

ENDANGERED FISH MONITORING AND NONNATIVE FISH CONTROL IN THE UPPER/MIDDLE SAN JUAN RIVER: 2010

FINAL REPORT

PREPARED FOR:

SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM



PREPARED BY:

BOBBY DURAN, JASON E. DAVIS AND ERNEST TELLER SR.

U.S. FISH AND WILDLIFE SERVICE

NEW MEXICO FISH AND WILDLIFE CONSERVATION OFFICE

3800 COMMONS N.E.

ALBUQUERQUE, NM 87109



ENDANGERED FISH MONITORING AND NONNATIVE FISH CONTROL IN THE
UPPER/MIDDLE SAN JUAN RIVER: 2010

PREPARED BY:

BOBBY RAY DURAN, JASON E. DAVIS, AND ERNEST TELLER SR.

BOBBY_DURAN@FWS.GOV JASON_E_DAVIS@FWS.GOV ERNEST_TELLER@FWS.GOV

UNITED STATES FISH AND WILDLIFE SERVICE

NEW MEXICO FISH AND WILDLIFE CONSERVATION OFFICE

3800 COMMONS N.E.

ALBUQUERQUE, NM 87109

SUBMITTED TO:

SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM

BIOLOGY COMMITTEE

06 JULY 2011

EXECUTIVE SUMMARY

1. Totals of 18,700 channel catfish and 451 common carp were removed from river miles (RM) 166.6 – 52.9 in 730.4 hours of electrofishing.
2. Channel catfish CPUE from PNM Weir to Hogback Diversion was similar to CPUE in 2007 – 2009 but was significantly lower ($p < 0.05$) than values observed from 2001-2006.
3. Channel catfish CPUE from Hogback Diversion to Shiprock Bridge was similar to CPUE in 2007 and 2008 but was significantly lower ($p < 0.05$) than values observed from 2003-2006 and 2009.
4. We observed a lower abundance of juvenile channel catfish in each of the uppermost removal sections compared to values observed in 2009. The increase in juvenile channel catfish abundance in 2009 was attributed to upstream immigration from areas of higher abundance.
5. Similar to 2009, juvenile channel catfish CPUE was significantly higher ($p < 0.05$) downstream of RM 120.0 and the Mancos River confluence (RM 122.5).
6. Channel catfish CPUE from PNM Weir to Hogback Diversion has been reduced by 91% since the initiation of intensive removal in 2001. An 88% reduction in channel catfish CPUE has been observed from Hogback Diversion to Shiprock Bridge since 2003.
7. Common carp collections were infrequent throughout the study area.
8. Most razorback sucker captures occurred within 10 RM's of the stocking location at RM 158.6.
9. Twenty-one Colorado pikeminnow >400 mm total length (TL) were collected in 2010 including five fish >500 mm TL.
10. One individual Colorado pikeminnow with a total length of 770 mm was collected in 2010. This fish was the 4th largest Colorado pikeminnow caught in the San Juan River since 1997.

TABLE OF CONTENTS

EXECUTIVE SUMMARY.....	i
INTRODUCTION	1
STUDY AREA	2
METHODS	2
RESULTS	3
PNM WEIR TO HOGBACK DIVERSION.....	3
Channel catfish.....	4
Common carp.....	7
HOGBACK DIVERSION TO SHIPROCK BRIDGE.....	8
Channel catfish.....	9
Common carp.....	11
SHIPROCK BRIDGE TO MEXICAN HAT	13
Channel catfish.....	13
Common carp.....	17
RARE FISH COLLECTIONS	18
Colorado pikeminnow.....	18
Razorback sucker	20
DISCUSSION	22
SUMMARY AND CONCLUSIONS.....	28
ACKNOWLEDGEMENTS.....	29
LITERATURE CITED.....	30
APPENDICES.....	33-37

LIST OF TABLES

Table 1. Summary of Colorado pikeminnow by year class collected during nonnative fish removal; 2010..... 19

Table 2. Summary of razorback sucker by year class collected during nonnative fish removal; 2010..... 21

LIST OF FIGURES

Figure 1. Map of study area 3

Figure 2. Channel catfish CPUE (fish/hour) by trip within the PNM Weir to Hogback Diversion Section; 2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons..... 4

Figure 3. Channel catfish CPUE (fish/hour) by year, PNM Weir to Hogback Diversion; 2001-2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons..... 5

Figure 4. Length frequency histograms for channel catfish collected from PNM Weir to Hogback Diversion; 2001-2010. The y-axis represents percent (%) of catch and the x-axis represents total length 6

Figure 5. Common carp CPUE (fish/hour) by trip within the PNM Weir to Hogback Diversion Section; 2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons..... 7

Figure 6. Common carp CPUE (fish/hour) by year, PNM Weir to Hogback Diversion; 2001-2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). Letters above data points represent statistical comparisons of that individual year to 2009. A “d” means that year was statistically different than 2008 and an “s” means that year was not different from 2010 8

Figure 7. Channel catfish CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2010. Error bars represent ± 1 SE. The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons. 9

Figure 8. Channel catfish CPUE (fish/hour) by year, Hogback Diversion to Shiprock Bridge; 2003-2010. Error bars represent ± 1 SE. The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons. 10

Figure 9. Length frequency histograms for channel catfish collected from Hogback Diversion to Shiprock Bridge; 2003-2010. The y-axis represents percent (%) of catch and the x-axis represents total length..... 11

Figure 10. Common carp CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters represent that significant differences were detected among comparisons 12

Figure 11. Common carp CPUE (fish/hour) by year, Hogback Diversion to Shiprock Bridge; 2003-2010. Error bars represent ± 1 SE. Letters represent comparisons among years (Nemenyi post-hoc). Letters above data points represent statistical comparisons of that individual year to 2009. A “d” means that year was statistically different than 2008 and an “s” means that year was not different from 2010..... 13

Figure 12. Chanel catfish CPUE (fish/hour) by trip from Shiprock Bridge to Mexican Hat; 2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons..... 14

Figure 13. Channel catfish CPUE (fish/hour) by ten river mile segments from Shiprock Bridge to Mexican Hat; 2010. Error bars represent ± 1 SE..... 15

Figure 14. Channel catfish CPUE (fish/hour) from Shiprock Bridge to Mexican Hat;2008 - 2010. Error bars represent ± 1 SE..... 16

Figure 15. Length frequency histograms by trip for channel catfish collected from Shiprock Bridge to Mexican Hat, Utah; 2010. The y-axis represents percent (%) of catch and the x-axis represents total length..... 17

Figure 16. Common carp CPUE (fish/hour of electrofishing) during 2010 nonnative removal trips from Shiprock Bridge to Mexican Hat. Error bars represent ± 1 SE 17

Figure 17. Common carp CPUE (fish/hour of electrofishing) during nonnative removal trips from Shiprock Bridge to Mexican Hat, 2008 - 2010. Error bars represent ± 1 SE. 18

Figure 18. Days and years post-stocking verses river mile for Colorado pikeminnow encounters during nonnative fish removal trips conducted by NMFWCO; 2010 19

Figure 19. Length frequency histogram for Colorado pikeminnow collected during intensive nonnative fish removal trips; 2010. The y-axis represents percent (%) of catch and the x-axis represents total length..... 20

Figure 20. Days and years post-stocking verses river mile for razorback sucker encounters during nonnative fish removal trips conducted by NMFWCO; 2010. 21

Figure 21. Length frequency histogram for razorback sucker collected during intensive nonnative fish removal trips; 2010. The y-axis represents percent (%) of catch and the x-axis represents total length..... 22

Appendix A-1. Mean discharge, effort and total count of major species collected during intensive nonnative fish removal efforts from PNM Weir to Hogback Diversion, 2009. Species listed by the first three letters of the Genera and first three letters of the Species (i.e. *Ptychocheilus lucius* = *Ptyluc*). ¹ Mean discharge from USGS gauge #09368000 near Shiprock, New Mexico 33

Appendix A-2. Mean discharge, effort and total count of major species collected during intensive nonnative fish removal efforts from Hogback Diversion to Shiprock Bridge, 2009. ¹ Mean discharge from USGS gauge #09368000 near Shiprock, New Mexico 33

Appendix A-3. Mean discharge, effort and total count of major species collected during intensive nonnative fish removal efforts from Shiprock Bridge to Mexican Hat, Utah; 2009. ¹ Mean discharge from USGS gauge #09371010 near Four Corners, Colorado 34

Appendix B. Channel catfish CPUE (fish/hour of electrofishing) by individual removal section 35

Appendix C. Riverwide population estimates for Colorado pikeminnow and razorback sucker..... 36

INTRODUCTION

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 2010):

San Juan River Recovery Implementation Program's Long Range Plan (2010 Draft):

Element 3. Interactions between native and nonnative fish species

Goal 3.1- Control of problematic nonnative fishes as needed

Action 3.1.1- Develop, implement, and evaluate the most effective strategies for reducing problematic nonnative fishes.

Task 3.1.1.8- 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 on 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 2010 marked the tenth 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 in 2008 to include intensive removal from Shiprock Bridge to Mexican Hat, UT (RM 147.9 – 52.9). In 2010, 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 fishes 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.

STUDY AREA

Intensive nonnative removal efforts in 2010 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 was exclusively located in Geomorphic Reach 6, Hogback Diversion to Shiprock Bridge encompassed portions of both Geomorphic reaches 6 and 5, and Shiprock Bridge to Mexican Hat was in reaches 5 – 2.

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 fishes 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.

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 > 150 mm TL, a 134.2 kHz PIT tag was implanted and the capture status was recorded as a new capture (Davis 2010).

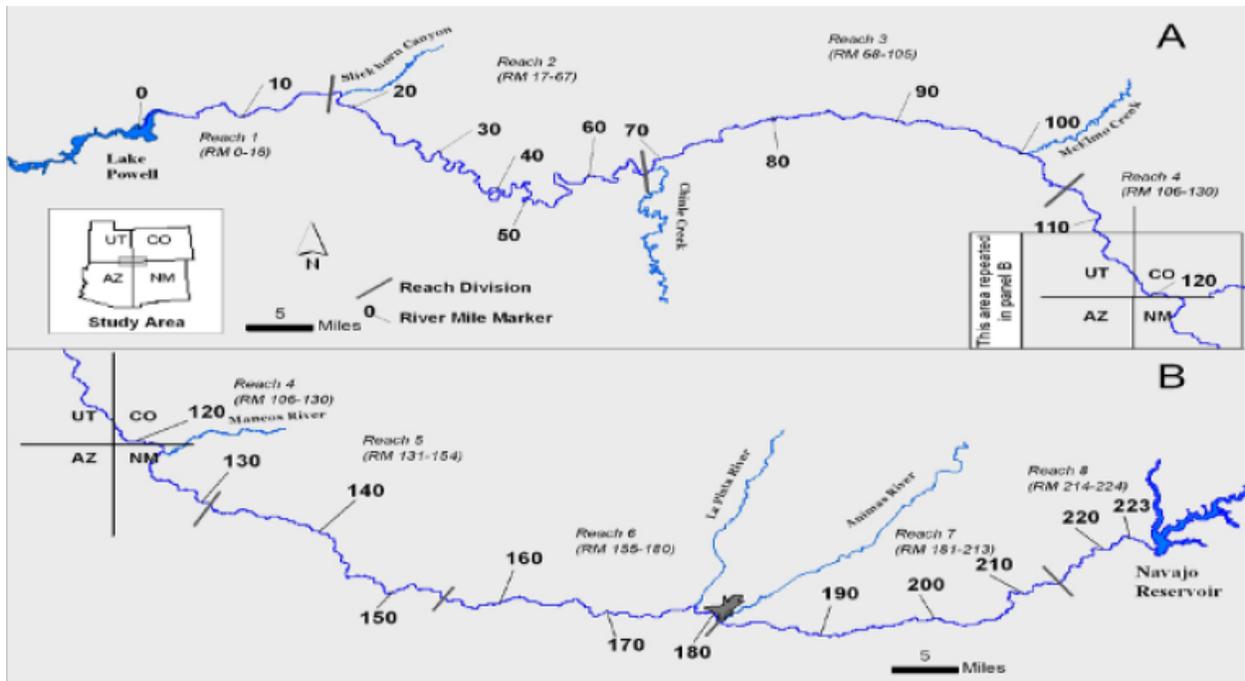


Figure 1. Map of study area – map provided by UNM MSB

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. Sampling units varied among section but typically ranged from 2 – 3 river miles. Species CPUE was calculated as the total number of fish collected in a sampling unit divided by the total effort of sampling (hours of electrofishing). To determine trends in distribution and abundance, mean catch rates (fish per hour of electrofishing; CPUE) and standard errors (± 1 SE) were calculated using the software package SPSS version 13.0 (2004). Data were summarized by section, trip, and year.

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

PNM WEIR TO HOGBACK DIVERSION (RM 166.6 – 159.0)

A total of 129 channel catfish and 35 common carp were removed from this section throughout four trips (March to October) and 52.4 hours of electrofishing (Appendix A-1). Additional nonnative fishes removed from the section included rainbow trout *Oncorhynchus*

mykiss, brown trout *Salmo trutta*, bullhead catfishes *Ameiurus spp.*, largemouth bass *Micropterus salmoides*, smallmouth bass *Micropterus dolomieu*, green sunfish *Lepomis cyanellus*, and bluegill *Lepomis macrochirus*. No striped bass *Morone saxatilis* or walleye *Sander vitreus* were collected or observed.

CHANNEL CATFISH

Channel catfish CPUE was < 1.0 fish/hour during the March and October trips (Figure 2). Catch rates increased from 0.1 fish/hour in March to 3.6 fish/hour in June (ANOVA; $F_{(3, 36)} = 9.146$; $p < 0.001$). In 2010, the mean Channel catfish CPUE for all life stages combined was 2.0 fish/hour (Figure 3).

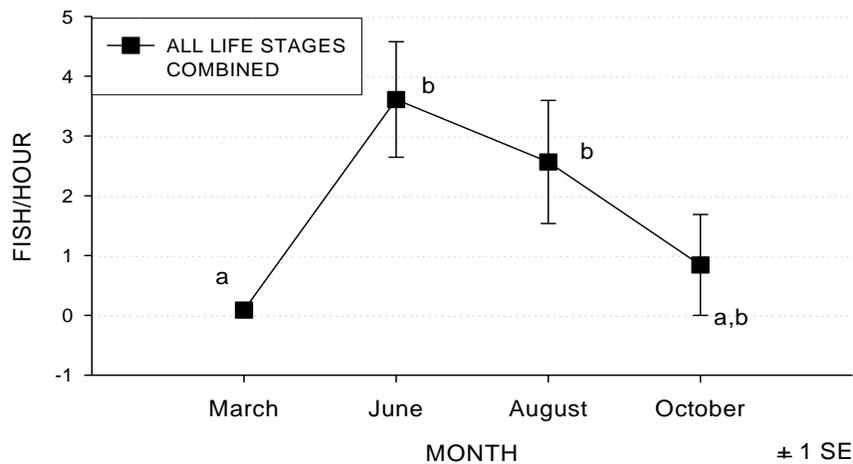


Figure 2. Channel catfish CPUE (fish/hour) by trip within the PNM Weir to Hogback Diversion Section; 2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

Mean channel catfish CPUE in 2010 was similar to catch rates observed from 2007-2009 but was significantly lower than CPUE from 2001-2006 (ANOVA; $F_{(9, 525)} = 11.084$; $p < 0.05$). Catch rates in 2010 were the lowest observed since the initiation of nonnative removal in 2001. For the third consecutive year, 2008-2010, channel catfish CPUE was < 5.0 fish/hour (Figure 3).

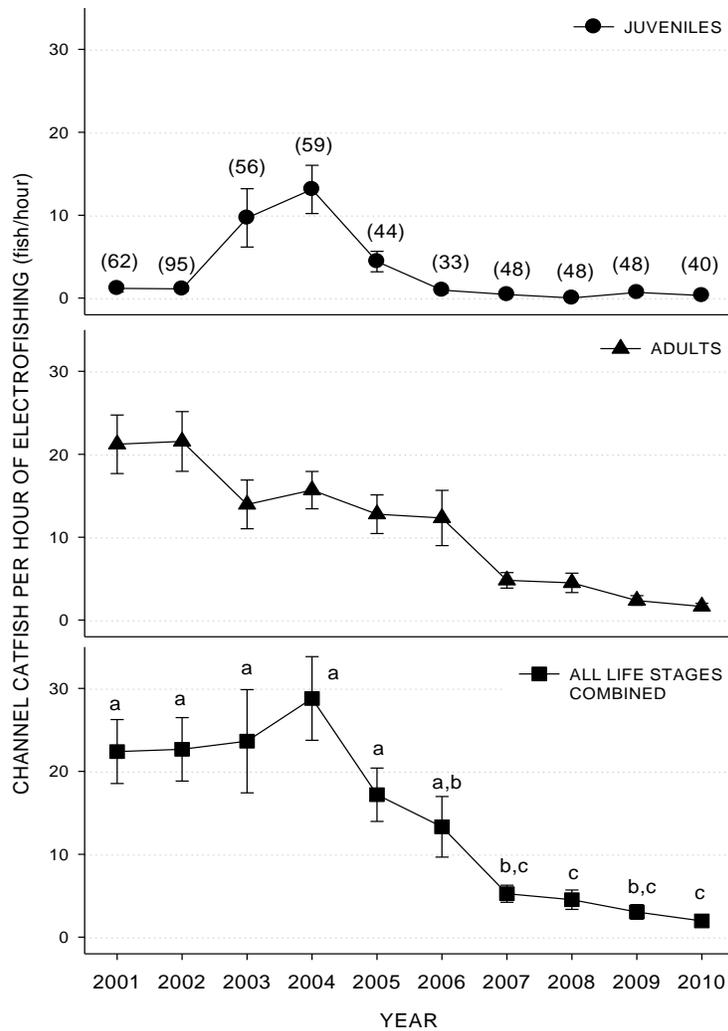


Figure 3. Channel catfish CPUE (fish/hour) by year, PNM Weir to Hogback Diversion; 2001-2010. Error bars represent ± 1 SE. Letters represent comparisons among years (Nemenyi post-hoc). Similar letters indicate that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons. Sample size presented parenthetically.

The mean total length (TL) of channel catfish in 2010 was 427mm and lengths ranged from 226 to 604 mm TL (Figure 4). The length frequency distribution of channel catfish in 2010 was similar to patterns observed in 2003 and 2009; however, the overall number of fish has been greatly reduced (n= 3,954 in 2001; n= 129 in 2010).

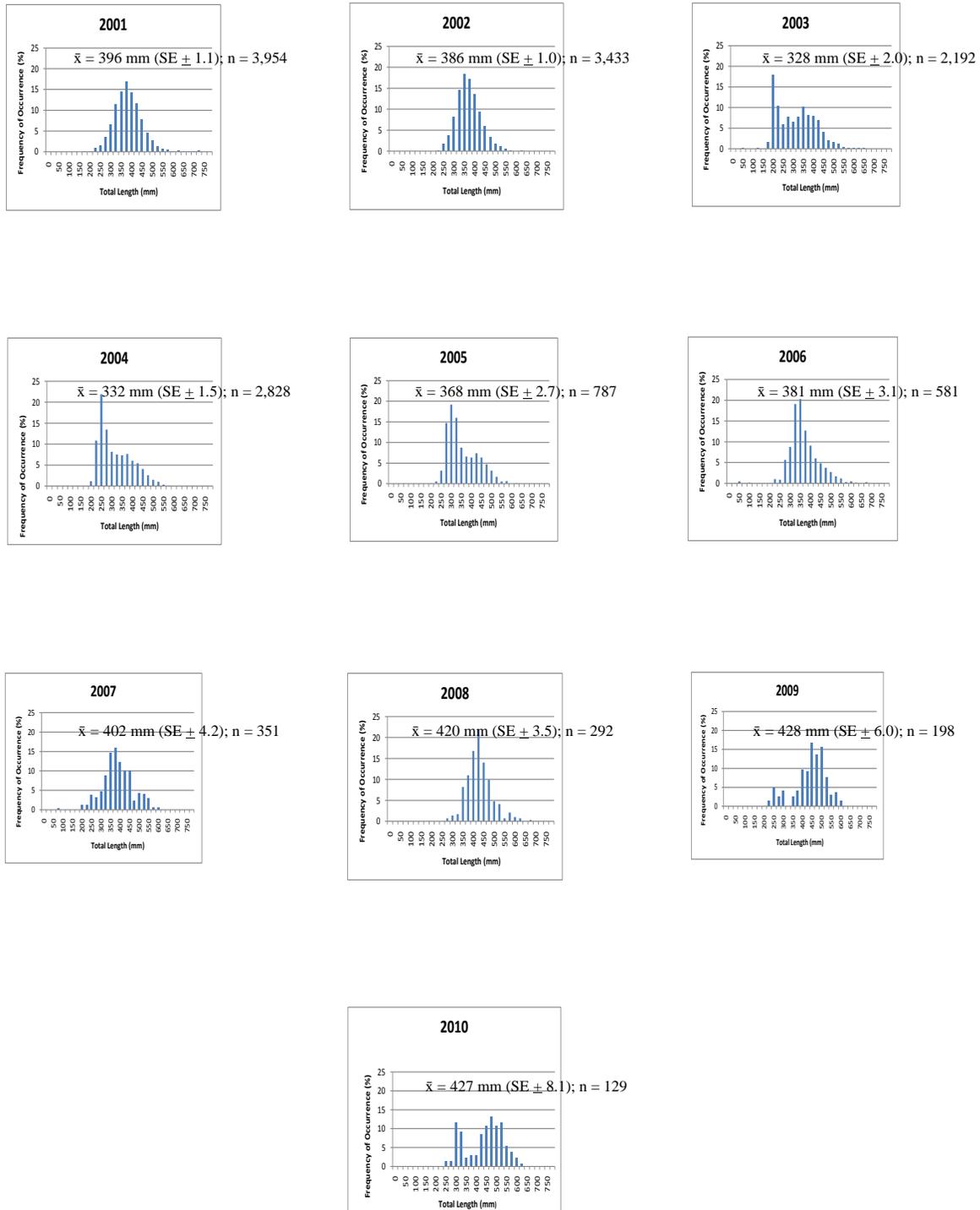


Figure 4. Length frequency histograms for channel catfish collected from PNM Weir to Hogback Diversion; 2001 - 2010. The y-axis represents percent (%) of catch and the x-axis represents total length.

COMMON CARP

Common carp CPUE varied little during the four trips in 2010 (Figure 5). Catch rates were < 1.1 fish/hour during each trip and ranged from 1.0 fish/hour in June to 0.3 fish/hour in August. Mean common carp CPUE, all life stages combined, in 2010 was 0.6 fish/hour (Figure 6).

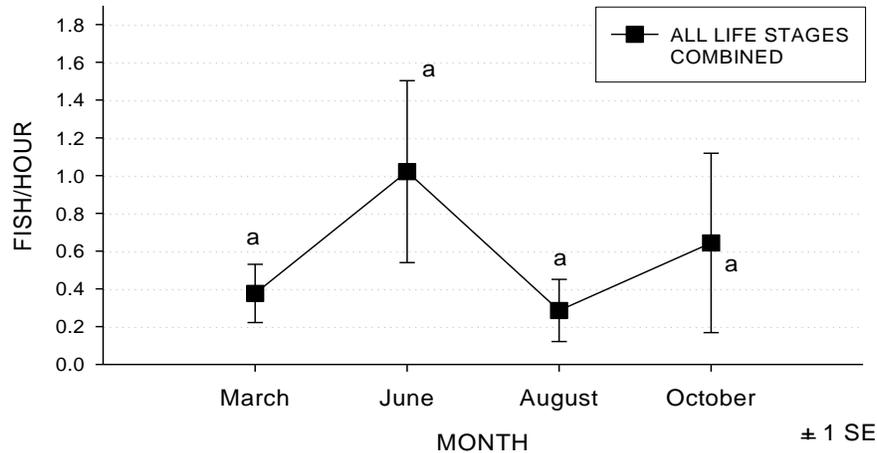


Figure 5. Common carp CPUE (fish/hour) by trip within the PNM Weir to Hogback Diversion Section; 2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

Comparison of common carp CPUE among years showed a continuing decline in catch rates resulting in 2010 having the lowest observed catch rates since nonnative removal began in 2001. Catch rates in 2010 were similar to values observed in 2008 and 2009 but were significantly lower than all previous years (ANOVA; $F_{(9,525)} = 60.345$; $p < 0.05$) (Figure 6). Common carp mean CPUE was < 1.0 fish/hour for the second consecutive year. Common carp continue to be uncommon in all collections within this section.

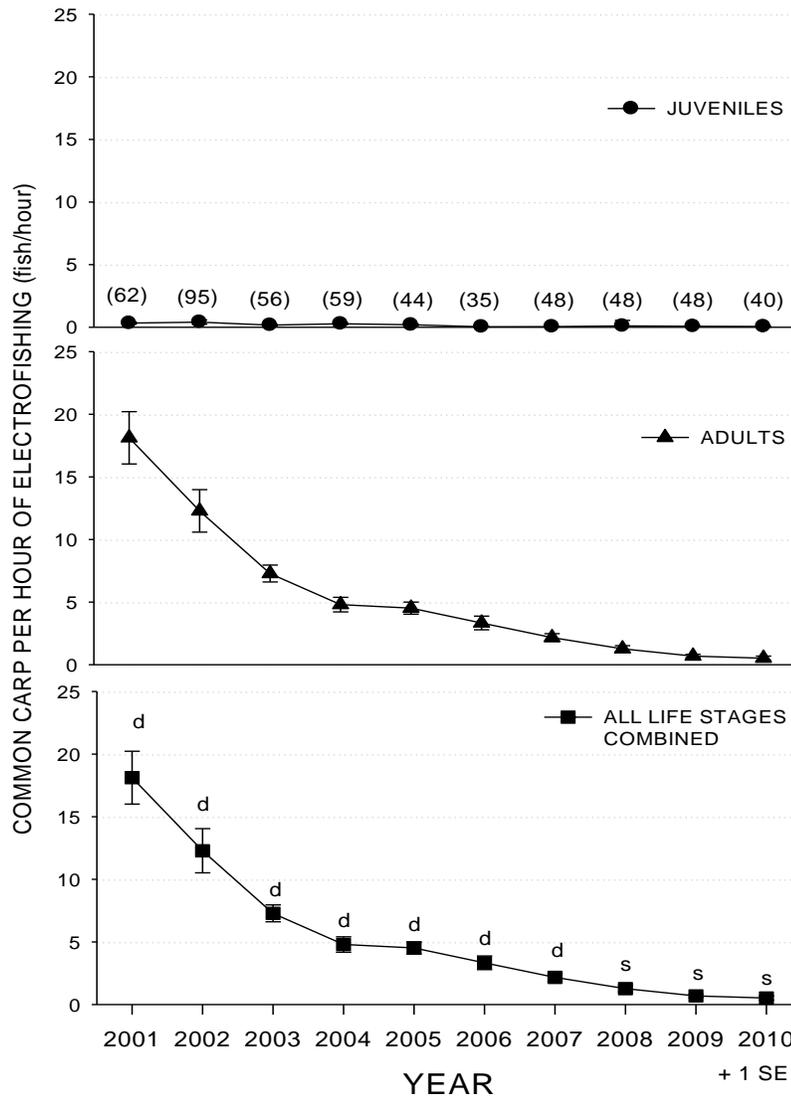


Figure 6. Common carp CPUE) fish/hour by year, PNM Weir to Hogback Diversion; 2001-2010. Error bars represent ± 1 SE. Letters represent comparisons among years (Nemenyi post-hoc). Letter above data points represent statistical comparisons of that individual year to 2010. A “d” means that year was statistically different than 2010 and an “s” means that year was similar to 2010. Sample size presented parenthetically.

HOGBACK DIVERSION TO SHIPROCK BRIDGE (RM158.8 – 147.9)

A total of 803 channel catfish and 66 common carp were removed during four trips (March to October) and 86.4 hours of electrofishing (Appendix A-2). In addition to channel catfish and common carp, other nonnative fishes collected included rainbow trout, brown trout, bullhead catfishes, green sunfish and bluegill.

CHANNEL CATFISH

Channel catfish CPUE in 2010 ranged from 1.9 fish/hour to 10.8 fish/hour (Figure 7). The CPUE of 2010 in April was significantly lower than all trips, excluding October (ANOVA; $F_{(3,126)} = 27.785$; $p < 0.05$). The CPUE did not differ among the remaining three trips. The highest juvenile CPUE of 2010 occurred in July (5.1 fish/hour) and the mean channel catfish CPUE, all life stages combined, was 7.2 fish/hour (Figure 8).

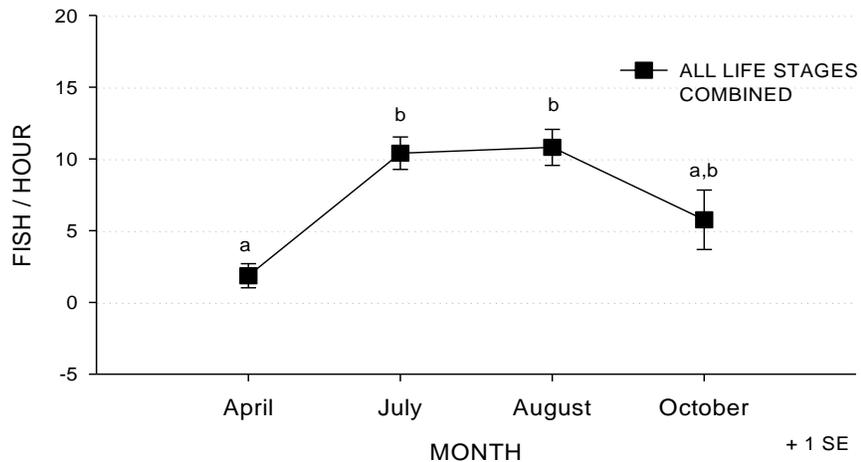


Figure 7. Channel catfish CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

The channel catfish CPUE has significantly declined since the initiation of intensive removal in 2003. Channel catfish CPUE in 2003 was 57.7 fish/hour compared to a CPUE of 7.2 fish/hour in 2010 (ANOVA; $F_{(7, 1,056)} = 66.350$; $p < 0.001$) (Figure 8). Catch rates in 2010 were similar to values observed in 2007-2008 but were significantly lower than values observed from 2003-2006 and 2009. Juvenile channel catfish CPUE decreased from 8.4 fish/hour in 2009 to 2.3 fish/hour in 2010 (ANOVA; $F_{(7, 1,056)} = 51.379$; $p = 0.04$).

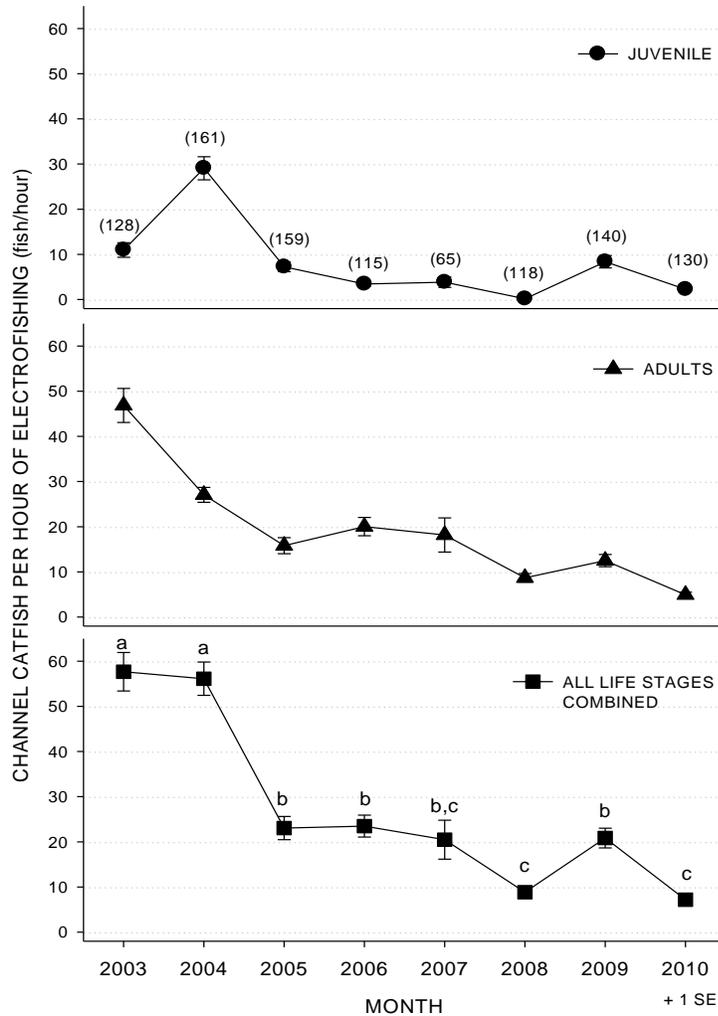


Figure 8. Channel catfish CPUE (fish/hour) by year, Hogback Diversion to Shiprock Bridge; 2003-2010. Error bars represent ± 1 SE. Letters represent comparisons among years (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons. Sample size presented parenthetically.

The mean total length (TL) of channel catfish in 2010 was 381mm (Figure 9) and lengths ranged from 90 to 679 mm TL. The highest mean TL (421mm TL; SE \pm 2.0) of the study period occurred in 2008 but the mean TL decreased to 381mm TL in 2010.

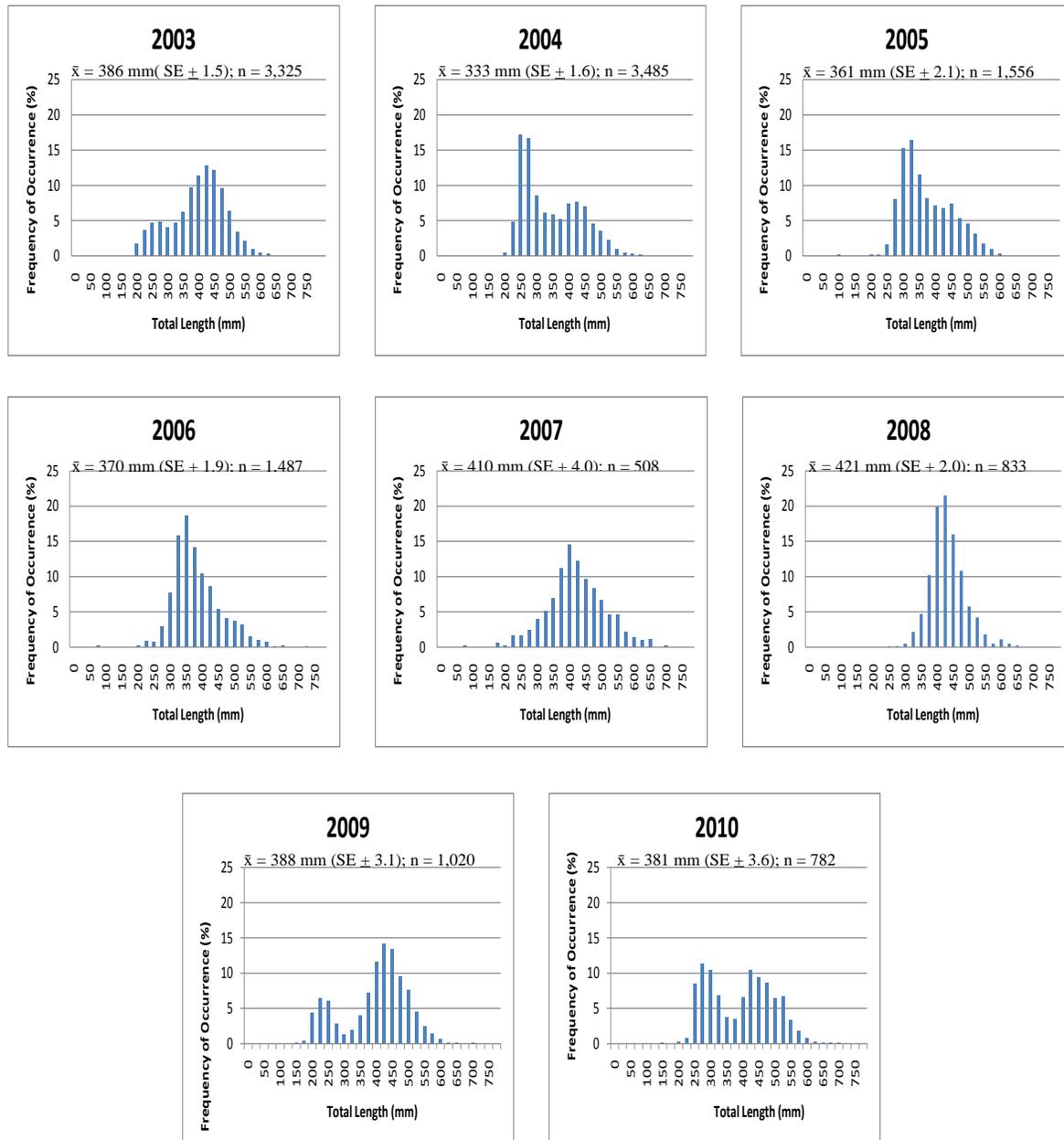


Figure 9. Length frequency histograms for channel catfish collected from Hogback Diversion to Shiprock Bridge; 2003 - 2010. The y-axis represents percent (%) of catch and the x-axis represents total length.

COMMON CARP

Common carp catch rates were < 1.0 fish/hour and varied little among the four 2010 trips (Figure 10). Mean common carp CPUE, all life stages combined, in 2010 was 0.6 fish/hour (Figure 11).

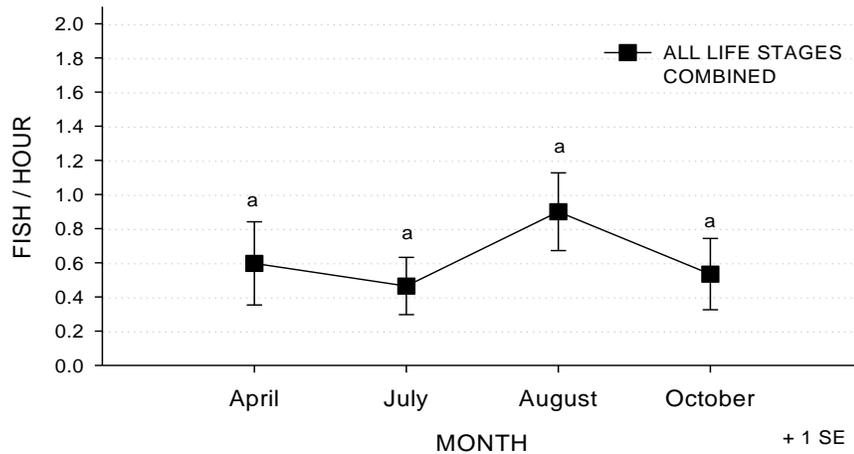


Figure 10. Common carp CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

Common carp CPUE has declined significantly since the initiation of intensive removal in 2003 and in 2010 the CPUE (0.62 fish/hour) was lower than values observed from 2003-2009 (ANOVA; $F_{(7, 1,056)} = 151.873$; $p < 0.001$); common carp CPUE was 29.0 fish/hour in 2003 (Figure 11). Common carp continue to be infrequently collected from Hogback Diversion to Shiprock Bridge and 2010 marked the fourth consecutive year that common carp CPUE was < 3.0 fish/hour.

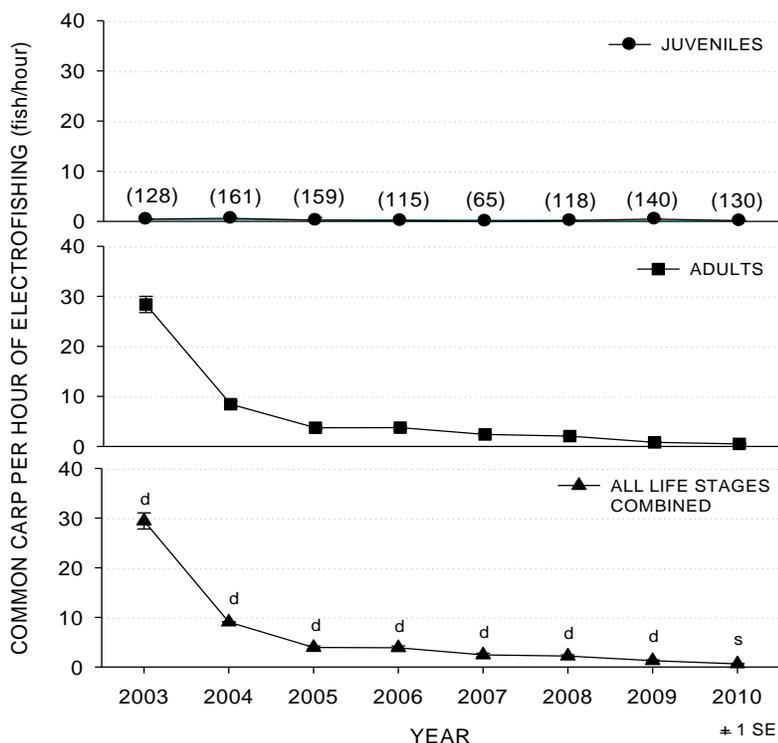


Figure 11. Common CPUE (fish/hour) by year, Hogback Diversion to Shiprock Bridge; 2003-2010. Error bars represent ± 1 SE. Letters represent comparisons among years (Nemenyi post-hoc). Letter above data points represent statistical comparisons of that individual year to 2010. A “d” means that year was statistically different than 2010 while an “s” means that year was similar to 2010. Sample size presented parenthetically.

SHIPROCK BRIDGE TO MEXICAN HAT (RM 147.9 - 52.9)

Three removal trips (April/May, July, and September) were conducted from Shiprock Bridge to Mexican Hat in 2010, removing 14,437 channel catfish and 293 common carp in 455.8 hours of electrofishing. Nonnative fish removal also took place in conjunction with FWS Colorado River Fishery Project’s annual fall monitoring in September/October, resulting in the removal of an additional 3,331 channel catfish and 57 common carp in 135.8 hours of electrofishing. For the year, a total of 17,768 channel catfish and 350 common carp were removed during 591.6 hours of electrofishing in this section (Appendix A-3). Other nonnative fishes removed included 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 life stages combined, varied among trips in 2010. The highest mean CPUE of 41.3 fish/hour was during the April/May trip, and the lowest mean CPUE of 12.3

fish/hour was during the July trip (Figure 12). Excluding the July trip, juvenile channel catfish CPUE was similar among trips.

Similar to 2009, juvenile catch rates increased as sampling proceeded downstream. Catch rates were < 7.0 fish/hour from RM's 147.9 to 120 and peaked at 29.0 fish/hour from RM's 60 to 52.9 (Figure 13). Catch rates significantly increased downstream of RM 122.5, the Mancos River confluence (ANOVA; $F_{(9, 502)} = 19.931$; $p < 0.001$). In contrast, young-of-year catch rates were highest (6.1 fish/hour) from RM's 100 to 90, near the McElmo Creek confluence and were lowest from RM's 147.9 to 140 (0.07 fish/hour).

In 2010, the mean channel catfish CPUE, all life stages combined, was 28.0 fish/hour which was significantly lower than the 2009 CPUE of 60.3 fish/hour (ANOVA; $F_{(2, 1,602)} = 113.465$; $p < 0.001$). Adult CPUE declined from 18.0 fish/hour to 9.8 fish/hour, and juvenile CPUE declined from 41.0 fish/hour in 2009 to 15.3 fish/hour in 2010 (Figure 14).

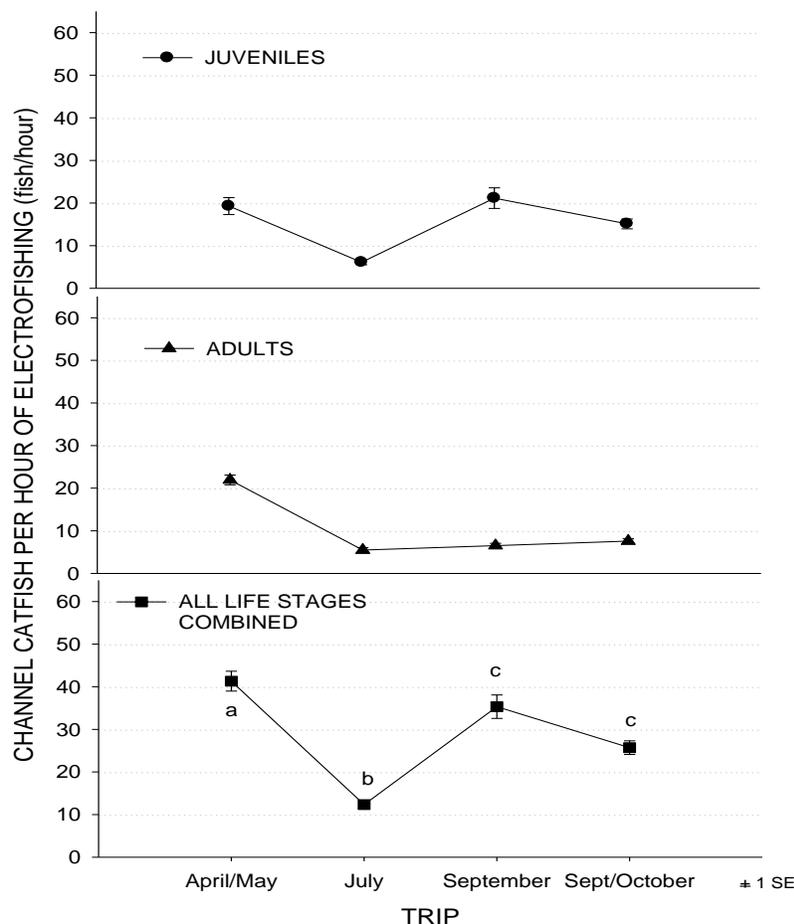


Figure 12. Channel catfish CPUE (fish/hour) by trip from Shiprock Bridge to Mexican Hat; 2010. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

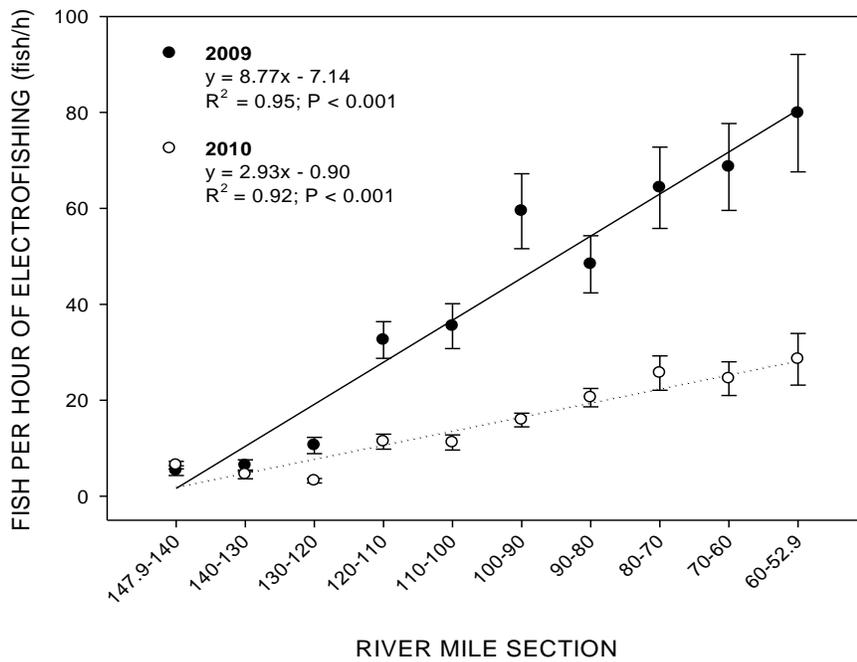


Figure 13. Juvenile channel catfish CPUE (fish/hour) by 10 river mile segments from Shiprock Bridge to Mexican Hat; 2009 and 2010. Error bars represent ± 1 SE.

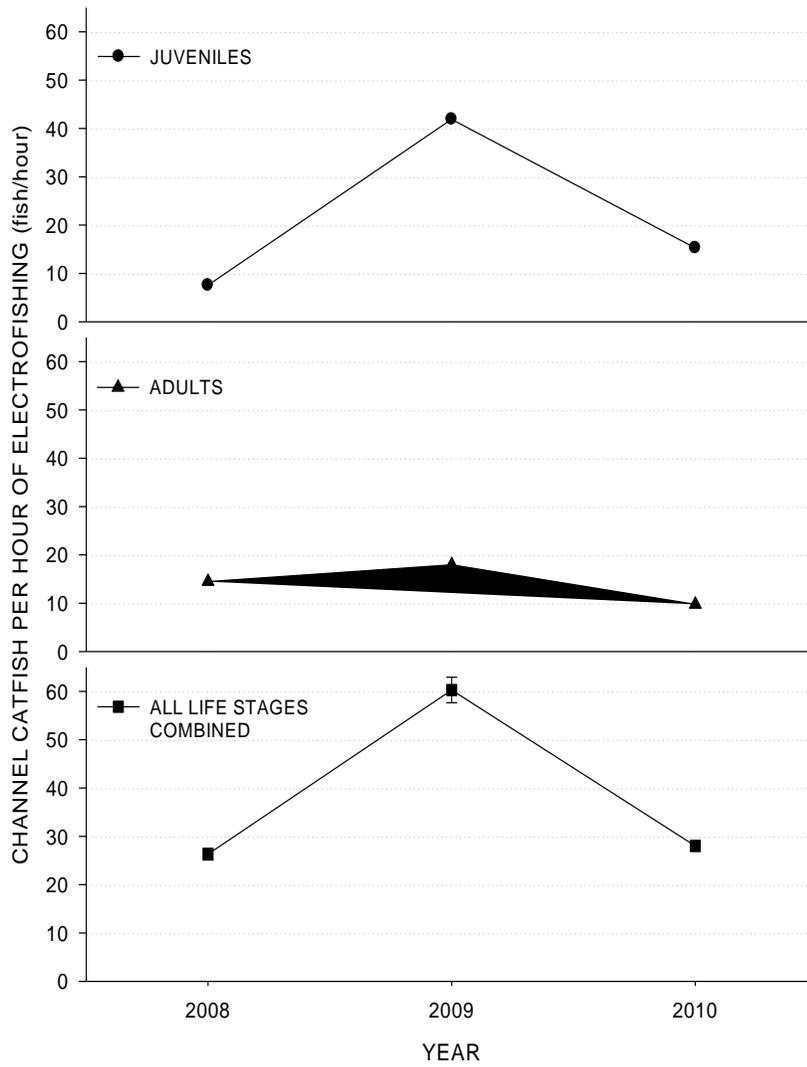


Figure 14. Channel catfish CPUE (fish/hour) from Shiprock Bridge to Mexican Hat; 2008 - 2010. Error bars represent ± 1 SE.

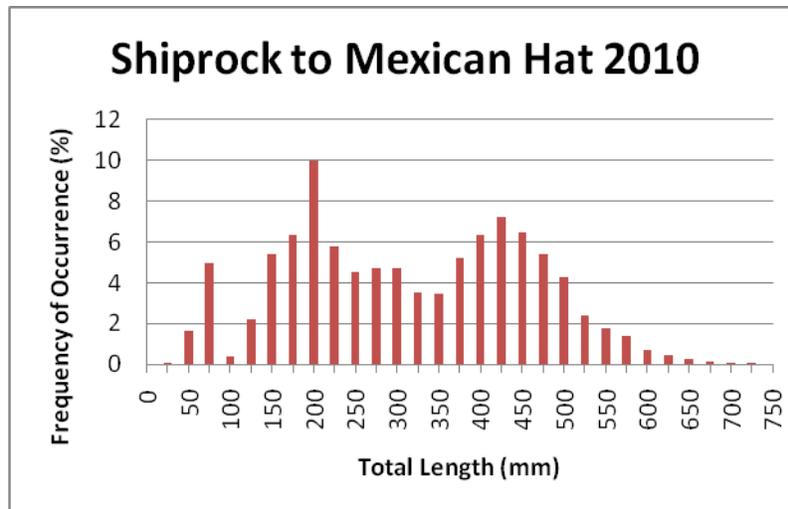


Figure 15. Length frequency histograms by trip for channel catfish collected from Shiprock Bridge to Mexican Hat Utah; 2010. The y-axis represents percent (%) of catch and the x-axis represents total length.

Channel catfish TL ranged from 25 to 720 mm in 2010 (mean = 304mm TL) (Figure 15). The majority of measured channel catfish (50.4 %) were < 300 mm TL, 42.2 % were between 300 – 500 mm TL, and 7.4% were > 500 mm TL.

COMMON CARP

CPUE for Common carp averaged 0.61 fish/hour and did not differ significantly among the four sample trips (Figure 16). Mean CPUE of common carp in 2010 was significantly lower than CPUE values observed in 2008 and 2009 (ANOVA; $F_{(2, 1,602)} = 60.487$; $p < 0.001$) (Figure 17). Similar to other sections, common carp were uncommon in our collections.

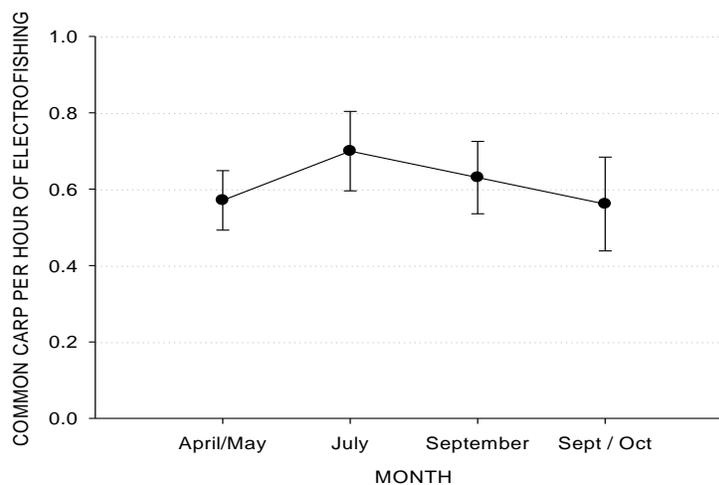


Figure 16. Common carp CPUE (fish/hour of electrofishing) during 2010 nonnative removal trips from Shiprock Bridge to Mexican Hat. Error bars represent + 1 SE.

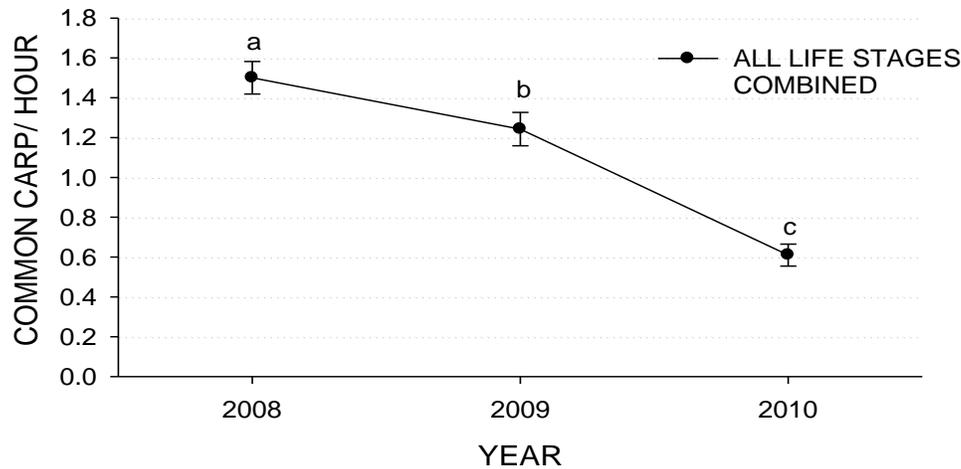


Figure 17. Common carp CPUE (fish/hour of electrofishing) during nonnative removal trips from Shiprock Bridge to Mexican Hat, 2008 – 2010. Error bars represent + 1 SE.

RARE FISH COLLECTIONS

A total of 1,729 Colorado pikeminnow and 1,144 razorback sucker were captured during nonnative removal trips from PNW Weir to Mexican Hat, Utah (Appendix A-3). Fifty-one Colorado pikeminnow and 437 razorback sucker were collected from PNW Weir to Hogback Diversion; 335 Colorado pikeminnow and 541 razorback sucker were collected from Hogback Diversion to Shiprock Bridge; and 1,343 Colorado pikeminnow and 166 razorback sucker were collected from Shiprock Bridge to Mexican Hat. These totals do not include rare fishes collected during annual sub-adult and adult fish community monitoring conducted by U.S Fish and Wildlife Service- Colorado Fishery Project. For analyses purposes, fishes that were recaptured multiple times on an individual trip or throughout the year were included but recaptures of an individual fish on the same day were excluded.

COLORADO PIKEMINNOW

All Colorado pikeminnow collected in 2010 were considered to be stocked fish. A total of 205 individual fish had PIT tags at time of capture. Recaptures ranged from one to 1,511 days since first encounter. The majority of these fish ($n=168$) were captured < 365 days since first encounter (Figure 18) and only 11 fish were recaptured > 730 days since first encounter. Various age classes were collected dating back to 2004, but the majority of recaptures were from the 2008 and 2009 year classes (Table 1).

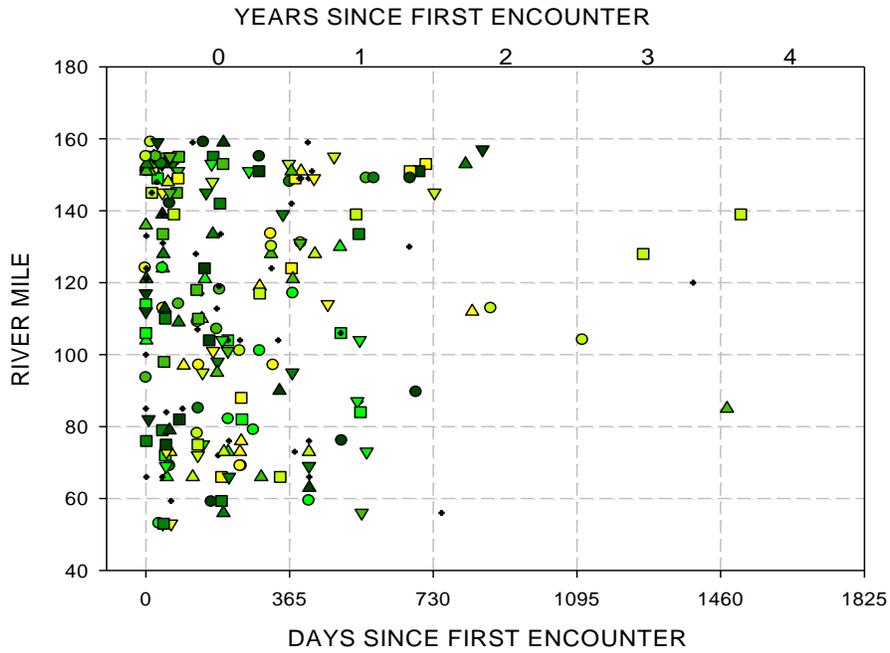


Figure 18. Days and years since first encounter versus river mile for Colorado pikeminnow encounters during nonnative fish removal trips conducted by NMFWCO; 2010. Different symbols and colors represent individual capture encounters.

Table 1. Summary of Colorado pikeminnow by year class collected during nonnative fish removal; 2010.

Year class	N
2004	2
2005	2
2006	37
2007	37
2008	753
2009	835

A total of 1,067 Colorado pikeminnow were implanted with a PIT tag at the time of capture. These newly implanted fish ranged in size from 138 – 770 mm TL, with a mean total length of 215 mm. Four-hundred-twenty-five captures were not implanted with a PIT tag because they were < 150 mm TL. Colorado pikeminnow collected in 2010 ranged from 83 – 770 mm TL (Figure 19). Fish < 150 mm TL made up 25% (n = 425) of total catch, and fish > 400 mm TL composed only 1.2 % (n = 21) of the catch. Three Colorado pikeminnow were collected between 450 – 500 mm TL and five individuals were > 500 mm TL. One individual Colorado pikeminnow with a TL of 770 mm was collected during the September trip. This individual did not have a PIT tag at time of capture and was the 4th largest Colorado pikeminnow caught in the San Juan River since 1997. The mean TL for Colorado pikeminnow collected in 2010 was 208 mm TL.

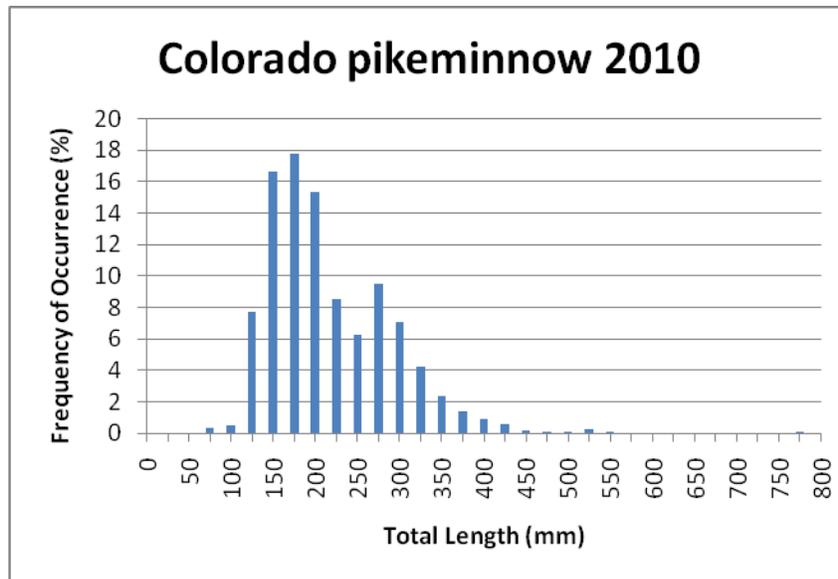


Figure 19. Length frequency histograms for Colorado pikeminnow collected during intensive nonnative fish removal trips; 2010. The y-axis represents percent (%) of catch and the x-axis represents total length.

RAZORBACK SUCKER

All razorback sucker collected in 2010 were considered to be stocked fish. Although 135 razorback sucker were lacking PIT tags at time of capture, we assumed these fish were stocked from Navajo Agricultural Products Industry (NAPI) ponds in 2006 and 2007 without tags. All 135 of these fish were implanted with a 134.2kHz PIT tag and released. Various known age classes were recaptured dating back to 1997 with the majority (71%) of recaptures from the 2007 year class (Table 2).

Table 2. Summary of razorback sucker by age class collected during nonnative fish removal; 2010.

Year class	N
1997	1
1999	9
2000	17
2001	45
2002	12
2003	20
2004	2
2005	5
2006	51
2007	572
2008	71
Unknown	244

Days in river since first encounter ranged from 1 - 4097 days (Figure 20). Of the 998 razorback sucker that had a known stocking history, 70% (n=698) were recaptured < 1 year since first encounter and 8.3% (n=83) were recaptured > 5 years since first encounter. One individual was recaptured 11 years since first encounter.

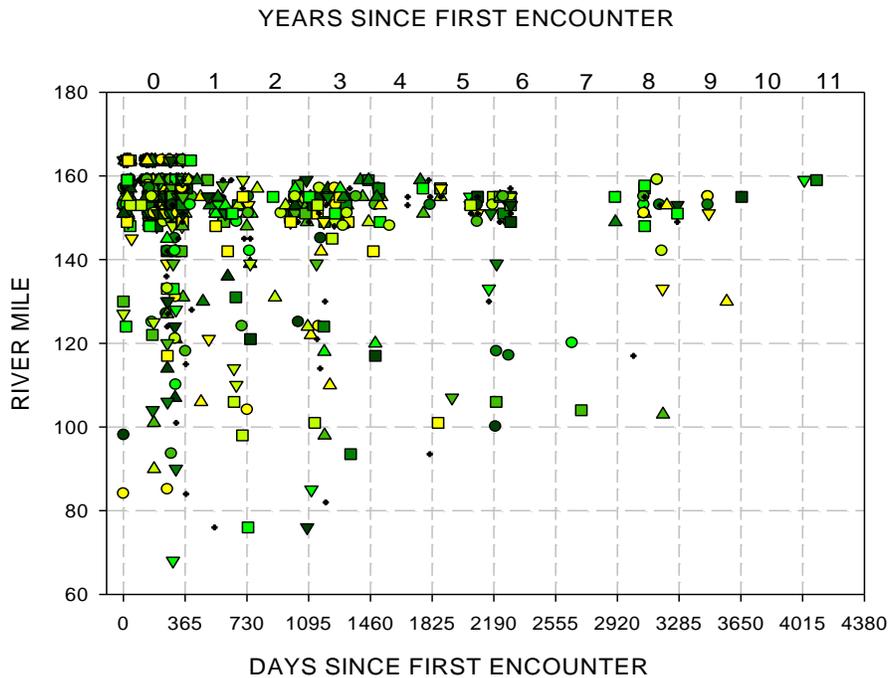


Figure 20. Days and years since first encounter versus river mile for razorback sucker encounters during nonnative fish removal trips conducted by NMFWCO; 2010. Different symbols and colors represent individual capture encounters.

Razorback sucker collected in 2010 ranged from 224 – 590 mm TL (mean = 413mm TL) (Figure 21). Based on size, the minimum total length to be classified as an adult razorback sucker is 400 mm. Of the 1,130 measured fish, 44% (n=497) were between 400 – 500 mm TL, and 10% (n=110) were > 500 mm TL.

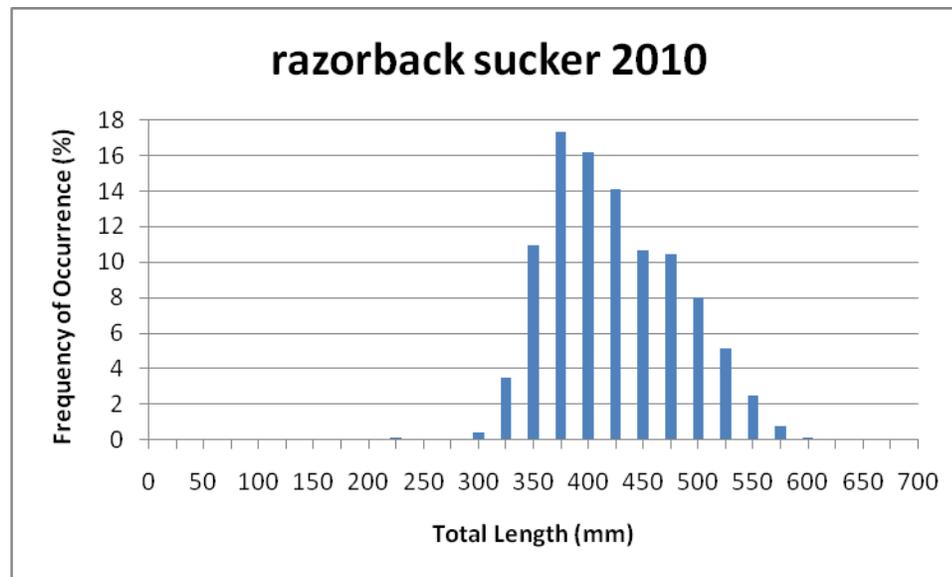


Figure 21. Length frequency histograms for razorback sucker collected during intensive nonnative fish removal trips; 2010. The y-axis represents percent (%) of catch and the x-axis represents total length.

DISCUSSION

Channel catfish abundance from PNM Weir to Hogback Diversion in 2010 was the lowest observed since the initiation of intensive nonnative removal in 2001. Channel catfish catch rates have shown some level of decline for the past six years. The decline is likely the cumulative result of intensive removal efforts in this section and adjacent downstream sections. Seasonal variance in catch rates occurred in this section and could be caused by fish moving upstream in to the study reach during particular times of the year. In 2003, nonnative removal efforts were expanded to include the Hogback Diversion to Shiprock Bridge section. Channel catfish abundance in this section was higher than the abundance of channel catfish at the start of removal in the adjacent upstream section, PNM Weir to Hogback Diversion, and after two years of removal, channel catfish CPUE was reduced to levels less than half of that at the initiation of removal.

The potential for fish to move into study reaches from downstream could potentially contribute to variable catch rates resulting in a lack of significant declines in abundance (Davis and Furr 2007). 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 expanding removal efforts to include Hogback Diversion to Shiprock Bridge and reducing overall abundance in this section, the potential source of fish to repopulate the PNM Weir to Hogback Diversion section has been reduced. Channel catfish abundance from Hogback Diversion to Shiprock Bridge in 2010 was the lowest observed since the initiation of intensive removal in this section in 2003. An 88% reduction in channel catfish CPUE was observed in 2010 compared to CPUE in 2003. This reduction may have been the result of intensive removal downstream of Shiprock Bridge using the multiple pass strategy initiated in 2008 from Shiprock Bridge to Mexican Hat, Utah. It appears that a reduction in channel catfish abundance downstream of Hogback Diversion has similarly decreased the potential for upstream immigration, as well as lessened seasonal variability in CPUE. As large numbers of nonnative fishes are removed downstream of Shiprock Bridge, we anticipate continued declines in abundance in upstream removal sections, as well as lowered channel catfish abundance riverwide.

An increase in juvenile channel catfish abundance in each removal sections was observed in 2009, most noticeably in the Hogback Diversion to Shiprock Bridge, and Shiprock Bridge to Mexican Hat sections. However, juvenile channel catfish abundance significantly declined in 2010 in each of these sections. The pulse of juveniles in 2009 may have been a reproductive response by channel catfish to exploitation from Shiprock Bridge to Mexican Hat, Utah. Within each of the upper removal sections (PNW Weir to Hogback and Hogback to Shiprock Bridge) peaks in juvenile abundance were observed during some period of removal. Increases from PNM Weir to Hogback Diversion in 2003 and 2004 may have been a reproductive response to exploitation or to the previous year's hydrologic conditions. The low water year of 2002 may have been equally responsible for the shift to smaller fish because nonnative fish densities generally increase when daily summer mean discharge is $< 500 \text{ ft}^3 / \text{second}$ (Propst and Gido 2004). However, the observed increase in age-0 and age-1 channel catfish during sub-adult and adult monitoring in 2008 and 2009 (Ryden 2009) suggest that a reproductive response to exploitation, as opposed to low hydrologic conditions, may have occurred because mean summer discharge in 2008 was $998 \text{ ft}^3 / \text{second}$.

The increased abundance of juvenile channel catfish in the two uppermost sections could be a result of wide spread movement of channel catfish in the San Juan River. Data collected from a mark recapture study conducted by Utah Division of Wildlife Resources (UDWR) suggest that upstream movement into these sections was the likely cause of the increased abundance of juvenile channel catfish. In March 2010, UDWR tagged 995 channel catfish downstream of RM 52.9 (Darek Elverud personal communication). Of these fish, 32 were recaptured during nonnative removal efforts and adult monitoring in the upper removal sections and had moved on average 33.5 RM's upstream from their original tagging mile. Four of these fish (Mean TL = 274 mm) moved an average 94.6 (range = 47.8 – 126.5) RM's upstream in 3 – 5 months. Similarly, in 2009 UDWR tagged 701 channel catfish downstream of RM 52.9 and of these fish, 21 were recaptured in upper removal sections in 2009. While this is a limited data set,

it suggests that channel catfish in the San Juan River exhibit widespread upstream movement and can potentially reoccupy upper removal sections in a relatively short amount of time.

Initial shifts towards smaller fish may be important in long term suppression of channel catfish 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/fish 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 the relatively low number 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). 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 our intensive nonnative fish removal efforts are similar to those Pitlo (1997) observed as evidence of overexploitation of channel catfish in the Mississippi River. Pitlo observed that as the number of large fish declined, 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 have occurred within the two uppermost intensive removal sections. 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 overall reproductive potential of channel catfish. With continued exploitation and the lack of size-selective removal, we expect juvenile fish will be removed prior to reproduction resulting in decreased recruitment in future years.

Expansion of removal efforts since 2008 is expected to result in significant declines in channel catfish abundance river wide. Channel catfish abundance in recent years has been significantly decreased compared to abundance at the initiation of nonnative removal in the two uppermost removal sections. Although an increase in juvenile channel catfish abundance occurred in 2009, juvenile channel catfish catch rates declined in 2010 similar values similar to those observed in 2008. Regardless of the reason, it is critical to maintain or even increase intensive removal efforts from Shiprock Bridge to Mexican Hat in order to remove juvenile fish prior to recruitment to adulthood. We anticipate that focusing removal efforts in this section will result in a reduction in overall channel catfish abundance river wide in 3 to 5 years. This management action would result in large numbers of fish being removed from the 95 RM section

and would reduce the potential for fish to repopulate the two uppermost removal sections. Reducing this potential may lead to a reduction in effort and trips in upper sections to include only periodic “maintenance” trips to keep the low numbers of channel catfish in these sections in check.

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 they are collected infrequently across all studies (Elverud 2009; Ryden 2009). Common carp were the sixth most abundant fish collected in 2009 sub-adult and adult fish community monitoring and comprised only 0.9% of the total catch (Ryden 2010).

Compared to channel catfish, 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 (thrashing motion or induced movement without orientation) when exposed to pulsed direct current (PDC). This behavior enables netters to easily identify and net common carp in turbid conditions. Conversely, channel catfish often 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 affects capture efficiency.

Decreased common carp abundance may limit 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 in abundance and the subsequent declines in carp biomass may allow for higher utilization of resources by native fishes with limited levels of interspecific competition.

Because 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, initially 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 stocking events.

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 2010 with 88% of captures occurring within 10 RM's of 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 multiple times throughout the years exhibited little movement between captures (± 5 RM's), even with recapture events occurring as much as two years apart. One razorback sucker was captured at RM 164.0 in 2002 and was not captured again until 2010 at RM 159. Because 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 provide more extensive data on fish movement and perhaps determine whether fish undergo regular movements or if they exhibit little movement suggesting that our gear type is not overly effective at collecting individual fish.

Similar to previous years, Colorado pikeminnow captures were widely distributed in 2010. Although captures of adult Colorado pikeminnow in our collections were higher than previous years, more 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. Additionally, tracking radio-implanted adults to possible spawning bars and timing sampling trips to collect these adult fish may provide important data regarding probabilities of capture. To evaluate current population densities of rare fishes, the Program is analyzing recapture data across all studies to relate this information to overall stocking success. These analyses will guide future augmentation decisions including numbers to be stocked, location of stockings, and will help determine when and if stand-alone 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 129 channel catfish and 35 common carp were collected during four removal trips in 2010.
- Channel catfish CPUE in 2010 was lower than CPUE from 2001-2006.
- Channel catfish CPUE in 2010 has been reduced by 91% compared to 2001 catch rates.
- Common carp CPUE in 2010 was similar to that observed in 2008 and 2009 but was significantly lower ($p < 0.05$) than values observed from 2001-2007.
- Common carp were uncommon in collections.

HOGBACK DIVERSION TO SHIPROCK BRIDGE (RM 158.8 – 147.9)

- A total of 803 channel catfish and 66 common carp were collected during four removal trips in 2010.
- Channel catfish CPUE in 2010 was similar to values observed in 2007 and 2008 but were significantly ($p < 0.001$) lower than values observed from 2003-2006 and 2009.
- Juvenile channel catfish CPUE declined in 2010 compared to values observed in 2009 ($p=0.04$).
- Common carp CPUE in 2010 was significantly ($p < 0.05$) lower than 2003 to 2009.
- Common carp were uncommon in collections.

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

- A total of 17,768 channel catfish and 350 common carp were removed during four (8 passes) removal trips in 2010.
- Juvenile channel catfish CPUE, by trip, in 2010 ranged from 6.1 to 21.0 fish/hour of electrofishing.
- Juvenile channel catfish CPUE significantly ($p < 0.001$) increased downstream of river mile 120.
- 2010 channel catfish CPUE, all life stages combined, was similar to CPUE values observed in 2008 but were significantly ($p < 0.001$) lower than values observed in 2009.
- Common carp CPUE was < 1.0 fish/hour during each of the four removal trips.
- Common carp were uncommon in collections.

RARE FISH CAPTURES

- A total of 1,729 Colorado pikeminnow and 1,144 razorback sucker were encountered during 2010 sampling from RM 166.6 – 52.9.
- Majority of razorback sucker encounters were documented within 10 RM's of stocking location at RM 158.6.
- Twenty-one individual Colorado pikeminnow > 400 mm TL were collected in 2010.
- One individual Colorado pikeminnow with a TL of 770 mm was collected and was the 4th largest Colorado pikeminnow caught in the San Juan River since 1997.

ACKNOWLEDGEMENTS

We would like to thank the staffs of New Mexico Department of Game and Fish, Conservation Services Division; Utah Department of Wildlife Resources, Moab Field Station; U.S. Fish and Wildlife Service, Colorado River Project (Grand Junction); American Southwest Ichthyological Researchers, L.L.C. and U.S. Bureau of Indian Affairs, Farmington, NM for participating on our intensive nonnative fish removal trips in 2010. Special thanks to Susan Maestas, NMFWCO, for assisting with travel arrangements and contractual obligations. Collection permits were issued by New Mexico Department of Game and Fish, Colorado Division of Wildlife, Utah Department of Natural Resources and Navajo Nation Department of Fish and Wildlife. Funding for this work was provided through authorizing legislation for the SJRIP and administered by U.S. Bureau of Reclamation, Salt Lake City, Utah.

LITERATURE CITED

- Bliesner, R. and V. Lamarra. 2000. Hydrology, Geomorphology and Habitat Studies. San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.
- Brooks, J.E., M.J. Buntjer, and J.R. Smith. 2000. Non-native species interactions: Management implications to aid in recovery of the Colorado pikeminnow *Ptychocheilus lucius* and razorback sucker *Xyrauchen texanus* in the San Juan River, CO-NM-UT. San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Cooper, E.L. ed. 1987. Carp in North America. American Fisheries Society. Bethesda, Maryland.
- Davis, J.E. and S.M. Coleman. 2004. Non-native species monitoring and control in the upper San Juan River 2002-2003 and Assessment of fish movement through the non-selective fish ladder at Hogback Diversion, New Mexico 2003. Progress Report for the San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Davis, J.E. and D.W. Furr. 2007. Non-native species monitoring and control in the upper San Juan River, New Mexico: 2006. Final Report for the San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Davis, J.E. 2010. Passive Integrated Transponder (PIT) tagging methodologies for the San Juan Basin Recovery Implementation Program. Final Report for the San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Elverud, D.S. 2009. Nonnative control in the lower San Juan River 2008. Interim Progress Report for the San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Helms, D.R. 1975. Variations in the abundance of channel catfish year classes in the upper Mississippi River and causative factors. Iowa Conservation Commission, Iowa Fisheries Technical Series 75-1, Des Moines.
- Jackson, J.A. 2005. Non-native control in the lower San Juan River, 2004 (DRAFT). Interim Progress Report for the San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Kitcheyan, D. C. and M. Montagne. 2005. Movement, migration, and habitat use by Colorado pikeminnow, *Ptychocheilus lucius*, in a regulated river below Flaming Gorge Dam, Utah. Draft Final Report submitted to Dinosaur National Monument and Central Utah Project Act Office, Department of the Interior.

- Kolz, A.L., Reynolds, J.B., Boardman, J., Temple, A., and Lam, D. 1998. Principles and techniques of electrofishing (course manual), Branch of Aquatic Resources Training, U.S. Fish and Wildlife Service National Conservation Training Center, Shepherdstown, West Virginia.
- Minckley, W.L. 1991. Native Fishes of the Grand Canyon Region: An Obituary? Colorado River Ecology and Dam Management. National Academy Press. Washington, D.C. pp. 124-177.
- Mueller, G.A. 2005. Predatory fish removal and native fish recovery in the Colorado River mainstem: What have we learned? Fisheries. 30(9):10-19.
- Pitlo, J. Jr. 1997. Response of upper Mississippi River channel catfish populations to changes in commercial harvest regulations. North American Journal of Fisheries Management. 17: 848-859.
- Propst, D.L and K.B. Gido 2004. Responses of native and nonnative fishes to natural flow regime mimicry in the San Juan River. Transactions of the American Fisheries Society, 133:922-931.
- Ryden, D.W. 2000. Adult fish community monitoring on the San Juan River, 1991-1997. San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Ryden, D.W. 2005. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 2004. Interim Progress Report for the San Juan River Recovery Implementation Program. U.S. Fish and Wildlife Service, Albuquerque, NM.
- Ryden, D.W. 2009. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 2008. Interim Progress Report for the San Juan River Recovery Implementation Program. U.S. Fish and Wildlife Service, Albuquerque, NM.
- Ryden, D.W. 2008. Augmentation of the San Juan River razorback sucker population: 2007. Interim Progress Report for the San Juan River Recovery Implementation Program. U.S. Fish and Wildlife Service, Albuquerque, NM.
- Ryden, D.W. 2009. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 2008. Interim Progress Report (Draft) for the San Juan River Recovery Implementation Program. U.S. Fish and Wildlife Service, Albuquerque, NM.
- Ryden, D.W. 2010. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 2008. Interim Progress Report for the San Juan River Recovery Implementation Program. U.S. Fish and Wildlife Service, Albuquerque, NM.
- San Juan River Recovery Implementation Program. 2008. Long Range Plan. U.S. Fish and Wildlife Service, Albuquerque, NM.

SPSS. 2004. SPSS 13.0 Brief Guide. SPSS Inc., Chicago, Illinois, U.S.A. 231 pp.

U.S. Fish and Wildlife Service. 2002a. Colorado pikeminnow (*Ptychocheilus lucius*) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

U.S. Fish and Wildlife Service. 2002b. Razorback sucker *Xyrauchen texanus* Recovery Goals: amendment and supplement to the Razorback Sucker Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

Zar, J.H. 1996. Biostatistical Analysis. 4th edition. Prentice-Hall, Upper Saddle River, New Jersey.

Appendix A-1. Mean discharge, effort and total count of major species collected during intensive non-native removal efforts from PNM Weir to Hogback Diversion, 2010. Species listed by the first three letters of the Genera and first three letters of Species (i.e. *Ptychocheilus lucius* = *Ptyluc*). ¹ Mean discharge from USGS gauge #09368000 near Shiprock, New Mexico.

Trip	Discharge ¹ (ft ³ /sec)	Effort (hours)	<i>Ptyluc</i>	<i>Xyrtex</i>	<i>Ictpun</i>	<i>Cypcar</i>	<i>Micsal</i>	<i>Ameiurus</i> <i>spp</i>	<i>Saltru</i>
March 23-25	951	16.7	0	212	1	6	0	1	48
June 22 – 24	626	17.2	17	68	69	20	4	3	49
August 10 – 12	733	18.5	11	58	53	6	7	2	0
October 21*	711	5.1	23	99	6	3	0	4	1
Totals		52.4	51	437	129	35	11	10	98

- Due to heavy rainstorms access to raft takeout was inaccessible for the remainder of the trip.

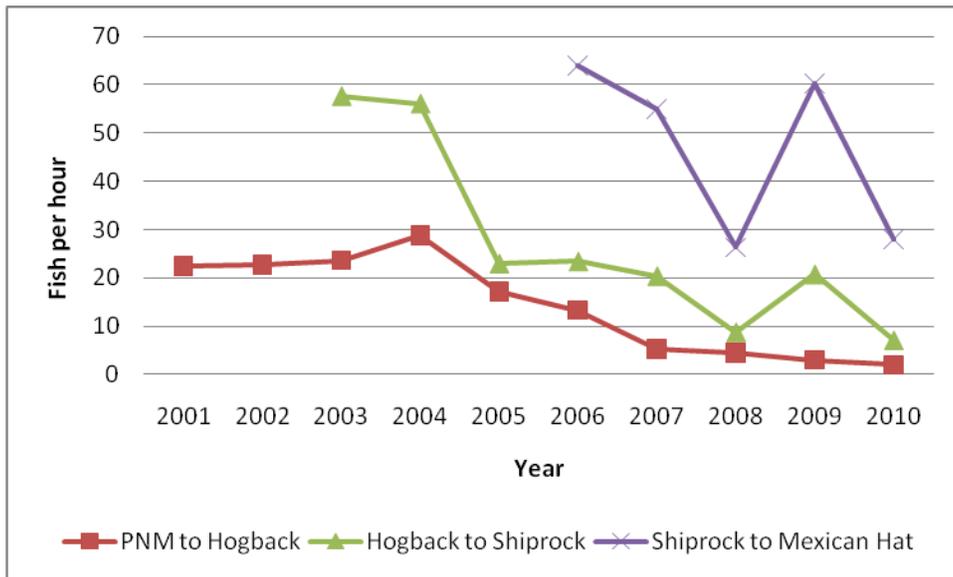
Appendix A-2. Mean discharge, effort and total count of major species collected during intensive non-native removal efforts from Hogback Diversion to Shiprock Bridge, 2010. ¹ Mean discharge from USGS gauge #09368000 near Shiprock, New Mexico.

Trip	Discharge ¹ (ft ³ /sec)	Effort (hours)	<i>Ptyluc</i>	<i>Xyrtex</i>	<i>Ictpun</i>	<i>Cypcar</i>	<i>Micsal</i>	<i>Ameiurus</i> <i>spp</i>	<i>Saltru</i>
April 6-8	653	29.0	17	240	45	16	0	5	25
July 7 – 9	818	27.6	69	80	301	12	5	4	19
August 17 – 19	731	29.8	103	66	321	26	10	38	1
October 18 - 20	629	28.7	146	155	136	12	1	19	0
Totals		86.4	335	541	803	66	16	66	45

Appendix A-3. Mean discharge, effort and total count of major species collected during intensive non-native removal efforts from Shiprock Bridge to Mexican Hat, Utah; 2010. Endangered fish were not collected by upstream boats (n/a). ¹ Mean discharge from USGS gauge #09371010 near Four Corners, Colorado.

Trip	Discharge ¹ (ft ³ /sec)	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 30 – May 7	1,328								
<i>Downstream boats</i>		76.0	195	28	3,789	57	6	5	2
<i>Upstream boats</i>		71.0	n/a	n/a	2,610	27	1	3	0
Totals for trip		147.0	195	28	6,399	84	7	8	2
July 22 – 30	1,231								
<i>Downstream boats</i>		76.5	472	67	1,222	72	113	38	1
<i>Upstream boats</i>		71.1	1	n/a	739	39	42	20	0
Totals for trip		147.6	473	67	1,961	111	155	58	1
September 8 - 16	1,209								
<i>Downstream boats</i>		86.7	672	71	3,426	55	2	35	0
<i>Upstream boats</i>		74.5	3	n/a	2,651	43	8	29	0
Totals for trip		161.2	675	71	6,077	98	10	64	0
**September 20 , 21	664/726								
October 4-9									
<i>Downstream boats</i>		54.2	350	63	1,565	35	2	29	0
<i>Upstream boats</i>		81.6	1	0	1,766	22	0	21	1
Totals for trip		135.8	351	63	3,331	57	2	50	1
Totals		591.6	1,694	229	17,768	350	174	180	4

** 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 section. The years 2007 and 2008 are included in the Shiprock to Mexican Hat section for comparison although only one trip per year was completed.

Appendix C.

Riverwide population estimates for Colorado pikeminnow and razorback sucker, 2010

Nonnative fish removal efforts occur throughout most of the designated critical habitat for both Colorado pikeminnow and razorback sucker. Several passes throughout these sections of river are conducted annually and have contributed to the highest number of capture encounters for each species of any study on the San Juan River. Since both NMFWCO and UDWR conduct trips during the same time of year an opportunity to conduct preliminary riverwide population estimates presented itself.

In order to run the estimate, data were used from a variety of sampling trips conducted within one month of each other. Table C1 is a summary of the Section sampled and dates used for each of the three passes. Only age 2+ Colorado pikeminnow that had been in the river for one over-winter period were used in this estimate. These same dates were utilized for the razorback sucker population estimate and all razorback sucker, regardless of age, that had been in the river for one over-winter period were used in the estimate. Program MARK was used to generate the estimates. The M_0 (null model) was used when capture probabilities were similar among passes while the M_t (time variable model) was used when capture probabilities varied among passes (Elevrud 2009). Population estimates are preliminary and may not be representative of actual population size.

Table C1. Summary of Section sampled and dates utilized for each pass for the generation of riverwide population estimates for Colorado pikeminnow and razorback sucker, 2010.

River Section	Pass 1	Pass 2	Pass 3
PNM to Hogback	3/23/2010	6/22/2010	8/10/2010
Hogback to Shiprock	4/6/2010	7/7/2010	8/17/2010
Shiprock to Mexican Hat	4/30-5/7/2010	7/22-30/2010	9/8-16/2010
Mexican Hat to Clay Hills	4/13-17/2010	8/9-13/2010	8/19-23/2010

Table C2. Matrices used for riverwide population estimates for Colorado pikeminnow and razorback sucker, 2010.

Colorado pikeminnow	razorback sucker
<u>Passes N</u>	<u>Passes N</u>
100 = 249	100 = 164
010 = 188	010 = 110
001 = 258	001 = 88
110 = 8	110 = 5
101 = 14	101 = 6
011 = 11	011 = 6
111 = 1	

Table C3. Riverwide (RM’s 166.6 – 2.9) Colorado pikeminnow population estimate, 2010. CI represents the profile likelihood interval. CV represents the coefficient of variation and p-hat represents the probability of capture.

YEAR	PASSES	MODEL	ESTIMATE	CI	CV	p-hat
2009	1-3	M(o)	4,666	3,497 – 6,501	0.16	0.05
2010	1-3	M(t)	5,418	4,049 – 7,549	0.16	0.05
2010	1-3	M(o)	5,466	4,082 – 7,614	0.16	0.05

Table C4. Riverwide (RM’s 166.6 – 2.9) razorback sucker population estimate, 2010. CI represents the profile likelihood interval. CV represents the coefficient of variation and p-hat represents the probability of capture.

YEAR	PASSES	MODEL	ESTIMATE	CI	CV	p-hat
2009	1-3	M(t)	2,047	1,063 – 5,000	0.38	0.04
2010	1-3	M(o)	3,021	2,007 – 4,940	0.23	0.04
2010	1-3	M(t)	2,928	1,952 – 4,796	0.23	0.04