feyrera and Healey 2003). Similar movements have been observed in the San Juan River in the spring. Although it has been speculated that turbid flows in the fall may preclude striped bass from persisting in the river through the year, based on the biology of striped bass, turbidity may not be a factor. Instead these fish may simply move back downstream after spawning or be affected by rising river temperatures. Striped bass in Lake Powell are unique in their ability to reproduce in the reservoir itself (Gustaveson et al. 1984). In 2002, during the first year of this project, striped bass were found inhabiting the lower river in low numbers. Other researchers collected striped bass as far upstream as Farmington, NM (RM 166-158; Davis 2002). Striped bass movement into the San Juan River was positively correlated with Lake Powell water temperatures, and catch rates were highest in June when they were first observed in the river (Jackson 2003).

No striped bass or walleye were collected or observed in the lower San Juan River in 2003. As a result of this observation in the first few months of sampling, combined with anecdotal reports that these fish may not have access to the San Juan River because of low flows between Clay Hills and Lake Powell (Quentin Bradwisch, personal communication), a trip was made by vehicle to Piute Farms in July of 2003. At that time, a waterfall of approximately 15 meters wide and 1 meter high was discovered. The waterfall apparently blocked upstream passage of striped bass and walleye into the San Juan River. Similarly, Beasley and Hightower (2000) found that a one-meter high (3.28 ft) low head dam on the Neuse River in North Carolina was a barrier to spawning migrations of striped bass. It is unknown if walleye are able to pass a barrier of this size. High flows in the river may eventually cause the river to flow around the waterfall or to wash it out entirely thereby allowing fishes to pass and move upstream again. Since 2003, after the waterfall formed, the focus of this project has been to suppress other nonnative fishes in the lower San Juan River, as well as to track the abundance and distribution of endangered fishes.

The presence of the waterfall at Piute Farms may provide a rare opportunity to concentrate on removal of nonnative fishes while influx from the lake is eliminated. Continuing nonnative fish removal in the lower river will aid in removal efforts being conducted further upstream and potentially suppress predation and competition impacts on the endangered and native fish community by nonnative fishes.

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 4 and goal 4.1.

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

Raft mounted electrofishing gear was used during all passes to collect fish. A Smith-Root electrofishing system (5.0 GPP) was used with amperage set from 4-6 depending on water conductivity conditions. One boat electrofished each shoreline during sampling passes. A single sampling pass consists of one 5-day trip from Mexican Hat to Clay Hills. Sampling units consist of approximately 3-mile segments of river electrofished by a single electrofishing raft. Data are collected for approximately 30 samples per pass. When conditions allowed, a chase boat was used to net fishes not captured by the electrofishing boats. Beginning in 2007, a 6 foot X 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), except non-listed native suckers. Total and standard length (nearest millimeter, mm) and weight (nearest gram, g) were recorded for fish collected. When large numbers of channel catfish were collected within a three-mile stretch of river, 20 randomly selected catfish in each life stage (YOY [0-79 mm TL], juvenile [80-299 mm TL], adult [300+ mm TL]) were measured and the rest of the channel catfish in the life stage were enumerated. Endangered fishes $\geq$ 150 mm TL received a PIT tag (134 kHz) if one was not already present. Endangered fish were released at or near the location of capture. River mile near the location of capture was recorded. From 2003-2006 and 2008-2011, all channel catfish $\geq$ 200 mm TL collected during the first pass (trip) were tagged and released. Channel catfish collected in 2009, 2010, and 2011 were uniquely marked with individually numbered tags. 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. Double marking allowed for tag loss to be evaluated between passes one and two. Channel catfish and all other large-bodied nonnative fish collected on subsequent passes were removed. River temperature, conductivity, and salinity were measured at least twice during each pass. Turbidity or water clarity was measured using a Secchi disk. River discharge was determined from the USGS gage # 09379500 near Bluff, UT. Lake Powell elevations and temperatures were taken from the Lake Powell water database website.

Data Analysis

Catch per unit effort (CPUE) was calculated using the number of fish caught per hour of electrofishing. Fishes that were collected by the chase boat or block seine were not included in the CPUE but were included in length-frequency analyses. About 30 samples were taken during each pass comprising the CPUE for approximately 3 river miles. These samples were then used to calculate means and variances. Mean TL and CPUE were compared between years and passes using non-parametric Kruskal-Wallis tests along with post hoc pair-wise multiple comparisons (Dunn's Method). The non-parametric Kruskal-Wallis test was used, as transformations did not successfully increase normality of CPUE and TL data.

A Lincoln-Peterson population estimate was generated for channel catfish ($\geq$ 200 mm) captured during the first two passes from 2003 to 2006 and 2008-2011. Captures of channel catfish during subsequent passes allows for monitoring ratios of marked to unmarked fish to aid in determining if assumptions of a closed population are being met. In 2007, no abundance estimate of channel catfish was calculated. Tag retention and exploitation by size class was assessed based on recaptures of tagged fish throughout the sampling season.

Population size was estimated for age-2+ Colorado pikeminnow (>150 mm) in the lower San Juan River using closed population models within program CAPTURE (Otis et al. 1978, White et al. 1982, Rexstad and Burnham 1991). Program CAPTURE allows for the use of two or more passes in generating population estimates. Several combinations of passes were selected for analysis to lessen the likelihood of violating assumptions of the models used. Program CAPTURE was used to determine a confidence interval around the estimate, the coefficient of variation, and the probability of capture. The M_o model (null model) was appropriate when capture probabilities (p-hat) remained similar among the passes in the model. The M_t model (time variable model) was used when p-hat was variable among passes. The Lincoln-Peterson method was used to determine population estimates between two passes. For the models run through program CAPTURE, likelihood profiles were provided in lieu of 95% confidence intervals. The likelihood profile helps to account for model selection uncertainty by providing a wider confidence interval.

RESULTS

Nine sampling passes were conducted on the San Juan River between Mexican Hat and Clay Hills, UT in 2011 (Figure 1). Sampling dates were: March 1-5, March 10-14, March 19-23, March 29-April 2, April 5-8, June 28-July 1, July 8-11, August 3-6, and August 15-19. Eight large-bodied fish species, including Colorado pikeminnow and razorback sucker, were collected in the lower San Juan River during nonnative control. Five non-native species were captured during 2011 sampling (Table 1). One suspected razorback-flannelmouth sucker hybrid was collected in 2011. Native bluehead sucker and flannelmouth sucker were present during all passes but not netted during nonnative control efforts because of their large population size. Electrofishing effort totaled 314 hours and resulted in 3,446 fishes captured (Table 1). No striped bass or walleye were collected in 2011 in the lower San Juan River above the waterfall.

Nonnative Species

Channel catfish

In 2011, channel catfish comprised 89% of the total catch during non-native removal passes in the lower San Juan River. Mean catch rates of channel catfish varied significantly between some passes and ranged from 10.33 to 70.42 fish per hour ($p < 0.001$; Table 2, Figure 2). Mean catch rates for channel catfish in 2011 were 37.91 fish per hour and were the second highest CPUE observed since this project began in 2002. Significantly different ($p<0.001$) catch rates were observed between 2011 and 2002-2004, 2006-2008, and 2010. Catches were statistically similar in 2005 and 2009 (Figure 3). The mean catch rate of adult (>300 mm TL) channel catfish in 2011 was significantly lower than in 2002, 2008 and 2009 (Figure 4). There was no significant difference in adult channel catfish CPUE between 2011 and other years.

The mean total length of channel catfish collected in the lower San Juan River in 2011 was 218 mm. The mean total length in 2011 was significantly lower than the mean total length in 2002 – 2004, 2006 and 2008 ($p < 0.05$; Figure 5). Analysis of length-frequency histograms of channel catfish showed that the majority of catfish collected during 2011 were fish under 300 mm with a large proportion of juvenile catfish under 200 mm (Figure 5). The percentage of adult (≥300 mm TL) channel catfish in the total catch was similar to previous years (Figure 6) with the exception of 2008 when adult channel catfish comprised a larger proportion of the total catch. Large-bodied adult channel catfish greater than 400 mm represented a small proportion of the overall catch. Channel catfish greater than ≥ 400mm TL have declined from 9.4% in 2002 to 1.1% in 2011 of the total channel catfish catch.

Channel catfish populations were assessed using data from pass 1 and 2 with a Lincoln-Peterson population estimate for 2011 (Figure 7). Seven hundred forty nine channel catfish greater than 200 mm TL were tagged during the first sampling trip, and 47 channel catfish with tags were recaptured during the second sampling trip. In 2011, 8,453 individuals (95% CI = 6,148-10,759) were estimated within the lower San Juan River. The 2011 estimate is significantly lower than the 2003, 2005, 2006, 2008 and 2010 estimates. The 2011 channel catfish population estimate is within the confidence intervals for 2004 and 2009 respectively.

In 2011, the exploitation rate of channel catfish by size class was assessed using tag return data. Exploitation rate increased concomitantly with size class (Table 3). Exploitation ranged from 21.2% for channel catfish between 200-299 mm TL to 37.5% for channel catfish between 400-499 mm TL (Table 3). Exploitation rates were also considerably higher on nonnative removal trips 1-5 conducted prior to spring runoff when compared to the exploitation rate on trips after runoff (Table 3). Sixty-six tagged channel catfish were captured by collaborators within the San Juan River Basin Recovery Program upstream of our sampling reach. Tag recapture data indicated substantial upstream movement of over 100 miles by a few individuals.

Common carp

In 2011, mean catch rates of common carp remained low when compared to catch rates during the first two years of nonnative control in the lower San Juan River (2002, 2003). Catch rates of common carp were not significantly different between passes in 2011 (Figure 8). From 2002 to 2011, catch rates of common carp decreased significantly ($p < 0.05$; Figure 9). When compared to 2011, the mean catch rate of common carp was significantly higher from 2002 and 2005 ($p < 0.05$), but was not significantly lower than in 2006 to 2010. Mean TL of common carp captured in 2011 was significantly different ($p<0.05$) from carp TL in 2007, 2009, and 2010 (Figure 10). This analysis may not have sufficient power (i.e. small sample size) to accurately determine difference in mean TL between years.

Endangered Species

Colorado pikeminnow

A total of 317 Colorado pikeminnow were collected in 2011 during nonnative control efforts in lower San Juan River. Catch of Colorado pikeminnow declined from 2010 to 2011. However, catch rates for 2011 were still higher than catches from 2003 to 2008 (Figure 11). Catch rates of Colorado pikeminnow in 2011 were significantly higher than catch rates from 2003 to 2008 ($p<0.05$), but were not significantly different from 2009 and 2010 catch rates. Catch rates of Colorado pikeminnow in 2011 varied by pass. In general catch rates were highest during the first 5 passes of the year (March-April; Figure 12). In 2011, the majority of juvenile Colorado pikeminnow captured were age-1 and age-2 individuals (Figure 13). These fish are from the 2009 (Age 2) and 2010 (Age 1) fish stocking program. Colorado pikeminnow captures were widely distributed throughout the study reach in 2011. Catch of pikeminnow was lowest for river miles 3 to 15 and generally evenly distributed between river miles 15 to 53. Pikeminnow capture locations appear to be consistent with distributional patterns observed in previous years (Figure 14).

Population estimates of Colorado pikeminnow have been generated for the lower San Juan River since 2004 (Table 4). Two population estimates were calculated using different set of passes (passes 1-5 and passes 1-9) to estimate the population size of Colorado pikeminnow $\geq$ 150 mm TL. Passes 1-5 were completed prior to spring runoff. In 2011, population estimates of Colorado pikeminnow in the lower San Juan River were: 1,010 for passes 1-5 and 1,160 for passes 1-9. Capture probability was 0.10 for passes 1-5 and 0.06 for passes 1-9 combined. The coefficients of variation for these estimates were 9% for passes 1-5 and 7% for passes 1-9. Population estimates in the lower San Juan River indicated that abundance increased from 2004 to 2009 and has stabilized around 1100 individuals from 2009 to 2011. Increases in pikeminnow in the lower San Juan River are likely a result of increased stocking efforts as part of augmentation programs throughout the river.

Captures of adult (>450 mm TL) Colorado pikeminnow have been low since this project began in 2002. One adult pikeminnow (501 mm TL) was captured in 2011 and one sub-adult pikeminnow (400 mm) was captured in 2010. No adult Colorado pikeminnow have been collected since 2004 in the lower San Juan River. 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. All of these Colorado pikeminnow are believed to have come from the stockings in 1996 and 1997.

Razorback sucker

Twenty-nine 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 was significantly lower in 2011 than in 2007 (Figure 15). No significant difference in catch rate exists between the 2011 catch rate and other years. Catch rate of razorback sucker did not vary by pass (Figure 16). The total number of razorback suckers captured in the lower San Juan River during nonnative control has been decreasing since 2007. These decreases coincide with decreases in the number of razorback sucker stocked the previous two years. One suspected razorback-flannelmouth hybrid was collected in 2011 in the lower San Juan River.

Other Observations

Over the course of this project, important information has also been obtained on endangered fishes in the lower San Juan River. We have observed the apparent spawning aggregation of razorback sucker in spring 2002 at Slickhorn Rapid (RM?), located another possible spawning aggregation near RM 23.5 in 2006, documented the distribution and abundance of Colorado pikeminnow stocked in 2002 –2009, generated preliminary population estimates for juvenile Colorado pikeminnow from 2004 to 2011, and documented the first cases of channel catfish predation on stocked juvenile razorback sucker and Colorado pikeminnow in the San Juan River in 2004 (Jackson 2005).

The increases in catch rates of juvenile Colorado pikeminnow in the lower San Juan River from 2003 to 2010 are correlated with the stocking of age-0 fish each year. From 2004 to 2010, age-2 Colorado pikeminnow made up the majority of the catch. In the past the number of Colorado pikeminnow in this size class decreased in collections, as was the case after the 1996-1998 stocking events. USFWS Colorado River Fisheries Program (CRFP) fall monitoring data (Ryden 2003) show that catch rates of age-3 fish diminished one year after a good catch of age-2 fish.

DISCUSSION

The waterfall near Piute Farms persisted for most of 2011 and was a barrier to upstream movement of fish from Lake Powell. However, due to above average inflows caused by above average snowpack in 2011 the waterfall became inundated by Lake Powell for a two week period in July. As runoff ceased and releases from Glen Canyon Dam increased to provide equalization flows to Lake Mead, Lake Powell water levels declined and the waterfall once again became an impassable barrier. Based on fish monitoring activities after July, there was no evidence of nonnative fish movement from Lake Powell into the lower San Juan during the two week period in July.

The channel catfish catch rate in 2011 was significantly higher than in 2010, but was similar catch rates observed in 2009. In general, catch rates in 2011 were higher than those observed in 2002-2008. Overall, CPUE trends from 2002 to 2011 appear to be increasing slightly or remaining stable. Many factors may have contributed to the higher catch rates in 2011. Time of year, discharge, water temperature, turbidity, netter, raft operator and pass number all interact to influence catchability which wasn't evaluated under the current sampling regime. These covariates in part drive the variation in observed CPUE between electrofishing passes and years. The declining trend in CPUE between passes in 2011 may be a result of our depletion efforts, movement outside of the study reach, changing capture probability between passes and behavioral responses to electrofishing gear. The use of CPUE as an index of population abundance is a popular easy way to assess fish populations. 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.

Exploitation rate for channel catfish was estimated using tag return data from individually marked fish. Exploitation rate of channel catfish 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. Exploitation was also observed to be higher during sampling trips conducted prior to runoff. Increased exploitation rate was also observed for larger size classes and prior to spring runoff in 2009 and 2010 (Elverud 2010). The reduced exploitation rate of channel catfish post runoff may be the result of numerous factors. Capture probability may change between pre and post runoff periods accounting for our reduced exploitation rate later in the season. Channel catfish tagged in the lower San Juan have been observed to make movements 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.

Population estimates of channel catfish ≥ 200 mm TL have been conducted in the lower San Juan River since 2003. The 2011 population estimate was significantly lower than the 2003, 2005, 2006, 2008 and 2010 estimate and within the confidence limits of the 2004 and 2009 estimate. In general, there seems to be a slight decline in overall spring abundances of channel catfish since 2003. Large declines in the channel catfish population greater than 400 mm have also been observed. The concern over tag loss and violation of Lincoln-Peterson model assumptions was minimized by conducting pass two within a week of the marking pass and assessing tag retention (Elverud 2010).

The increase in the number of juvenile channel catfish in the lower San Juan River could be the result of numerous factors. 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. This pattern of compensatory improvement in juvenile survival rates has been noted in numerous fish populations throughout North America. 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 (Hubert 1991). Hubert (1991) reported that an annual exploitation rate of 22% would result in a 75% reduction in overall abundance of catfish ≥ 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 2011, only 11 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 the CPUE of common carp (Davis 2009). River-wide adult and sub-adult monitoring has also shown a significant decline in CPUE of common carp (Ryden 2009).

Population estimates generated for stocked juvenile Colorado pikeminnow indicate that pikeminnow abundance has increased since monitoring began in 2002. The estimated abundance for 2011 was between 863 to1348 individuals. The preciseness of the estimate is dependent on the estimate of capture probability. Years (2006 in particular) which have a low estimate capture probability (less than 5%) estimate abundance poorly while 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. Additionally, it may be beneficial to estimate abundance for pre-runoff and post-runoff trips. This may help stabilize capture probability and determine the proportion of fish that migrate outside of the study reach during the summer.

The catch of adult Colorado pikeminnow has been low and declined slightly over the period of this study (2002-2011). The reasons for this decline is unknown but might be explained by several factors: 1) Colorado pikeminnow adults may have ‘gotten smart’ and learned to avoid the electrofishing field; 2) emigrated below the waterfall outside of the study area; 3) emigrated upstream of the study reach; 4) or suffered 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). Pikeminnow observed to avoid the electrofishing boats ranged from 521 to 948 mm TL. Pikeminnow avoidance of rafts has been documented by other researchers as well (Bestgen et. al 2004). Bestgen et al. (2004) examined Colorado pikeminnow avoidance to electrofishing boats indirectly during population estimates conducted in the Green River. In contrast to channel catfish, capture probabilities for pikeminnow declined with increased 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, habitat suitable for adult pikeminnow may not be present within the lower San Juan River. Adult pikeminnow rely on deep pools for foraging and resting. These habitats are scarce in the lower river and may explain in part for the lack of adults in this stretch of river.

The total number of razorback suckers captured in the lower San Juan River in 2011 was lower than the number captured the previous three years, and the CPUE of razorback sucker is significantly lower than in 2006 and 2007. River-wide monitoring has shown no significant decrease in razorback sucker catch rate in the previous years (Ryden 2010). The likely reason for the decline in total number of razorback sucker captures and CPUE is the decrease in the total number stocked the previous two years. The high CPUE observed in 2007 was the result of large numbers of razorback suckers being stocked the previous year.

CONCLUSIONS AND RECOMMENDATIONS

• Population estimates of channel catfish in the lower San Juan River indicate a slight decline from 2003 to 2011. Estimates of channel catfish populations were relatively imprecise (indicated by large confidence intervals) from 2003 to 2006 but have improved in recent years. The proportion the channel catfish ≥ 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 relative population size at the beginning of each removal year. Along with population estimates, mark/recapture using individually number tags allows for determination of exploitation rate by size class, monitoring of channel catfish growth rates and movement throughout the river.

• The CPUE and mean TL of channel catfish in 2011 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. Expansion of nonnative control into the middle San Juan beginning in 2008 may decrease the number of spawning channel catfish upstream of the lower San Juan removal reach.

• Catch rates of common carp decreased significantly from 2002 to 2011. 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 remained stable at around 1100 individuals since 2009. From 2004 to 2011, the majority of captures were age-1 and age-2 fish. Age-0 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.

• One adult Colorado pikeminnow was collected in the lower San Juan River in 2011. The lack of adult pikeminnow in the catch may reflect: avoidance of electrofishing rafts, movement outside of the study area or mortality.

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Table 1. Total count of fish species collected during electrofishing sampling in the lower San Juan River in 2011.

	Sampling Trip Dates									2011 Total
	3/1-3/5	**3/10-3/14**	**3/19-3/23**	**3/29-4/2**	**4/5-4/8**	**6/28-7/1**	**7/8-7/11**	**8/3-8/6**	**8/15-8/19**	
Black bullhead	1	5	2	0	3	5	1	2	3	22
Brown trout	0	0	0	0	0	5	2	0	0	7
Channel Catfish	1131	540	125	173	262	285	314	59	169	3058
Colorado pikeminnow	37	34	99	53	38	18	17	5	16	317
Common carp	1	1	1	0	0	2	3	0	3	11
Razorback sucker	7	5	5	0	0	2	0	4	6	29
Razorback-Flannelmouth Hybrid	0	0	0	0	0	0	0	0	1	1
Yellow bullhead	0	1	0	0	0	0	0	0	0	1

Table 2. Mean catch per unit effort (fish/electrofishing hour) of most abundant fish species collected during electrofishing sampling in the lower San Juan River in 2011. The numbers in parenthesis in the trip column are the number of samples during trips. The standard error (SE) is in parenthesis beside each mean CPUE.

Trip	Colorado Pikeminnow	Razorback Sucker	Channel Catfish	Common Carp
3/1-3/5 (32)	1.64(0.32)	0.36(0.1)	43.54(4.3)	0.05(0.04)
3/10-3/14 (30)	1.92(0.37)	0.26(0.09)	38.19(3.8)	0.05(0.03)
3/19-3/23 (26)	4.15(0.58)	0.26(0.08)	70.42(8.78)	0.02(0.02)
3/29-4/2 (30)	2.16(0.29)	0.06(0.04)	54.61(6.76)	0(0)
4/5-4/8 (24)	2.76(0.44)	0.18(0.1)	28.82(4.76)	0(0)
6/28-7/1 (27)	1.22(0.25)	0.05(0.04)	30.93(4.22)	0.11(0.06)
7/8-7/11(26)	1.05(0.2)	0(0)	35.7(6.92)	0.18(0.08)
8/3-8/6 (24)	0.69(0.17)	0.2(0.07)	10.33(2.49)	0.03(0.03)
8/15-8/19 (28)	0.75(0.17)	0.25(0.12)	23.28(4.43)	0.12(0.06)

Table 3. Percentage of total catch, number of channel catfish tagged by size class and exploitation rate of channel catfish by size class in 2011 in the lower San Juan River. Numbers below percentages are the actual number caught.

	Total Length (mm) of Channel Catfish at Time of Tagging					
	200-299 mm	300-399 mm	400-499 mm	500-599 mm	600+ mm	Total
Number Marked	74.27%	24.72%	1.01%	0.00%	0.00%	
	1178	392	16	0	0	1586
Trips 1 to 5	14.94%	19.39%	37.50%	0.00%	0.00%	
	176	76	6	0	0	258
Trips 6 to 9	0.80%	3.48%	0.00%	0.00%	0.00%	
	8	11	0	0	0	19
UDWR Total	15.62%	22.19%	37.50%	0.00%	0.00%	
	184	87	6			277
Other Sampling	5.6%	7.4%	0.0%	0.0%	0.0%	
	66	29	0	0	0	95
Total of All Efforts	21.2%	29.6%	37.5%	0.0%	0.0%	
	250	116	6	0	0	372

Table 4. 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	0.10
2005	1-3	Mo	536	288-1,283	0.37	0.06
	1-4	Mt	537	321-1,064	0.30	0.06
	1-6	Mt	696	454-1,189	0.24	0.03
	3-6	Mt	582	293-1,556	0.41	0.04
	7-9	Mo	681	241-3,950	0.67	0.03
2006	1-3	Mo	202	112-2,135	0.94	0.03
	4-6	Mo	124	78-237	0.30	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	0.10
	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	0.10
2011	1-5	Mt	1010	863-1207	0.09	0.10
	1-9	Mt	1160	1014-1348	0.07	0.06

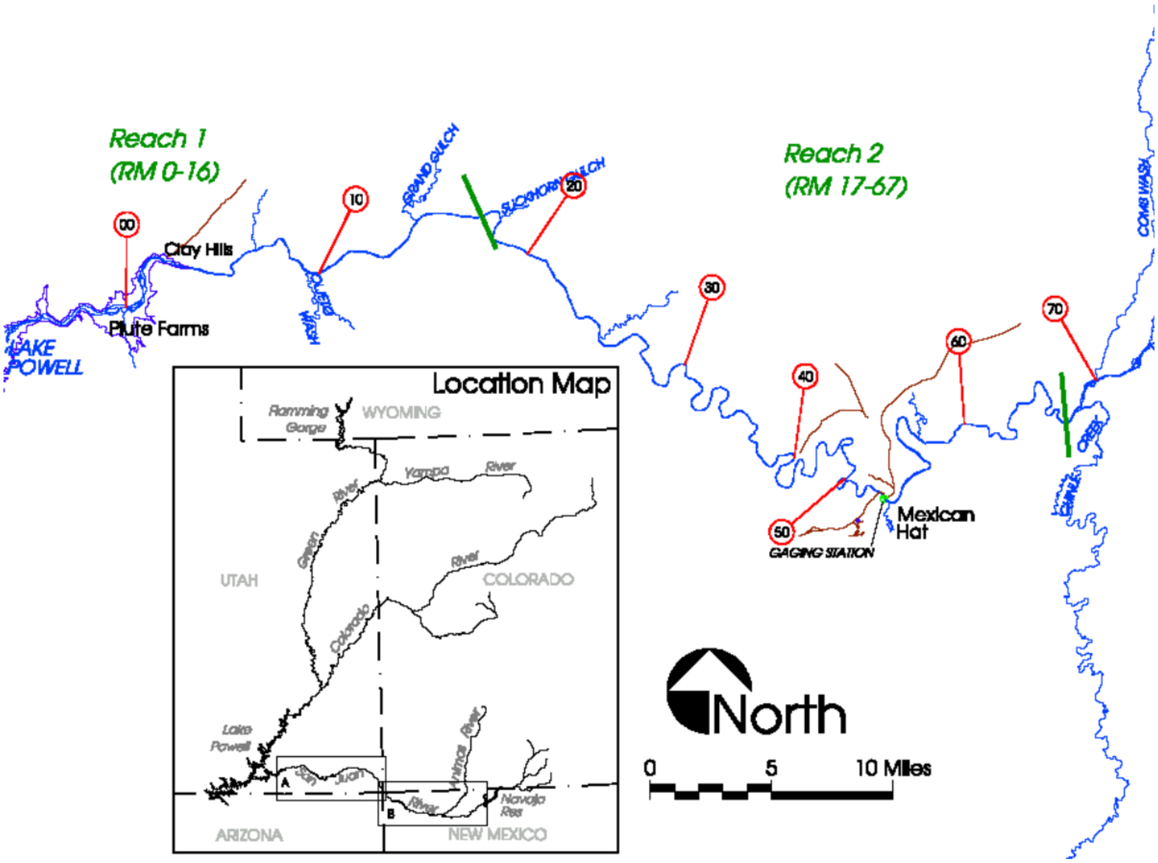

Figure 1. Map of the study area for nonnative fish control in the lower San Juan River. Sampling area extends from Mexican Hat to Clay Hills.

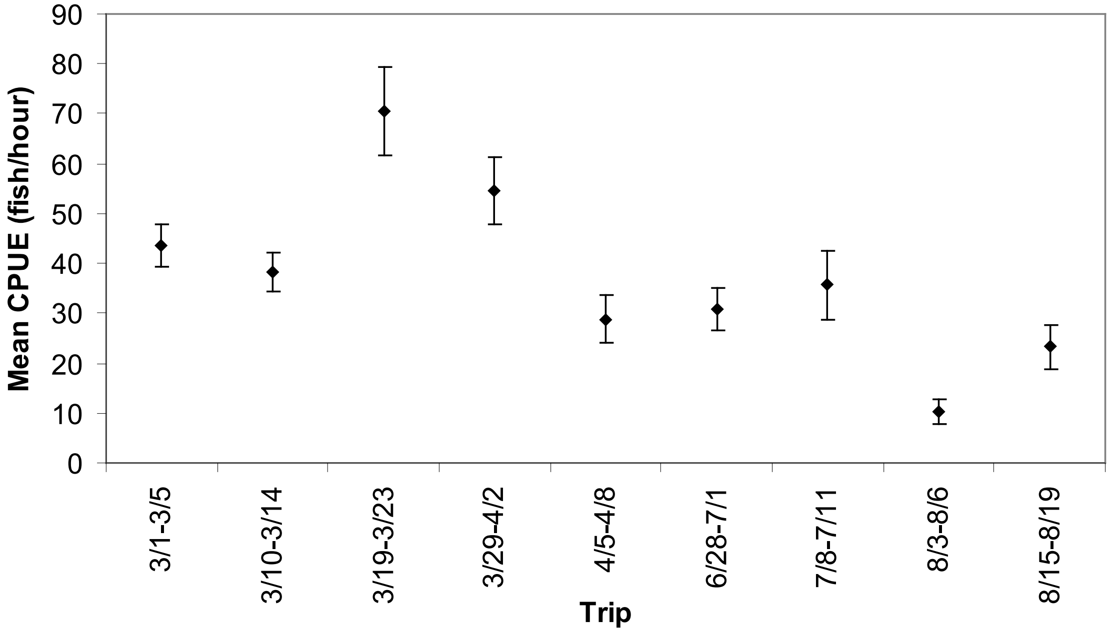

Figure 2. Mean electrofishing catch per unit effort of channel catfish in the lower San Juan River by pass in 2011. Error bars represent ± 1 standard error.

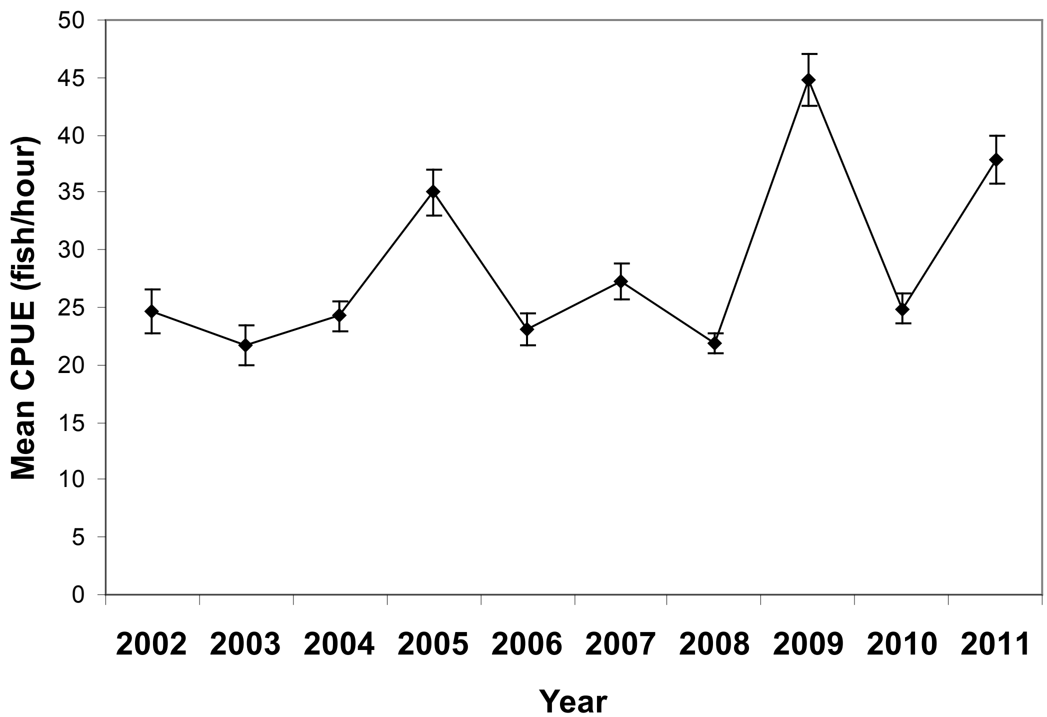

Figure 3. Mean electrofishing catch per unit effort of channel catfish in the lower San Juan River from 2002 to 2011. Error bars represent ± 1 standard error.

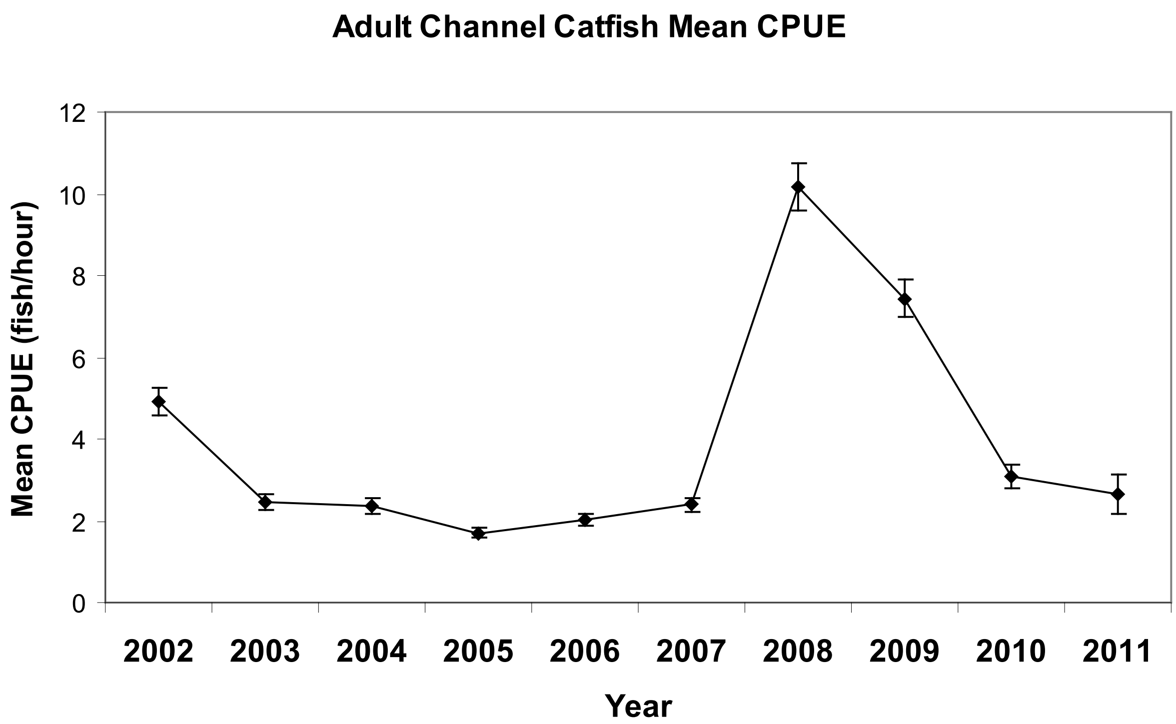

Figure 4. Mean electrofishing catch per unit effort of adult (>300 mm TL) channel catfish in the lower San Juan River from 2002 to 2011. Error bars represent ± 1 standard error.

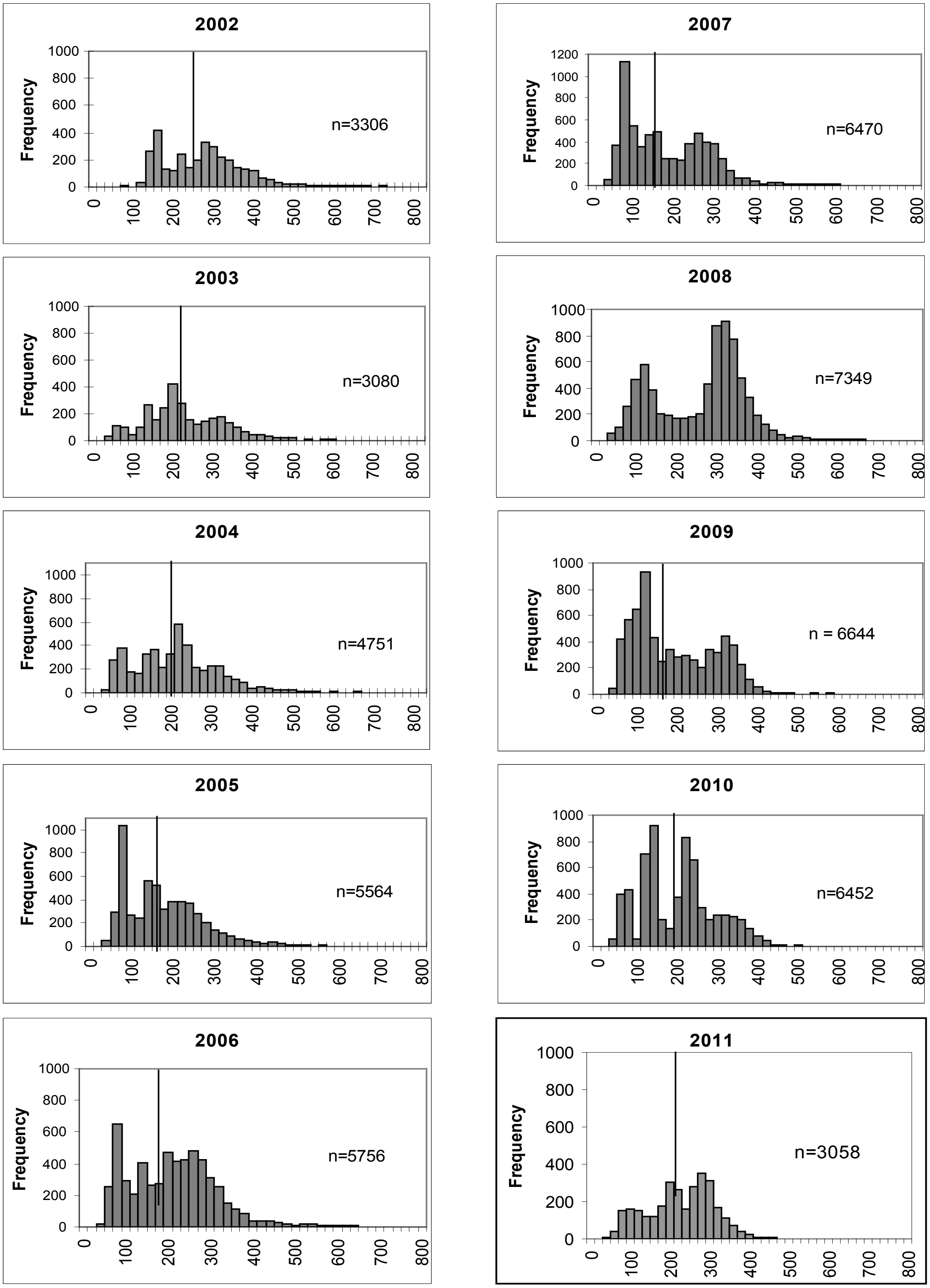

Figure 5. Length-frequency histograms of channel catfish in the lower San Juan River from 2002 to 2011. Vertical lines indicate mean TL by year.

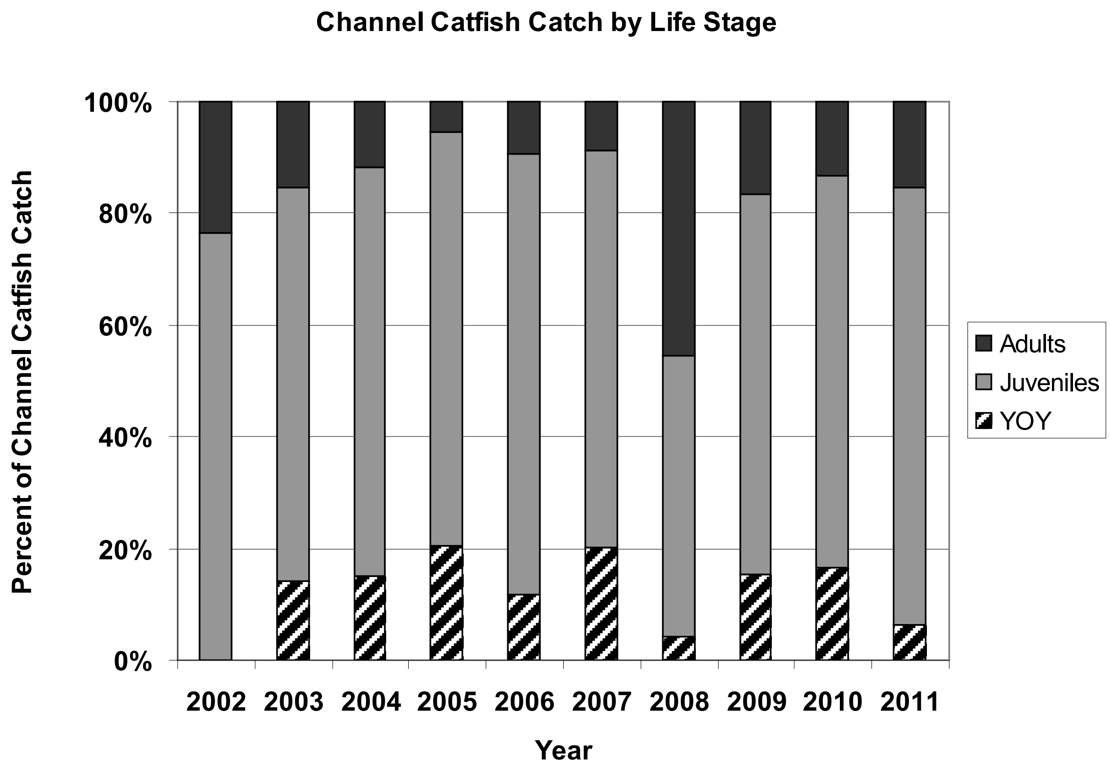

Figure 6. Percent of each life stage of channel catfish in the total channel catfish catch from 2002 to 2011. Note: YOY and juveniles life stages were not differentiated in 2002.

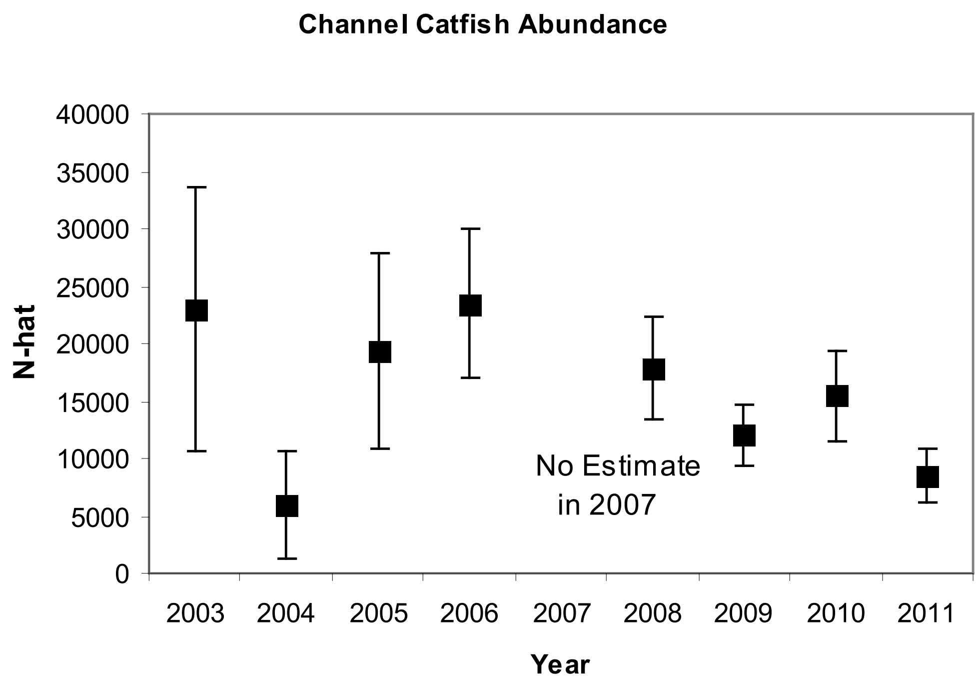

Figure 7. Abundance estimates (N-hat) of channel catfish from 2003 to 2011 in the lower San Juan River. Error bars represent 95% confidence intervals.

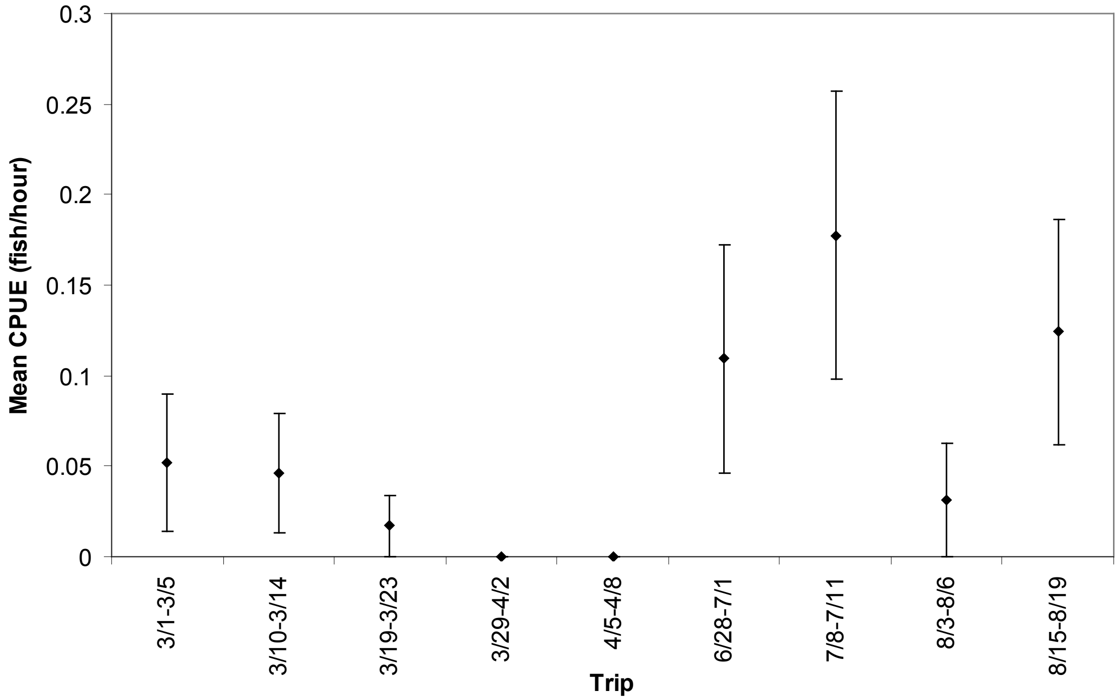

Figure 8. Mean electrofishing catch per unit effort of common carp by pass in the lower San Juan River in 2011. Error bars represent $\pm$ 1 standard error.

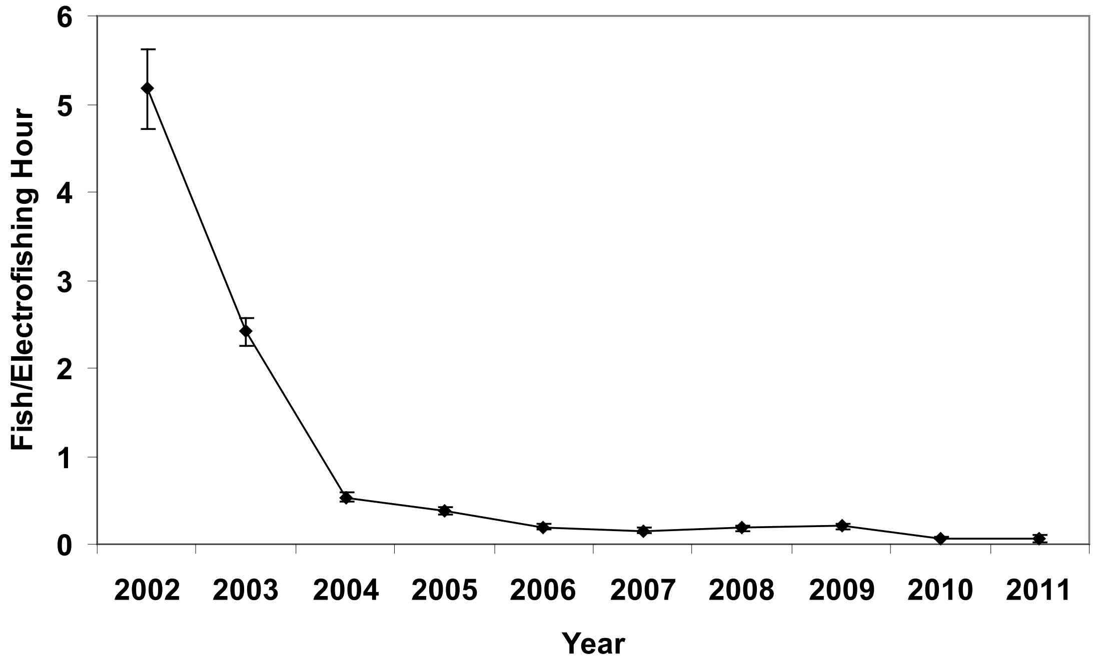

Figure 9. Mean electrofishing catch per unit effort of common carp from 2002 to 2011 in the lower San Juan River. Error bars represent ± 1 standard error.

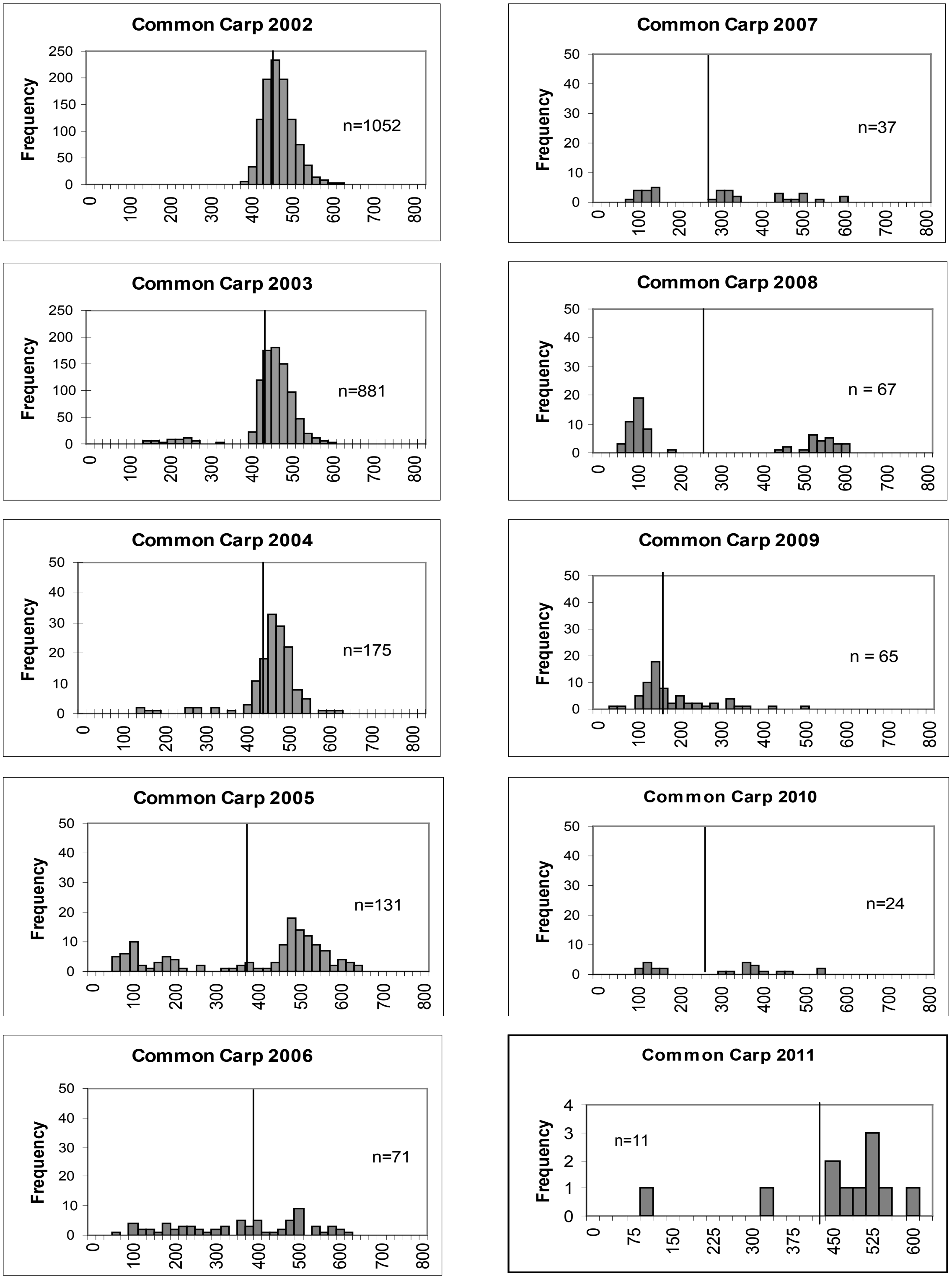

Figure 10. Length-frequency histograms of common carp in the lower San Juan River from 2002 to 2011. Vertical lines indicate mean TL by year. Note: Y-axis scale is different between years 2002-2003, 2004-2010 and 2011.

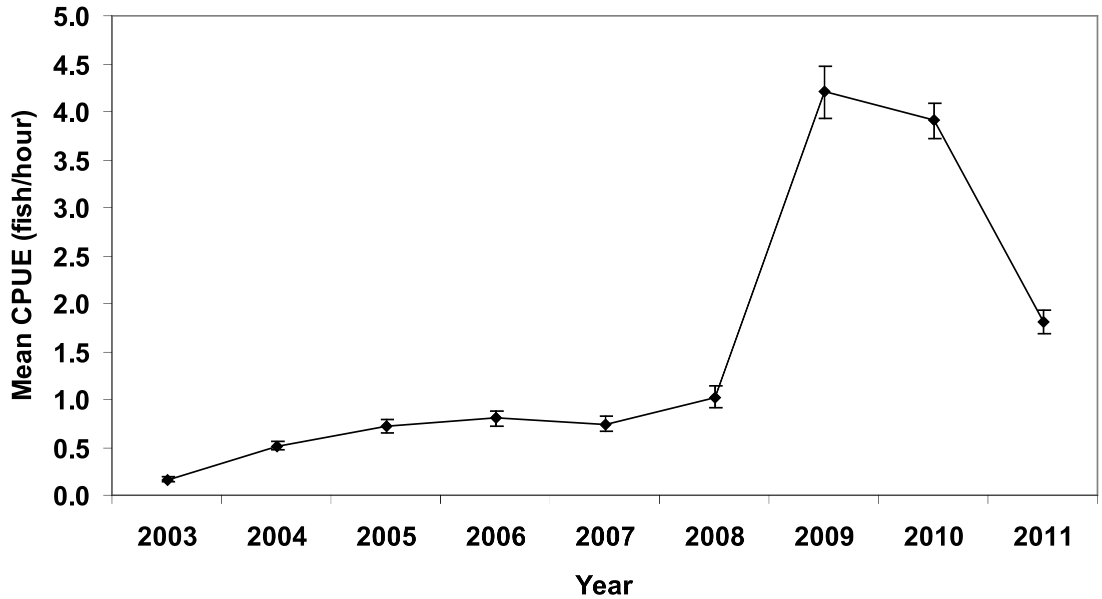

Figure 11. Mean electrofishing catch per unit effort of Colorado pikeminnow in the lower San Juan River from 2003 to 2011. Error bars represent ± 1 standard error.

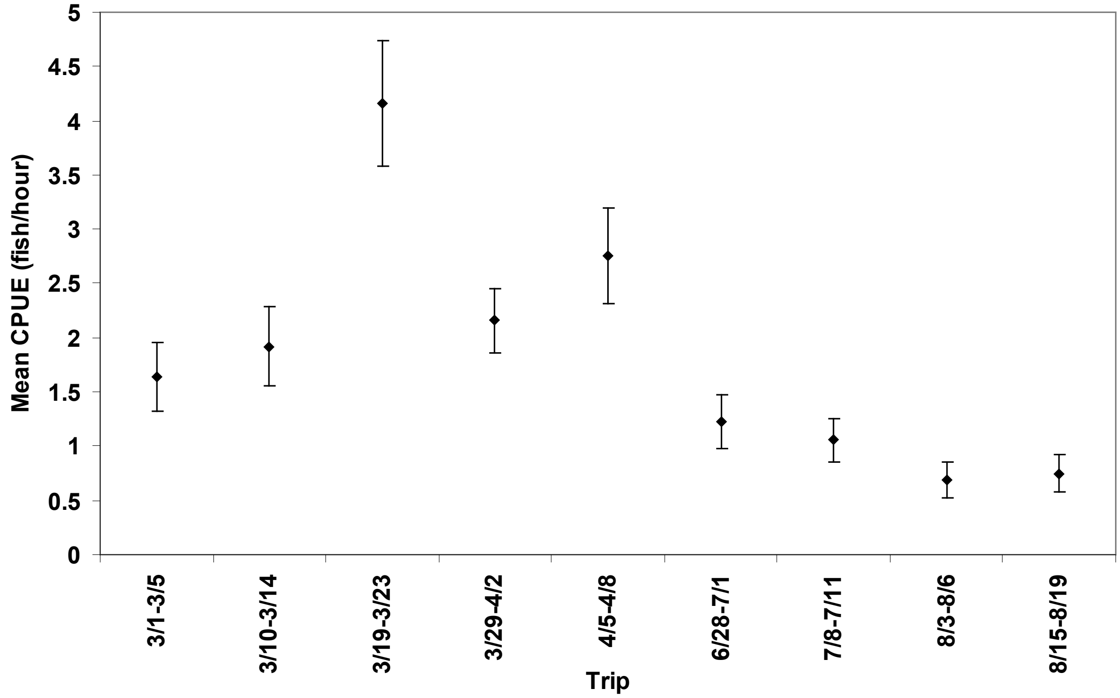

Figure 12. Mean electrofishing catch per unit effort of Colorado pikeminnow by pass in the lower San Juan River during 2011. Error bars represent ± 1 standard error.

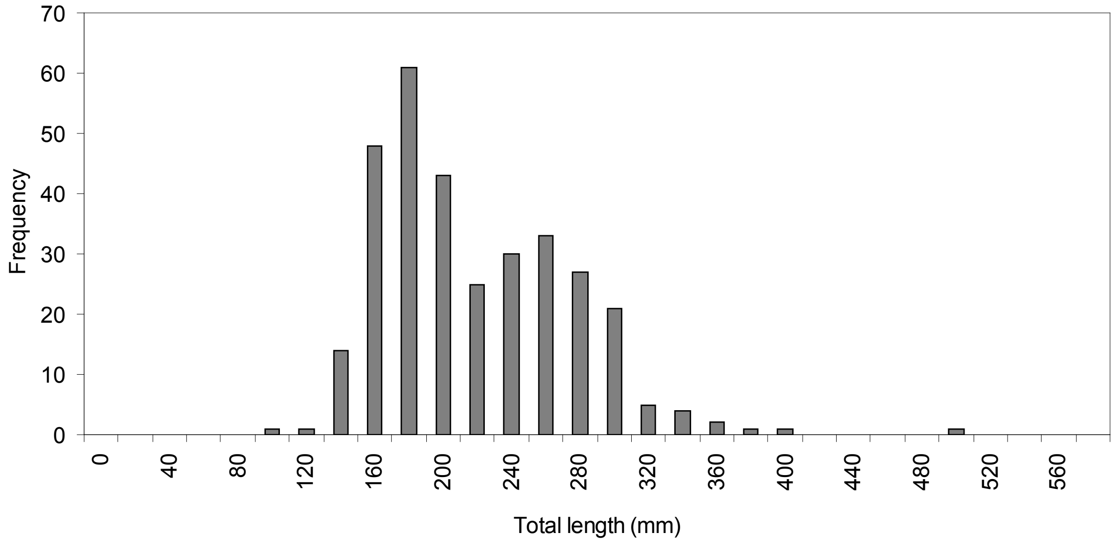

Figure 13. Length-frequency histogram of Colorado pikeminnow in the lower San Juan River during 2011.

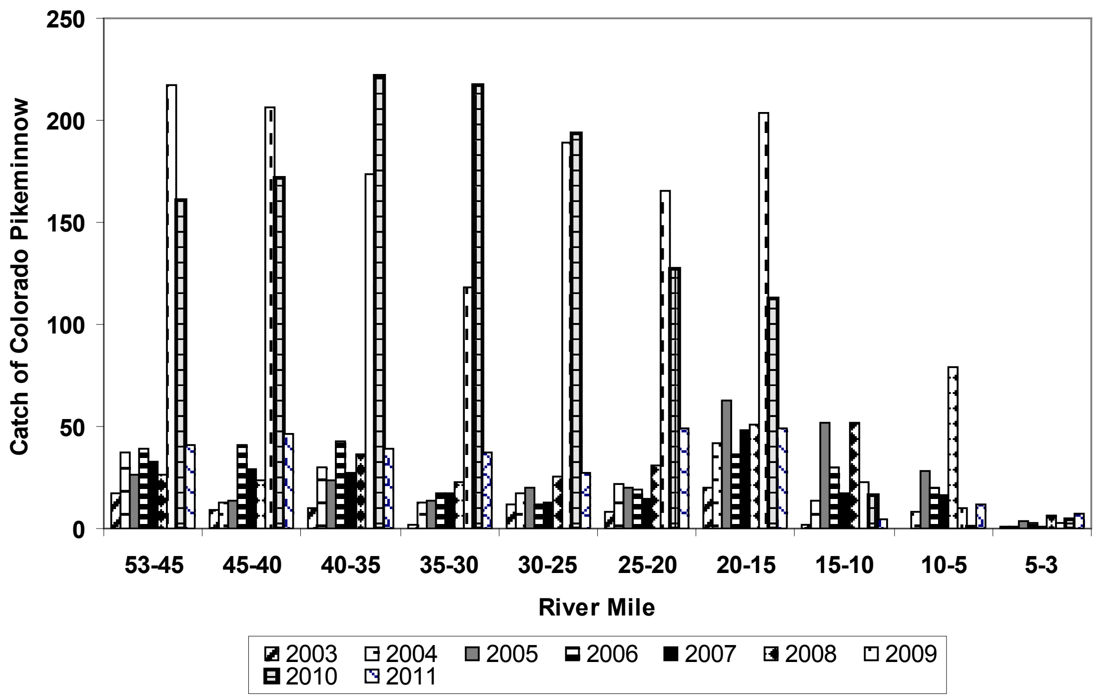

Figure 14. Distribution of Colorado pikeminnow captures by river mile from 2003 to 2011 in the lower San Juan River.

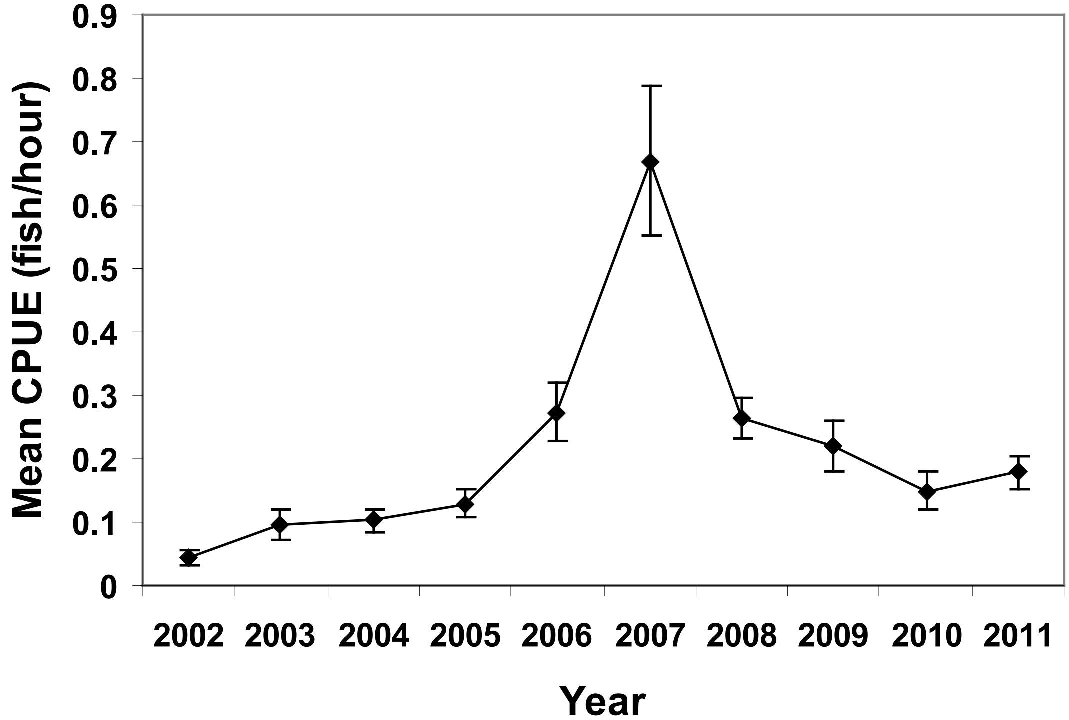

Figure 15. Mean electrofishing catch per unit effort of razorback sucker in the lower San Juan River from 2002 to 2011. Error bars represent ± 1 standard error.

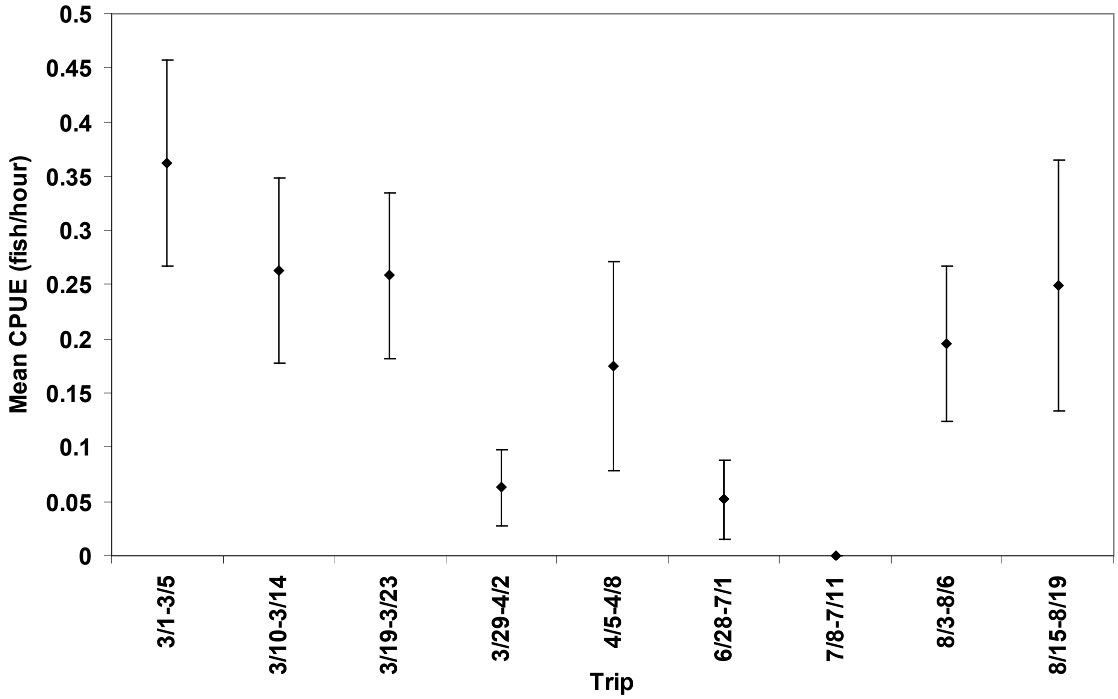

Figure 16. Mean electrofishing catch per unit effort of razorback sucker by pass in the lower San Juan River in 2011.

Appendix A. Average daily flow (USGS gage 09379500 near Bluff, Utah), average water temperature and average turbidity (mm to Secchi disk disappearance) during sampling trips on the lower San Juan River in 2010.

Pass	Date	Mean Discharge (cfs)	Mean Temperature (C°)	Mean Turbidity (mm)
1	3/1-3/5	805	8	211
2	3/10-3/14	867	11	134
3	3/19-3/23	800	10	290
4	3/29-4/2	658	13	333
5	4/5-4/8	947	12	96
6	6/28-7/1	2310	22	152
7	7/8-7/11	1549	26	158
8	8/3-8/6	942	26	13
9	8/15-8/19	604	25	25

Appendix B. Average daily flow (USGS gage 09379500 near Bluff, Utah) during the 2011 field season on the lower San Juan River.