NONNATIVE SPECIES MONITORING AND CONTROL IN THE UPPER/MIDDLE SAN JUAN RIVER: 2009

FINAL REPORT

PREPARED FOR:

SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM

PREPARED BY:

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

U.S. FISH AND WILDLIFE SERVICE

NEW MEXICO FISH AND WILDLIFE CONSERVATION OFFICE

3800 COMMONS N.E.

ALBUQUERQUE, NM 87109

San Juan River Basin Recovery Implementation Program

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SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM

BIOLOGY COMMITTEE

09 JUNE 2010

EXECUTIVE SUMMARY

1. A total of 37,735 channel catfish and 970 common carp were removed from river miles (RM) 166.6 – 52.9 in 841.74 hours of electrofishing.

2. Channel catfish CPUE from PNM Weir to Hogback Diversion was similar to CPUE in 2008 but was significantly ($p < 0.05$) lower than values observed from 2001-2005.

3. Channel catfish CPUE from Hogback Diversion to Shiprock Bridge was significantly ($p < 0.05$) higher than CPUE in 2008 but was lower ($p < 0.05$) than values observed from 2003-2004.

4. Increased abundance of juvenile fish was observed in each of the uppermost removal sections and was attributed to upstream immigration from areas of higher abundance.

5. Young of year and juvenile channel catfish CPUE was significantly ($p < 0.05$) higher downstream of RM 120.0 and the Mancos River confluence (RM 122.5) than CPUE upstream.

6. An 86% reduction in channel catfish CPUE from PNM to Hogback Diversion (2001 – 2009), and a 64% reduction from Hogback Diversion to Shiprock Bridge (2003 -2009) were observed.

7. Common carp collections were infrequent throughout the study area.

8. Significant changes in long term trends of native sucker abundance and condition factor, as a response to intensive nonnative fish removal, were not observed.

9. Majority of razorback sucker captures occurred within 10 RM’s of the stocking location at RM 158.6.

10. The highest number of Colorado pikeminnow recaptures and CPUE occurred near the stocking location at RM 134.9.

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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* was identified as a detriment to the recovery of Colorado pikeminnow *Ptychocheilus lucius* and razorback sucker *Xyrauchen texanus* (USFW 2002a and 2002b) and their control was specifically 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 (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 location 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 2009 marked the ninth 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, 2008), efforts were expanded to include intensive removal from Shiprock Bridge to Mexican Hat, UT (RM 147.9 – 52.9). In 2009, 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.

STUDY AREA

Intensive nonnative removal efforts in 2009 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.

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.

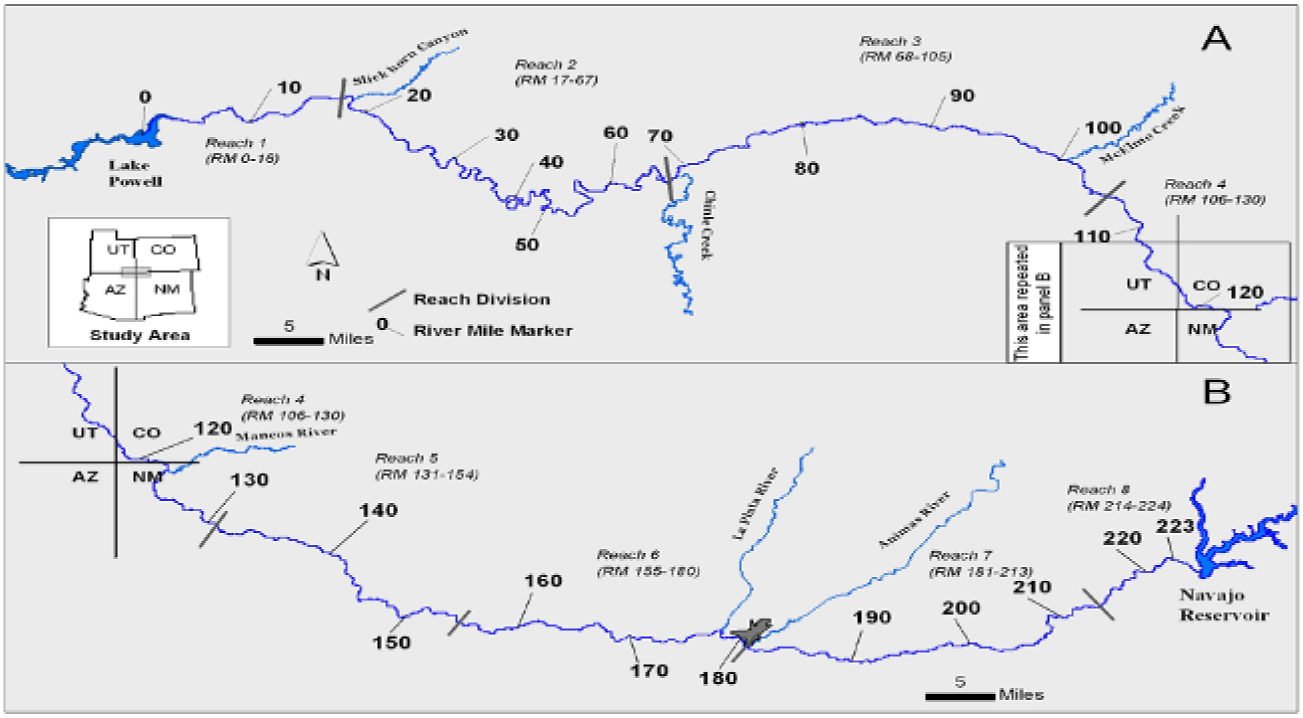

Figure 1. Map of study area – map provided by UNM MSB

A representative sub-sample of each species (blind grab) were measured (nearest 1 mm) for total (TL) and standard lengths (SL) 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 ≥ 150 mm TL, a 134.2 kHz PIT tag 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 (± 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. Data from annual sub-adult and adult fish community monitoring, conducted by USFWS – Colorado River Project, was analyzed to evaluate native fish response specific to intensive nonnative removal.

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 254 channel catfish and 56 common carp were collected during four trips (March to October) and 68.59 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*, smallmouth bass *Micropterus dolomeiu,* 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 < 2.0 fish/hour during March and June trips (Figure 2). Catch rates in August increased to 9.9 fish/hour (ANOVA; $F_{(3, 44)} = 23.340$; $p < 0.001$). Channel catfish CPUE decreased to 0.12 fish/hour in November and was not statistically different than the March catch. Channel catfish CPUE for all trips and all life stages combined was 3.0 fish/hour (Figure 3).

Channel catfish CPUE in 2009 was significantly lower than CPUE from 2001-2005 (ANOVA; $F_{(8, 486)} = 9.719$; $p < 0.05$). Catch rates for all life stages combined were at the lowest level (3.0 fish/hour) observed among 2001-2009 comparisons (Figure 3). Juvenile CPUE was <1.0 fish in 2009 and was not statistically different to CPUE in 2006, 2007 and 2008. Adult channel catfish comprised the majority of the catch in 2009 and CPUE was significantly lower

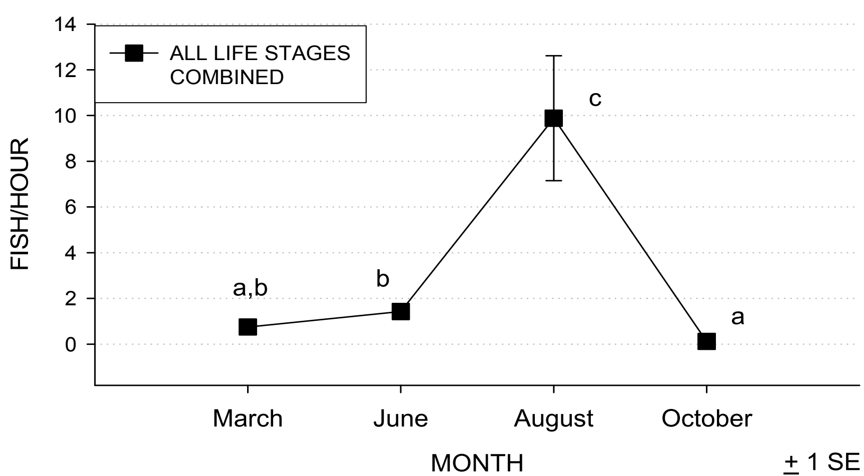

Figure 2. Channel catfish CPUE (fish/hour) by trip within the PNM Weir to Hogback Diversion Section; 2009. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). The same letter indictes that significant differences did not exist and different letters indicate that significant differences were detected among comparisons.

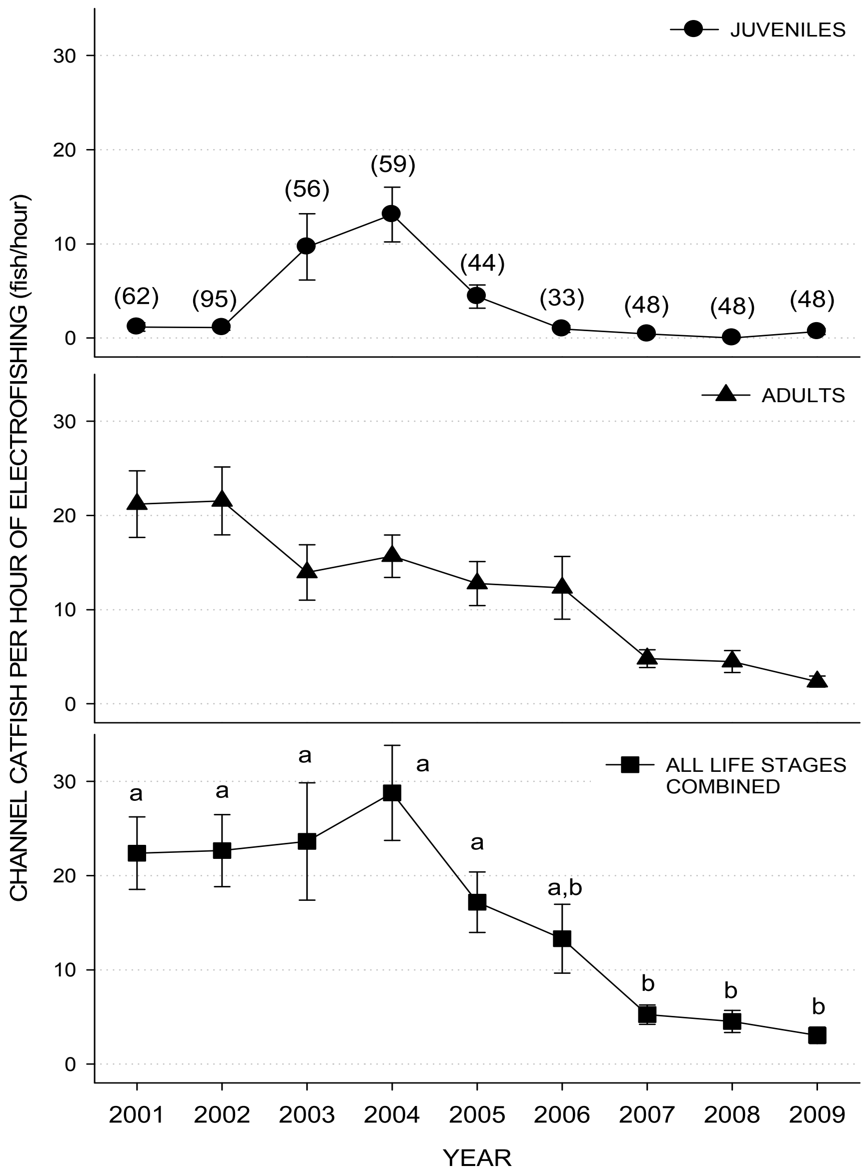

Figure 3. Channel catfish catch per unit effort (CPUE; fish/hour) by year, PNM Weir to Hogback Diversion; 2001-2008. Error bars represent ± 1 SE. Letters represent comparisons among years (Nemenyi post-hoc). The same letter indicates that significant differences did not exist and different letters indicate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

than CPUE from 2001-2005 (ANOVA; $F_{(8, 486)} = 9.593$; $p < 0.05$). Channel catfish CPUE in this section was reduced by 86% from 2001 to 2009 (Appendix B).

Mean total length (TL) of channel catfish in 2009 was 428 mm (SE ± 6.0) and represented the highest value observed during the study period (Figure 4). Measured lengths ranged from 198 to 598 mm TL (median = 445 mm). The number of channel catfish measured in 2009 was greatly reduced from 2001 (n = 3,954 in 2001; n = 198 in 2009) and was

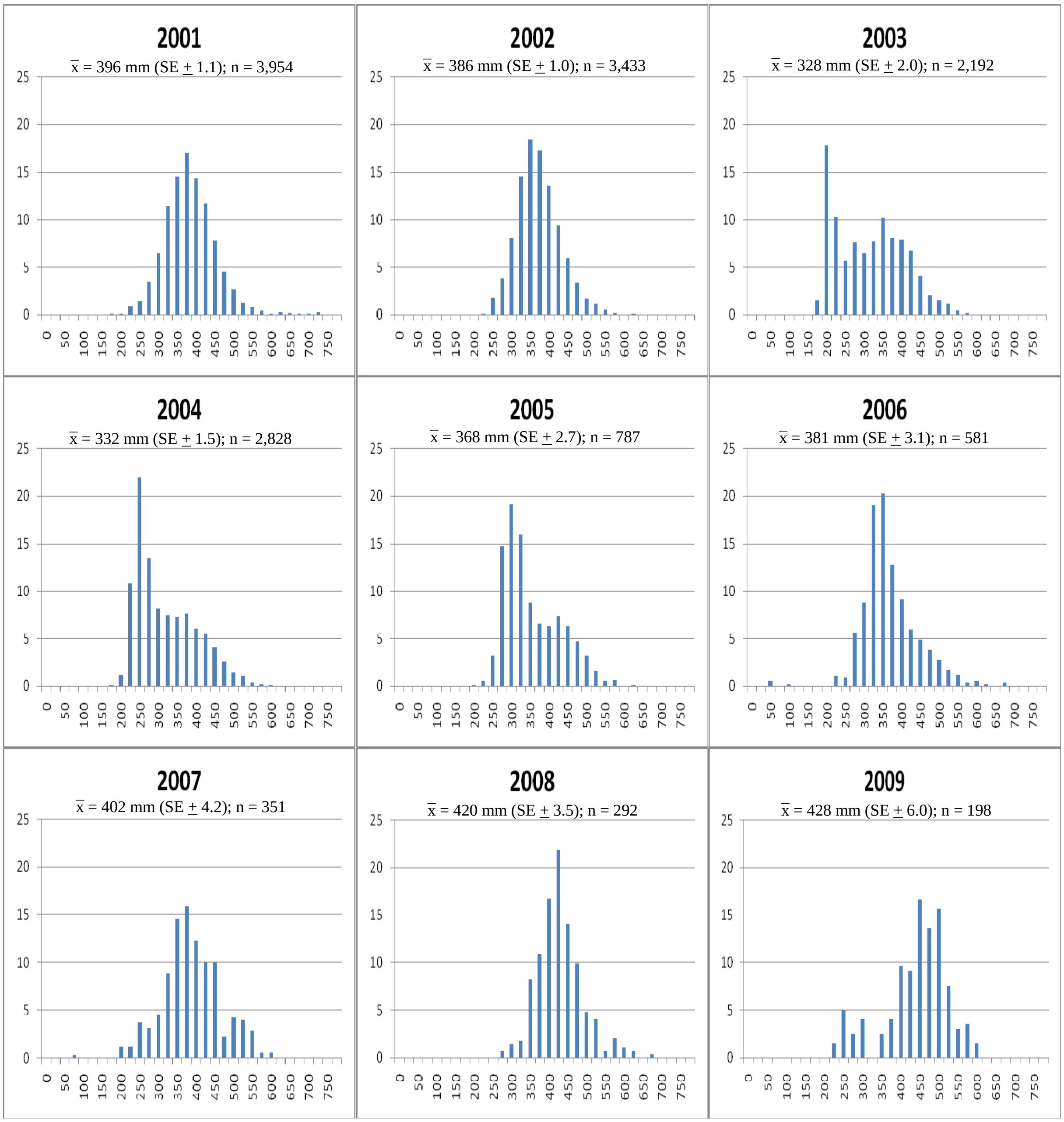

Figure 4. Length frequency histograms for channel catfish collected from PNM Weir to Hogback Diversion; 2001-2009. The y-axis represents percent (%) of catch and the x-axis represents total length.

representative of the overall reduced abundance observed since 2001. After observing the lowest mean TL (328 mm TL, SE ± 1.5) of the study period in 2003, mean TL increased in each of the past six years (2004-2009).

COMMON CARP

Common carp CPUE varied little among trips in 2009 and was < 2.0 fish/hour for each of the four trips (Figure 5). The highest value for CPUE was in March and varied between 0.2 and 1.1 fish/hour during the remaining trips. The four trip mean CPUE in 2009 was 0.8 fish/hour (Figure 6).

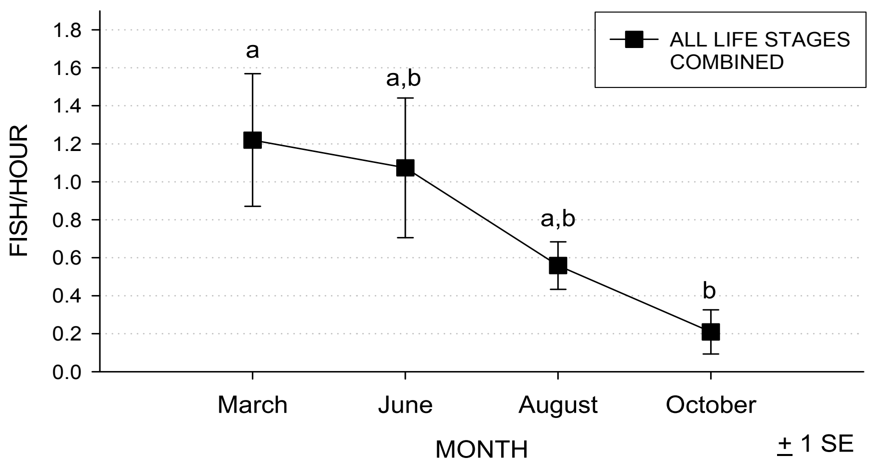

Figure 5. Common carp CPUE (fish/hour) by trip within the PNM Weir to Hogback Diversion Section; 2009. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons.

Comparison of common carp CPUE among years showed significant declines since 2001 resulting in the lowest CPUE since intensive nonnative removal began (ANOVA; $F_{(8, 486)}$= 50.200; p <0.001). Common carp CPUE in 2009 was not statistically different from values observed in 2008 but was significantly lower than all previous years (Figure 6). Common carp were collected infrequently in 2009 from PNM Weir to Hogback Diversion and annual CPUE has been < 5.0 fish/hour since 2004.

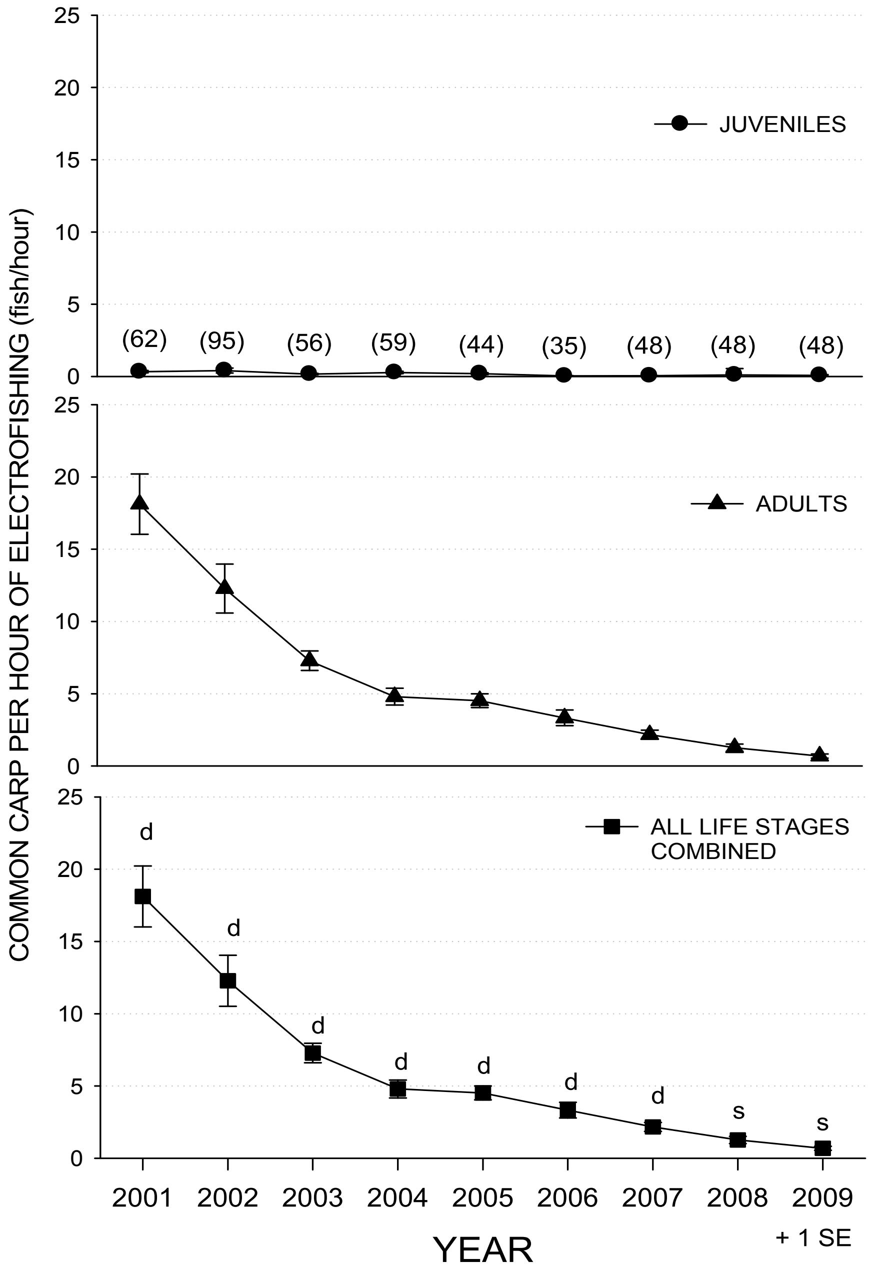

Figure 6. Common carp catch per unit effort (CPUE; fish/hour) by year, PNM Weir to Hogback Diversion; 2001-2009. Error bars represent ± 1 SE. Letters represent comparisons among years (Nemenyi post-hoc. Letter above data points represent statistical comparisons of that individual year to 2008. A “d”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

HOGBACK DIVERSION TO SHIPROCK BRIDGE (RM 158.8 – 147.9)

A total of 2,338 channel catfish and 144 common carp were collected during four trips (April to November) and 117.1 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 and bluegill. No striped bass or walleye were collected or observed. A total of two roundtail chub *Gila robusta* were collected.

CHANNEL CATFISH

Channel catfish CPUE varied by trip in 2009 and ranged from 10.7 to 47.2 fish/hour (Figure 7). Channel catfish CPUE during the August trip was significantly higher than all other trips (ANOVA; $F_{(3,136)} = 35.430$, $p < 0.001$). Over 63% (n = 1,474) of all channel catfish

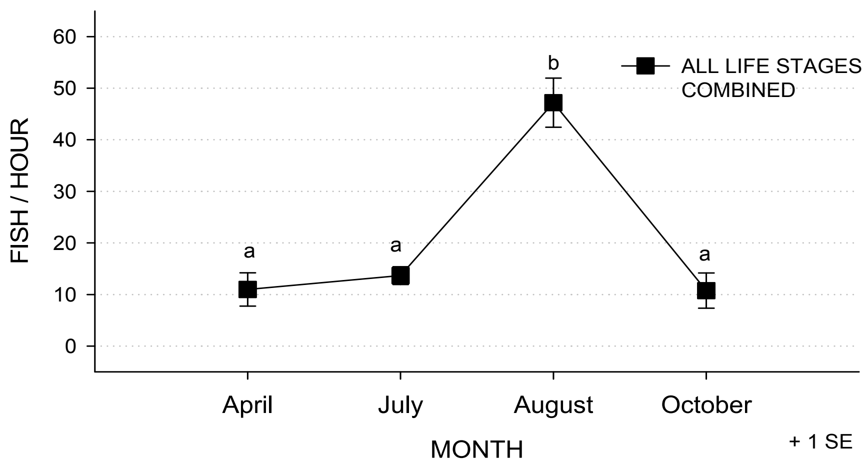

Figure 7. Channel catfish CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2009. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons.

removed from this Section were collected during the August trip. Catch rates decreased to 10.7 fish/hour during the October trip (ANOVA; $F_{(3, 136)} = 35.430$; $p < 0.001$). The four trip mean CPUE in 2009 was 20.8 fish/hour (Figure 8).

Channel catfish CPUE declined from 57.7 to 20.8 fish/hour from 2003 to 2009 (ANOVA; $F_{(6, 680)} = 51.538$; $p < 0.001$) (Figure 8). Channel catfish CPUE in 2009 was significantly higher than CPUE in 2008 but was not different than values observed from 2005 to 2007. Increased catch rates, all life stages combined, in 2009 were attributed to increased juvenile channel

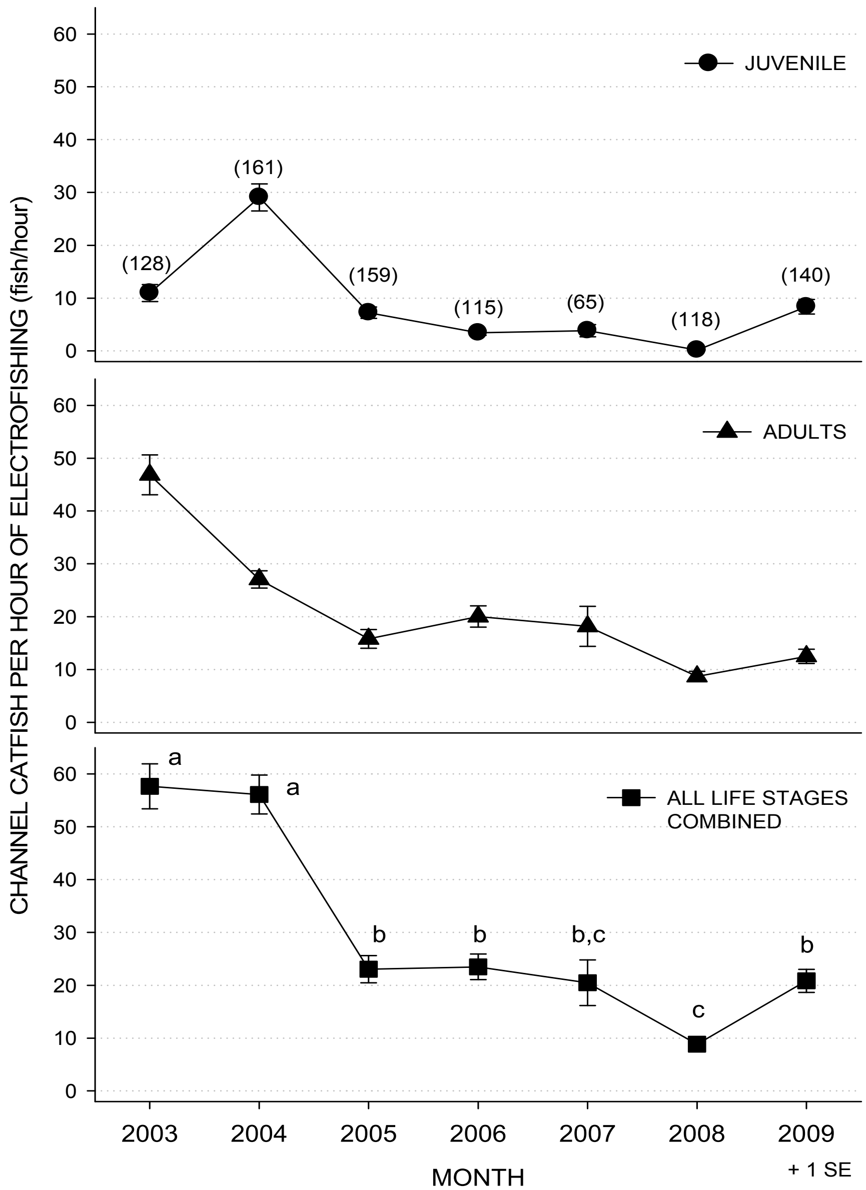

Figure 8. Channel catfish catch per unit effort (CPUE; fish/hour) by year, Hogback Diversion to Shiprock Bridge; 2003-2009. Error bars represent ± 1 SE. Letters represent comparisons among years (Nemenyi post-hoc. The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons. Sample size presented parenthetically.

catfish CPUE. Juvenile CPUE increased from 0.2 fish/hour in 2008 to 8.4 fish/hour in 2009 (ANOVA; $F_{(6, 680)} = 50.861$; $p < 0.001$) Channel catfish CPUE in this Section has been reduced by 64% from 2003 to 2009 (Appendix B).

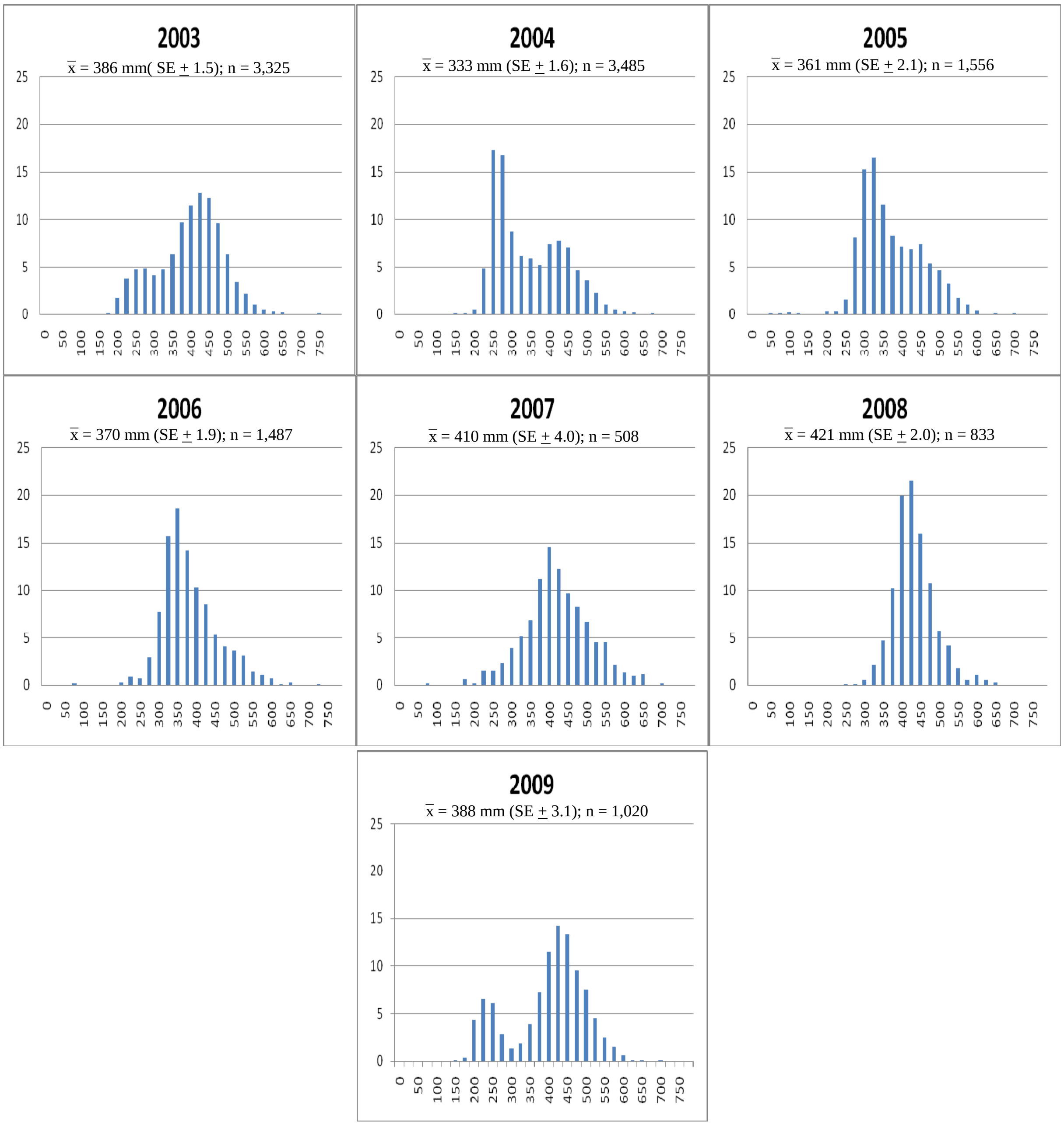

Figure 9. Length frequency histograms for channel catfish collected from Hogback Diversion to Shiprock Bridge; 2003-2009. The y-axis represents percent (%) of catch and the x-axis represents total length.

Mean total length (TL) of channel catfish in 2009 was 388 mm (SE ± 3.1) (Figure 9). Measured lengths ranged from 132 to 696 mm TL (median = 410 mm). After observing the highest mean TL (421 mm TL; SE ± 2.0) of the study period in 2008, mean TL decreased in 2009.

COMMON CARP

Common carp CPUE varied little among trips in 2009 and was < 2.0 fish/hour for each of the four trips (Figure 10). Common carp CPUE varied between 1.0 and 1.5 fish/hour during the four trips. The four trip mean CPUE in 2009 was 1.3 fish/hour (Figure 11).

Common carp CPUE in 2009 significantly declined compared to that of 2003 to 2006 resulting in the lowest observed CPUE since intensive nonnative removal began (ANOVA; $F_{(6, 927)} = 142.781$; $p < 0.001$). Common carp CPUE in 2009 was not different than values observed in 2007 and 2008 but was significantly lower than all previous years (Figure 11). Common carp were collected infrequently in 2009 from Hogback Diversion to Shiprock Bridge and annual CPUE has been < 5.0 fish/hour since 2005.

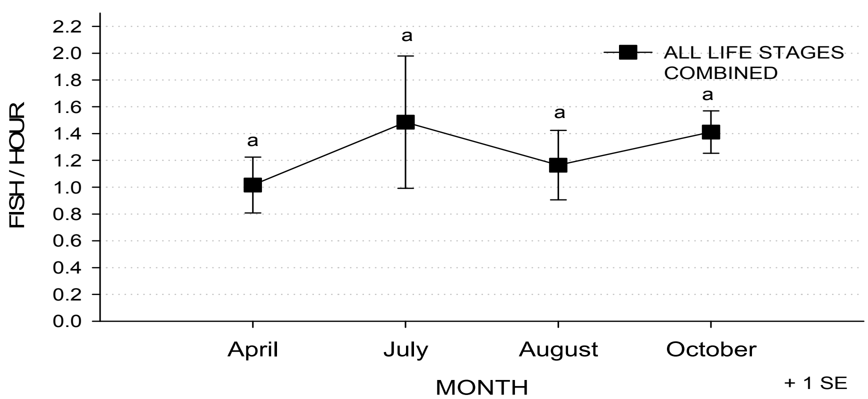

Figure 10. Common carp CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2009. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons.

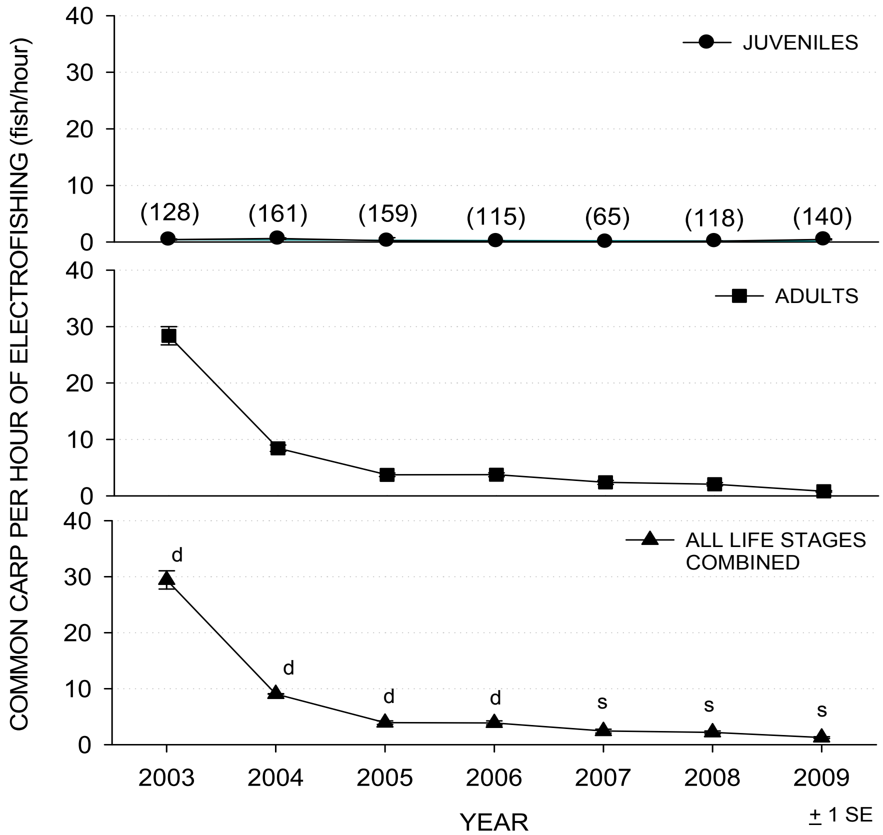

Figure 11. Common carp catch per unit effort (CPUE; fish/hour) by year, Hogback Diversion to Shiprock Bridge; 2003-2009. Error bars represent ± 1 SE. Letters represent comparisons among years (Nemenyi post-hoc. Letter above data points represent statistical comparisons of that individual year to 2008. A "d" means that year was statistically different than 2008 while an "s" means that year was not different from 2008. Sample size presented parenthetically.

SHIPROCK BRIDGE TO MEXICAN HAT (RM 147.9 – 52.9)

Three removal trips (April, July and September) were conducted in 2009 from Shiprock Bridge to Mexican Hat, Utah yielding 21,688 channel catfish and 562 common carp in 516.72 hours of electrofishing. Nonnative fish removal was also conducted in conjunction with fall monitoring in September/October and yielded 13,455 channel catfish and 208 common carp in 139.4 hours of electrofishing. For the year, a total of 35,143 channel catfish and 770 common carp were removed from Shiprock Bridge to Mexican Hat in 656.1 hours of electrofishing (Appendix A-3). 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 and life stages combined was 31.2 fish/hour during the April trip (Figure 12). Catch rates during July and September were significantly higher than April CPUE (ANOVA; $F_{(3, 542)} = 37.720$; $p < 0.001$) . The highest CPUE, 103.8 fish/hour, was during the September/October sampling trip. Mean juvenile catch rates were higher than adult catch rates during each trip (Figure 12). Juvenile CPUE in September/October was significantly higher than all other trips (ANOVA; $F_{(3, 542)} = 20.987$; $p < 0.001$).

Juvenile catch rates increased as sampling proceeded downstream. Catch rates were < 10 fish/hour from RM's 147.9 to 130.0 and peaked at 80 fish/hour from RM's 60.0 to 52.9 (Figure 13). Catch rates significantly increased downstream of RM 122.5, the Mancos River confluence (ANOVA; $F_{(9, 536)} = 42.634$; $p < 0.001$). Additionally, young-of-year catch rates were the highest, 5.3 fish/hour, from RM's 60.0 to 52.9 and the lowest, 0.03 fish/hour, from RM's 147.9 to 140.0.

The four trip mean CPUE, all passes and life stages combined, was 60.29 fish/hour and was significantly higher than 2008 CPUE (Mann-Whitney Test; $Z = -12.974$; $p < 0.001$). Both juvenile and adult channel catfish catch rates in 2009 were significantly ($p < 0.05$) higher than 2008 values. Adult CPUE increased from 14.5 fish/hour to 18.0 fish/hour, and juvenile CPUE increased from 7.6 fish/hour to 40.9 fish/hour, 2008 to 2009 (Figure 14).

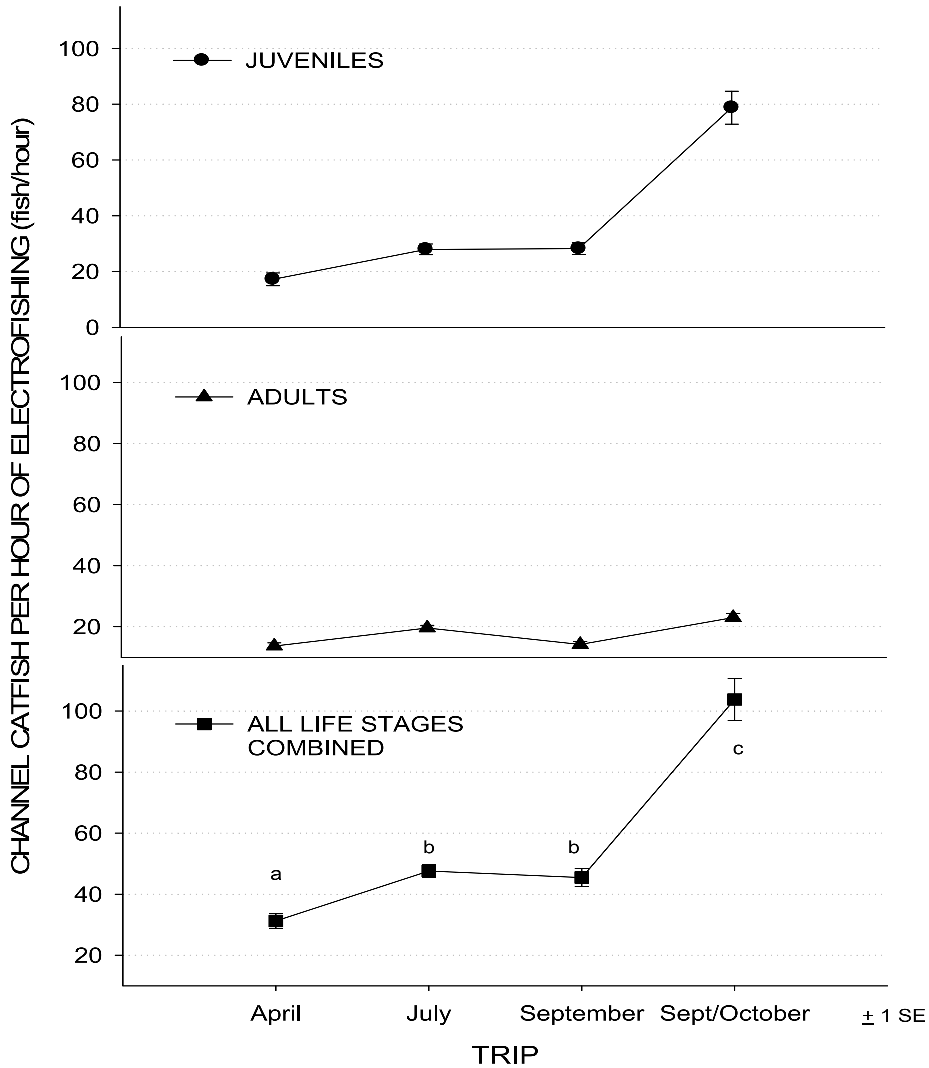

Figure 12. Channel catfish CPUE (fish/hour) by trip from Shiprock Bridge to Mexican Hat; 2009. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). The same letter indicates that significant differences did not exist and different letters indicate that significant differences were detected among comparisons.

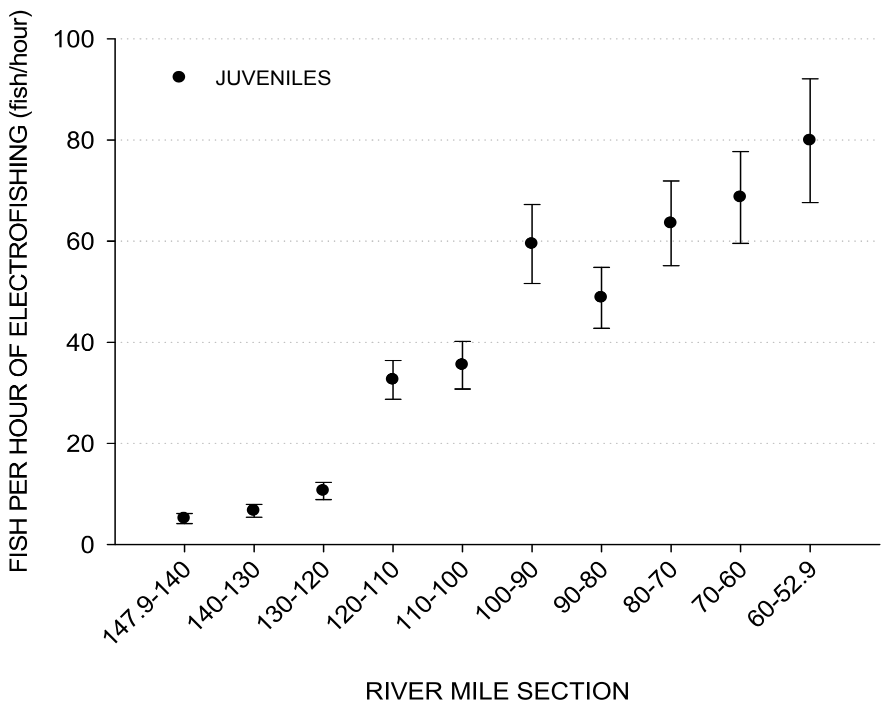

Figure 13. Channel catfish CPUE (fish/hour) by ten river mile segments from Shiprock Bridge to Mexican Hat; 2009. Error bars represent ± 1 SE.

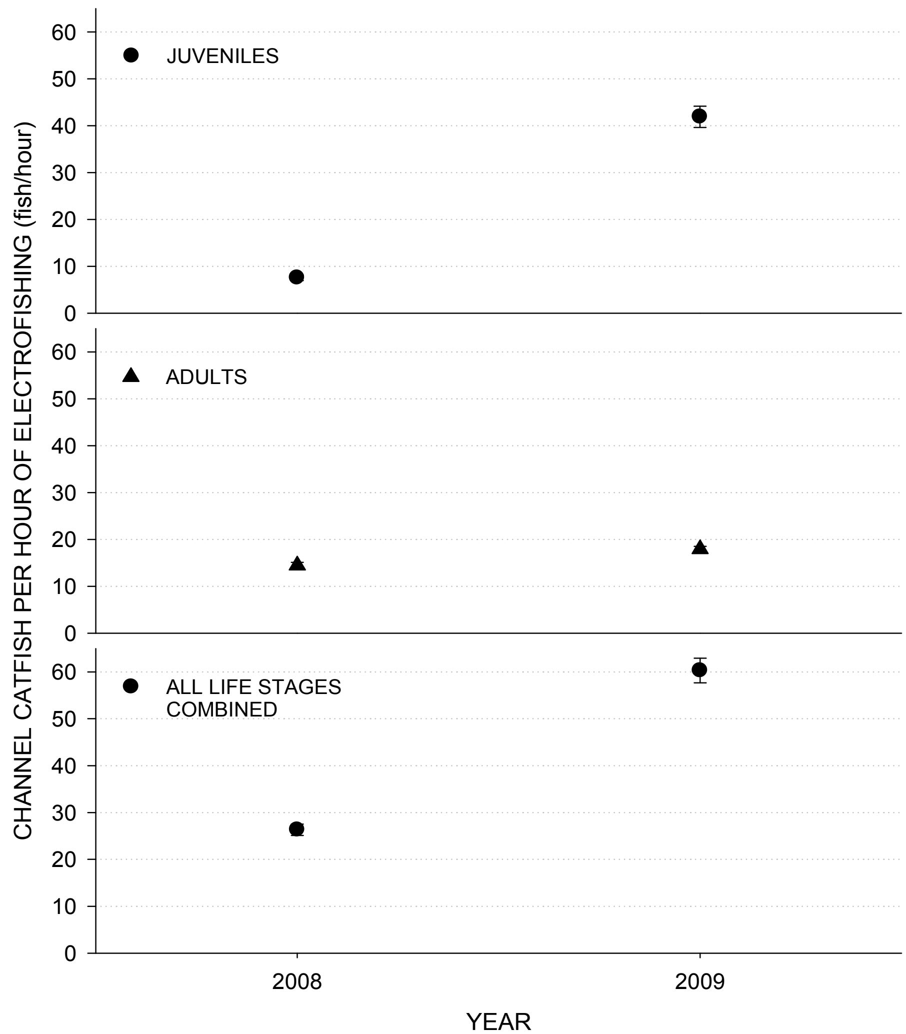

Figure 14. Channel catfish CPUE (fish/hour) from Shiprock Bridge to Mexican Hat; 2008-2009. Error bars represent ± 1 SE.

Channel catfish mean TL in 2009 varied among trips. The largest mean TL was in July (322 mm TL, SE = ± 2.4) (Figure 15). Channel catfish ≤ 300 mm TL comprised 37% of measured fish in both April and July compared to > 50% during September and September/October trips. Fish < 200 mm TL comprised a lower percentage of the catch in July compared to trips in April, September and September/October (Figure 15).

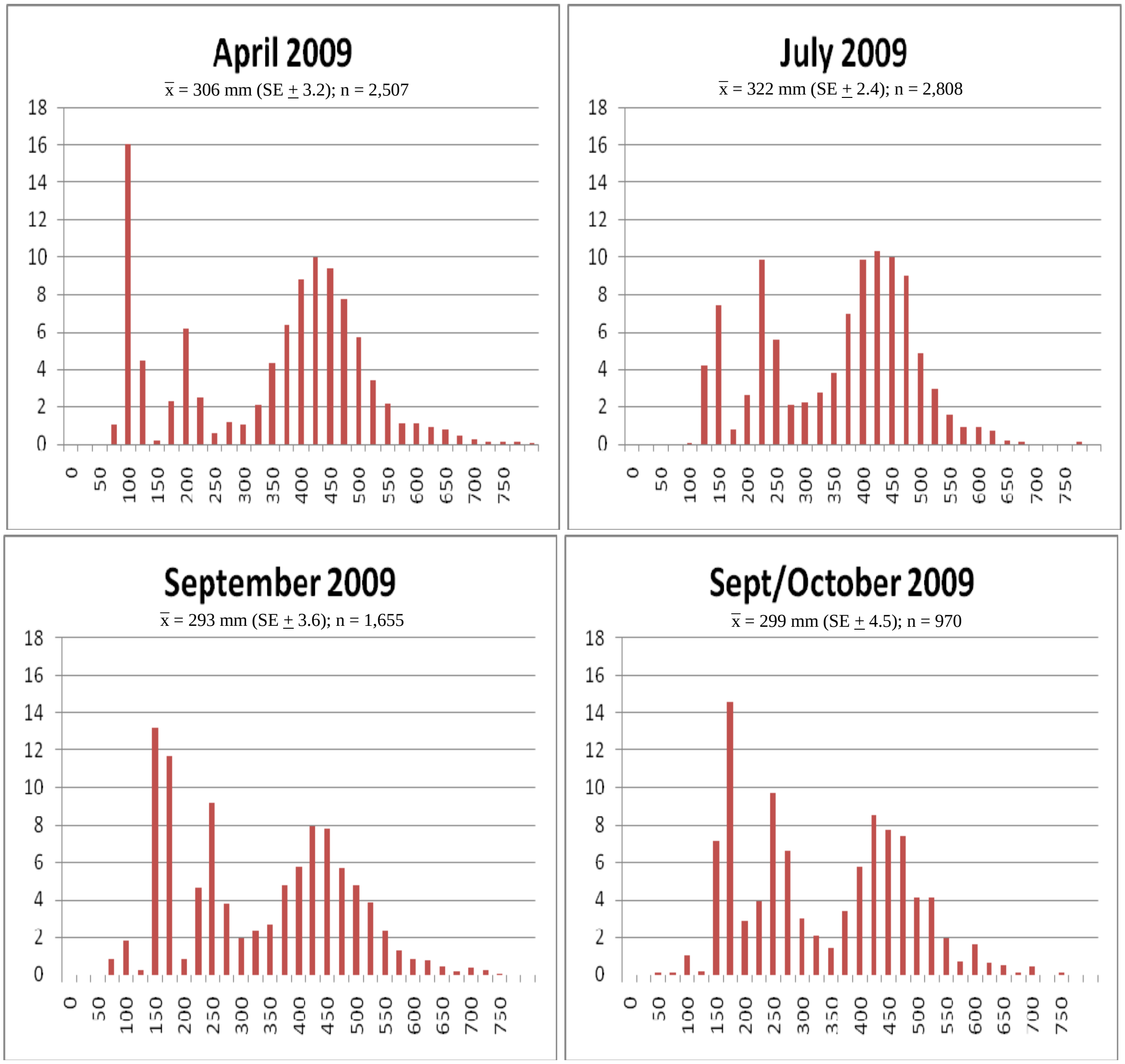

Figure 15. Length frequency histograms by trip for channel catfish collected from Shiprock Bridge to Mexican Hat Utah; 2009. The y-axis represents percent (%) of catch and the x-axis represents total length.

COMMON CARP

Common carp CPUE varied between 0.9 and 1.6 fish/hour in 2009 (Figure 16). The four trip mean CPUE in 2009 was 1.2 fish/hour (Figure 17). Common carp CPUE in 2009 was significantly lower than CPUE in 2008 (Mann-Whitney Test; $Z = -3.812$; $p < 0.001$).

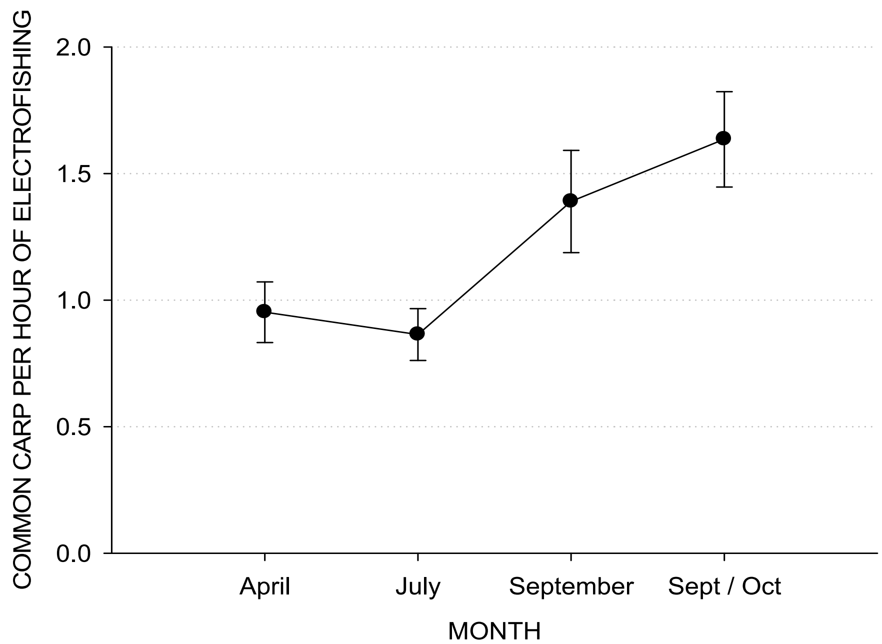

Figure 16. Common carp CPUE (fish/hour of electrofishing) during 2009 nonnative removal trips from Shiprock Bridge to Mexican Hat. Error bars represent ± 1 SE.

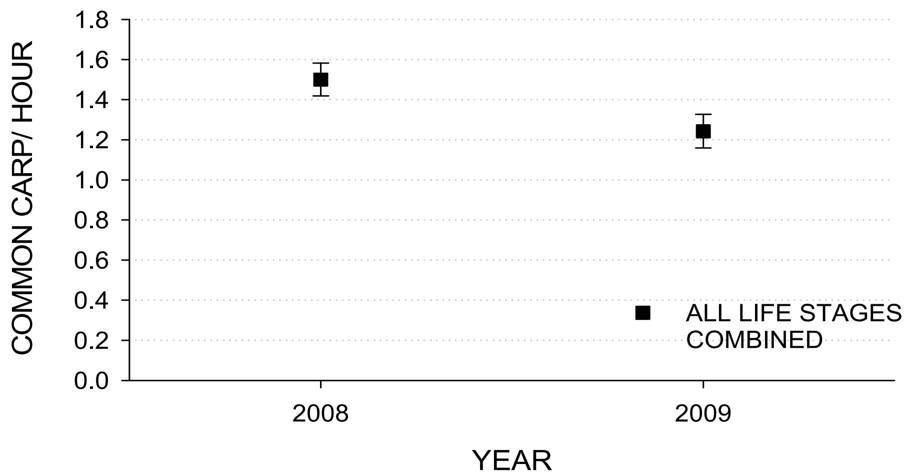

Figure 17. Common carp CPUE (fish/hour of electrofishing) during nonnative removal trips from Shiprock Bridge to Mexican Hat, 2008 and 2009. Error bars represent ± 1 SE.

RARE FISH COLLECTIONS

A total of 760 razorback sucker and 2,272 Colorado pikeminnow were caught during nonnative fish removal trips from PNM Weir to Mexican Hat, Utah. Fish 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 captures. Of these fish, 152 razorback sucker and 123 Colorado pikeminnow were collected from PNM Weir to Hogback Diversion; 370 razorback sucker and 584 Colorado pikeminnow were collected from Hogback Diversion to Shiprock Bridge; and 238 razorback sucker and 1,565 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 2009 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 1997 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; 2009.

Age Class	**N**	**Mean TL(range)**
1997	2	544 (533, 555)
1998	0	n/a
1999	14	492 (443 – 532)
2000	18	481 (422 – 514)
2001	60	480 (416 – 550)
2002	20	460 (421 – 520)
2003	36	490 (430 – 567)
2004	5	455 (430 – 489)
2005	2	403 (360, 445)
2006	167	360 (229 – 503)
2007	56	362 (295 -455)
Unknown	319	444 (223 – 600)

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 18). The highest number and CPUE for razorback sucker were from RM's 158.8 – 150.0 and declined as sampling proceeded downstream. Razorback sucker CPUE by 10 RM segments ranged from 0.2 to 3.3 fish/hour (Figure 18).

Of the 308 razorback sucker that had known stocking information, 31% were recaptured ≤ 1 year post-stocking and 44% were recaptured ≤ 2 years post-stocking (Figure 19). Twenty eight razorback sucker were recaptured ≥ 6 years post-stocking including one individual that was recaptured 9 years (3,291 days) post-stocking (Figure 19).

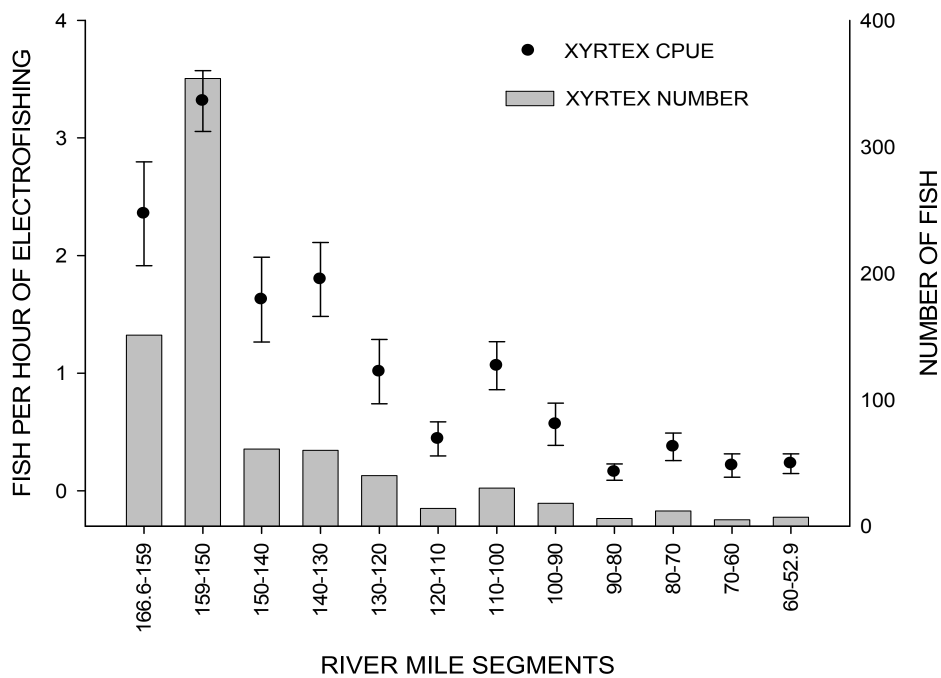

Figure 18. Longitudinal distribution of razorback sucker encounters during nonnative fish removal trips conducted by NMFWCO, 2009. Vertical bars represent number of fish captured and dots represents razorback sucker CPUE (fish/hour). Error bars represent ± 1 SE.

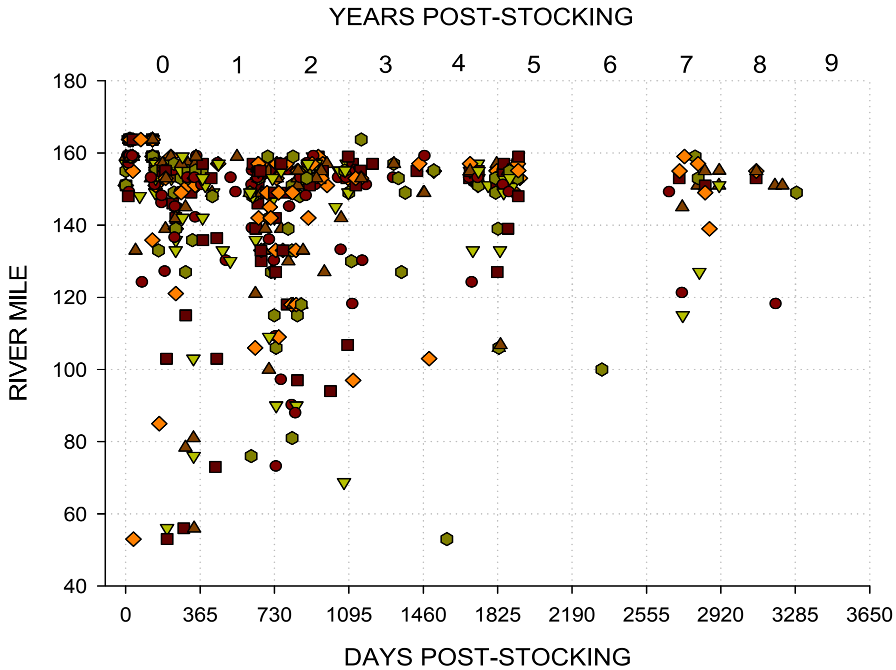

Figure 19. Days and years post-stocking verses river mile for razorback sucker captures during nonnative fish removal trips conducted by NMFWCO; 2008. Different symbols and colors represent individual captures.

Razorback sucker collected in 2008 ranged from 223 – 600 mm TL (Figure 20). The majority of fish (95%) were ≥ 300 mm TL although 11 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 2009. The mean TL for all razorback sucker was 422 mm TL.

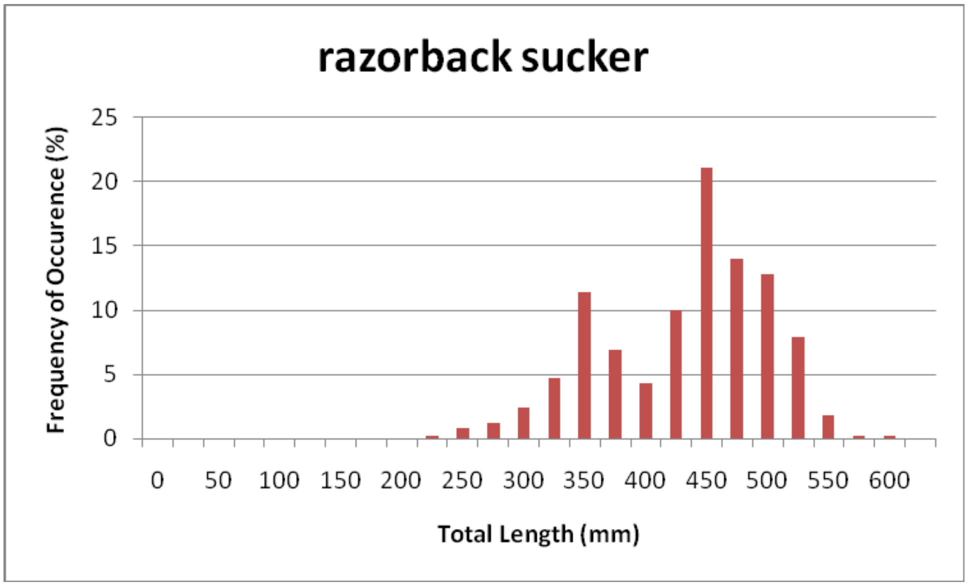

Figure 20. Length frequency histograms for razorback sucker collected during intensive nonnative fish removal trips; 2009. The y-axis represents percent (%) of catch and the x-axis represents total length.

COLORADO PIKEMINNOW

All Colorado pikeminnow collected during intensive nonnative fish removal trips in 2009 were considered to be stocked fish. Colorado pikeminnow were distributed throughout the study area with the majority (69%; n = 1,558) of encounters occurring from RM 166.6 – 120.0 (Figure 21). Colorado pikeminnow CPUE by 10 RM segments ranged from 1.5 to 12.0 fish/hour with the highest mean CPUE occurring from RM's 140-130. These high catch rates corresponded with proximity to recent 'soft' release locations (fish acclimatized to riverine conditions for up to 24 hours prior to release) for Colorado pikeminnow at RM's 134.9 and 133.5.

Colorado pikeminnow recaptures, with associated PIT tag data, occurred one to 1,202 days post stocking (Figure 22). The majority of these fish (88%; n = 625) were captured < 365 days post stocking. A total of 693 fish (98%) were recaptured < 730 days post stocking. A total of 749 Colorado pikeminnow were collected and implanted with a PIT tag during nonnative removal trips. These fish ranged in size from 148 – 437 mm TL and were composed of various year classes (2006 n = 14; 2007 n = 232; 2008 n = 503).

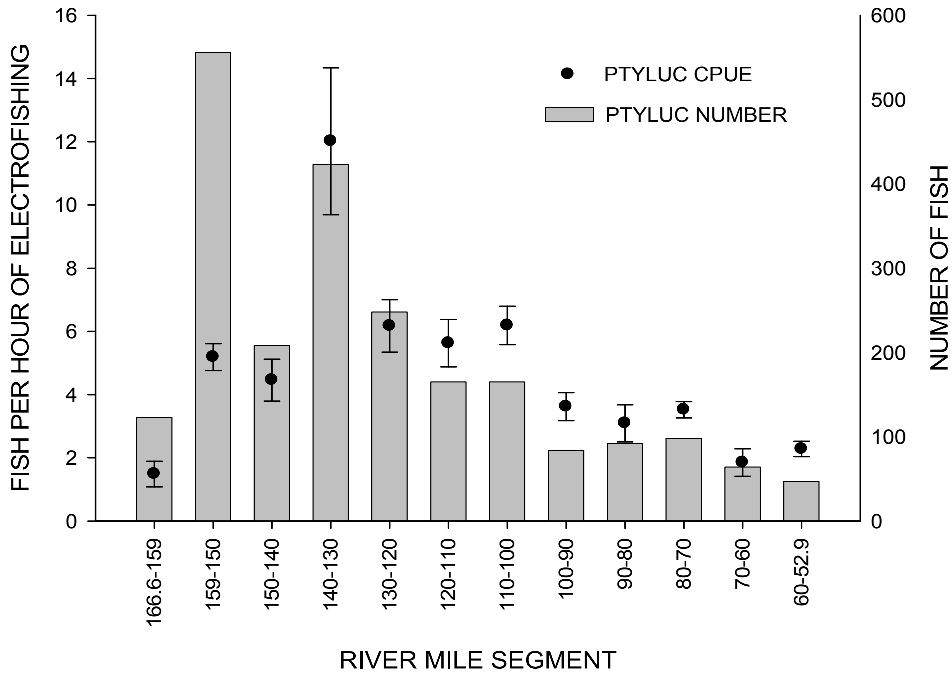

Figure 21. Longitudinal distribution of Colorado pikeminnow encounters during nonnative fish removal trips conducted by NMFWCO, 2009. Vertical bars represent number of fish encountered and scatter plot represents razorback sucker CPUE (fish/hour). Error bars represent ± 1 SE.

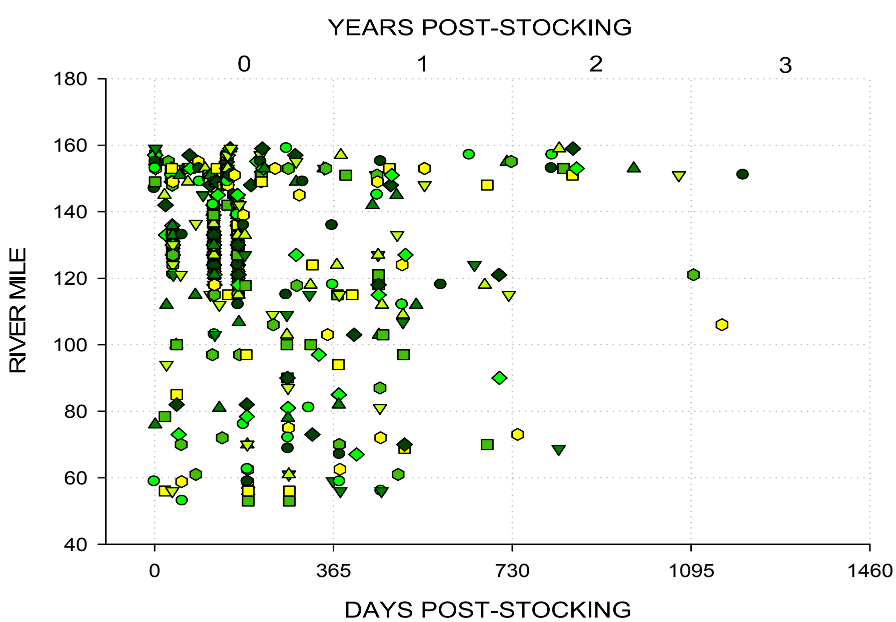

Figure 22. Days and years post-stocking verses river mile for Colorado pikeminnow encounters during nonnative fish removal trips conducted by NMFWCO; 2009. Different symbols and colors represent individual capture encounters.

Colorado pikeminnow collected in 2009 ranged from 65 – 616 mm TL (Figure 23). Fish ≤ 150 mm TL comprised 38% (n = 357) of the catch while Colorado pikeminnow ≥ 350 mm TL comprised 3% (n = 11) of the catch. Thirty-four individual fish < 100 mm TL were collected in 2009 and were considered to be small age-1 fish stocked as age-0 fish at RM 166.6 in the fall of 2008. Mean TL for Colorado pikeminnow collected in 2009 was 209 mm (Figure 23).

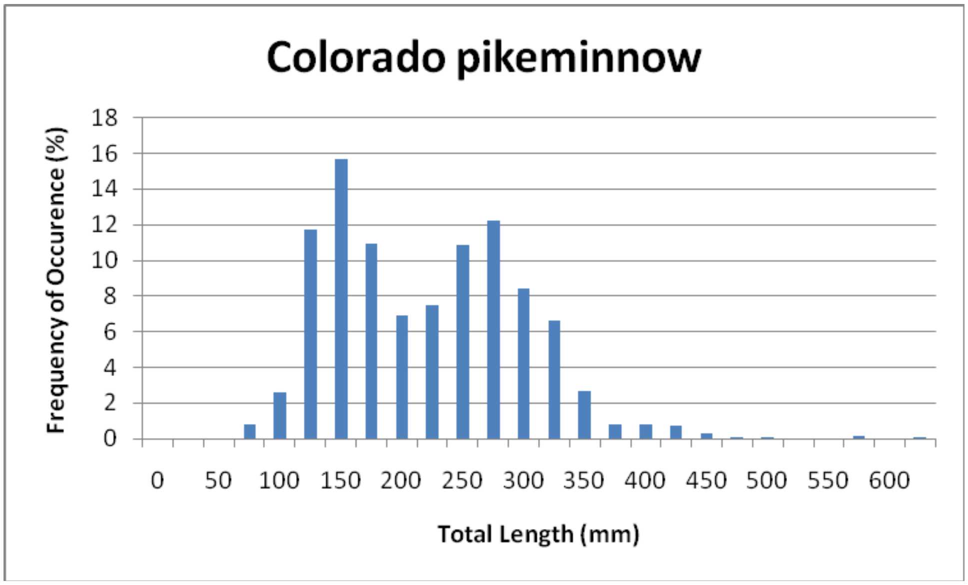

Figure 23. Length frequency histograms for Colorado pikeminnow collected during intensive nonnative fish removal trips; 2009. The y-axis represents percent (%) of catch and the x-axis represents total length.

NATIVE FISH RESPONSE TO INTENSIVE REMOVAL

Juvenile flannelmouth and bluehead sucker CPUE was highly variable and did not show a consistent response to nonnative removal efforts from 1998-2009 (Figure 24). Juvenile flannelmouth sucker CPUE in 2009 was significantly higher (ANOVA; $F_{(11, 285)} = 10.783$; $p < 0.001$) than that in 1998 but was similar to all other years except 2003. Juvenile bluehead sucker CPUE in 2009 was not different than CPUE values prior to the initiation of intensive nonnative fish removal (1998-2000) but was significantly higher than values observed in 2001 (ANOVA; $F_{(11, 285)} = 6.620$; $p = 0.02$).

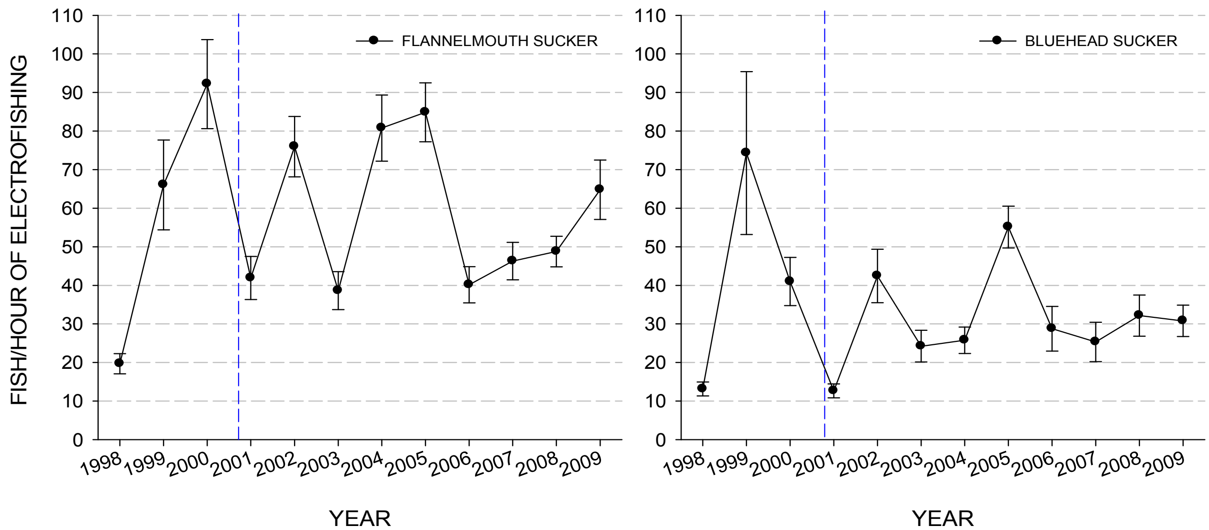

Figure 24. Flannelmouth and bluehead sucker CPUE (fish/hour) from PNM Weir to Shiprock Bridge, 1998-2009. Error bars represent ± 1 SE. Blue vertical lines represent the beginning of intensive nonnative removal in 2001.

Similar to CPUE, condition factor (Fulton-type; $K_f = \text{Weight/Length}^3 * 100,000$) of juvenile flannelmouth and bluehead suckers did not show a consistent response to nonnative removal efforts (Figure 25). Flannelmouth sucker condition factor in 2009 was similar to that from 1998 and 2001 and exhibited variability throughout the study period (Figure 25). Condition factor in 2009 was significantly higher than values from 2005 to 2008 (ANOVA; $F_{(11, 2930)} = 12.883$; $p \leq 0.05$). Bluehead sucker condition factor in 2009 was similar to 1998 but was significantly higher than condition factor in 2000 which was years prior to intensive nonnative removal (ANOVA; $F_{(10, 1442)} = 39.533$; $p < 0.001$). Condition factor in 2009 was significantly higher than that in 2006 and exhibited a general upward trend in each of the last three years (Figure 25).

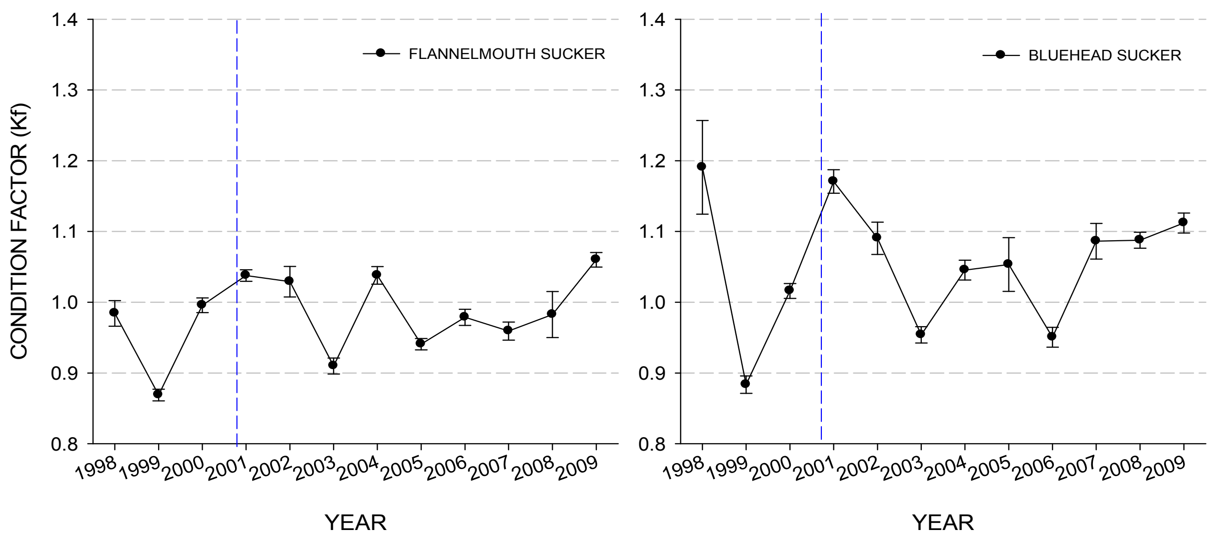

Figure 25. Flannelmouth and bluehead sucker condition factor (K_f; Weight/Length^3 * 100,000) from PNM Weir to Shiprock Bridge, 1998-2009. Error bars represent ± 1 SE. Blue vertical lines represent the beginning of intensive nonnative removal.

DISCUSSION

Channel catfish abundance from PNM Weir to Hogback Diversion in 2009 was lower than abundance metrics at the initiation of intensive nonnative removal in 2001. Declines during the past three 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 this reach and 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 (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^3/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^3/second (Appendix C). Regardless of the reason, initial shifts towards smaller fish may be 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 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 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 the two uppermost intensive removal sections with the majority of fish collected in 2009 comprised of the 2002/2003 cohorts and ranging from 400-475 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.

Of interesting note was the increased abundance of juvenile channel catfish in the two uppermost removal sections in 2009. Although these increases may be an indication of successful reproductive years within these sections in 2007 and 2008, data collected from a mark recapture conducted by Utah Division of Wildlife Resources (UDWR) suggest that upstream movement and immigration into these sections was the likely cause. In March 2009, UDWR tagged 701 channel catfish in the lower canyon (Darek Elverud personal communication). Of these fish, 21 were recaptured during nonnative removal efforts and adult monitoring. These 21 fish moved on average 52.9 RM's from their original tagging river mile. Four of these fish (Mean TL = 263 mm) moved an average of 114 (range = 94.2 – 135.0) river miles upstream in 4 to 5 months. These data, albeit limited numbers, suggest that juvenile channel catfish in the San Juan River exhibit widespread upstream movement and can potentially reoccupy removal sections that have been intensively managed for nonnative fishes. Therefore, we feel that it is critical to maintain or even increase intensive nonnative removal efforts from Shiprock Bridge to Mexican Hat in order to remove these juvenile fish prior to sexual maturity. If removal of the majority of these juvenile fishes is possible, we anticipate this management action to result in a reduction in overall channel catfish CPUE in 3 to 5 years. Focusing removal efforts in areas of known high juvenile fish abundance may shorten the anticipated response time. If this can be accomplished, periodic "maintenance" trips may be utilized to keep the channel catfish population 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 were common carp are collected infrequently across all studies (Elverud 2009 and Ryden 2009). Common carp were the sixth most abundant fish collected in 2008 sub-adult and adult fish community monitoring and comprised only 1.7% of the total catch (Ryden 2009).

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 our 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.

With recent flow conditions in the San Juan River lacking overbank flow, available low flow or slackwater, spawing 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, 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. 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 2009 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 $\geq$ 6 times exhibited little movement between captures (± 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 at collecting individual fish.

Colorado pikeminnow recaptures were widely distributed in 2009. Although 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 tracking radio implanted adults to possible spawning bars and timing sampling trips to collect these adult fish.

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, 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 254 channel catfish and 56 common carp were collected during four removal trips in 2009.
- Channel catfish CPUE in 2009 was lower than CPUE from 2001-2005.
- Channel catfish mean TL was larger than that observed in 2001 but overall abundance of large adult channel catfish has been reduced.
- Common carp CPUE in 2009 was similar to 2008 but significantly ($p < 0.05$) lower than 2001 to 2007.
- Common carp were uncommon in collections.

HOGBACK DIVERSION TO SHIPROCK BRIDGE (RM 158.8 – 147.9)

- A total of 2,338 channel catfish and 144 common carp were collected during four removal trips in 2009.
- Channel catfish CPUE in 2009 increased compared to that in 2008 and was similar to values observed from 2005 to 2007. Catch rates in 2009 were significantly ($p < 0.05$) lower than values observed in 2003 and 2004.
- Channel catfish mean TL was lower in 2009 than in 2008 and may be attributed to upstream immigration by juvenile channel catfish from areas of higher abundance.
- Common carp CPUE in 2009 was similar to that in 2008 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 35,143 channel catfish and 770 common carp were removed during four (8 passes) removal trips in 2009.
- Juvenile channel catfish CPUE by trip in 2009 ranged from 17 to 79 fish/hour of electrofishing.
- Juvenile channel catfish CPUE significantly ($p < 0.05$) increased downstream of river mile 120.

- 2009 channel catfish CPUE, all life stages combined, was more than twice as high as CPUE values observed in 2008 (60 and 26 fish/hour, respectively).
- Common carp CPUE was < 2 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 760 razorback sucker and 2,272 Colorado pikeminnow were encountered during 2009 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.
- Colorado pikeminnow CPUE and numbers were the highest from RM 166.6 – 120.0 with large collections occurring near the 'soft' release stocking sites at RM's 134.9 and 133.5.
- Sixteen individual Colorado pikeminnow $\geq$ 400 mm TL were collected in 2009.

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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, 2009. 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)	Mean Clarity (mm)	Effort (hours)	*Ptyluc*	*Xyrtex*	*Ictpun*	*Cypcar*	*Micsal*	*Ameiurus spp*	*Saltru*
March 24-26	1,083	186	15.35	8	76	13	20	0	0	47
June 23-25	1,270	> 600	16.61	31	5	26	20	7	1	45
August 18-20	502	643	20.37	80	8	213	12	130	2	32
October 22-24	672	123	16.26	4	63	2	4	12	0	37
Totals			**68.59**	**123**	**152**	**254**	**56**	**149**	**3**	**161**

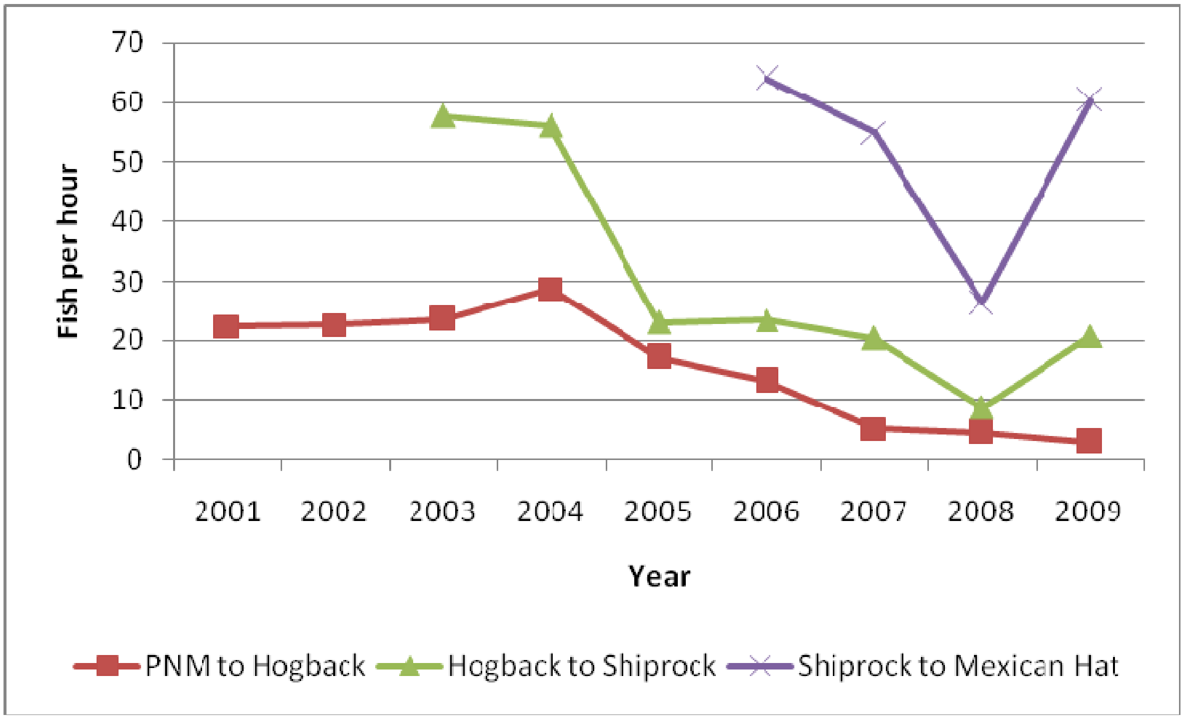
Appendix A-2. Mean discharge, mean clarity, effort and total count of major species collected during intensive non-native removal efforts from Hogback Diversion to Shiprock Bridge, 2009. [1] Mean discharge from USGS gauge #09368000 near Shiprock, New Mexico.

Trip	Discharge[1] (ft^3/sec)	Mean Clarity (mm)	Effort (hours)	*Ptyluc*	*Xyrtex*	*Ictpun*	*Cypcar*	*Micsal*	*Ameiurus* spp	*Saltru*
April 7-9	729	n/a	30.60	44	164	256	32	0	2	24
July 7-9	757	640	26.96	133	55	366	35	5	5	25
August 11-13	679	550	31.38	305	67	1,474	37	85	3	23
October 19-21	712	380	28.12	102	84	242	40	41	2	38
Totals			**117.06**	**584**	**370**	**2,338**	**144**	**131**	**12**	**110**

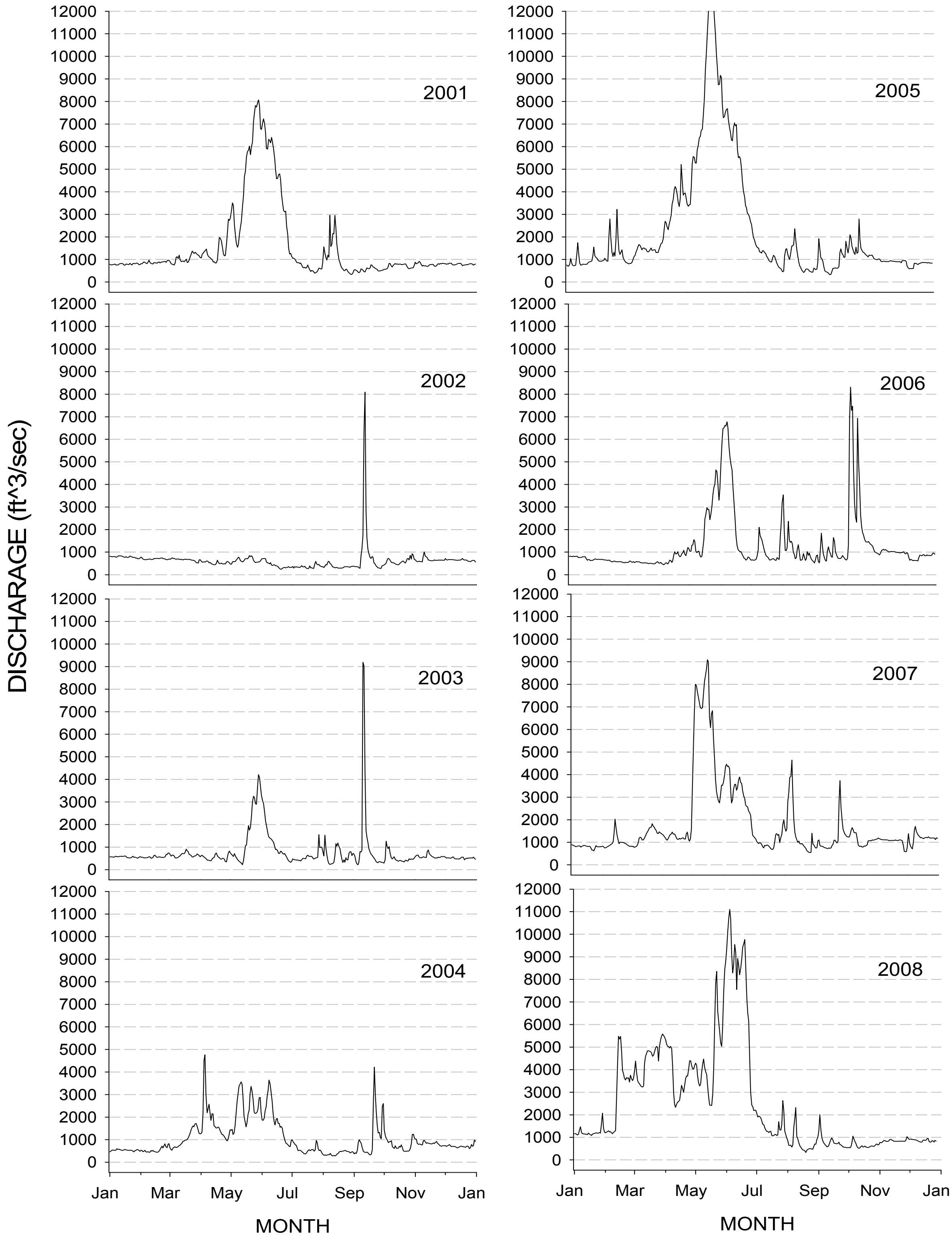
Appendix A-3. Mean discharge, mean clarity, effort and total count of major species collected during intensive non-native removal efforts from Shiprock Bridge to Mexican Hat, Utah; 2009. Endangered fish were not collected by upstream boats (n/a). [1] Mean discharge from USGS gauge #09371010 near Four Corners, Colorado.

Trip	Discharge[1] (ft^3/sec)	Effort (hours)	*Ptyluc*	*Xyrtex*	*Ictpun*	*Cypcar*	*Micsal*	*Ameiurus* spp	*Saltru*
April 22 –30	1,666								
Downstream boats		81.16	327	85	2,964	93	1	2	4
Upstream boats		81.91	n/a	n/a	2,121	74	1	5	1
Totals for trip		**163.07**	**327**	**85**	**5,085**	**167**	**2**	**7**	**5**
July 15 – July 23	865/633								
Downstream boats		81.43	433	43	3,901	96	6	7	4
Upstream boats		82.25	n/a	n/a	3,941	49	11	5	0
Totals for trip		**163.68**	**433**	**43**	**7,842**	**145**	**17**	**12**	**4**
September 2-10	516/799								
Downstream boats		96.03	516	72	3,400	138	127	11	2
Upstream boats		93.94	n/a	n/a	5,361	112	121	11	1
Totals for trip		**189.97**	**516**	**72**	**8,761**	**250**	**248**	**22**	**3**
**September 20 , 21 October 5-10									
Downstream boats		56.19	289	38	6,097	105	45	4	3
Upstream boats		83.18	n/a	n/a	7,358	103	43	5	2
Totals for trip		**139.37**	**289**	**38**	**13,455**	**208**	**88**	**9**	**5**
Totals		**656.09**	**1,565**	**238**	**35,143**	**770**	**355**	**50**	**17**

** 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.



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

Appendix D.

Riverwide population estimates for Colorado pikeminnow and razorback sucker

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 riverwide population estimates presented itself.

Darek Elverud, UDWR, organized the data used in the population estimate for Colorado pikeminnow. In order to run the estimate, data were used from a variety of sampling trips conducted within one month of each other. Table D1 is a summary of the Section sampled and dates used for each of the three passes. Only age 2+ Colorado pikminnow 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 size, 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_o (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 D1. Summary of Section sampled and dates utilized for each pass for the generation of riverwide population estimates for Colorado pikeminnow and razorback sucker.

River Section	Pass 1	Pass 2	Pass 3
PNM to Hogback	3/25/2009	6/23/2009	8/18/2009
Hogback to Shiprock	4/7/2009	7/7/2009	8/11/2009
Shiprock to Mexican Hat	4/22-30/2009	7/15-23/2009	9/2-10/2009
Mexican Hat to Clay Hills	4/6-10/2009	7/1-5/2009	8/24-28/2009

Table D2. Matrices used for riverwide population estimates for Colorado pikeminnow and razorback sucker.

Colorado pikeminnow

Passes	N
100 =	287
010 =	213
001 =	138
110 =	13
101 =	15
111 =	1

razorback sucker

Passes	N
100 =	131
010 =	30
001 =	44
110 =	2
101 =	4

Table D3. Riverwide (RM's 166.6 – 2.9) Colorado pikeminnow population estimate, 2009. 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

Table D4. Riverwide (RM's 166.6 – 2.9) razorback sucker population estimate, 2009. 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