Nonnative Control in the Lower San Juan River 2006

Interim Progress Report
for the
San Juan River Recovery
Implementation Program

Prepared by:

Darek S. Elverud and Julie A. Jackson
Utah Division of Wildlife Resources
Moab Field Station
Utah

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EXECUTIVE SUMMARY

The fifth consecutive year of nonnative control in the lower San Juan River was conducted in 2006. This project was initiated to remove nonnative fish species, and to identify factors involved in movement of striped bass (*Morone saxatilis*) and other reservoir 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 2006, nine removal passes were made, beginning in mid-March and continuing through 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). Mean daily river flows ranged from 620-7,610 cubic feet per second (cfs) during sampling trips.

Lake Powell elevations have dropped 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 15 meters wide and 1 meter high was observed near Piute Farms (RM -0.5) in July 2003. Because no striped bass or walleye (*Sander vitreum*) was collected or observed in 2003, it was concluded that low lake elevations, the waterfall, or a combination of both was preventing movement of these species upstream into the San Juan River. The waterfall at Piute Farms was present throughout sampling in 2006, and again no striped bass or walleye were collected.

The majority of nonnative specimens collected in 2006 were channel catfish (*Ictalurus punctatus*). Nine thousand one hundred seventy channel catfish were removed. Catch rates of channel catfish varied between trips, similar to previous years. Mean catch rates of channel catfish in 2006 were not significantly different than catch rates in 2002, 2003 or 2004, but were significantly lower than catch rates in 2005. A significant decrease in the size structure of channel catfish between 2002 and 2006 has also been observed. Differences among abundance estimates generated for channel catfish in 2003, 2005 and 2006 were insignificant.

In 2002 and 2003, common carp (*Cyprinus carpio*) were the second most abundant species collected. In 2004, 2005 and 2006, the mean catch rate of common carp was significantly lower than 2002 and 2003. Size structure of common carp has remained similar among years. 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 twenty endangered fish were collected during 2006 sampling in the lower San Juan River. Two hundred forty-four were juvenile and sub-adult (< 450 mm Total

Length [TL]) Colorado pikeminnow (*Ptychocheilus lucius*) stocked in 2003 through 2005 near Farmington, NM. Twelve of the large (410 mm mean TL when stocked) Colorado pikeminnow from Bubbling Ponds Hatchery stocked in early August were also captured. One hundred forty-nine juvenile and sub-adult Colorado pikeminnow greater than 150 mm (TL) were collected and PIT tagged during nonnative control efforts in the lower San Juan in 2006. Twenty-seven of the 149 juvenile Colorado Pikeminnow were recaptured in the lower San Juan during nonnative control and fall monitoring. Many of these fish moved upstream 10 to 80 miles, while others moved more than one mile downstream of their original capture location. Preliminary population estimates of Colorado pikeminnow were quite variable and depended upon the set of passes used in the estimate. While the population estimates were variable, they are similar to or higher than estimates from 2004 and 2005. Sixty-four razorback suckers (*Xyrauchen texanus*) were collected and PIT tagged in 2006 during nonnative control in the lower San Juan. Three of these were recaptured during the year during nonnative control and fall monitoring in the lower San Juan River. No razorback suckers < 300 mm TL) was found in 2006. Four suspected razorback x flannelmouth (*Catostomus latipinnis*) hybrids were collected in 2006, compared to 12 collected in 2005, 10 collected in 2004, and two collected in 2003.

In 2006, sampling was conducted below the waterfall at Piute Farms to determine species present and blocked by the waterfall to upstream movement. Five trips were conducted between April and September. During the first three trips, two waterfalls were present. The lower waterfall appeared to be at least a partial barrier to fish movement because the majority of fish were collected below the lower waterfall. By August, the lower waterfall had eroded away and the upper waterfall increased in height to 7 or 8 meters. One adult razorback sucker and two adult gizzard shad (Dorosoma cepedianum) were collected below the barrier. Channel catfish, common carp, and juvenile native suckers were collected in this area as well. The razorback sucker was released upstream of the waterfall.

The lower San Juan River has proven to contain valuable habitat for endangered fish species. Due to the increased 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 may reduce predation and competition impacts on the endangered and native fish community, and improve recruitment of stocked and naturally produced endangered fishes.

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 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 congregated around Slickhorn Rapid (RM 17.7) in the spring of 2002, and around RM 23.5 in the spring of 2006 during this study. 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 for this study 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 2003-2005, 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. 2005).

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 upper 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). 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 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 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 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 nursery habitat for native and endangered fish species (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. 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 non-listed native suckers were not (Appendix B). Total and standard lengths to the nearest millimeter (mm) and weight to the 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 fish received a PIT tag (125 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. A global position system (GPS) reading and river mile where the fish was captured was recorded. All channel catfish greater than 200 mm total length collected during the first pass (trip) were tagged and released. Channel catfish collected on subsequent passes (trips) and all other nonnative species 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. 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 two-day sampling trips were conducted below the waterfall at RM -0.6 from April through September. Angling, cast netting, seining, and fyke netting 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 counted 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. Length frequency distributions and CPUE were compared between years using non-parametric Kruskal-Wallis tests 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 (> 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 size was estimated 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 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

Ten sampling passes, including the Fall Monitoring pass, were conducted on the San Juan River between Mexican Hat and Clay Hills, UT (Figure 1). Sampling dates were: March 23-27, April 4-8, April 18-22, May 16-20, June 6-10, June 20-24, July 5-9, July 18-22, August 7-11 and October 7-9. Nine different large-bodied fish species were collected in the lower San Juan River during nonnative control and adult monitoring in 2006. Two of the nine species were endangered Colorado pikeminnow and razorback sucker and the remaining seven species were nonnative. Native bluehead sucker and flannelmouth sucker were present during all passes, but not netted during nonnative control efforts. Electrofishing effort totaled 388 hours and resulted in approximately 10,850 fish captured (Table 1). No striped bass or walleye was collected in 2006 in the lower San Juan River.

Nonnative Species

Channel catfish

In 2006, channel catfish comprised > 95% of the total catch in the lower San Juan River. Mean catch rates of channel catfish varied significantly between passes and ranged from 5 to 42 fish per hour ($p < 0.001$; Table 2, Figure 2). Mean catch rates of all life stages of channel catfish in 2006 were not significantly different from 2002 to 2004 (Figure 3), but were significantly lower than in 2005 ($p<0.05$, Figure 3). Mean catch rates of adult (>300 mm TL) channel catfish remained similar to years 2003-2005 (Figure 4).

Mean total length of channel catfish decreased from 269 mm (SD = 107) in 2002 to 204 mm (SD = 104) in 2006 ($p < 0.05$; Figure 5 and 6). Length-frequency histograms show that the majority of catfish collected during the early-summer months were small juveniles (Figure 7). Additionally, the percentage of adult channel catfish remain similar to years 2003-2005 and lower than 2002, the first year of intensive control in the lower San Juan River (Figure 8).

In 2006, the Lincoln-Peterson population estimate for channel catfish was 23,472 fish greater than 200 mm TL (Figure 9). The 95% confidence interval for the estimate was 17,037 - 29,907 fish. The 2006 population estimate is similar to Lincoln-Peterson population estimates generated in 2003 and 2005. In 2004, the Lincoln-Peterson population estimate was lower than in 2006 (Figure 9).

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, 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 predation on endangered fish was observed in 2006. Unidentifiable suckers and non-endangered native suckers were found upon examination

of stomach contents of large channel catfish. Nonnative channel catfish and bullhead species were also found infrequently in the stomachs of large channel catfish.

Common carp

In 2006, mean catch rates of common carp continued to decline. Catch rates of common carp were variable across passes within years from 2002 to 2006 (Figure 10). From 2002 to 2006, catch rates of common carp decreased significantly ($p < 0.001$; Figure 11). In 2006, the mean catch rate of common carp was significantly lower than in 2005 ($p < 0.05$). Size structure of common carp has remained similar among years of nonnative removal (Figures 12 and 13).

Endangered Species

Colorado pikeminnow

A total of 256 Colorado pikeminnow were collected in 2006 during nonnative control efforts in lower San Juan River. Catch rates of Colorado pikeminnow increased from 2003 to 2006 (Figure 14) and varied by pass (Figure 15). In 2006, the majority of juvenile Colorado pikeminnow captured were age-2 (2004 cohort). This pattern is similar to the trend in previous years. Age-3 (2003 cohort) Colorado pikeminnow catch rates were the lowest of all size classes collected in 2006 (Figure 16). Age-1 Colorado pikeminnow made up a larger proportion of the catch than in previous years (Figure 16). Length-frequency histograms by pass further illustrate that the majority of juvenile Colorado pikeminnow collected in 2006 were age-2 fish stocked in November 2004 (Figure 17).

In 2003, age-1 Colorado pikeminnow appeared to concentrate in two sections in the lower river, RM 52-36 and RM 29-14, with the highest concentrations between RM 20 and 17 (Figure 18). Colorado pikeminnow collected in 2004 through 2005, (age-1-3) were distributed throughout the entire sample reach, yet were still concentrated between RM 25-15. In 2006, RM 25-15 still contained a high concentration of juvenile Colorado pikeminnow, but RM 53-40 also contained more Colorado pikeminnow than in previous years (Figure 18).

In 2006, 27 of the 149 Colorado pikeminnow greater than 150 mm TL were recaptured during nonnative control and fall monitoring on the lower San Juan River. Sixty-three percent of the recaptures had moved upstream more than 1 mile with an average movement of approximately 21 miles. Twenty-six percent of the recaptures had moved downstream greater than 1 mile with an average of five miles. Eleven percent of the recaptures had moved less than 1 mile between the two capture occasions. Additionally, two Colorado pikeminnow initially captured on the lower San Juan were recaptured approximately 80 miles upstream in New Mexico during the fall monitoring trip (Dale Ryden, personal communication). As the timing of movement is uncertain, no relationship between environmental factors and movement can be determined.

Population estimates of Colorado pikeminnow have been generated for the lower San Juan River since 2004. Several population estimates were calculated using different passes to formulate a rough idea of population size of Colorado pikeminnow greater than 150 mm TL. 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. 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 to 696 individuals depending on the model and number of passes chosen. The coefficient of variation around the highest 2005 population estimate (696) was 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). In 2006, population estimates ranged from 124 to 1267 Colorado pikeminnow greater than 150 mm TL in the lower San Juan River depending upon which set of sampling passes were included in the model (Table 3). The coefficients of variation for the lowest (124) and highest (1267) population estimates were 30% and 67% respectively.

Captures of adult Colorado pikeminnow have diminished since this project began in 2002. No adult Colorado pikeminnow were collected in 2005 or 2006. 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 stocking events from 1996 and 1997.

Razorback sucker

Sixty-four razorback suckers were collected in the lower San Juan River (Table 1) in 2006. Mean catch rate of razorback suckers was higher in 2006 than in previous years (Figure 19), but the difference is not significant. In 2006, highest catch rates occurred on sampling trips during spring and fall (Figure 20), similar to data from 2002-2004. 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 and were smaller than stocked razorback suckers. No juvenile razorback sucker was captured in 2006 in the lower San Juan. Four suspected razorback-flannelmouth hybrids were collected in 2006 compared to 12 in 2005, 10 in 2004, and two in 2003. Fin clips were taken so genetic analysis may be evaluated in the future.

<u>Waterfall</u>

Five sampling trips below the San Juan waterfall(s) were conducted in 2006. Trip dates were April 24, May 22, June 8, August 14 and September 5. Two waterfalls were present during the first three sampling trips. Similar to waterfall conditions in late summer 2005, the lower waterfall was approximately 1.5 meters high, and the upstream waterfall was

approximately 4 meters high. The lower waterfall appeared to be acting as a movement barrier as most fish were collected below it during the first three waterfall sampling trips. Between the third and fourth sampling trip, the downstream waterfall eroded away and the upstream waterfall increased in height to approximately 7 to 8 meters. Fish sampling methods below the waterfall(s) include fyke nets, seines, cast nets and angling.

Fish collected at the waterfall during 2006 included native, nonnative and one endangered species. Species collected included: channel catfish, common carp, flannelmouth sucker, gizzard shad (*Dorosoma cepedianum*), razorback sucker and bullheads (*Ameiurus spp.*). Juvenile channel catfish dominated the catch. Two adult gizzard shad were collected during the first trip. The one large razorback sucker captured (total length 514 mm) during trip 4 contained an old (400 kHz) PIT tag. This razorback originated from stocking in 2004 at 360 mm total length. This fish was tagged with a new (125 kHz) PIT tag and released above the waterfall. Cast net sampling collected the gizzard shad and razorback sucker.

Other Observations

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; located another possible spawning aggregation near RM 23.5 in 2006, documented the distribution and abundance of Colorado pikeminnow stocked in 2002 -2005; generated preliminary population estimates for juvenile Colorado pikeminnow in 2004, 2005 and 2006; 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 2006 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, 2005, and 2006 age-2 fish made up the majority of the catch. It has been observed in the past that the number of Colorado pikeminnow in this size class decreases 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.

The catch of adult Colorado pikeminnow has declined over the period of this study (2002-2006). 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. 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.

DISCUSSION

In 2006, the waterfall near Piute Farms 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 3598 ft., approximately 100 ft below full pool. It is unlikely water levels of Lake Powell will inundate the waterfall barrier anytime in the near future.

Nine thousand one hundred seventy channel catfish were mechanically removed from the lower San Juan River in 2006. The channel catfish catch rate in 2006 was lower than in 2005 and similar to rates from 2002 to 2004. Many factors may have contributed to the high catch rates in 2005. First, removal of the larger channel catfish may be providing more opportunity for smaller channel catfish to persist. 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, high flows during 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 may result in capturing small juvenile channel catfish. To further support this hypothesis, on subsequent passes after fish were marked, recaptures of marked channel catfish were low until the July trip when fish were recaptured. Flows at this time had returned to pre run-off levels, therefore making it easier to capture larger fish. Third, reproductive success of channel catfish may have been greater in 2004 than in previous years increasing the abundance of small channel catfish in 2005.

The mean total length of channel catfish in 2006 removed from the lower San Juan River increased slightly from 2005 but was similar to the mean total length in 2004. The mean total length in 2006 (204 mm) was also significantly ($p < 0.05$) different from the mean total length (268 mm) from 2002, the first year of nonnative control in the lower river. The same factors that may have caused the increased catch rate in 2005, such as blind sweeping, may have affected the lower mean TL of captured channel catfish in 2005. Overall, nonnative control appears to be maintaining a shift towards smaller mean total lengths of channel catfish in the lower San Juan River. The decrease in adult channel catfish mean CPUE and the decreasing percentage of adults in the total channel catfish catch data also suggest reduced abundance of large channel catfish in the lower San Juan River. Unfortunately, no mark/recapture population estimate was attempted in 2002 when mean CPUE of adult channel catfish was ~250 percent higher than in 2006.

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 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. Alternately, increasing the probability of a Colorado pikeminnow encountering a channel catfish may be unlikely as the two species are certain to interact as channel catfish are and have been abundant and ubiquitously distributed throughout the lower San Juan River since the nonnative control began in 2002. The expectation is that Colorado pikeminnow will choose flannelmouth sucker and bluehead sucker over channel catfish, especially when these prey are more abundant.

Population estimates generated for channel catfish in the last four 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 efficiency of capturing channel catfish based on flow, turbidity, netter ability, and unknown factors. Three channel catfish tagged in the section of river near Farmington, NM where NMFRO conducts mechanical removal were collected during sampling on the lower San Juan in 2006. Additionally, NMFRO captured three catfish in 2006 tagged in 2005 in the lower San Juan River greater than 100 miles upstream from the tagging site in 2005. These data indicate catfish moving long distances throughout the San Juan River. Using the first two passes, conducted within one month, 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. With the expansion of nonnative removal upstream, as proposed for 2008, movement of channel catfish from upstream into the lower San Juan 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.

Since 2002, a significant and continuing decline in catch rates of common carp has been observed. 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. Carp are rarely captured in the first 35 miles of the lower nonnative control section. The majority of carp removed from the lower San Juan River are captured in the bottom 12-14 miles of the reach. This indicates carp are not occupying the majority of the lower San Juan River nonnative control reach.

Sampling at the base of the waterfall in 2005 and 2006 showed that both endangered and nonnative fish 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. 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 in two consecutive years, 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 basis for future estimates. In 2004 and 2006, Colorado pikeminnow were found moving extended distances during the summer. Population estimates constructed during the summer (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 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. If riverwide population estimates are attempted in the future, late summer or early fall would be a logical time as age-1 fish begin reaching a size where they are more susceptible to capture by electrofishing. A riverwide estimate would also alleviate concern about a closed population, as the entire river would be sampled above the waterfall.

CONCLUSIONS AND RECOMMENDATIONS

• No striped bass or walleye were collected in 2005 or 2006. This finding is directly related to the presence of the waterfall at Piute Farms. Sampling at the base of the waterfall should continue in 2007 to determine if striped bass and walleye are moving from the lake up to the waterfall. As no striped bass or walleye have been captured in 2005 or 2006 below the waterfall, either these two species are not migrating upstream to the waterfall or our sampling techniques are ineffective at capturing them. In 2007, barge or canoe electrofishing will be conducted below the waterfall to see if striped bass and walleye can be sample with this type of gear. If striped bass and walleye are collected, 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. If no striped bass and walleye are found below the waterfall in 2007, the waterfall sampling should be reevaluated and possibly discontinued. 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, and common carp 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 fishes, and complement removal efforts being conducted further upstream.

• Population estimates of channel catfish remained similar from 2003 to 2006; 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 2007, into the upstream reach may aid in alleviating some immigration 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 2006, while the size structure has remained relatively unchanged. 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 2005. In 2006, the catch rates and population estimates were similar to 2005. In 2004, 2005, and 2006, 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 2006; 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.

• Captures of razorback/flannelmouth sucker hybrids continues. Fin clips from suspected hybrids should be collected. Collecting fin clips now could prove valuable if introgression is deemed an issue in the future.

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Table 1. Total count of most abundant fish species collected during electrofishing sampling in the lower San Juan River in 2006.

Trip	Ptyluc	Xyrtex	Ictpun	Cypcar	Amemel & Amenat
March 23-27	11	4	1864	17	2
April 4-8	17	3	1681	7	0
April 18-22	17	13	1345	7	6
May 16-20	26	15	658	4	5
June 6-10	20	8	626	10	1
June 20-24	47	2	1781	11	14
July 5-9	23	1	1040	5	5
July 18-22	24	1	839	8	4
August 7-11	41	3	501	3	1
October 7-9	30	14	73	2	3
Total	256	64	10408	74	41

Table 2. Mean CPUE of most abundant fish species collected during electrofishing sampling in the lower San Juan River in 2006.

Trip	Ptyluc	Xyrtex	Ictpun	Cypcar	Micsal	Lepcya	Amemel & Amenat
March 23-27	0.24	0.09	42.11	0.43	0.00	0.00	0.03
April 4-8	0.38	0.07	37.88	0.16	0.00	0.00	0.00
April 18-22	0.37	0.28	28.72	0.14	0.00	0.00	0.14
May 16-20	0.63	0.36	15.31	0.08	0.00	0.00	0.11
June 6-10	0.62	0.25	21.97	0.21	0.00	0.00	0.02
June 20-24	0.88	0.04	33.98	0.20	0.00	0.00	0.26
July 5-9	0.54	0.02	23.78	0.11	0.00	0.00	0.10
July 18-22	0.54	0.02	17.83	0.22	0.00	0.00	0.10
August 7-11	2.00	0.15	25.90	0.20	0.00	0.00	0.02
October 7-9	1.82	0.85	4.72	0.12	0.00	0.00	0.19

Table 3. Population estimates for juvenile Colorado pikeminnow greater than 150 mm TL in the lower San Juan River from 2004 to 2006. 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	0.1
2005	1-3	Mo	536	288-1,283	0.37	0.06
	1-4	Mt	537	321-1,064	0.3	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	0.3	0.14
	7-9	Mt	976	237-4,775	0.94	0.02
	7-10	Mt	1267	417-4,296	0.67	0.02
	1-10	Mt	455	340-640	0.16	0.04

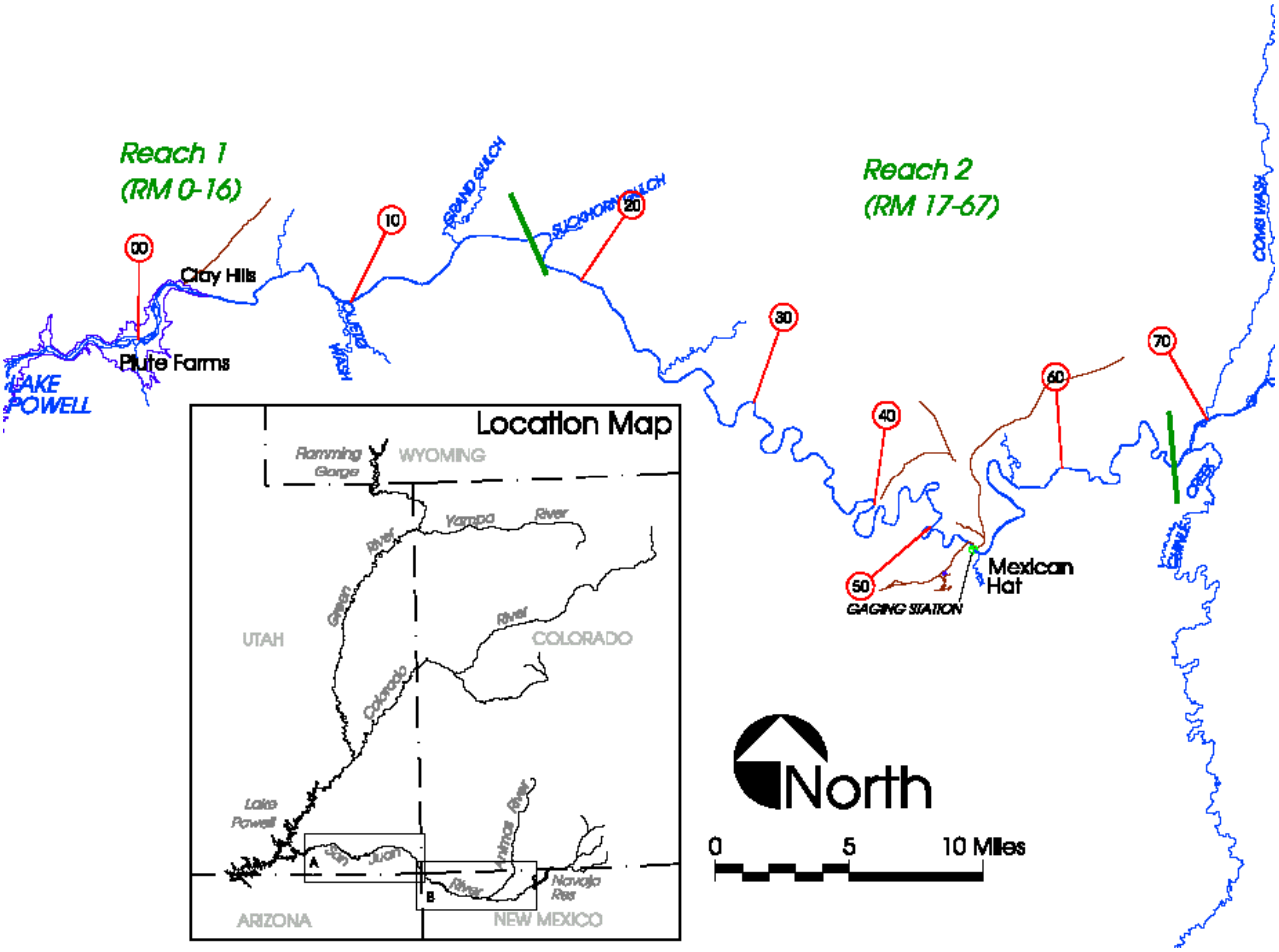

Figure 1. Map of the study area for nonnative control in the lower San Juan River. Sampling extends from Mexican Hat to Clay Hills.

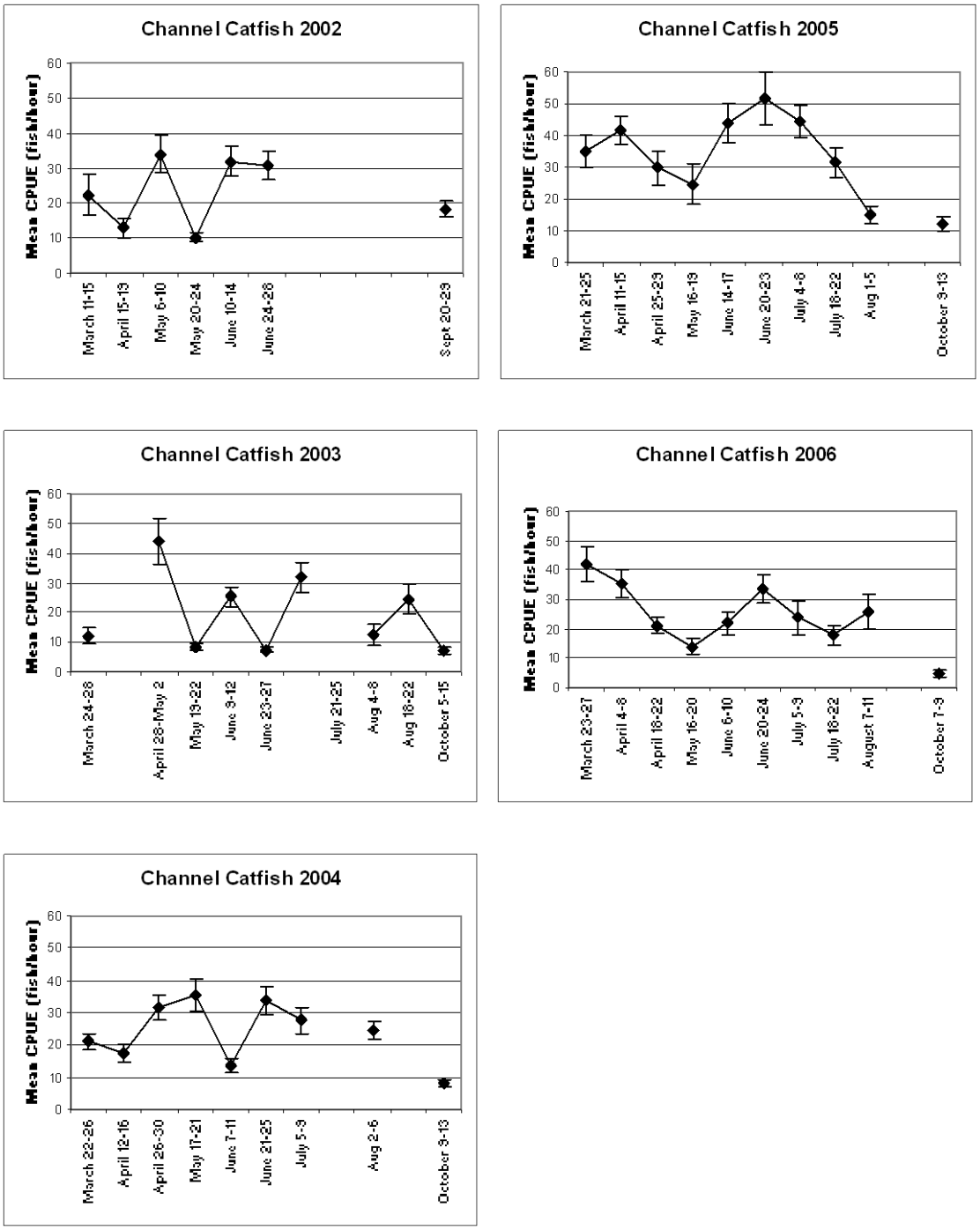

Figure 2. Mean electrofishing catch rates of channel catfish in the lower San Juan River by pass for years 2002 to 2006. Error bars represent ± 1 standard error.

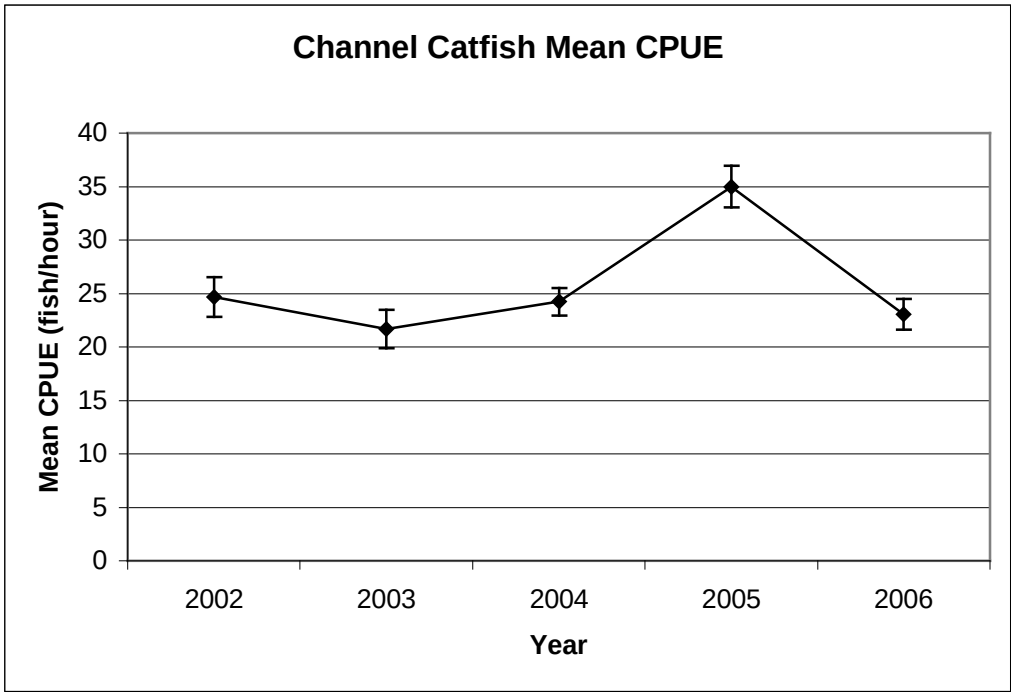

Figure 3. Mean electrofishing catch rate of channel catfish in the lower San Juan River by year. Error bars represent ± 1 standard error.

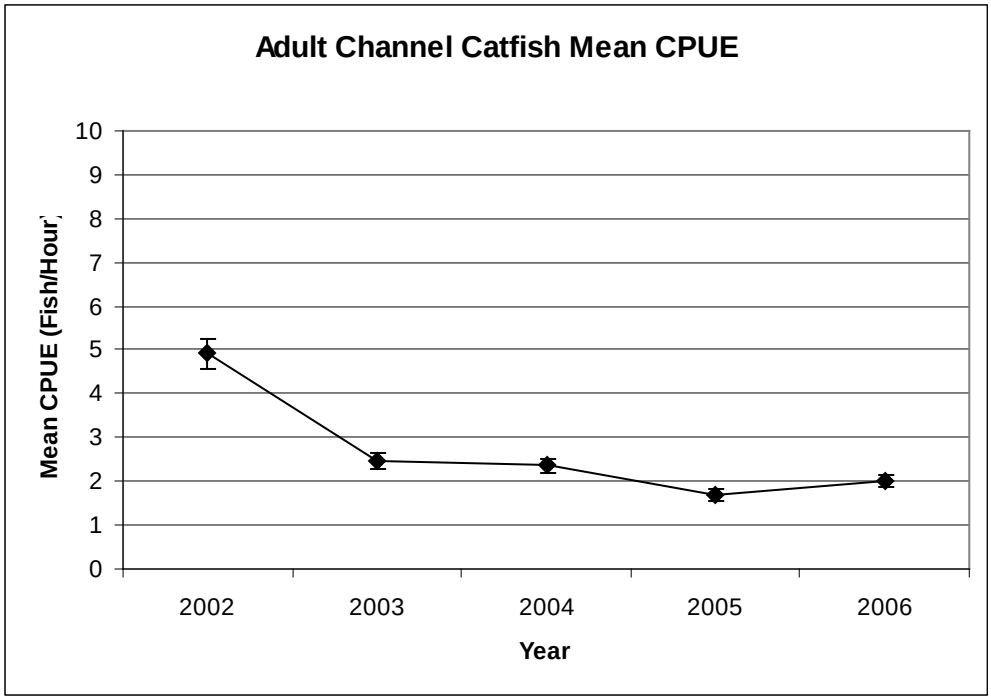

Figure 4. Mean adult (>300 mm) electrofishing catch rate of channel catfish in the lower San Juan River by year. Error bars represent ± 1 standard error.

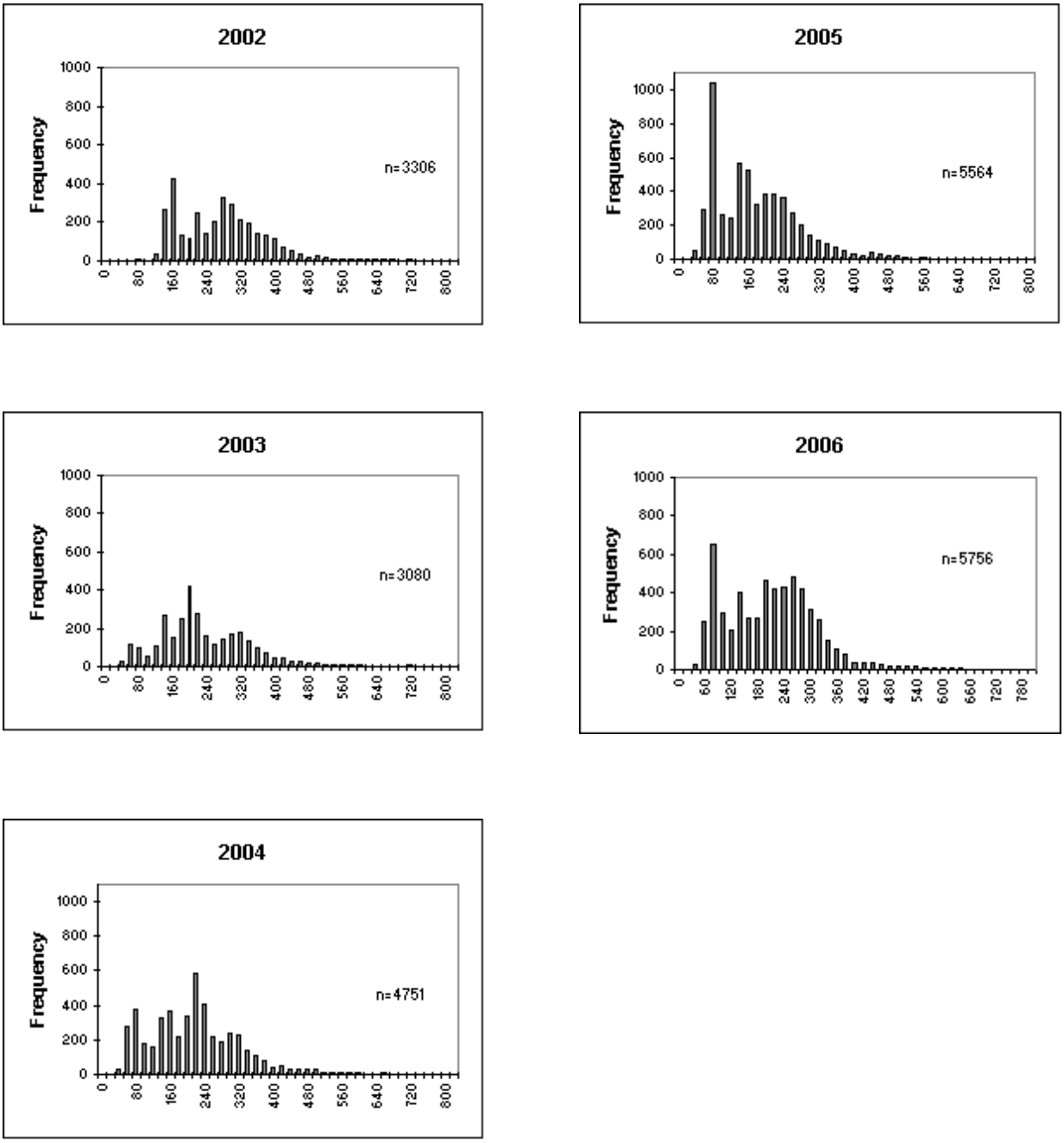

Figure 5. Length-frequency histograms of channel catfish collected by electrofishing in the lower San Juan River from 2002 to 2006.

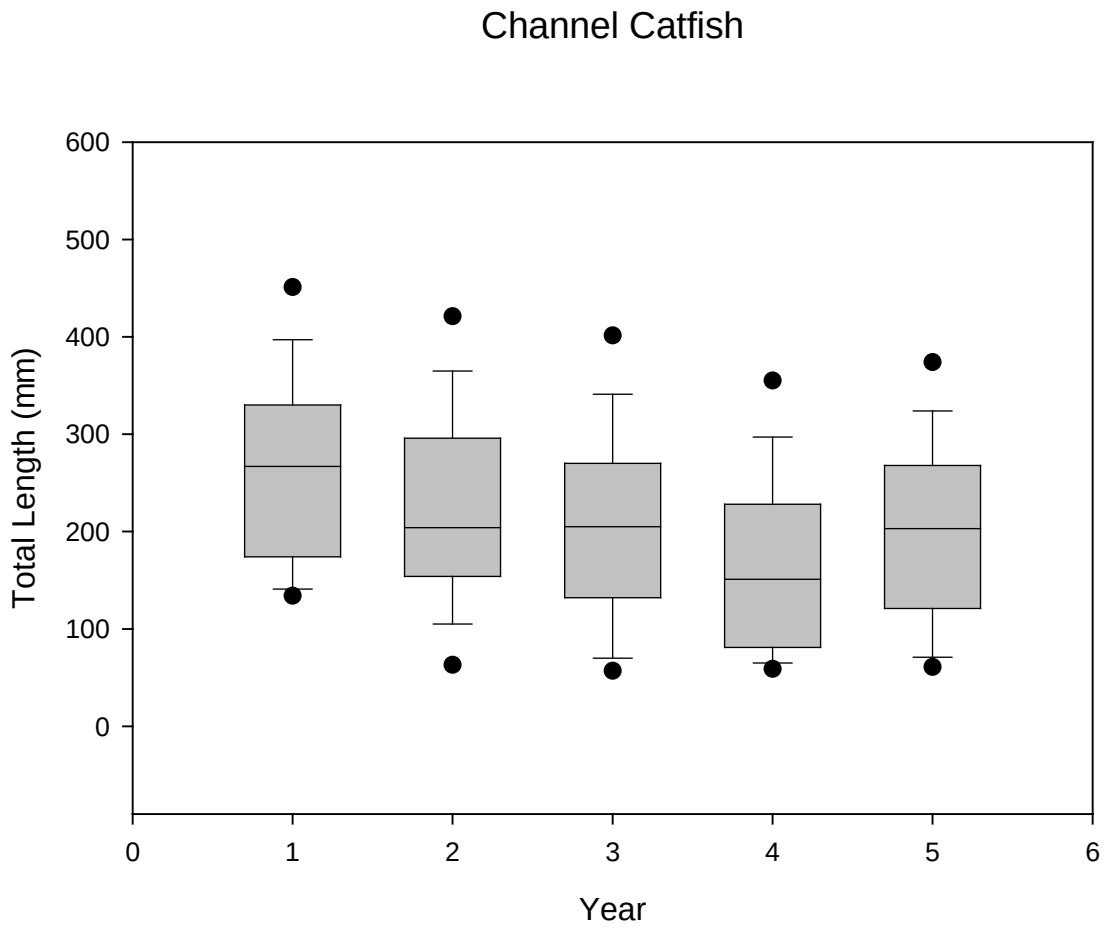

Figure 6. Distribution of total lengths of channel catfish by year from the lower San Juan River (Year 1: 2002, Year 2: 2003, Year 3: 2004, Year 4: 2005, Year 5: 2006). Gray rectangles represent 25th and 75th percentiles. Horizonal line within the gray rectangles is the median total length. Whiskers represent 10th and 90th percentiles. Black dots represent 5th and 95th percentiles.

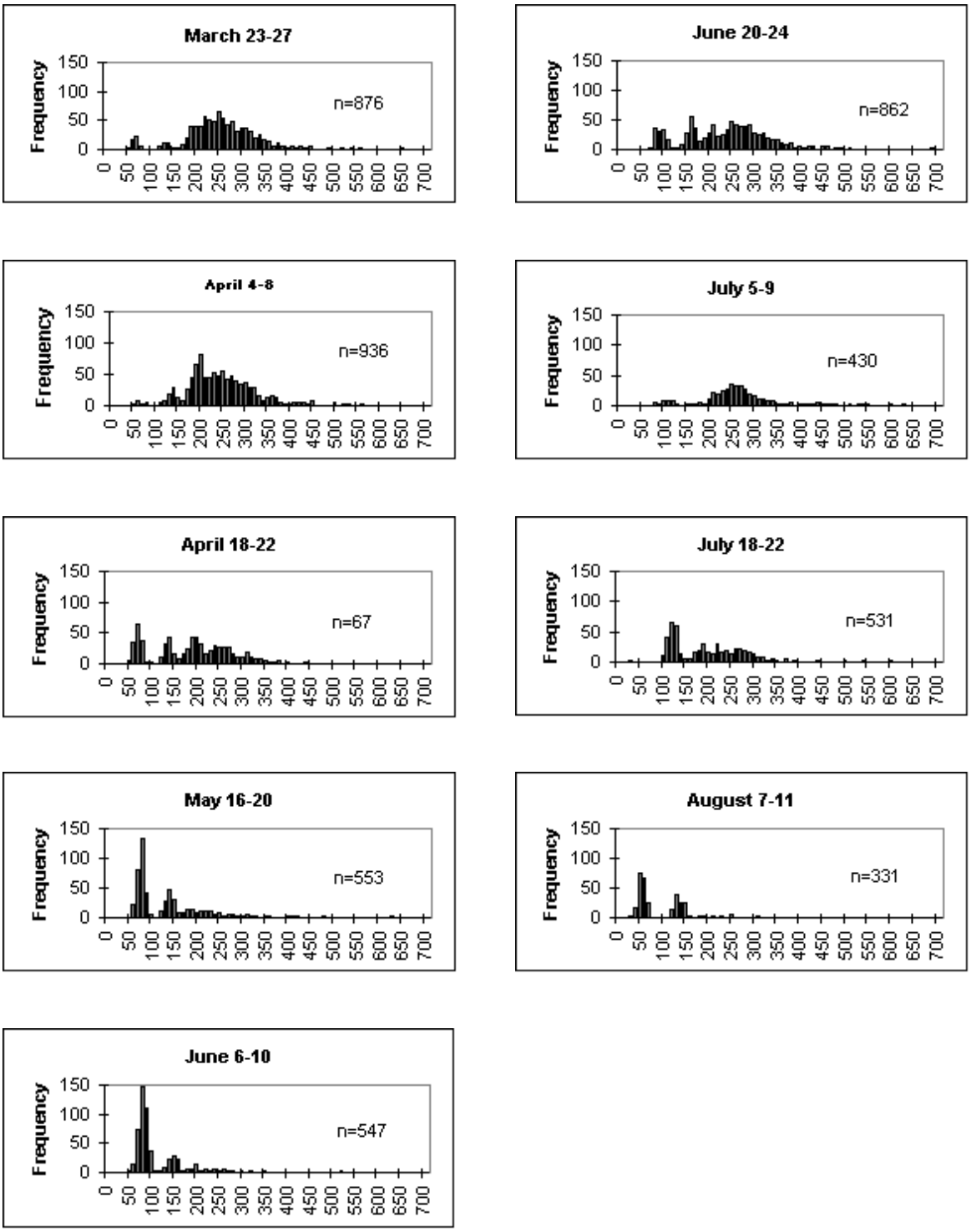

Figure 7. Length-frequency histograms of channel catfish collected by pass in the lower San Juan River in 2006.

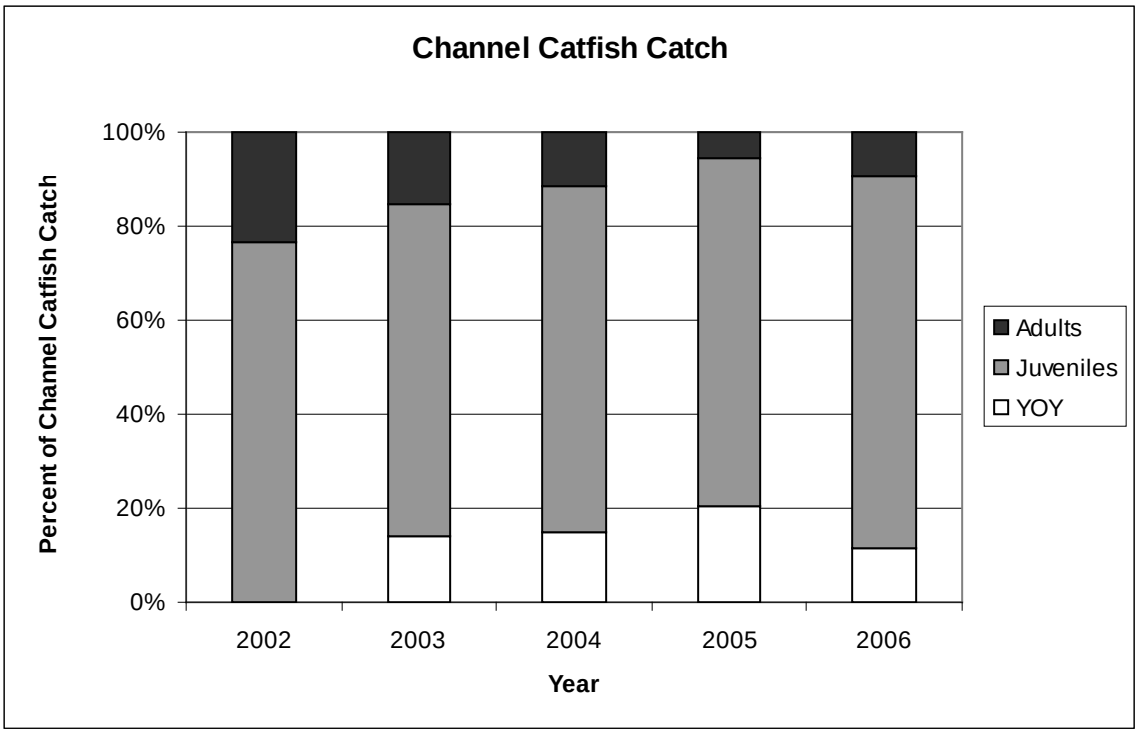

Figure 8. Percent of each life stage of channel catfish in the total channel catfish catch by year. Note: YOY and juveniles life stages were not differentiated in 2002.

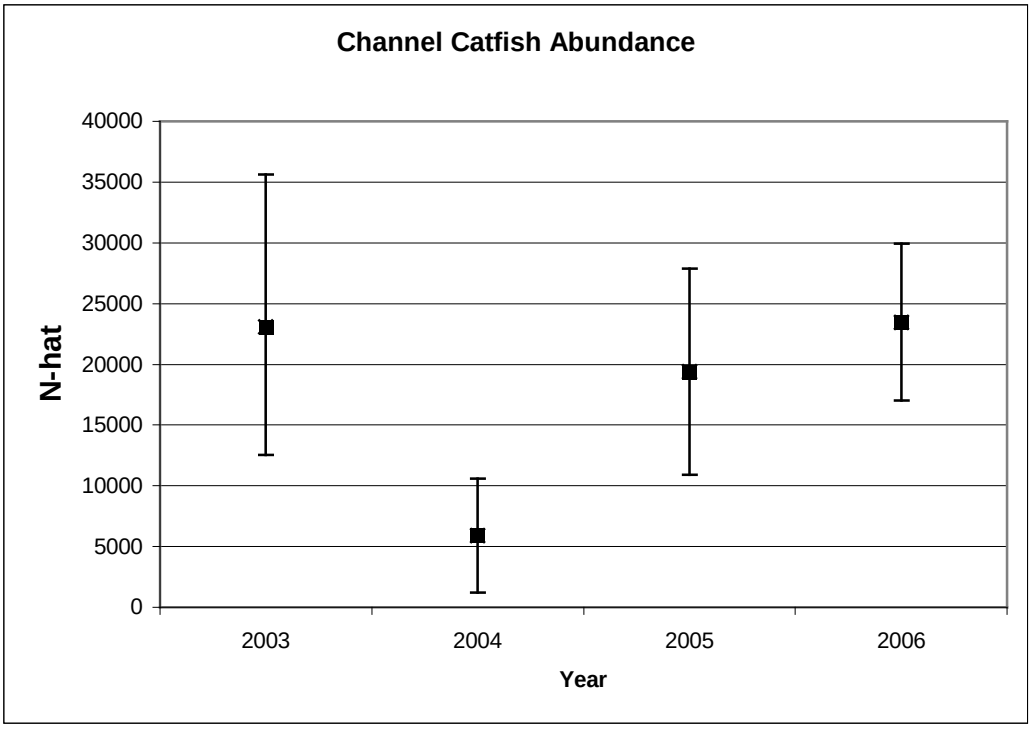

Figure 9. Abundance estimates (N-hat) of channel catfish by year in the lower San Juan River. Error bars represent 95% confidence intervals.

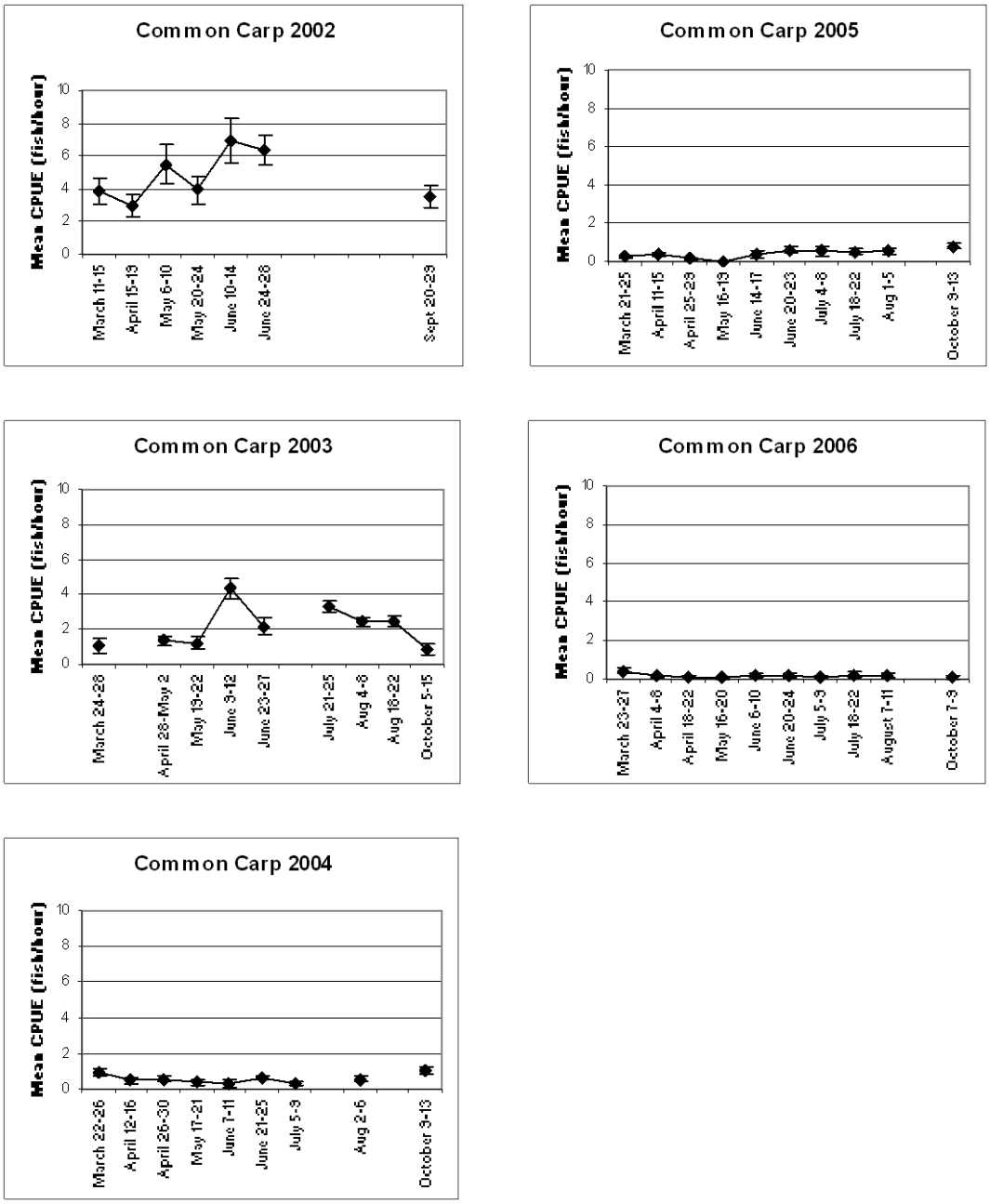

Figure 10. Mean electrofishing catch rate of common carp by pass from 2002 to 2006 in the lower San Juan River. Error bars represent ± 1 standard error.

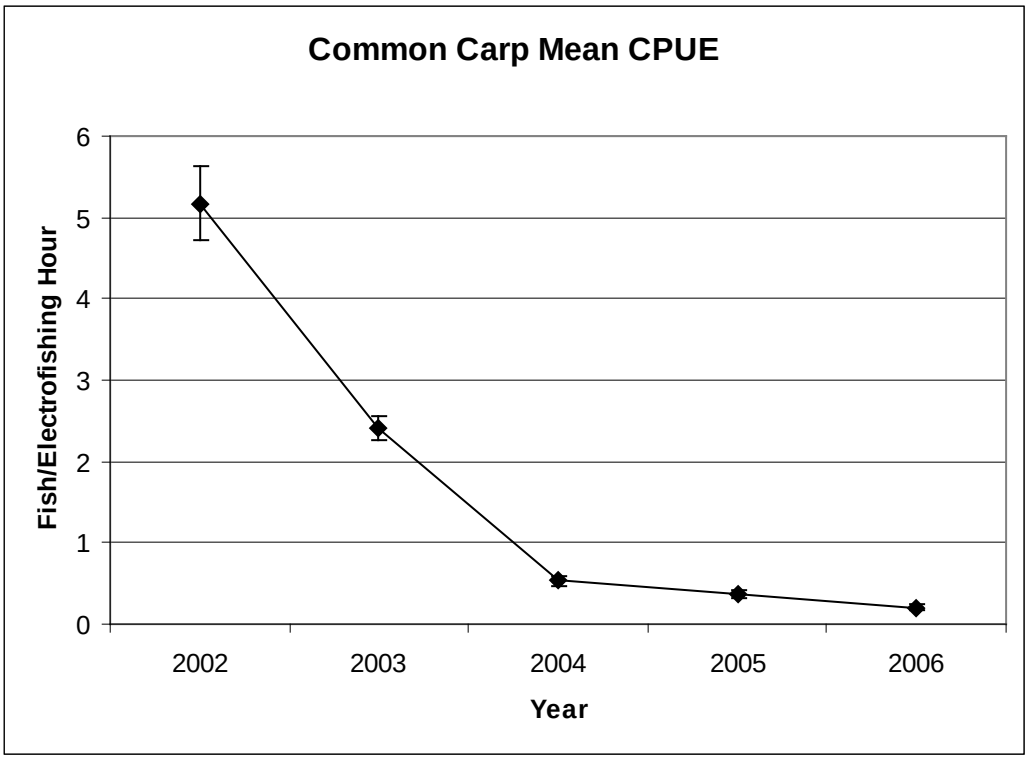

Figure 11. Mean common carp electrofishing catch rate by year from 2002 to 2006 in the lower San Juan River. Error bars represent ± 1 standard error.

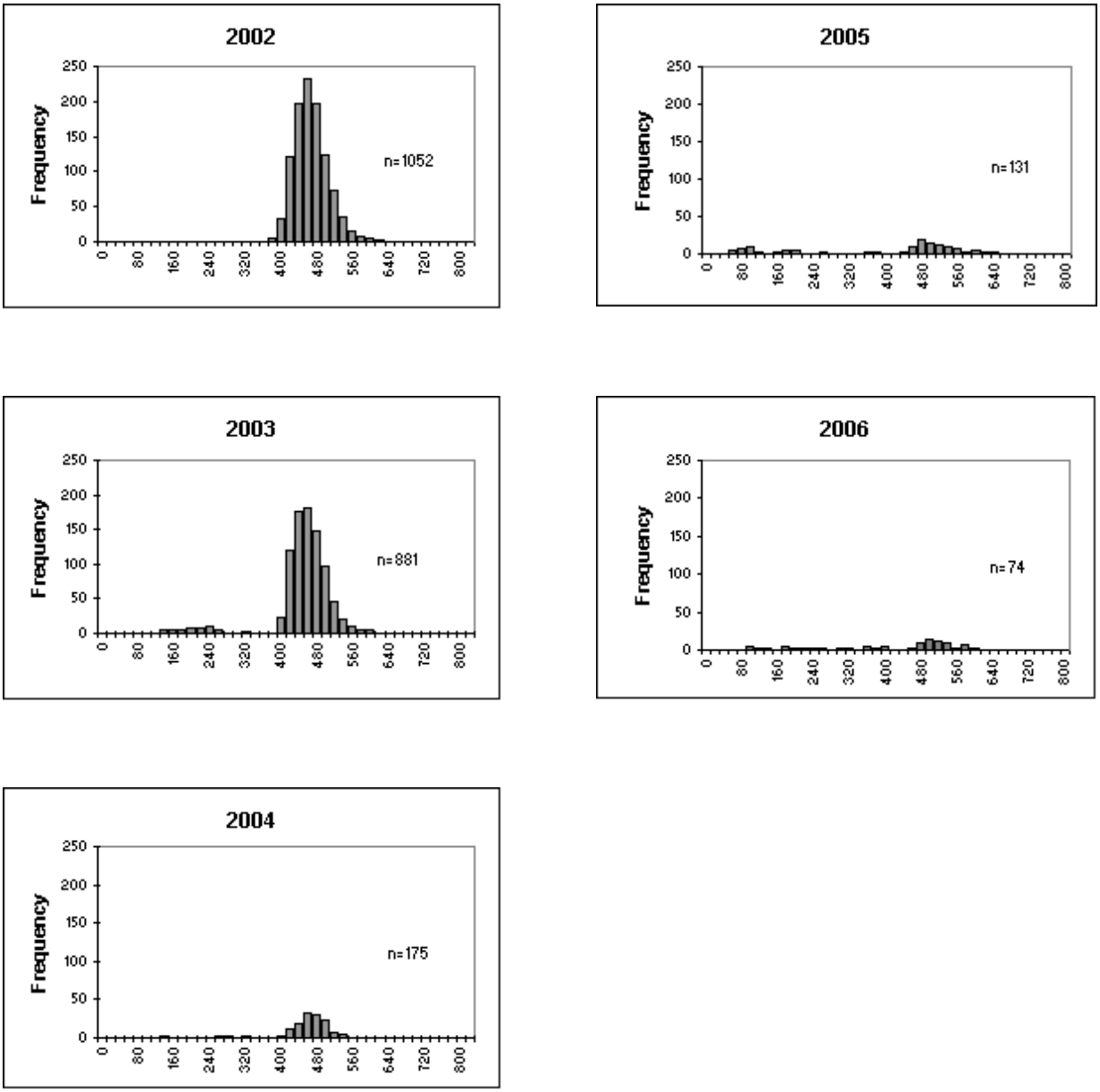

Figure 12. Length-frequency histograms of common carp in the lower San Juan River by year from 2002 to 2006.

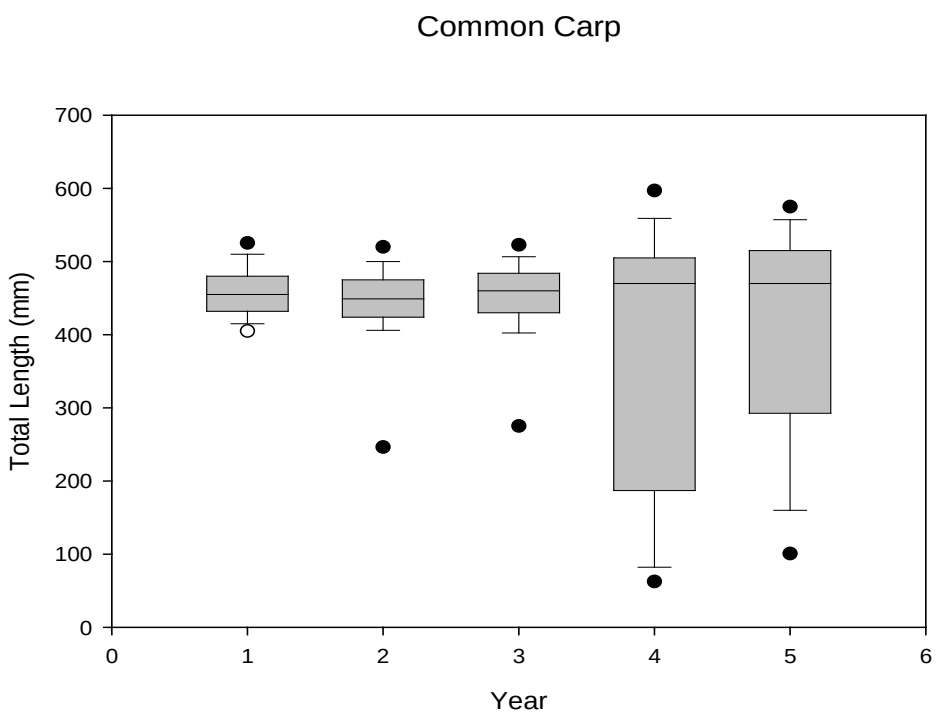

Figure 13. Distribution of total length of common carp by year from the lower San Juan River (Year 1: 2002, Year 2: 2003, Year 3: 2004, Year 4: 2005, Year 5: 2006). Gray rectangles represent 25th and 75th percentiles. The horizontal line within the gray rectangles is the median total length. Whiskers represent 10th and 90th percentiles. Black dots represent 5th and 95th percentiles.

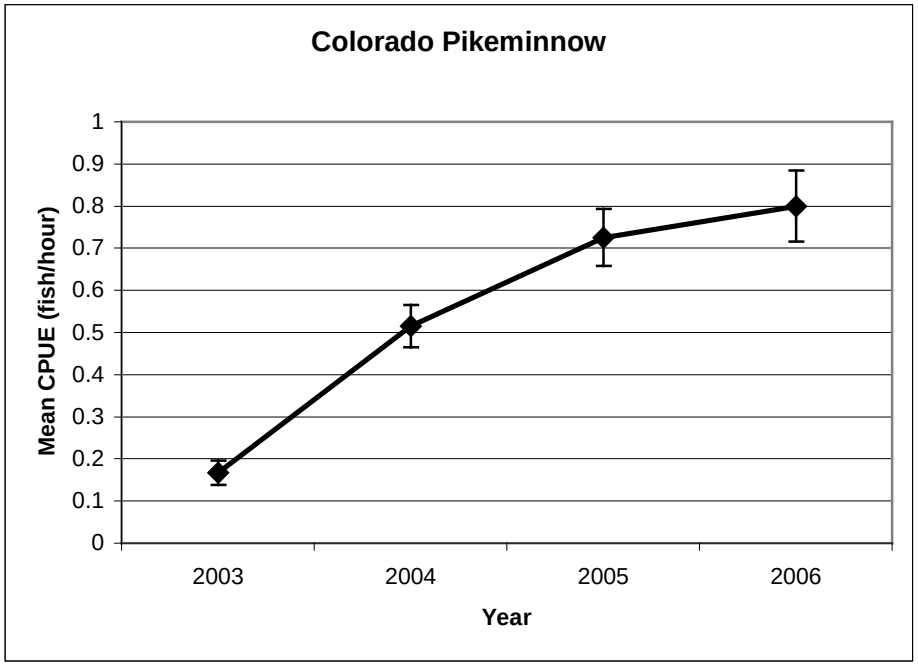

Figure 14. Mean catch rate of Colorado pikeminnow in the lower San Juan River by year from 2003 to 2006. Error bars represent ± 1 standard error.

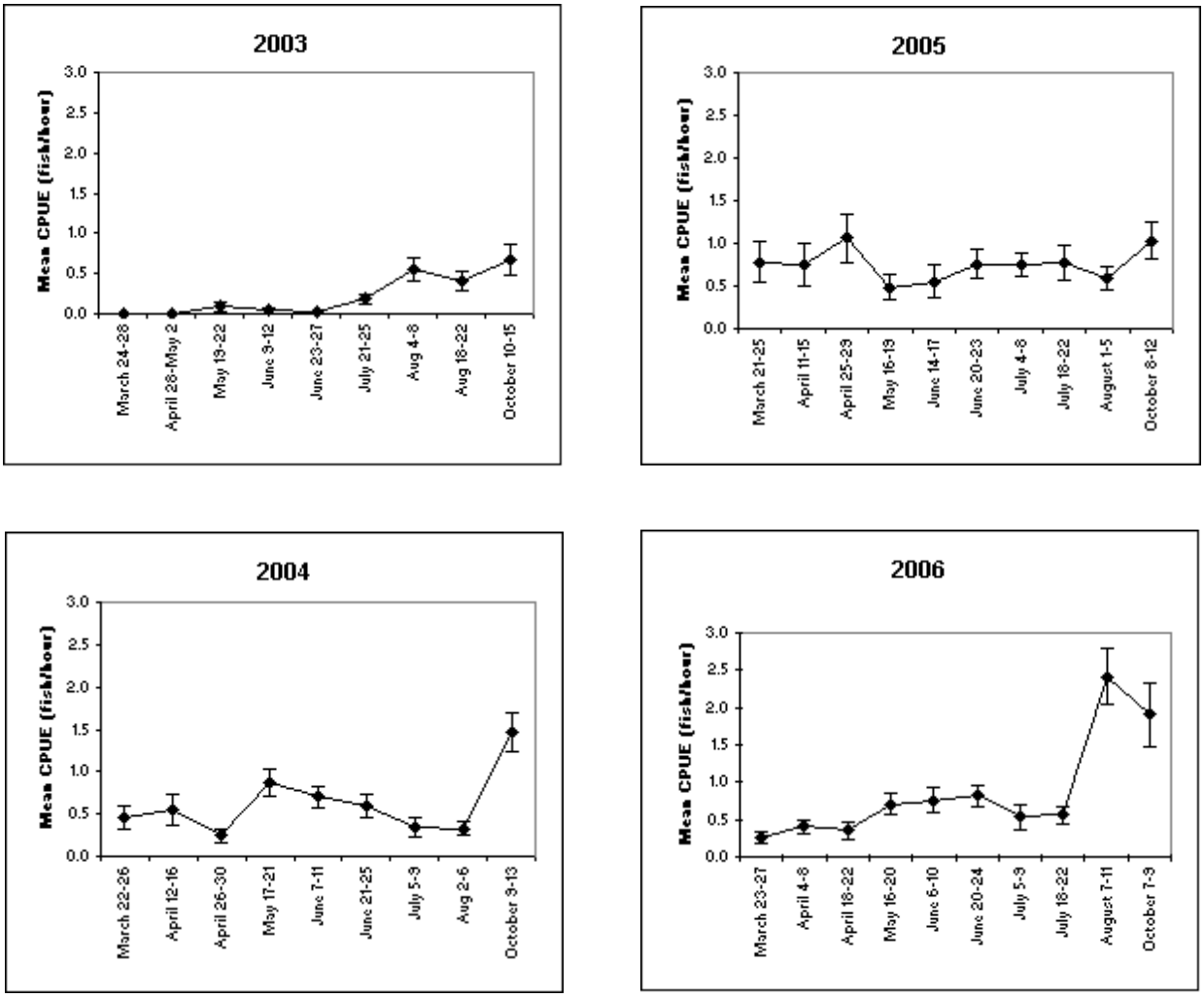

Figure 15. Mean Colorado pikeminnow electrofishing catch rate by pass from 2003 to 2006 in the lower San Juan River. Error bars represent $\pm$ 1 standard error.

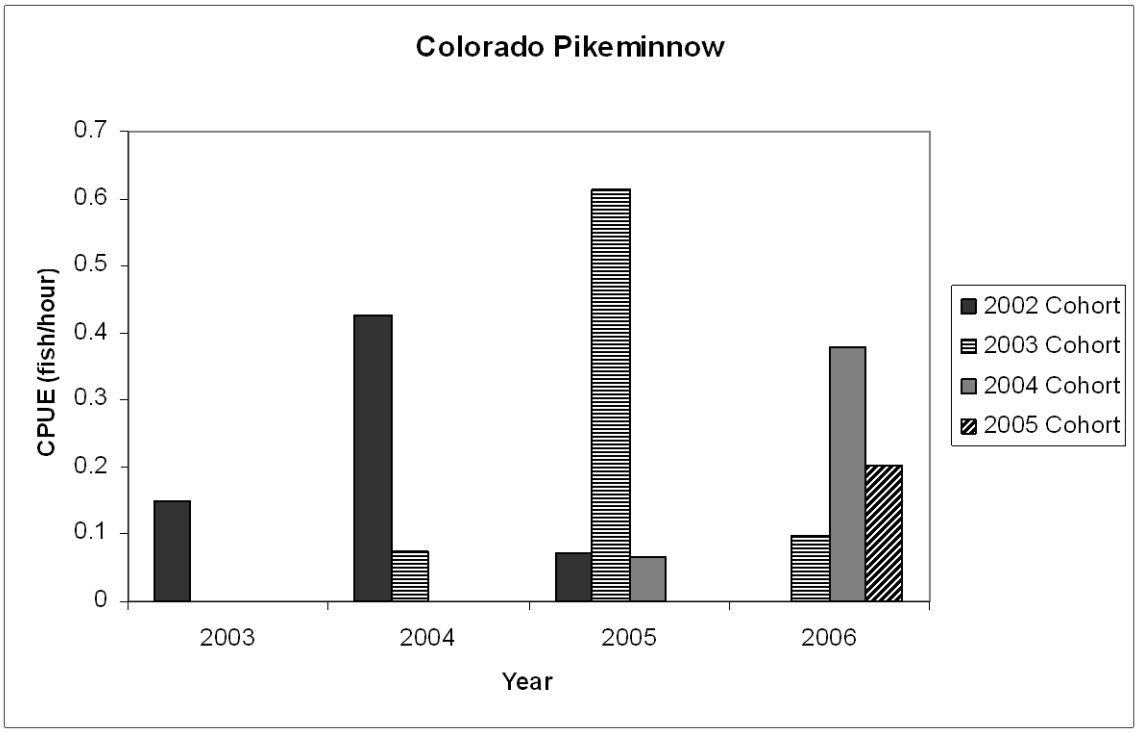

Figure 16. Colorado pikeminnow electrofishing catch rate by cohort across years from 2003 to 2006 in the lower San Juan River.

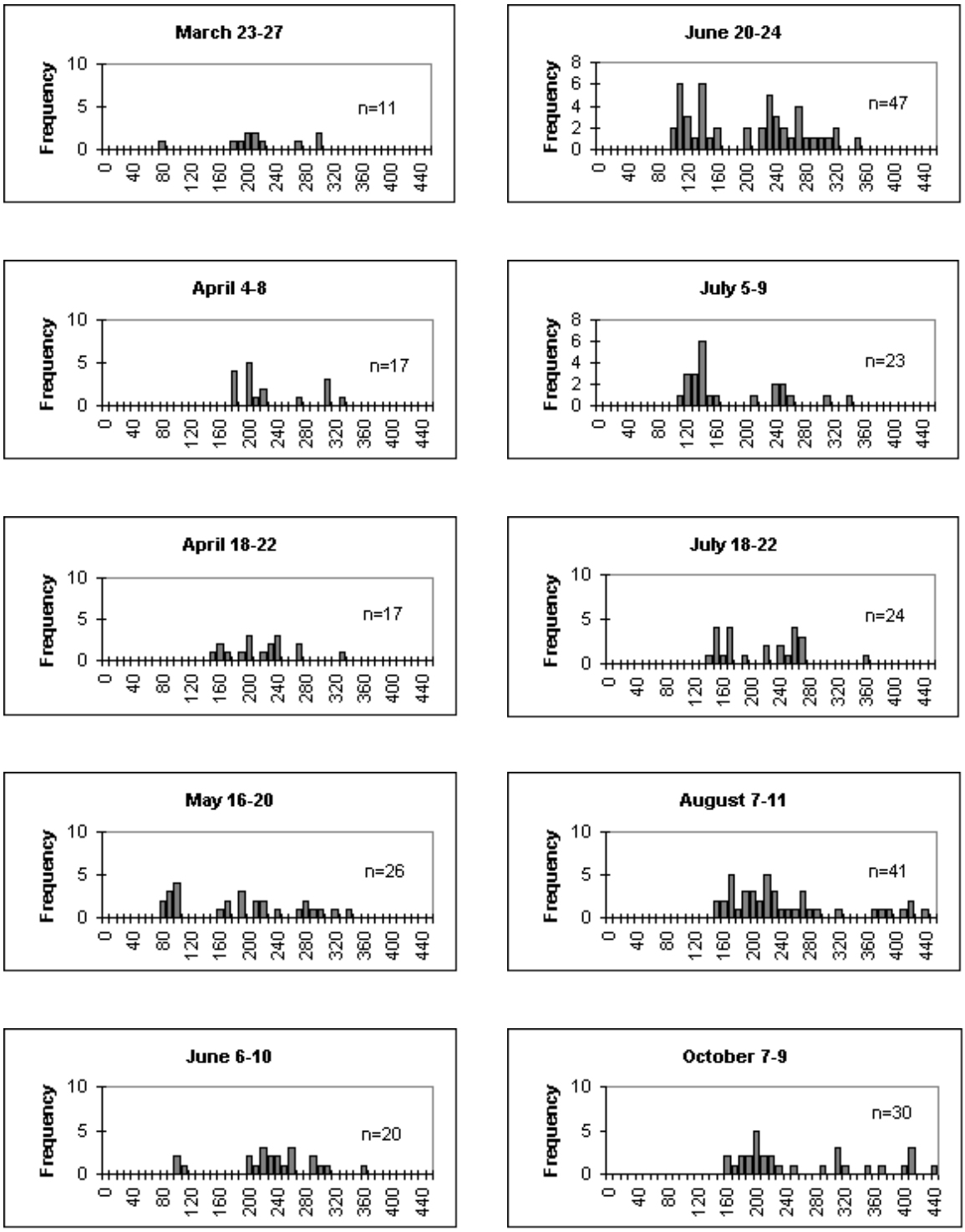

Figure 17. Length-frequency histograms of Colorado pikeminnow collected by pass in the lower San Juan River in 2006.

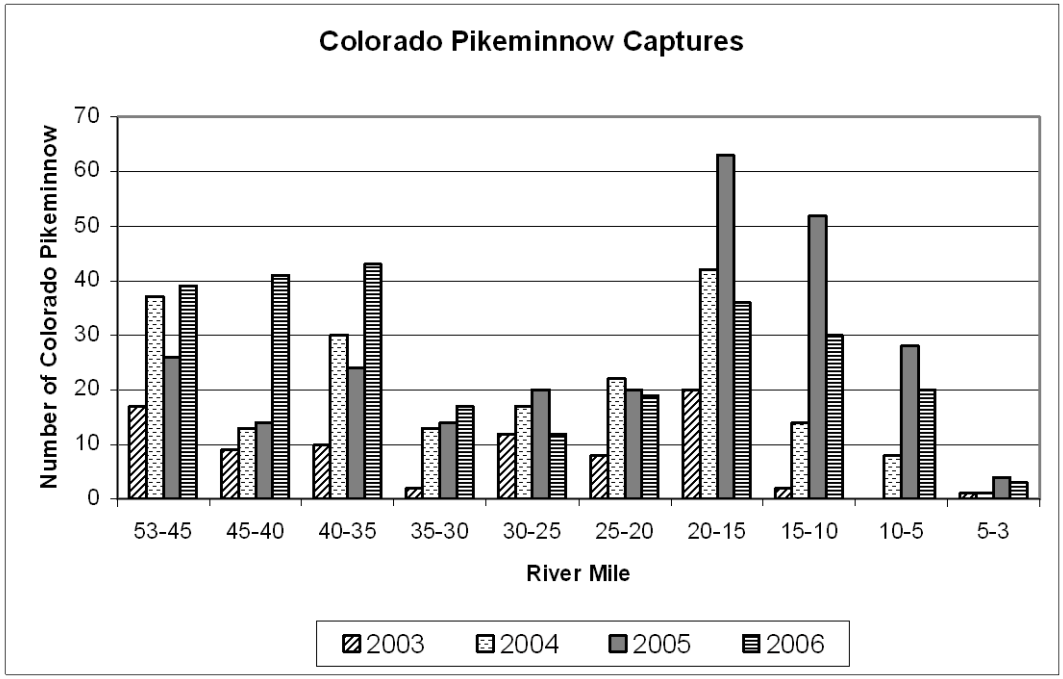

Figure 18. Distribution of Colorado pikeminnow captures by river mile from 2003 to 2006 in the lower San Juan River.

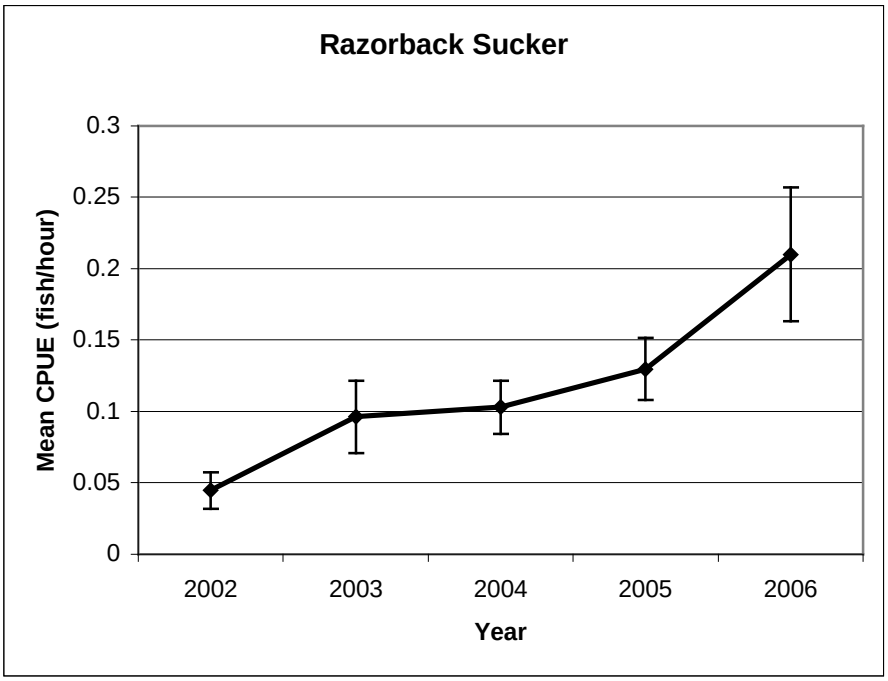

Figure 19. Mean electrofishing catch rate of razorback sucker in the lower San Juan River by year from 2002 to 2006. Error bars represent $\pm$ 1 standard error.

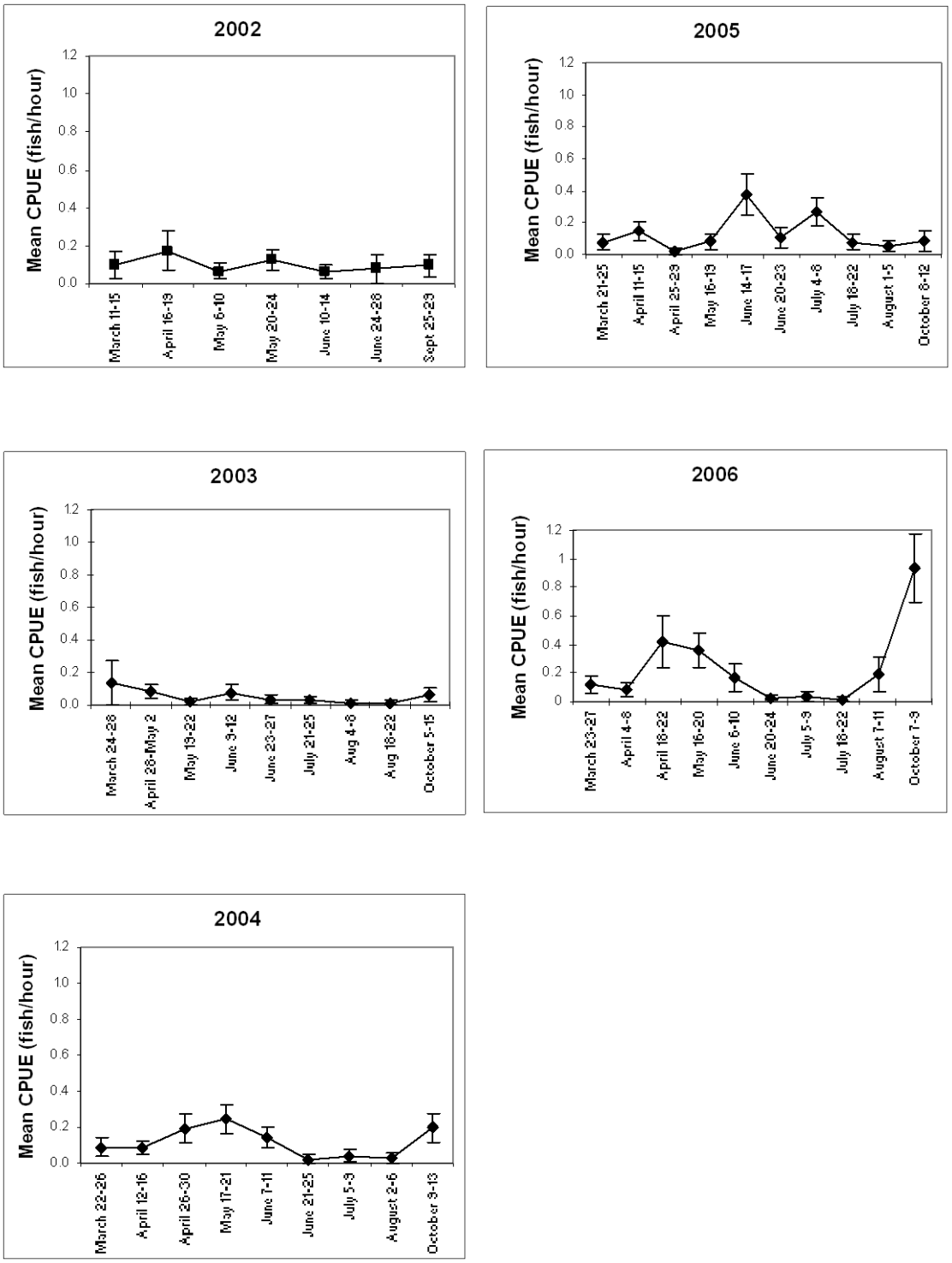

Figure 20. Mean electrofishing catch rate of razorback sucker by trip across years from 2002 to 2006 in the lower San Juan River.

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 2006.

Trip Date	Average Flow (ft^3/s)	Average Water Temp. (C°)	Average Turbidity (mm)
March 23-27	650	10.6	670
April 4-8	745	14.9	293
April 18-22	1143	16.2	133
May 16-20	2278	22.9	85
June 6-10	5675	18.7	79
June 20-24	956	26.4	251
July 5-9	893	26.7	351
July 18-22	723	28.6	75
August 7-11	1813	26.1	29
October 7-9	7273	14.1	NA

Appendix B. Common name, scientific name and abbreviations for 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