Nonnative Control in the Lower San Juan River 2005

Interim Progress Report
Final

for the
San Juan River Recovery
Implementation Program

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EXECUTIVE SUMMARY

The fourth year of nonnative control in the lower San Juan River was conducted in 2005. This project was initiated to remove nonnative fish species, and to identify factors involved in the movement of striped bass (*Morone saxatilis*) and other lacustrine species out of Lake Powell and into the river. Relationships between these factors and nonnative catch rates were intended to help in the refinement of removal effort timing. Since the formation of the new waterfall at Piute Farms in 2003, channel catfish and other resident nonnative fish have been the focus of removal actions.

In 2005, nine passes were conducted, beginning in mid-March and continuing until mid-August. Results from the October adult monitoring pass, conducted by USFWS-Grand Junction (CRFP), were also incorporated in the analysis. Electrofishing was conducted from Mexican Hat to Clay Hills, UT (river mile (RM) 52.8-2.9). River flows ranged from 570-7,700 cubic feet per second (cfs) throughout sampling.

Lake Powell elevations have dropped steadily since the beginning of 2002, and have been below 1988-1995 levels (3,670 - 3,623 ft above sea level) when a waterfall was present at RM 0.5. Lake elevations averaged 3,619 ft above sea level in January 2003, and by July, lake elevations were 3,616 ft above sea level; 84 ft below full pool. A waterfall approximately 50 ft wide and 4 ft high was observed near Piute Farms (RM -0.5) in July 2003. Since no striped bass or walleye (*Sander vitreum*) had been collected or observed that year we concluded that low lake elevations, the waterfall, or a combination of both was inhibiting movement of these species up into the San Juan River. The waterfall at Piute Farms was present throughout sampling in 2005, and again no striped bass or walleye were collected. Furthermore, the waterfall had increased to approximately 15 ft high by July 2005.

The majority of nonnative species collected in 2005 were channel catfish (*Ictalurus punctatus*). Almost 11,000 of these fish were removed. Catch rates of channel catfish decreased between the first trip and the fall trip in 2005. This trend is fairly typical, and variability among trips is typically high as well. Overall, catch rates of channel catfish increased from 2002 to 2005. However, a significant decrease was observed in the size structure of channel catfish between 2002 and 2005. Abundance estimates generated for channel catfish showed little variation between 2003 and 2005.

In previous years, 2002 and 2003, common carp (*Cyprinus carpio*) were the second most abundant species collected. In 2004 and 2005, their numbers had dropped significantly. Size structure of common carp has remained similar among years, yet in 2005 more juveniles were collected than from 2002-2004. The mechanism that caused the drop in catch rates of common carp is unknown. A number of factors may be responsible, including the presence of the waterfall, low river flows, and mechanical removal of these fish. It is likely that all of these factors are responsible to some extent.

Three hundred thirty-three endangered fish were collected during 2005 sampling in the lower San Juan River. Two hundred eighty-seven were yoy and juvenile Colorado pikeminnow that had been stocked in November 2002 - 2004 near Farmington, NM. A few of these individuals were age-2 and 3 fish stocked from the Mumma Fish Hatchery in 2004 and 2005. Of the 209 juvenile Colorado pikeminnow greater than 150 mm total length (TL) collected and tagged in 2005, 24 were recaptures. Several of these fish exhibited upstream movement through the year of 10 to 35 miles, while a couple moved more than one mile downstream of their original capture location. Preliminary population estimates suggest that the number of juvenile Colorado pikeminnow occupying the lower San Juan River is approximately 550 fish with confidence intervals from 300 to 1,500, an increase from the 2004 estimate. Forty-six razorback sucker were collected in 2005, three of these fish were recaptured during the year. Two razorback sucker collected were less than 300 mm TL (174 and 180 mm TL), did not have PIT tags, and appear to be wild spawned fish. Twelve suspected razorback- flannelmouth hybrids were collected in 2005, compared to ten collected in 2004, and two collected in 2003.

In 2005, sampling was conducted at Piute Farms just below the waterfall to determine which species were present but blocked from upstream movement by the waterfall. Five trips were conducted between May and August. During the first two trips there were two additional small waterfalls downstream of the largest waterfall. These two were apparently a barrier to fish movement since the majority of fish were collected below them. By July the third barrier was gone and the second had increased in size. Three adult razorback, two juvenile Colorado pikeminnow, and one adult gizzard shad were collected below the second and third waterfalls. Channel catfish, common carp, and juvenile native suckers were collected in this area as well. All endangered fish were released upstream of the largest waterfall.

The lower San Juan River has proven to contain valuable habitat for endangered fish species and is essential to their success. Due to the increased effort of stocking of endangered fish, evidence of natural reproduction of razorback sucker and Colorado pikeminnow, and the presence of the waterfall at Piute Farms, it is extremely important to continue suppression of nonnative species by mechanical removal. Continued removal of nonnative fish in the lower San Juan River will reduce predation and competition impacts on the endangered and native fish community.

INTRODUCTION

The lower San Juan River is likely to be essential in the recovery of the Colorado pikeminnow and razorback sucker. It contains nursery habitats comparable to those existing on the Green and Colorado rivers, where wild young-of-year and juvenile Colorado pikeminnow are typically found. Within the past five years, collections of endangered fish 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 single collection of razorback sucker larvae in 2003 came from a backwater in Reach 1 at RM 8.1 (Brandenburg et al. 2004). The most recent finding from 2004 was the collection of two wild spawned Colorado pikeminnow larvae at RM 46.3 and 18.1 (Brandenburg et al. 2005). Additionally, adult razorback sucker were found congregating around Slickhorn Rapid (RM 17.7) in the spring of 2002, during this study, and were apparently using this area for spawning. 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 during this study resulted in low numbers of Colorado pikeminnow subadults and adults (246-590 mm TL), presumably from the 1996-1997 stocking efforts, using the lower canyon (Reaches 2 and 1) of the San Juan River in the spring and summer. From 2003-2005, young-of-year 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, this study).

This project was originally initiated in an attempt to target striped bass and other nonnative predatory fish species such as largemouth bass (*Micropterus salmoides*) and walleye that move from Lake Powell into the San Juan River. Striped bass became of 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 San Juan River (RM 147.9-129.0; Ryden 2001). United States Fish and Wildlife Service New Mexico Fishery Resources Office (NMFRO) 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*) and 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). During the October 2000 trip, this was further evidenced by higher numbers of flannelmouth sucker, bluehead sucker, and common carp above the PNM weir near Farmington, NM, where striped bass were not found.

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 many nonnative 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 were presumed to have invaded from the lake as well.

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 Juaquin 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. However, it had 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. In addition, 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).

In 2003, no striped bass or walleye were collected or observed. 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. At that time, a waterfall of approximately 50 ft wide and 4 ft high was discovered. It was presumed by the author that this was the direct reason none of the target species were observed in the river. 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 fish to pass and move upstream again. Since discovery of the waterfall, the focus of this project has been to suppress other nonnative fish in the lower San Juan River, as well as to track the abundance and distribution of endangered fish.

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

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 new waterfall; 2) generate a population estimate of channel catfish by mark-recapture data from Mexican Hat to Clay Hills; 3) characterize abundance of endangered fish in the San Juan River just below the waterfall; 4) characterize abundance of predators moving out of Lake Powell into the San Juan River upstream to the new waterfall; and 5) relate striped bass movement from Lake Powell into the San Juan River to lake and river conditions (including temperature, flows and turbidity).

METHODS

Study Area

The study area included 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 important nursery habitat for native and endangered fish species (Archer et al. 2000).

Sampling

Nine sampling passes were conducted on the San Juan River between Mexican Hat and Clay Hills, UT. Sampling dates were: March 21-25, April 11-15, April 25-29, May 16-19, June 14-17, June 20-23, July 4-8, July 18-22, August 1-5. Adult fall monitoring conducted by CRFP was conducted October 8-12. Raft mounted electrofishing gear was used during all trips. A Smith-Root electrofishing unit was utilized with amperage ranges set from 4-6 depending on water conditions. One boat electrofished each shoreline during sampling passes. When conditions allowed, a chase boat would follow to net fish not captured by the electrofishing boats. All nonnative and endangered species were netted, while native suckers were not (Appendix B). Collected fish were measured to the nearest millimeter (mm) and weighed to the nearest gram (g). In some instances, nonnative fish were counted and weighed in mass, or simply counted. Endangered fish received a PIT tag if one was not already present and general condition of the fish was noted. In most cases, endangered fish were released at the location of their capture. A global position system (GPS) reading and river mile where the fish was captured was recorded. Stomach contents, sex and reproductive status of lacustrine predators were recorded. All nonnative fish species were removed from the river. Channel catfish collected during the first pass (trip) received an anchor tag and were returned to the river. Channel catfish collected on subsequent passes (trips) were removed from the river. Channel catfish that were large (>400 mm TL) or had distended stomachs, had their stomach contents examined. River temperature, conductivity, and salinity were measured at least two times per trip. Turbidity 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 at Bluff, UT. Lake Powell elevations and temperatures were taken from the Lake Powell water database website.

Sampling was conducted below the waterfall at RM -0.6 from May through August. Five trips typically consisted of two days each of sampling. Angling, cast netting, seining, and trotline were used to collect fish. Endangered fish collected were measured and weighed and scanned for a PIT tag as described above. All endangered fish collected were released upstream of the waterfall. Nonnative and other native fish were noted anecdotally but were not weighed and measured.

Data Analysis

Catch per unit effort (CPUE) was calculated using the number of fish caught per hour of electrofishing. Fish that were collected by the chase boat were not included in the CPUE, but were included in length-frequency analyses and the population estimate. Approximately thirty samples were taken during each pass comprising the CPUE for every 2 to 3 miles sampled. These samples were then used to calculate the mean and associated variation. CPUE and length-frequency distributions were compared between years using non-parametric Kruskal-Wallis ANOVA along with pair-wise multiple comparisons (Dunn's Method) to examine the equality of samples. All statistical tests were performed using SigmaStat 3.0, (SPSS Inc).

A Lincoln-Peterson population estimate was generated for channel catfish ($\geq$ 200 mm) captured during the first two passes. The Lincoln-Peterson model was used for channel catfish since fish were marked with non-numerical tags, therefore precluding the ability to determine on which pass fish were originally marked. 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.

Population estimates were determined for juvenile 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 in order to lessen the likelihood of violating assumptions of the models used. Program CAPTURE was used to determine confidence intervals around the estimate, the coefficient of variation, and the probability of capture. In most cases the M_o model (null model) was used, since all capture probabilities (p-hat) remained similar among the passes. 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 wider confidence intervals. In addition, these intervals tend to give more precise confidence intervals 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. Sampling dates were: March 21-25, April 11-15, April 25-29, May 16-19, June 14-17, June 20-23, July 4-8, July 18-22, August 1-5. Adult fall monitoring conducted by CRFP was conducted October 8-12. Average river discharge from March through August was 3,571 cfs. The lowest mean daily flow was 570 cfs, which occurred during the August pass; the highest mean daily flow was 7,700 cfs during the May pass. Mean daily flow during the fall monitoring pass was 1,590 cfs. Lake Powell elevations remained low in 2005, and the waterfall that had emerged at Piute Farms in 2003, has increased to approximately 15 ft high.

Nonnative Species

A total of ten different fish species were collected in the lower San Juan River during nonnative control and adult monitoring trips in 2005. Of the most abundant species collected, two were endangered and the remaining were nonnative (Table 1). Electrofishing effort totaled 364 hours and produced approximately 11,700 fish. No striped bass or walleye were collected during the 2005 sampling effort. Channel catfish dominated the total catch with over 11,000 individuals.

Channel catfish

In 2005, catch rates of channel catfish varied significantly between passes and ranged from 12 to 51 fish per hour during each pass ($p < 0.001$; Table 2, Figure 2). Catch rates of channel catfish among years were significantly higher in 2005 than 2002-2004 ($p < 0.05$; Figure 3). Mean total length of channel catfish decreased from 268.4 mm (SD = 107) in 2002 to 171.2 mm (SD = 99) in 2005 ($p < 0.05$; Figures 4 and 5). Length-frequency histograms show that the majority of small juvenile catfish were collected primarily during the mid-summer months (Figure 6).

The Lincoln-Peterson population estimate generated for channel catfish ($\geq$ 200 mm) in 2003, from the first to the second pass was 23,075 individuals (95 % confidence intervals = 12,554-35,605). In 2004, the population estimate for channel catfish ($\geq$ 200 mm) was 5,905 individuals (95% confidence intervals = 1,210 – 10,599). In 2005, the population estimate for channel catfish was 19,414 individuals (95% confidence intervals = 10,923- 27,904; Figure 7).

Direct predation was observed in the spring and summer of 2004 when a recently stocked razorback sucker and Colorado pikeminnow were found in the stomachs of two different channel catfish. The channel catfish that had eaten the razorback sucker was 690 mm TL, while the razorback sucker measured 325 mm TL. Within the same channel catfish was a native sucker, presumably a flannelmouth sucker, which was approximately 280 mm TL. The channel catfish that had eaten the Colorado pikeminnow, was collected on June 21 and measured 416 mm TL, while the Colorado pikeminnow measured 212 mm TL at the time of stocking on June 9, 2004. No direct predation on endangered fish was observed in 2005. However, several unidentifiable suckers were found upon stomach examination of large channel catfish.

Common carp

Catch rates of common carp were variable across passes within years from 2002 to 2005 (Figure 8). In 2002 and 2003, common carp catch rates were highest in June and ranged from one to four fish per hour across all passes. From 2002 to 2004, catch rates of common carp dropped significantly ($p < 0.001$; Figure 9), and remained low in 2005. Size structure of common carp has remained similar among years, yet in 2005 more juveniles were collected than from 2002 to 2004 (Figures 10 and 11).

<u>Endangered Species</u>

Colorado pikeminnow

A total of 287 Colorado pikeminnow were collected in 2005, 62 more than were collected in 2004 (Table 1). Catch rates of Colorado pikeminnow have increased from 2003 to 2005 (Figure 12). Catch rates of all Colorado pikeminnow were highest during the Adult Monitoring pass in 2003 and 2004, and comparable to the April pass in 2005 (Table 2; Figure 13). In 2003, catch rates of age-1 fish (2002 cohort) increased considerably during the July through October passes. In 2004, even though catch rates of Colorado pikeminnow overall were higher, catch rates of age-1 fish (2003 cohort) fish were lower than those for age-1 (2002 cohort) fish the previous year. Catch rates of the age-2 (2003 cohort) were higher in 2005 than for the age-2 fish (2002 cohort) in 2004. Age-3 (2002 cohort) Colorado pikeminnow catch rates were the lowest of all size classes collected in 2005 (Figure 14).

Length-frequency histograms by pass further illustrate that the majority of juvenile Colorado pikeminnow collected in 2005 were age-2 fish stocked in November 2003 (Figure 15). In 2003, the 2002 Colorado pikeminnow cohort were not collected by electrofishing until the May pass. Conversely, age-1 Colorado pikeminnow (2003 cohort) were collected during the first pass in March 2004. In 2005, the majority of age-1 fish were collected at the end of June after runoff. Comparisons of August collections between 2003 and 2004 illustrated that the 2002 cohort (mean TL = 161(135-190) n=24) grew faster through their first summer than did the 2003 cohort (mean TL = 142 (115-153) n=9). In 2005, the 2004 cohort (mean TL = 142 (122-166) n=6) appeared to grow at a similar rate as the 2002 cohort.

In 2003, age-1 Colorado pikeminnow appeared to concentrate in two sections of river, RM 52-36 and RM 29-14, with the highest concentrations between RM 20 and 17 (Figure16). Colorado pikeminnow collected in 2004 and 2005, (age-1-3) were distributed throughout the entire sample reach, yet were still concentrated between RM 25-15.

In 2003, four age-1 Colorado pikeminnow were recaptures from previous 2003 trips. Two were found within one mile of their original capture location, while the other two had moved 5 and 20 miles downstream. In 2004, 24 of 164 individuals greater than 150 mm TL (>150 mm TL) were recaptures marked in either 2003 or 2004. Forty-two percent had moved 10-31 miles upstream, while there was no considerable downstream movement (beyond one mile). Colorado pikeminnow that were moving these extended distances upstream were between 220 and 240 mm TL. In 2005, 24 of 209 individuals >150 mm TL were recaptures. Sixty-eight percent of these recaptures moved upstream, and half of those moved 10-35 miles upstream. Thirteen percent of recaptures moved 1-6 miles downstream and eighteen percent of recaptures did not move beyond a mile of their original capture location. Colorado pikeminnow moving these extended distances were 170 mm –300 mm TL.

Preliminary population estimates could be generated for Colorado pikeminnow since many were recaptured in 2004 and 2005. Several population estimates were calculated using different passes to formulate a rough idea of population size of Colorado pikeminnow greater than 150 mm TL occupying the lower San Juan River. In 2004, estimates ranged from 160 to 315 individuals depending on the model and the number of passes chosen. The coefficient of variation around the highest estimate (315) was 22 % using passes 1-5 and the null model. While passes 4-6 had the highest probability of capture (13%) and a coefficient of variation of 27%. In 2005, estimates were approximately double those generated in 2004. Estimates ranged from 536-696 individuals depending on the model and number of passes chosen. The coefficient of variation around the highest 2005 estimate was (696) 24% using passes 1-6 and the time variable model. Passes 1-3 and 1-4 had the highest probabilities of capture (6% for both) and a coefficient of variation of 37% and 30%, respectively (Table 3).

Captures of adult Colorado pikeminnow have diminished since this project began in 2002. No adult Colorado pikeminnow were collected in 2005. During the first year, six Colorado pikeminnow were collected. One of these was a juvenile at 246 mm TL, the other five were adults ranging from 460 mm to 539 mm TL. 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 stocking events from 1996 and 1997.

Razorback sucker

Forty-six razorback sucker were collected in 2005 throughout the lower San Juan River (Table 1). The majority of razorback sucker were recaptures from previous stockings. Catch rates for razorback sucker tended to be highest in the summer, in contrast from previous years in which they were highest in spring and fall (Figure 18). As from 2002-2004, most razorback sucker collected in 2005 were within a few miles of Slickhorn Rapid (RM 17.7), but high concentrations, observed in April 2002, have not been repeated. Razorback sucker were collected throughout the lower reach. In 2003 and 2004, six juvenile razorback suckers were collected (including one collected during 2003 adult monitoring), and two in 2005. It is presumed that the stocked adult razorback suckers spawned these juveniles. These fish ranged from 120 mm TL to 280 mm TL. Twelve suspected razorback- flannelmouth hybrids were collected in 2005, compared to ten collected in 2004, and two collected in 2003. The lengths of the hybrids ranged from 271-306 mm TL. Fin clips were taken on a portion of these fish for genetic analysis.

Waterfall

Trips were conducted on May 5, June 27, July 13, July 28, and August 24. During the first trip in May, three waterfalls were present; the most downstream waterfall was about 2/10 of a mile below the primary and largest waterfall (RM –0.6). This third waterfall was clearly acting as a barrier to fish movement, since most fish were caught at the base and downstream. By the second trip in June, the third waterfall was gone, while the second had grown larger. By July, the second waterfall was a barrier to fish movement and most fish were collected below.

Native, nonnative and endangered fish were collected at the waterfall in 2005. Channel catfish, common carp, and native suckers were captured on almost every trip. All endangered fish collected were released upstream of the primary waterfall. During the May trip, two juvenile Colorado pikeminnow were collected by seine below the third waterfall. During the July 28 trip, notable fish collected were one adult razorback sucker and one adult gizzard shad. Both of these fish were collected in a pool just below the second waterfall by cast net. During the last trip in August, notable fish collected were two adult razorback sucker collected in the same location as the previous trip and by cast net.

DISCUSSION

In 2005, the waterfall persisted and was a barrier to upstream movement of fish from Lake Powell. Lake Powell elevations rose from last year but remained far below full pool and below elevations that would inundate the waterfall. At the time of this report, Lake Powell's elevation was 3589 ft., approximately 110 ft below full pool.

Over 11,000 channel catfish and approximately 170 common carp were mechanically removed. The increase in channel catfish catch rate in 2005 may be attributable to a variety of factors. First, removal of the larger channel catfish may be providing more opportunity for smaller channel catfish to persist. Second, high flows during the approximately half of the sampling trips in 2005 may have resulted in netters " blind sweeping" (i.e. dragging net through the water where fish are expected) when larger fish were not apparent. This method tends to result in capturing small juvenile channel catfish. To further back this hypothesis, on subsequent passes after fish were marked, recaptures of marked channel catfish were low until the July trip when 8 fish were recaptured. Flows at this time had returned to pre run-off levels, therefore making it easier to capture larger fish. The decrease in channel catfish TL in 2005 was probably affected by the flow to some extent. However, based on the 2002-2004 data and the other nonnative control and adult monitoring findings, it is likely the effect of flow was minimal.

Overall, the decrease in the mean TL of channel catfish is encouraging; it does appear that our efforts are generating a shift in the population size structure to smaller individuals. The significant decline in catch rates of common carp is equally encouraging. However, it is unclear if this decline is directly related to removal efforts, the presence of the waterfall, or the low water conditions that have been present over the period of this project. It is probable that a combination of these factors is causative to some extent. The continuation of removal efforts for both these species will aid in the illumination of contributory factors and the evaluation of the success of this project and similar nonnative control efforts.

Population estimates generated for channel catfish in the last three years are cursory, and may not reflect the actual population size in the lower San Juan River. The ratios of captures and recaptures of channel catfish on subsequent passes illustrates the large variability in the efficacy of capturing channel catfish based on flow, turbidity, netter ability, and possibly other unknown factors. These ratios also suggest that large numbers of fish are moving into the removal section from upstream reaches. Using the first two passes, which are typically conducted within one month, reduces the likelihood of large immigration and emigration. Channel catfish that are tagged in the section of river near Farmington, NM where NMFRO conducts mechanical removal are often collected during our sampling, exemplifying the long distances these fish move. 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. Even though these factors exist, mark-recapture population estimates will continue for channel catfish at the beginning of each year. With the expansion of nonnative removal upstream, as proposed for 2006, influx from these areas should be reduced.

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 greater than 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 are being observed further upstream (Davis 2005) and on a river-wide scale (Ryden 2005), 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. It is anticipated that once a reliable population estimate is obtained, we can estimate the exploitation rate of our removal on the channel catfish population. Estimates at the beginning of each year, once riverwide removal is incorporated, may help to evaluate removal effectiveness.

Over the course of this project, important information has also been obtained on endangered fish. We have observed the apparent spawning aggregation of razorback sucker in spring 2002 at Slickhorn Rapid; documented the distribution and abundance of Colorado pikeminnow stocked in 2002 -2004; generated preliminary population estimates for juvenile Colorado pikeminnow in 2004 and 2005; and documented the first cases of channel catfish predation on stocked juvenile razorback sucker and Colorado pikeminnow in the San Juan River.

The increases in catch rates of juvenile Colorado pikeminnow in the lower San Juan River from 2003 to 2005 are correlated with the stocking of yoy fish each year. From our collections, it is evident that once the fish approach 150 mm TL, they are more likely to be captured by electrofishing. In 2004 and 2005, age-2 fish made up the majority of the catch. Age-3 fish were not as common as one would suspect based on last years (2004) catch of this cohort. It has been observed in the past that Colorado pikeminnow in this size class fall out of the collections, as was the case after the 1996-1998 stocking events. 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.

The catch of adult Colorado pikeminnow has declined over the period of this study (2002-2005). 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. 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. The largest Colorado pikeminnow collected in recent years in the San Juan River was 590 mm TL; therefore it is likely that Colorado pikeminnow in the lower San Juan River are escaping capture to some extent.

Sampling at the base of the waterfall in 2005 found that both endangered and nonnative fish are blocked to upstream movement. It is possible that the larger pikeminnow that were collected in 2002-2004 have moved below that waterfall and can not return upstream. However, we could not directly determine this since no adults were caught at the waterfall. Future sampling at this location may eventually provide data to support this assumption. With the collection of the adult gizzard shad it is evident that the waterfall is performing an important function in preventing yet another nonnative species from invading the lower San Juan River.

Population estimates generated for stocked juvenile Colorado pikeminnow, although preliminary at this point, provide a foundation for future estimates. In 2004, Colorado pikeminnow were found moving extended distances during the summer months, the population estimates constructed at that time (passes 4-6 and 5-8) may be biased if the closure assumption was violated. An estimate with the shortest time between passes, either in the spring or fall is likely to be the most reliable estimate. Comparisons of estimates in 2004, showed the difference to be negligible. In 2005, spring estimates appeared to be the most precise, with the lowest variation coefficients. Large-scale movements were again seen during the summer months suggesting estimates conducted during this time are biased.

While the shift in size structure of channel catfish is encouraging, and may eventually lead to decreased average fecundity and a reduction of the overall population, the risk to Colorado pikeminnow is unknown. 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. The expectation is that Colorado pikeminnow will choose flannelmouth sucker and bluehead sucker over channel catfish, especially when these prey are more abundant.

CONCLUSIONS AND RECOMMENDATIONS

- No striped bass or walleye were collected in 2005. This finding is directly related to the presence of the waterfall at Piute Farms. Sampling at the base of the waterfall should continue in 2006 to determine if striped bass and walleye are moving from the lake up to the waterfall. From this information an assessment may be made on the conditions present in the lake and river that affect these upstream movements, so that these movements can be predicted and removal actions taken accordingly. Furthermore, the barrier is preventing other nonnative fish species (such as channel catfish, common carp, and largemouth bass) from moving up into the river. Since it is probable that the waterfall will persist for several years, channel catfish, common carp and largemouth bass already existing in the river should be considered the primary target species for removal actions. Continued removal of these species in the lower San Juan River will aid in relieving the pressure applied by these species on native and endangered fish, and compliment removal efforts being conducted further upstream.

- Channel catfish catch rates from 2002 to 2005 increased, while the size structure has shifted to smaller individuals. Population estimates of channel catfish remained similar from 2003 to 2005; however, large confidence intervals indicate poor precision of these estimates. Channel catfish movement from Lake Powell and the river below the waterfall has been eliminated, while movement from upstream reaches continues. Expansion of nonnative control, as proposed for 2006, into the upstream reach may aid in alleviating some immigration from that reach into the estimate reach. Channel catfish should continue to be marked during the first pass in order to determine relative population size at the beginning of each removal year. From these population estimates, estimates of exploitation rates may eventually be attained.

- Catch rates of common carp have decreased significantly from 2002 to 2005, while the size structure has remained relatively unchanged. However, some smaller individuals were collected in the last two years. The cause of the decreasing trend in catch rate for these fish is unknown. Several factors may be acting synergistically: 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 fish.

- Catch rates of juvenile Colorado pikeminnow increased from 2003 to 2005. Mean total length of juvenile Colorado pikeminnow similarly has increased. In 2004 and 2005, the majority of captures were age-2 fish. Preliminary population estimates of juvenile Colorado pikeminnow (>150 mm TL) in the lower San Juan River were approximately 200 with a range of 100 to 500 in 2004 and increased in 2005 to approximately 550 individuals with a range of 300 to 1,500. Population estimates of juvenile Colorado pikeminnow in the lower San Juan River should continue.

- The occurrence of adult Colorado pikeminnow in the lower San Juan River has dropped from 2002 to 2005; the reasons for this are unknown. Electrofishing in the lower San Juan River should continue to attempt to capture these fish. In addition, sampling should continue at the base of the waterfall at Piute Farms in order to determine if Colorado pikeminnow are below the waterfall and unable to move upstream. Captures of juvenile razorback sucker were first documented in 2003 and continued into 2005; catch of hybrid razorback sucker have increased as well. Fin clips of potential hybrids should be taken whenever possible.

- This project has provided valuable information on the success of endangered fish in the lower San Juan River. Endangered species abundance, growth, and movement in the lower San Juan River should continue to be documented in conjunction with nonnative removal.

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Table 1. Total count of most abundant fish species collected during Nonnative Control and Adult Monitoring in the lower San Juan River in 2005.

Trip	Ptyluc	Xyrtex	Ictpun	Cypcar	Micsal	Amemel
March 21-25	33	5	1414	11	0	10
April 11-15	38	6	1595	16	0	12
April 25-29	39	1	836	7	0	2
May 16-19	14	3	517	5	0	5
June 14-17	16	9	1208	15	0	9
June 20-23	31	3	1555	24	0	15
July 4-8	33	10	1689	20	1	5
July 18-22	32	4	1326	22	2	16
August 1-5	26	3	660	24	8	6
October 8-11	25	2	277	22	0	3
Totals	287	46	11119	166	11	83

Table 2. Mean CPUE of most abundant fish species collected during Nonnative Control and Adult Monitoring in the lower San Juan River in 2005.

Trip	Ptyluc	Xyrtex	Ictpun	Cypcar	Micsal	Amemel
March 21-25	0.78	0.08	34.86	0.25	0	0.15
April 11-15	0.75	0.14	41.60	0.38	0	0.25
April 25-29	1.05	0.02	29.79	0.15	0	0.04
May 16-19	0.48	0.08	24.47	0.11	0	0.16
June 14-17	0.55	0.37	43.9	0.53	0	0.20
June 20-23	0.75	0.11	51.8	0.62	0	0.38
July 4-8	0.75	0.26	44.3	0.56	0.03	0.12
July 18-22	0.76	0.08	31.43	0.50	0.04	0.36
August 1-5	0.58	0.05	14.96	0.52	0.18	0.11
October 8-11	1.03	0.08	12.09	0.82	0	0.08

Table 3. Population estimates for juvenile Colorado pikeminnow greater than 150 mm TL in the lower San Juan River during 2004 and 2005. Models used include the null model (Mo) and 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

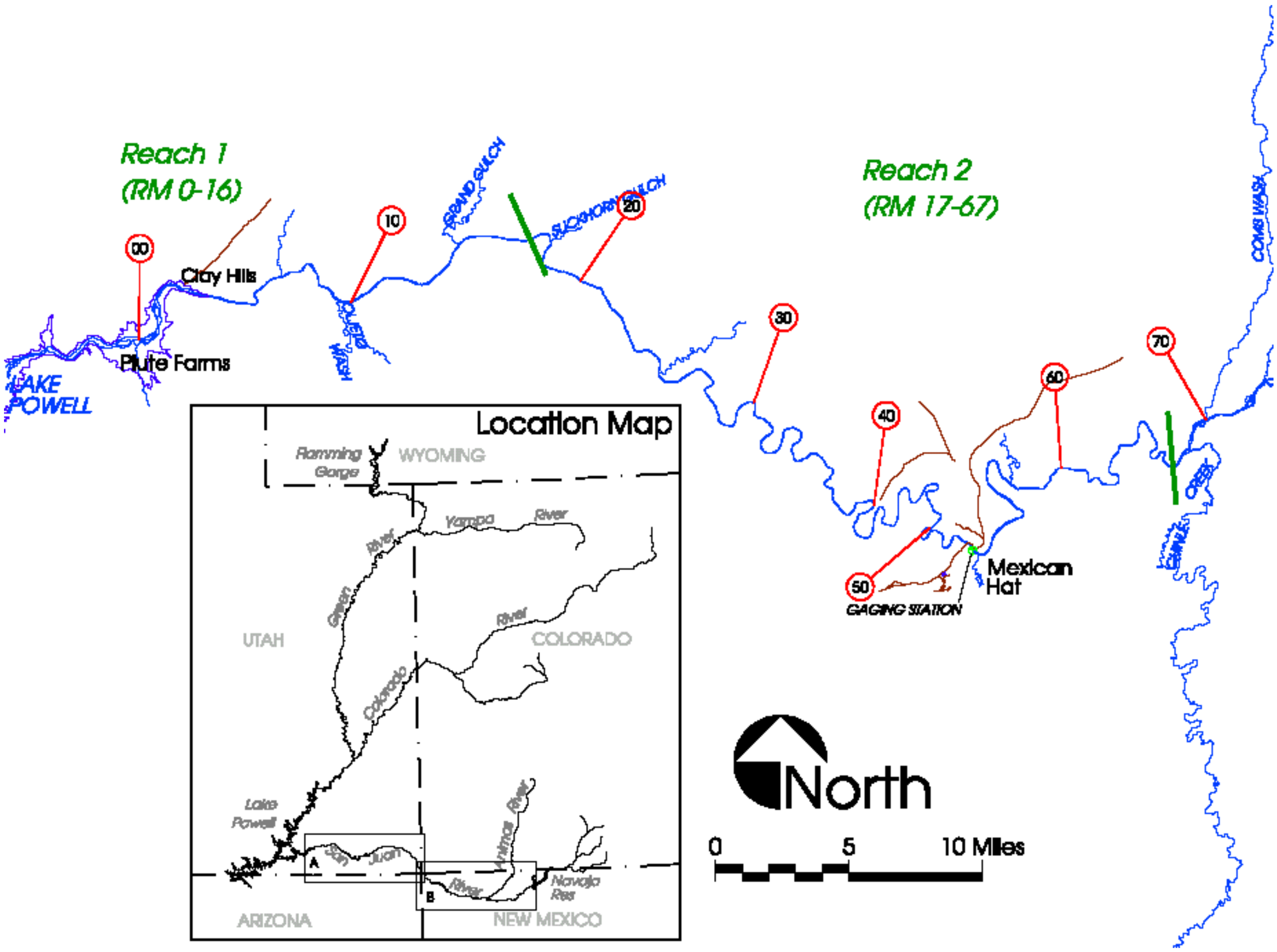


Figure 1. Map of the study area for Nonnative Control in the lower San Juan River. Sampling begins at Mexican Hat and ends at Clay Hills.

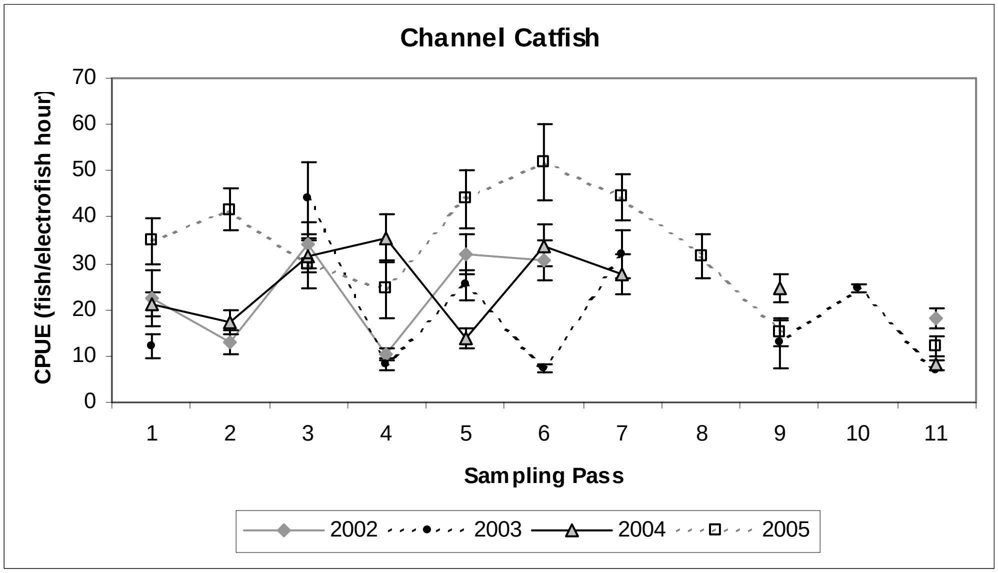


Figure 2. Channel catfish catch rates across passes from 2002 to 2005 Nonnative Control and Adult Monitoring in the lower San Juan River. Error bars represent ± 1 standard error. Note: Numbers on x-axis represent similar times of the year that sampling was conducted from 2002 to 2005 (1: March 11-28, 2: April 11-19, 3: April 25- May 10, 4: May 16-24, 5: June 7-17, 6: June 20-28, 7: July 4-9, 8: July 18-25, 9: August 1-8, 10: August 18-22, 11: September 20- October 15).

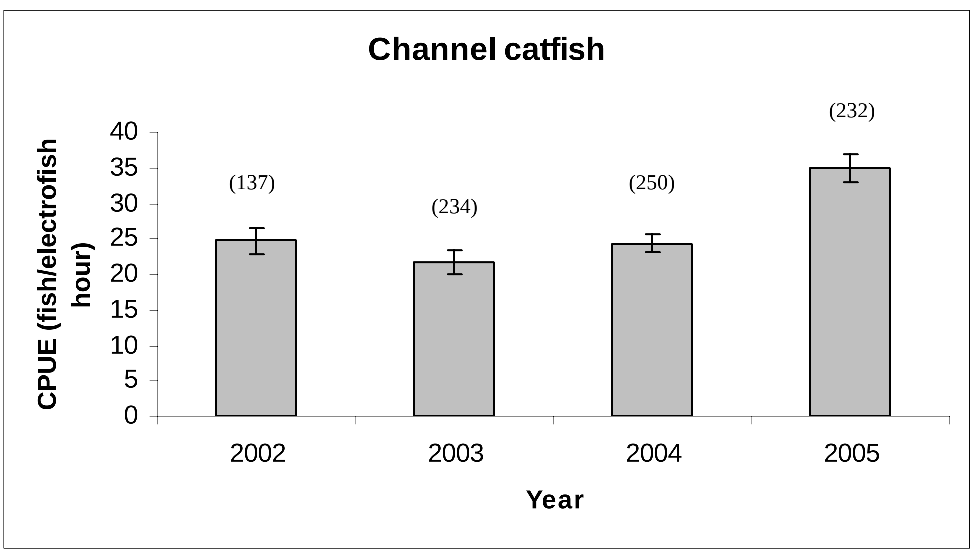


Figure 3. Mean catch rate of channel catfish from 2002 to 2005 during Nonnative Control in the lower San Juan River. Error bars represent ± 1 standard error and sample size presented parenthetically.

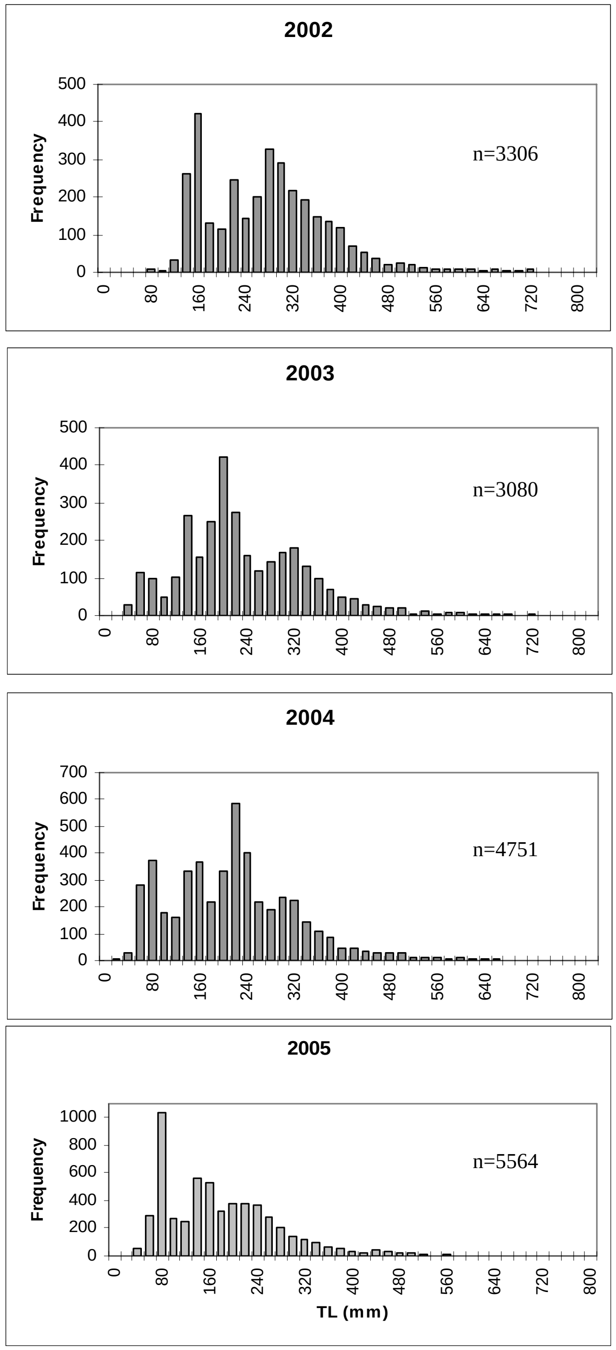


Figure 4. Length-frequency histograms of channel catfish from 2002 to 2005 during Nonnative Control in the lower San Juan River.

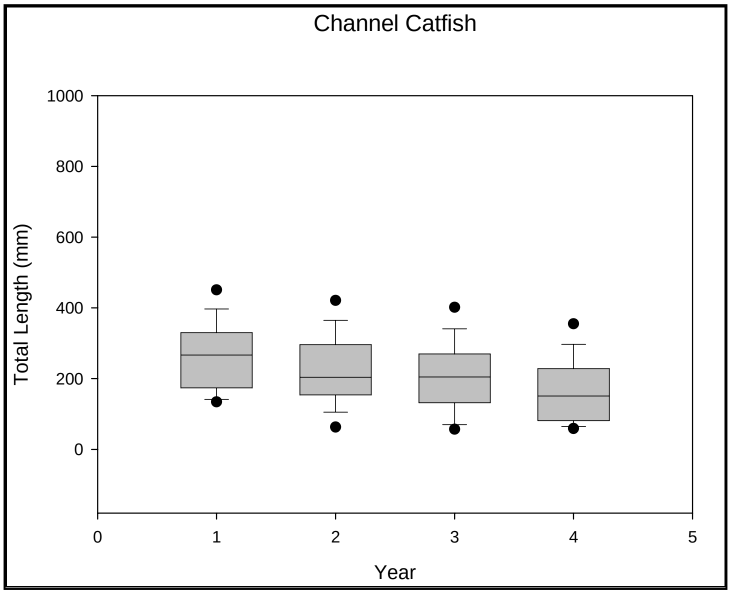


Figure 5. Mean total length of channel catfish during each year of the Nonnative Control in the lower San Juan River (Year 1: 2002, Year 2: 2003, Year 3: 2004, Year 4: 2005). Bars represent 5th and 95th percentiles, dots represent outliers.

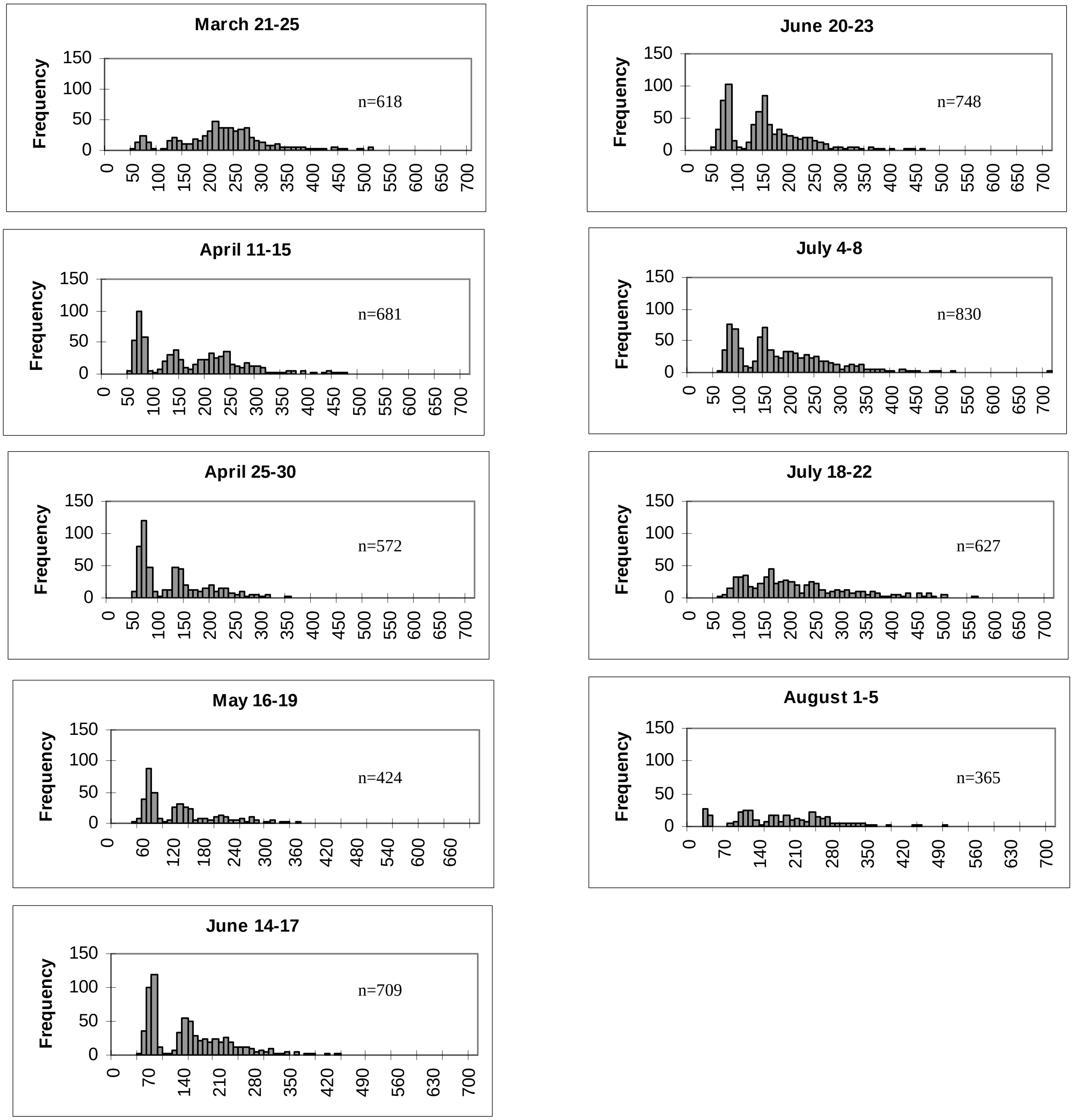


Figure 6. Length-frequency histograms of channel catfish collected by month during Nonnative Control in the lower San Juan River in 2005.

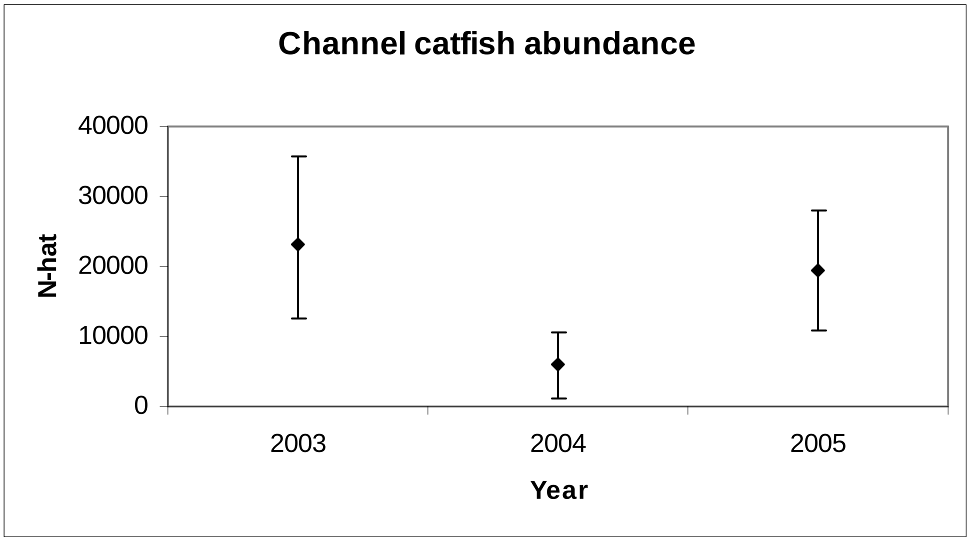


Figure 7 . Abundance estimates (N-hat) of channel catfish during each year of the Nonnative Control in the lower San Juan River. Error bars represent 95% confidence intervals.

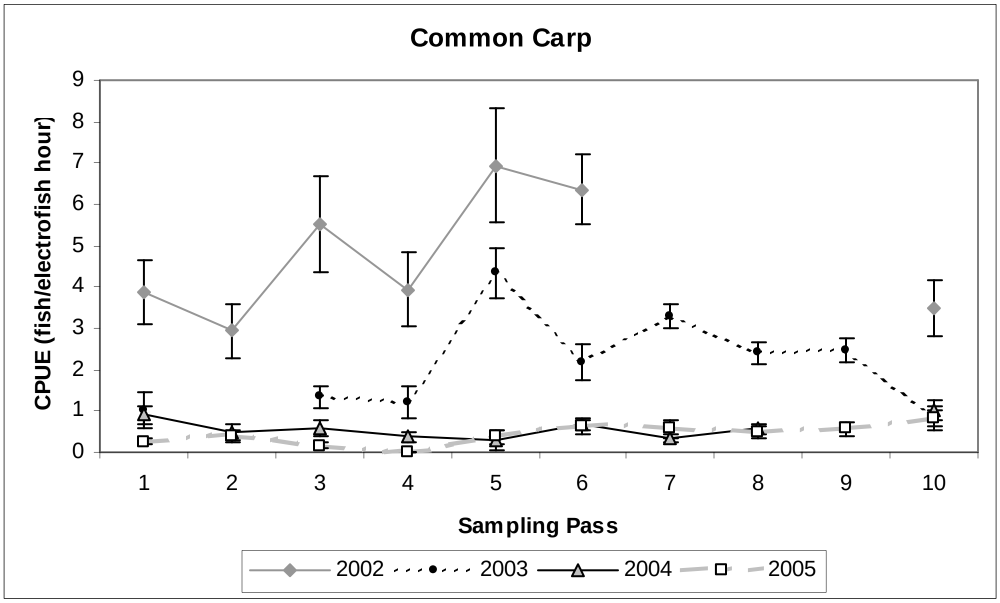


Figure 8. Common carp catch rates across passes during 2002 and 2003 Nonnative Control in the lower San Juan River. Error bars represent ± 1 standard error. Note: Numbers on x-axis represent similar times of the year that sampling was conducted in 2002 and 2003 (1: March 11-28, 2: April 15-19, 3: April 28-May 10, 4: May 19-24, 5: June 9-14, 6: June 23-28, 7: July 21-28, 8: August 4-8, 9: August 18-22, 10: September 20- October 15).

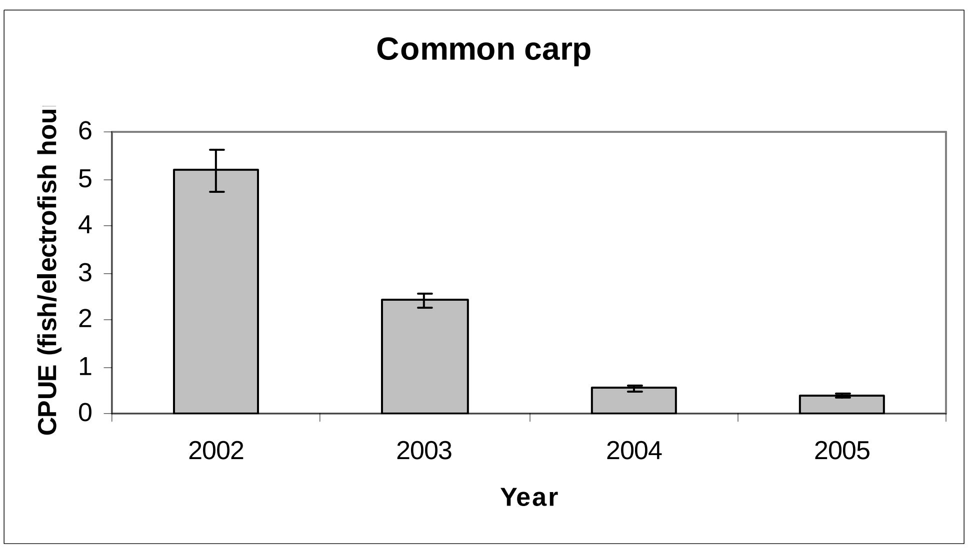


Figure 9. Mean catch rate of common carp from 2002 to 2005 during Nonnative Control in the lower San Juan River. Error bars represent ± 1 standard error.

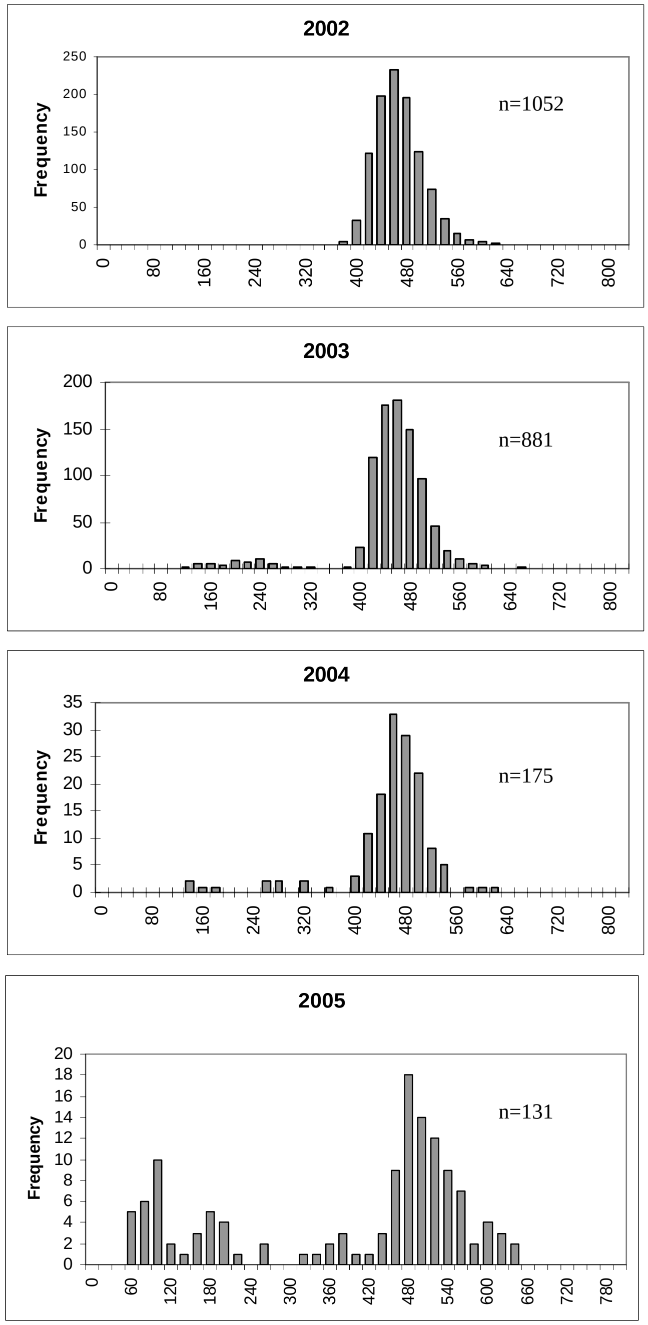


Figure 10. Length-frequency histograms of common carp from 2002 to 2005 during Nonnative Control in the lower San Juan River.

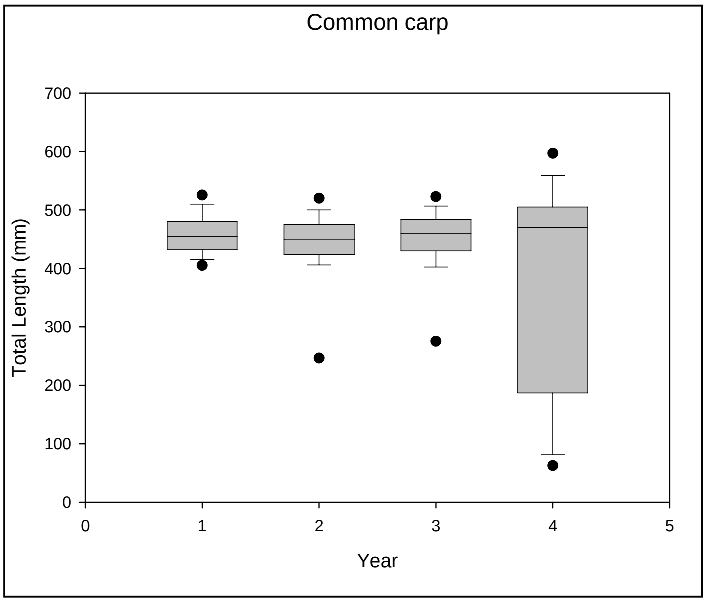


Figure 11. Mean total length of common carp during each year of the Nonnative Control in the lower San Juan River (Year 1: 2002, Year 2: 2003, Year 3: 2004, Year 4: 2005). Bars represent 5th and 95th percentiles, dots represent outliers.

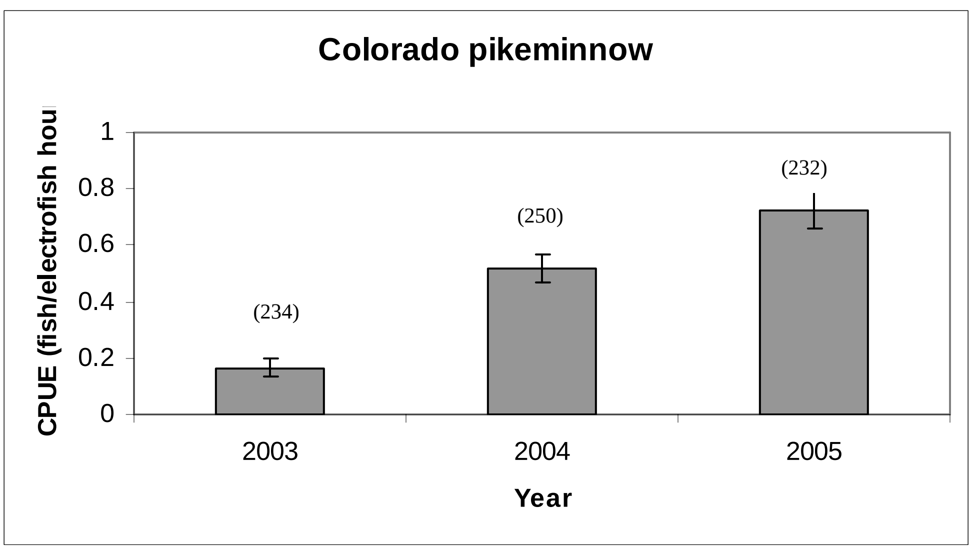
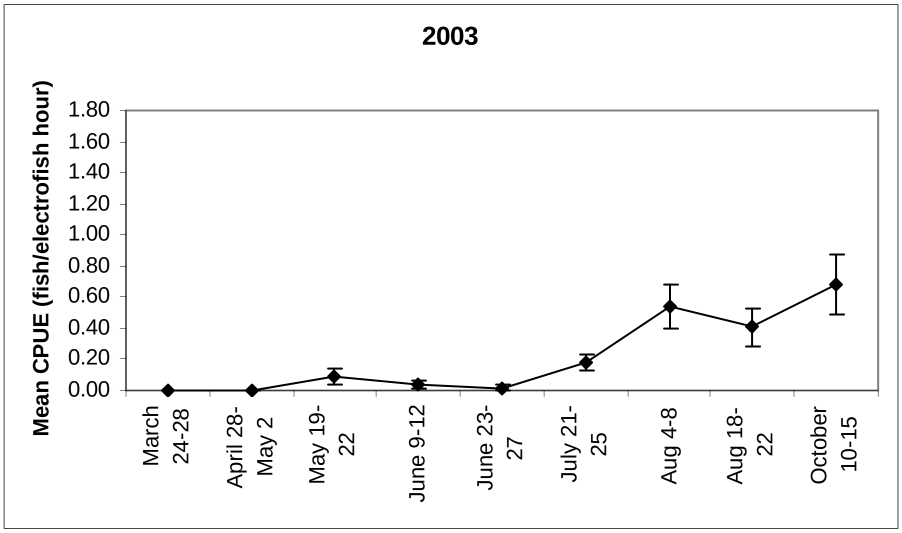
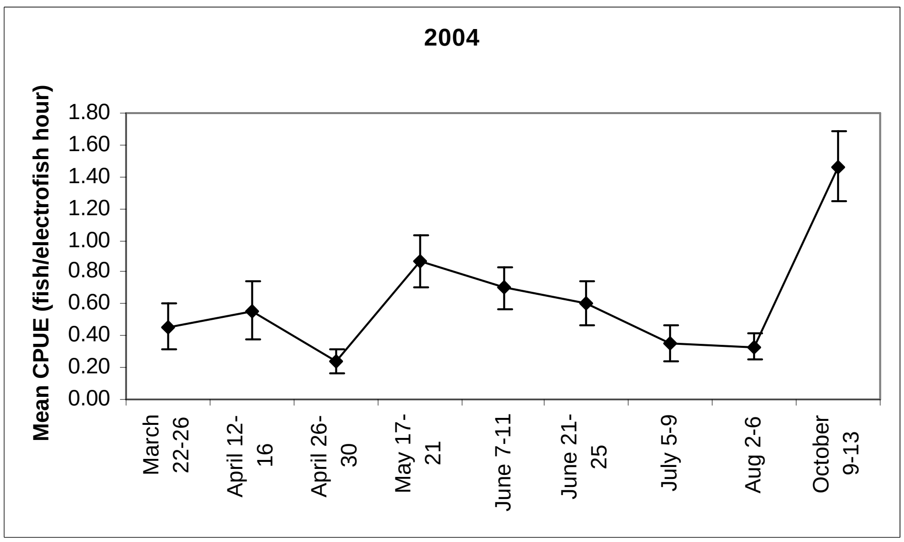


Figure 12. Mean catch rate of Colorado pikeminnow from 2003 to 2005 during Nonnative Control in the lower San Juan River. Error bars represent ± 1 standard error and sample size presented parenthetically.





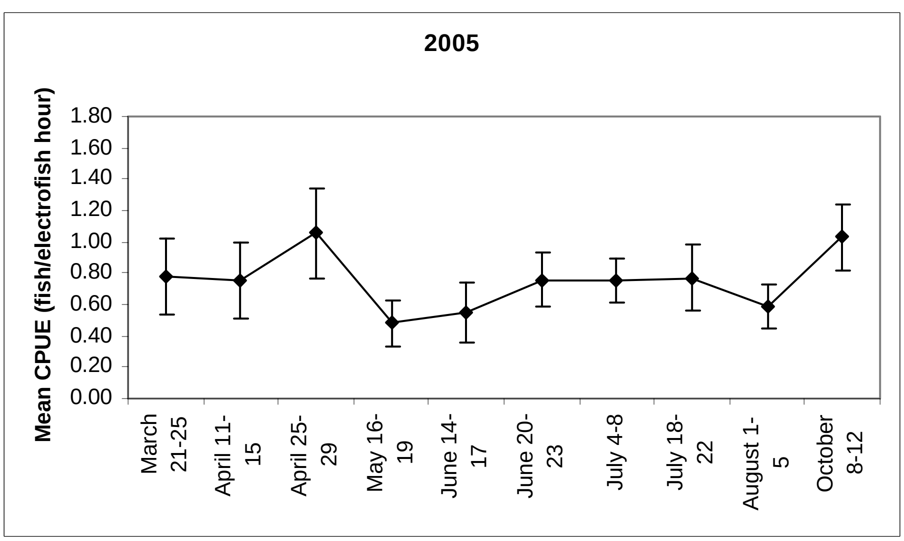


Figure 13. Mean catch rates by pass for all Colorado pikeminnow collected from 2003 to 2005 during Nonnative Control and Adult Monitoring in the lower San Juan River. Error bars represent ± 1 standard error.

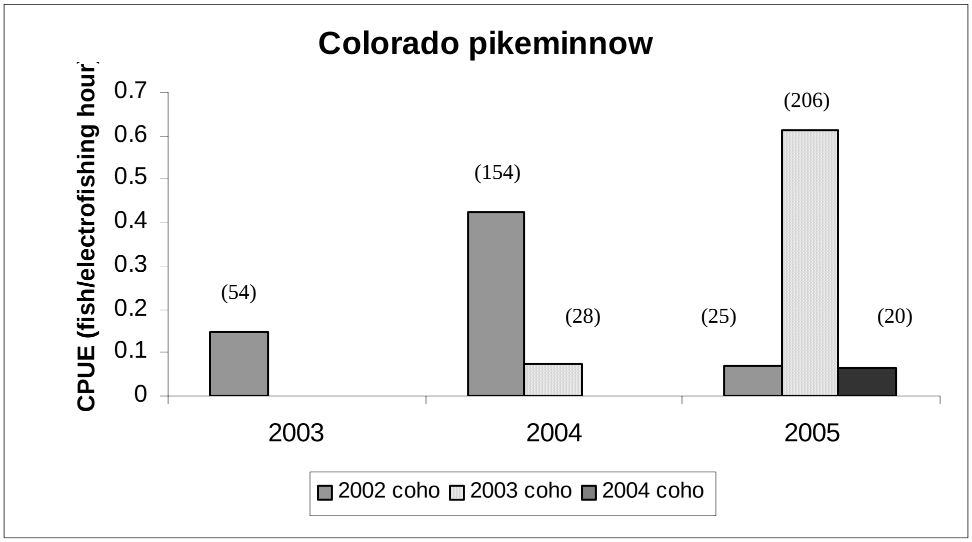


Figure 14. Catch rates of Colorado pikeminnow by cohort from 2003 to 2005 during Nonnative Control in the lower San Juan River. Sample size presented parenthetically.

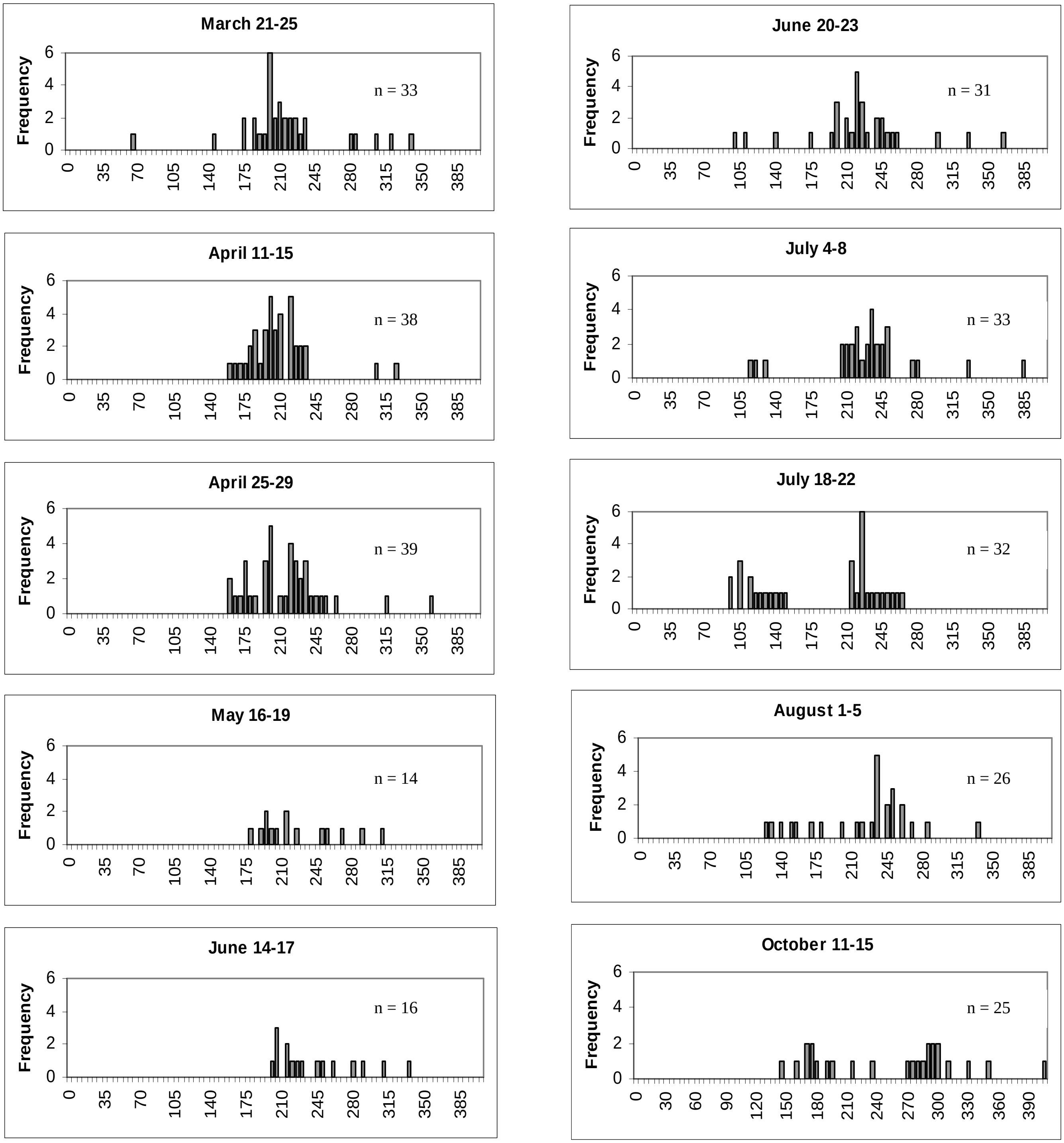


Figure 15. Length-frequency histograms of Colorado pikeminnow collected by month during Nonnative Control and Adult Monitoring in the lower San Juan River in 2005.

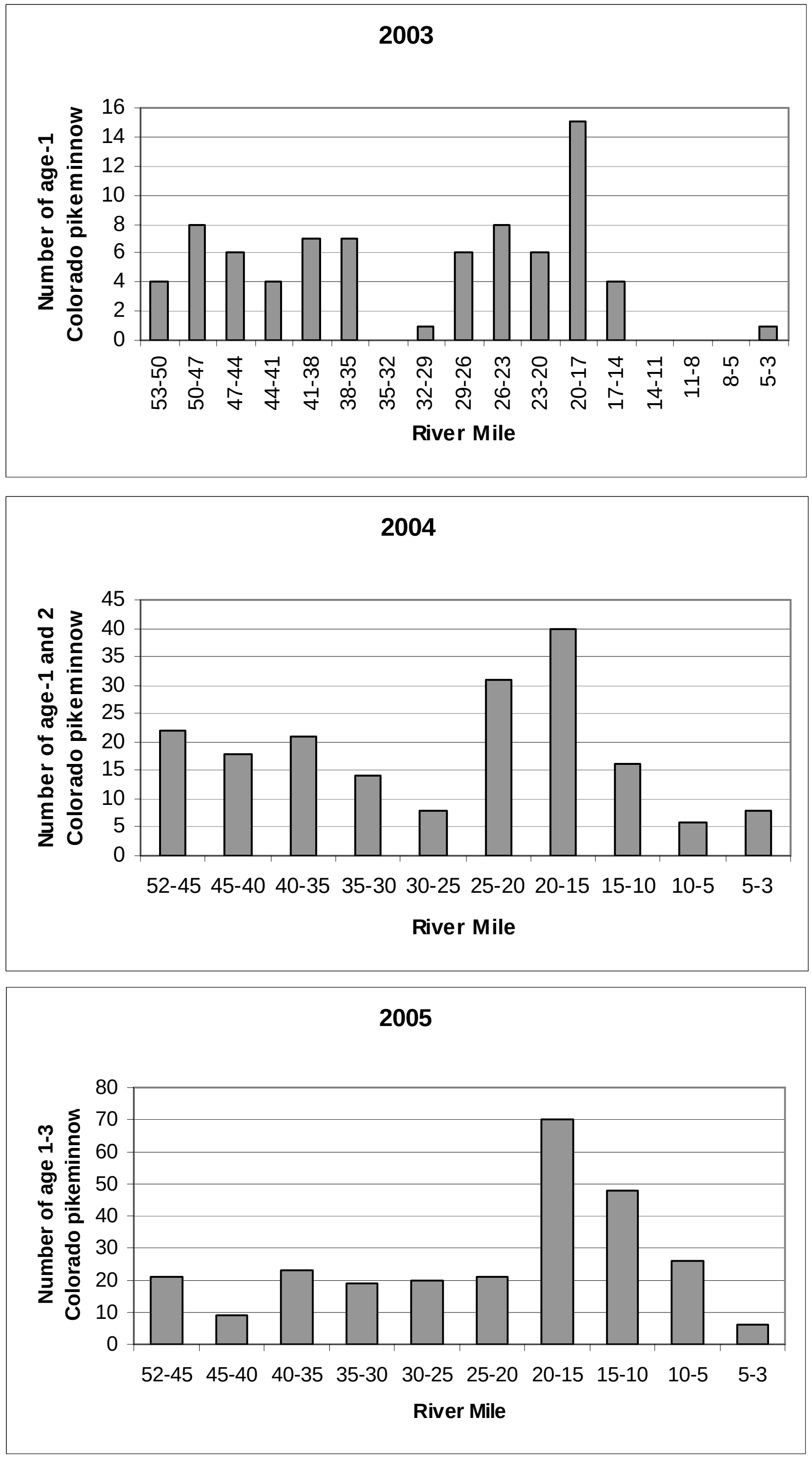


Figure 16. River distributions of Colorado pikeminnow from 2003 to 2005 during Nonnative Control sampling on the lower San Juan River.

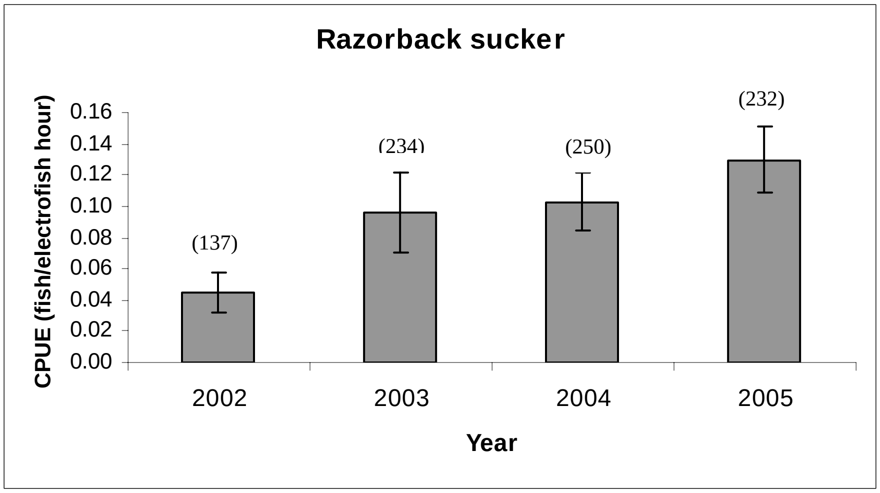


Figure 17. Mean catch rate of razorback sucker from 2002 to 2005 during Nonnative Control in the lower San Juan River. Error bars represent ± 1 standard error, sample size presented parenthetically.

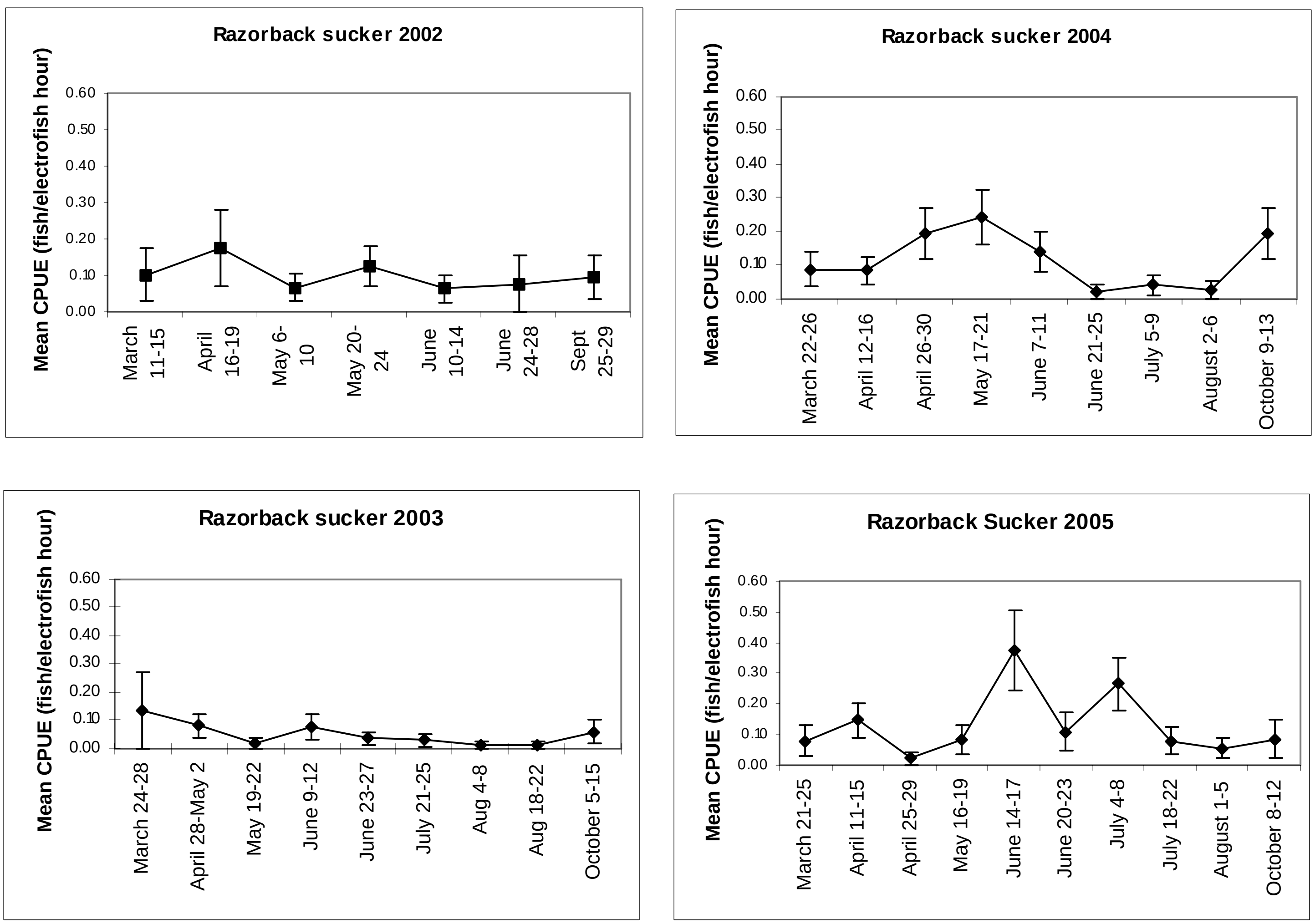


Figure 18. Mean catch rates by pass of razorback sucker collected during Nonnative Control and Adult Monitoring in the lower San Juan River in 2002-2005. Note: In 2002 during the April trip, ten razorbacks were not netted and in 2003, two razorbacks during the April trip were not netted.

Appendix A. Flow, water temperature (Celsius), and turbidity (mm to Secchi depth disappearance), at the time of sampling on the San Juan River in 2005.

Pass	**Average Flow (ft^3/s)**	**Average H_20 (^oC)**	**Average Turbidity (mm)**
March 21-25	1425	10.6	98
April 11-15	2650	13.4	55
April 25-29	4933	13.5	20
May 16-19	7086	16.2	68
June 14-17	5953	18.6	12
June 20-23	5223	18.6	115
July 4-8	2306	23.6	243
July 18-22	1242	27.8	300
August 1-5	758	25.7	36
October 8-12	1786	14	130

Appendix B. Common name, scientific name and abbreviations of fish in the lower San Juan River.

Common name	**Scientific name**	**Abbreviation**
striped bass	*Morone saxatilis*	Morsax
walleye	*Sander vitreum*	Sanvit
channel catfish	*Ictalurus punctatus*	Ictpun
largemouth bass	*Micropterus salmoides*	Micsal
green sunfish	*Lepomis cyanellus*	Lepcya
bluegill	*Lepomis macrochirus*	Lepmac
common carp	*Cyprinus carpio*	Cypcar
brown trout	*Salmo trutta*	Saltru
rainbow trout	*Oncorhynchus mykiss*	Oncmyk
black bullhead	*Ameiurus melas*	Amemel
Colorado pikeminnow	*Ptychocheilus lucius*	Ptyluc
razorback sucker	*Xyrauchen texanus*	Xyrtex

Appendix C. Number of channel catfish marked, captured and recaptured during Nonnative Control in the lower San Juan River in 2005.

Pass	Marked	Captured	Recaptured
March 21-25	708		
April 11-15		520	18
April 25-29			2
May 16-19			1
June 14-17			1
June 20-23			1
July 4-8			8
July 18-22			3
August 1-5			1