

# NONNATIVE SPECIES MONITORING AND CONTROL IN THE UPPER SAN JUAN RIVER: 2008

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## FINAL REPORT

PREPARED FOR:

SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM



PREPARED BY:

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ERNEST TELLER SR.

U.S. FISH AND WILDLIFE SERVICE

NEW MEXICO FISH AND WILDLIFE CONSERVATION OFFICE

3800 COMMONS N.E.

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SUBMITTED TO:

SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM

BIOLOGY COMMITTEE

3 JUNE 2009

## EXECUTIVE SUMMARY

1. A total of 16,968 channel catfish and 1,173 common carp were removed from river miles (RM) 166.6 – 52.9 in 769.63 hours of electrofishing.
2. Channel catfish CPUE from PNM Weir to Hogback Diversion was similar to CPUE in 2007 but was significantly ( $p < 0.05$ ) lower than values observed from 2001-2005.
3. Channel catfish CPUE from Hogback Diversion to Shiprock Bridge was similar to CPUE in 2007 but was significantly ( $p < 0.05$ ) lower than values observed from 2003-2006.
4. The lowest channel catfish CPUE over the duration of the study period was recorded in each of the two upper Sections of the San Juan River.
5. Mean total length (TL) of channel catfish in the upper Sections of the San Juan River has increased over the last several years; however, overall abundance of larger fish have been greatly reduced.
6. The channel catfish population structure was primarily composed of 2002/2003 cohorts with few younger (Age-0 or Age-1) cohorts.
7. Since the initiation of intensive nonnative fish removal in each Section an 80% reduction in channel catfish CPUE was observed from PNM to Hogback Diversion (2001 – 2008), an 85% reduction from Hogback Diversion to Shiprock Bridge (2003 -2008) and a 59% reduction from Shiprock Bridge to Mexican Hat, Utah (2006 – 2008).
8. Decreased abundance of nonnative fishes in downstream Sections reduced the potential source of fish to immigrate into upper removal Sections resulting in declined abundance within these upper Sections.
9. Common carp collections were infrequent throughout the study area.
10. Significant changes in long term trends of native sucker abundance and condition factor, as a response to intensive nonnative fish removal, were not observed.
11. Majority of razorback sucker captures occurred within 10 RM's of the stocking location at RM 158.6.
12. Razorback sucker captured six or more times were collected within seven river miles of the stocking locations. Time between recaptures ranged from two months to > 2 years and were documented within 3 RM's of previous capture.
13. The highest number of Colorado pikeminnow recaptures and CPUE was documented near the stocking location at RM 134.9.
14. Short term retention (< 150 days) near the stocking site of acclimatized Colorado pikeminnow was observed although subsequent captures were documented throughout the study area.

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## INTRODUCTION

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The introduction and establishment of nonnative fishes has been recognized as one of several factors leading to the decline of native fish populations. Introductions of nonnative fishes in western North American riverine systems can affect native fish populations due to the depauperate nature of these systems and the evolution of native species in the absence of predators (Minckley and Douglas 1991). The control of nonnative fishes has become an increasingly important management action in programs aimed at the recovery of federally protected species (Mueller 2005). The establishment of channel catfish *Ictalurus punctatus* and common carp *Cyprinus carpio* has been identified as a detriment to the recovery of Colorado pikeminnow *Ptychocheilus lucius* and razorback sucker *Xyrauchen texanus* (USFW 2002a and 2002b) and their control has specifically been identified as a management element in the San Juan River Basin Recovery Implementation Program's Long Range Plan (U.S. Fish and Wildlife Service 2008):

***San Juan River Recovery Implementation Program's Long Range Plan (2008):***

***Element 4. Interactions between native and nonnative fish species***

***Goal 4.1- Control of problematic nonnative fishes as needed***

***Action 4.1.1- Develop, implement, and evaluate the most effective strategies for reducing problematic nonnative fishes.***

***Task 4.1.1.8- Evaluate effects of nonnative fish control on distribution, abundance, and demographics (e.g. fish size, age, sexual maturity) of nonnative fish populations***

Removal efforts by U.S. Fish and Wildlife Service, New Mexico Fish and Wildlife Conservation Office (NMFWCO) began on a limited basis in 1998 with intensified efforts beginning in 2001. These efforts focused on a 7.6 river mile (RM) reach near Fruitland, NM. Location of intensive removal efforts was influenced by information on adult fish distribution and abundance reported by Ryden (2000). Numbers of channel catfish and common carp were lower upstream of PNM Weir (RM 166.6) and the majority of nonnative fishes within Geomorphic Reaches 6 and 5 (Bliesner and Lamarra 2000) were considered adult. The presence of water diversion structures that served as potential impediments to upstream fish movement and the high densities of large adult nonnative fishes in these upper Sections determined where intensive removal efforts would focus.



Efforts in 2008 marked the eighth consecutive year of intensive nonnative removal from PNM Weir to Hogback Diversion (RM 166.6 - 159.0). In addition to this Section, intensive nonnative removal from Hogback Diversion to Shiprock Bridge (RM 158.8 – 147.9) has been conducted since 2003. Based on increased channel catfish abundance trends (Ryden 2007 and 2008), efforts were expanded to include intensive removal from Shiprock Bridge to Mexican Hat, UT (RM 147.9 – 52.9). In 2008, intensive nonnative removal conducted by NMFWCO encompassed 113.7 river miles.

Study objectives were as follows:

1. Continue data collection and mechanical removal of large bodied nonnative fish during main channel and rare fish monitoring efforts.
2. Evaluate distribution and abundance patterns of nonnative species to determine effects of mechanical removal.
3. Characterize distribution and abundance of endangered fish in the upper reaches of the San Juan River.
4. Relate distribution and abundance patterns of both common and uncommon native fishes to nonnative removal.
5. Continue and expand transplanted channel catfish to closed impoundments isolated from the San Juan River with the assistance of New Mexico Department of Game and Fish, Navajo Nation Fish and Wildlife Service and the SWTFC.

## **STUDY AREA**

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Intensive nonnative removal efforts in 2008 focused on three individual Sections of the San Juan River, New Mexico, Colorado, Utah, encompassing 113.7 river miles (RM). Sections sampled included PNM Weir to Hogback Diversion (RM 166.6 – 159.0), Hogback Diversion to Shiprock Bridge (RM 158.8 – 147.9), and Shiprock Bridge to Mexican Hat, Utah (RM 147.9 – 52.9) (Figure 1). Nonnative removal was conducted in portions of Geomorphic reaches 6 – 2 (Bliesner and Lamarra 2000). PNM Weir to Hogback Diversion is exclusively located in Geomorphic Reach 6, Hogback Diversion to Shiprock Bridge encompasses portions of both Geomorphic reaches 6 and 5, and Shiprock Bridge to Mexican Hat lies in reaches 5 – 2.

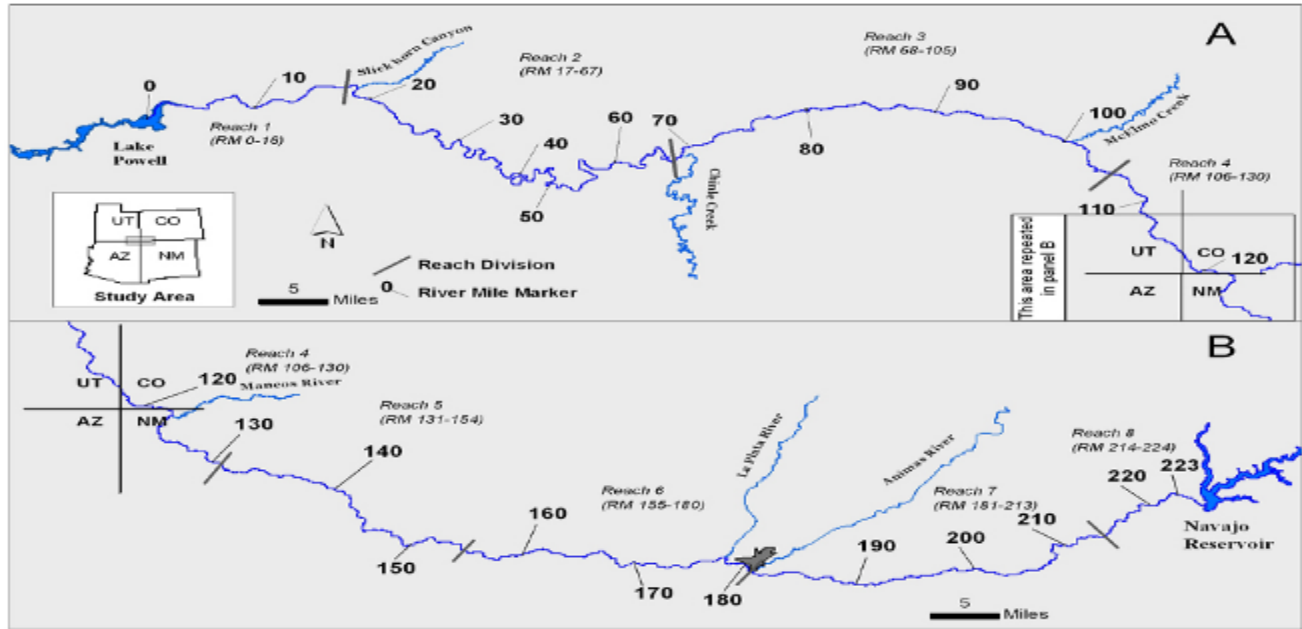


Figure 1. Map of study area – map provided by UNM MSB

**METHODS**

Nonnative fishes were collected using raft-mounted electrofishing units (Smith-Root 5.0 GPP). Rafts sampled near each shoreline and netters attempted to collect any nonnative fish observed. In addition to nonnative species, native rare fishes were netted during all efforts. All nonnative fishes or a representative sub-sample (blind grab) were measured (nearest 1 mm) for total and standard lengths and weighed (nearest 5 g) for mass. Seconds of electrofishing were recorded to determine effort. All nonnative fishes collected were removed from the river. A total of four trips were conducted in each of the three Sections. Two electrofishing rafts sampled for three consecutive days/trip from PNM Weir to Hogback Diversion and Hogback Diversion downstream to Shiprock Bridge. During sampling from Shiprock Bridge to Mexican Hat, a total of four electrofishing rafts were used. Two rafts began sampling one to two hours prior to the remaining rafts resulting in the completion of two electrofishing passes per trip.

When feasible, channel catfish were held for transplantation. Channel catfish were kept in live wells treated with salt and stress coat to alleviate stress caused by holding and transporting. A battery powered aeration system or compressed oxygen was used for circulation and aeration. Channel catfish were transported from the San Juan River to closed impoundments in distribution trucks provided by the Navajo Nation Department of Fish and Wildlife.

Native rare fishes collected were immediately placed in a live well separate to that of nonnative fishes. Shocking crews periodically stopped to measure (nearest 1 mm), weigh (nearest 5 g) and check for the presence of a Passive Implant Transponder (PIT) tag. If a PIT tag was detected, the number was recorded and it was noted that the fish was a recaptured fish. If the presence of a PIT tag was not detected and the fish was  $\geq 150$  mm TL, a 134.2 kHz PIT was implanted and the capture status was recorded as a new capture.

All available capture data were analyzed independently by Section. For example, catch rates among years from PNM to Hogback, Hogback to Shiprock and Shiprock to Mexican Hat were compared only with the same Section and not among Sections. To determine trends in distribution and abundance, mean catch rates (fish per hour of electrofishing; CPUE) and standard errors ( $\pm 1$  SE) were calculated using the software package SPSS version 13.0 (2004). Species CPUE was calculated as the total number of fish collected divided by the total effort of sampling (hours of electrofishing). Data were summarized by Section, trip, and year. For sampling efforts from Shiprock Bridge to Mexican Hat downstream (1<sup>st</sup> pass) raft data were analyzed and reported on independently from upstream (2<sup>nd</sup> pass) data on trips conducted from Shiprock Bridge to Mexican Hat. To evaluate native fish response specific to intensive nonnative removal we analyzed data from annual sub-adult and adult fish community monitoring conducted by USFWS – Colorado River Project.

If CPUE data met the assumptions of normality and equality of variance, a One Way Analysis of Variance (ANOVA) was conducted to determine if significant differences existed. Multiple pairwise comparisons using Bonferroni post hoc tests were used to determine where specific differences existed. If data were heteroscedastic, and transformations were unsuccessful in attaining equal variance, an ANOVA on ranked data (Kruskal-Wallis) was conducted with Nemenyi post hoc tests to determine where specific differences existed (Zar 1996).

## **RESULTS**

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### **PNM WEIR TO HOGBACK DIVERSION (RM 166.6 – 159.0)**

A total of 378 channel catfish and 68 common carp were collected during four trips (March to November) and 59.68 hours of electrofishing (Appendix A-1). In addition to channel

catfish and common carp, other nonnative fishes removed from this Section included rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, bullhead catfishes *Ameiurus spp.*, largemouth bass *Micropterus salmoides*, and green sunfish *Lepomis cyanellus*. No striped bass (*Morone saxatilis*) or walleye (*Sander vitreus*) were collected or observed.

#### CHANNEL CATFISH

No channel catfish were collected during the March and June trips (Figure 2). Catch rates increased for the August trip to 16.3 fish/hour (ANOVA;  $F_{(3,44)} = 37.769$ ; Nemenyi post-hoc,  $p < 0.001$ ). Channel catfish catch rates decreased to  $< 5.0$  fish/hour for the November trip and were statistically similar to the first two trips. Channel catfish CPUE for all trips and all life stages combined was 4.5 fish/hour (Figure 3).

Channel catfish CPUE in 2008 was significantly lower than CPUE from 2001-2005 (ANOVA;  $F_{(7,439)} = 7.910$ ; Nemenyi post-hoc,  $p < 0.05$ ). Catch rates for all life stages combined were at the lowest level (4.5 fish/hour) observed among 2001-2008 comparisons (Figure 3). Juvenile CPUE was  $< 1.0$  fish in 2008 and was similar to that in 2006 and 2007. Adult channel catfish comprised the majority of the catch in 2008 and CPUE was similar to that in 2007 but

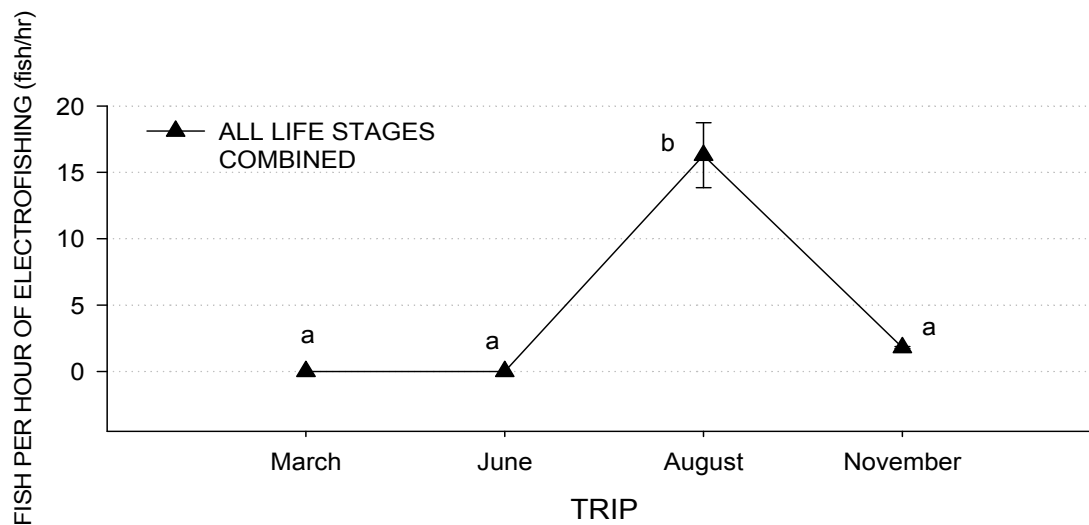


Figure 2. Channel catfish CPUE (fish/hour) by trip within the PNM Weir to Hogback Diversion Section; 2008. Error bars represent  $\pm 1$  SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

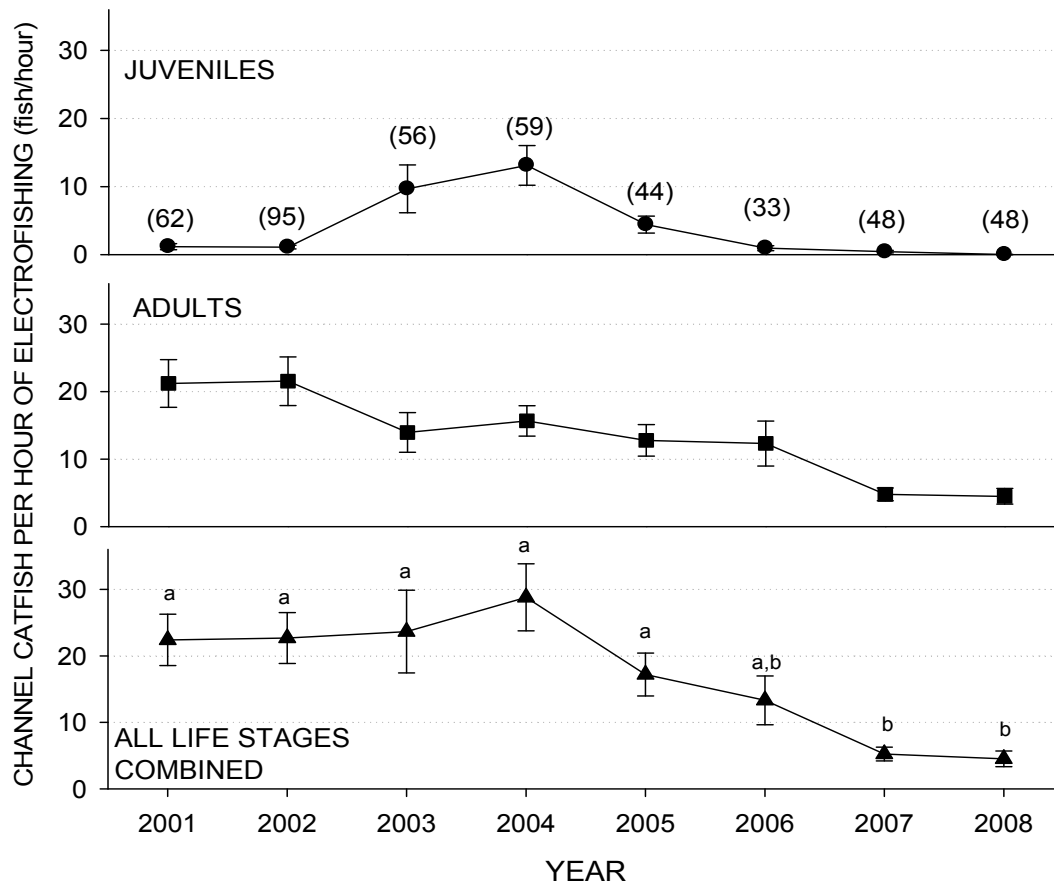


Figure 3. Channel catfish catch per unit effort (CPUE; fish/hour) by year, PNM Weir to Hogback Diversion; 2001-2008. Error bars represent  $\pm 1$  SE. Letters represent comparisons among years (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons. Sample size presented parenthetically.

significantly lower than CPUE from 2001-2006 (ANOVA;  $F_{(7, 439)} = 7.577$ ; Nemenyi post-hoc;  $p < 0.05$ ). Channel catfish CPUE in this Section was reduced by 80% from 2001 to 2008 (Appendix B).

Mean total length (TL) of channel catfish in 2008 was 420 mm (SE  $\pm 3.5$ ) and represented the highest value observed during the study period (Figure 4). Measured lengths ranged from 296 to 660 mm TL (median = 410 mm). The number of channel catfish measured in 2008 was greatly reduced from 2001 ( $n = 3,954$  in 2001;  $n = 292$  in 2008) and was representative of the overall reduced abundance observed since 2001. After observing the lowest mean TL (328 mm TL, SE  $\pm 1.5$ ) of the study period in 2003, mean TL increased in each of the past five years (2004-2008).

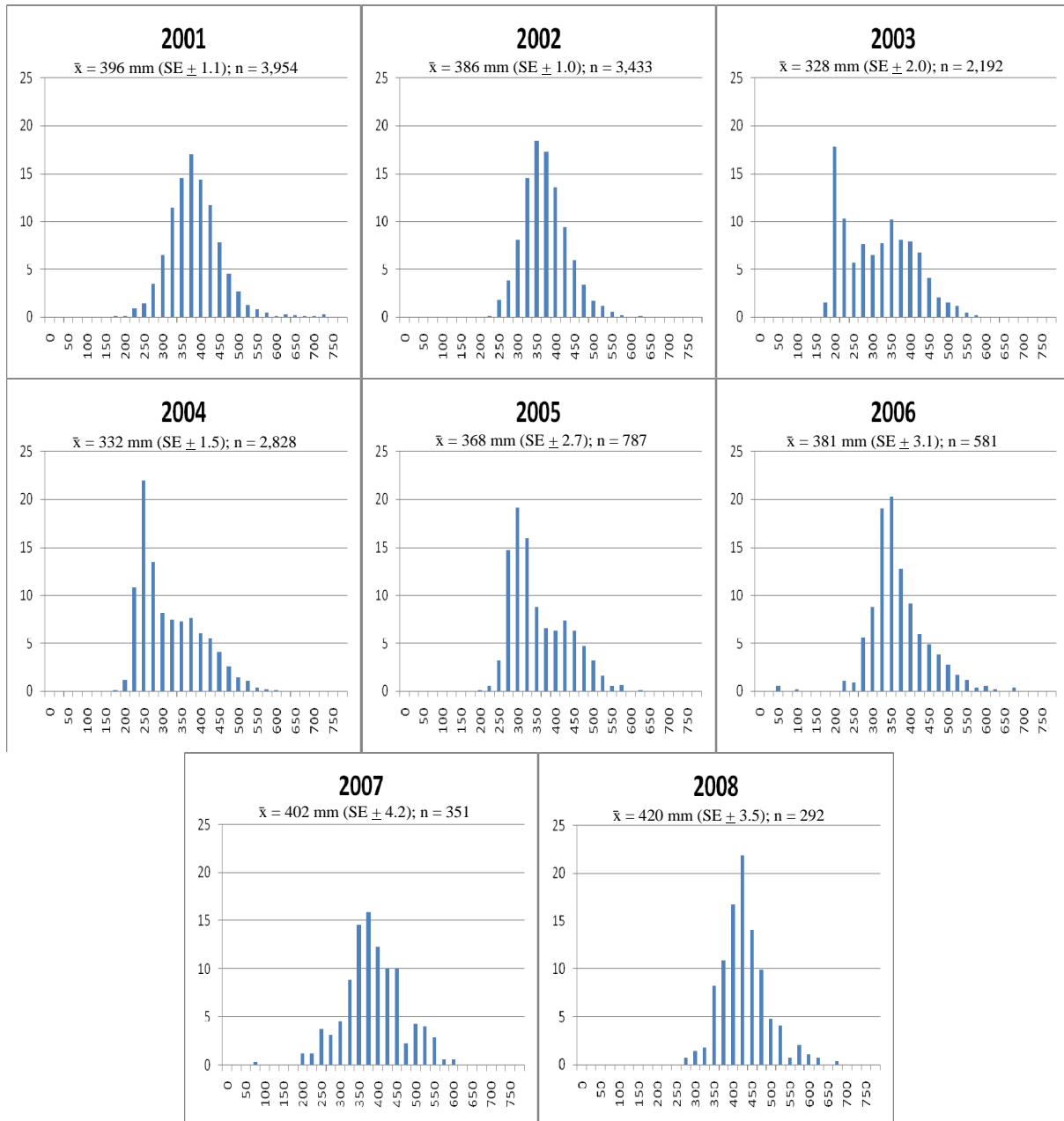


Figure 4. Length frequency histograms for channel catfish collected from PNM Weir to Hogback Diversion; 2001-2008. The y-axis represents percent (%) of catch and the x-axis represents total length.

## COMMON CARP

Common carp CPUE varied little among trips in 2008 and was < 5.0 fish/hour for each of the four trips (Figure 5). The highest value for CPUE was in March and varied between 0.6 and 1.1 fish/hour during the remaining trips. The four trip mean CPUE in 2008 was 1.4 fish/hour (Figure 6).

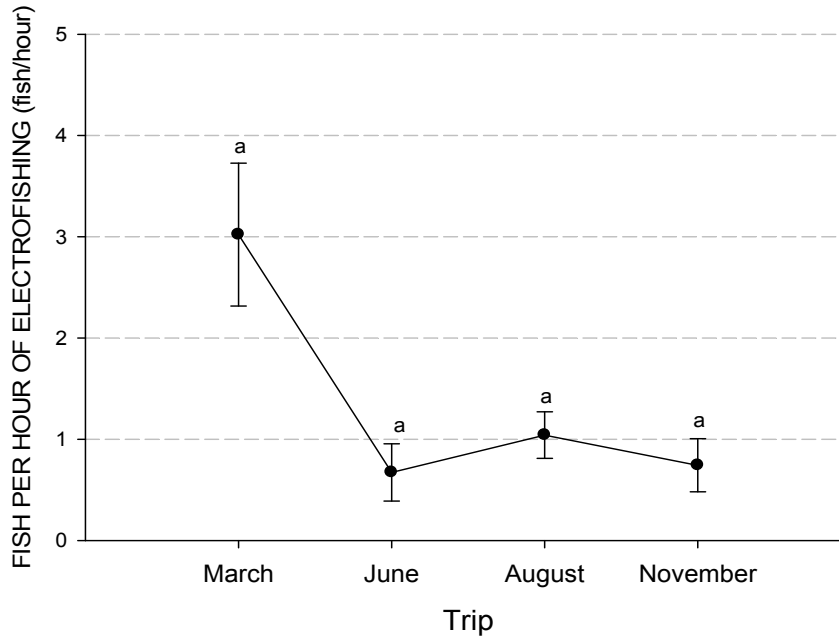


Figure 5. Common carp CPUE (fish/hour) by trip within the PNM Weir to Hogback Diversion Section; 2008. Error bars represent  $\pm 1$  SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

Comparison of common carp CPUE among years showed significant declines since 2001 resulting in the lowest CPUE since intensive nonnative removal began (ANOVA;  $F_{(7, 439)} = 35.791$ ; Nemenyi post-hoc;  $p < 0.001$ ). Common carp CPUE in 2008 was similar to values observed in 2007 but was significantly lower than all previous years (Figure 6). Common carp were collected infrequently in 2008 from PNM Weir to Hogback Diversion and annual CPUE has been < 5.0 fish/hour since 2004.

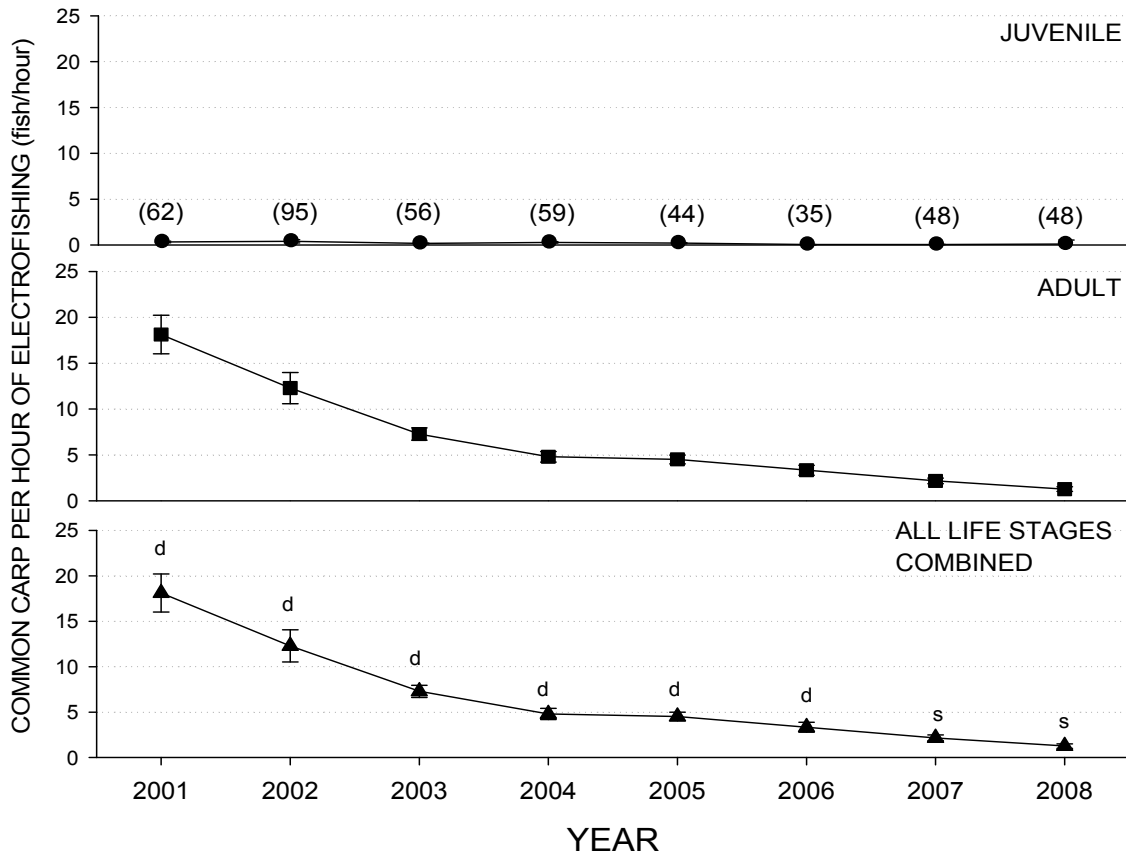


Figure 6. Common carp catch per unit effort (CPUE; fish/hour) by year, PNM Weir to Hogback Diversion; 2001-2008. Error bars represent  $\pm 1$  SE. Letters represent comparisons among years (Nemenyi post-hoc. Letter above data points represent statistical comparisons of that individual year to 2008. A “d” means that year was statistically different than 2008 and an “s” means that year was similar to 2008. Sample size presented parenthetically.

**HOGBACK DIVERSION TO SHIPROCK BRIDGE (RM 158.8 – 147.9)**

A total of 891 channel catfish and 183 common carp were collected during four trips (April to November) and 94.3 hours of electrofishing (Appendix A-2). In addition to channel catfish and common carp, other nonnative fishes removed included, rainbow trout, brown trout, bullhead catfishes, green sunfish, bluegill (*Lepomis macrochirus*) and white sucker (*Catosomus commersoni*). No striped bass or walleye were collected or observed.



## CHANNEL CATFISH

Channel catfish CPUE varied by trip in 2008 and ranged from 0.43 to 17.02 fish/hour (Figure 7). Channel catfish CPUE was 0.43 fish/hour during the March trip and represented the lowest CPUE observed for channel catfish in this Section during the study period. Over 90%

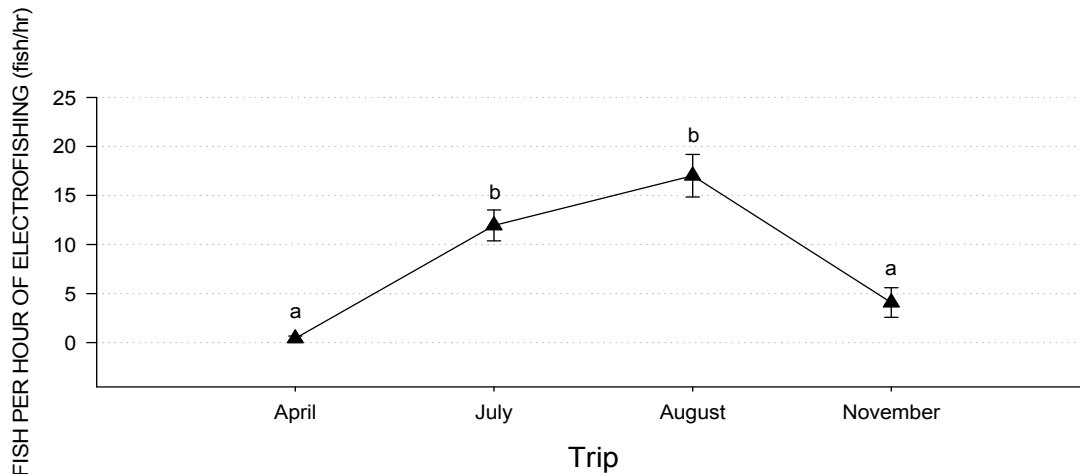


Figure 7. Channel catfish CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2008. Error bars represent  $\pm 1$  SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

( $n = 802$ ) of all channel catfish removed from this Section were collected during the July and August trips (Figure 7). Catch rates decreased to 4.9 fish/hour during the November trip (ANOVA;  $F_{(3, 114)} = 23.808$ ; Tukey post-hoc;  $p < 0.001$ ). The four trip mean CPUE in 2008 was 8.8 fish/hour (Figure 8).

Channel catfish CPUE declined from 57.7 to 8.8 fish/hour from 2003 to 2008 (ANOVA;  $F_{(5, 722)} = 55.414$ ; Nemenyi post-hoc;  $p < 0.001$ ) (Figure 8). Channel catfish CPUE was similar to 2007 but was significantly lower than 2003-2006 ( $p < 0.05$ ). The differences in catch rates from 2005 and 2006 to 2008 were the result of lower relative abundance of adult fish in our collections. The four trip mean CPUE of 8.8 fish/hour represented the lowest catch rate in this Section during the study period. Channel catfish CPUE in this Section was reduced by 85% from 2003 to 2008 (Appendix B).

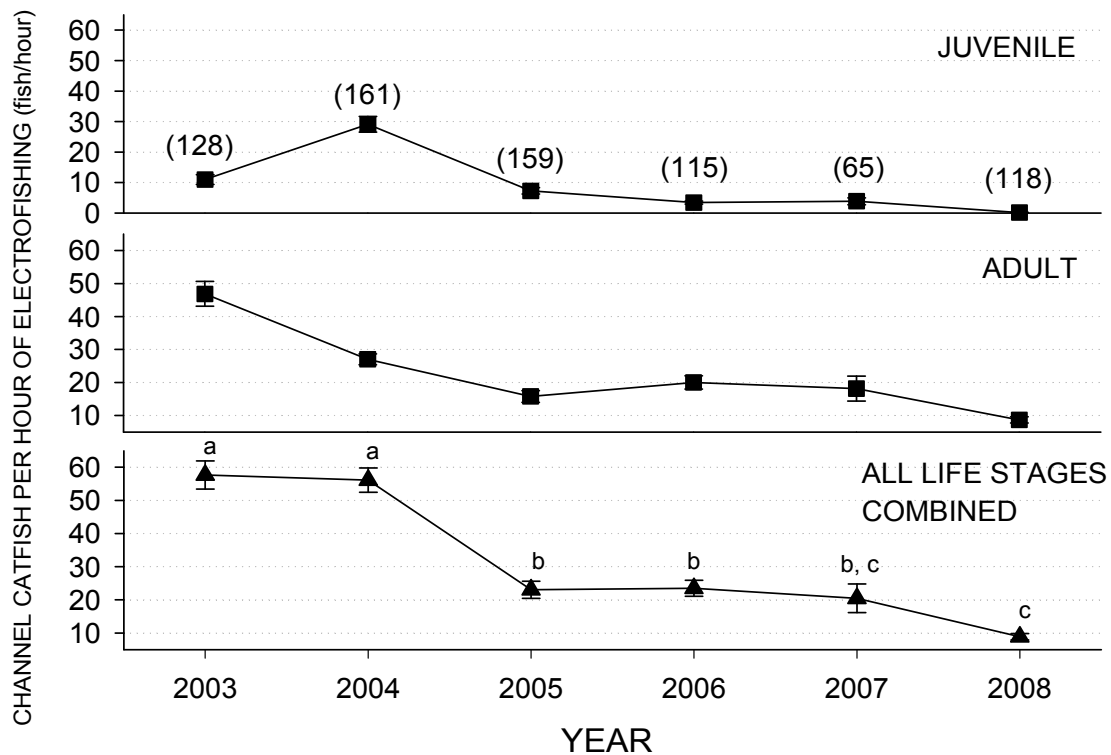


Figure 8. Channel catfish catch per unit effort (CPUE; fish/hour) by year, Hogback Diversion to Shiprock Bridge; 2003-2008. Error bars represent  $\pm 1$  SE. Letters represent comparisons among years (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons. Sample size presented parenthetically.

Mean total length (TL) of channel catfish in 2008 was 421 mm ( $SE \pm 2.0$ ) and represented the highest value observed during the study period (Figure 9). Measured lengths ranged from 231 to 646 mm TL (median = 413 mm). The number of channel catfish measured in 2008 was greatly reduced from 2003 to 2008 ( $n = 3,325$  in 2003;  $n = 833$  in 2008) and was representative of the reduced abundance observed since 2003. After observing the lowest mean TL (333 mm TL;  $SE \pm 1.6$ ) of the study period in 2004, mean TL increased in each of the past four years (2005-2008).

#### COMMON CARP

Common carp CPUE varied little among trips in 2008 and was below 5.0 fish/hour for each of the four trips (Figure 10). The highest value for CPUE was in April and CPUE varied

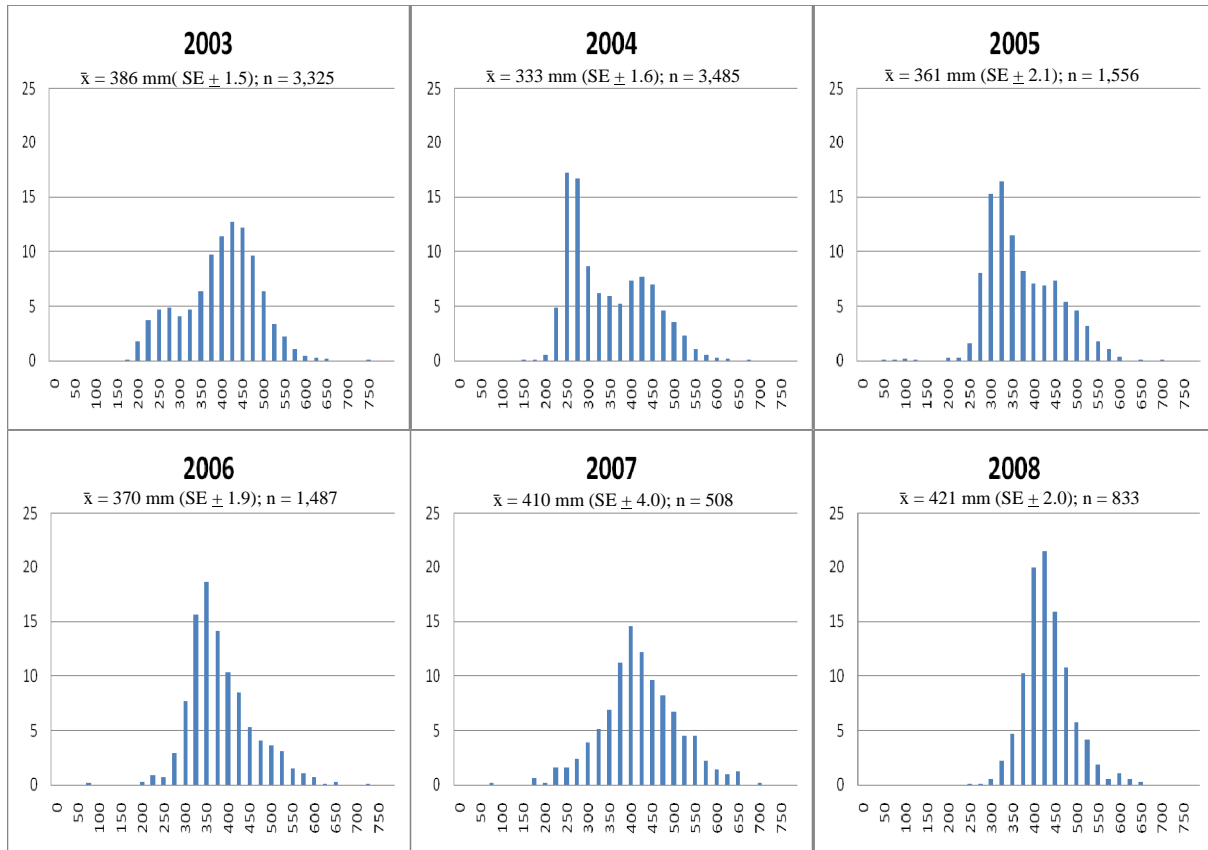


Figure 9. Length frequency histograms for channel catfish collected from Hogback Diversion to Shiprock Bridge; 2003-2008. The y-axis represents percent (%) of catch and the x-axis represents total length.

between 1.3 and 2.1 fish/hour on the remaining trips. The four trip mean CPUE in 2008 was 2.2 fish/hour (Figure 11).

Common carp CPUE in 2008 significantly declined compared to that of 2003 resulting in the lowest observed CPUE since intensive nonnative removal began (ANOVA;  $F_{(5, 770)} = 140.474$ ; Nemenyi post-hoc;  $p < 0.001$ ). Common carp CPUE in 2008 was similar to values observed in 2007 but was significantly lower than all previous years (Figure 11). Common carp were collected infrequently in 2008 from Hogback Diversion to Shiprock Bridge and annual CPUE has been  $< 5.0$  fish/hour since 2003.

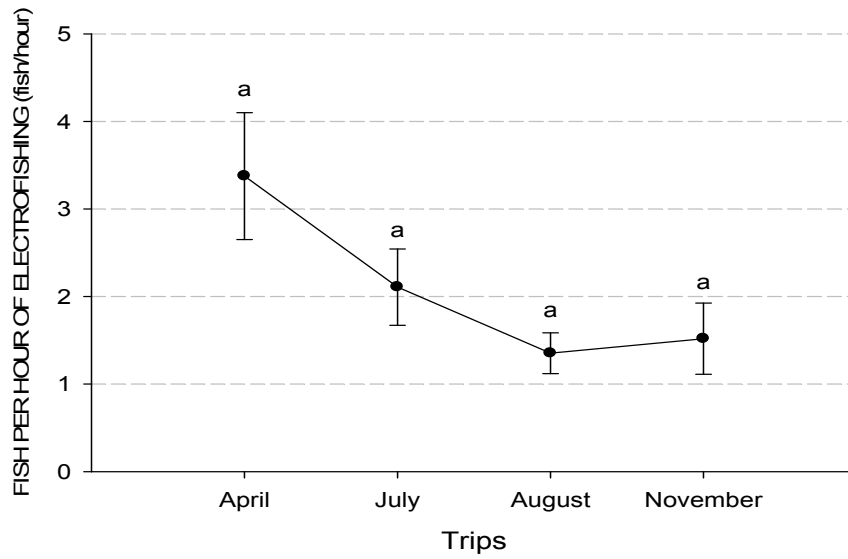


Figure 10. Common carp CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2008. Error bars represent  $\pm 1$  SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

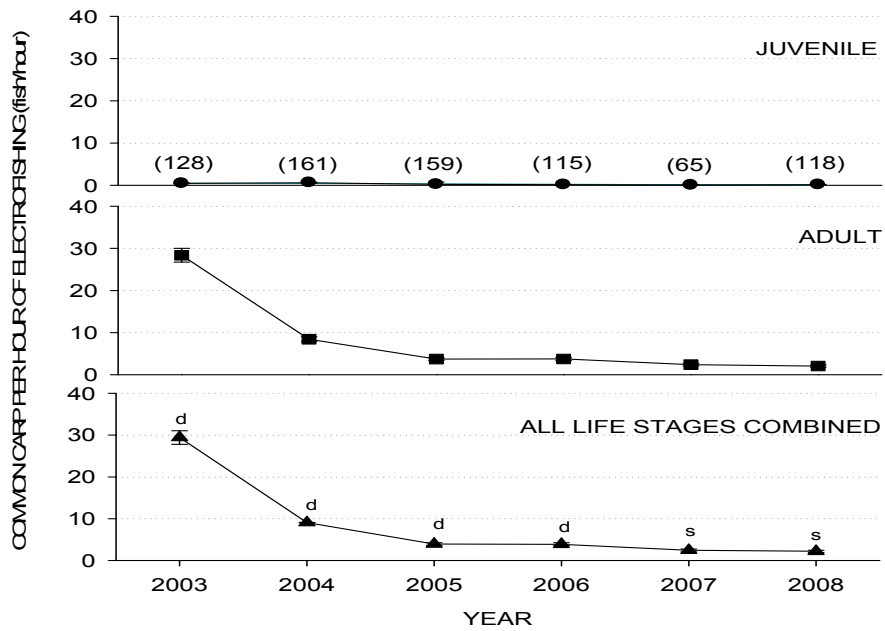


Figure 11. Common carp catch per unit effort (CPUE; fish/hour) by year, Hogback Diversion to Shiprock Bridge; 2003-2008. Error bars represent  $\pm 1$  SE. Letters represent comparisons among years (Nemenyi post-hoc). Letter above data points represent statistical comparisons of that individual year to 2008. A “d” means that year was statistically different than 2008 while an “s” means that year was similar to 2008. Sample size presented parenthetically.

**SHIPROCK BRIDGE TO MEXICAN HAT (RM 147.9 – 52.9)**

Three removal trips (April, July and September) were conducted from Shiprock Bridge to Mexican Hat, Utah yielding 9,791 channel catfish and 733 common carp in 482.81 hours of electrofishing (Appendix A-3). Nonnative fish removal was also conducted in conjunction with fall monitoring in October and yielded 5,908 channel catfish and 178 common carp in 131.1 hours of electrofishing. For the year, a total of 15,699 channel catfish and 911 common carp were removed from Shiprock Bridge to Mexican Hat in 613.9 hours of electrofishing. In addition to channel catfish and common carp, other nonnative fishes removed included rainbow trout, brown trout, bullhead catfishes, green sunfish, bluegill, and largemouth bass. No striped bass or walleye were collected or observed.

**CHANNEL CATFISH**

Channel catfish CPUE, all passes combined, was 23.4 fish/hour during the April trip. Due to poor sampling conditions (i.e. decreased visibility) catch rates decreased to 4.3 fish/hour during the July trip (ANOVA;  $F_{(3, 543)} = 152.383$ ; Nemenyi post-hoc,  $p < 0.001$ ) (Figure 12). The highest CPUE was in October, 41.6 fish/hour. Prior to September, the majority of the channel catfish catch was comprised of adult fish. Significant increases in juvenile CPUE were observed in both September and October (ANOVA;  $F_{(3, 543)} = 121.991$ ; Nemenyi post-hoc,  $p < 0.001$ ). The four trip mean CPUE for all passes combined was 29.5 fish/hour. Channel catfish CPUE in this Section was reduced by 59% from 2006 to 2008 (Appendix B).

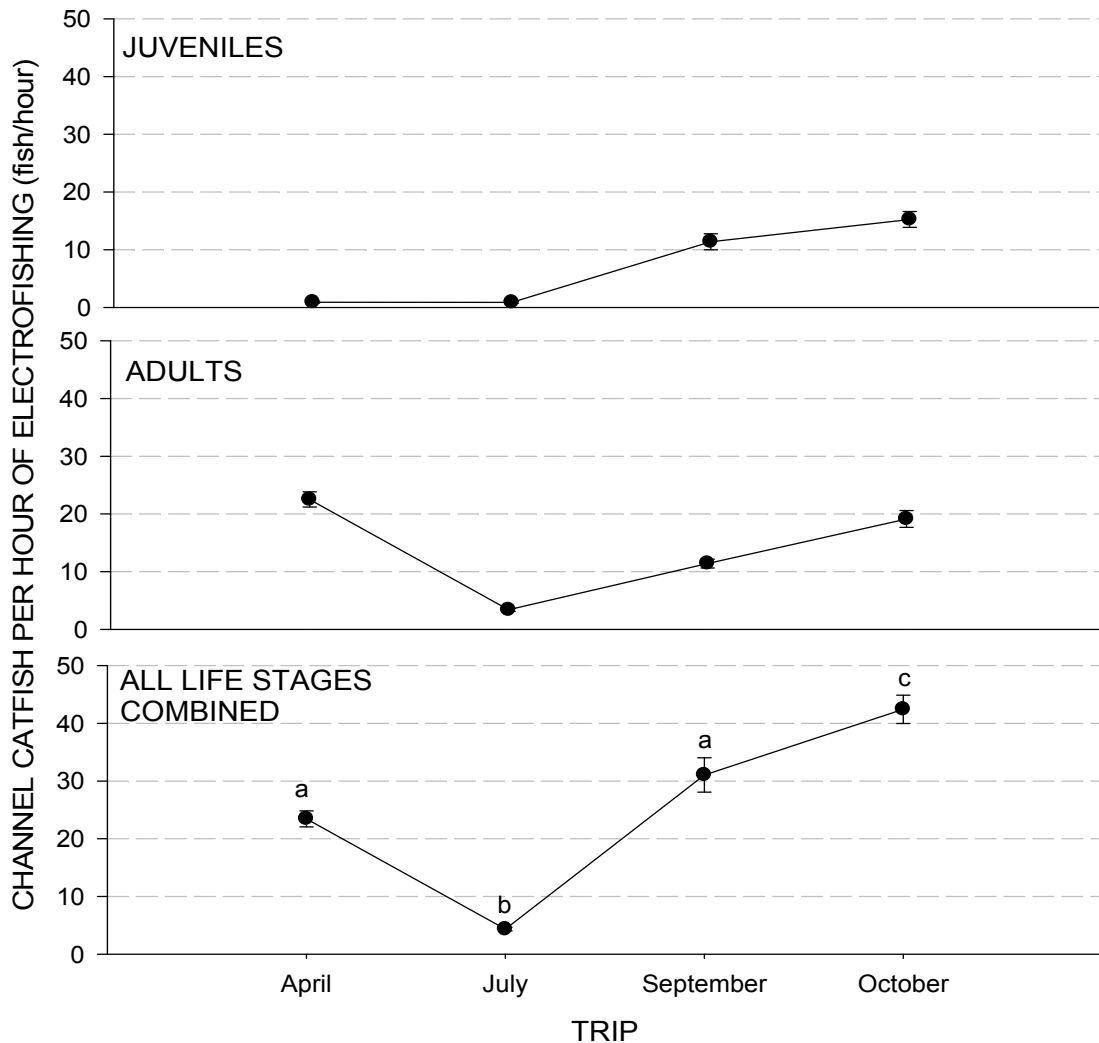


Figure 12. Channel catfish CPUE (fish/hour) by trip from Shiprock Bridge to Mexican Hat; 2008. Error bars represent  $\pm 1$  SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

Channel catfish mean TL in 2008 varied among trips. The largest mean TL was in April (403 mm TL) and decreased with each subsequent trip (Figure 13). Fish > 400 mm TL comprised 20% of the catch in April compared to 14% in October. Fish < 200 mm TL comprised a higher percentage of the catch in July compared to April (26.9% and 1.2%, respectively) and made up 36.2% of the catch during the October trip (Figure 13). October mean TL was significantly lower than April mean TL (ANOVA;  $F_{(3, 6982)} = 239.8$ ; Nemenyi post-hoc,  $p < 0.001$ ) and was attributed to increased captures of age-0 and small age-1 channel catfish.

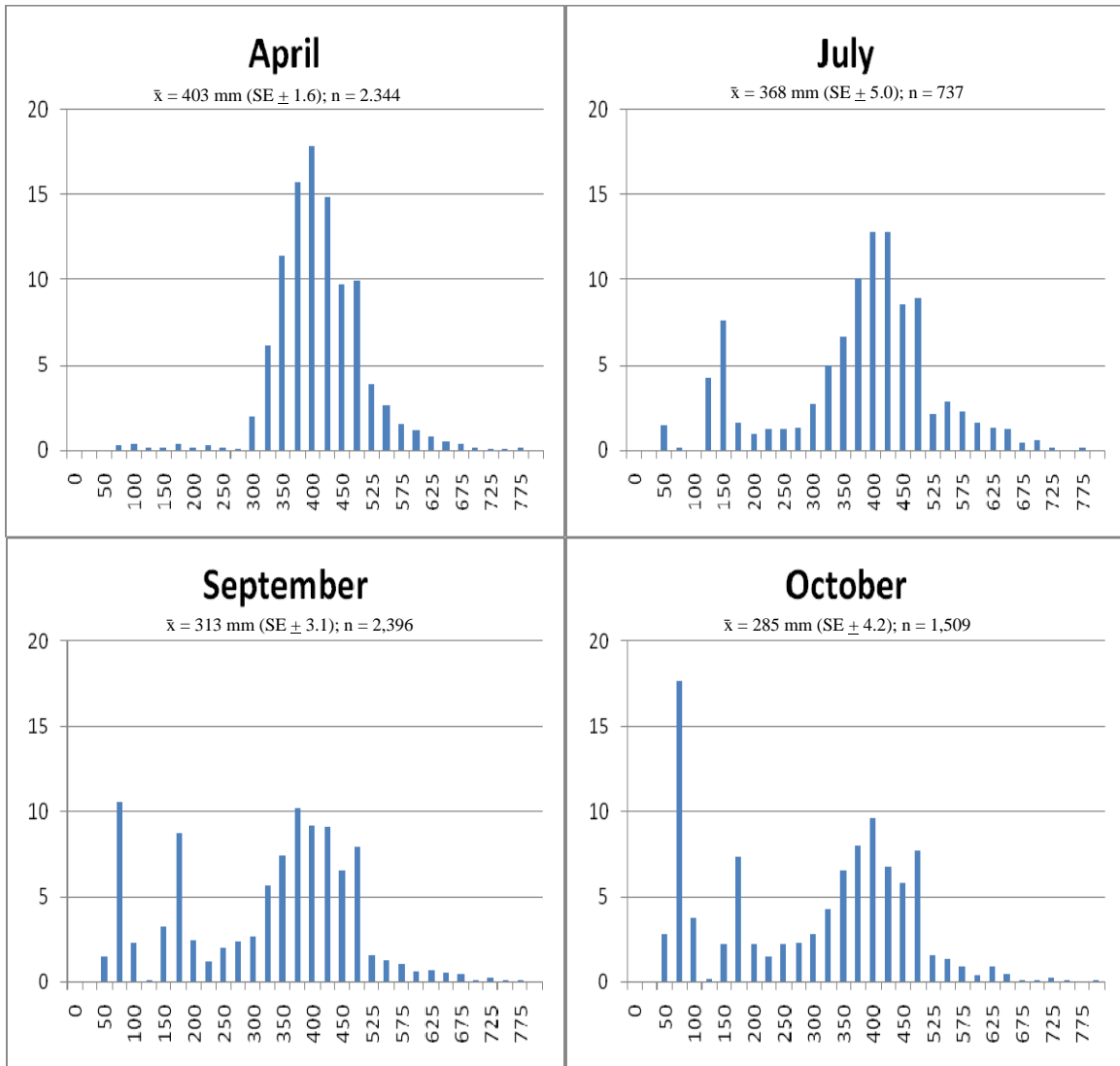


Figure 13. Length frequency histograms by trip for channel catfish collected from Shiprock Bridge to Mexican Hat Utah; 2008. The y-axis represents percent (%) of catch and the x-axis represents total length.

Channel catfish CPUE varied little among pass and trip comparisons. First pass catch rates for all life stages combined ranged from 5.2 to 43.9 fish/hour compared to 2nd pass catch rates that ranged from 3.5 to 41.6 fish/hour (Figure 14). The highest CPUE for each pass occurred during the October trip. Adult channel catfish CPUE was higher than juvenile CPUE prior to the September trip but similar during the September and October trips (Figure 14).

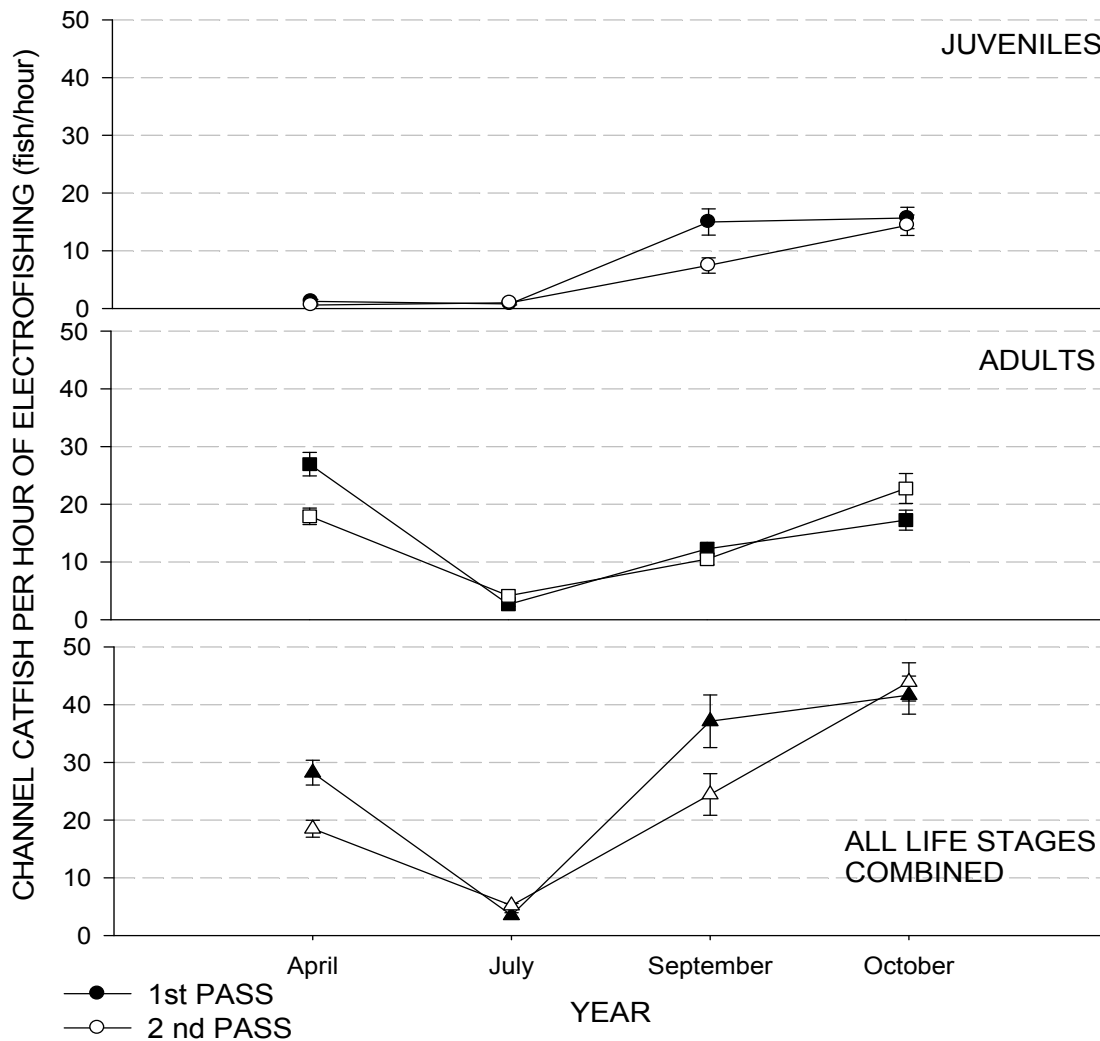


Figure 14. Channel catfish CPUE (fish/hour) by pass and trip from Shiprock Bridge to Mexican Hat; 2008. Error bars represent  $\pm 1$  SE.

The four trip mean TL of channel catfish for 1<sup>st</sup> pass boats was 338 mm TL compared to 348 mm TL for 2<sup>nd</sup> pass boats ( $t = -3.0$ ;  $p = 0.003$ ). Although mean TL between passes differed, the distributions across size classes were similar (Figure 15). Fish < 100 mm TL comprised 12.1% of channel catfish collected on 1<sup>st</sup> passes compared to 9% on the 2<sup>nd</sup> pass. Fish < 100 mm were likely age-0 fish while fish > 100 mm TL were considered to be age-1 fish. Channel catfish  $\geq 500$  mm TL comprised 9% of the total catch for each of the two passes combined.



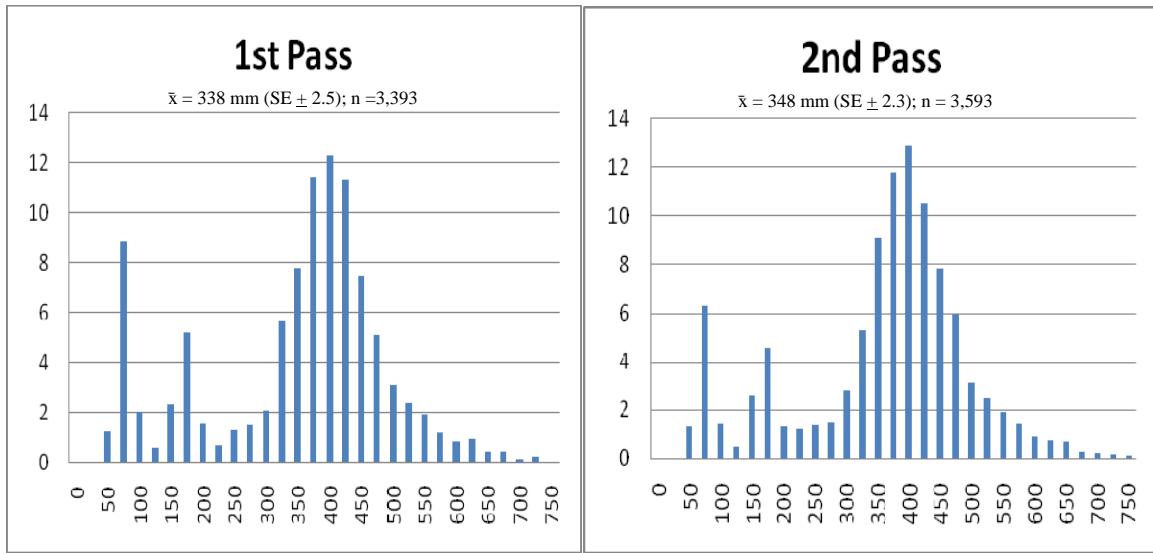


Figure 15. Length frequency histograms by boat/pass for channel catfish collected from Shiprock Bridge to Mexican Hat, Utah; 2008. The y-axis represents percent (%) of catch and the x-axis represents total length.

COMMON CARP

Common carp CPUE was similar among trips and between passes of the same trip (Figure 16). The highest CPUE was the 2<sup>nd</sup> pass of the April trip at 2.3 fish/hour while the lowest CPUE was the first pass during the September trip, 0.9 fish/hour. The four trip mean CPUE for 1<sup>st</sup> pass boats was 1.6 fish/hour compared to the 2<sup>nd</sup> pass mean CPUE of 1.3 fish/hour. The four trip mean CPUE for all boats combined was 1.5 fish/hour. Similar to upstream removal Sections common carp were infrequently collected during sampling from Shiprock Bridge to Mexican Hat.

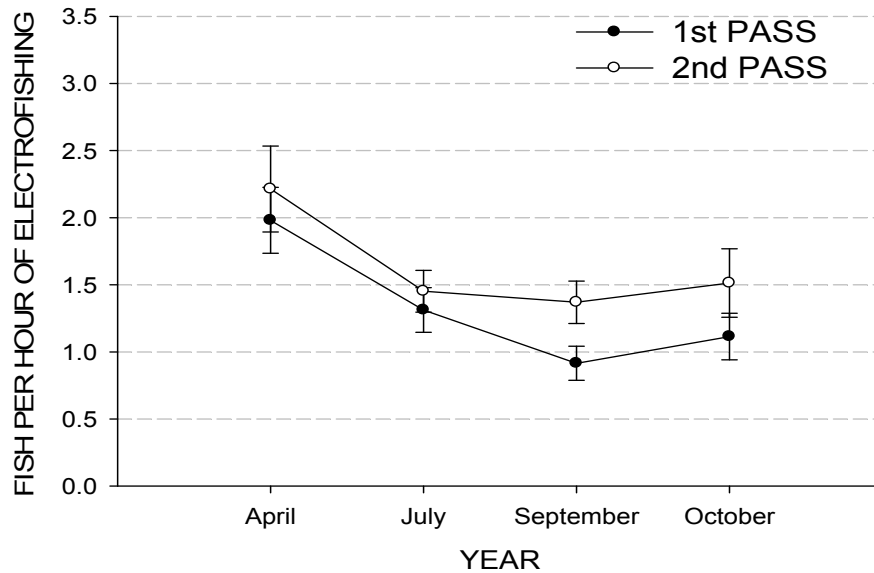


Figure 16. Common carp CPUE (fish/hour) by pass and trip from Shiprock Bridge to Mexican Hat; 2008. Error bars represent  $\pm 1$  SE.

**RARE FISH COLLECTIONS**

A total of 557 razorback sucker and 887 Colorado pikeminnow encounters were documented during nonnative fish removal trips from PNM Weir to Mexican Hat, Utah. Fish that were captured multiple times during an individual trip were included in analyses, but fish captured multiple times on the same day were excluded from the total number of encounters. Of these fish, 24 razorback sucker and 62 Colorado pikeminnow were collected from PNM Weir to Hogback Diversion; 359 razorback sucker and 138 Colorado pikeminnow were collected from Hogback Diversion to Shiprock Bridge; and 194 razorback sucker and 637 Colorado pikeminnow were collected from Shiprock Bridge to Mexican Hat (Appendix A-3). These totals include rare fish collected during annual sub-adult and adult fish community monitoring conducted by U.S. Fish and Wildlife Service – Colorado Fishery Project.

**RAZORBACK SUCKER**

All razorback sucker collected in 2008 were considered to be stocked fish. Although razorback sucker were recaptured lacking PIT tags it was assumed these were fish stocked from Navajo Agricultural Products Industry (NAPI) ponds in 2006 and 2007 without tags and were

not recruited wild spawned fish. Various known age classes were recaptured dating back to 1992 with the majority of the recaptures comprising 2006 year class fish that were recently stocked into the San Juan River (Table 1).

Table 1. Summary of razorback sucker by age class collected during nonnative fish removal; 2008.

<b>Age Class</b>	<b>N</b>	<b>Mean TL(range)</b>
1992	1	465
1993	0	n/a
1994	0	n/a
1995	0	n/a
1996	0	n/a
1997	1	540
1998	0	n/a
1999	13	489 (450 – 531)
2000	22	475 (423 – 555)
2001	61	477 ( 422 – 595)
2002	9	445 (415 – 490)
2003	90	480 (422 – 549)
2004	4	415 (382 – 430)
2005	0	n/a
2006	107	369 (225 – 511)

Razorback sucker were captured throughout the study area and exhibited both downstream movement to Mexican Hat and movement upstream of both the stocking location (RM 158.6) and Hogback Diversion (Figure 17). The highest number of encounters (55% of all razorback sucker collected) and CPUE for razorback sucker were from RM's 158.8 – 151.0 and declined as sampling proceeded downstream. Razorback sucker CPUE by 10 RM segments ranged from 4.8 to 0.1 fish/hour (Figure 17).

Of the 308 razorback sucker that had known stocking information, 39% were recaptured < 1 year post-stocking and 64% were recaptured < 2 years post-stocking (Figure 18). Thirty-five razorback sucker were recaptured  $\geq$  6 years post-stocking including one individual that was recaptured 13.8 years (5,042 days) post-stocking (Figure 18).

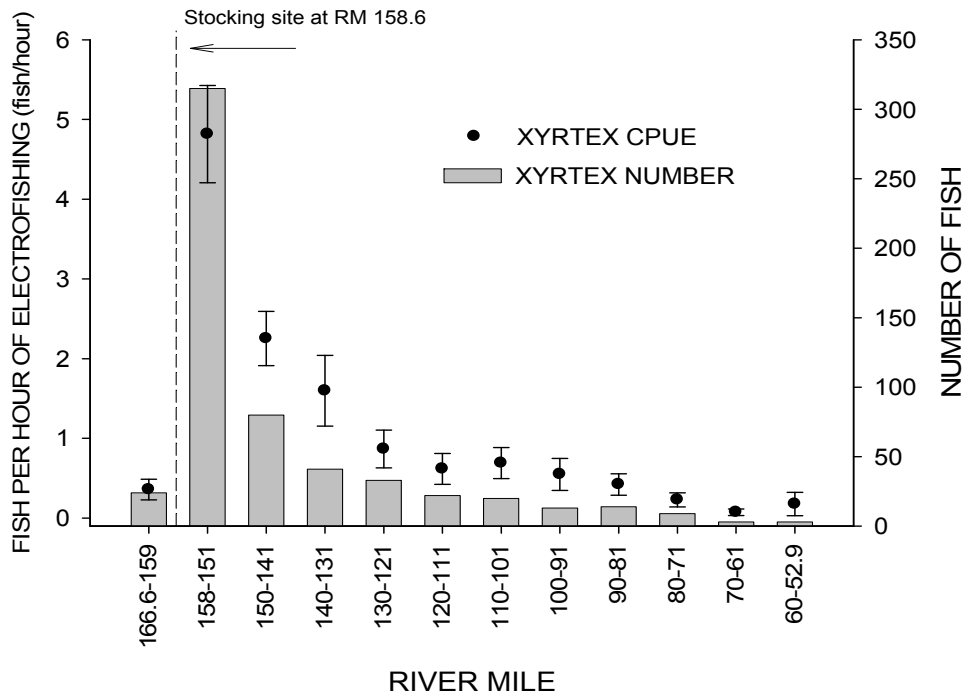


Figure 17. Longitudinal distribution of razorback sucker encounters during nonnative fish removal trips conducted by NMFWCO, 2008. Vertical bars represent number of fish encountered and scatter plot represents razorback sucker CPUE (fish/hour). Error bars represent  $\pm 1$  SE.

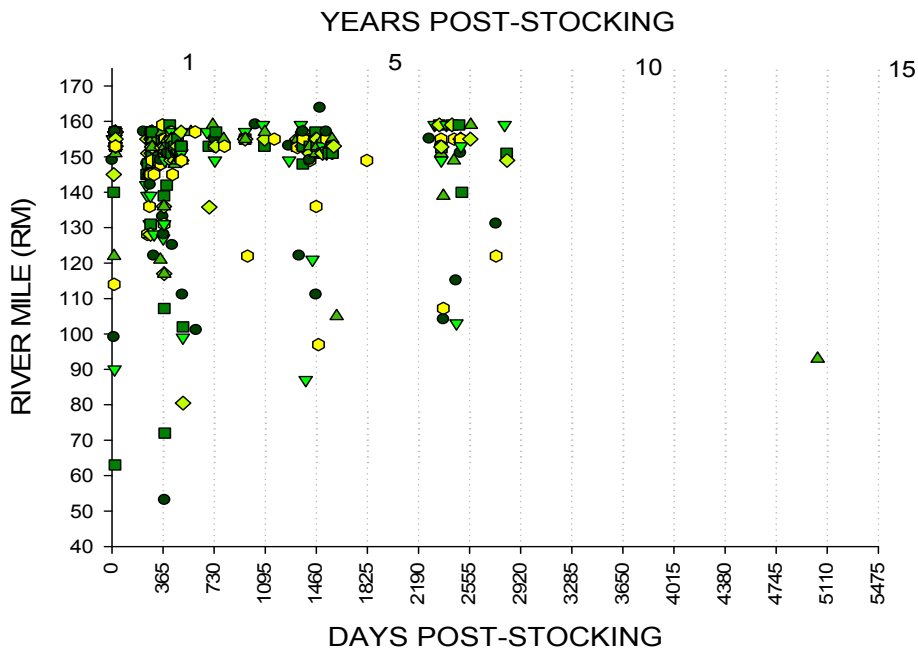


Figure 18. Days post-stocking versus river mile for razorback sucker encounters during nonnative fish removal trips conducted by NMFWCO; 2008. Different symbols and colors represent individual capture encounters.

Four individual razorback sucker recaptured > 6 times, across a variety of studies, exhibited little movement over multiple years of sampling (Figure 19). Each of these fish was recaptured within seven river miles of the stocking location at RM 158.6. Although multiple recaptures during one calendar year were observed, gaps as long as two years between capture events were documented. These fish exhibited both upstream and downstream movement between recapture events (Figure 19).

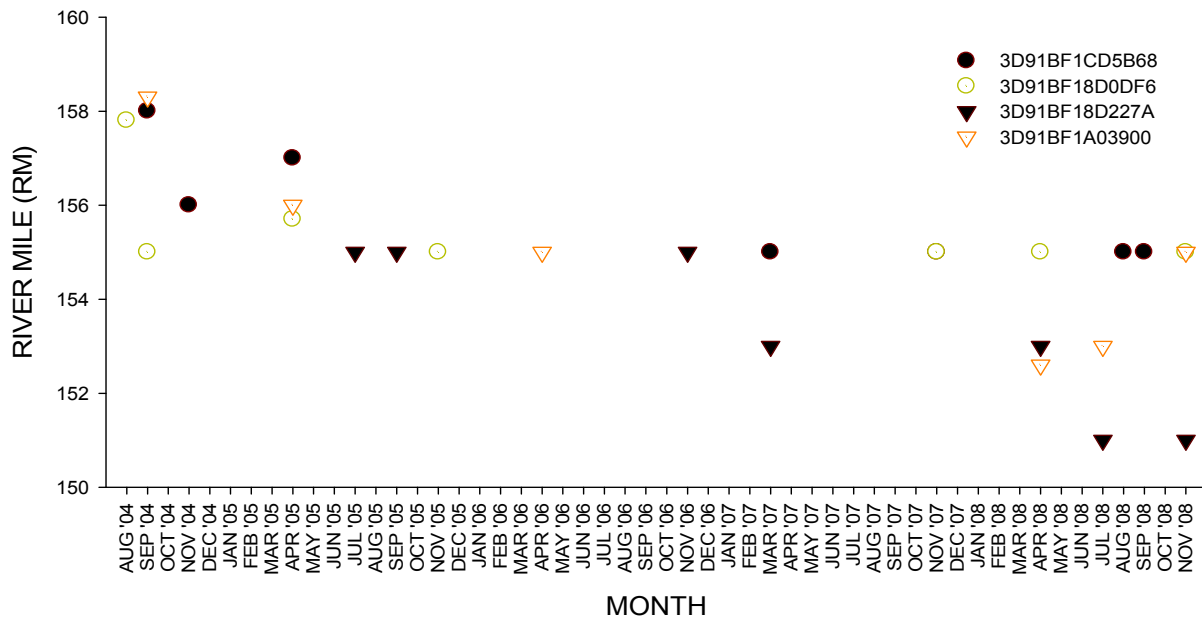


Figure 19. Distribution of razorback sucker that have been collected six or more times during intensive nonnative removal trips conducted by NMFWCO; 2003-2008.

Razorback sucker collected in 2008 ranged from 203 – 595 mm TL (Figure 20). The majority of fish (97%) were  $\geq 300$  mm TL although a total of 36 fish were less than the recommended stocking size of 300 mm TL. Based on size, no fish considered to be age-1 were collected during intensive nonnative removal trips in 2008. The mean TL for all razorback sucker was 430 mm TL.

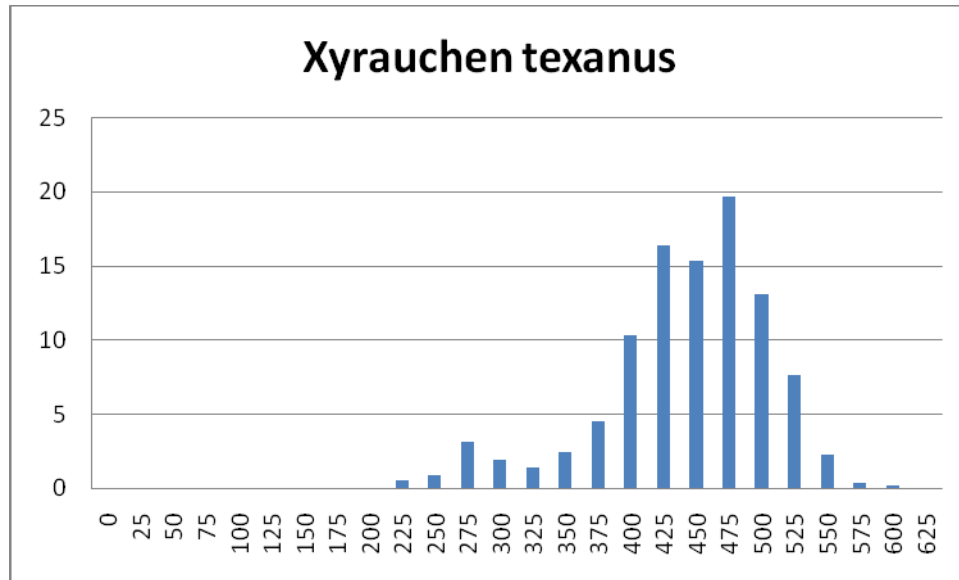


Figure 20. Length frequency histograms for razorback sucker collected during intensive nonnative fish removal trips; 2008. The y-axis represents percent (%) of catch and the x-axis represents total length.

#### COLORADO PIKEMINNOW

Based on limited documentation of recruitment into juvenile life stages, all Colorado pikeminnow collected during intensive nonnative fish removal trips in 2008 were considered to be stocked fish. Colorado pikeminnow were distributed throughout the study area with the majority (64%;  $n = 536$ ) of encounters occurring from RM 166.6 – 121.0 (Figure 21). Colorado pikeminnow CPUE by 10 RM segments ranged from 0.2 to 6.4 fish/hour with the highest mean CPUE from RM's 140-131 and 130-121 (6.4 and 5.4 fish/hour; respectively). These high catch rates corresponded with proximity to the 'soft' release location (fish acclimatized to riverine conditions for up to 24 hours prior to release) for Colorado pikeminnow at RM 134.9.

Utilizing data from several studies revealed that Colorado pikeminnow recaptures by individual stockings varied over time with relatively high numbers of recaptures occurring near the stocking location (RM 134.9) < 150 days post-stocking (Figure 22). Evaluation of short term retention was dependent on stocking timing and subsequent sampling frequency. All sampling ended by mid-November 2007 and recommenced in early March 2008. The majority of recaptured Colorado pikeminnow from the October 2007 stockings occurred during intensive nonnative removal conducted by UDWR in 2008 and were primarily downstream of RM 52.9.

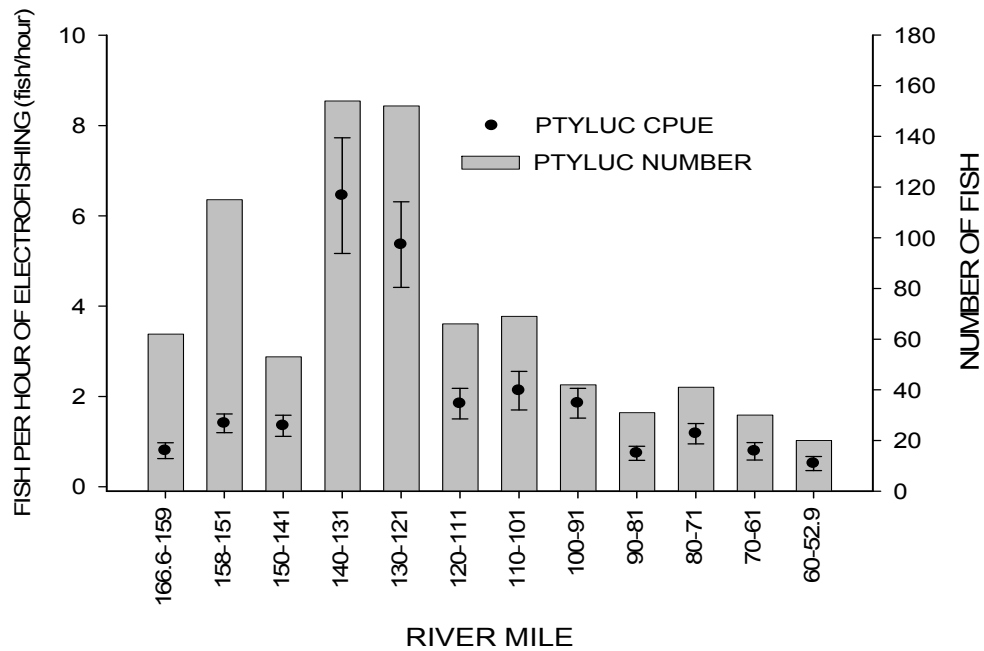


Figure 21. Longitudinal distribution of Colorado pikeminnow encounters during nonnative fish removal trips conducted by NMFWCO, 2008. Vertical bars represent number of fish encountered and scatter plot represents razorback sucker CPUE (fish/hour). Error bars represent  $\pm 1$  SE.

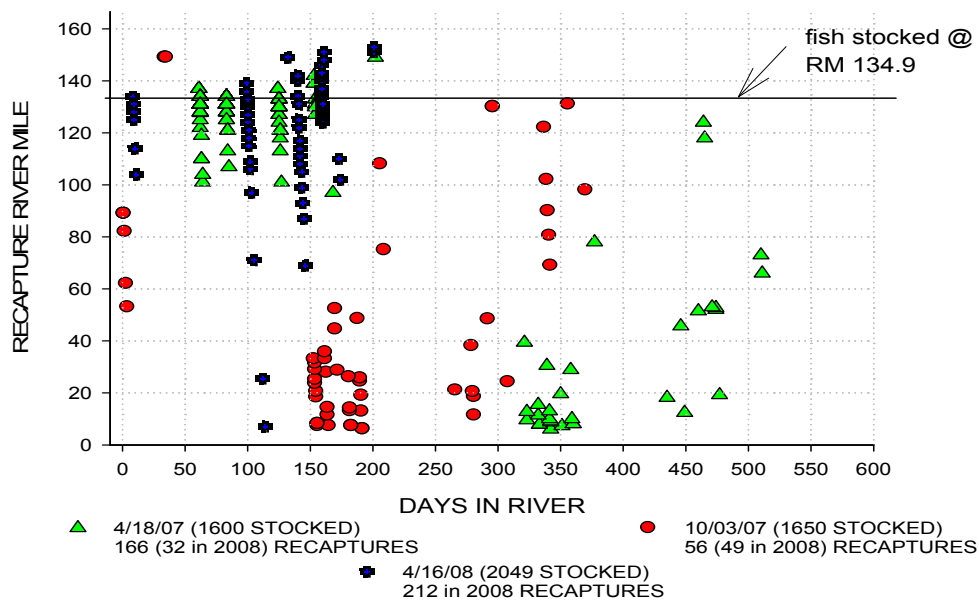


Figure 22. Colorado pikeminnow recaptures by individual stockings. Recapture data includes recaptures from nonnative removal trips conducted by NMFWCO and UDWR and adult fish community monitoring by USFWS-CRP.

These collections occurred after a cessation of sampling from November 2007 to March 2008 and following one over winter period. Due to the cessation in sampling, immediate post-stocking evaluation of the October 2007 stockings was not possible. Recaptures of stocked age 1+ Colorado pikeminnow were distributed throughout the study area as sampling continued in 2008 (Figure 22). The majority of recaptured age-1+ Colorado pikeminnow in 2008 were fish stocked in April 2008 with fewer numbers of documented recaptures the further out from the stocking date (Figure 22). Generally, age-1+ fish stocked in 2007 and 2008 have exhibited trends toward downstream movement.

Colorado pikeminnow collected in 2008 ranged from 67 – 465 mm TL (Figure 23). Fish  $\leq 150$  mm TL comprised 17% ( $n = 141$ ) of the catch while Colorado pikeminnow  $\geq 350$  mm TL comprised 5% ( $n = 43$ ) of the catch. Three individual fish  $< 100$  mm TL were collected in 2008 and were considered to be small age-1 fish stocked as age-0 fish at RM 166.6 in the fall of 2007. Mean TL for Colorado pikeminnow collected in 2008 was 205 mm (Figure 23).

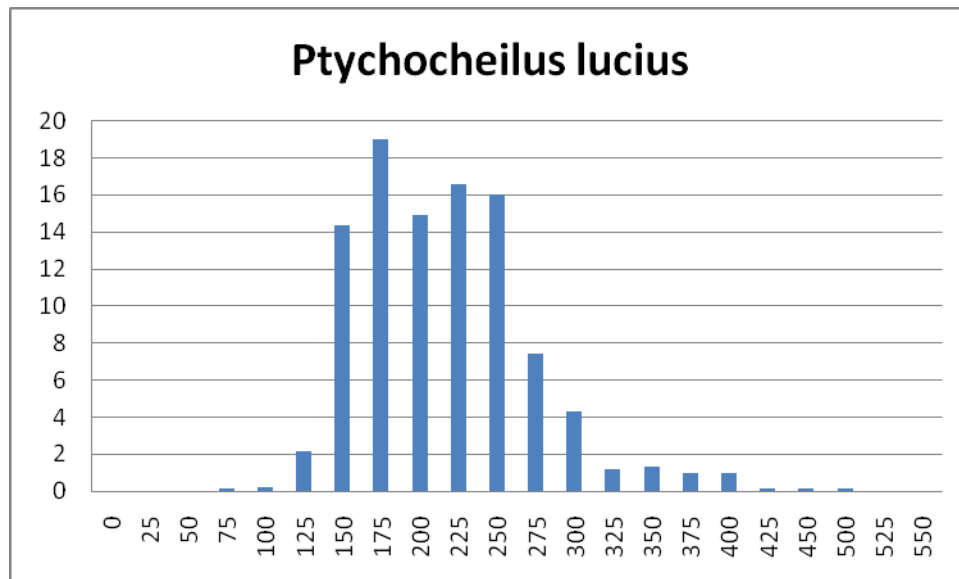


Figure 23. Length frequency histograms for Colorado pikeminnow collected during intensive nonnative fish removal trips; 2008. The y-axis represents percent (%) of catch and the x-axis represents total length.



**NATIVE FISH RESPONSE TO INTENSIVE REMOVAL**

Although highly variable, the CPUE of juvenile flannemouth and bluehead suckers did not show consistent response to nonnative removal efforts (Figure 24). Juvenile flannemouth sucker CPUE in 2008 was significantly higher (ANOVA;  $F_{(10, 262)} = 12.423$ ; Nemenyi post-hoc,  $p < 0.001$ ) than that in 1998 but was generally lower than observed values in 1999 and 2000. Catch rates were similar between 2001 and 2008 but increases in juvenile CPUE in 2002, 2004

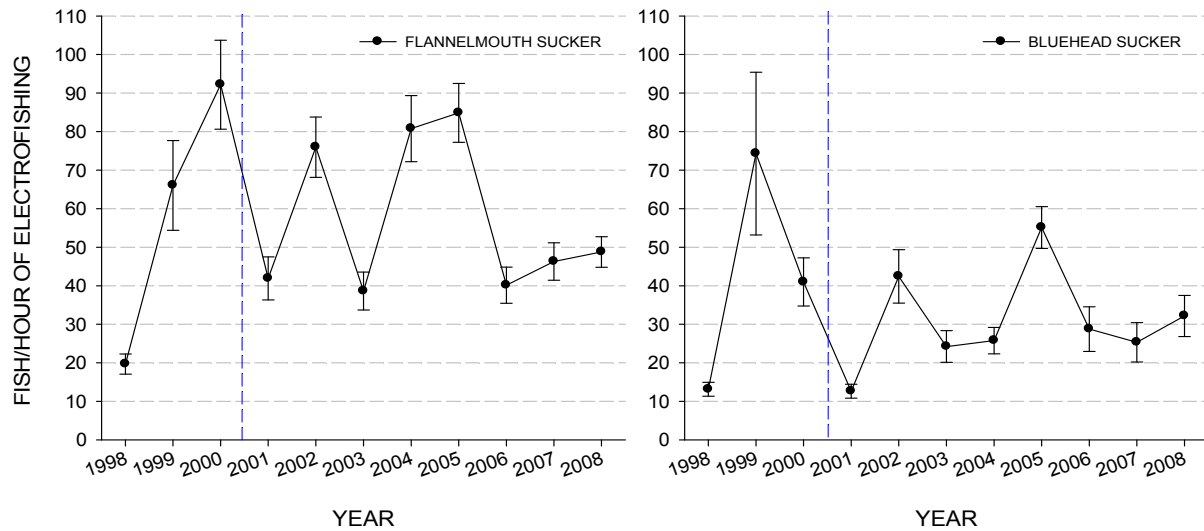


Figure 24. Flannemouth and bluehead sucker CPUE (fish/hour) from PNM Weir to Shiprock Bridge, 1998-2008. Error bars represent  $\pm 1$  SE. Blue vertical lines represent the beginning of intensive nonnative removal in 2001.

and 2005 were observed (Figure 24). Juvenile bluehead sucker CPUE in 2008 was similar to CPUE values prior to the initiation of intensive nonnative fish removal (1998-2000) but was significantly higher than that in 2001 (ANOVA;  $F_{(10, 262)} = 7.272$ ; Nemenyi post-hoc,  $p = 0.04$ ).

Similar to CPUE, condition factor (Fulton-type;  $K_f = \text{Weight}/\text{Length}^3 * 100,000$ ) of juvenile flannemouth and bluehead suckers did not show consistent response to nonnative removal efforts (Figure 25). Flannemouth sucker condition factor in 2008 was similar to that from 1998 and 2001 and exhibited variability throughout the study period (Figure 25). Bluehead sucker condition factor was similar to 1998 but was significantly higher than condition factors in 1999 and 2000 (ANOVA;  $F_{(10, 1442)} = 39.533$ ; Nemenyi post hoc,  $p < 0.001$ ). Bluehead sucker

condition factor in 2008 was significantly lower than that in 2003 and 2006 but was similar to values observed in 2004, 2005 and 2007 (Figure 25).

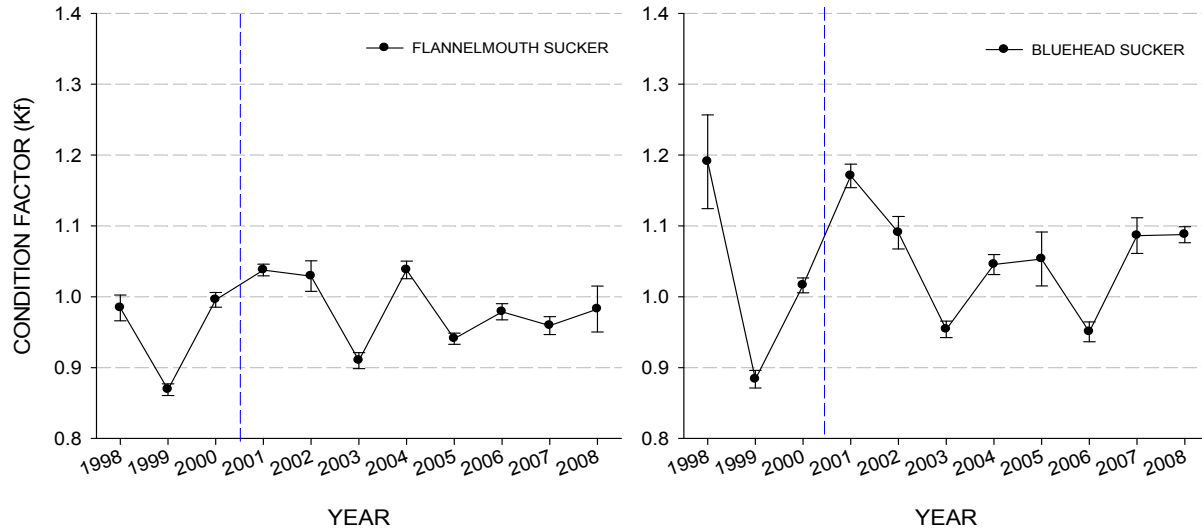


Figure 25. Flannelmouth and bluehead sucker condition factor ( $K_f$ ;  $\text{Weight/Length} \times 100,000$ ) from PNM Weir to Shiprock Bridge, 1998-2008. Error bars represent  $\pm 1$  SE. Blue vertical lines represent the beginning of intensive nonnative removal.

## DISCUSSION

Channel catfish abundance from PNM Weir to Hogback Diversion in 2008 was lower than abundance metrics at the initiation of intensive nonnative removal in 2001. Declines during the past two years mark the first time that CPUE was significantly lower than early years of removal. These declines were likely the cumulative result of varying levels of nonnative fish removal in adjacent downstream reaches. Beginning in 2003, nonnative removal expanded efforts to include the Hogback Diversion to Shiprock Bridge Section. Channel catfish abundance was higher in this Section than beginning abundance metrics in the PNM Weir to Hogback Diversion Section and after two years of removal, channel catfish CPUE from Hogback Diversion to Shiprock Bridge was reduced to levels less than half of that at the initiation of removal.

A small scale mark-recapture study showed that both nonnative and native fishes moved upstream of Hogback Diversion via a non-selective fish passage (Davis and Coleman 2004). By

reducing overall abundance downstream of Hogback Diversion, the potential source of fish to repopulate the PNM Weir to Hogback Diversion Section has been reduced. Prior to 2007, seasonal fluctuations in channel catfish CPUE from PNM Weir to Hogback Diversion contributed to highly variable catch rates resulting in the lack of significant declines in abundance (Davis and Furr 2007). It appears that a reduction in channel catfish abundance downstream of Hogback Diversion decreased the potential for upstream immigration and lessened seasonal increases and variability in CPUE from PNM Weir to Hogback Diversion. We expect to see continued declines in abundance in upstream removal Sections as intensive nonnative removal downstream of Shiprock Bridge continues.

This “step-down” (i.e. upstream to downstream) removal process (i.e. shifting effort based on downstream abundance) was anticipated to occur and continues downstream of Shiprock Bridge. Based on increased trends in channel catfish abundance reported on by Ryden (2007), nonnative fish removal efforts were expanded from upstream Sections to include removal trips from Shiprock Bridge to Mexican Hat, Utah. Incorporating new information as part of the adaptive management process and expanding effort to priority reaches is expected to result in lowered channel catfish abundance riverwide. Utilizing a multiple pass strategy in this Section is expected to remove large numbers of nonnative fishes resulting in significant declines in channel catfish abundance within a short period of time (i.e. 3-5 years).

Although the mean TL of removed channel catfish has varied over time, the overall reduction in large (> 500 mm TL) channel catfish abundance is encouraging. Within each of the upper removal Sections (PNM Weir to Hogback and Hogback to Shiprock) peaks in juvenile fish abundance were observed during some period of removal. Increases in juvenile fish abundance from PNM Weir to Hogback Diversion in 2003 and 2004 may have been a reproductive response to exploitation as much as the previous years hydrologic conditions. The low water year of 2002 may have equally been responsible for the shift to smaller fish observed as nonnative fish densities generally increase when daily summer mean discharge is < 500 ft<sup>3</sup>/second (Propst and Gido 2004). However, the observed increase in age-0 and age-1 channel catfish during sub-adult and adult fish community monitoring in 2008 (Ryden 2009) suggest that a reproductive response to exploitation, as opposed to low hydrologic conditions, may have occurred since mean summer discharge in 2008 was 998 ft<sup>3</sup>/second (Appendix C). Regardless of the reason, initial shifts

towards smaller fish are important in long term suppression of channel catfish numbers in the San Juan River by reducing overall reproductive potential and recruitment. Helms (1975) found that 1 of 10 channel catfish were sexually mature at 330 mm TL, compared to 5 of 10 at 380 mm TL. In addition, he found that channel catfish at 330 mm TL produced around 4,500 eggs/fish compared to the production of 41,500 eggs at 380 mm TL.

A reduced abundance of large channel catfish is also important in limiting overall predatory impacts on native fishes by channel catfish. Brooks et al. (2000) found that San Juan River channel catfish < 300 mm TL consumed almost exclusively macroinvertebrates and Russian olive fruits. Piscivory occurred most frequently in fish > 450 mm TL. Documentation of predation on endangered fishes during their study was not observed due to the relatively low numbers of endangered fishes in the San Juan River at the time of their study, but has been documented elsewhere in SJRIP work (Davis and Furr 2007 and Jackson 2005). If unchecked, as augmentation efforts continue and rare fishes increase in abundance, documented predation by channel catfish will undoubtedly increase.

Equally important as size reduction is the dependence of an exploited population on single year classes. Results from the upper San Juan River are similar to those Pitlo (1997) observed as evidence of overexploitation of channel catfish in the Mississippi River. Pitlo observed that as the numbers of large fish decline, the population became highly dependent on newly recruited fish, resulting in large fluctuations in catch and dependence on the strength of individual year-classes. This appears to be occurring within intensive removal Sections with the majority of fish collected in 2008 comprised of the 2002/2003 cohorts and ranging from 375-450 mm TL. Measurable channel catfish recruitment (i.e. increased juvenile catch rates) in upper Sections of the San Juan River has not been documented since 2002 suggesting that a reduction in the abundance of adult channel catfish has limited the overall reproductive potential of channel catfish. With continued exploitation, and non-size selective removal, it is expected that juvenile fish will be removed prior to reproduction resulting in limited recruitment in future years.

Common carp were once ubiquitous in the San Juan River and during 1991-1997 SJRIP studies were found to be the fourth most abundant fish in electrofishing collections (Ryden

2000). Corresponding with the initiation of intensive removal, common carp abundance has been greatly reduced to a level where common carp were collected infrequently across all studies. Common carp were the seventh most abundant fish collected in 2007 sub-adult and adult fish community monitoring and were found in only 15% of samples (Ryden 2008a).

Compared to channel catfish, immediate significant reductions in common carp abundance estimates may be a result of the “catchability” of common carp under various sampling conditions. Common carp oftentimes exhibit electrotaxis (induced movement towards the anode) or oscillotaxis (induced movement without orientation or thrashing motion) when exposed to pulsed direct current (PDC). This behavior enables netters to easily identify and net common carp in turbid conditions. Conversely, channel catfish oftentimes exhibit tetany (electrically induced immobility with rigid muscles) when exposed to PDC and are slow in breaching the water surface (Kolz et al. 1998). This reaction makes it difficult for netters to effectively identify and capture channel catfish during turbid river conditions and likely affect capture efficiency.

Decreased common carp abundance limits competitive interactions with native fishes and negative habitat modifications often associated with common carp (i.e. uprooting of aquatic plants causing increased turbidity, possible cause of noxious algae blooms by recycling of nutrients from silt substrates) (Cooper 1987). These decreases and the subsequent declines in carp biomass will allow for higher utilization of resources by native fishes with limited levels of interspecific competition.

With recent flow conditions in the San Juan River lacking overbank flow available low flow or slackwater, spawning and nursery habitats, for common carp has been limited. This lack of available nursery habitat may have influenced recent common carp abundance trends as much as mechanical removal, and it is possible that common carp abundance will increase following the reoccurrence of overbank flows. Extended high flows in 2008 (Appendix C) and the subsequent creation of suitable spawning and nursery habitats for common carp likely influenced the slight observed increase in juvenile common carp in 2008 (Ryden 2009). This increase was not significantly higher than juvenile CPUE from 2005-2007 and will most likely not lead to a comeback in the numbers of adult fish.

In spite of the lack of a positive response in native fish (i.e. flannelmouth and bluehead suckers and speckled dace) abundance since the initiation of intensive nonnative fish removal, we still see the benefit in continuing with our efforts. The lack of response in juvenile native fishes can be confounded by sampling bias towards larger sized fish, a lack of ideal flow conditions to facilitate reproduction and recruitment of native fishes and the introduction of large numbers of rare fishes (i.e. Colorado pikeminnow and razorback sucker) into the same Sections of river where positive responses may have been realized.

Spatial and trophic interactions between nonnative large-bodied fishes and native suckers may have been reduced during the study period but changes in native juvenile sucker abundance were not observed. As large numbers of nonnative fishes were removed and biomass reduced, competition for resources (food and space) were likely reduced. However, newly created resource opportunities may not have been fully utilized by native common suckers due to the large numbers of rare fishes that were stocked into these same Sections during the study period. Investigation on native fish responses, including comparisons of speckled dace abundance pre and post removal, specific to our efforts will be conducted as our study continues.

Since only limited stocking of rare fishes occurred prior to the initiation of intensive nonnative removal a comparison of stocking success in the absence of removal was not possible. Based on documented predatory impacts of channel catfish on rare fishes (Davis and Furr 2007, Jackson 2005) it is likely that the limited success that the augmentation programs have seen to date would not have been realized in the absence of some level of nonnative fish removal. Rare fishes would have been stocked into Sections of the river that were dominated by large adult channel catfish and common carp possibly limiting post-stocking survival through direct predation and competition for resources. A more concerted effort by SJRIP researchers to quantify predation on native rare fishes by channel catfish is suggested. Predation on early life stages of razorback sucker and Colorado pikeminnow could be one of many limiting factors for the lack of documented recruitment into juvenile life stages of these two species.

In addition to our goal of removing large-bodied nonnative fishes, intensive nonnative removal trips have contributed to the gathering of information on rare fish distribution and abundance and may be used as a barometer to measure the success of current augmentation

programs. The frequency and range of our trips, near stocking locations and now riverwide, provide the opportunity to gather large amounts of data on stocked fish and may be used to evaluate the success of individual stockings.

We reported earlier on the relatively high number of razorback sucker that were recaptured near the stocking location at RM 158.6 (Davis and Furr 2007). These trends in distribution and abundance of stocked razorback sucker continued in 2008 with the highest numbers of encounters and catch rates occurring near the stocking site. Although individuals were recaptured multiple times the majority of fish collected were considered to be first time captures. However, razorback sucker that had been collected > 6 times exhibited little movement between captures ( $\pm 3$  RM's) with recapture events occurring as much as two years apart.

Since these fish appear to exhibit some site fidelity near stocking locations and individuals are not recaptured on each sampling trip questions regarding current densities of razorback sucker and our capture probabilities arise. Preliminary analyses of these data have prompted the Program to investigate multiple stocking locations both upstream and downstream of the current stocking location.

Tracking movement near stocking locations could be conducted using techniques similar to a study by Kitcheyan and Montagne (2005). Utilizing radio tag implanted razorback sucker with stationary telemetry loggers would determine if these fish emigrate sometime in the year only to return to the stocking location at a later date or if fish exhibit little movement suggesting that our gear type is not overly effective in collecting individual fish.

Colorado pikeminnow recaptures were widely distributed in 2008. Unlike 2007, few Colorado pikeminnow > 400 mm TL were captured in 2008. Although the captures of adult Colorado pikeminnow in our collections were sparse, adults may persist in the San Juan River and our ability to detect these fish may be low. Discussions on new methodologies to detect the presence of adult Colorado pikeminnow have occurred and include utilizing flat-plate or floating antennas which would remotely detect PIT tags and the adjustment of monitoring protocols to include sampling of areas of the river (i.e. mid-channel) that are not frequently sampled.

Beginning in 2007, age-1+ Colorado pikeminnow were stocked into the San Juan River utilizing a 'soft' release protocol. This method allows stocked fish to acclimatize to a myriad of conditions prior to release into the system. Preliminary recapture data indicated short term retention, < 150 days, near the stocking site but as time from stocking increased fish were distributed as far downstream as RM 6.0. Current data is too sparse to definitely determine the success of these stocking efforts, however, a change in stocking protocol implemented in May 2008 (control vs. treatment groups) will assist us in answering this question.

To evaluate current population densities of rare fishes, there is a need for the Program to analyze recapture data across all studies and relate this information to overall stocking success. These analyses will guide future augmentation decisions including numbers to be stocked, and location of stockings, and will help determine when and if population estimates on the rare fishes are needed.

Mechanical removal of nonnative fishes, primarily channel catfish and common carp, continues to be supported by the SJRIP as one management tool for the recovery of Colorado pikeminnow and razorback sucker. Complete eradication of these species is not expected; however, utilizing multiple pass sampling has and is expected to continue to reduce abundance to manageable levels. By reducing abundance and biomass of these species, spatial and trophic interactions with common and rare native fishes should be reduced resulting in improved post-stocking survival of stocked rare fishes. Collecting data on growth, distribution and abundance of rare fishes in conjunction with intensive nonnative fish removal continues to supplement monitoring data of these two species and will assist researchers with future management decisions and assessing progress towards recovery.



## SUMMARY AND CONCLUSIONS

### PNM WEIR TO HOGACK DIVERSION (RM 166.6 – 159.0)

- A total of 378 channel catfish and 141 common carp were collected during four removal trips in 2008.
- Channel catfish CPUE in 2008 was lower than CPUE from 2001-2005.
- Channel catfish mean TL was larger than mean TL observed in 2001 but overall abundance of large adult channel catfish has been reduced.
- Common carp CPUE in 2008 was similar to 2007 but significantly ( $p < 0.05$ ) lower than 2001 to 2006.
- Common carp were uncommon in collections.

### HOGBACK DIVERSION TO SHIPROCK BRIDGE (RM 158.8 – 147.9)

- A total of 891 channel catfish and 183 common carp were collected during four removal trips in 2008.
- Channel catfish CPUE in 2008 was lower than CPUE from 2003-2006.
- Channel catfish mean TL was larger than mean TL observed in 2001 but overall abundance of large adult channel catfish has been reduced.
- Common carp CPUE in 2008 was similar to 2007 but significantly ( $p < 0.05$ ) than 2003 to 2006.
- Common carp were uncommon in collections.

### SHIPROCK BRIDGE TO MEXICAN HAT, UTAH (RM 147.9 – 52.9)

- A total of 15,699 channel catfish and 791 common carp were removed during four (8 passes) removal trips in 2008.
- Channel catfish CPUE by trip in 2008 ranged from 4.3 to 41.6 fish/hour of electrofishing.
- Mean channel catfish TL decreased throughout the year with age-0 and age-1 fish comprising a large portion of the catch during September and October.
- Little differences in CPUE or TL existed among pass comparisons of the same trip.
- Common carp CPUE were  $< 5$  fish/hour during each of the four removal trips
- Common carp were uncommon in collections

NATIVE FISH RESPONSE

- Juvenile flannelmouth and bluehead sucker abundance from PNM Weir to Shiprock Bridge (RM 166.6-147.9) changed little since the initiation of intensive nonnative removal.
- Flannelmouth and bluehead sucker condition factor (Fulton-type) from PNM Weir to Shiprock Bridge changed little since the initiation of intensive nonnative removal.

RARE FISH CAPTURES

- A total of 557 razorback sucker and 887 Colorado pikeminnow were encountered during 2008 sampling from RM 166.6 – 52.9.
- Majority of razorback sucker encounters were documented within 10 RM's of the stocking location at RM 158.6.
- Razorback sucker collected > 6 times were recaptured within 3 river miles of the previous capture and as long as two years between capture events.
- Colorado pikeminnow CPUE and numbers were the highest from RM 166.6 – 121.0 with large collections occurring near the 'soft' release stocking site at RM 134.9.
- Only four individual Colorado pikeminnow > 400 mm TL were collected in 2008.

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Appendix A-1. Mean discharge, mean clarity, effort and total count of major species collected during intensive non-native removal efforts from PNM Weir to Hogback Diversion, 2008. Species listed by the first three letters of the Genera and first three letters of Species (i.e. *Ptychocheilus lucius* = *Ptyluc*). <sup>1</sup> Mean discharge from USGS gauge #09368000 near Shiprock, New Mexico.

Trip	Discharge (ft <sup>3</sup> /sec)	Mean Clarity (mm)	Effort (hours)	<i>Ptyluc</i>	<i>Xyrtex</i>	<i>Ictpun</i>	<i>Cypcar</i>	<i>Micsal</i>	<i>Ameiurus</i> spp	<i>Saltru</i>
March 25-27	5,230 <sup>1</sup>	133.75	10.63	6	5	0	31	0	0	5
June 24-26	3,217 <sup>1</sup>	438.33	12.35	1	7	0	10	0	1	30
August 12-14	734 <sup>1</sup>	128.33	20.20	21	8	351	23	9	3	1
November 6-8	792 <sup>1</sup>	253.33	16.50	34	4	27	15	2	1	1
<b>Totals</b>			<b>59.68</b>	<b>62</b>	<b>24</b>	<b>378</b>	<b>79</b>	<b>11</b>	<b>5</b>	<b>37</b>

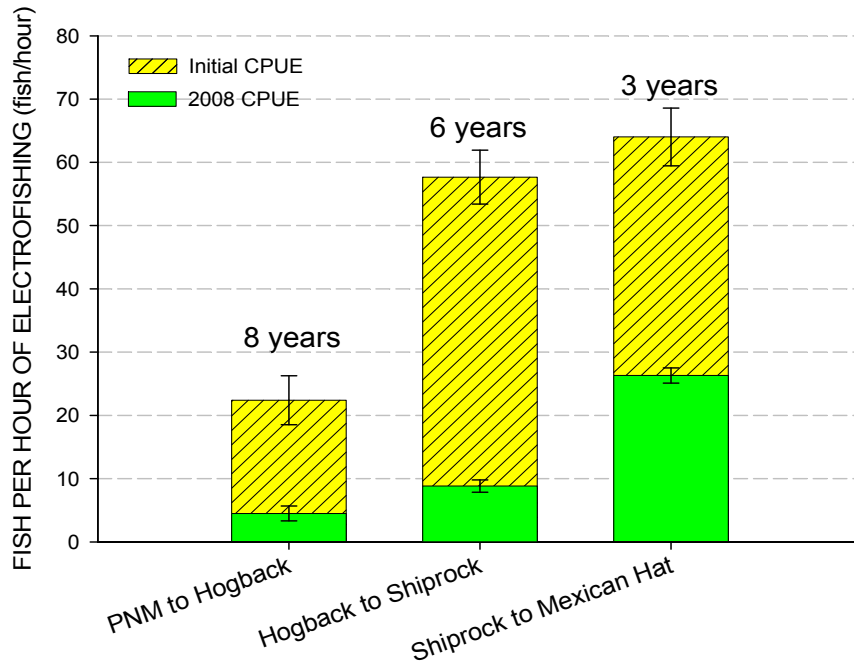
Appendix A-2. Mean discharge, mean clarity, effort and total count of major species collected during intensive non-native removal efforts from Hogback Diversion to Shiprock Bridge, 2008. <sup>1</sup> Mean discharge from USGS gauge #09368000 near Shiprock, New Mexico.

Trip	Discharge (ft <sup>3</sup> /sec)	Mean Clarity (mm)	Effort (hours)	<i>Ptyluc</i>	<i>Xyrtex</i>	<i>Ictpun</i>	<i>Cypcar</i>	<i>Micsal</i>	<i>Ameiurus</i> spp	<i>Saltru</i>
April 8-10	3,620 <sup>1</sup>	196.17	21.23	4	138	7	60	0	0	1
July 8-10	1,397 <sup>1</sup>	913.00	27.19	24	57	307	58	4	11	16
August 26-28	572 <sup>1</sup>	155.00	29.11	55	86	495	39	6	3	2
November 3-5	832 <sup>1</sup>	268.75	16.51	55	78	82	26	3	2	2
<b>Totals</b>			<b>94.04</b>	<b>138</b>	<b>359</b>	<b>891</b>	<b>183</b>	<b>13</b>	<b>16</b>	<b>21</b>

Appendix A-3. Mean discharge, mean clarity, effort and total count of major species collected during intensive non-native removal efforts from Shiprock Bridge to Mexican Hat, Utah; 2008. Endangered fish were not collected by upstream boats (n/a). <sup>1</sup> Mean discharge from USGS gauge #09371010 near Four Corners, Colorado.

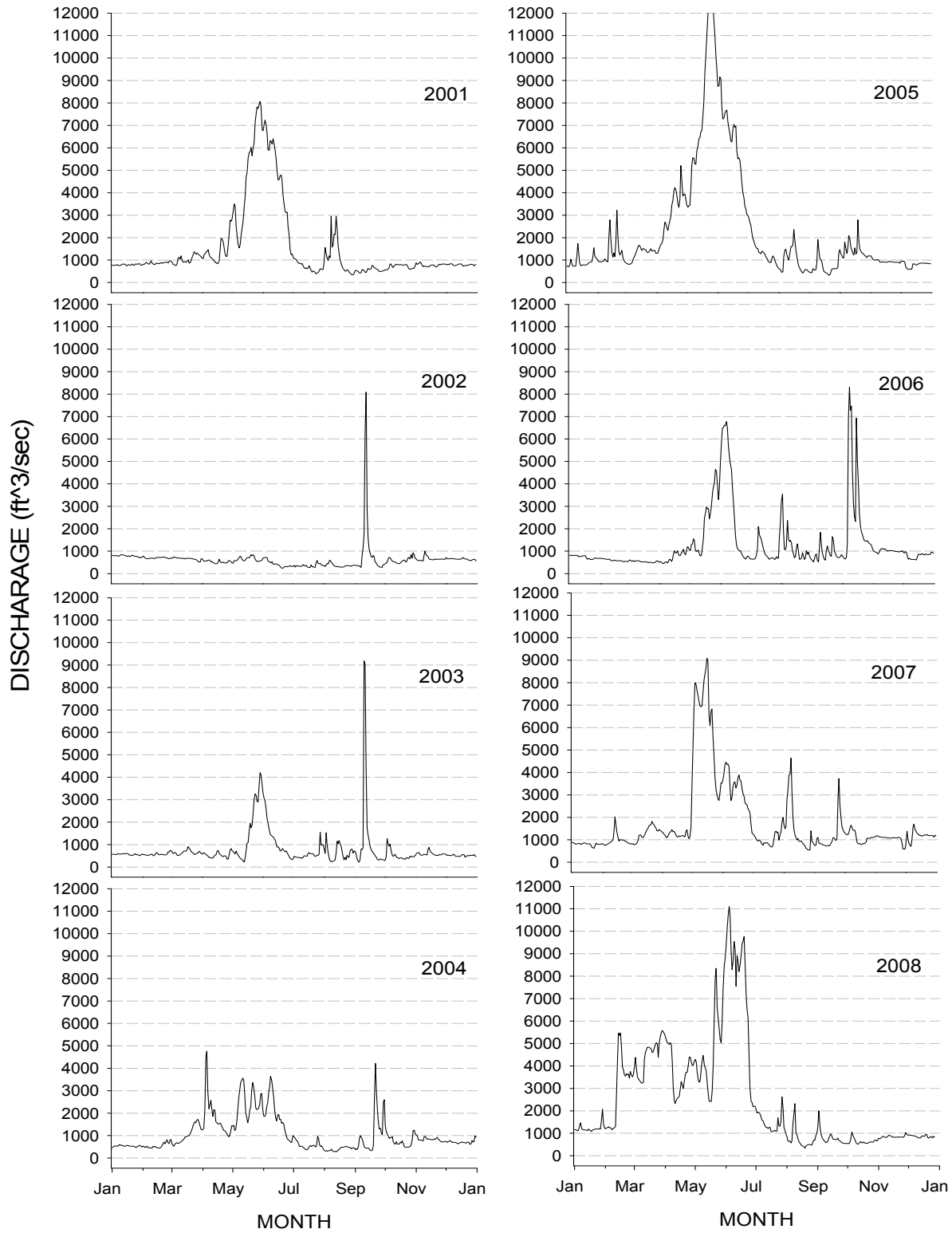
Trip	Discharge (ft <sup>3</sup> /sec)	Mean Clarity (mm)	Effort (hours)	<i>Ptyluc</i>	<i>Xyrtex</i>	<i>Ictpun</i>	<i>Cypcar</i>	<i>Micsal</i>	<i>Ameiurus</i> spp	<i>Saltru</i>
April 24 – May 1	4,506 <sup>1</sup>	116.67								
<i>Downstream boats</i>			69.08	105	99	2,029	157	0	5	2
<i>Upstream boats</i>			71.32	n/a	n/a	1,329	142	0	5	0
<b><i>Totals for trip</i></b>			<b>140.40</b>	<b>105</b>	<b>99</b>	<b>3,358</b>	<b>299</b>	<b>0</b>	<b>10</b>	<b>2</b>
July 24 – August 1	1,736 <sup>1</sup>	< 10								
<i>Downstream boats</i>			83.40	190	25	298	125	2	3	0
<i>Upstream boats</i>			84.25	n/a	n/a	438	111	2	2	0
<b><i>Totals for trip</i></b>			<b>167.65</b>	<b>190</b>	<b>25</b>	<b>736</b>	<b>236</b>	<b>4</b>	<b>5</b>	<b>0</b>
September 3 -11	848 <sup>1</sup>	156.00								
<i>Downstream boats</i>			90.13	185	38	3,571	122	3	7	0
<i>Upstream boats</i>			84.63	n/a	n/a	2,126	76	1	4	0
<b><i>Totals for trip</i></b>			<b>174.76</b>	<b>185</b>	<b>38</b>	<b>5,697</b>	<b>198</b>	<b>4</b>	<b>11</b>	<b>0</b>
**September 22/23 – October 6-11	746 <sup>1</sup> 834 <sup>1</sup>									
<i>Downstream boats</i>			54.18	155	32	2,334	88	4	5	1
<i>Upstream boats</i>			78.92	2	n/a	3,574	90	2	5	0
<b><i>Totals for trip</i></b>			<b>133.1</b>	<b>157</b>	<b>32</b>	<b>5,908</b>	<b>178</b>	<b>6</b>	<b>8</b>	<b>1</b>
<b>Totals</b>			<b>615.91</b>	<b>637</b>	<b>194</b>	<b>15,699</b>	<b>911</b>	<b>14</b>	<b>34</b>	<b>3</b>

\*\* Nonnative removal trip conducted in conjunction with annual sub-adult and adult fish community monitoring. Downstream boats sampled using standardized sampling protocols as defined in *San Juan River Monitoring Plan and Protocols (Propst et al. 2006)*. Downstream boats sampled in one river mile increments, with two of every three river miles sampled. When possible, upstream boats sampled all river miles and did not skip the same miles as the downstream boats.



Appendix B. Channel catfish CPUE (fish/hour of electrofishing) by individual removal Sections for the initial year of removal and 2008 values. Error bars represent  $\pm 1$  SE.





Appendix C. Discharge (ft<sup>3</sup>/second) recorded at USGS gauge #09368000 near Shiprock, New Mexico; 2001-2008.