Nonnative Control in the Lower San Juan River 2009

Interim Progress Report

for the
San Juan River Recovery
Implementation Program

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EXECUTIVE SUMMARY

The eighth consecutive year of nonnative control in the lower San Juan River was conducted in 2009. This project was initiated to remove nonnative fish species, and to identify factors involved in movement of striped bass (*Morone saxatilis*) and other reservoir fish species out of Lake Powell and into the lower San Juan River. Relationships between these factors and nonnative catch rates were intended to help in the refinement of removal effort timing. In 2003 a waterfall formed at Piute Farms on the lower San Juan River. This waterfall created a barrier to fish movement out of the reservoir and into the San Juan River. Thus, the nonnative removal focus shifted to channel catfish (*Ictalurus punctatus*) and other nonnative fishes that occur in the San Juan River.

In 2009, nine removal passes were made, beginning in early-March and continuing through early October. Electrofishing was conducted from Mexican Hat to Clay Hills, UT (river mile, RM, 52.8-2.9). Mean daily river flows ranged from 466-1910 cubic feet per second (cfs) during sampling trips in 2009.

The majority of nonnative specimens collected in 2009 were channel catfish (N = 14,433 individuals). Catch rates of channel catfish varied between trips. Mean catch rates of channel catfish in 2009 were significantly higher than catch rates in previous years. In 2009, mean total length (TL) of channel catfish collected during sampling in the lower San Juan River was significantly less than in the years 2002, 2003, 2004, 2006 and 2008.

In 2002 and 2003, common carp (*Cyprinus carpio*) was the second most abundant nonnative species collected. From 2004 to 2009 the mean catch rate of common carp was significantly lower than in 2002 and 2003. Size structure of common carp remained similar from 2002 to 2006. In 2009, mean TL of common carp captured was significantly lower than from 2002 to 2008

In 2009 sampling, 1,366 endangered fishes were collected in the lower San Juan River. Of these, 1,309 were juvenile or sub-adult (< 450 mm TL) Colorado pikeminnow (*Ptychocheilus lucius*) stocked in 2003 through 2008 near Farmington, NM. Population estimates generated from capture/recapture data of Colorado pikeminnow were less variable than population estimates from previous years. In 2009, 57 razorback suckers (*Xyrauchen texanus*) were collected.

In 2009, sampling was conducted below the waterfall at Piute Farms to determine species present, but blocked by the waterfall to upstream movement. Five sampling trips were conducted directly below the waterfall. Four age-1 Colorado pikeminnow and zero razorback suckers were collected below the waterfall in 2009. Walleye (*Sander vitreus*), striped bass, gizzard shad (*Dorosoma cepedianum*), channel catfish, and common carp, were also collected in this area.

INTRODUCTION

The lower San Juan River is likely to be essential in the recovery of the Colorado pikeminnow and razorback sucker in the San Juan River Basin. It contains nursery habitats comparable to those existing on the Green and Colorado rivers, where wild young-of-year (YOY) and juvenile Colorado pikeminnow are typically found. In past years, collections of endangered fishes have been increasing in the lower San Juan River. The largest collection of razorback sucker larvae in 2002 was from Reach 2 (RM 21.2; Brandenburg et al. 2003) and 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 2003-2008, age-0 Colorado pikeminnow stocked in the fall of the previous year near Farmington, NM, were also found using the lower portions of the San Juan River (Golden et al. 2006, Elverud 2008). In 2004, wild-spawned Colorado pikeminnow larvae were collected at RM 46.3 and RM 18.1 (Brandenburg et al. 2005), 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)

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 high 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 later 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 the abundance of these species found 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 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 (Lee et al. 1980). 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 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 was directly responsible for the lack of striped bass and walleye in the sampling. 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 forming of the waterfall, 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 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 were to: 1) continue mechanical removal efforts of large bodied nonnative species in the lower portion of the San Juan River from Mexican Hat to Clay Hills and sample just below the waterfall; 2) generate a population estimate of channel catfish by mark-recapture data from Mexican Hat to Clay Hills; 3) characterize abundance of endangered fishes in the San Juan River just below the waterfall; and 4) characterize abundance of predators moving out of Lake Powell into the San Juan River upstream to the waterfall. 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-type habitat. The river is canyon bound with an active alluvial bed from RM 16 to Clay Hills (RM 2.9). Habitats within this section are heavily influenced by the shifting thalweg, changing river flow, and 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 trips. A Smith-Root electrofishing unit (5.0 GPP) was used with amperage ranges set from 4-6 depending on water 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 trip. When conditions allowed, a chase boat would follow 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 out into the river and held in place for several minutes after the electrofishing raft had passed downstream. Personnel limitations during 2009 prevented use of the seine for capturing channel catfish.

All nonnative and endangered species were netted (Table 1), but non-listed native suckers were not captured. Total and standard lengths (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 ≥ 150 mm TL received a PIT tag (134 kHz) if one was not already present and general condition of the fish was noted. Endangered fish were released at or near the location of capture. River mile and a global position system (GPS) reading in Universal Transverse Mercator (UTM) Zone 12 (NAD27) near the location of capture were recorded. From 2003-2006 and 2008-2009, all channel catfish ≥ 200 mm TL collected during the first pass (trip) were tagged and released. Channel catfish collected in 2009 were uniquely marked with individually numbered tags. Prior to 2009, channel catfish were tagged with colored tags only and were not uniquely marked. In 2009, channel catfish ≥ 200 mm TL were tagged and received an adipose fin clip. The purpose of the adipose fin clip was to determine if tag loss was a concern for the population estimate. Channel catfish collected on subsequent passes (trips) and all other nonnative species were removed from the river. River temperature, conductivity, and salinity were measured at least two times per trip. Light penetration was measured using a Secchi disk with depth to disappearance of disk measured in millimeters at least twice per trip. 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.

Five sampling trips were conducted directly below the waterfall at RM -0.5 in 2009 and angling, cast netting, seining, and fyke netting were methods used to collect fish. Any endangered fishes collected were measured, weighed and scanned for a PIT tag as described above. All endangered fishes collected directly below the waterfall were released upstream of the barrier. Walleye and striped bass captured below the waterfall were measured; other nonnative fishes were enumerated but not weighed and measured.

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 every 2 to 3 miles sampled. 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 (> 200 mm) captured during the first two passes from 2003 to 2006 and 2008-2009. 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, profile likelihood intervals were provided in lieu of 95% confidence intervals. The profile likelihood interval helps to account for model selection uncertainty by providing a wider confidence interval. In addition, these intervals are more precise for small samples (Ross Moore, Mathematics Dept., Macquarie University, Sydney Australia *personal communication*).

RESULTS

Nine sampling passes were conducted on the San Juan River between Mexican Hat and Clay Hills, UT (Figure 1). Sampling dates were: March 2-6, March 10-14, March 23-27, April 6-10, April 15-19, July 1-5, August 3-7, August 24-28, and October 2-6. Eleven large-bodied fish species, including Colorado pikeminnow and razorback sucker, were collected in the lower San Juan River during nonnative control. One roundtail chub was also captured in the lower San Juan River in 2009. This individual is the only roundtail chub captured since this project began in 2002. The remaining eight species were nonnative. Native bluehead sucker and flannelmouth sucker were present during all passes but not netted during nonnative control efforts. Electrofishing effort totaled 310 hours and resulted in 15,924 fishes captured (Table 1). One hundred twenty-nine channel catfish were captured using chase boats. No striped bass or walleye were collected in 2009 in the lower San Juan River above the waterfall.

<u>Nonnative Species</u>

Channel catfish

In 2009, channel catfish comprised > 91% of the total catch in the lower San Juan River. Mean catch rates of channel catfish varied significantly between some passes and ranged from 31 to 70 fish per hour ($p < 0.05$; Table 2, Figure 2). Mean catch rates of all life stages of channel catfish combined in 2009 were significantly higher ($p<0.05$) than catch rates in 2002, 2003, 2004, 2006, or 2008 (Figure 3). The mean catch rate of adult (>300 mm TL) channel catfish was significantly higher in 2009 compared to 2003 to 2007 ($p<0.05$, Figure 4). There was no significant difference in adult channel catfish CPUE between 2009 and 2002 or 2008.

The mean total length of channel catfish collected in the lower San Juan River in 2009 was 186 mm. The mean total length in 2009 was significantly lower than the mean total length in 2002 – 2004, 2006 and 2008 ($p < 0.05$; Figure 5). Length-frequency histograms show the majority of catfish collected during the summer months were small juveniles (Figure 5). Additionally, the percentage of adult channel catfish in the total catch is similar to previous years (Figure 6) with the exception of 2008 when adult channel catfish comprised a larger portion of the total catch.

A Lincoln-Peterson population estimate for channel catfish was calculated in 2009 (Figure 7). In 2009, the Lincoln-Peterson population estimate for channel catfish was 12,080. This estimate is within the confidence limits of similar estimates calculated in the 2003, 2004, 2005, and 2008 and is significantly lower than the estimate calculated in 2006.

In 2009, exploitation of channel catfish by size class and tag retention were analyzed using the mark/recapture data from the Lincoln-Peterson population estimate. Exploitation rate of channel catfish increased with size class (Table 3). Exploitation ranged from 26% for channel catfish tagged at sizes from 200-299 mm TL and 100% exploitation rate for channel catfish tagged at 500-599 mm TL. Exploitation rates were also considerably higher (24.8%) on nonnative removal trips conducted prior to runoff versus the exploitation rate (3.3%) on trips after runoff (Table 3). Capture of 18 tagged channel catfish by other researchers in the San Juan River upstream of our sampling reach indicate substantial movement within 2009. Three channel catfish captures were greater than 100 river miles upstream of the tagging location. Tag retention rates determined from adipose fin clips ranged from > 99% during spring sampling trips and 61% on sampling trips conducted during summer and fall.

Common carp

In 2009, mean catch rates of common carp remained low compared to the catch rates during the first two years of nonnative control in the lower San Juan River. Catch rates of common carp were not significantly different between passes in 2009 (Figure 8). From 2002 to 2009, catch rates of common carp decreased significantly ($p < 0.05$; Figure 9). In 2009, the mean catch rate of common carp was significantly lower than from 2002 and 2003 ($p < 0.05$), but was not significantly lower than in 2004 to 2008. Mean size of common carp remained similar among years from 2002 to 2006, but was significantly lower ($p<0.05$) in 2009 than in years 2002 to 2008 (Figure 10). The percentage of adult carp in the total carp catch has also continued to decline since the initiation of control efforts (Figure 11).

Endangered Species

Colorado pikeminnow

A total of 1309 Colorado pikeminnow were collected in 2009 during nonnative control efforts in lower San Juan River. The 2009 total of 1309 Colorado is approximately four times greater than the total number of Colorado pikeminnow captured in any previous year of this study. Catch rates of Colorado pikeminnow increased significantly from 2003 to 2009 ($p<0.05$, Figure 12). Catch rates of Colorado pikeminnow also varied by pass (Figure 13). In 2009, the majority of juvenile Colorado pikeminnow captured were age-2 (2007 cohort). This pattern is similar to the trend in previous years (Figure 14). Length-frequency histograms by pass further illustrate that the majority of juvenile Colorado pikeminnow collected in 2009 were age-2 fish. While age-2 fish made up the majority Colorado pikeminnow captured in 2009, four cohorts (age-1, age-2, age-3 and age-4) were well represented in the 2009 data (Figure 14) unlike previous years.

Distribution of Colorado pikeminnow captures in 2009 appears similar to capture locations in previous years with the exception of 2008 (Figure 15). In 2008, a large increase in the number of captures from river mile 10 to river mile 5 was observed. The increase in Colorado pikeminnow captures in the lower portion of the study reach is possibly the result of high spring flows in 2008 resulting from abnormally high releases from Navajo Dam.

Population estimates of Colorado pikeminnow have been generated for the lower San Juan River since 2004 (Table 4). Several population estimates were calculated using different set of passes (passed 1-4, passes 6-9, and passes 1-4 and 6-9 combined) to formulate a rough idea of population size of Colorado pikeminnow $\geq$ 150 mm TL. Pass five was not included in any of the population estimates because of weather conditions during pass five preventing effective sampling. In 2009, population estimates of Colorado pikeminnow in the lower San Juan River were: 1078 for passes 1-4, 1221 for passes 6-9, and 1452 for passes 1 to 4 and 6-9 combined. The coefficients of variation for these estimates were: 6%, 33% and 6% respectively. The observed variation in the population estimates within and among years makes identifying trends in the number Colorado pikeminnow difficult, but confidence limits for population estimates in 2009 do not overlap with estimates from many of the previous years indicating an increase in the number of juvenile Colorado pikeminnow in the lower San Juan River in 2009.

Captures of adult Colorado pikeminnow have diminished since this project began in 2002. No adult Colorado pikeminnow have been collected since 2004 in the lower San Juan River. During the first year (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

Fifty-seven razorback suckers were collected in the lower San Juan River (Table 1) in 2009 during nonnative removal trips. Mean catch rate of razorback suckers was not significantly different in 2009 than previous years (Figure 16). Catch rate of razorback sucker did not vary by pass (Figure 17). 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. Two suspected razorback-flannelmouth hybrids were also collected in 2009 in the lower San Juan River.

<u>Waterfall</u>

Five sampling trips below the San Juan waterfall(s) were conducted in 2009. Similar to conditions in summer 2006 through 2008, the waterfall remains about 7-8 meters high. Fish sampling methods below the waterfall(s) include fyke nets, seines, cast nets and angling. Sampling gears, effort and timing of sampling below the waterfall has varied between years.

Fishes collected below the waterfall during 2009 included native, nonnative and endangered species (Table 5). Four age-1 Colorado pikeminnow were captured directly below the waterfall in April 2009. No razorback sucker were collected below the waterfall in 2009. Other species collected included: channel catfish, common carp, gizzard shad (*Dorosoma cepedianum*), striped bass and walleye.

<u>Other Observations</u>

Over the course of this project, important information has also been obtained on endangered fishes. We have observed the apparent spawning aggregation of razorback sucker in spring 2002 at Slickhorn Rapid, located another possible spawning aggregation near RM 23.5 in 2006, documented the distribution and abundance of Colorado pikeminnow stocked in 2002 –2008, generated preliminary population estimates for juvenile Colorado pikeminnow from 2004 to 2009, 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 2009 are correlated with the stocking of YOY fish each year. From 2004 to 2009, 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

In 2009, the waterfall near Piute Farms persisted and was a barrier to upstream movement of fishes from Lake Powell. Lake Powell rose approximately 35 feet from the spring of 2009 to mid-July 2009, but water levels remained below full pool and below elevations that would inundate the waterfall. At the time of this report, Lake Powell's elevation was 3629 feet above sea level, approximately 71 feet below full pool. Lake Powell is not expected to inundate the waterfall in 2010.

The channel catfish catch rate in 2009 was significantly higher than in previous years. Many factors may have contributed to the high catch rates in 2009. First, removal of the larger channel catfish may be providing more opportunity for smaller channel catfish to persist. Cursory stomach content examinations from the lower river do not show large numbers of small channel catfish in the stomachs of large (>400 mm TL) channel catfish. As large channel catfish stomachs infrequently contain small channel catfish, conspecific predation by large channel catfish is not likely precipitating an increase in juvenile and YOY channel catfish abundance, but increased habitat and food resource availability may be improving survival of small channel catfish. Second, favorable environmental condition in the previous year may have resulted in above average reproductive success and above average survival of juvenile catfish. Length frequency histograms indicate an increase in age-1 channel catfish captured in 2009. The apparent increase in age-1 channel catfish was also observed by researchers in the middle San Juan (Davis, 2009, personal communication). The decrease in mean TL of channel catfish in 2009 also further substantiate the increased CPUE of channel catfish resulting from increased catch of small channel catfish. Additionally, the Lincoln-Peterson population estimate for channel catfish in the lower San Juan River do not indicate an increase in channel catfish $\geq$ 200 mm TL.

Identifying the mechanism or mechanisms responsible for the increase in age-1 channel catfish is difficult. Environmental conditions vary substantially from year to year in the San Juan River basin. The influence of environmental conditions on reproductive success and survival of channel catfish in the San Juan River is also not well understood. The possibility exists that the shift in size structure of the channel catfish population is creating a less palatable food base for Colorado pikeminnow by increasing the chance of mortality of Colorado pikeminnow attempting to consume channel catfish. Alternatively, increasing the probability of a Colorado pikeminnow encountering a channel catfish is unlikely as the two species are certain to interact. Channel catfish are and have been abundant and ubiquitously distributed throughout the lower San Juan River since the nonnative control began in 2002.

The use of individually number tags to mark channel catfish in 2009 allowed for exploitation to be calculated for different size classes of channel catfish. Exploitation of channel catfish varied greatly depending on total length at the time of tagging and increased with total length. Electrofishing, which is the sole gear used for removal of nonnative species in the San Juan, is documented to be biased toward collecting larger individuals. Along with the documented variability in exploitation of channel catfish by size class, exploitation was much higher during sampling trips conducted prior to runoff. Movement of tagged channel catfish upstream and out of our reach, as documented by captures of tagged channel catfish by other researches, likely contributes to the trend of decreasing exploitation after runoff. Increased water temperature could also play a roll in exploitation rate of channel catfish. While the exact mechanism or mechanisms responsible for the decrease in exploitation after runoff is unknown, these data are informative as to when sampling is most effective at removing channel catfish from the lower San Juan River. The higher exploitation rate observed prior to runoff in the lower San Juan River may not apply to other sections of the San Juan River. As 2009 was the first year in which individually numbered tags were used to mark channel catfish, no year to year comparisons can be made at this point to assess exploitation by size class relative to environmental conditions.

Population estimates of channel catfish ≥ 200 mm TL have been conducted in the lower San Juan River since 2003. The 2009 population estimate was significantly lower than the 2006 estimate, but confidence intervals associated with estimates from all other years overlap. Tag retention data from 2009 indicate tag loss is not of concern when the mark and recapture passes are conducted over a short period of time. Eighteen channel catfish tagged in the lower San Juan River were recaptured by mechanical removal efforts upstream in the middle and upper San Juan in 2009. Additionally, three channel catfish tagged in March 2009 in the lower San Juan River were recaptured greater than 100 river miles from the tagging location. Using the first two passes, conducted within two weeks, reduces the likelihood of immigration and emigration affecting the mark/recapture Lincoln-Peterson population estimate of channel catfish. Dames et al. (1989) documented that a channel catfish traveled 469 km upstream in the Missouri River in just 72 days, while Hale et al. (1986) observed movement of 108 km upstream in 22 days in the St. Johns River in Florida. Channel catfish movement into the lower San Juan River from downstream sources is unlikely because of the waterfall at Piute Farms. While these data indicate movement and tag retention are not a concern when the mark and recapture passes are conducted over a short period of time, they do indicate catfish moving large distance throughout the year and eliminate the possibility of using a multiple removal pass population estimate for estimating channel catfish population size.

Continuing population estimates for channel catfish will allow for evaluation of removal effectiveness and exploitation rate of the channel catfish population. Gerhardt and Hubert (1991) reported that in the Powder River drainage, the Ricker and Thompson-Bell model indicated that population structure and abundance of channel catfish would change considerably as exploitation rates (harvest) increased. They reported that an annual exploitation rate of 22% would result in a 75% reduction in overall abundance of fish ≥ 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, as well as in the lower section. Continued removal of all size classes of channel catfish in the San Juan River should facilitate the reduction of the overall impact that these fish have on the native and endangered fish community.

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 2009, only 65 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). Riverwide adult and subadult monitoring has also shown a significant decline in CPUE of common carp (Ryden 2009). The majority of carp removed from the lower San Juan River are captured in the bottom 14 miles of the reach. This indicates carp are not occupying the majority of the lower San Juan River nonnative control reach.

In 2009, the size structure of common carp removed form the lower San Juan showed a significant decrease from previous years of sampling. From 2002 to 2006, the mean total length of common carp removed from the lower San Juan River ranged from 382 to 459 mm TL compared to 168 mm TL in 2009. The percentage of adult carp in the total carp catch has also declined since nonnative control began. The decrease in the percentage of adult carp has also been documented riverwide (Ryden 2009). In 2009, YOY and juvenile carp made up $\geq$ 60% of the carp catch. While the percentage of YOY and juvenile carp has increased, the number of YOY and juvenile carp captured each year has remained low. The increase in the percentage of juvenile and YOY carp in the total carp catch has resulted from the large reduction in the number of carp captured each year. These data may indicate low levels of carp reproduction in the lower San Juan River.

Population estimates generated for stocked juvenile Colorado pikeminnow, although preliminary at this point, provide a basis for future estimates. In 2005, spring estimates appeared to be the most precise, with the lowest coefficients of variation. In 2006, Colorado pikeminnow estimates were quite variable across all sets of passes making the validity of the estimates questionable other than for exploratory purposes. In the spring of 2009, Colorado pikeminnow estimates were quite precise relative to past years. The precision of the population estimates point to increasing abundance of Colorado pikeminnow in the lower San Juan River. These data coincide with the significant increase in CPUE of Colorado pikeminnow in 2009. While data from the lower San Juan nonnative removal project seems to indicate increasing abundance of Colorado pikeminnow, no increasing trend in CPUE data has been observed in riverwide monitoring as of 2008 (Ryden 2009).

In 2006 and 2007, Colorado pikeminnow were found moving extended distances during the summer. Population estimates may be biased if the closure assumption was violated. In 2006 and 2007, mark/recapture data indicates some Colorado pikeminnow were indeed moving large distances (80-129 river miles) throughout the summer. These data indicate that some unknown percent of fishes captured in the lower San Juan during spring or early summer are indeed moving upstream and out of our sample reach. An estimate with the shortest time between passes, either in the spring or fall is likely to be the most reliable. A riverwide estimate would also alleviate concern about a closed population, as the entire river would be sampled above the waterfall.

The catch of adult Colorado pikeminnow has declined over the period of this study (2002-2009). The reasons for this decline is unknown but might be explained by several factors: 1) Colorado pikeminnow adults may become accustomed to electrofishing boats and learn to avoid the electrofishing field; 2) they may have moved below the waterfall and are unable to move back upstream; 3) they may have moved upstream out of the lower reach into river sections that are not as heavily sampled and thus are less likely to be captured; 4) mortality may also be the reason for the absence of adult Colorado pikeminnow in the lower San Juan River. Radio telemetry of adult Colorado pikeminnow on the San Juan River in the 1990's indicated that three radio tagged fish were detected (either visually or sonically) moving ahead (downstream) of electrofishing boats and in some cases crossing from one shoreline to the other (Ryden, 2000). The eventual capture of these fish was achieved when the fish were forced to swim back upstream to avoid crossing shallow riffle-sandbar complexes. The fish avoiding the electrofishing boats ranged from 521 to 948 mm TL. Additionally, researchers documented Colorado pikeminnow avoidance of rafts without electrofishing setups. Bestgen et al. (2004) examined Colorado pikeminnow avoidance to electrofishing boats indirectly by analyzing relationships of capture to fish size during population estimates conducted in the Green River. Capture probabilities described by TL of individuals, indicated that fish < 580 mm TL were progressively easier to capture, while the relationship was found to decline for larger fish. They speculated that fish larger than 580 mm TL may be powerful enough to evade the electrofishing field, or they may be occupying deeper water.

While the number of adult Colorado pikeminnow captured in the lower San Juan River has declined since nonnative removal began, the significant increase in CPUE in 2009 is encouraging. The increase in CPUE includes several cohorts (age-1 to age-4) of Colorado pikeminnow. All Colorado pikeminnow captured in 2009 are likely the result of augmentation efforts. These data may indicate a higher rate of survival rates of stocked Colorado pikeminnow the previous year or years.

The total number of razorback suckers captured in the lower San Juan River in 2009 was lower than the number captured the previous two years, but no significant difference in CPUE of razorback sucker was found. Riverwide monitoring has also shown no significant decrease in razorback sucker catch rate in the previous years (Ryden 2009). 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 year. The high CPUE observed in 2007 was the result of large numbers of razorback suckers being stocked the previous year.

Sampling at the base of the waterfall in 2005 to 2009 showed that both endangered and nonnative fishes are blocked from moving upstream. It is possible that the larger pikeminnow that were collected in 2002-2004 have moved below the waterfall and cannot return upstream. No adult Colorado pikeminnow have been captured below the waterfall, but in 2007 hook and line sampling below the waterfall collected one large (397 mm TL) Colorado pikeminnow. This Colorado pikeminnow is larger than any other captured in the lower San Juan since 2004 with the exception of the large Colorado pikeminnow stocked in the summer of 2006. After being released above the waterfall, this fish was recaptured 12 days later during a nonnative control trip 48 miles upstream from the waterfall. Electrofishing sampling form the waterfall to Lake Powell did not result in the capture of any adult pikeminnow.

A total of four age-1 Colorado pikeminnow were captured below the waterfall in 2009 indicating some loss of stocked endangered fishes over the waterfall. Zero razorback sucker were captured below the waterfall in 2009, but razorback suckers were captured at the waterfall in all previous years of sampling. At this time, no estimate of the number of endangered fishes passing over the waterfall is available. Sampling directly below the waterfall is difficult, and the probability of capture may be low.

CONCLUSIONS AND RECOMMENDATIONS

• Population estimates of channel catfish remained similar during most years from 2003 to 2009; however, large confidence intervals indicate poor precision of these estimates. 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 tag allows for determinate of exploitation rate by size class, monitoring of channel catfish growth rates and movement throughout the river.

• The CPUE of channel catfish increased over all previous years in the lower San Juan. Length-frequency histograms, the mark/recapture population estimate and the decrease in mean TL indicate the increase resulted from an increased abundance of age-1 channel catfish. Expansion of nonnative control, as occurred in 2008, into the middle San Juan reach may decrease the number of spawning channel catfish upstream of the lower San Juan removal reach.

• Catch rates of common carp and the size structure decreased significantly from 2002 to 2009. The cause of the decreasing trend in catch rate for these fish is unknown. Several factors may be acting together: the presence of the waterfall which has been reducing or eliminating reinvasion into the removal section from downstream; low water conditions present during the first three years of removal; and finally, removal actions that may be contributing to the decline. Common carp should continue to be removed from the lower San Juan River to reduce competition with native and endangered fishes.

• Catch rates and population estimates of juvenile Colorado pikeminnow increased from 2003 through 2009. From 2004 to 2009, the majority of captures were age-2 fish. Age-1 fish are likely more abundant, but electrofishing sampling effectiveness increases with fish size. Population estimates of juvenile Colorado pikeminnow in the lower San Juan River should continue.

• No adult Colorado pikeminnow have been collected in the lower San Juan River from 2004 to 2008; the reasons for this are unknown. Mortality, avoidance of electrofishing rafts or movement from the lower river to upstream sections may be explanations for the disappearance of age-3 Colorado pikeminnow. Life history studies could possibly illuminate food or habitat shifts at age-3, which might be causing a bottleneck.

• Sampling at the base of the waterfall documented the presence of stocked endangered fish below the waterfall and the presence of numerous nonnative species. It is recommended that sampling at the waterfall be discontinued at this time. The current amount of sampling at the waterfall is inadequate to estimate the number of fish present below the waterfall.

LITERATURE CITED

Archer, E.K., T.A. Crowl, and M.A. Trammell. 2000. Abundance of age 0 native fish species and nursery habitat quality and availability in the San Juan River in New Mexico, Colorado, and Utah. Final Report to the San Juan River Recovery Implementation Program: Biology Committee. Utah Division of Wildlife Resources. Salt Lake City, UT.

Beasley, C. A., and J. E. Hightower. 2000. Effects of a low-head dam on the distribution and characteristics of spawning habitat used by striped bass and American shad. Transactions of the American Fisheries Society 129:1372-1386.

Bennet, G.W., 1971. Management of lakes and ponds, 2nd edition. Van Nostrand Rienhold, New York.

Bestgen, K.R., J.A. Hawkins, G.C. White, K. Christopherson, M. Hudson, M. Fuller, D.C. Kitcheyan, R. Brunson, P. Badame, G.B. Haines, J.A. Jackson, C.D. Walford, and T.A. Sorenson. 2004. Status of Colorado pikeminnow in the Green River Basin, Utah and Colorado. Projects 22i and 22j for the Colorado River Recovery Implementation Program. Draft Final Report. Colorado State University, Larval Fish Laboratory. Fort Collins, CO.

Brandenburg, W.H., M.A. Farrington, S.J. Gottlieb. 2003. Razorback sucker larval fish survey in the San Juan River in 2002. Final Report. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM

Brandenburg, W.H., M.A. Farrington, S.J. Gottlieb. 2004. Razorback sucker larval fish survey of the San Juan River in 2003. Final Report. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM

Brandenburg, W.H., M.A. Farrington, S.J. Gottlieb. 2005. San Juan River 2004 Colorado pikeminnow and razorback sucker larval surveys. Final Report. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM

Brandenburg, W.H. and Farrington, M.A. 2008. Colorado pikeminnow and razorback sucker larval fish survey in the San Juan River during 2007. Final Report. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM

Davis, J.E. 2002. Non-native species monitoring and control, San Juan River 1999-2001. Progress Report for the San Juan River Recovery Implementation Program. Final Report. U.S. Fish and Wildlife Service, Albuquerque, NM.

Davis, J.E. 2005. Non-native species monitoring and control in the Upper San Juan River, New Mexico 2004. Progress Report for the San Juan River Recovery Implementation Program. Final Report. U.S. Fish and Wildlife Service, Albuquerque, NM.

Davis, J.E., D.W. Furr, E. Teller. 2009. Nonnative species monitoring and control in the upper San Juan River:2008. Progress Report for the San Juan River Recovery Implementation Program. Final Report. U.S. Fish and Wildlife Service, Albuquerque, NM.

Feyrera, F. and M.P. Healey. 2003. Fish community structure and environmental correlates in the highly altered southern Sacramento-San Joaquin Delta. Environmental Biology of Fishes 66: 123-132.

Gerhardt, D.R. and W.A. Hubert. 1991. Population dynamics of a lightly exploited channel catfish stock in the Powder River system, Wyoming-Montana. North American Journal of Fisheries Management 11: 200-205.

Golden, M.E., P.B. Holden, S.K. Dahle. 2006. Retention, growth and habitat use of stocked Colorado pikeminnow in the San Juan River: 2002-2005 Final Report. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM

Gustaveson, W. A., T. D. Pettingill, J. E. Johnson, and J. R. Wahl. 1984. Evidence of In-Reservoir Spawning of Striped Bass in Lake Powell, Utah-Arizona. North American Journal of Fish Management 4: 540-546.

Jackson, J.A. 2003. Nonnative control in the lower San Juan River, 2002. Interim Progress Report for the San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Jackson, J.A. 2005. Nonnative control in the lower San Juan River, 2004. Interim Progress Report for the San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R.E. Jenkins, D. E. McAllister, J. R. Stauffer, Jr.1980. Atlas of North American Freshwater Fishes. North Carolina State Museum of Natural History.

McHugh, J.L. 1984. Industrial fisheries, pages 68-80 in R.T. Barber, C.N.K. Mooers, M.J. Bowman, and B. Zeitschel, editors. Lecture notes on coastal and estuarine studies. Springer-Verlag, New York.

Otis, D.L., K.P Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs. 62:1-135.

Pitlo, J.Jr., 1997. Response of upper Mississippi River channel catfish populations to changes in commercial harvest regulations. North American Journal of Fisheries Management 17: 848-859.

Rexstad, E. and K. Burnham. 1991. User's guide for interactive program CAPTURE. Unpublished report, Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, Colorado.

Ryden, D. W. 2000. Adult fish community monitoring on the San Juan River, 1991-1997. Final Report. U.S. Fish and Wildlife Service, Grand Junction CO. 269 pp.

Ryden, D. W. 2001. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River, 2000. Interim Progress Report. U.S. Fish and Wildlife Service. Grand Junction, CO. 61 pp.

Ryden, D. W. 2003. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 1999-2001 Integration Report. U.S. Fish and Wildlife Service. Grand Junction, CO. 68 pp.

Ryden, D. W. 2005. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River, 2004. Interim Progress Report. U.S. Fish and Wildlife Service. Grand Junction, CO.

Ryden, D. W. 2009. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River, 2008. Interim Progress Report. U.S. Fish and Wildlife Service. Grand Junction, CO.

Schaugaard, C. and W. Gustaveson. 1997. Nonnative invasion between Lake Powell and the San Juan River, 1996. Completion Report. Utah Division of Wildlife Resources. Salt Lake City, UT. 16 pp.

Sigler, W. F. and J. W. Sigler. 1996. Fishes of Utah. University of Utah Press. Salt Lake City.

White, G.C., D.R. Anderson, K.P. Burnham, and D.L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, LA-8787-NERP, Los Alamos, New Mexico.

Table 1. Total count of fish species collected during sampling in the lower San Juan River in 2009.

	Sampling Trip Dates									
	March 2-6	**March 10-14**	**March 23-27**	**April 6-10**	**April 15-19**	**July 1-5**	**August 3-7**	**August 24-28**	**October 2-6**	**2009 Total**
Black bullhead *(Ameiurus melas)*	1	6	0	0	0	4	3	1	0	15
Brown trout (*Salmo trutta)*	0	0	2	0	2	2	0	0	0	6
Channel Catfish (*Ictalurus punctatus)*	1245	1897	1354	2583	1042	976	1645	2698	993	14433
Colorado pikeminnow *(Ptychocheilus lucius)*	225	244	219	237	116	98	98	56	16	1309
Common carp (*Cyprinus carpio)*	15	8	6	9	3	11	7	5	1	65
Green sunfish (*Lepomis cyanellus)*	0	0	0	2	0	5	1	0	0	8
Largemouth bass (*Micropterus salmoides)*	0	0	0	0	0	0	5	5	5	15
Razorback sucker *(Xyrauchen texanus)*	8	8	7	10	2	7	5	7	3	57
Roundtail chub *(Gila robusta)*	1	0	0	0	0	0	0	0	0	1
Smallmouth bass *(Micropterus dolomieu)*	0	0	0	0	0	0	0	1	0	1
Yellow bullhead (Ameiurus natalis)	2	1	0	0	0	10	0	0	1	14

Table 2. Mean CPUE (fish/electrofishing hour) of most abundant fish species collected during electrofishing sampling in the lower San Juan River in 2009. The numbers in parenthesis below the trip dates are the number of samples during trips. The standard error (SE) is in parenthesis below each mean CPUE.

Trip	*Ptyluc*	*Xyrtex*	*Ictpun*	*Cypcar*	*Amemel & Amenat*
March 2-6	5.93 (0.75)	0.19 (0.10)	31.35 (4.05)	0.42 (0.13)	0.10 (0.07)
March 10-14	6.65 (1.01)	0.25 (0.10)	50.07 (4.93)	0.21 (0.08)	0.16 (0.08)
March 23-27	5.84 (0.93)	0.21 (0.08)	36.76 (3.60)	0.15 (0.06)	0.00 (0.00)
April 6-10	6.57 (0.65)	0.31 (0.10)	66.02 (6.11)	0.24 (0.07)	0.00 (0.00)
April 15-19	7.99 (1.63)	0.12 (0.08)	58.21 (10.97)	0.15 (0.11)	0.00 (0.00)
July 1-5	2.27 (0.26)	0.22 (0.10)	24.96 (4.15)	0.27 (0.08)	0.33 (0.12)
August 3-7	2.35 (0.34)	0.13 (0.05)	38.73 (4.23)	0.17 (0.06)	0.06 (0.05)
August 24-28	1.54 (0.25)	0.21 (0.13)	70.18 (9.41)	0.14 (0.08)	0.03 (0.03)
October 2-6	0.53 (0.16)	0.32 (0.26)	40.54 (8.80)	0.03 (0.03)	0.03 (0.03)

Table 3. Percentage of total catch and number of channel catfish tagged by size class and exploitation rate of channel catfish by size class in 2009 in the lower San Juan River. Numbers in parenthesis are the actual number caught.

	Total Length (mm) of Channel Catfish at Time of Tagging					
	200-299 mm TL	300-399 mm TL	400-499 mm TL	500-599 mm TL	600+ mm TL	Total
Mark Pass	51.1% (358)	46.9% (329)	1.7% (12)	0.3% (2)	0.0% (0)	100% (701)
Trips 2-5	20.9% (75)	27.4% (90)	58.3% (7)	100.0% (2)	- -	24.8% (174)
Trips 6-9	1.4% (5)	5.2% (17)	8.3% (1)	- -	- -	3.3% (23)
UDWR Total	22.3% (80)	32.5% (107)	66.7% (8)	- -	- -	28.1% (197)
Other Sampling	3.6% (13)	2.4% (8)	0.0% (0)	- -	- -	3.0% (21)
Grand Total	26.0% (93)	35.0% (115)	66.7% (8)	100.0% (2)	- -	31.1% (218)

Table 4. Population estimates for juvenile Colorado pikeminnow ≥ 150 mm TL in the lower San Juan River from 2004 to 2009. Models used include the null model (Mo) and the time variable model (Mt) from Program Capture. CI represents the profile likelihood interval. CV indicates the coefficient of variation, and p-hat indicates the probability of capture.

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	0.1
	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

Table 5. Total count of fish species collected below the waterfall on the lower San Juan River from 2006 to 2009. Note: Sampling gears, sampling effort and timing of trips varied by year and influenced total catch and catch rates.

Species	Year			
	2006	2007	2008	2009
Black bullhead *(Ameiurus melas)*	3	1	0	0
Channel Catfish (*Ictalurus punctatus)*	426	1272	91	77
Colorado pikeminnow *(Ptychocheilus lucius)*	2	8	0	4
Common carp (*Cyprinus carpio)*	2	23	0	18
Flannelmouth sucker *(Catostomus latipinnis)*	92	24	6	0
Gizzard Shad *(Dorsoma cepedianum)*	2	502	1	22
Largemouth bass (*Micropterus salmoides)*	0	0	0	1
Razorback sucker *(Xyrauchen texanus)*	4	2	3	0
Red shiner *(Cyprinella lutrensis)*	0	150	6	1600
Sand shiner *(Notropis ludibundus)*	0	10	0	0
Speckled dace *(Rhinichthys osculus)*	0	2	0	0
Striped bass *(Morone saxatilis)*	0	3	0	2
Threadfin shad *(Dorosoma petenense)*	0	0	0	4
Walleye *(Sander vitreus)*	0	3	0	1
Yellow bullhead *(Ameiurus natalis)*	4	0	0	0

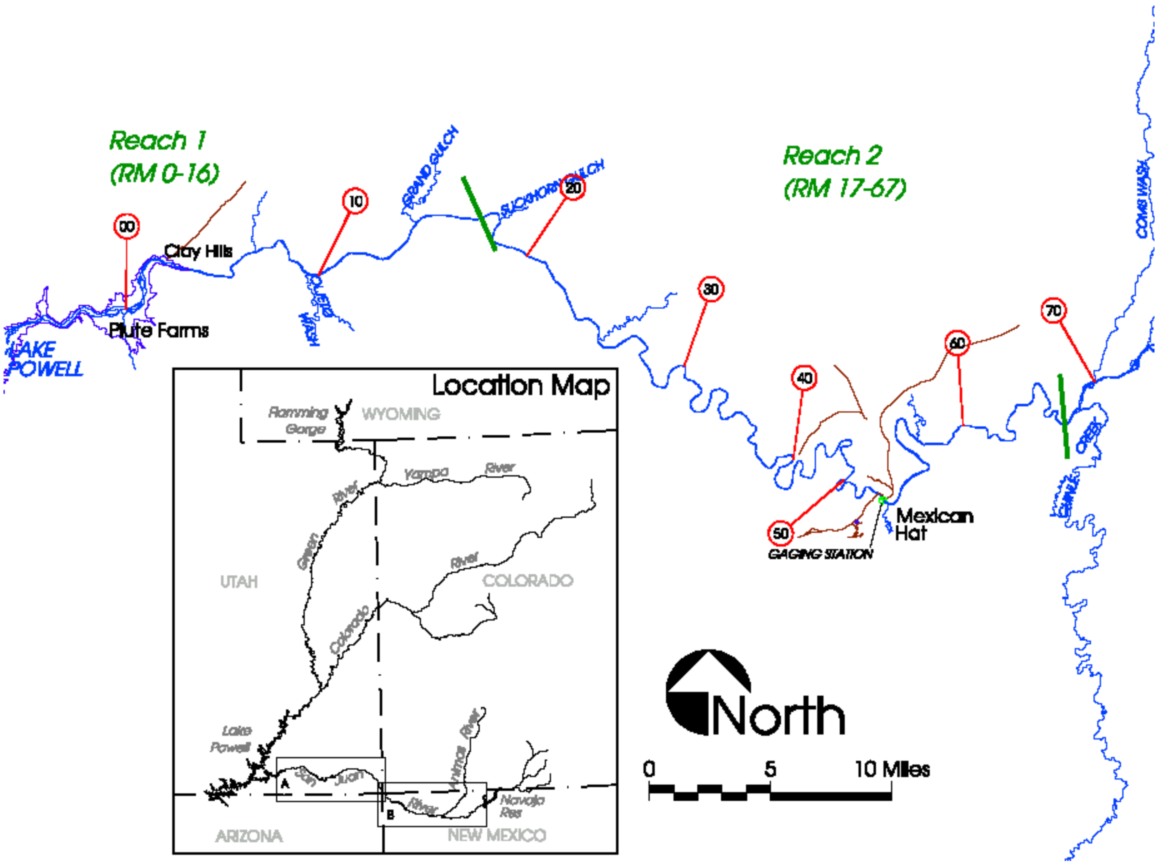

Figure 1. Map of the study area for Nonnative Control in the lower San Juan River. Sampling begins at Mexican Hat and ends at Clay Hills.

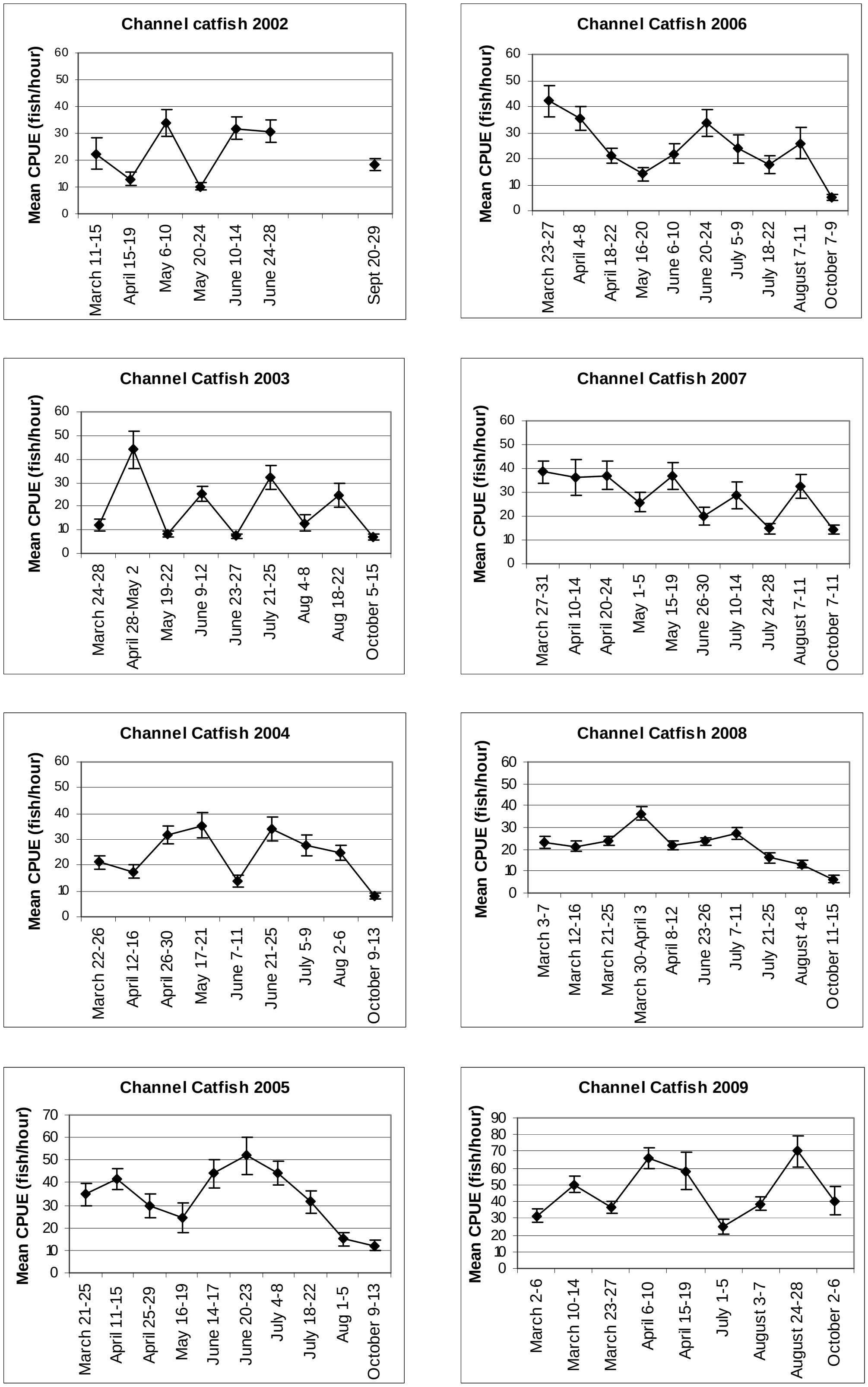

Figure 2. Mean electrofishing catch rates of channel catfish in the lower San Juan River by pass for years 2002 to 2009. Error bars represent ± 1 standard error.

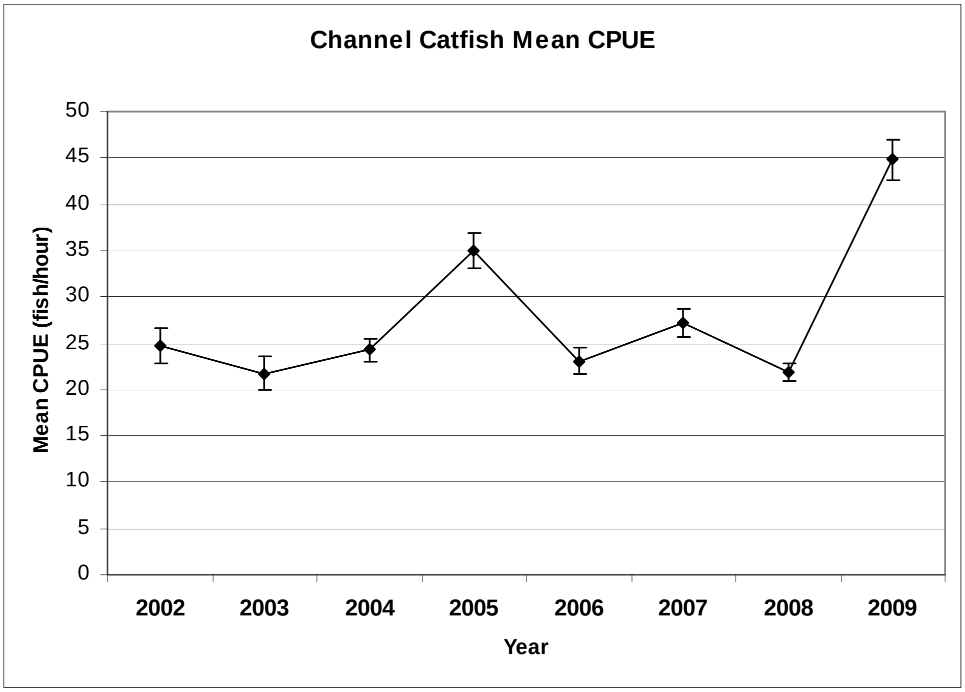

Figure 3. Mean electrofishing catch rates of channel catfish in the lower San Juan River by year. Error bars represent ± 1 standard error.

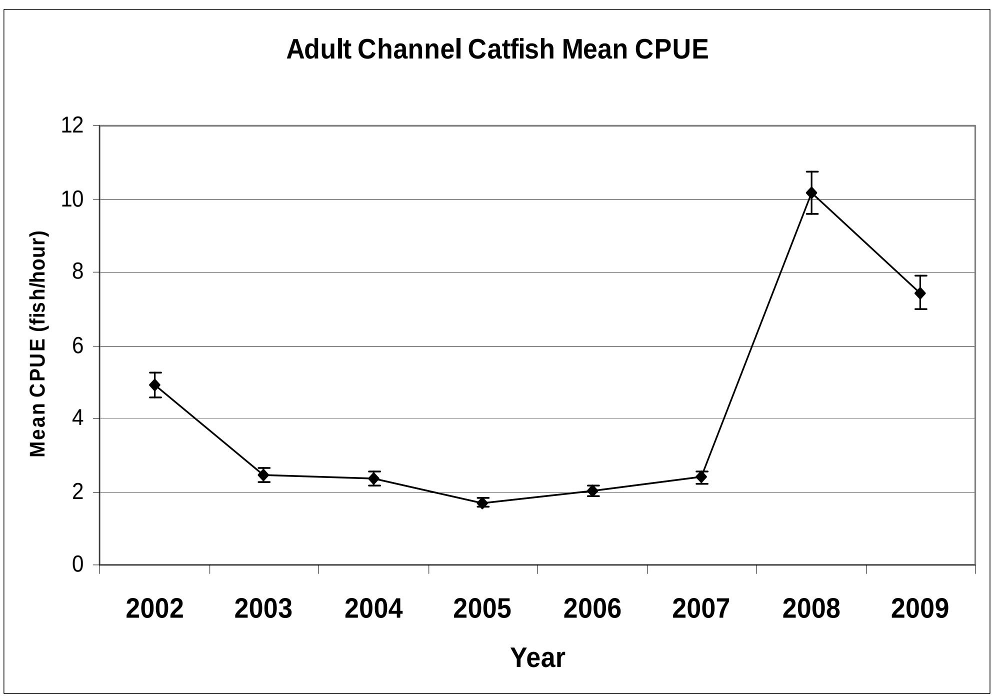

Figure 4. Mean adult (>300 mm) electrofishing catch rates of channel catfish in the lower San Juan River by year. Error bars represent ± 1 standard error.

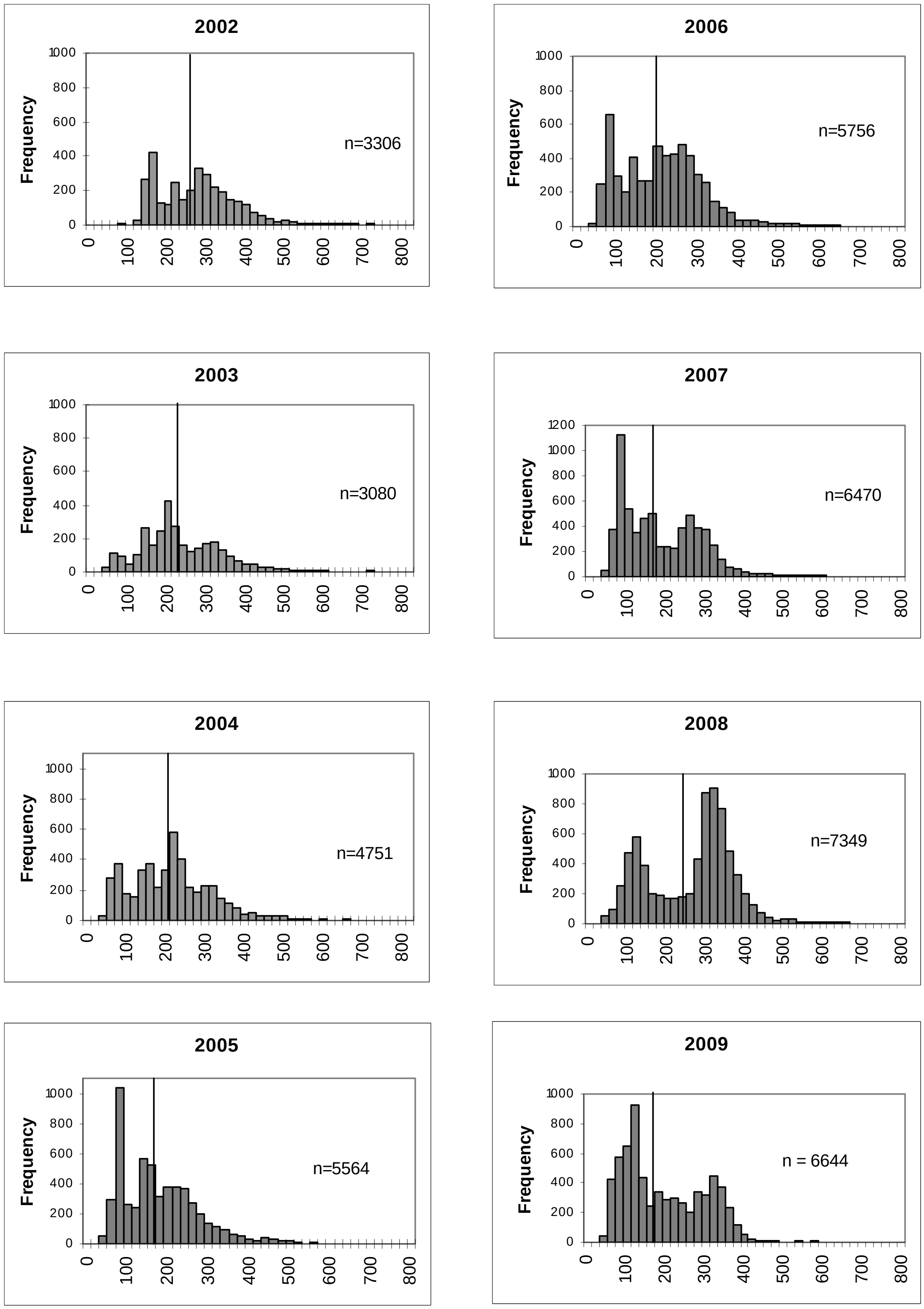

Figure 5. Length-frequency histograms of channel catfish in the lower San Juan River by year from 2002 to 2009. Vertical lines indicate mean TL by year.

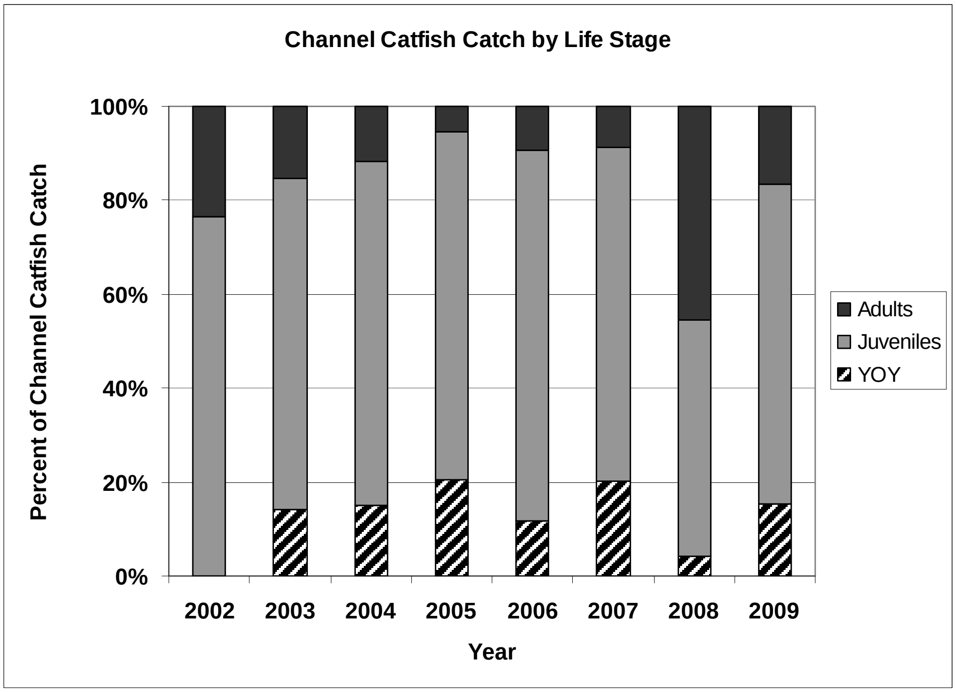

Figure 6. Percent of each life stage of channel catfish in the total channel catfish catch by year. Note: YOY and juveniles life stages were not differentiated in 2002.

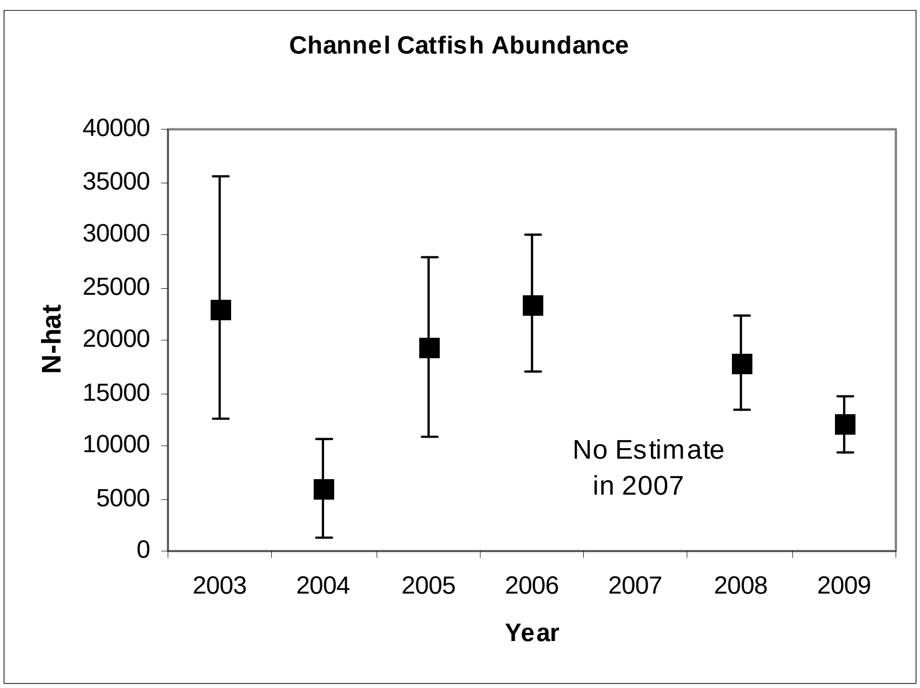

Figure 7. Abundance estimates (N-hat) of channel catfish by year in the lower San Juan River. Error bars represent 95% confidence intervals.

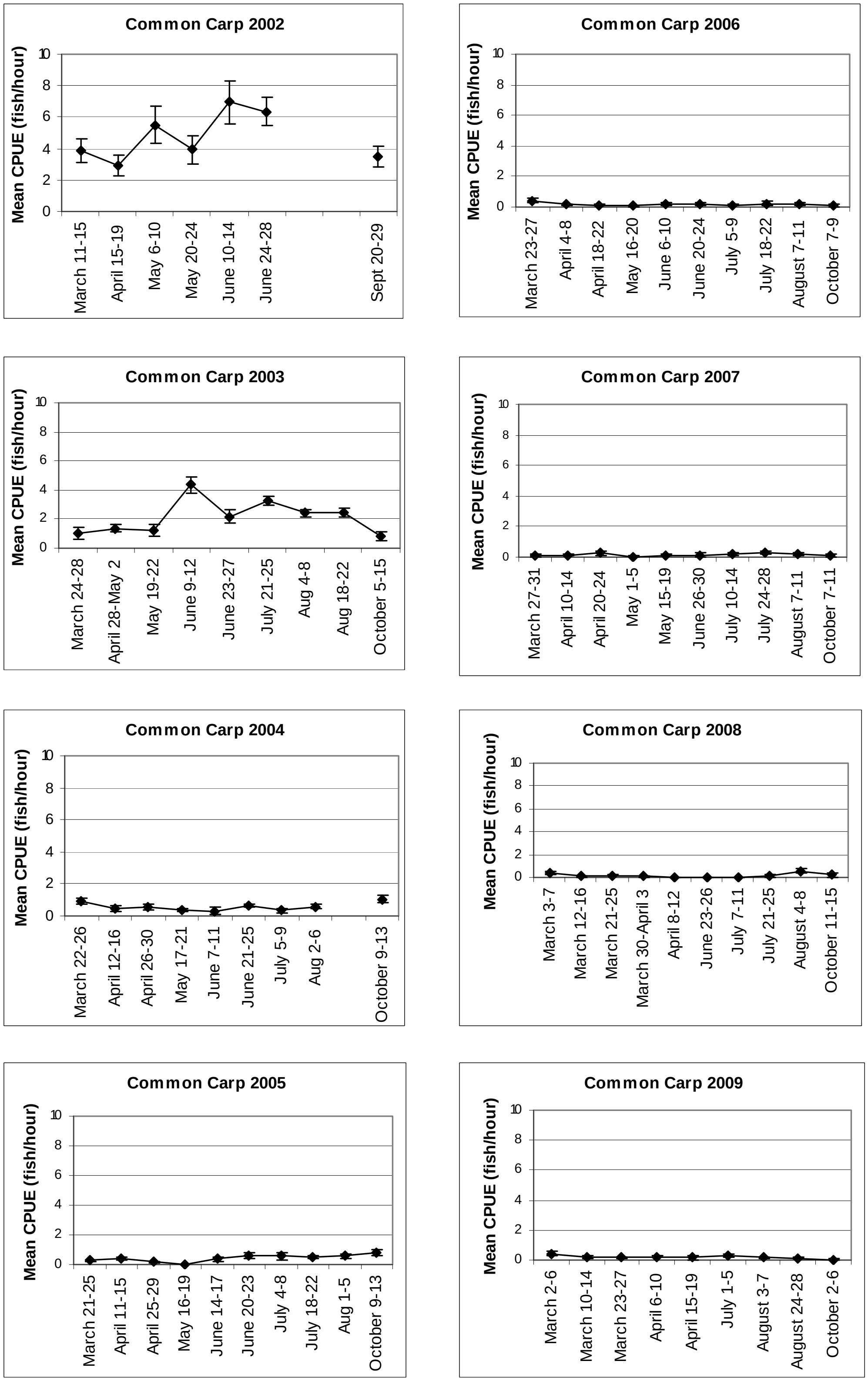

Figure 8. Mean electrofishing catch rate of common carp by pass from 2002 to 2009 in the lower San Juan River. Error bars represent + 1 standard error.

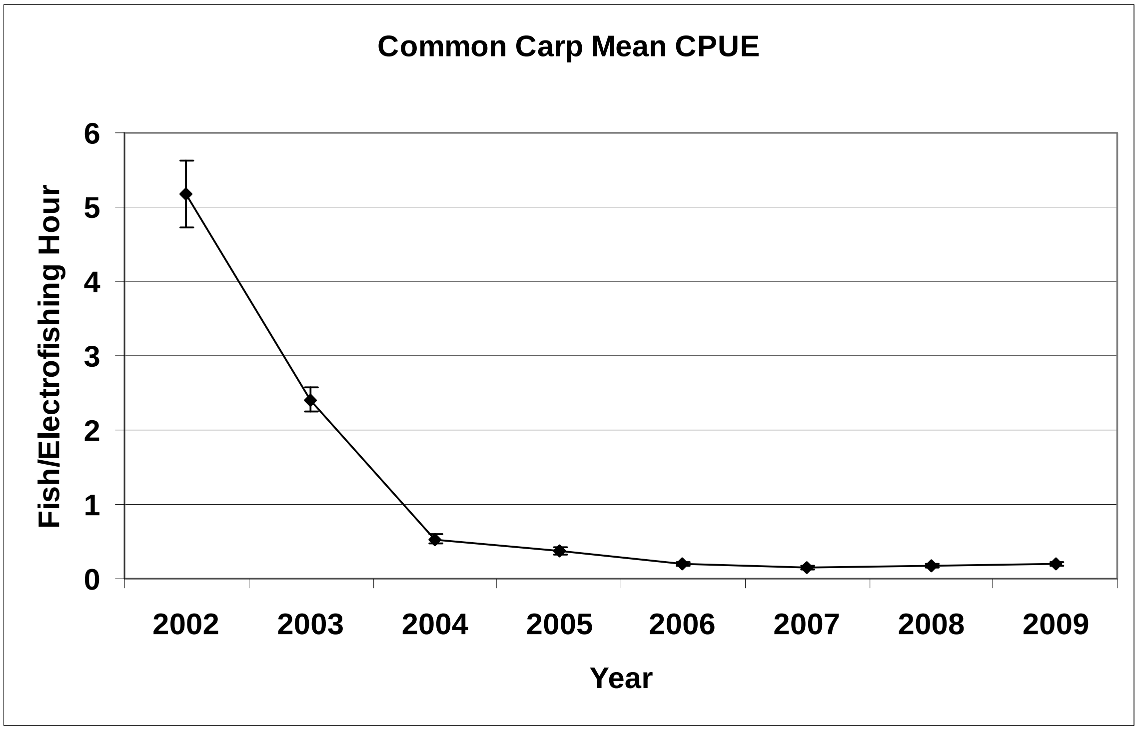

Figure 9. Mean common carp electrofishing catch rate by year from 2002 to 2009 in the lower San Juan River. Error bars represent ± 1 standard error.

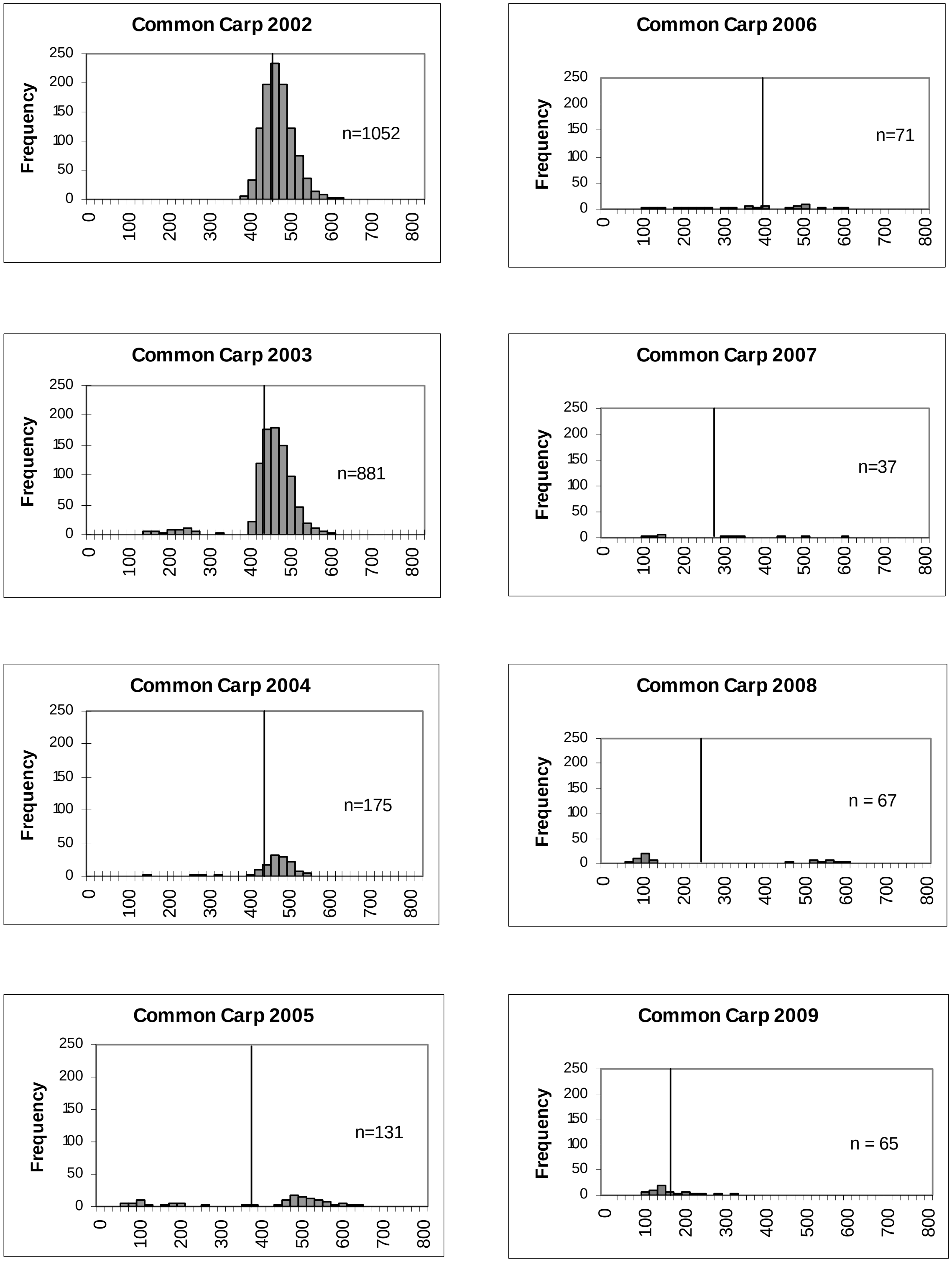

Figure 10. Length-frequency histograms of common carp in the lower San Juan River by year from 2002 to 2009. Vertical lines indicate mean TL by year.

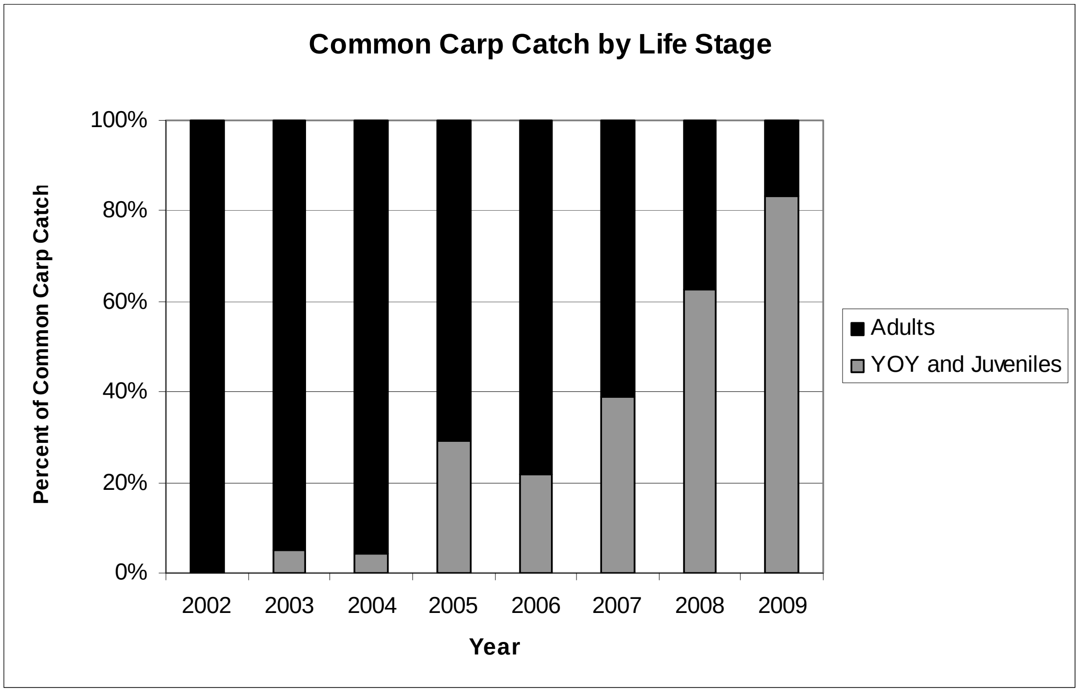

Figure 11. Percent of each life stage of common carp in the total common carp catch by year.

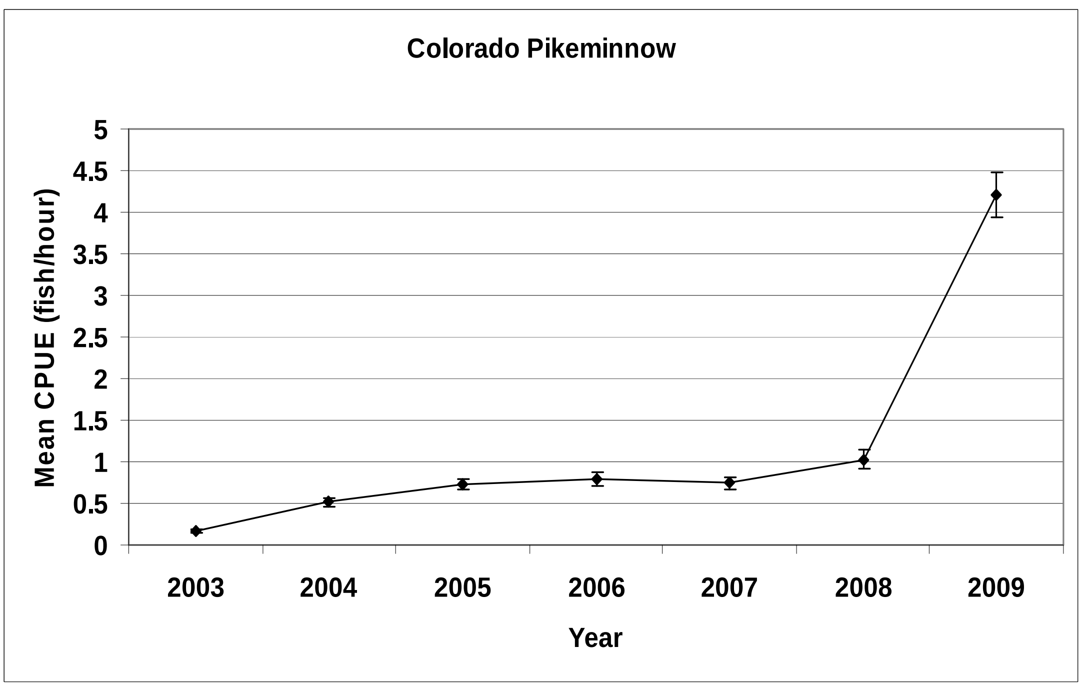

Figure 12. Mean catch rate of Colorado pikeminnow in the lower San Juan River by year from 2003 to 2009. Error bars represent ± 1 standard error.

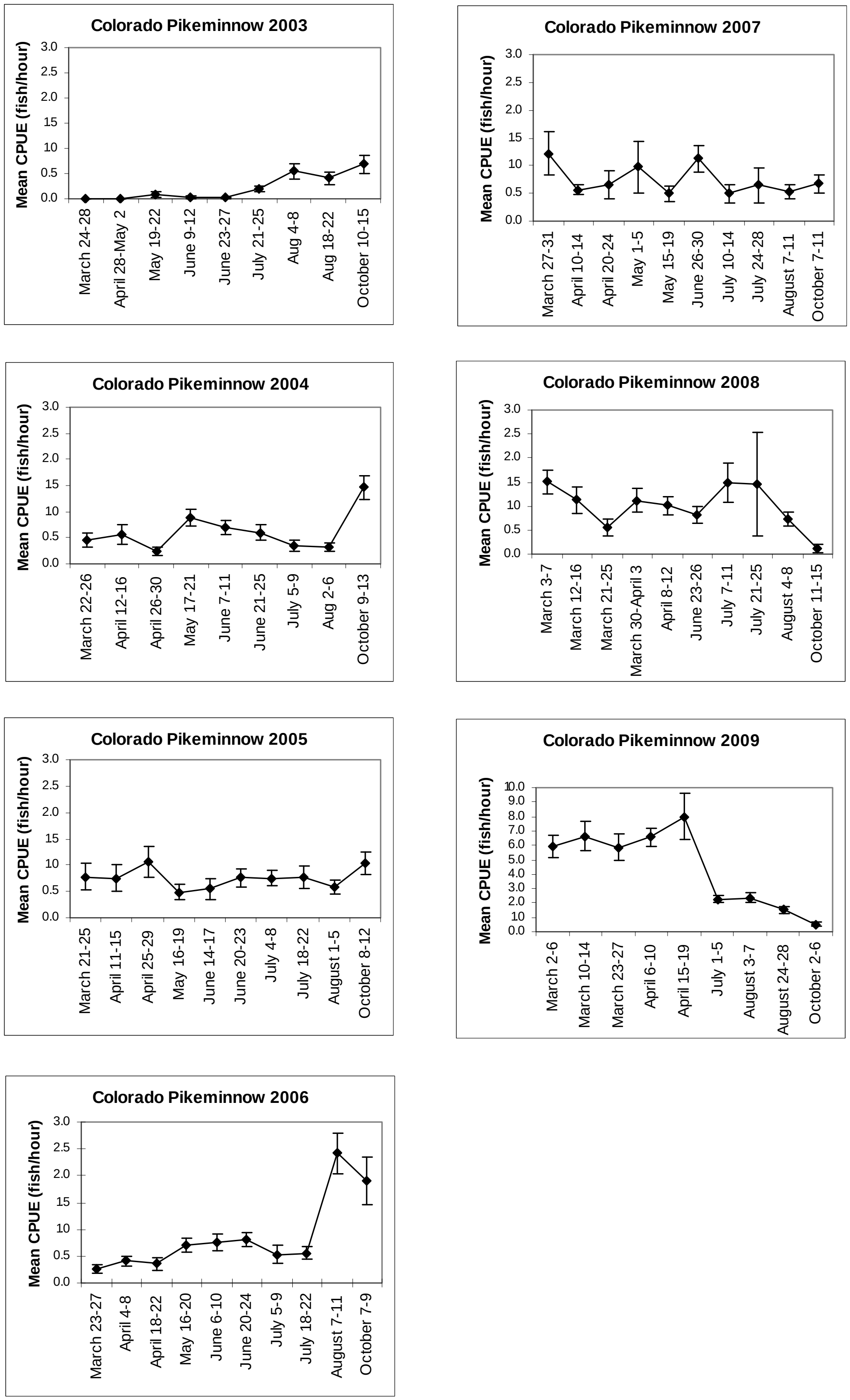

Figure 13. Mean Colorado pikeminnow electrofishing catch rate by pass from 2003 to 2009 in the lower San Juan River. Error bars represent ± 1 standard error.

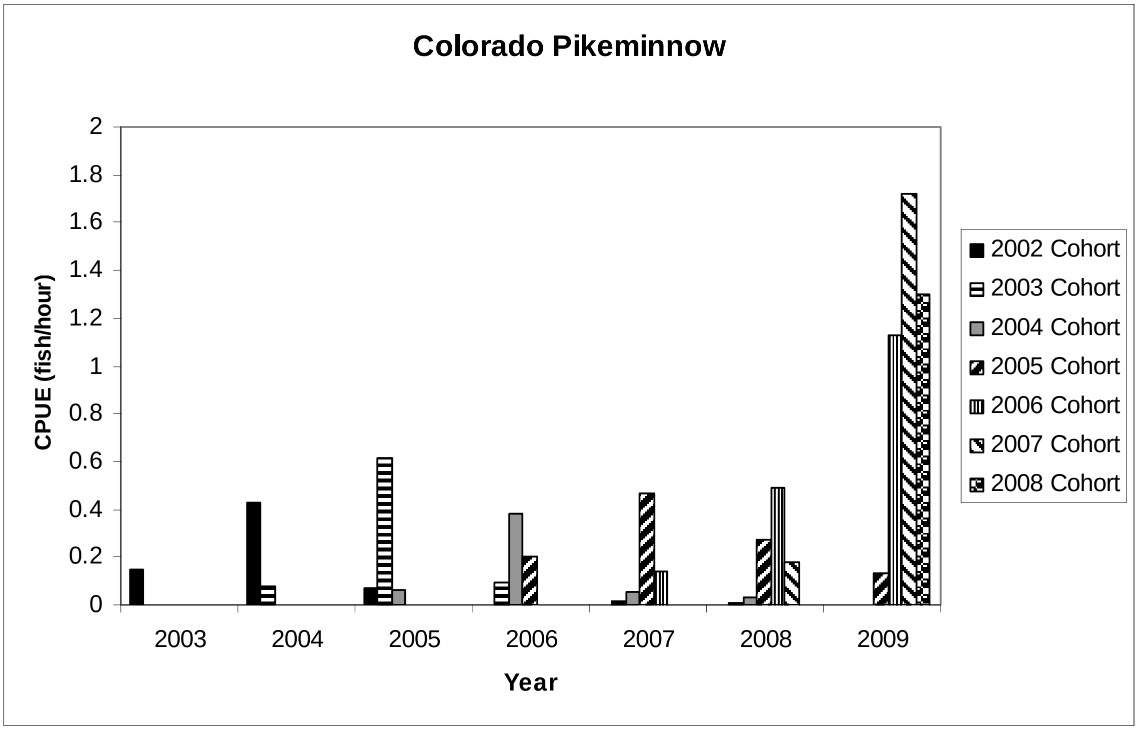

Figure 14. Colorado pikeminnow electrofishing catch rate by cohort across years from 2003 to 2009 in the lower San Juan River.

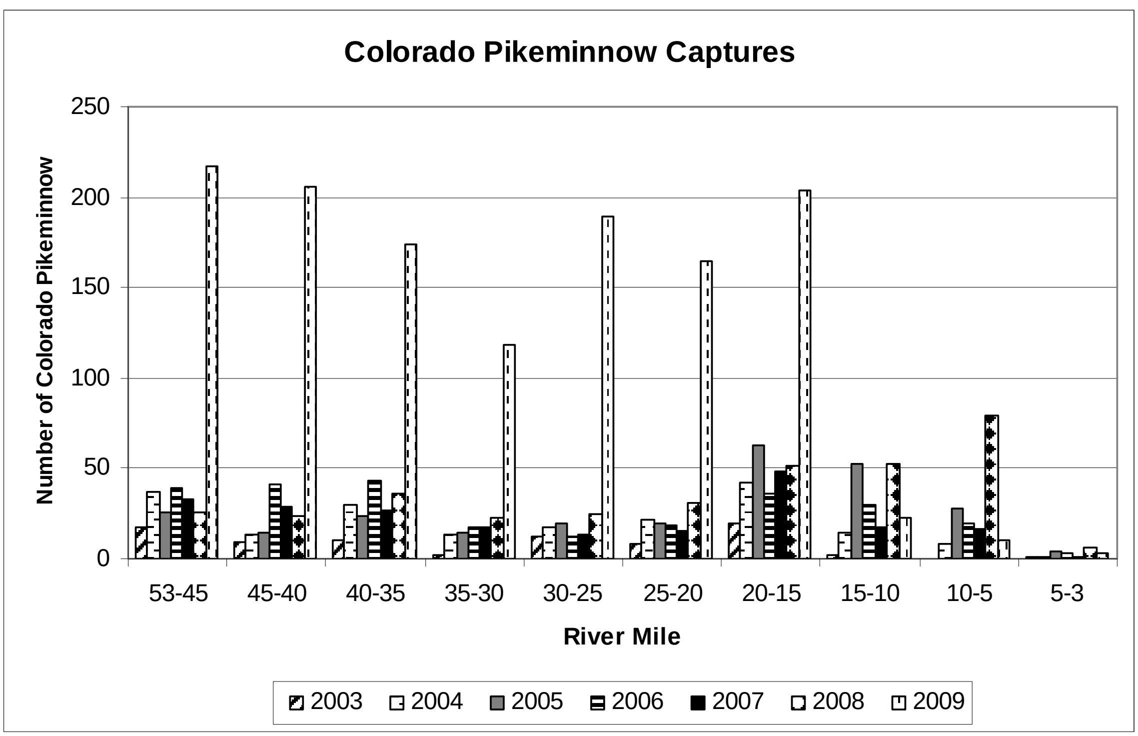

Figure 15. Distribution of Colorado pikeminnow captures by river mile from 2003 to 2009 in the lower San Juan River.

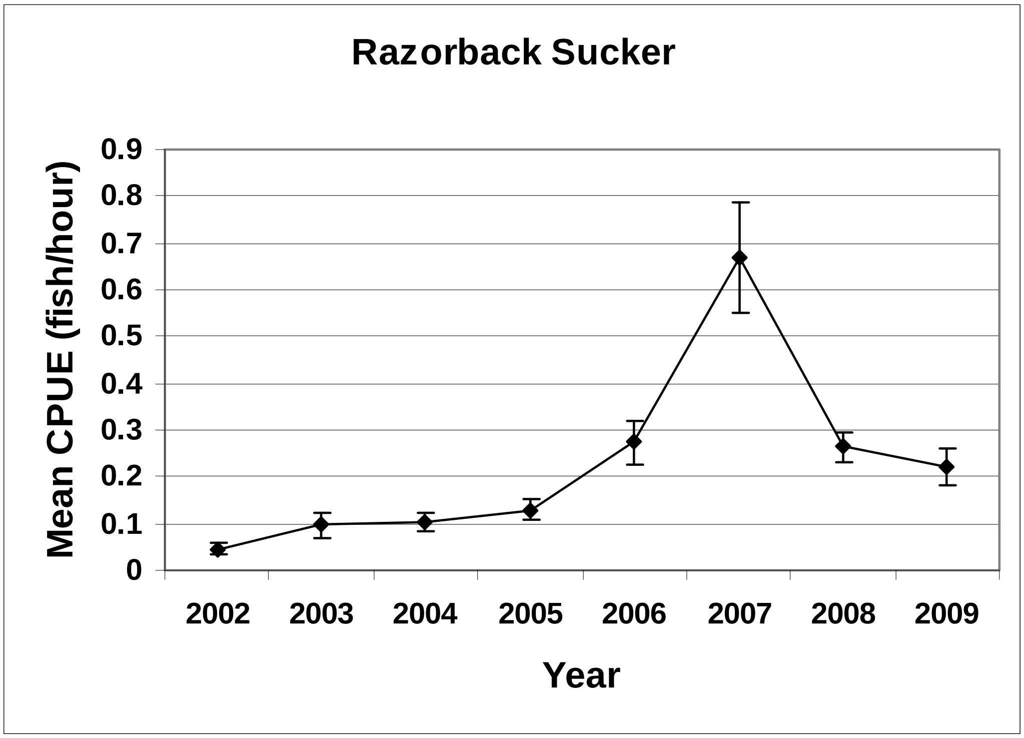

Figure 16. Mean electrofishing catch rate of razorback sucker in the lower San Juan River by year from 2002 to 2009. Error bars represent ± 1 standard error.

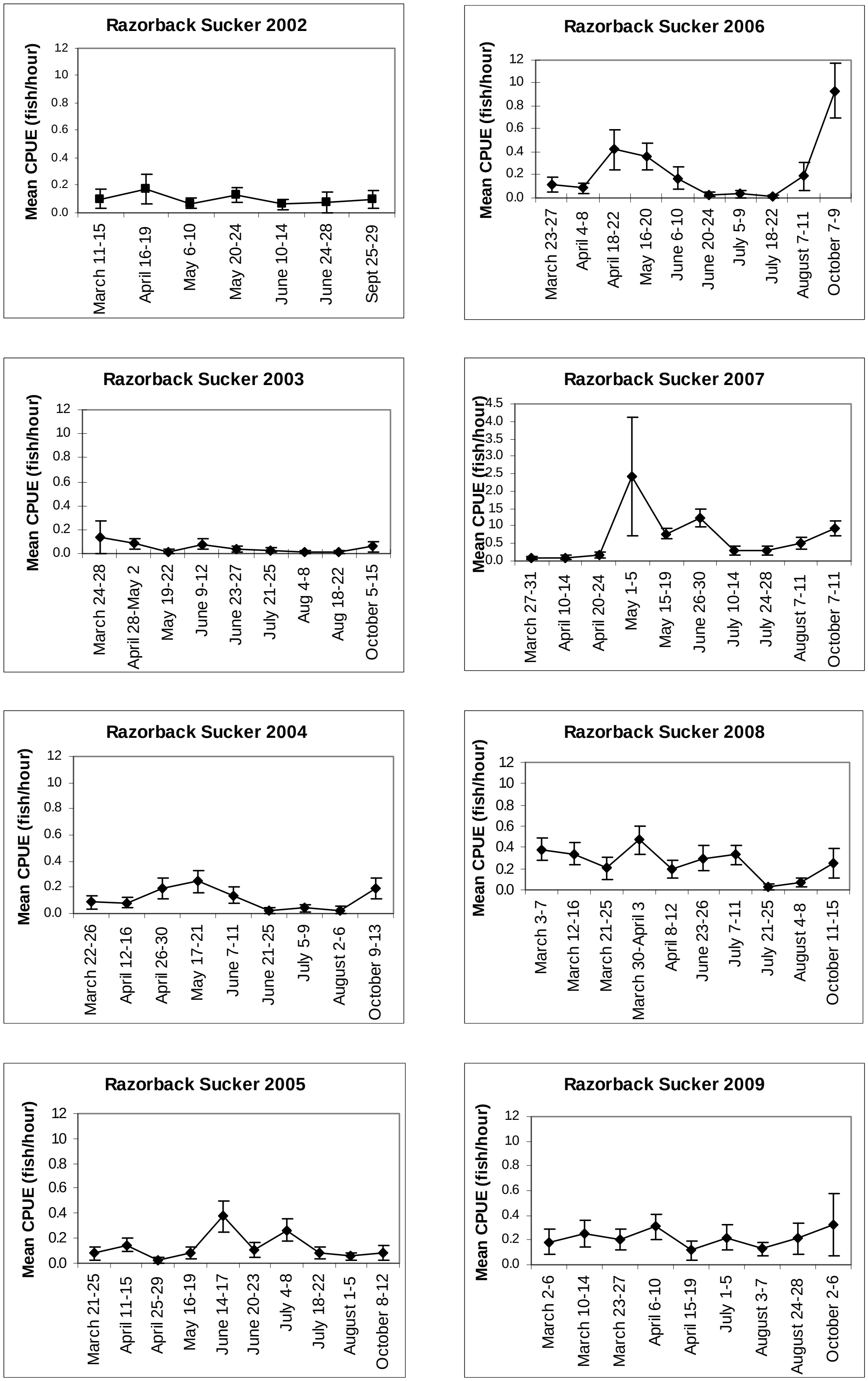

Figure 17. Mean electrofishing catch rate of razorback sucker by trip across years from 2002 to 2009 in the lower San Juan River. Note: Y-axis scale is different in 2007 graph.

Appendix A. Average daily flow, average water temperature and average turbidity (mm to Secchi disk disappearance) during sampling trips on the lower San Juan River in 2009.

Trip	Trip Date	Average Flow (ft^3/s)	Average Water Temp. (C°)	Average Turbidity (mm)
1	March 2-6	896	9.2	76
2	March 10-14	870	9.3	129
3	March 23-27	1,082	9.7	109
4	April 6-10	797	12.0	162
5	April 15-19	935	12.0	NA
6	July 1-5	1,494	24.7	66
7	August 3-7	604	26.7	86
8	August 24-28	689	24.2	205
9	October 2-6	NA	13.2	NA