Endangered Fish Monitoring and Nonnative species Monitoring and Control in the Upper/Middle San Juan River: 2012

Final Report

Prepared for:

San Juan River Basin Recovery Implementation Program

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ENDANGERED FISH MONITORING AND NONNATIVE SPECIES MONITORING AND CONTROL IN THE UPPER/MIDDLE SAN JUAN RIVER: 2012

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UNITED STATES FISH AND WILDLIFE SERVICE

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SUBMITTED TO:

SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM

BIOLOGY COMMITTEE

3 JULY 2013

EXECUTIVE SUMMARY

1. A total of 42,697 channel catfish and 190 common carp were removed from river miles (RM) 166.6 – 52.9 in 785.5 hours of electrofishing.

2. Juvenile channel catfish CPUE, during fall monitoring, significantly declined from PNM Weir to Hogback Diversion, 2001-2012.

3. Juvenile channel catfish CPUE, from Shiprock Bridge to Mexican Hat, Utah, was highest during the June and September fall monitoring trips. Adult channel catfish CPUE was the highest during the September fall monitoring trip.

4. Juvenile channel catfish CPUE, during fall monitoring from Shiprock Bridge to Mexican Hat, Utah, has generally increased over time, 1996-2012.

5. Mean common carp CPUE was <0.6 fish/hour in all three removal sections.

6. Common carp CPUE, during annual fall monitoring in all three removal sections, significantly declined after the initiation of nonnative removal.

7. A total of 1,051 Colorado pikminnow and 1,793 razorback sucker were collected during our efforts in 2012.

8. Twenty-five adult Colorado pikeminnow (>450 mm total length (TL)) were collected in 2012 including 19 individual adult fish >500 mm TL.

9. A possible spawning aggregation of adult Colorado pikeminnow was observed in June near RM 119.

10. Razorback sucker continue to show long-term persistence in the river. Twelve individual fish captured in 2012 had been in the San Juan River 10 or more years.

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INTRODUCTION

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 a diverse suite of predators (Minckley and Douglas 1991). The San Juan River is home to two federally endangered fishes, Colorado pikeminnow *Ptychocheilus lucius* and razorback sucker *Xyrauchen texanus.* The establishment of channel catfish *Ictalurus punctatus* and common carp *Cyprinus carpio* has been identified as a detriment to the recovery of Colorado pikeminnow and razorback sucker (USFW 2002a, b). Reducing the impacts of nonnative fishes 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 2012):

San Juan River Recovery Implementation Program's Long Range Plan 2012:
- ***Element 3.*** *Management of nonnative 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 3.1.1.1-*** *Mechanically remove nonnative fish to achieve objectives.*

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 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 observed increases in channel catfish abundance (Ryden 2007, 2008), efforts were expanded in 2008 to include intensive removal from Shiprock Bridge to Mexican Hat, UT (RM 147.9 – 52.9). In 2012, intensive nonnative removal conducted by NMFWCO encompassed 113.7 river miles.

Study objectives were as follows:

1. Continue to remove nonnative fishes, primarily channel catfish and common carp, from 113.7 river miles of the San Juan River
2. Implement riverwide mark/recapture to determine exploitation rates for channel catfish
3. Evaluate distribution and abundance patterns of nonnative species to determine effects of mechanical removal
4. Characterize distribution and abundance of endangered fishes in the upper and middle reaches of the San Juan River

STUDY AREA

Intensive nonnative removal efforts in 2012 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). Electrofishing settings were standardized to run pulsed direct current (PDC) on high range. Percent of power was adjusted by raft operators to maintain an output current of 4 amperes. 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. Electrofishing proceeded downstream and fish were processed at designated stops.

All nonnative fishes or a representative sub-sample (blind grab) were measured (nearest 1 mm) for total (TL) and standard length (SL) and weighed (nearest 5 g). Seconds of electrofishing were recorded to determine effort at the end of each sampling unit. Sampling units ranged from two to three miles depending on the section. All nonnative fishes collected were removed from the river. Two electrofishing rafts sampled for three consecutive days/trip from PNM Weir to Hogback Diversion and Hogback Diversion to Shiprock Bridge. During sampling from Shiprock Bridge to Mexican Hat, a total of four electrofishing rafts were used. Two rafts began sampling one hour 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 or five-gallon bucket separate from that of nonnative fishes. Rare native fishes were measured (nearest 1 mm), weighed (nearest 5 g) and checked 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).

A mark and recapture study from Shiprock Bridge to Mexican Hat for channel catfish was initiated in 2011. The purpose of this effort was to determine exploitation rates and generate population estimates. All channel catfish and common carp ≥ 200 mm TL were tagged with individually numbered anchor tags and released back to the river. All tagged fish were also adipose fin clipped in case of tag loss. A population estimate was calculated for adult and juvenile channel catfish using a Lincoln-Petersen estimate with Chapman's Correction. The estimate was based on fish recaptured during the first trip conducted after tagging. Fish that moved upstream of Shiprock Bridge were not included in the calculation of exploitation rates or the population estimate. Exploitation rates, *u*, were estimated as the proportion of recaptured marked fish to marked fish (Deroba et al. 2005),

$$u = R/M$$

where, R represents number of recaptured fish and M represents number of marked fish.

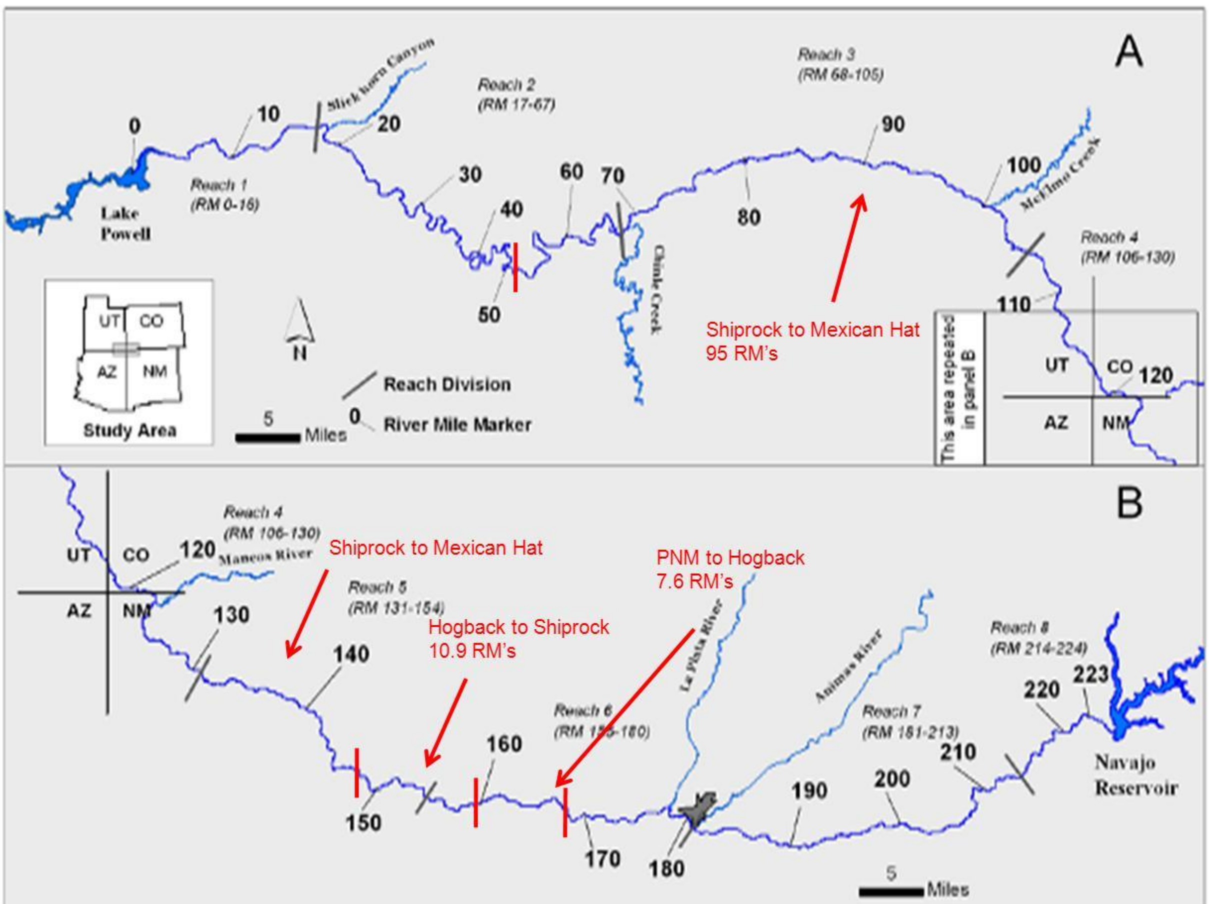

Figure 1. Map of study area – map provided by UNM MSB

Determination of trends in distribution and abundance, mean catch rates (fish per hour of electrofishing; CPUE) and standard error (± 1 SE) were calculated using the software package SPSS version 13.0 (2004). Species CPUE were calculated as the total number of fish collected divided by the total sampling effort (hours of electrofishing). 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 significant 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 significant differences existed (Zar 1996). Significance levels were set at P<0.05.

Data for each removal section were summarized by trip. Catch rates among individual trips were analyzed to assess temporal changes within the year. Due to difference in the number and timing of removal trips conducted in each section among years, we used data collected during the annual sub-adult and adult fall monitoring to assess long term trends in catch rates. These data were collected under standardized monitoring protocols with the primary assumptions that sampling methods employed were appropriate to the species, size, and habitats being sampled, and that sampling efficiency remained relative constant (SJRIP 2012). Catch data pre and post intensive removal were analyzed to assess the effects of removal on nonnative fishes.

RESULTS

PNM WEIR TO HOGBACK DIVERSION (RM 166.6 – 159.0)

A total of 301 channel catfish and 18 common carp were removed from this section during two trips (July and August) and 33.6 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,* and green sunfish *Lepomis cyanellus*.

CHANNEL CATFISH

In 2012, mean channel catfish CPUE for all life stages combined was 7.5 fish/hour. Catch rates were similar between trips and ranged from 5.1 fish/hour in July to 10.8 fish/hour in August. In 2012, more adult fish but fewer juvenile fish were removed in this section compared to 2011. In 2011, 263 channel catfish were removed including 91 juveniles and 172 adults. This is compared to 2012 where a total of 301 channel catfish were removed including 19 juveniles and 282 adults.

Juvenile channel catfish CPUE trends, generated using fall monitoring data, declined since nonnative removal was initiated in this section in 2001 (Figure 2). Additionally, juvenile channel catfish were collected during all years prior to the initiation of intensive removal while 2012 marked the fourth consecutive year, post–removal, no juvenile fish were collected during fall monitoring. In 2012, adult channel catfish catch rates were significantly lower than all years prior to the start of intensive removal and were significantly lower than values observed in 2001, 2003, 2007 and 2008.

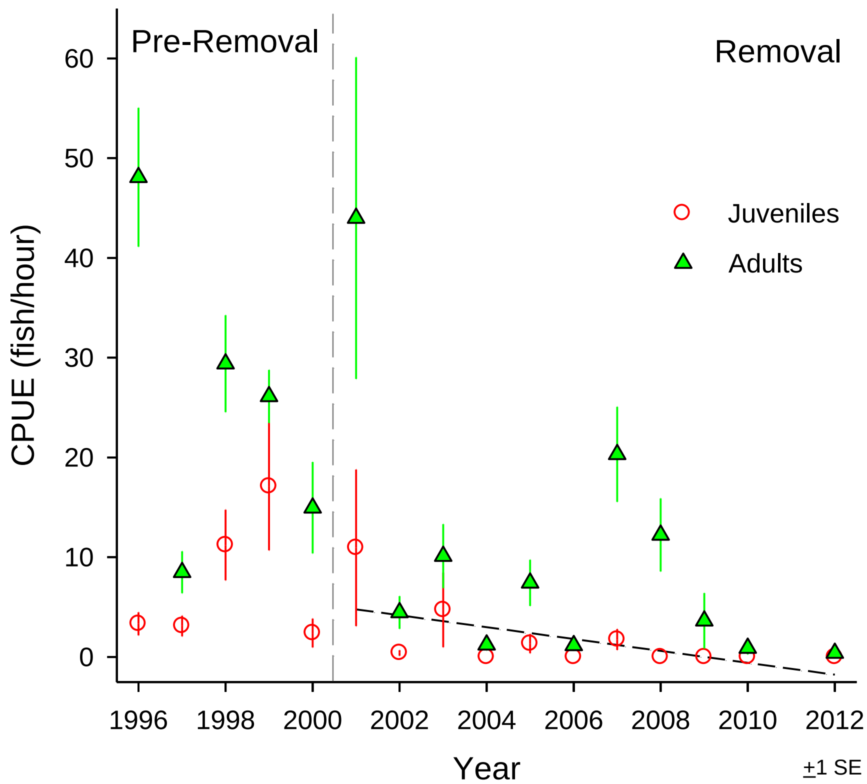

Figure 2. Channel catfish CPUE (fish/hour) during annual fall monitoring by year, PNM Weir to Hogback Diversion; 1996-2012. Adult CPUE is represented by triangles. Juvenile CPUE is represented by circles. A line was fitted if the trend was significant (y= 4.937 – 0.638x; r^2 = 0.39; p = 0.04). The vertical hash line represents the initiation of intensive nonnative removal in this section. Error bars represent ± 1 SE.

Mean total length of channel catfish in 2012 was 404 mm TL (range 260 to 620 mm TL) (Figure 3). The length frequency distribution of channel catfish in 2012 shifted slightly compared to patterns observed in 2011. The majority of channel catfish collected in 2011 were comprised of small, sub-adult fish and newly recruited adults compared to 2012 where newly recruited adults (300-400 mm TL) and juvenile fish composed only 1.1% of total fish measured. The reduction in juvenile fish collected influenced the mean TL observed in 2012 and was the primary reason for the increased mean TL observed between 2011 and 2012.

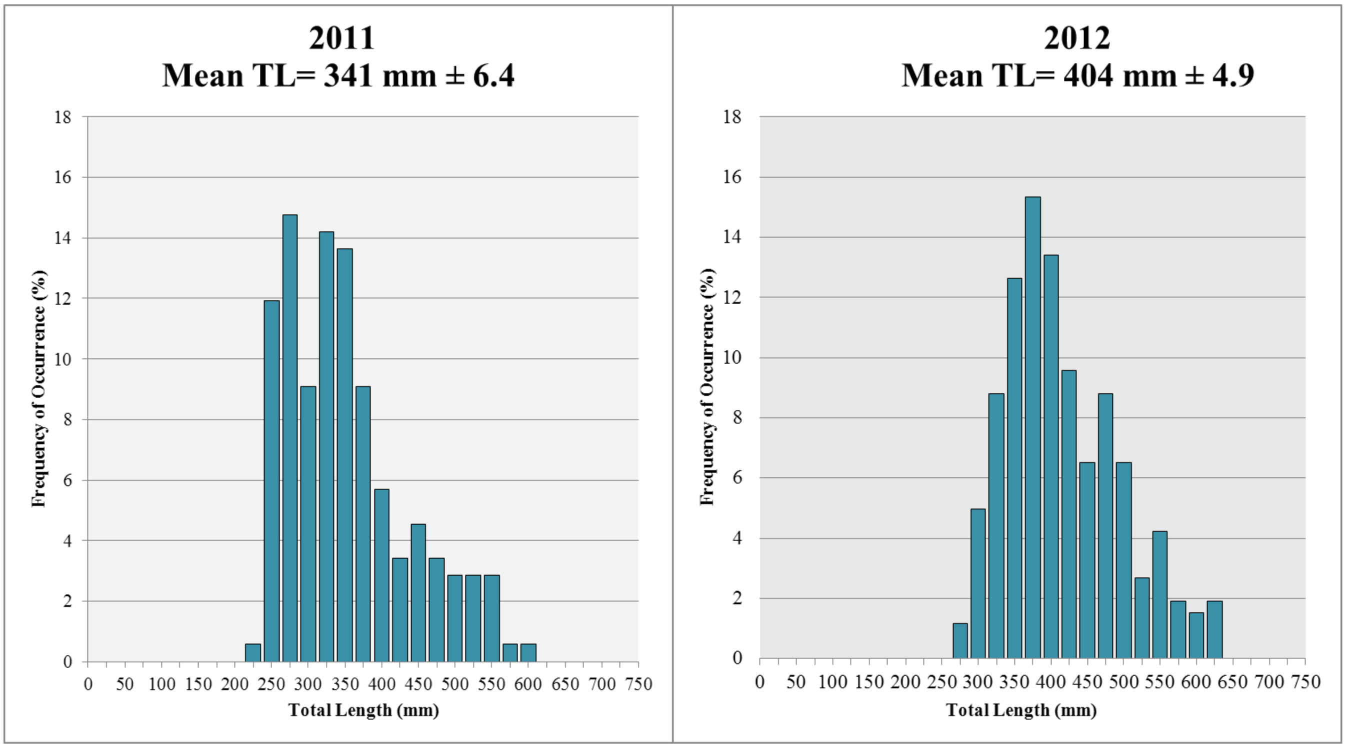

Figure 3. Mean TL (1 SE) and length frequency histograms for channel catfish collected from PNM Weir to Hogback Diversion; 2011 -2012. The y-axis represents percentage (%) of catch and the x-axis represents total length.

COMMON CARP

Common carp CPUE varied little between the two trips conducted in 2012 (Figure 4). Catch rates were ≤ 1.0 fish/hour during each trip and ranged from 0.8 fish/hour in July to 0.2 fish/hour in August. Mean common carp CPUE, all life stages combined, in 2012 was 0.5 fish/hour.

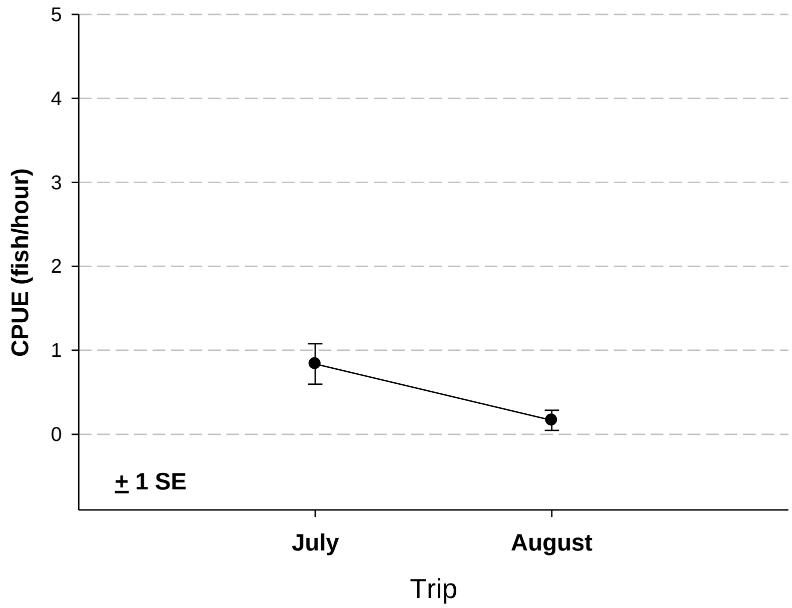

Figure 4. Common carp CPUE (fish/hour) by trip within the PNM Weir to Hogback Diversion Section; 2012. Error bars represent ± 1 SE.

Common carp CPUE trends generated using fall monitoring data, declined since nonnative removal was initiated in 2001 (Figure 5). Common carp mean CPUE was < 1.0 fish/hour from 2008-2012. Common carp continue to be uncommon in all collections within this section.

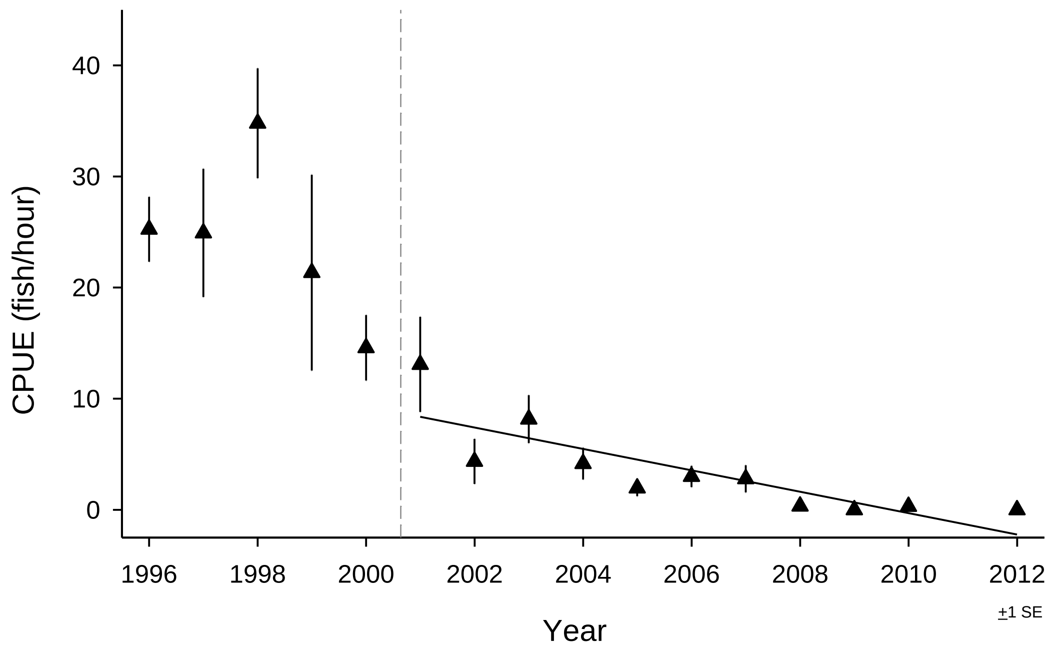

Figure 5. Common carp CPUE (fish/hour) during annual fall monitoring by year, PNM Weir to Hogback Diversion; 1996-2012. A line was fitted to the data if the trend was significant (y= 8.601 – 1.027x; r^2= 0.71; p= 0.001). The vertical hash line represents the initiation of intensive nonnative removal in this section. Error bars represent ± 1 SE.

HOGBACK DIVERSION TO SHIPROCK BRIDGE (RM 158.8 – 147.9)

A total of 1,000 channel catfish and 39 common carp were removed during three trips (March, July and August) and 77.2 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, largemouth bass, and green sunfish.

CHANNEL CATFISH

Channel catfish CPUE in 2012 ranged from 3.4 fish/hour to 28.4 fish/hour (Figure 6). Catch rates observed in August were significantly higher than all other trips (ANOVA; $F_{(2, 85)}$ = 55.435; $p < 0.05$). The mean channel catfish CPUE in 2012, all life stages combined, was 12.8 fish/hour. Of the 1,000 channel catfish removed, 336 were juveniles while 664 were adults. Of these fish, 19 fish that were tagged downstream of Shiprock Bridge and12 fish that were tagged downstream of Mexican Hat, Utah had moved upstream and were recaptured in this section.

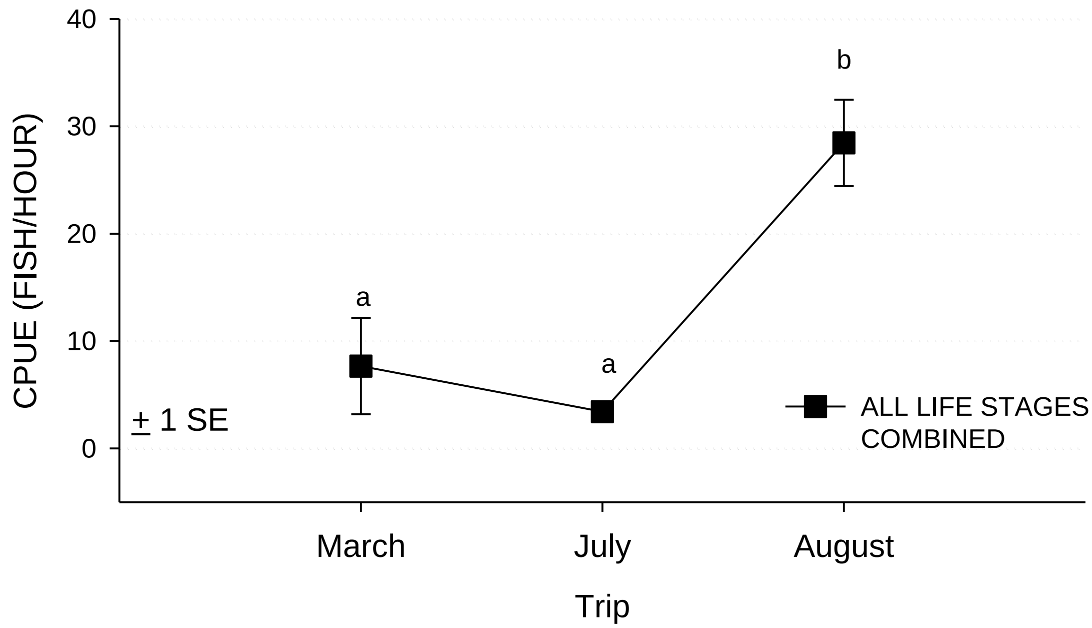

Figure 6. Channel catfish CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2012. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). Similar letters represent that significant differences did not exist and unlike letters indicate that significant differences were detected among comparisons.

No significant trends of either juvenile or adult channel catfish catch rates were observed in this section pre or post removal (Figure 7). However the percentage of years with juvenile catch rates >15 fish/hour of electrofishing was greater pre-removal than post (86% and 50%, respectively). Additionally, juvenile catch rates in 2012 were significantly higher than values observed from 2008-2010. Adult CPUE has fluctuated over time and have not realized significant declines since the initiation of intensive removal.

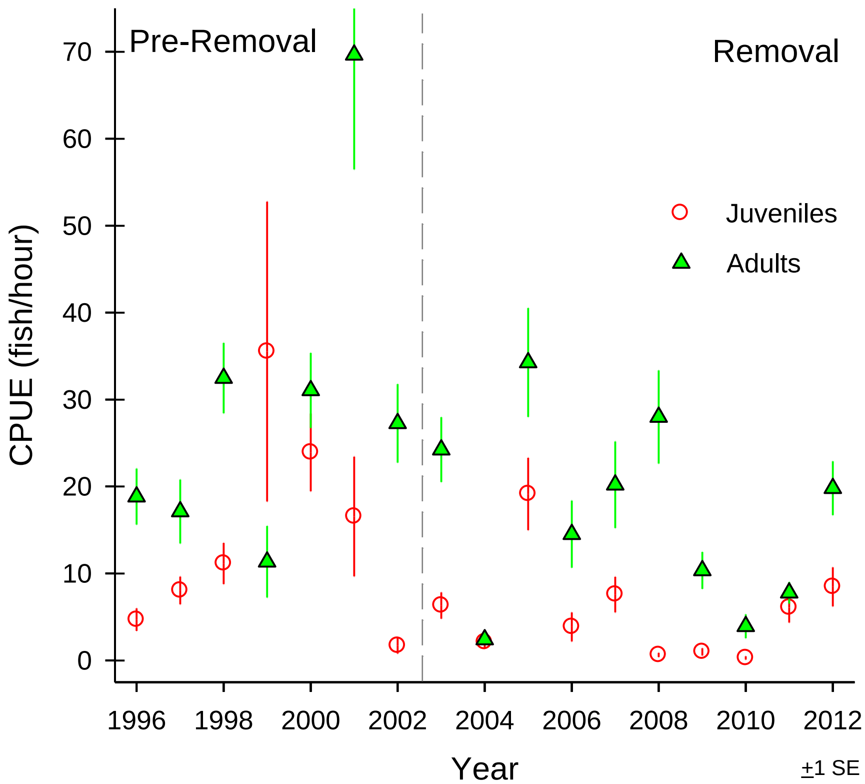

Figure 7. Channel catfish CPUE (fish/hour) during annual fall monitoring by year, Hogback Diversion to Shiprock Bridge; 1996-2012. Adult CPUE is represented by triangles. Juvenile CPUE is represented by circles. The vertical hash line represents the initiation of intensive nonnative removal in this section. Error bars represent ± 1 SE.

Mean total length of channel catfish in 2012 was 344 mm (range 210 to 627 mm) (Figure 8). The length frequency distribution of channel catfish in 2012 shifted slightly compared to patterns observed in 2011.The majority of channel catfish collected in 2011 were comprised of juvenile and sub-adult fish (175-300 mm TL) compared to 2012 where newly recruited adults (300-400mm TL) comprised the majority of the catch. In 2012, 73% of the measured fish were adults between 300-400 mm TL.

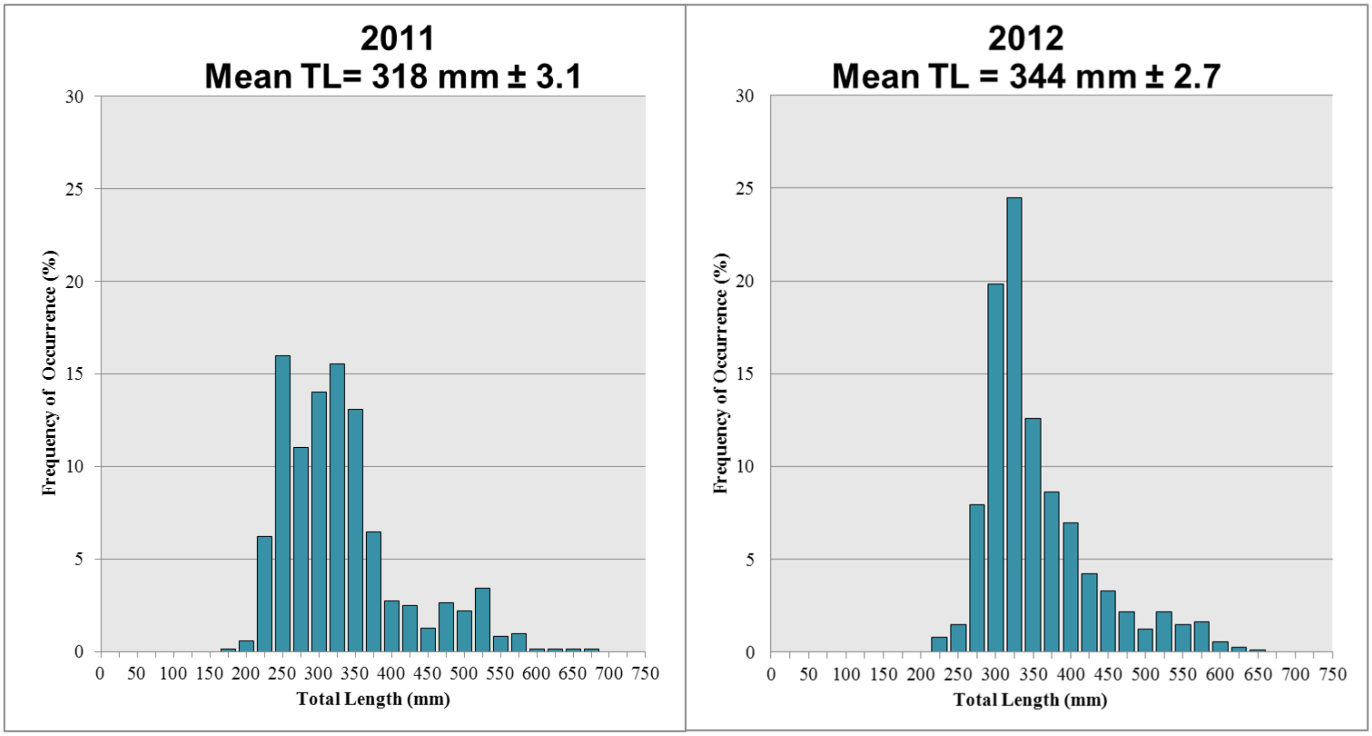

Figure 8. Mean TL (1 SE) and length frequency histograms for channel catfish collected from Hogback Diversion to Shiprock Bridge; 2011 - 2012. The y-axis represents percentage (%) of catch and the x-axis represents total length.

COMMON CARP

Common carp catch rates, by trip, were < 1.0 fish/hour and varied little among the three trips in 2012. Mean common carp CPUE, all life stages combined, in 2012 was 0.5 fish/hour (Figure 9).

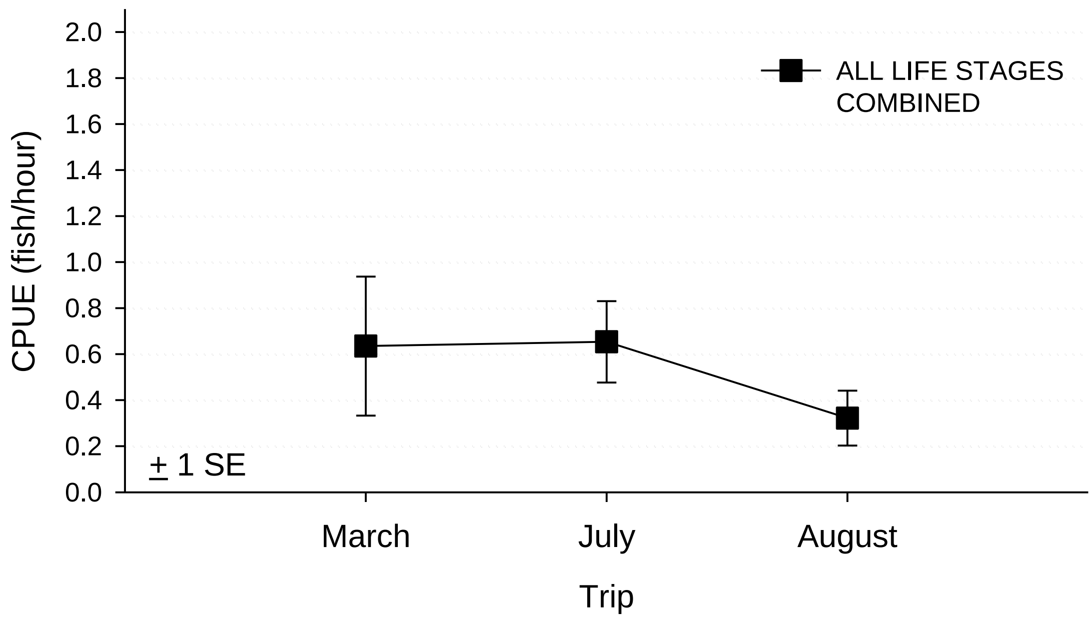

Figure 9. Common carp CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge section; 2012. Error bars represent ± 1 SE.

Common carp CPUE trends generated using fall monitoring data, declined since nonnative removal was initiated in 2003 (Figure 10). Common carp continue to be infrequently collected from Hogback Diversion to Shiprock Bridge and 2012 marked the fifth consecutive year that common carp CPUE was < 1.0 fish/hour during annual fall monitoring.

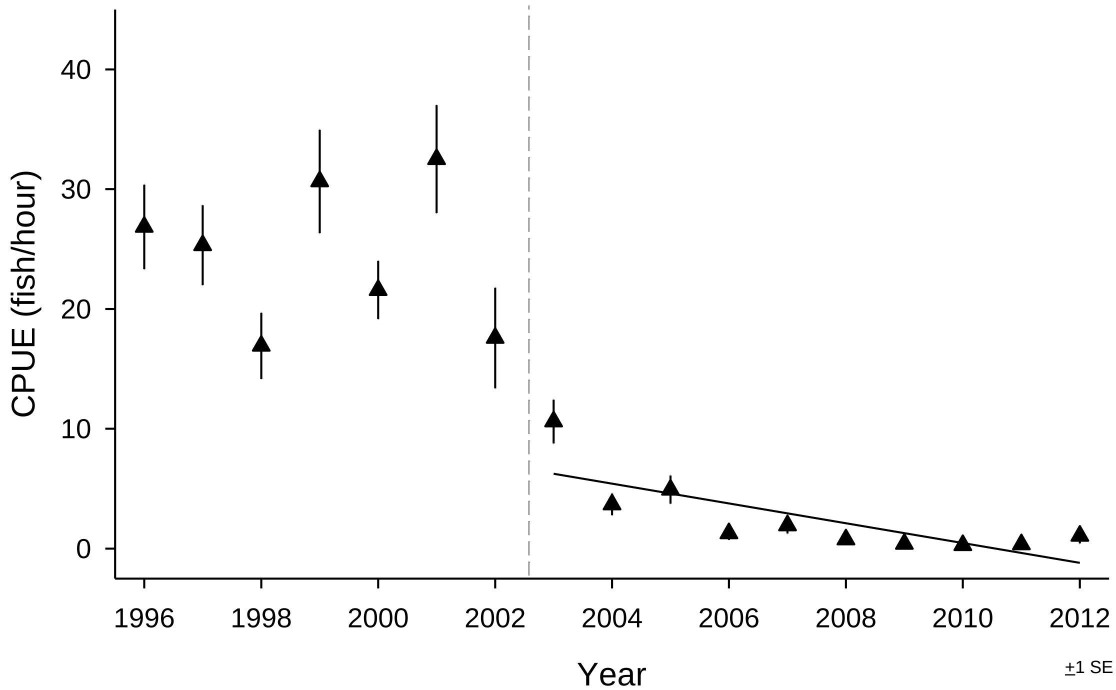

Figure 10. Common carp CPUE (fish/hour) during annual fall monitoring by year, Hogback Diversion to Shiprock Bridge; 1996-2012. A line was fitted to the data if the trend was significant (y=6.241 - 0.825x; r^2= 0.60; p= 0.009). The vertical hash line represents the initiation of intensive nonnative removal in this section. Error bars represent ± 1 SE.

SHIPROCK BRIDGE TO MEXICAN HAT (RM 147.9 - 52.9)

One tagging trip and three removal trips (April/May, June, and September) were conducted from Shiprock Bridge to Mexican Hat in 2012. During removal trips, a total of 29,383 channel catfish and 100 common carp were removed in 525 hours of electrofishing. Nonnative fish removal also took place in conjunction with FWS Colorado River Fishery Project's annual fall monitoring in September, resulting in the removal of an additional 12,013 channel catfish and 33 common carp in 149.7 hours of electrofishing. For the year, a total of 41,396 channel catfish and 133 common carp were removed during 674.7 hours of electrofishing (Appendix A-3). Other nonnative fishes removed included brown trout, rainbow trout, bullhead catfishes, green sunfish, and largemouth bass. No striped bass or walleye were collected or observed. In 2012, 11 roundtail chub *Gila robusta* were collected.

MARK AND RECAPTURE

A total of 3,152 channel catfish and 13 common carp were collected and implanted with individual alphanumeric anchor tags during a trip from Shiprock Bridge to Mexican Hat, UT. Total length measurements were taken from all fish that were tagged to determine exploitation rates by size classes. Adult channel catfish, ≥ 300mm TL, composed 37% of the total number of channel catfish tagged (N=1,154), while juvenile channel catfish composed 63% (N=1,991). In addition to nonnative fishes collected, we captured 72 Colorado pikeminnow and 252 razorback sucker during the tagging trip.

Exploitation rates for channel catfish were generated for each size class by individual trips and total exploitation for the year (Table 1). The highest total exploitation rate, among trips was 6% and was observed during the first post-tagging trip. Exploitation rates for all size classes were the highest during the first post-tagging trip while the lowest catch rates were observed during the last trip of the year. The combined exploitation rate for all size classes and trips was 15.2 %. Total exploitation rates ranged from 11.8 % for juvenile channel catfish to 37.3 % for fish 500-599 mm TL. Exploitation rates for adult channel catfish were consistently higher, among trips, than those of juvenile fish.

Table 1. Channel catfish exploitation rates from Shiprock Bridge to Mexican Hat, UT, 2012. Numbers in parentheses in the Mark Pass row represent total number of channel catfish tagged in that size class. Numbers in parentheses in the Trip 1-4 rows represent total number of channel catfish recaptured for that size class and trip and percentage is the exploitation rate for that size class during that trip.

	Total Length (mm) of Channel Catfish at Time of Tagging					
	200-299 mm TL	300-399 mm TL	400-499 mm TL	500-599 mm TL	600+ mm TL	Total
Mark Pass	63%	20%	12%	4.5%	.60%	(3,152)
	(1,991)	(630)	(363)	(142)	(19)	(3,152)
Trip 1 April/May	4.2%	7.3%	7.7%	18.3%	15.8%	6.0%
	(84)	(46)	(28)	(26)	(3)	(187)
Trip 2 June	4.0%	5.5%	5.8%	7.8%	12.5%	4.6%
	(75)	(32)	(18)	(9)	(2)	(136)
Trip3 Sept	1.6%	1.8%	3.6%	5.6%	-	2.0%
	(30)	(10)	(10)	(6)	-	(56)
Trip 4 Sept (Fall Mont.)	2.6%	5.0%	5.0%	12.0%	7.1%	3.6%
	(46)	(27)	(15)	(12)	(1)	(101)
Middle section Total	11.8%	18.3%	19.6%	37.3%	31.6%	15.2%
	(235)	(115)	(71)	(53)	(6)	(480)

During the tagging trip, 1,154 adult, $\geq$ 300 mm TL, channel catfish were tagged. On the first removal trip in April/May, 1,470 adult fish were captured including 103 anchor-tagged fish. The Lincoln-Petersen population estimate for adult channel catfish from Shiprock Bridge to Mexican Hat, UT was 16,336 (95% CI = 13,262-19,409; CV=9.41%, SE=1,537).

A total of 1,991 juvenile fish (200-299mm TL) were tagged in 2012. During the post tagging removal trip, a total of 3,121 juvenile fish were captured including 84 anchor-tagged fish. The Lincoln-Petersen population estimate for juvenile channel catfish from Shiprock Bridge to Mexican Hat, UT was 73,164 (95% CI = 57,601-88,727; CV=10.64%, SE=7,781).

A Lincoln-Petersen population estimate was not completed for common carp in 2012 due to having no recaptured fish during the post tagging removal trip.

Using the population estimates for juvenile and adult channel catfish and the actual numbers of fish removed each trip; we estimated the percentage of the estimated population removed as well as estimated number of fish remaining in the population after each trip and at the end of the year. This estimate does not take in to account any assumptions such as fish mortality and recruitment, or immigration and emigration to and from the study reach. If these estimates are accurate, we potentially removed 52% of the adult channel catfish population estimate (Table 2) and 24% of the juvenile population estimate (Table 3) from Shiprock Bridge to Mexican Hat, Utah in 2012. A similar estimate of percentage of fish removed in 2011 for adult channel shows that the pre-exploitation estimate for 2012 did not surpass the pre-exploitation estimate for 2011 (Figure 11).

Table 2. Number of adult channel catfish removed during each trip. The % of population estimate removed each trip is based off of the population estimate for adult channel catfish from Shiprock Bridge to Mexican Hat. The estimated number of fish remaining is determined from the population estimate.

Trip	Adults Removed	% of Pop Estimate	Estimated # of Fish Remaining
April	1,470	8.9	14,896
June	2,205	14.8	12,691
September	1,824	14.3	10,867
Fall monitoring	2,994	27.5	7,873
Total	**8,493**	**51.9**	**7,873**

Table 3. Number of juvenile channel catfish removed during each trip. The % of population estimate removed each trip is based off of the population estimate for juvenile channel catfish from Shiprock Bridge to Mexican Hat. The estimated number of fish remaining is determined from the population estimate.

Trip	Juveniles Removed	% of Pop Estimate	Estimated # of Fish Remaining
April	3,121	4.3	70,043
June	6,205	8.9	63,838
September	3,141	4.9	60,697
Fall monitoring	4,736	7.8	55,961
Total	**17,203**	**23.5**	**55,961**

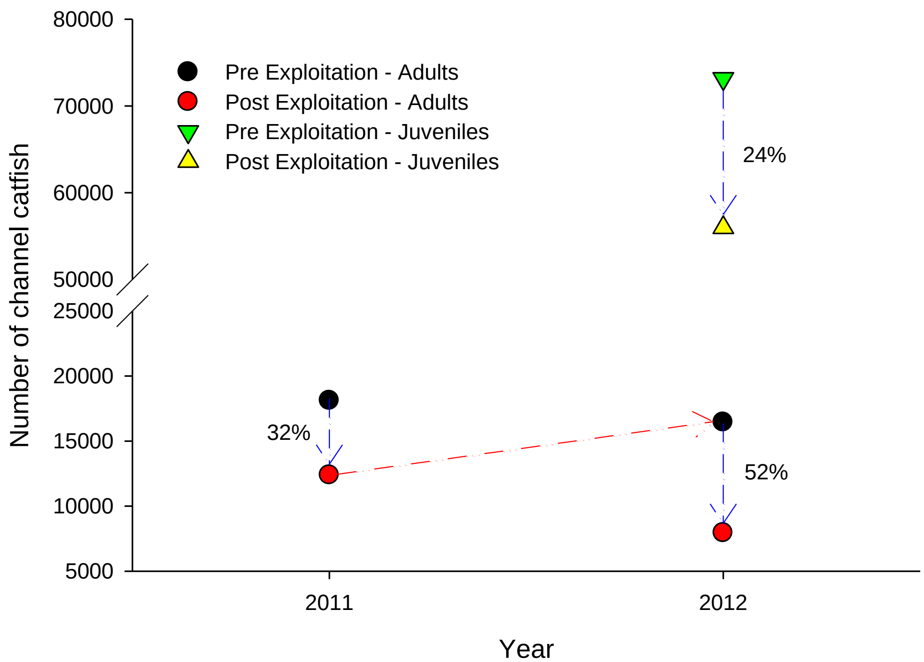

Figure 11. Pre and post exploitation estimates for adult and juvenile channel catfish, Shiprock Bridge to Mexican Hat, Utah: 2011-2012. Percentages represent the reduction between population estimates at the beginning of the year before sampling versus the estimated number of fish remaining after the four removal trips.

REMOVAL TRIPS

CHANNEL CATFISH

Channel catfish CPUE, all life stages combined, varied among trips in 2012 (Figure 12). Juvenile channel catfish CPUE ranged from 31 to 62.6 fish/hour, with the highest catch rates occurring in June and September (fall monitoring). Adult channel catfish CPUE ranged from 8.0 to 20.7 fish/hour of electrofishing. September (fall monitoring) adult CPUE was significantly higher than all other trips (ANOVA; $F_{(3, 526)} = 23.420$; $p < 0.001$).

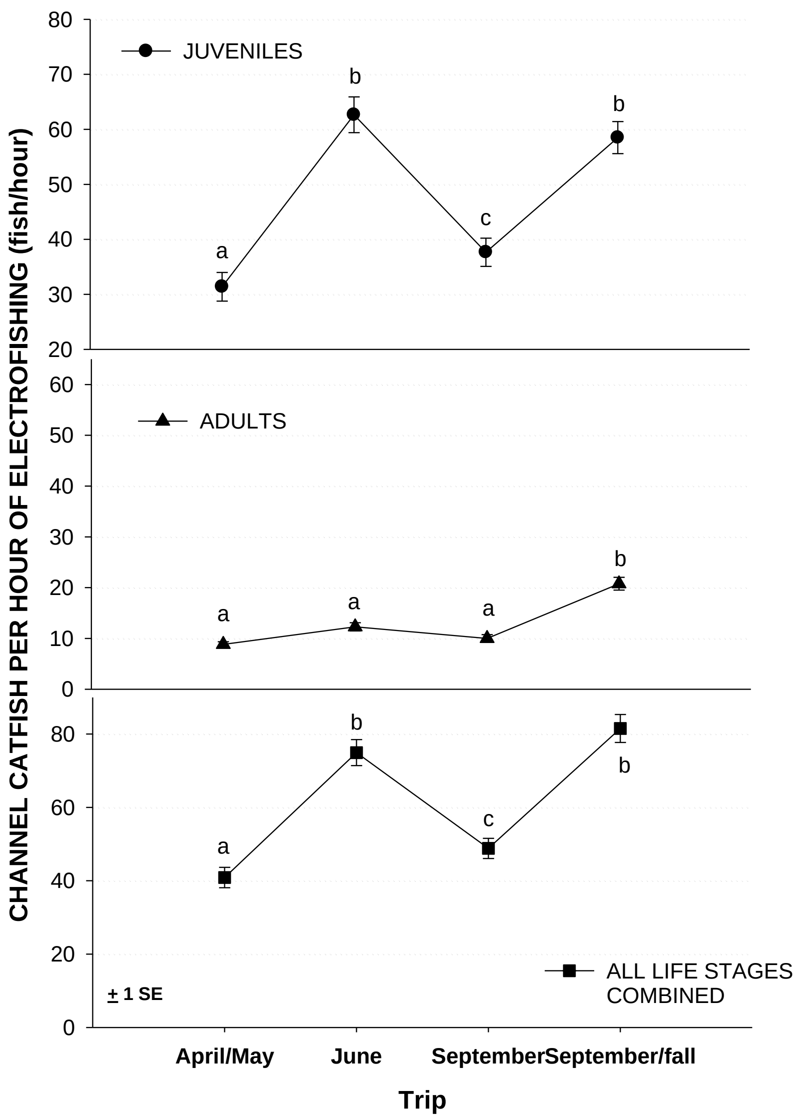

Figure 12. Channel catfish CPUE (fish/hour) by trip from Shiprock Bridge to Mexican Hat; 2012. Error bars represent ± 1 SE. Letters represent comparisons among trips (Nemenyi post-hoc). Trips with the same letter did not differ from each other.

Before intensive removal began in 2006, juvenile channel catfish catch rates generated from fall monitoring data were fairly consistent among years (Figure 13). After removal efforts began, juvenile catch rate trends have exhibited a general increase over time, although this trend was not significant. Adult CPUE in 2012 was similar to that observed during the first four years of removal and was significantly higher than values from 2010and 2011.

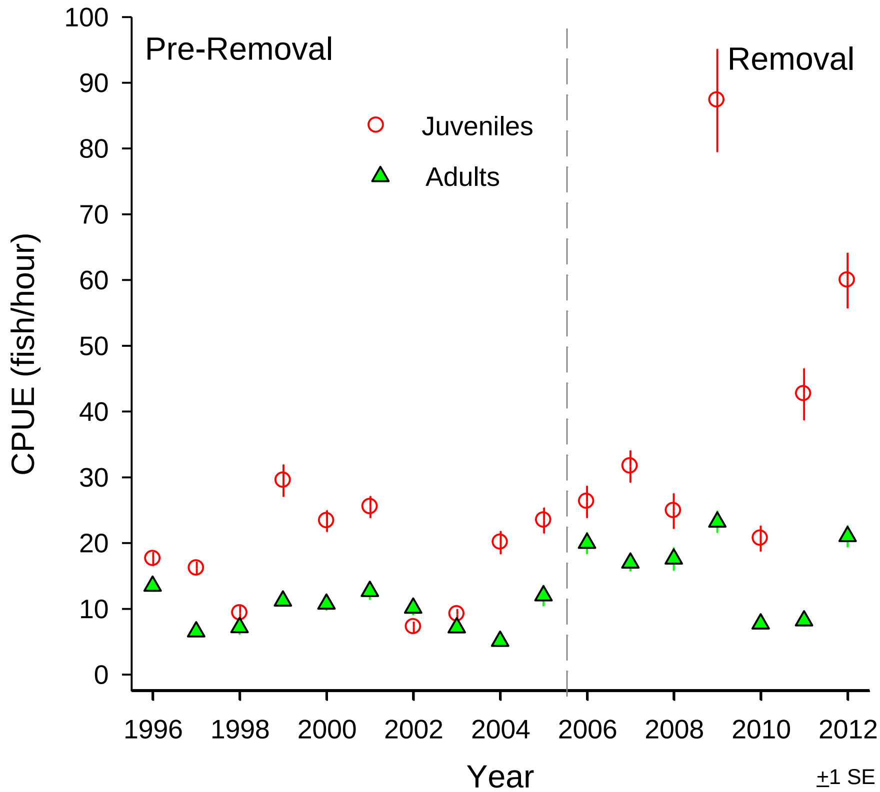

Figure 13. Channel catfish CPUE (fish/hour) during annual fall monitoring by year, Shiprock Bridge to Mexican Hat; 1996-2012. Adult CPUE is represented by triangles. Juvenile CPUE is represented by circles. The vertical hash line represents the initiation of intensive nonnative removal in this section. Error bars represent ± 1 SE.

Mean total length of channle catfish in 2012 was 279 mm (range 41 to 755mm)(Figure 14). The majority of measured channel catfish (54 %) were < 300 mm TLwhile 31.1 % were between 300 – 400 mm TL, and 14.8 % were > 400 mm TL. Compared to previous years, and similar to 2011, the majority of the size structure in 2012 was composed of juvenile and sub-adult fish. Larger adult channel catfish, 425 – 575 mm TL, composed 21.7 % of the total catch in 2011 compared to 14.8% of the catch in 2012.

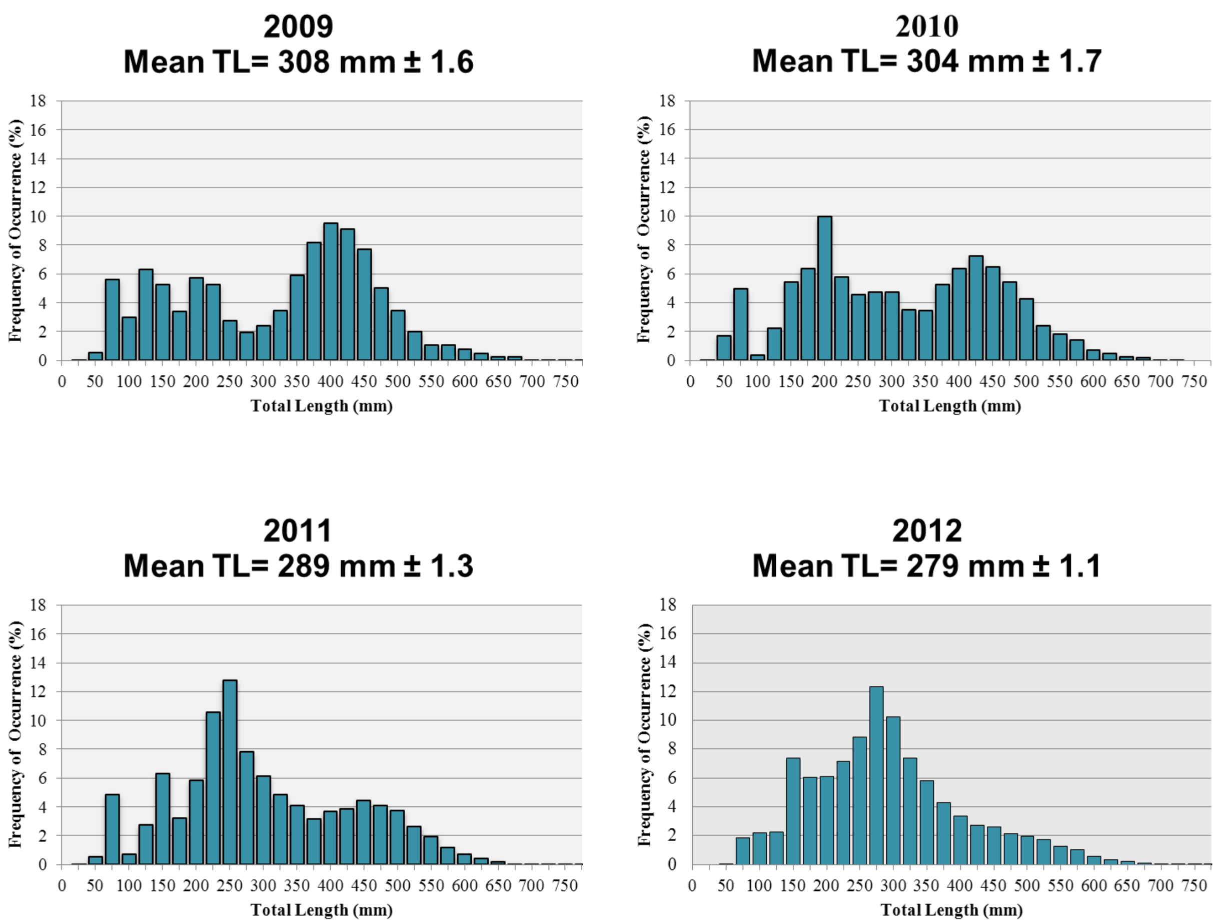

Figure 14. Mean TL (1 SE) and length frequency histograms by trip for channel catfish collected from Shiprock Bridge to Mexican Hat Utah; 2009-2012. The y-axis represents percentage (%) of catch and the x-axis represents total length

COMMON CARP

Catch rates for common carp were < 0.25 fish/hour during each of the four removal trips coducted in 2012 (Figure 15). Mean common carp CPUE in 2012 was 0.19 fish/hour. This catch rate was the lowest observed for common carp, riverwide, since nonnative removal began on the San Juan River. Common carp remain to be infrequently collected in this section throughout the year.

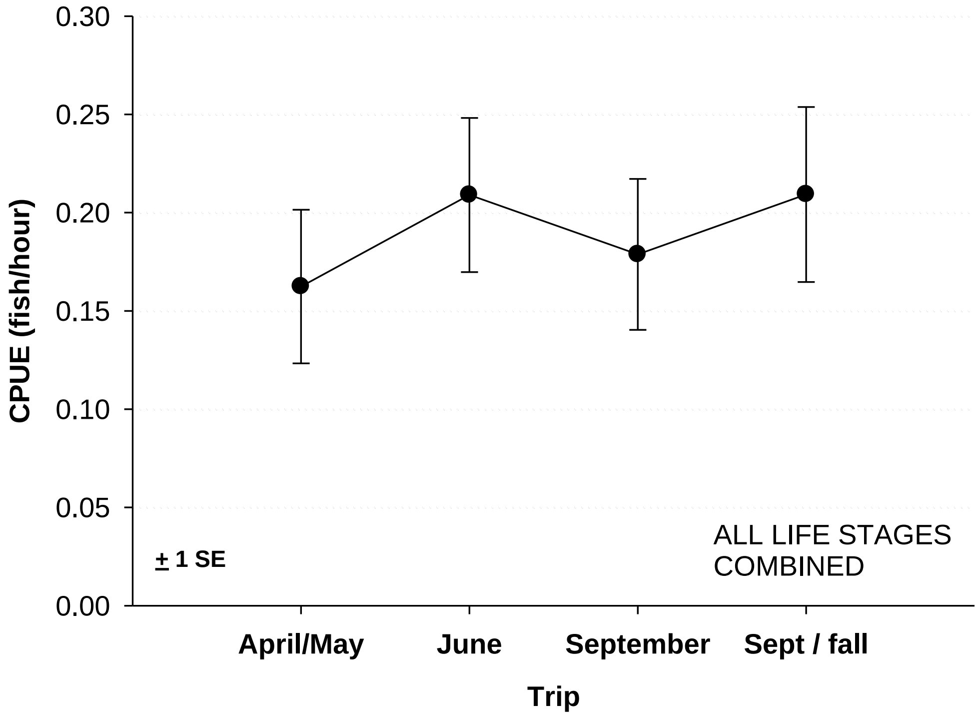

Figure 15. Common carp CPUE (fish/hour of electrofishing) during 2012 nonnative removal trips from Shiprock Bridge to Mexican Hat. Error bars represent + 1 SE.

A comparison of common carp catch rates among years of adult fall monitoring shows a decline in CPUE during pre-removal efforts and a continuing decling trend after intensive removal began in 2006 (Figure 16). Catch rates have remained < 1.0 fish/hour for the last four years. Catch rates in 2012 were significantly lower than those observed from 1996-2007.

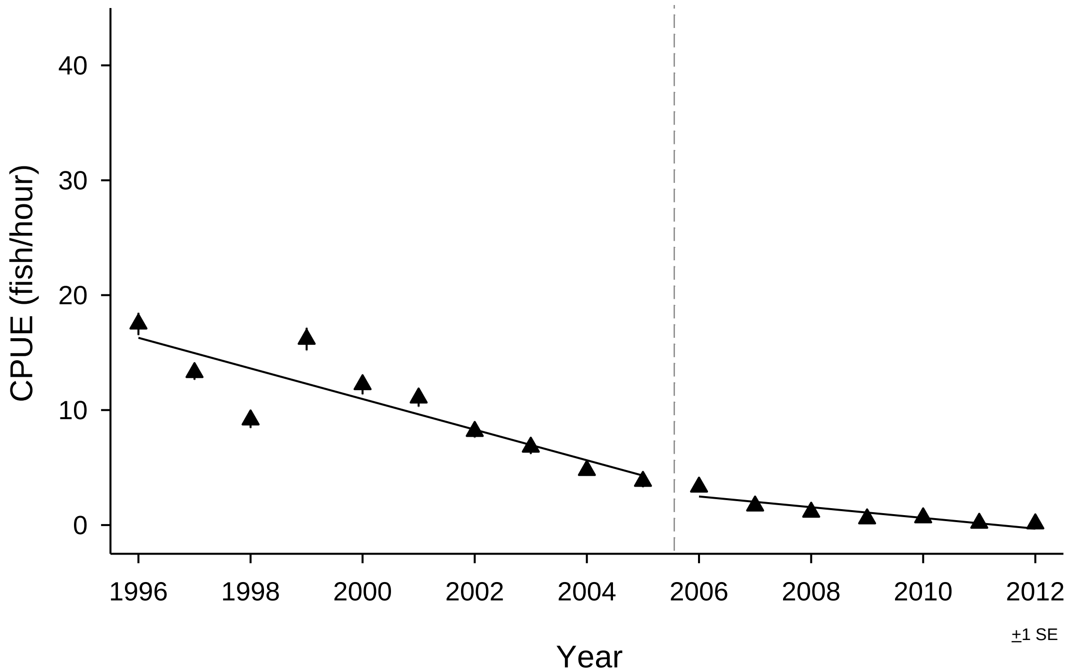

Figure 16. Common carp CPUE (fish/hour) during annual fall monitoring by year, Shiprock Bridge to Mexican Hat; 1996-2012. A line was fitted to the data if the trend was significant (96-05: y= 16.289 – 1.332x; r^2 = 0.77; p<0.001; 06-12: y= 2.484 – 0.467; r^2= 0.81; p=0.01). The vertical hash line represents the initiation of intensive nonnative removal in this section. Error bars represent ± 1 SE.

RARE FISH COLLECTIONS

A total of 1,124 Colorado pikeminnow and 2,029 razorback sucker were captured during nonnative removal trips from PNM Weir to Mexican Hat, Utah (Appendix A-3). Two hundred and twenty-nine Colorado pikeminnow and 614 razorback sucker were collected from PNM Weir to Hogback Diversion; 258 Colorado pikeminnow and 580 razorback sucker were collected from Hogback Diversion to Shiprock Bridge; and 563 Colorado pikeminnow and 599 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 but do include the rare fish collected during the tagging trip in early April from Shiprock Bridge to Mexican Hat. For analysis purposes, fish 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 2012 were considered to be stocked fish. A total of 140 individual fish had PIT tags at time of capture. Recaptures of PIT tagged fish ranged from 1- 3,648 days since first encounter. Fish were classified as first encounters when the fish was stocked in the river or collected and tagged in the river. Days since first encounter could not be calculated for all PIT tagged Colorado pikeminnow due to errors when recording PIT tag numbers. The majority of PIT tagged fish (82%, n= 93) were captured < 730 days since first encounter and 20 fish were recaptured > 730 days since first encounter. Various age classes were collected dating back to 2004; however, the 2010 year class comprised the majority of recaptures (Table 5). These were likely recaptures of fish stocked in May 2011.

Table 4. Summary of Colorado pikeminnow, by known year class, collected during nonnative fish removal; 2012.

Year class	N
2004	3
2005	2
2006	4
2007	5
2008	5
2009	49
2010	338
2011	323

A total of 652 Colorado pikeminnow were implanted with a PIT tag at the time of capture. These newly implanted fish ranged in size from 129 – 546 mm TL, with a mean TL of 209 mm. Three hundred- fourteen captures were not implanted with a PIT tag because they were < 150 mm TL. Mean TL of Colorado pikeminnow collected during our efforts in 2012 was 198 mm TL (range = 49 – 704 mm TL) (Figure 17). Fish < 150 mm TL composed 13.6 % (n = 145) of the total catch while fish > 400 mm TL composed 3.4 % (n = 36) of the catch. Twenty-five adult Colorado pikeminnow were collected including five fish ranging from 450 – 500 mm TL and 19 individuals > 500 mm TL.

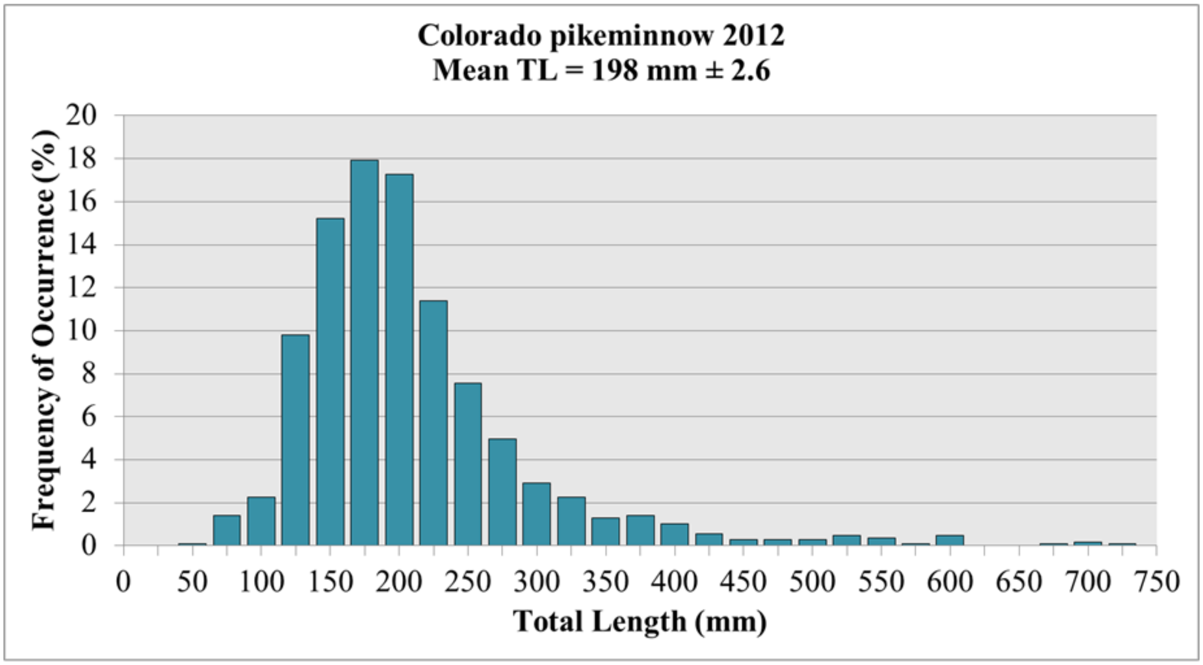

Figure 17. Mean TL (1 SE) and length frequency histogram for Colorado pikeminnow collected during intensive nonnative fish removal trips; 2012. The y-axis represents percentage (%) of catch and the x-axis represents total length.

A possible spawning aggregation of adult Colorado pikeminnow was found June 23 at RM 119. The netter on the raft was able to net six adult fish and observed more adults that went uncaptured. The six fish captured were all tuberculated males ranging from 450- 546 mm TL. On the opposite side shoreline the other shocking raft also picked up a small aggregation of three Colorado pikeminnow at the same time. One of these fish was a 660 mm TL tuberculate male and the other two were 434 and 452 mm TL.

RAZORBACK SUCKER

All razorback sucker collected in 2012 were considered to be stocked fish. Although 164 razorback sucker were lacking PIT tags at time of capture, we assumed these fish were stocked fish. The majority of razorback sucker implanted with a PIT tag in 2012 had scales collected for the study using elemental analysis to determine razorback sucker natal origin. All 164 of these fish were implanted with a 134.2 kHz PIT tag and subsequently released. Various known age classes of razorback sucker were recaptured dating back to 1992 with the majority (85%) of recaptures composed of the 2008-2009 year class (Table 6).

Table 5. Summary of razorback sucker by age class collected during nonnative fish removal; 2012.

Year class	N
1992	1
1999	5
2000	10
2001	23
2002	9
2003	3
2004	3
2005	1
2006	29
2007	128
2008	610
2009	605

Days in river since first encounter ranged from 1 – 6,045 days. Of the 1,349 razorback sucker that had a known stocking history, 52.7% (n=815) were recaptured < 1 year since first encounter and 5.5% (n=85) were recaptured > 5 years since first encounter. Twelve individuals were recaptured 10 years since first encounter. One fish stocked in the San Juan River in 1995 was recaptured in 2012. This was the 5th recapture of this fish in 16.5 years.

Mean razorback sucker TL in 2012 was 422 mm and sizes ranged from 265 – 590 mm TL (Figure 18). Of the 1,756 measured fish, 70% (n = 1,237) were considered to be adult fish (> 400mm TL). Of these adult fish, 99 fish were >500mm TL.

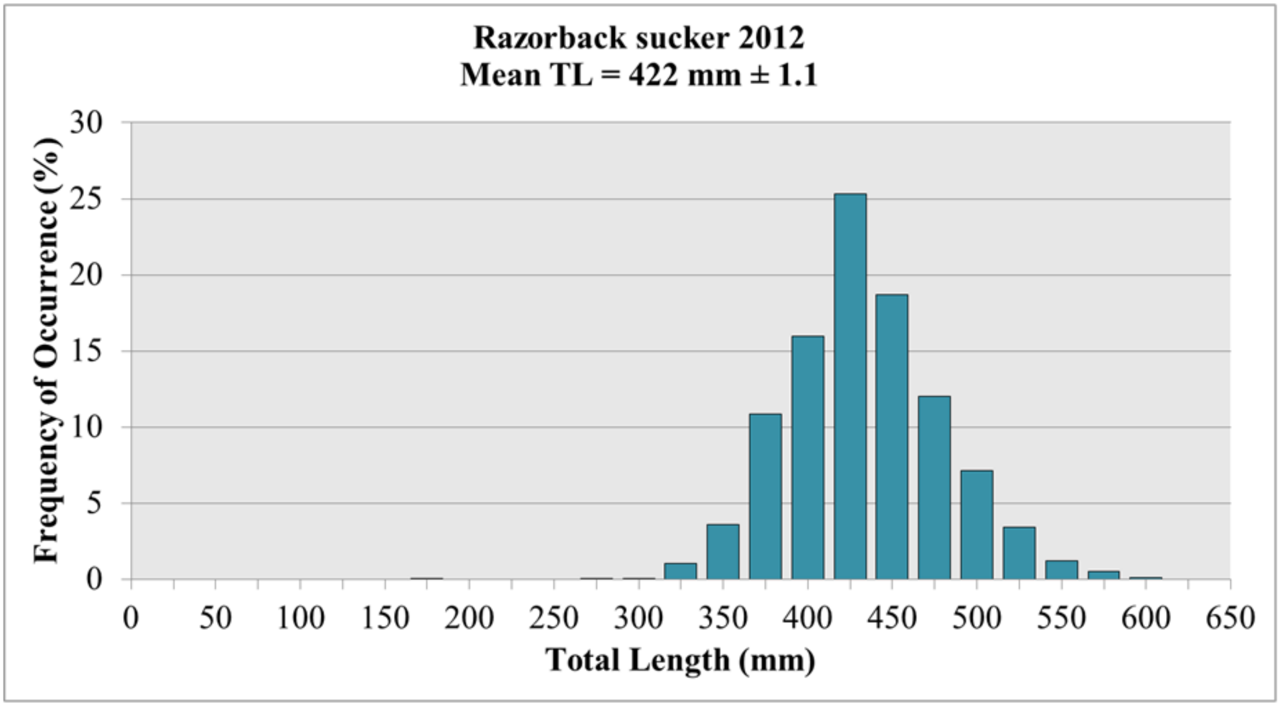

Figure 18. Mean TL (1 SE) and length frequency histogram for razorback sucker collected during intensive nonnative fish removal trips; 2012. The y-axis represents percentage (%) of catch and the x-axis represents total length.

DISCUSSION

Intensive nonnative removal completed its 12th consecutive year from PNM Weir to Hogback Diversion in 2012. There was an increase in the number of adult fish removed in this section compared to 2011; however, the majority of adult fish removed in 2012 were newly recruited adults and juvenile fish only composed 1% of total catch. The increase in adult fish in 2012 was perhaps a factor of recruitment of new adults from late juvenile-stage fish or immigration from downstream reaches. Ten adult channel catfish that were tagged from Shiprock Bridge to Mexican Hat, Utah and five adults tagged from Mexican Hat, Utah to Clay Hills, Utah were recaptured in this section in 2012. This upstream movement of 8-140 river miles indicates that fish from lower river sections are capable of repopulating upstream reaches. In 2011, the selective fish ladder at PNM Weir experienced a large increase in channel catfish using the fish passage in late July and August, supporting the idea that upstream movement of channel catfish was occurring. Unfortunately, the fish ladder was inoperative in 2012 to compare if channel catfish again tried to use the fish passage during a short window in those two months.

Prior to 2001, channel catfish catch rates, during fall monitoring, varied among years but exhibited relatively high adult channel catfish abundance. After the initiation of removal in 2001, catch rates for both juvenile and adult channel catfish still varied among years but both size classes exhibited general declining trends. The observed decline in juveniles is likely the cumulative result of intensive removal efforts in this section and adjacent downstream sections coupled with a reduction in the abundance of adult channel catfish and potential reduction in reproductive output. Variation in CPUE data among years may be partially responsible for the failure to detect significant declining trends in adult channel catfish catch rates in this section during our study period. While adult CPUE trends have not changed over time, catch rates in 2012 were significantly lower than values observed prior to removal.

In 2003, nonnative removal efforts were expanded to include the Hogback Diversion to Shiprock Bridge section. The majority of channel catfish collected in this section in 2012 were composed of newly recruited adults. It is unknown if these fish recruited to the adult size class in this section or immigrated from downstream reaches. Recaptures of channel catfish that were tagged downstream of Shiprock Bridge and Mexican Hat, Utah illustrate widespread upstream movement and the potential to repopulate upstream removal reaches throughout the year. With recent increases in juvenile fish abundance, coupled with lowered exploitation rates for smaller fish, the subsequent observed increase in adult fish was not entirely unexpected. Although adult fish abundance increased in 2012, the majority of these fish were newly recruited adults. Although each section removal section is analyzed and presented independently, it is important to recognize the effect that high channel catfish abundance in downstream areas may have on other removal sections because of immigration/emigration.

Beginning in 2008, the expansion of removal efforts to include two passes per trip from Shiprock Bridge to Mexican Hat, UT, was expected to result in significant declines in channel catfish abundance riverwide. In 2012, fall monitoring data showed that juvenile channel catfish catch rates continued to increase. Adult catch rates were stable the first four years of intensive removal and were reduced in 2010-2011 only to increase in 2012. However, the size of adult channel catfish in this section has declined and was primarily composed of newly recruited adults. The observed increases in juvenile catch rates may be an artifact of fish recruiting to our gear type several years after a successful spawn. Similar increases in juvenile channel catfish abundance were observed after the initial years of intensive removal in the two uppermost sections of our study only to decline with continued exploitation (Davis and Duran 2009). An increase in smaller size classes of fish and a reliance on single year classes has been documented as a response to exploitation of channel catfish in the Mississippi River (Pitlo 1997). Maintaining or even increasing intensive removal efforts from Shiprock Bridge to Mexican Hat in order to remove these fish as they recruit into adulthood will be important in reducing riverwide abundance of channel catfish.

Throughout the year, tagged channel catfish were documented to have moved out of our study section and were collected in other sections of the river. Nineteen channel catfish (6 juveniles, 13 adults) moved an average of 44.7 river miles upstream in a range of 89 to 122 days and were recaptured in the two removal sections upstream of Shiprock Bridge. No tagged channel catfish were captured during nonnative fish removal trips conducted by Utah Department of Wildlife Resources (UDWR) downstream of Mexican Hat, Utah. Since channel catfish in this section are not a closed population, we are violating the assumption that fish are not moving in or out of this section. Due to unknown variables such as tag loss, mortality, emigration and immigration, it was suggested that we base our exploitation estimate only for the first post-tagging trip. For reporting purposes we decided to leave all four trip exploitation rates and total exploitation rates in the table to show the decline in exploitation rates as the year went on, which could be due to the unknown variables. Although one trend that is present is channel catfish exploitation rates were consistently higher for adults than sub-adults over all sampling times.

Equally important in the management of this species is a better understanding of our capture techniques and the associated efficiency of capturing various life stages of our target species. Previous analyzes of our nonnative fish removal data by others suggest that our success in capturing channel catfish < 300mm TL may be limited (J. Morel unpublished data). A similar analysis of catch curves by 1-inch size groups suggests that channel catfish are fully recruited to our gear size once they attain a minimum length of 304-356mm TL (J. Davis unpublished data). Gerhardt and Hubert (1991) reported that in the Powder River drainage, the Ricker and Thompson-Bell model indicated that population structure and abundance of channel catfish would change considerably as exploitation rates (harvest) increased. They reported that an annual exploitation rate of 22% would result in a 75% reduction in overall abundance of fish ≥ 300 mm TL, and cause a substantial shift towards smaller individuals. Using the population estimate for juvenile channel catfish and the actual numbers we removed throughout the year from Shiprock Bridge to Mexican Hat, we estimated a 24% reduction between the population estimate and the estimated number of juvenile fish remaining after all the nonnative removal trips. It is also estimated that we removed 52% of the adult fish population estimate. Similar to 2011, our exploitation rates for adults were much higher than for juveniles. As juvenile fish in the river grow to sizes more susceptible to our gear type, we anticipate larger percentage reductions between pre-exploitation population estimates and the estimated number of fish remaining at the end of the year.

New methods and gear types for effectively capturing juvenile channel catfish are being considered for future efforts and include the use of electric seines, hoop nets and baiting areas prior to removal trips. By employing these new techniques it may be possible to focus our effort at removing size classes of channel catfish that we are currently ineffective in capturing and would likely result in an increase in our overall exploitation rates. Removing smaller sized fish, before reaching sexual maturity, may reduce 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.

Based on the length frequency histograms in all three removal sections, the majority of channel catfish captured in 2012 were juvenile, sub-adult and newly recruited adult fish. A reduction in abundance of large channel catfish, 400-600 mm TL, may be important in not only limiting the reproductive potential of channel catfish in the San Juan River but may also limit 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 and was likely due to the relatively low number of endangered fishes in the San Juan River at the time of their study.

Common carp were once ubiquitous in the San Juan River and during 1991-1997 SJRIP studies were the fourth most abundant fish in electrofishing collections (Ryden 2000). Corresponding with the initiation of intensive removal in each of the three sections, common carp abundance has been greatly reduced to a level of infrequent collection across all studies (Elverud 2010; Ryden 2010). Common carp catch rates in 2012 were < 0.6 in all three removal sections. Mean CPUE for 2012 from Shiprock Bridge to Mexican Hat was the lowest observed CPUE riverwide since intensive nonnative removal began. Prior to the initiation of nonnative removal in each of the three sections, common carp catch rates during annual fall monitoring were relatively high and showed little variance among years. After intensive nonnative removal began in each section, common carp CPUE immediately declined. Common carp CPUE during fall monitoring has been less than one fish per hour of electrofishing for the last five consecutive years in each of the three sections. These declines may not be a direct result of nonnative removal alone but could be a combination of limiting factors such as the regulated flow regime and lack of overbank flow and the natural waterfall prohibiting upstream movement of fish out of Lake Powell.

Common carp are one of the world’s most damaging and invasive fish. Their establishment in a system can lead to declines in vegetation, water quality and native fauna. Nonnative removal combined with other variables has drastically reduced the common carp population in the San Juan River from one of the most abundant fish in the 1990’s to one that is now infrequently collected river wide. This successful management of a very invasive nonnative species is often overshadowed by the trends of channel catfish abundance in the river. While common carp are not predatory, they can still negatively impact native fish communities and affect recovery efforts of endangered. 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.

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 collect large amounts of data on stocked fish and may be used to evaluate the success, or failure, of individual stocking events.

While all rare fish captured in 2012 were considered to be stocked fish, it is encouraging to see hatchery reared fish survive and persist in the river. In 2012, we captured 25 individual adult Colorado pikeminnow. This represents the highest number of adult fish collected during the course of one year of sampling. Additionally, the documented spawning aggregation of adult Colorado pikeminnow found in June of 2012 suggests that the number of sub-adult and adult fish in the San Juan River are reaching numbers that enable them to ‘find’ each other for spawning. Numbers of Colorado pikeminnow that had a PIT tag at time of capture were reduced in 2012 compared to previous years. It has unknown if these fish are still in the river and go undetected throughout the year or if they have moved out of the system or have perished. However with the recent work sampling tributaries of the San Juan River and the installation of remote PIT tag arrays in tributaries and the main stem San Juan, we should get a better idea of how many PIT tagged fish we are missing with our current sampling methodologies. Razorback sucker have shown long term persistence in the San Juan River. Twelve individual fish captured in 2012 had been in the river ten years or more, with one fish persisting in the river 16.5 years. We continued to collect razorback sucker without PIT tags in 2012; however, all fish without PIT tags had scales taken for the study using elemental analysis of scales to determine if they are wild fish or stocked fish that lost a PIT tag.

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. Under the framework of adaptive management, the SJRIP will continue to seek way to improve the efficacy of nonnative fish removal. Complete eradication of these species is not expected; however, using 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 and may result 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.

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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, 2012. 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)	*Ptyluc*	*Xyrtex*	*Ictpun*	*Cypcar*	*Micsal*	*Ameiurus spp*	*Saltru*
July 17-19	788	17.3	89	333	102	15	58	11	5
August 14-16	581	16.3	140	281	199	3	19	6	5
Totals		**33.6**	**229**	**614**	**301**	**18**	**77**	**17**	**10**

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, 2012. [1] Mean discharge from USGS gauge #09368000 near Shiprock, New Mexico.

Trip	Discharge[1] (ft^3/sec)	Effort (hours)	*Ptyluc*	*Xyrtex*	*Ictpun*	*Cypcar*	*Micsal*	*Ameiurus* spp	*Saltru*
March 20-22	944	24.3	33	248	129	13	0	4	5
July 10-12	1,257	27.0	56	143	96	18	6	9	3
August 7-9	581	25.9	170	189	775	8	17	19	2
Totals		**77.2**	**259**	**580**	**1000**	**39**	**23**	**32**	**10**

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; 2012. 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*
Tagging Trip April 12-20	1066								
Totals for trip		**71.5**	**72**	**252**	**4,477**	**19**	**0**	**7**	**5**
April 26 – May 4									
Downstream boats		79.8	88	253	3,042	17	0	18	2
Upstream boats	1,540	82.7	2	1	3,680	10	0	20	0
Totals for trip		**162.5**	**90**	**254**	**6,722**	**27**	**0**	**38**	**2**
June 21 - 29									
Downstream boats		92.3	227	186	7,227	19	4	37	0
Upstream boats	600	87.2	3	0	6,295	20	3	31	0
Totals for trip		**179.4**	**230**	**186**	**13,522**	**39**	**7**	**68**	**0**
August 31- Sept 8									
Downstream boats		94.3	237	143	4,686	18	3	37	0
Upstream boats	555	88.8	1	n/a	4,453	16	1	33	0
Totals for trip		**183.1**	**238**	**143**	**9,139**	**34**	**4**	**70**	**0**
****September 20 - 28**									
Downstream boats		59.4	241	188	4,762	11	3	27	0
Upstream boats	802	90.4	5	n/a	7,251	22	4	75	1
Totals for trip		**149.7**	**246**	**188**	**12,013**	**33**	**7**	**102**	**1**
Totals (excluding tagging trip)		**674.7**	**804**	**771**	**41,396**	**133**	**18**	**278**	**3**

** 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.