Endangered Fish Monitoring and Nonnative Fish Control in the Lower San Juan River 2014

Final Report

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EXECUTIVE SUMMARY

The thirteenth consecutive year of nonnative fish control in the lower San Juan River was conducted in 2014. 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 2014, nine nonnative fish removal passes were made, beginning in early-March and continuing through early November. Raft mounted electrofishing was conducted from Montezuma Creek to Clay Hills, Utah between river miles (RM) 93.5 and 2.9. In 2014, summer effort was shifted from the lower canyon to the middle canyon (Montezuma Creek to Mexican Hat). Mean daily river flow ranged from 224 to1,087 cubic feet per second (cfs) during sampling trips in 2014.

Channel catfish made up the 95% of large-bodied nonnative fishes collected in 2014. Mean catch per unit effort in the middle canyon was 30.8 fish per hour (fish/h) and in the lower canyon was 59.8 fish/h. Considerable variability in catch rates occurred among passes, but overall channel catfish abundance estimates have remained relatively stable since removal efforts began. Common carp catches remained low in 2014 with just 12 individuals being captured and removed.

In 2014 sampling, 410 Colorado pikeminnow (*Ptychocheilus lucius*) and 89 razorback sucker (*Xyrauchen texanus*) were collected in the middle and lower San Juan River. All Colorado pikeminnow captured are likely of hatchery origin and stocked within the San Juan River from 2003 through 2013 at upstream locations near Farmington, New Mexico. Abundance estimates based on capture-recapture data for Colorado pikeminnow indicated that there is a 95% probability that the abundance is between 148 and 250 fish in the lower San Juan River and between 247 and 704 fish in the middle canyon.

INTRODUCTION

Native fishes in the Southwestern United States have been negatively impacted by extensive water development, anthropogenic alteration of habitats, and the spread of nonnative fishes (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 introductions. The widespread distribution of nonnative species has led to the homogenization of fish communities throughout the Southwest and elsewhere and potentially affects the persistence of native fish communities (Rahel 2002). Within the Upper Colorado River Basin (i.e. Colorado, Green, and San Juan rivers), 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 (*Gila cypha*), and bonytail (*Gila elegans*) have been listed as endangered and are fully protected under the Endangered Species Act. Competitive and predatory interactions between native and nonnative fishes have been identified as potential factors 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 fishes (Mueller 2005).

The lower San Juan River in southeastern Utah contains remnant populations 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 re-establish populations (Ryden 2003). Since the threat of nonnative fishes exists and there was concern that striped bass and other Lake Powell resident fishes may colonize and establish reproducing populations within the Lower San Juan River (Gustaveson et al. 1984), the Utah Division of Wildlife Resources Moab Field Station (UDWRMFS) initiated the mechanical removal of nonnative fishes in the lower San Juan River from Mexican Hat, Utah to the Clay Hills Crossing beginning in 2002.

Since the initiation of the mechanical removal of nonnative fishes, conditions in the San Juan River have changed. A drought has persisted since 2002 causing elevation of Lake Powell to drop. Also the San Juan River channel has shifted and now has a waterfall that prohibits upstream movement of fishes. Lower reservoir levels coupled with the waterfall have kept resident Lake Powell fishes from colonizing the San Juan River, but channel catfish still persist in great numbers in the river. The channel catfish is main target of current removal efforts.

In the last few years seasonal channel catfish movements were documented and lower catch rates occurred in the lower canyon during the summer months (Gerig and Hines 2013, Hines 2014). To increase catch rates of channel catfish in 2014, UDWRMFS shifted its summer effort to the section between Montezuma Creek (RM 93.5) and Mexican Hat (RM 52.8) (Middle Canyon) in order to include areas that had higher channel catfish densities (Duran et al 2014). .

The objectives of this study include: (1) mechanical removal of large-bodied nonnative fish species in the San Juan River from Montezuma Creek to Clay Hills; (2) estimate abundance and exploitation rates of channel catfish from mark-recapture data from Mexican Hat to Clay Hills; (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 (U.S. Fish and Wildlife Service 2014).

METHODS

Study Area

The study area includes the Middle Canyon reach of the San Juan River from Montezuma Creek (RM 93.5) to Mexican Hat (RM 52.8) and the Lower Canyon reach from Mexican Hat (RM 52.8) to Clay Hills (RM 2.9), Utah (Figure 1). The river from Montezuma Creek to RM 67.7 is characterized by a braided and shifting channel that is dominated by riffle/run complexes. The river from RM 67.7 to RM 16.0 is primarily canyon bound with a bedrock substrate and dominated by riffle and run habitats. The river is also canyon bound with an active alluvial bed from RM 16.0 to Clay Hills (RM 2.9). Habitats within this section exhibit considerable heterogeneity and river geomorphology is 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 in the Middle Canyon and Lower Canyon of the San Juan River during nine five-day sampling trips in 2014. Trips occurred between March and early November. Each electrofishing boat was outfitted with an ETS electrofishing system to sample fish populations. Voltage for the ETS system was typically set between 350 and 450 depending on specific conductivity measurements and sampling occurred on each side of the river. Individual sampling units consisted of approximately three-mile segments of shoreline fished by each electrofishing raft. Data are collected for approximately 30 sample units per trip.

All nonnative and endangered species were netted. Total length (mm), standard length (mm), and weight (g) were measured for all endangered fishes and a sub-sample of nonnative fishes were also measured for total length and weight (g) during each trip. 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 to 2006 and from 2008 to 2011, all channel catfish $\geq$ 200 mm TL collected during the first pass (trip) were marked in various ways and released. Channel catfish collected from 2009 to 2014 were uniquely marked with individually numbered T-bar floy tags. Prior to 2009, channel catfish were tagged with colored tags 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 (Secchi disk), water temperature, and conductivity were measured each day unless an obvious change in flow or turbidity was observed, then measurements were taken again. River discharge was determined from the USGS gage # 09379500 near Mexican Hat, Utah.

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. CPUE was calculated for channel catfish, common carp, Colorado pikeminnow, and razorback sucker and summarized by trip and year.

During trips one and two of 2014, the abundance of channel catfish greater than 200 mm TL was estimated using a Lincoln-Petersen estimator with Chapman's correction (Equation 1) with 95% confidence intervals (Equation 2).

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

Equation 2: $$95\%\ CI = 1.96 * \sqrt{\left(\frac{(M+1)(C+1)(M-R)(C-R)}{\left((R+1)^2(R+2)\right)-1}\right)}$$

In Equation 1 and Equation 2, 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 channel catfish and upstream movement rates for channel catfish (Equation 3). Exploitation rate, µ, was estimated as the proportion of recaptured marked fish (R) to the total number of marked fish (M) (Deroba et al. 2005),

Equation 3: $$\mu = \frac{R}{M}$$

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 can be effective in assessing removal efforts.

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). Capture histories for Colorado pikeminnow were generated in Microsoft Excel and converted to a file for Program CAPTURE to read. Several combinations of passes were selected for analysis to lessen the likelihood of violating assumptions of the models used. There are two types of models used in Program CAPTURE: the M_o model (null model) was appropriate when capture probabilities (p-hat) remained similar among the passes in the model and the M_t model (time variable model) was used when p-hat was variable among passes. Confidence intervals, the coefficient of variation, and the probability of capture were also calculated within Program CAPTURE.

RESULTS

Nine sampling passes were conducted on the San Juan River between Montezuma Creek and Clay Hills, Utah in 2014. Sampling dates were: March 3-7, March 14-18, March 25-29, April 15-19, July 2-6, July 26-30, August 6-10, August 18-22, and November 3-7. Twelve fish species were encountered including Colorado pikeminnow, razorback sucker, and nine nonnative species (Table 1). Native bluehead suckers (*Catostomus discobulus*) and flannelmouth suckers (*Catostomus lattipinnis*) were present during all passes but not netted during nonnative control efforts because of their large population sizes. Electrofishing effort totaled 327.5 hours and resulted in the capture of 12,504 fish (Table 1). Similar to past years, channel catfish were the most abundant species captured; no striped bass or walleye were encountered.

Nonnative Species

Channel catfish

In 2014, channel catfish comprised 95% of the total catch during nonnative removal passes in the lower and middle San Juan River. The mean catch rate of all sizes of channel catfish was 30.8 fish/h in the Middle Canyon and 58.9 fish/h in the Lower Canyon; but catch rates varied among passes and ranged from 18.4 to 86.6 fish/h (Figure 2). Catch rates increased in 2014 and were the second highest catch rates observed for all channel catfish life stages since the project was initiated (Figure 3). The mean catch rate of adult (>300 mm TL) channel catfish in 2014 was 13.2 fish/h in the Middle Canyon and 10.1 fish/h in the Lower Canyon (Figure 4). In 2014, adult channel catfish catch rates were the highest observed by UDWRMFS. 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 2014 in the Lower Canyon was 251 mm and in the Middle Canyon was 229 mm. Analysis of length-frequency histograms showed that 72% of channel catfish collected during 2014 in the Middle Canyon were fish under 300 mm (Figure 5) and 62% of channel catfish collected in the Lower Canyon were fish under 300 mm (Figure 6). Visual observation of length frequency histograms in the Middle Canyon indicates four or possibly five distinct modes, which likely represent young of year to Age 3 or 4 fish (Figure 5). The visual observation of length frequency histograms in the Lower Canyon indicates four distinct modes, which likely represent young or year to Age 3 fish (Figure 6). The percentage of adult (≥300 mm TL) channel catfish in the total catch was the second highest since the project was initiated (Figure 7). The highest catch of adults, which occurred 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 ≥ 400mm TL was only 5% of the catch in the Lower Canyon and 7% of the catch in the Middle Canyon.

In 2014, the abundance of channel catfish greater than 200 mm TL was estimated (Figure 8). For the abundance estimate, 633 channel catfish were tagged during the first sampling trip; and 2,154 channel catfish were captured during second sampling trip with 72 recaptures. In 2014, 18,715 individuals (95% CI =14,772-22,658) were estimated to have been present within the lower San Juan River. The 2014 estimate was higher than the 2004 and 2009 estimates, but not different from all other years.

In 2014, the exploitation rate of channel catfish was estimated using tag return data. Estimated exploitation rates increased with length class (Table 2) and ranged from 5% for channel catfish of 200-299 mm TL to 25% for channel catfish of 500-599 mm TL (Table 2).

Upstream movements of channel catfish from the lower San Juan River to the middle San Juan River were observed in 2014. When UDWRMFS removal trips began in early March channel catfish were observed in great numbers below all rapids and in almost all riffles. During our final spring trip (April 15-19) channel catfish CPUE dropped by half and there were no concentrations of channel catfish observed in this same areas, which was a week and half later.

Common carp

In 2014, 12 common carp were captured and the mean catch rate among trips in the Middle Canyon was 0.04 fish/h and the mean catch rate among trips in the Lower Canyon was 0.05 fish/h. Fifty eight percent of the fish collected in 2014 were young of the year and juveniles. Catch rates precipitously declined from 2002 to 2004 and have not exceeded 0.2 fish/h since 2005 (Figure 9).

Endangered Species

Colorado pikeminnow

Four hundred and ten individual Colorado pikeminnow were collected in 2014. Catch rates in 2014 ranged from 0.88 fish/h, in the Lower Canyon, to 1.95 fish/h in the Middle Canyon (Figure 10). There was a decrease in CPUE in the Lower Canyon in 2014 compared to 2009 and 2010. Catch rates in 2014 ranged from 0.11 to 2.7 fish/h and varied among trips (Figure 11). Trips one-four and nine occurred in the Lower Canyon and had lower CPUE than trips five-eight, which occurred in the Middle Canyon (Figure 11).

Analysis of length frequency histograms from the Lower Canyon indicated five distinct modes to represent age-0, age-1, age-2, age-3, and age-4 fish (Figure 12). The small mode centered around 60 mm were fish that were stocked during the fall of 2013 and captured during our trip in early November (Figure 12). Analysis of length frequency histograms from the Middle Canyon indicated three distinct modes presumed to represent age-1, age-2, and age-3 fish (Figure 13). Colorado pikeminnow captures were widely distributed throughout the study reach in 2014 (Figure 14). Catches of Colorado pikeminnow were lowest for river miles 3.0 to 15.0 and generally highest between RM 58.0 to 35.0 in the Lower Canyon and RM 88-83 in the Middle Canyon (Figure 14). Colorado pikeminnow capture locations were consistent with distributional patterns observed in previous years, but fewer were captured in 2014 (Figure 14).

Population estimates of Colorado pikeminnow have been generated for the lower San Juan River since 2004 (Table 3). In 2014, since effort was shifted to the Middle Canyon a population estimate was generated for that section as well (Table 3). The Mo model (null) which estimates a year specific capture probability and a year specific abundance estimate was used in

2014 for both sections. Data from trips one-four were incorporated into the model for the Lower Canyon and data from trips five-eight were incorporated into the model for the Middle Canyon, so the assumption of closure was less likely violated. The model for the Lower Canyon estimated 185 Colorado pikeminnow with a 95% confidence interval of 148-250 individuals. Capture probability was 0.17 (Table 3). Population estimates for Colorado pikeminnow in the lower San Juan River indicate that abundance increased from 2004 to 2009 and stabilized around 1,100 individuals from 2009 to 2011. The abundance estimates indicated a nearly 50% reduction from 2011 to 2012, then increased in 2013. Then in 2014, the abundance estimates indicated a nearly 80% reduction. Increases and decreases in Colorado pikeminnow abundance in the lower San Juan River are likely affected by changes in stocking numbers, movements, and overwinter mortality rather than variable recruitment. This was the first year an abundance estimate was calculated for the Middle Canyon. The abundance of Colorado pikeminnow in the Middle Canyon was 398 individuals with 95% confidence interval of 246-704 individuals (Table 3). Capture probability was 0.06 (Table 3).

Captures of adult (>450 mm TL) Colorado pikeminnow have been low since this project began in 2002. No adult Colorado pikeminnow were captured in 2014. One fish was captured in 2012 (480 mm TL) and from 2002 to 2011 only eight adult Colorado pikeminnow were captured with lengths ranging from 460 to 590 mm TL.

Razorback sucker

Eighty nine individual razorback sucker were collected in the Middle and Lower canyons of the San Juan River in 2014. The mean catch rates were 0.45 fish/h in the Lower Canyon and 0.14 fish/h in the Middle Canyon (Figure 15). Catch rates varied among trips from 0.06 to 1.02 fish/h (Figure 16). Catch rates were generally higher during the early season trips compared to the late season trips except for trip nine in November (Figure 16). The mean length of razorback sucker captured in the Lower Canyon was 413 mm TL and ranged from 320 to 532 mm TL. The mean length of razorback sucker captured in the Middle Canyon was 421 mm TL and ranged from 199 to 517 mm TL. Razorback sucker catches were widely distributed throughout the Lower Canyon, but the greatest frequency of captures occurred between RM 18.0 to 20.0. During the early season many of the razorback sucker captures were aggregated in groups near cobble bars. A majority of the razorback sucker captured in the Lower Canyon in 2014 were captured during trip nine in November.

DISCUSSION

Channel catfish catch rates in 2014 were the highest that UDWRMFS has observed since the project was initiated. Overall, CPUE trends from 2002 to 2014 exhibit considerable yearly variation, but overall they have remained relatively stable. Many factors may have contributed to the higher catch rates in 2014 such as the time of year, river discharge, water temperature, turbidity, netter and raft operator experience, and pass number. The most likely cause of the increase in CPUE is due to the shifting of effort from the Lower Canyon to the Middle Canyon during the summer months. By shifting the effort during the summer passes we were able to follow the channel catfish as they emigrate from the Lower Canyon to the Middle Canyon. The decreasing trend in CPUE among passes in the spring may be a result of emigration, changing capture probability among passes, and behavioral responses to electrofishing gear. The decreasing trend in CPUE among passes in the summer is due to an increase in turbidity from monsoonal events (Appendix A). The temporal trend of adult CPUE follows the decrease that is observed in the spring and drops to near zero during the last trip in the spring. Then effort is shifted to the Middle Canyon during the summer months and adult channel catfish CPUE increases. This increase in the number of adults captured in the summer is likely a result of emigration occurring from the Lower Canyon to the Middle Canyon. Seasonal movements were observed in 2012 and 2013. Numerous adult channel catfish tagged in the Lower Canyon in the spring were recaptured in the middle San Juan during the summer. 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 variation in capture probability that may be obscuring overall population trends and the utility of CPUE as an abundance index.

Population estimates of channel catfish $\geq$ 200 mm TL have been conducted in the lower San Juan River since 2003. The 2014 population estimate was significantly higher than the 2004 and 2009 estimates. In general, abundance estimates have been relatively stable since 2003. The increases in abundance estimates of adult channel catfish in 2008 were likely a result of immigration of fish from the middle reaches of the San Juan River in response to high spring discharges from Navajo Dam. When considering both CPUE and the abundance estimate, channel catfish abundance estimates in the San Juan seem to be relatively stable.

Exploitation rates varied depending on fish length and increased with increasing total length. Electrofishing gear is biased toward collecting larger individuals because larger individuals have more surface area for the electrical field to come into contact with (Reynolds 1996). The increased estimate of exploitation rate in 2014 may be the result of numerous factors such as capture probability due to increased visibility, fish movement, or personnel. Exploitation rates were calculated during the first two sampling trips in the spring so model assumptions were not violated. Channel catfish tagged in the lower San Juan typically moved outside of the study reach in the spring. This movement may indicate a widespread upstream dispersal of channel catfish and result in a markedly reduced number of tagged fish within our study reach. Movements of individual fish in excess of 100 km have been observed in other channel catfish populations (Dames et al. 1989, Hale et al. 1986).

The large number of young of year and 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 channel 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 increase in juvenile channel catfish survival rates, which would account for the increase in survival of fish of 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 length structure of channel catfish were observed upstream (Davis 2005) and on a river-wide scale (Ryden 2005) after the initiation of nonnative fish removal. Continuing abundance estimates for channel catfish will allow for evaluation of removal effectiveness and exploitation rate of the channel catfish population.

Since 2002 there has been a significant decline in catch rates of common carp. During the first year of removal, 1,052 common carp were removed from the lower San Juan River. In 2013, only 12 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. Nonnative removal efforts in the upper San Juan River have also documented a significant decline in the CPUE of common carp (Davis 2010, Duran et al 2013). River-wide adult and sub-adult monitoring has also shown a significant decline in CPUE of common carp (Ryden 2010, Schleicher and Ryden 2013.

Abundance estimates generated for stocked juvenile Colorado pikeminnow indicate that abundance increased from 2002 to 2011 and declined from 2011 to 2012. The estimated abundance for 2014 had a 95% probability of being between 148 to 250 individuals. This was a nearly 80% reduction in estimated abundance and could be the result emigration/immigration in the Lower Canyon or low over winter survival of a year class. The population model is fairly precise with a range of 100 individuals, a coefficient of variation of 0.14, and capture probability of 0.17. This was the first year abundance estimates were generated for the Middle Canyon. After several more years trends in the population in this section can be assessed. 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 estimates of capture probability (less than 0.05) provide poor estimates of abundance, whereas years with higher capture probability (greater than 0.10) provide relatively precise estimates of abundance. Movements of Colorado pikeminnows outside of the study reaches may reduce capture probability within the study reach which reduces the accuracy of the estimate causing increased uncertainty in abundance estimates. A river-wide sampling trip which minimizes the length among passes may be a way to achieve more accurate estimates of abundance. The use of robust design population models and passive PIT tag antennas may be useful in understanding Colorado pikeminnow movements and mortality patterns in the Lower San Juan River.

The catch of adult Colorado pikeminnow has been low and declined slightly over the period of this study (2002-2014). No adult Colorado pikeminnow were captured in our study reach in 2014. 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 Colorado 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 River reach. Alternatively, the deep pools used for foraging and resting by adult fish are scarce in the lower river and may contribute to the lack of adults in this section.

The total number of razorback suckers captured in the Lower and Middle canyons in 2014 was higher than the previous year. This increase in catch rate in 2014 is a result of capturing recently stocked fish. Due to low flows in the spring a trip was canceled, but it was rescheduled in early November resulting in the capture of 45 razorback suckers. Of those 45 fish, 75% were stocked 2 weeks prior around Montezuma Creek.

CONCLUSIONS AND RECOMMENDATIONS

• Although there is considerable variation, abundance estimates of channel catfish in the lower San Juan River have been relatively stable since removal began in 2002. Estimates of channel catfish abundance were relatively imprecise (indicated by large confidence intervals) from 2003 to 2006, but have improved in recent years with the notable exception of 2012. Channel catfish should continue to be marked with numbered tags during the first pass in order to estimate abundance at the beginning of each removal year. Along with abundance estimates, mark/recapture using individually numbered tags allows for determination of exploitation rates by length class, and monitoring of channel catfish growth rates and movements throughout the river.

• The CPUE and mean total lengths of channel catfish in 2014 were similar to most of the previous years. Length-frequency histograms for fish captured in 2009-2011 indicated 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.

• In 2012 and 2013 large numbers of adult channel catfish emigrated from the Lower Canyon to the middle reaches of the San Juan River during the late spring/early summer months. These movements caused substantial declines in adult channel catfish catch rates in the Lower Canyon during the summer months. To continue the increase in catch rates, summer effort should continue to be shifted from the Lower Canyon to the middle reaches (Montezuma Creek to Mexican Hat) of the river. This shift in effort is likely to continue to remove more adult channel catfish.

• Catch rates of common carp decreased significantly from 2002 to 2013. The cause of the decreasing trend in catch rates is unknown. Several factors may be acting together, including: continued nonnative removal, the presence of the waterfall which prevents upstream colonization of common carp from Lake Powell, and low water conditions present during the first 3 years of removal which may have limited recruitment. Common carp should continue to be removed from the lower San Juan River to reduce potential competition with native and endangered fishes.

• Abundance estimates of juvenile Colorado pikeminnow increased from 2003 through 2011 and have declined from 2011 to 2012. From 2004 to 2014, 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. Monitoring and population estimates for Colorado pikeminnow should be continued in future monitoring programs.

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Table 1. Total counts of fish species collected during electrofishing sampling in the San Juan River, from RM 94-3, in 2014. Trips 1-4 and trip 9 were from RM 53-3 and trips 5-8 were from RM 94- 53.

	Trip 1	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip 6**	**Trip 7**	**Trip 8**	**Trip 9**	
	3/3-3/7	**3/14-3/18**	**3/25-3/29**	**4/15-4/19**	**7/2-7/6**	**7/26-7/30**	**8/6-8/10**	**8/18-8/22**	**11/3-11/7**	**Grand Total**
black bullhead	7	5	4	1	5	4	6	8	1	**41**
bluehead sucker										**0**
brown trout				1						**1**
channel catfish	752	2239	2365	875	1665	712	635	867	1755	**11865**
common carp					2	2	1	2	5	**12**
Colorado pikeminow	28	41	53	26	90	57	98	58	5	**456**
flannelmouth sucker	1	1		1	3	4	3	13		**26**
largemouth bass					1					**1**
rainbow trout					1					**1**
razorback sucker	12	4	16	6	2	6	8	7	35	**96**
smallmouth bass						1			1	**2**
white sucker						1	1			**2**
yellow bullhead						1				**1**
Grand Total	**800**	**2290**	**2438**	**910**	**1769**	**788**	**752**	**955**	**1802**	**12504**

Table 2. Percentage of total catch, number of channel catfish tagged by size class and exploitation rate of channel catfish by size class in 2014 in the lower San Juan River.

Trip	200-299	300-399	400-499	500-599	Total
(1) Number Tagged	239	317	65	12	633
(2) 3/14-3/18	12	42	15	3	72
Exploitation by size class	5.0%	13.2%	23.1%	25.0%	11.4%

Table 3. Population estimates for juvenile Colorado pikeminnow ≥ 150 mm TL in the lower San Juan River from 2004 to 2013. Population estimates in 2014 were done from RM 94-53 (middle) and RM 53-3 (lower). Models used include the null model (Mo) and the time variable model (Mt) from Program Capture. CI represents 95% confidence interval. 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	321-1,064	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	0.1
	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
2012	1-8	Mt	666	480-965	-	0.025-0.07
2013	5-9	Mt	862	609-1276	-	0.02-0.11
2014	Lower	Mo	185	148-250	0.14	0.17
2014	Middle	Mo	398	246-704	0.28	0.06

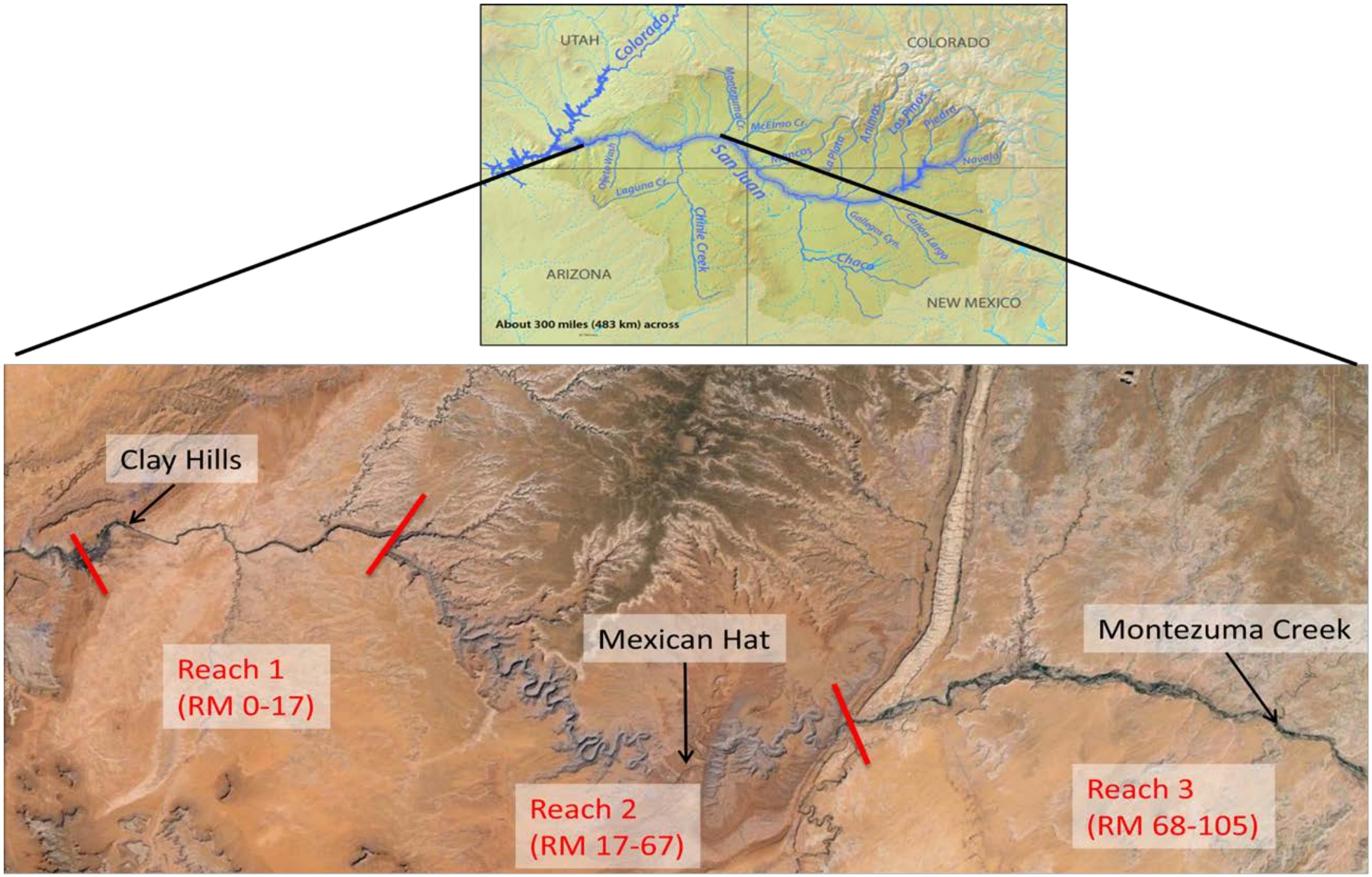

Figure 1. Map of the study area for nonnative fish control in the San Juan River. Sampling area extends from Montezuma Creek to Clay Hills. The black text is put-ins and take-outs. The red text is geomorphic reaches.

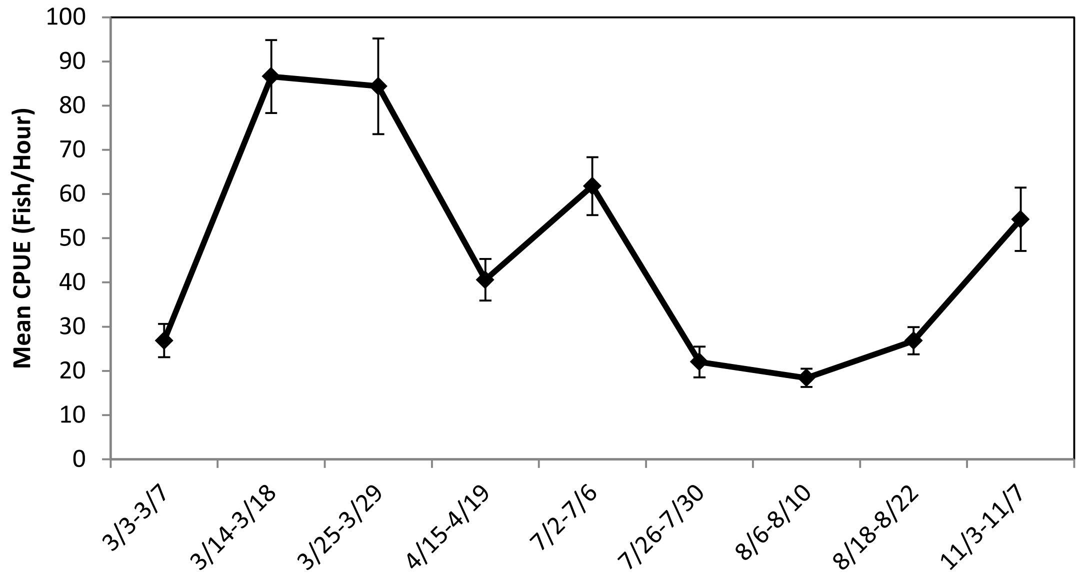

Figure 2. Mean electrofishing catch-per-unit-effort of channel catfish in the middle and lower San Juan River by pass in 2014. Error bars represent ± 1 standard error.

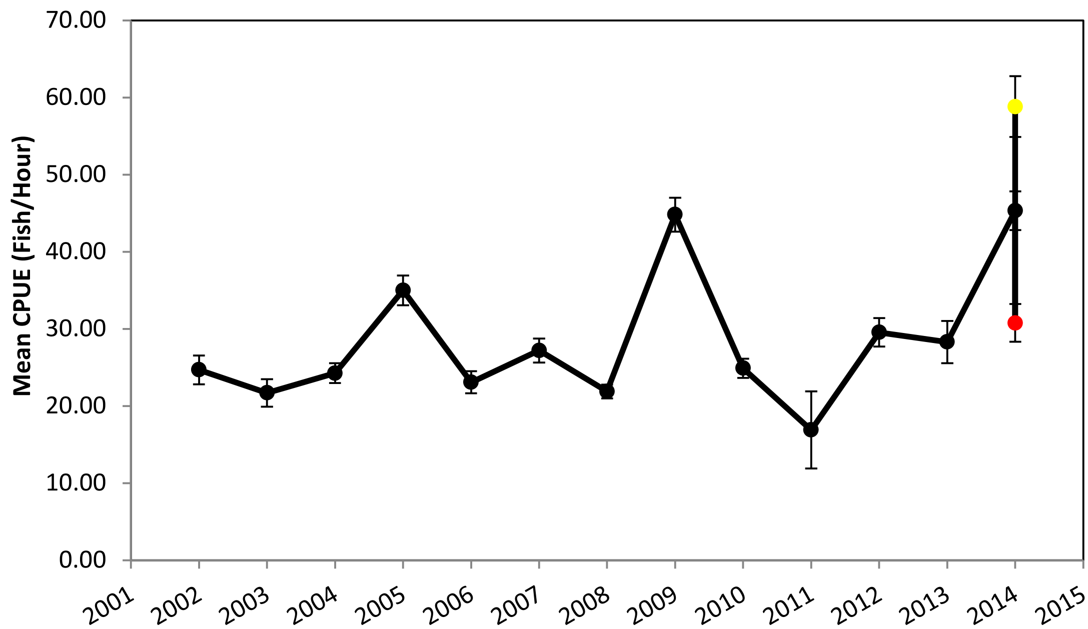

Figure 3. Mean electrofishing catch-per-unit-effort of all size classes of channel catfish in the lower San Juan River from 2002 to 2013. In 2014 sampling occurred in the Lower Canyon (yellow) and Middle Canyon (red). Black is the two combined. Error bars represent ± 1 standard error.

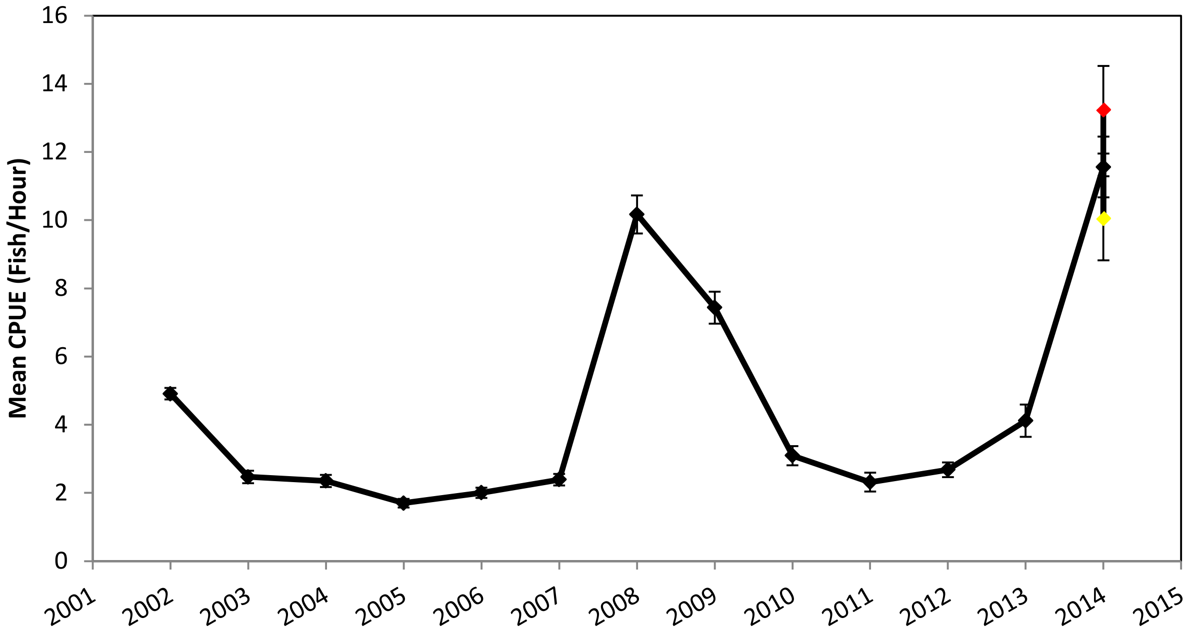

Figure 4. Mean electrofishing catch per unit effort of adult (>300 mm TL) channel catfish in the lower San Juan River from 2002 to 2013. In 2014 sampling occurred in the lower canyon (yellow) and middle canyon (red). Black is the two combined. Error bars represent ± 1 standard error.

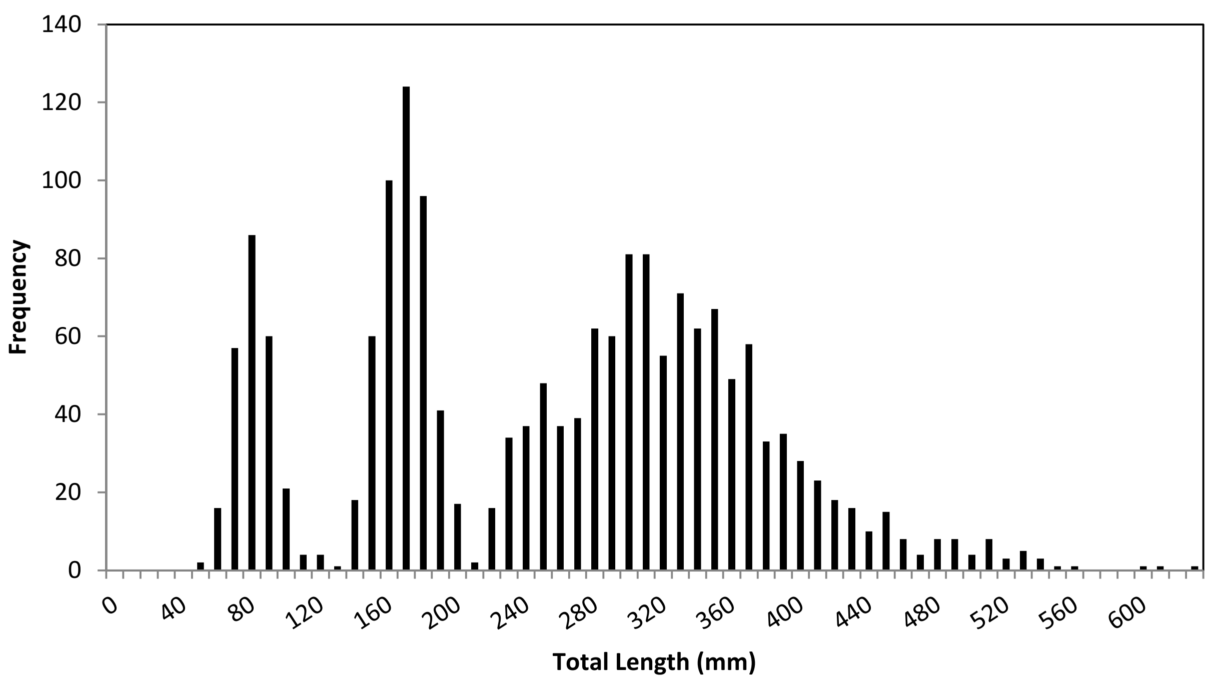

Figure 5. Length-frequency histograms of channel catfish in the lower San Juan River in 2014.

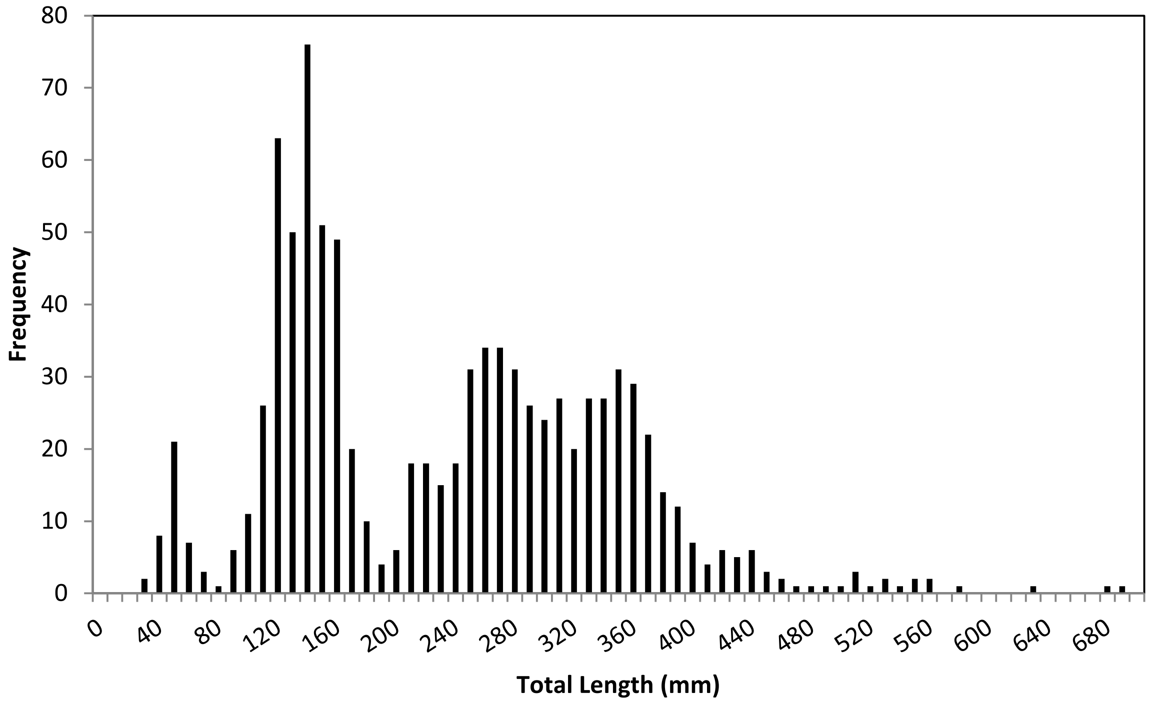

Figure 6. Length-frequency histograms of channel catfish in the middle San Juan River in 2014.

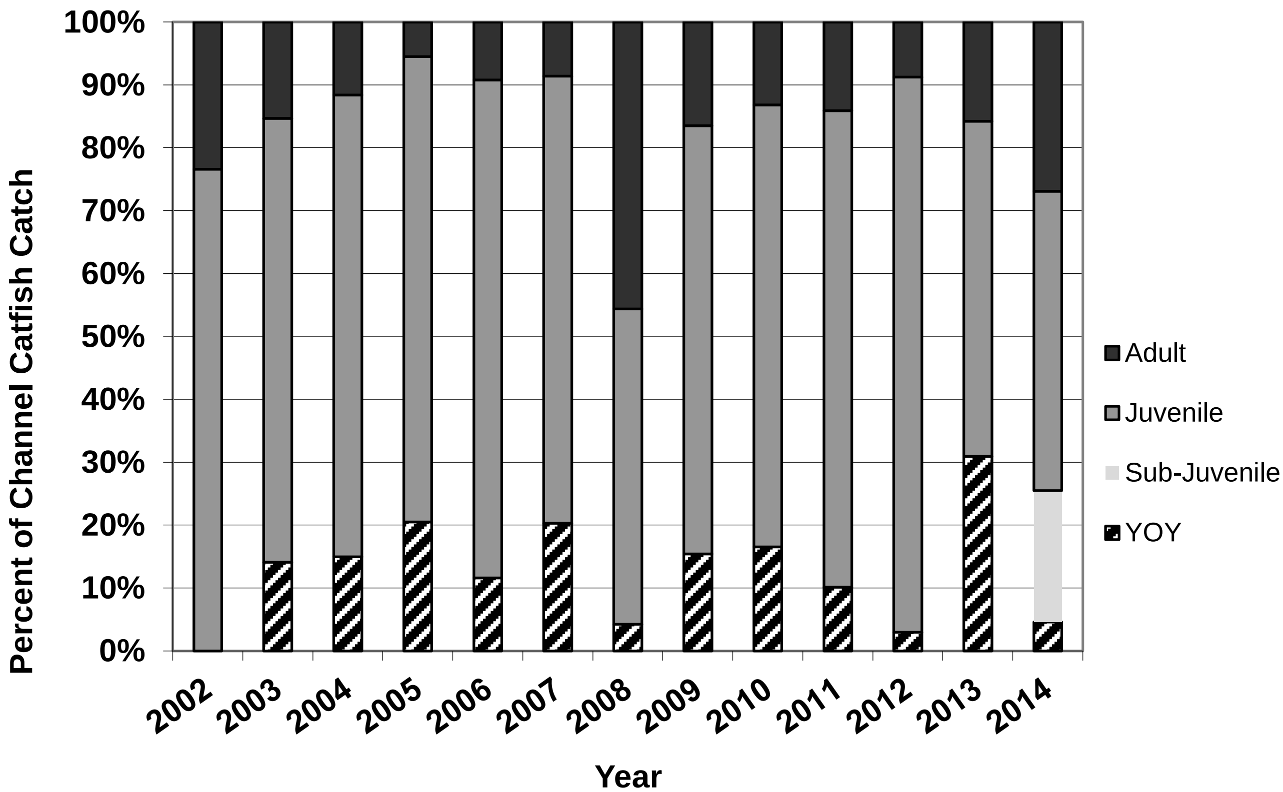

Figure 7. Percent of each life stage of channel catfish in the total channel catfish catch from 2002 to 2014. Note: YOY and juveniles life stages were not differentiated in 2002.

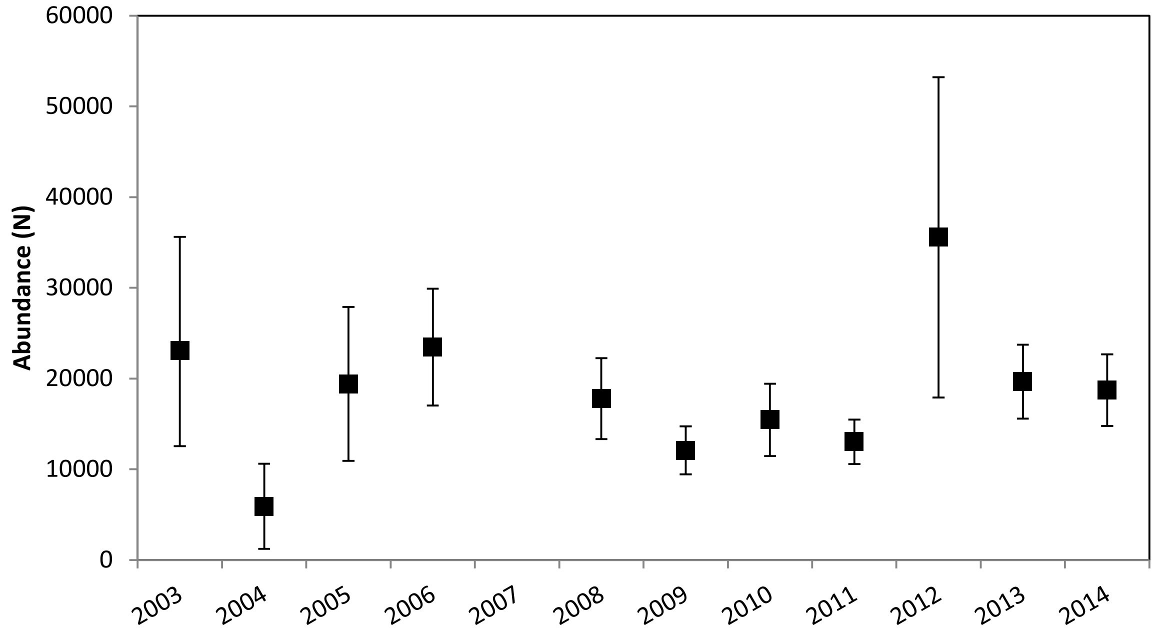

Figure 8. Abundance estimates for channel catfish from 2003 to 2014 in the lower San Juan River. Error bars represent 95% confidence intervals. Abundance estimates were calculated using the Lincoln-Peterson estimator with Chapman's correction.

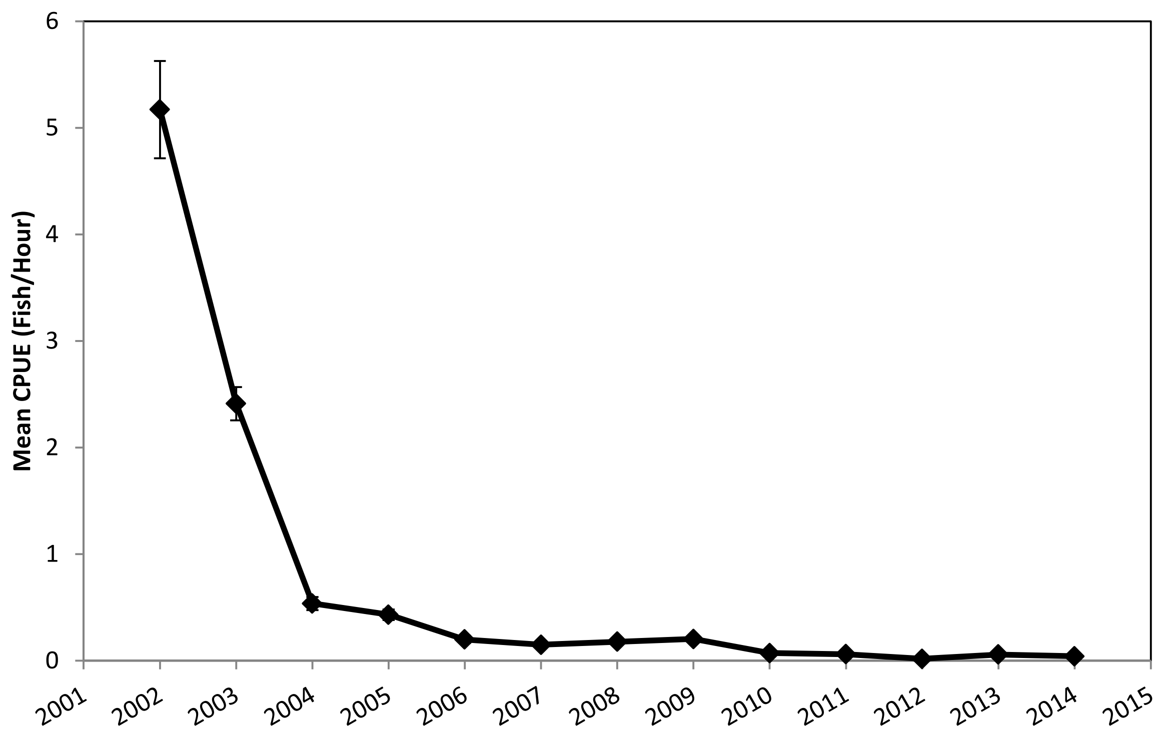

Figure 9. Mean electrofishing catch-per-unit-effort of common carp from 2002 to 2014 in the lower San Juan River. Error bars represent $\pm$ 1 standard error.

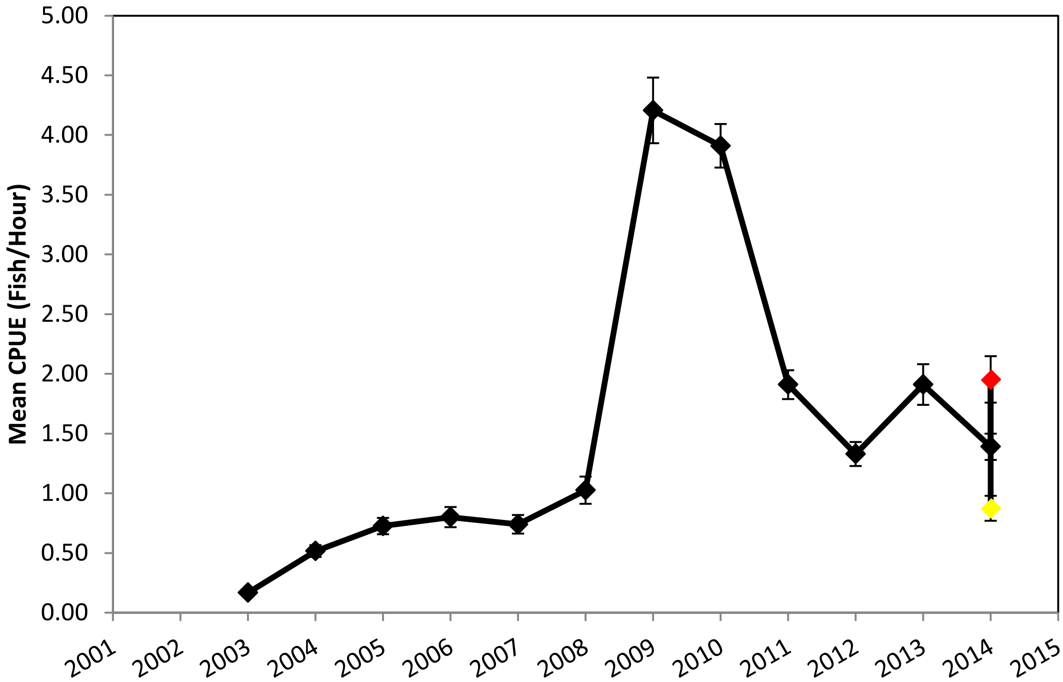

Figure 10. Mean electrofishing catch-per-unit-effort of Colorado pikeminnow in the lower San Juan River from 2003 to 2013. In 2014 sampling occurred in the lower canyon (yellow) and middle canyon (red). Black is the two combined. Error bars represent ± 1 standard error.

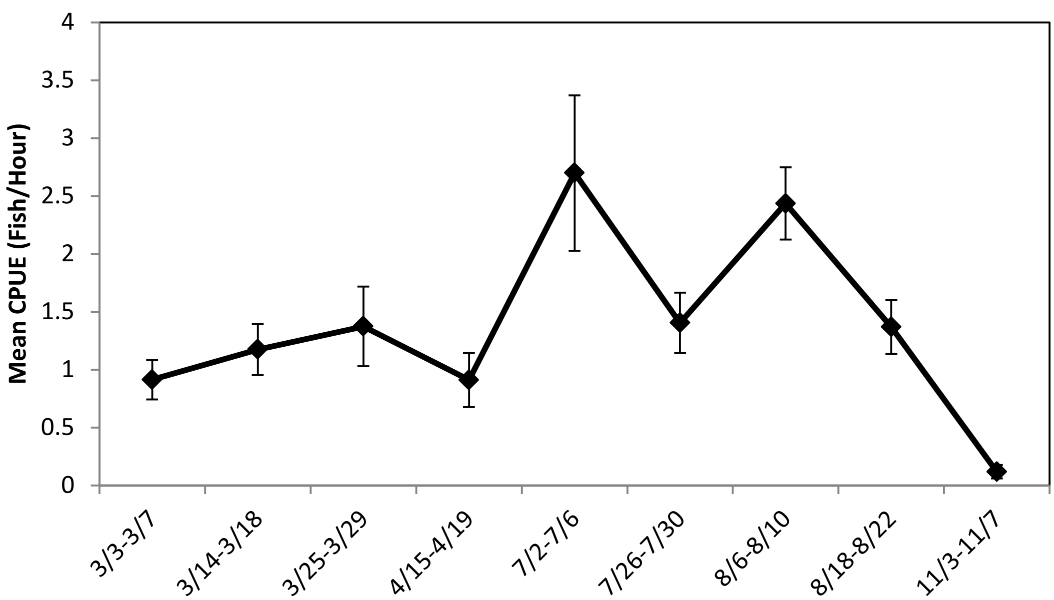

Figure 11. Mean electrofishing catch-per-unit-effort of Colorado pikeminnow by pass in the lower San Juan River during 2013. Error bars represent ± 1 standard error.

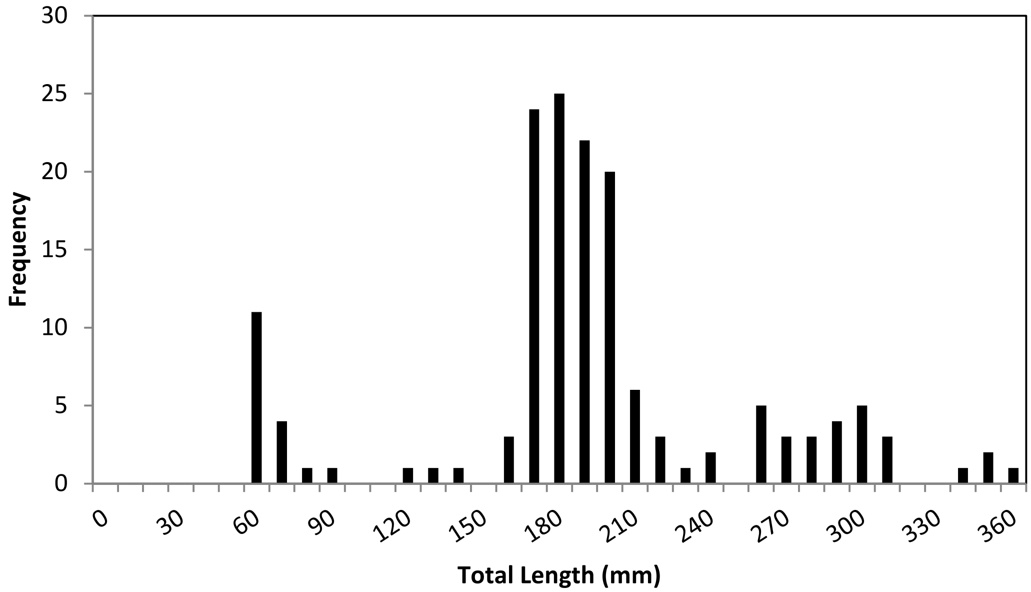

Figure 12. Length-frequency histogram of Colorado pikeminnow in the lower San Juan River during 2014.

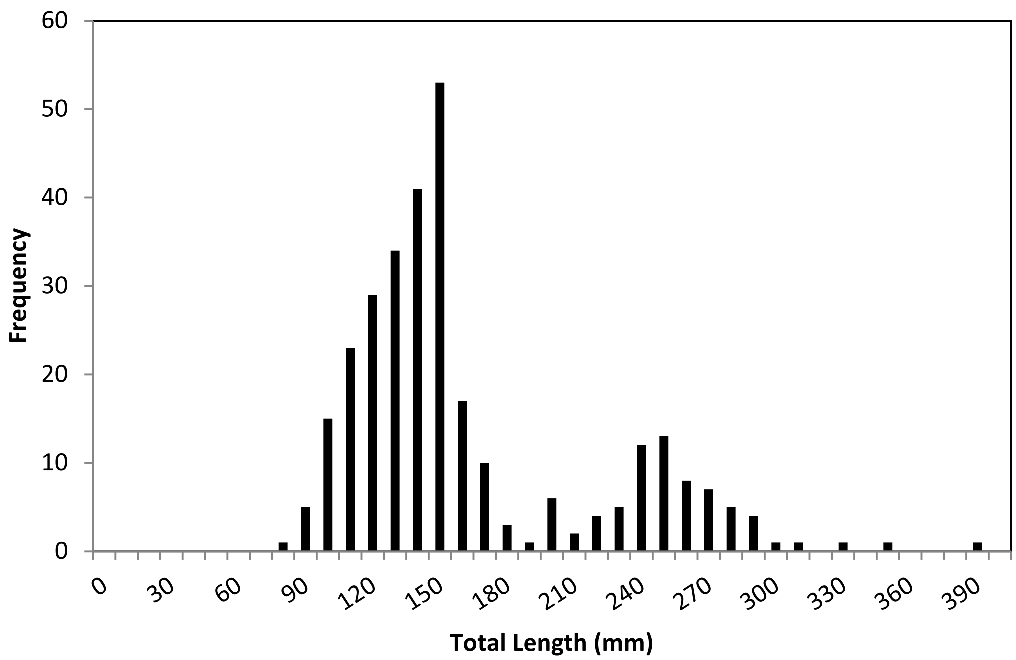

Figure 13. Length-frequency histogram of Colorado pikeminnow in the middle San Juan River during 2014.

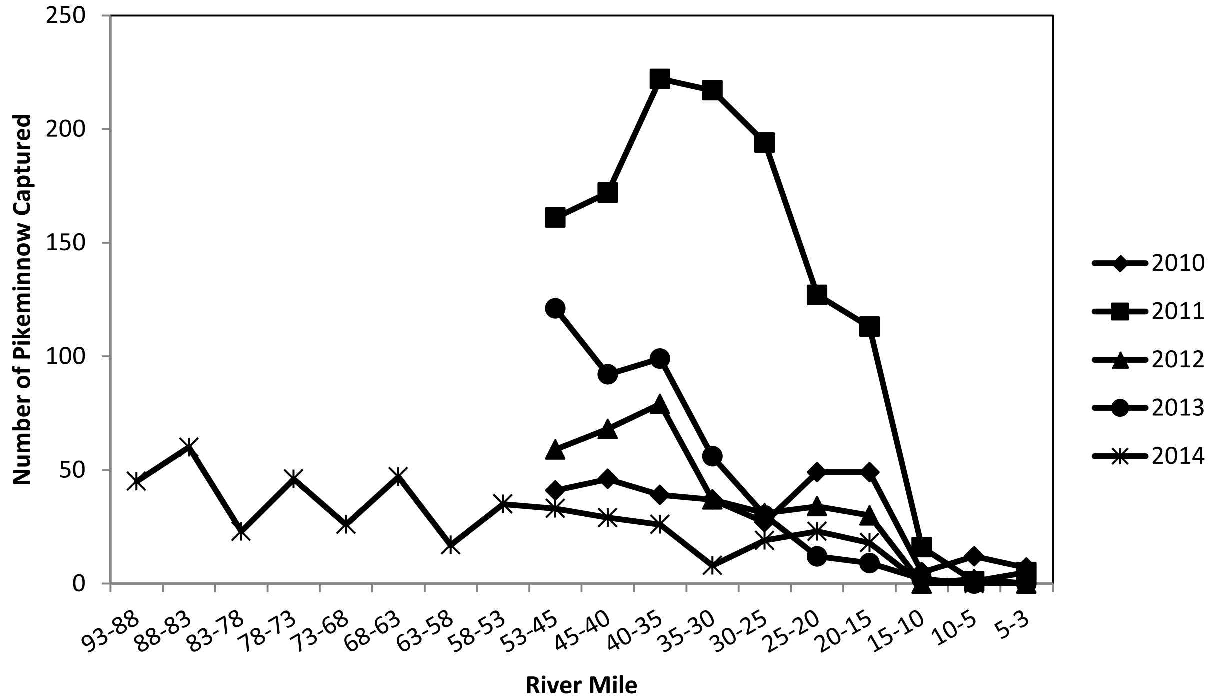

Figure 14. Distribution of Colorado pikeminnow captures by river mile from 2010 to 2014 in the lower San Juan River.

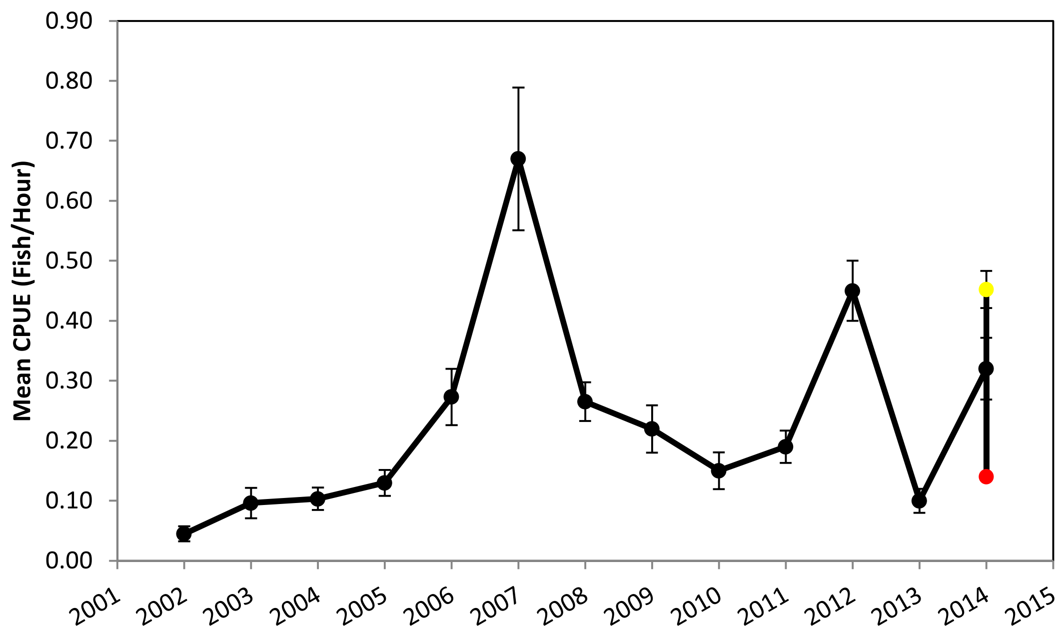

Figure 15. Mean electrofishing catch per unit effort of razorback sucker in the lower San Juan River from 2002 to 2013. In 2014 sampling occurred in the lower canyon (yellow) and middle canyon (red). Black is the two combined. Error bars represent $\pm$ 1 standard error.

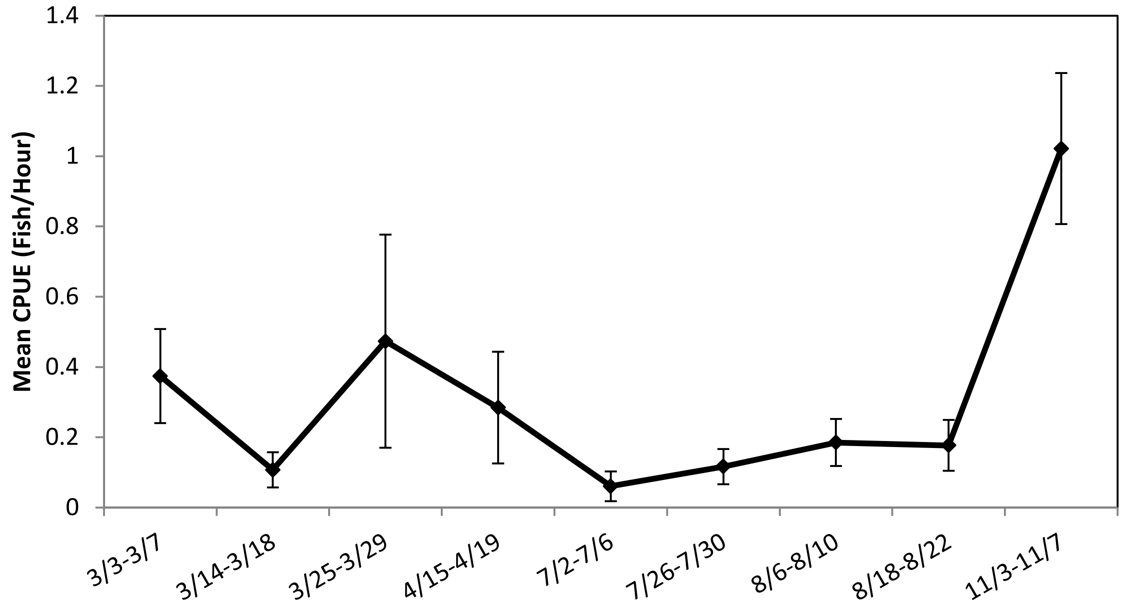

Figure 16. Mean electrofishing catch per unit effort of razorback sucker by pass in the middle and lower San Juan River in 2014.

Appendix A. Average daily flow (USGS gage 09379500 near Mexican Hat, Utah), average water temperature, average discharge, average specific conductivity, and average turbidity (mm to Secchi disk disappearance) during sampling trips on the middle and lower San Juan River in 2014.

Trip	Temp (°C)	Discharge (cfs)	Sp C (S/m)	Turbidity (mm)
3/3-3/7	9.6	838.6	833.7	40.0
3/14-3/18	10.4	650.0	726.1	207.3
3/25-3/29	12.0	538.7	767.4	273.5
4/15-4/19	13.6	829.4	583.9	90.0
7/2-7/6	26.2	789.0	485.9	431.0
7/26-7/30	25.7	471.6	590.6	44.2
8/6-8/10	23.8	855.5	491.4	15.0
8/18-8/22	23.4	628.6	677.5	31.5
11/3-11/7	9.4	888.2	697.8	98.8

Appendix B. Average daily flow (solid line) and temperature (dashed line) (USGS gage 09379500 near Mexican Hat, Utah) during the 2014 field season on the lower San Juan River.