ENDANGERED FISH MONITORING AND NONNATIVE SPECIES MONITORING AND CONTROL IN THE UPPER/MIDDLE SAN JUAN RIVER: 2014

FINAL REPORT

PREPARED FOR:

SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM

PREPARED BY:

BOBBY R. DURAN

U.S. FISH AND WILDLIFE SERVICE

NEW MEXICO FISH AND WILDLIFE CONSERVATION OFFICE

3800 COMMONS N.E.

ALBUQUERQUE, NM 87109

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SUBMITTED TO:

SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM

BIOLOGY COMMITTEE

JUNE 26, 2015

EXECUTIVE SUMMARY

1. A total of 20,033 channel catfish and 92 common carp were removed from river miles (RM) 158.7 – 52.9 in 797 hours of electrofishing.

2. Intensive nonnative removal did not take place from PNM Weir to Hogback Diversion. Effort from this section was shifted to removal efforts from Shiprock Bridge to Montezuma Creek, Utah.

3. Channel catfish CPUE values from Hogback Diversion to Shiprock Bridge have fluctuated over time and have not realized significant declines since the initiation of intensive removal.

4. Juvenile channel catfish were the most abundant size class collected from Shiprock Bridge to Mexican Hat, Utah, with catch rates near 20 fish/hour of electrofishing during June and September.

5. Channel catfish CPUE during fall monitoring from Shiprock Bridge to Mexican Hat, Utah, was significantly lower than 2006-07, 2009, and 2011-2012.

6. Mean common carp CPUE was < 1.0 fish/hour in all removal sections during nonnative removal trips as well as annual fall monitoring sampling.

7. A total of 502 (470 unique individuals) Colorado pikminnow and 1,448 (1,197 unique individuals) razorback sucker were collected during our efforts in 2014.

8. Thirty-three adult Colorado pikeminnow (≥ 450 mm total length (TL)) were collected in 2014 including 27 individual fish > 500 mm TL.

9. For the third consecutive year, 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. Twenty-one individual fish captured in 2014 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 (USFWS 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 2014):

Element 3 - Management of Nonnative Aquatic Species

Goal 3.1 Control Problematic Nonnative Fishes.

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

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. Intensified multiple pass electrofishing began in 2001and was focused from PNM Weir to Hogback Diversion (RM 166.6 - 159.0). As changes in distribution and abundance of channel catfish were documented, nonnative fish removal was expanded to include areas of high importance. For example, effort was expanded in 2003 to include another section of river from Hogback Diversion to Shiprock Bridge (RM 158.8 – 147.9) and 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 2014, intensive nonnative removal conducted by NMFWCO occurred over 105.8 river miles of the San Juan River.

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 2014 focused on two individual sections of the San Juan River, New Mexico, Colorado, Utah, encompassing 105.8 river miles (RM). Sections sampled included Hogback Diversion to Shiprock Bridge (RM 158.8 – 147.9), Shiprock Bridge to Montezuma Creek, Utah (RM 147.9 – 94) and Shiprock Bridge to Mexican Hat, Utah (RM 147.9 – 52.9) (Figure 1). Nonnative removal was conducted in portions of Geomorphic reaches 6 through 2 (Bliesner and Lamarra 2000). Hogback Diversion to Shiprock Bridge encompassed portions of both Geomorphic reaches 6 and 5, and Shiprock Bridge to Mexican Hat is 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 were enumerated by size class. At one random stop each day all nonnative fishes were measured (nearest 1 mm) for total length (TL). Seconds of electrofishing were recorded to determine effort at the end of each sampling unit. Sampling units ranged from two to three river miles depending on the section. All nonnative fishes collected were removed from the river. Two electrofishing rafts sampled for three consecutive days/trip from Hogback Diversion to Shiprock Bridge. During sampling from Shiprock Bridge to Mexican Hat, 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) for total and standard length, 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. 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.

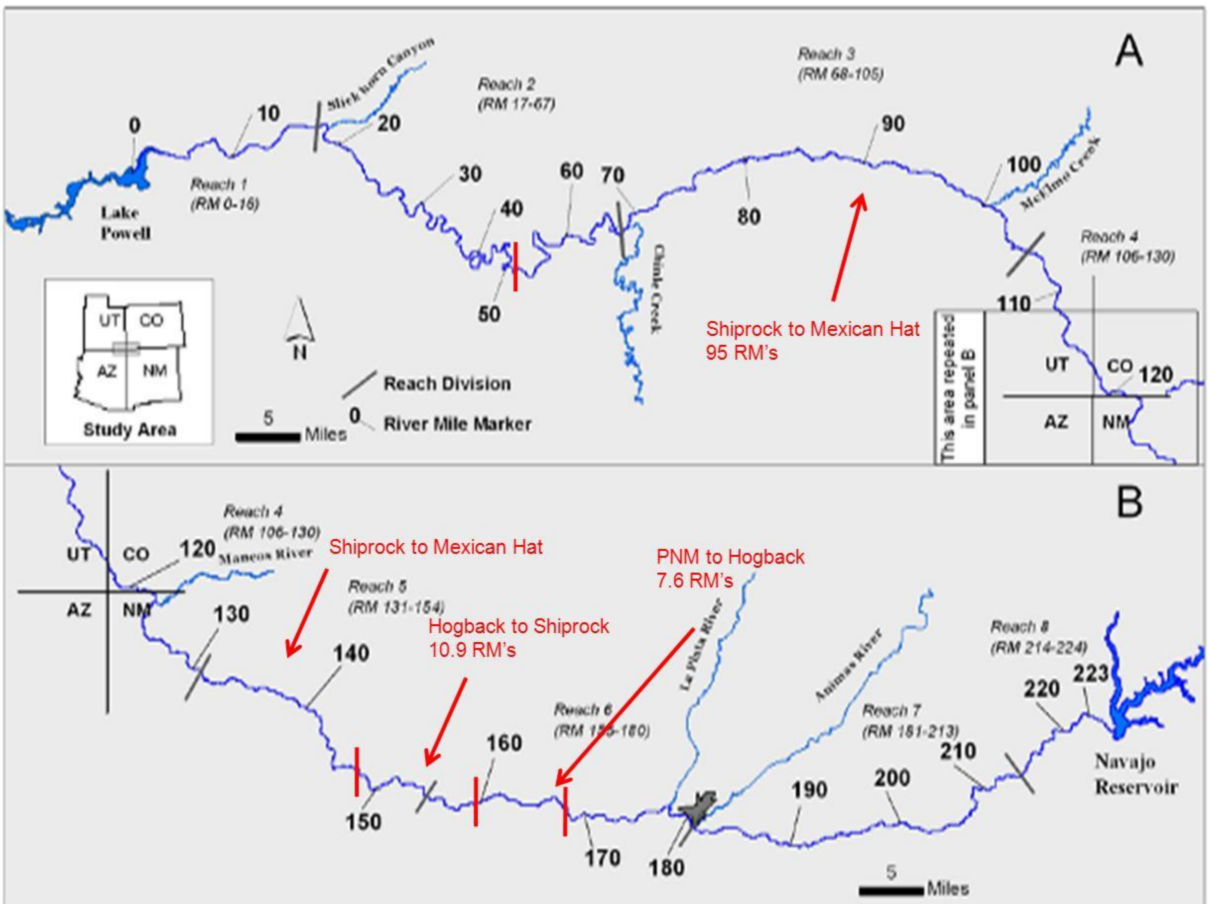

Figure 1. Map of study area – map provided by UNM MSB. Red bars represent boundaries of sampling sections. Black bars represent geomorphic reaches.

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 Systat version 13. Species CPUE was 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 Tukey post-hoc tests were used to determine where significant differences existed. 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 differences 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 fish community monitoring (FWS-Colorado River Project) 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)

Intensive nonnative removal did not take place from PNM Weir to Hogback Diversion in 2014. Effort was shifted to the middle section of the river where channel catfish abundance was higher. A five-day trip was completed from Shiprock Bridge to Montezuma Creek, Utah, in lieu of the two trips from PNM Weir to Hogback Diversion. A total of 769 channel catfish and eight common carp were removed in 52.7 hours of electrofishing (Appendix A-1) from Shiprock Bridge to Montezuma Creek in 2014. This compares with 42 channel catfish and 19 common carp removed during 31.3 hours of electrofishing from PNM Weir to Hogback Diversion in 2013. Only eight channel catfish and one common carp were collected in this section during annual sub-adult and adult fish community monitoring in 2014.

HOGBACK DIVERSION TO SHIPROCK BRIDGE (RM 158.8 – 147.9)

A total of 1,048 channel catfish and 35 common carp were removed during three trips (July and two trips in August) and 80.2 hours of electrofishing (Appendix A-2). In addition to channel catfish and common carp, other nonnative fishes collected included bullhead catfishes *Ameiurus spp.,* and largemouth bass *Micropterus salmoides*.

CHANNEL CATFISH

Channel catfish CPUE in 2014 ranged from 10.3 fish/hour to 15.2 fish/hour (Figure 2). Prior to 2014, a trip through this section was annually completed in March. Due to lower observed catch rates for channel catfish during March trips effort was moved from March to August in an attempt to maximize removal of channel catfish. During the rescheduled August trip 414 channel catfish were collected, compared to 114 fish removed during the March 2013 trip. Mean channel catfish CPUE in 2014, all life stages and trips, was 13.1 fish/hour. No significant differences in channel catfish CPUE were noted among trips in 2014. The majority

(66 %) of catfish collected in 2014 were adults ranging from 350 to 450 mm TL. Channel catfish in 2014 averaged 388 mm TL (range 166 - 730 mm TL).

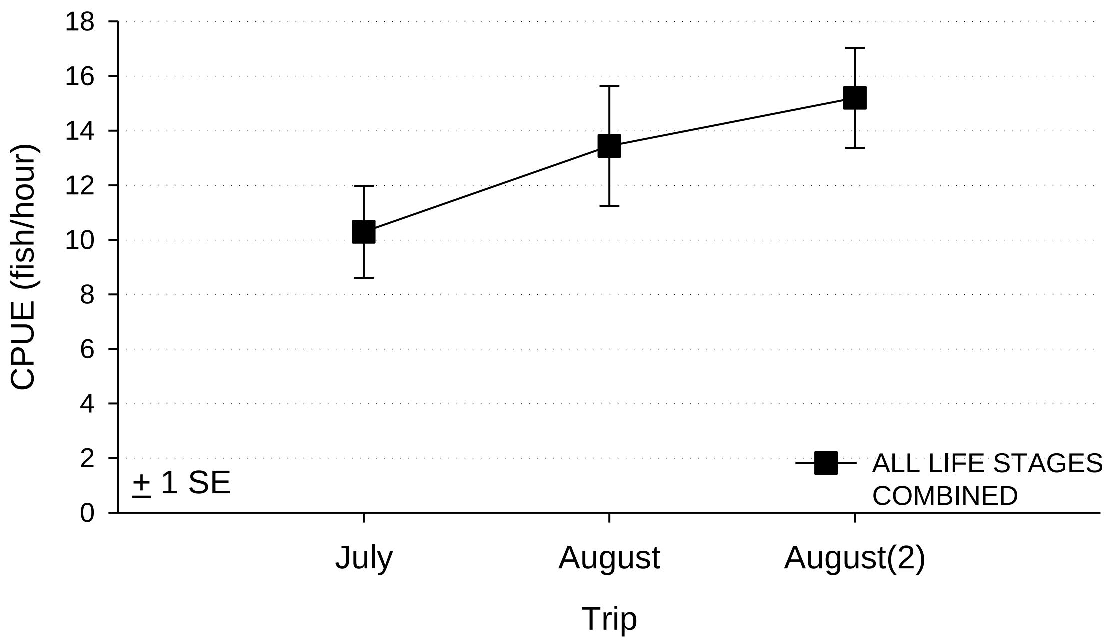

Figure 2. Channel catfish CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge Section; 2014. Error bars represent ± 1 SE.

Mean CPUE for juvenile channel catfish during fall monitoring in 2014 was 5.1 fish/hour compared to 0.7 fish/hour in 2013. Mean CPUE for adult channel catfish during 2014 fall monitoring was 16.1 fish/hour. Juvenile and adult channel catfish CPUE values fluctuated over time and have not realized significant declines pre or post removal (Figure 3).

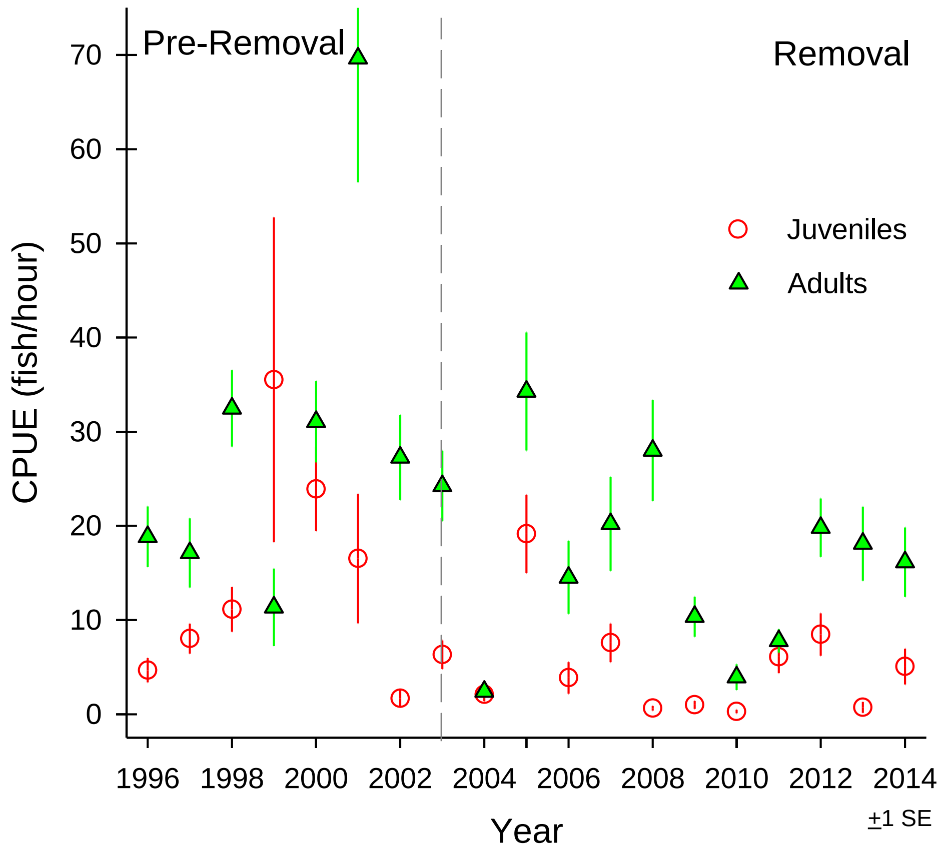

Figure 3. Channel catfish CPUE (fish/hour) during annual fall monitoring by year, Hogback Diversion to Shiprock Bridge; 1996-2014. Adult CPUE is represented by triangles. Juvenile CPUE is represented by circles. The vertical hash line represents the initiation of intensive nonnative removal in this section. Error bars represent ± 1 SE.

COMMON CARP

Common carp catch rates, by trip, were < 1.0 fish/hour and varied little among the three trips in 2014. Mean common carp CPUE, all life stages and trips combined; in 2014 was 0.4 fish/hour (Figure 4). This marked the 5th consecutive year that common carp CPUE was < 1.0 fish/hour.

No common carp were collected during 2013 fall monitoring sampling in this section, and only seven fish were collected during 2014 fall monitoring surveys. Common carp CPUE during annual fall monitoring was 0.9 fish/hour. Common carp CPUE trends generated using fall monitoring data, declined since nonnative removal was initiated in 2003 (Figure 5).

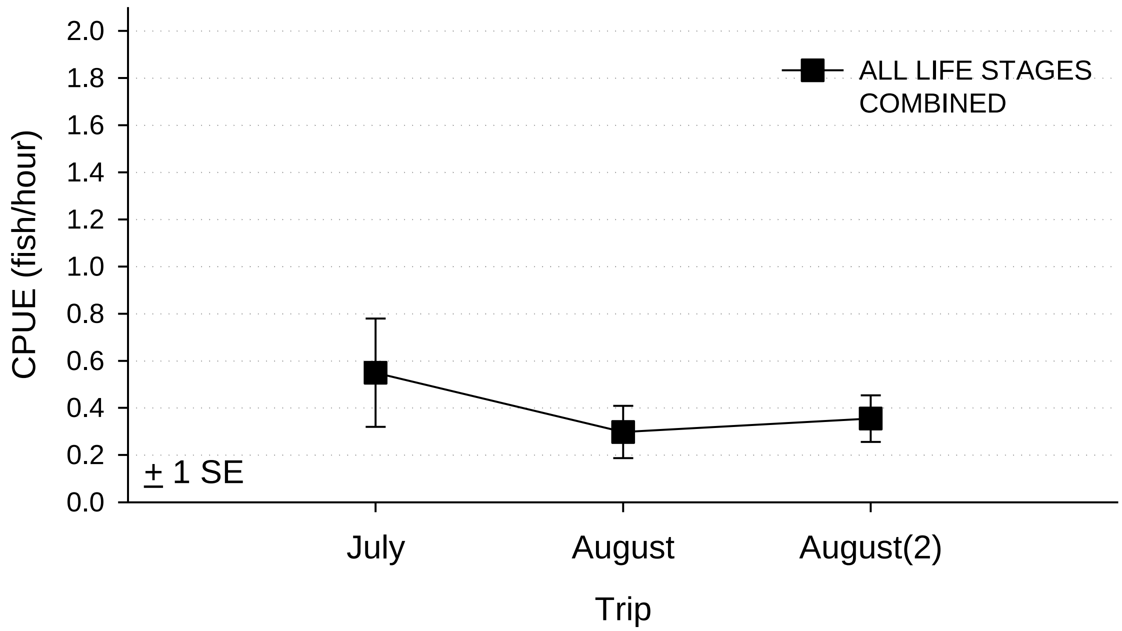

Figure 4. Common carp CPUE (fish/hour) by trip within the Hogback Diversion to Shiprock Bridge section; 2014. Error bars represent ± 1 SE.

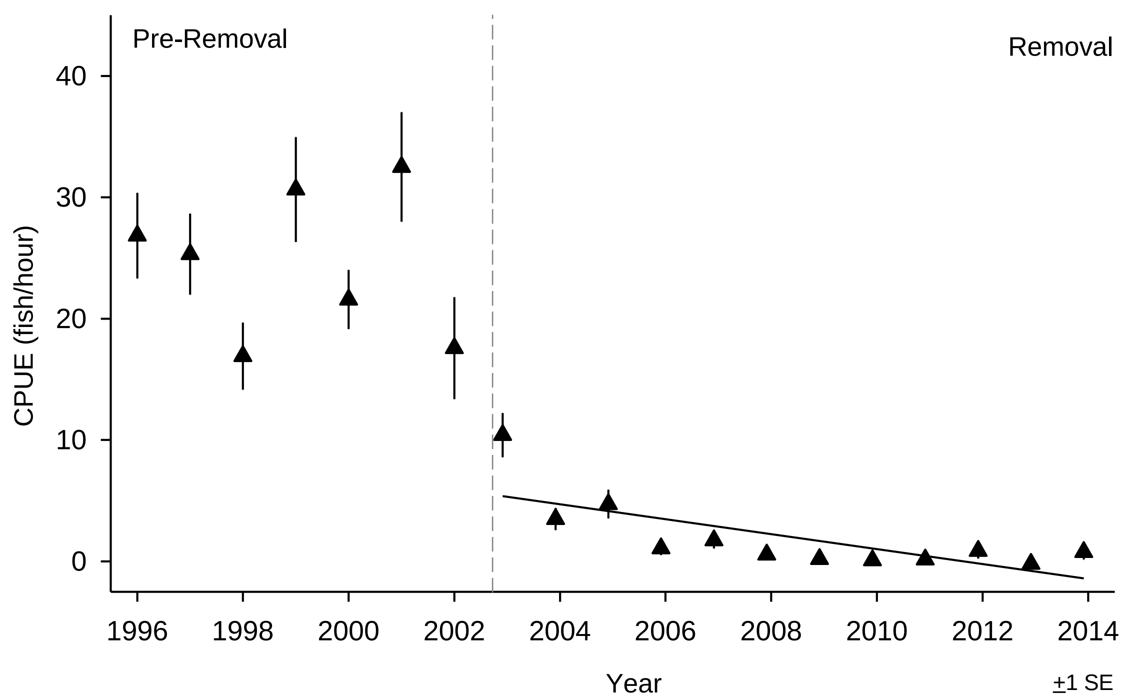

Figure 5. Common carp CPUE (fish/hour) during annual fall monitoring by year, Hogback Diversion to Shiprock Bridge; 1996-2014. A line was fitted to the data if the trend was significant ($y=5.572- 0.615x$; $r^2= 0.53$; $p= 0.007$). The vertical hash line represents the initiation of intensive nonnative 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 2014. During removal trips only, a total of 13,511 channel catfish and 37 common carp were removed in 521.2 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 4,705 channel catfish and 12 common carp in 142.9 hours of electrofishing (Appendix A-3). Due to high abundance of channel catfish in this section, effort was shifted from other reaches of the San Juan River to include additional removal passes in this section including one pass from Shiprock Bridge to Montezuma Creek completed by NMFWCO and four passes (four trips) from Montezuma Creek to Mexican Hat, Utah completed by Utah Division of Wildlife Resources (UDWR) resulting in an additional 4,648 channel catfish and 15 common carp removed in 207.2 hours of electrofishing. For the year, a total of 22,864 channel catfish and 64 common carp were removed during 871.3 hours of electrofishing from Shiprock Bridge to Mexican Hat, Utah. Other nonnative fishes removed included brown trout *Salmo trutta*, rainbow trout *Oncorhynchus mykiss*, bullhead catfishes, green sunfish *Lepomis cyanellus*, and largemouth bass. No striped bass or walleye were collected or observed. In 2014, seven roundtail chub *Gila robusta* were collected.

MARK AND RECAPTURE

To assess exploitation and generate population estimates, channel catfish and common carp collected in April from Shiprock Bridge to Mexican Hat, UT were fitted with an alphanumeric anchor tag. A total of 2,149 channel catfish and nine common carp were tagged during this effort. An additional 184 channel catfish were collected but were too small to tag and were removed from the river. Total length measurements were taken from all fish that were tagged to determine exploitation rates by size classes. Adult channel catfish, ≥ 300mm TL, composed 88% of the total number of channel catfish tagged (N=1,897), while juvenile channel catfish composed 12% (N=252). The majority of adult catfish tagged were newly recruited adults 300-399 mm TL. In addition to nonnative fishes collected, we captured 30 Colorado pikeminnow and 136 razorback sucker during the tagging trip.

Exploitation rates for each size class of channel catfish were generated using recaptures from the first post-tagging trip and for all trips combined including the single pass trips conducted in shorter reaches within this section (Table 1). Exploitation rates ranged from 3.6% for juveniles (200-299mm TL) to 10.1% for larger adults (500-599mm TL) during the post-tagging trip. Total exploitation rate for all size classes for the post-tagging trip was 7.1%. Issues with electrofishing gear and rafts during this trip could be a reason for the low observed exploitation rate. When combining all four removal trips and five single pass removal trips in this section, we observed exploitation rates to rise in each size class. The total exploitation rate for all trips combined was 14.1% with exploitation rates ranging from 7.9% for juveniles to 26.1% for adult channel catfish 600+ mm TL.

Table 1. Channel catfish exploitation rates from Shiprock Bridge to Mexican Hat, UT, 2014. 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 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	12%	53%	27%	5%	1%	100%
	(252)	(1,136)	(578)	(159)	(23)	(2,149)
Trip 1 April/May	3.6 %	7.6 %	6.9 %	10.1 %	8.7 %	7.1 %
	(9)	(86)	(40)	(16)	(2)	(153)
All trips combined including single passes by NMFWCO and UDWR	7.9 %	12.7 %	16.6 %	23.9 %	26.1 %	14.1 %
	(20)	(144)	(96)	(38)	(6)	(304)

During the tagging trip, 1,896 adult, ≥ 300 mm TL, channel catfish were tagged. On the first removal trip in April/May, 2,722 adult fish were captured including 145 anchor-tagged fish. The Lincoln-Petersen with Chapman's correction population estimate for adult channel catfish from Shiprock Bridge to Mexican Hat, UT was 35,379 (95% CI = 29,702-41,057; CV=8.02%, SE=2,839).

A total of 252 juvenile fish (200-299mm TL) were tagged in 2014. During the post tagging removal trip, a total of 1,080 juvenile fish were captured including nine anchor-tagged fish. The Lincoln-Petersen with Chapman's correction population estimate for juvenile channel catfish from Shiprock Bridge to Mexican Hat, UT was 27,348 (95% CI = 10,933-43,763; CV=30.01%, SE=8,208).

A Lincoln-Petersen with Chapman's correction population estimate was completed for common carp in 2014. Nine common carp were tagged and 18 common carp were collected during the first post tagging trip, with two fish being recaptured fish. The adult carp population estimate from Shiprock Bridge to Mexican Hat, UT was 62 (95% CI = 5-120; CV=45.88%, SE=28.6).

Using the generated population estimates for juvenile and adult channel catfish and the actual numbers of fish removed each trip; we calculated 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. Using these estimates, we removed 28.6 % of the adult channel catfish population estimate (Table 2) and 18.7% of the juvenile population estimate (Table 3) from Shiprock Bridge to Mexican Hat, Utah, in 2014. A similar estimate of percentage of fish removed has been completed annually since 2011(Figure 6). Juvenile channel catfish population estimates have declined each year resulting in a 2014 juvenile population estimate that was lower than the adult population estimate. This would be expected as larger population of juvenile fish from previous years recruit to adulthood.

Table 2. Number of adult channel catfish removed during each trip. The percent 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	2,574	7.3	32,805
June	2,642	8.1	30,163
September	1,135	3.8	29,028
Fall monitoring	1,604	5.5	27,424
Shifted effort single passes	1,424		
Total	9,379	28.6	23,426

Table 3. Number of juvenile channel catfish removed during each trip. The percent 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	1,080	3.9	26,268
June	1,824	6.9	24,444
September	546	2.2	23,898
Fall monitoring	538	2.3	23,360
Shifted effort single passes	913		
Total	4,901	18.7	21,367

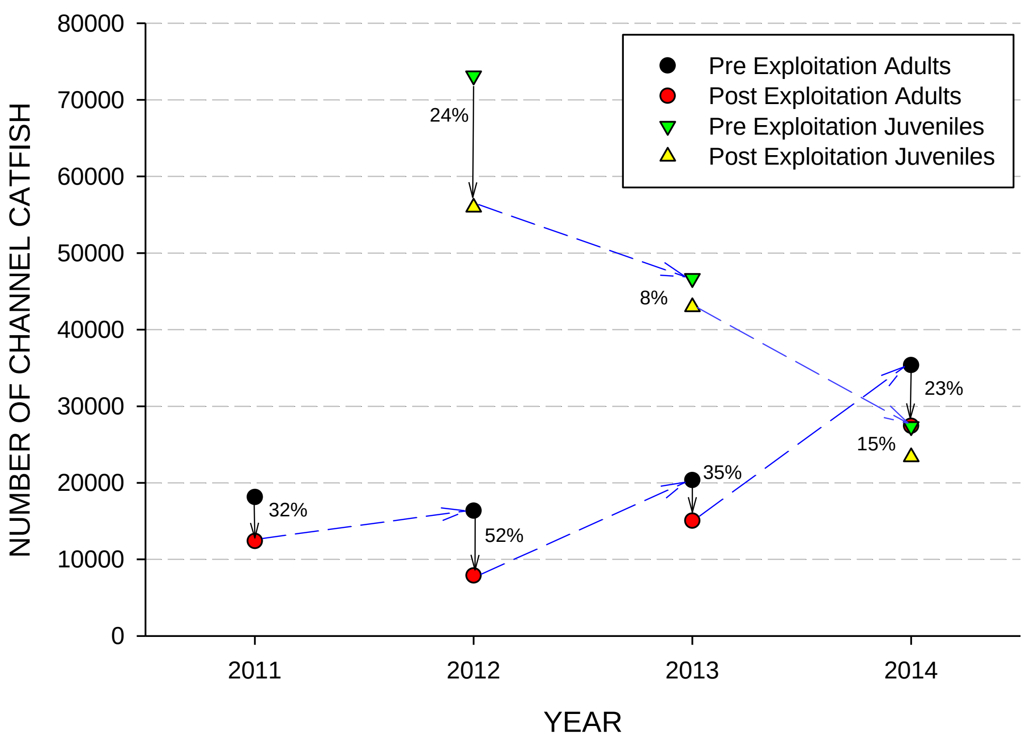

Figure 6. Pre and post exploitation estimates for adult and juvenile channel catfish, Shiprock Bridge to Mexican Hat, Utah: 2011-2014. Percentages represent the reduction between population estimates at the beginning of the year before sampling versus the estimated number of fish remaining after the four removal trips.

REMOVAL TRIPS

CHANNEL CATFISH

Channel catfish CPUE, all life stages combined, varied among trips in 2014 (Figure 7). Juvenile channel catfish CPUE ranged from 8.6 to 19.2 fish/hour, with the highest catch rates occurring in June and September (fall monitoring). Adult channel catfish CPUE ranged from 6.2 to 15.8 fish/hour of electrofishing. Mean CPUE for all life stages and trips combined was 27.3 fish/hour.

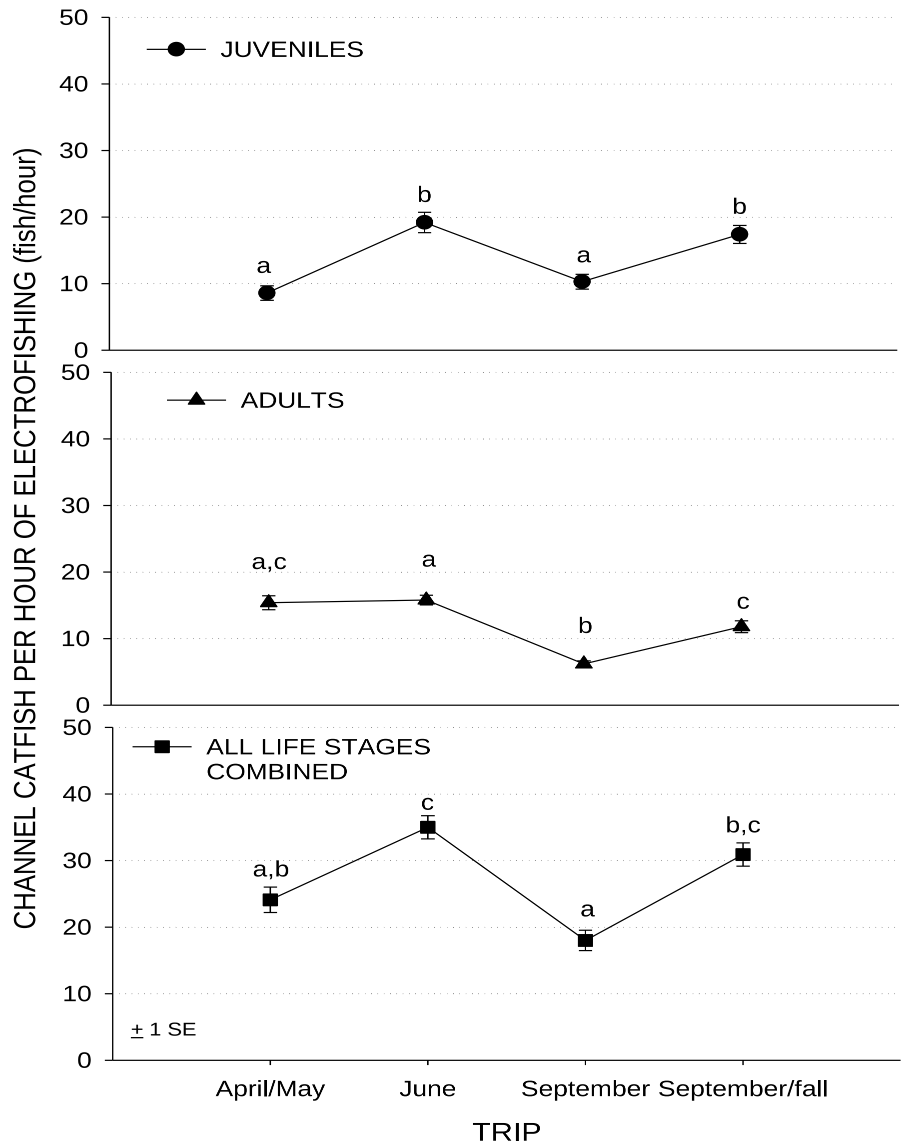

Figure 7. Channel catfish CPUE (fish/hour) by trip from Shiprock Bridge to Mexican Hat; 2014. Error bars represent ± 1 SE. Letters represent comparisons among trips (Tukey post-hoc). Trips with the same letter did not differ from each other.

Before intensive removal began in 2006, juvenile channel catfish catch rates generated from fall monitoring data were fairly consistent among years (Figure 8). Post removal, juvenile catch rate trends have exhibited a general increase over time; however, juvenile catch rates in 2014 were significantly lower than observed values in 2007, 2009, 2011 and 2012. Catch rates for juvenile and adult channel catfish in 2013 were the lowest observed values during fall monitoring since 1996. Adult catch rates during fall monitoring have fluctuated among years as newly recruited adults have become susceptible to our gear type. Adult catch rates in 2014 were higher than 2013 values but significantly lower than 2006, 2009 and 2012.

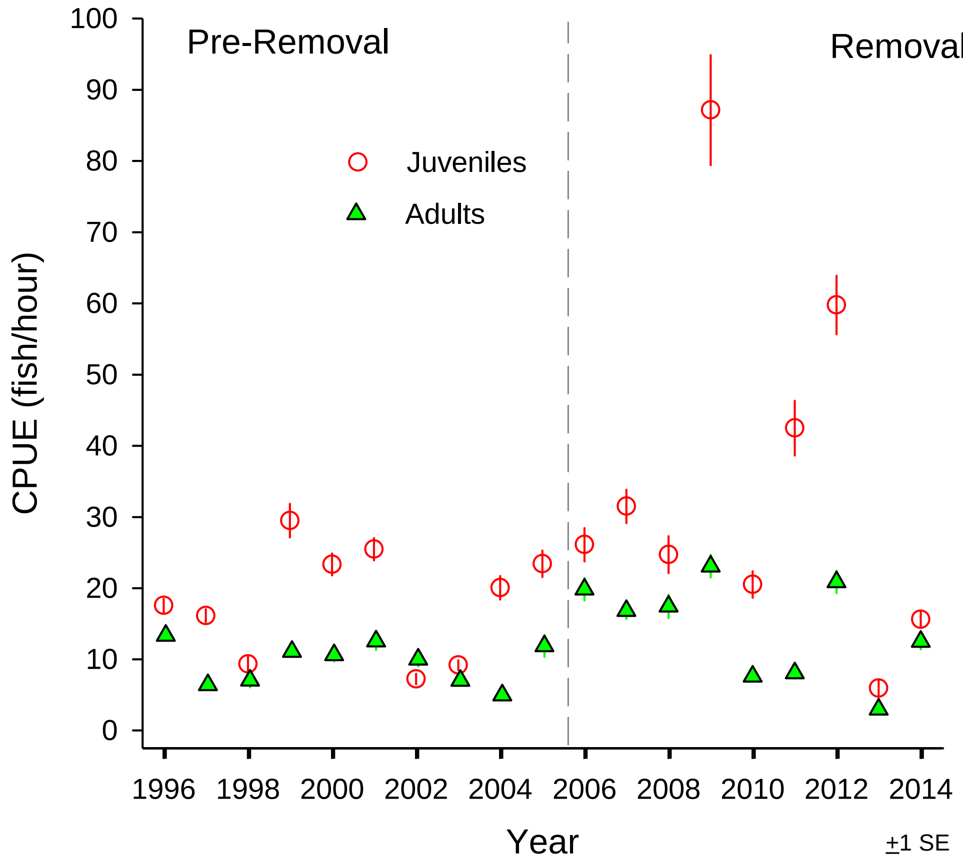

Figure 8. Channel catfish CPUE (fish/hour) during annual fall monitoring by year, Shiprock Bridge to Mexican Hat; 1996-2014. Adult CPUE is represented by triangles. Juvenile CPUE is represented by circles. The vertical hash line represents the initiation of intensive nonnative removal in this section. Error bars represent ± 1 SE.

Mean total length of channel catfish in 2014 was 280 mm (range 34 to 670 mm). Fifty percent of measured channel catfish were < 300 mm TL, 34.4 % were between 300 – 400 mm TL, and 15.7 % were > 400 mm TL. The distribution of size classes collected in 2014 was similar to that observed in 2013.

COMMON CARP

Catch rates for common carp were < 0.12 fish/hour during each of the four removal trips conducted in 2014 (Figure 9). Mean common carp CPUE in 2014 was 0.08 fish/hour. This was the lowest observed catch rate for common carp in this section since nonnative removal began on the San Juan River.

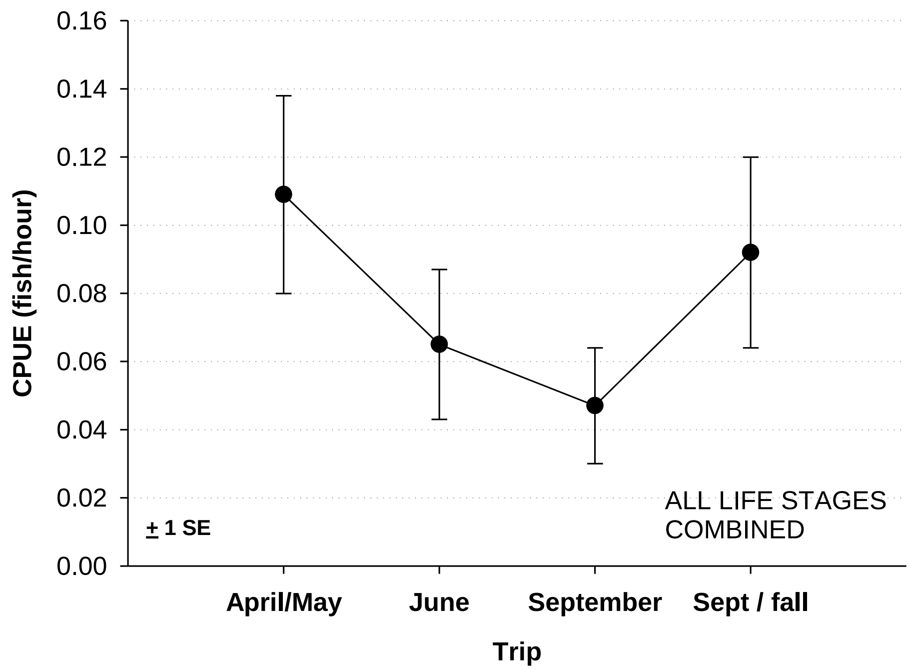

Figure 9. Common carp CPUE (fish/hour of electrofishing) during 2014 nonnative removal trips from Shiprock Bridge to Mexican Hat. Error bars represent ± 1 SE.

A comparison of common carp catch rates among years of adult fall monitoring shows a decline in CPUE during pre-removal efforts and continuing after intensive removal began in 2006 (Figure 10). Catch rates have remained < 1.0 fish/hour for the last six years. Catch rates in 2014 were significantly lower than observed values pre- removal.

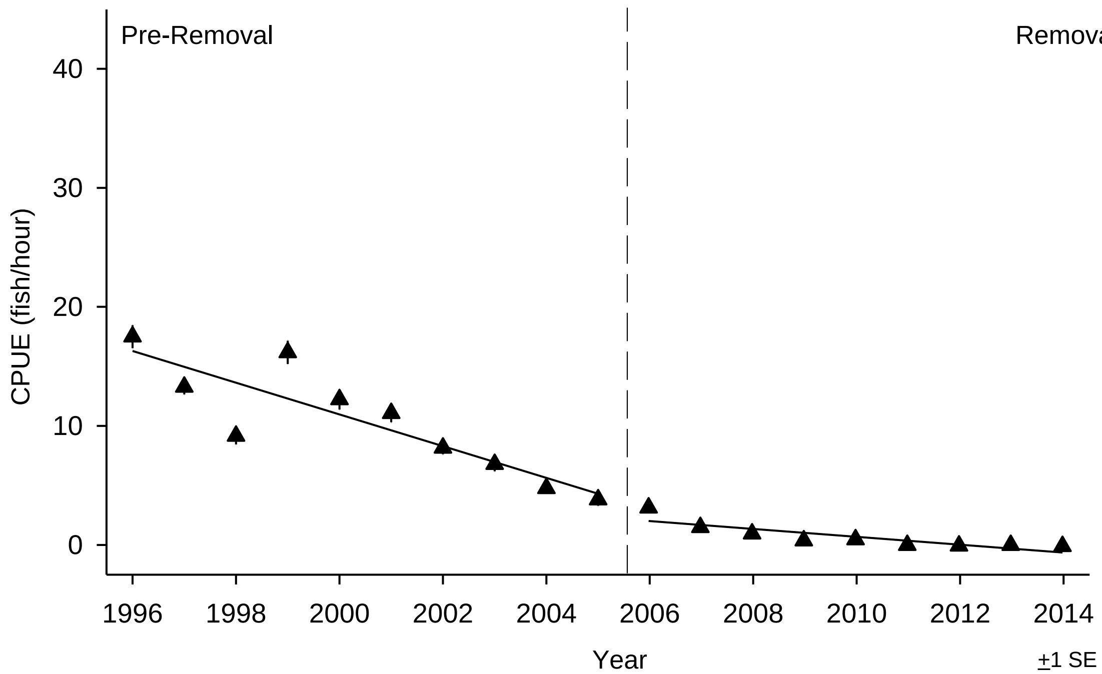

Figure 10. Common carp CPUE (fish/hour) during annual fall monitoring by year, Shiprock Bridge to Mexican Hat; 1996-2014. A line was fitted to the data if the trend was significant (96-05: y= 16.289 – 1.332x; $r^2 = 0.77$; $p<0.001$; 06-14: y= 2.194 – 0.331; $r^2= 0.73$; p=0.003). The vertical hash line represents the initiation of intensive nonnative removal in this section. Error bars represent ± 1 SE.

RARE FISH COLLECTIONS

A total of 502 Colorado pikeminnow (470 individual fish) and 1,448 razorback sucker (1,197 individual fish) were captured during nonnative removal trips from Hogback Diversion to Mexican Hat, Utah (Appendix A-3). A total of 91 Colorado pikeminnow and 570 razorback sucker were collected from Hogback Diversion to Shiprock Bridge; 105 Colorado pikeminnow and 128 razorback sucker were collected from Shiprock Bridge to Montezuma Creek; and 271 Colorado pikeminnow and 618 razorback sucker were collected from Shiprock Bridge to Mexican Hat. These totals do not include rare fishes collected during the shifted effort done from Montezuma Creek to Mexican Hat conducted by UDWR and does 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 fishes 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 2014 were considered to be stocked fish. A total of 59 individual fish had PIT tags at time of capture. Recaptures of PIT tagged fish ranged from 1 to 4,468 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 (66%, n= 39) were captured < 730 days since first encounter, and 25 fish were recaptured > 730 days since first encounter. Year classes were only assigned to fish with a known PIT tag history and did not include newly PIT tagged fish. Various year classes were collected dating back to 2004; however, the 2011 year class comprised the majority of recaptures (Table 4).

Table 4. Summary of Colorado pikeminnow, by known year class, collected during nonnative fish removal; 2014.

Year class	N
2004	1
2005	7
2006	8
2007	6
2008	2
2009	3
2010	1
2011	28
2012	14
2013	4

A total of 132 Colorado pikeminnow were implanted with a PIT tag at the time of capture. These newly implanted fish ranged in size from 148 – 620 mm TL, with a mean TL of 236 mm. Two hundred-sixty fish were not implanted with a PIT tag because they were < 150 mm TL. Mean TL of Colorado pikeminnow collected during our efforts in 2014 was 204 mm TL (range = 54 – 745 mm TL). Fish < 150 mm TL composed 51.7 % (n = 243) of the total catch while fish > 400 mm TL composed 8.5 % (n = 40) of the catch. Thirty-three adult Colorado pikeminnow were collected including six individual fish ranging from 450 – 500 mm TL and 27 individuals > 500 mm TL.

For the third consecutive year a possible spawning aggregation of adult Colorado pikeminnow was found at RM 118. Three adult, tuberculate, males (570-710 mm TL) were collected on June 21st in close proximity. An additional two adult Colorado pikeminnow (601,670 mm TL) were collected on June 20th around river mile 130. Both of these adults were tuberculate males. Suspected spawning aggregations from this data set were further verified under a separate study. Two submersible PIT tag readers were deployed around river mile 119 during the same time as nonnative fish removal. From June 25th to June 29th, 13 individual Colorado pikeminnow were detected by the readers. Capture history of these fish show that they were adult fish, with 11 of them being > 500 mm TL.

RAZORBACK SUCKER

All razorback sucker collected in 2014 were considered to be stocked fish. Sixty-seven razorback sucker were lacking PIT tags at time of capture. These fish ranged in size from 376 - 555 mm TL, with a mean of 468 mm TL, so we assumed these fish were stocked fish that lost a PIT tag or were stocked from NAPI ponds in earlier years without a PIT tag. The majority of untagged razorback sucker had fin rays collected for a study using elemental analysis to determine razorback sucker natal origin. All 67 of these fish were implanted with a 134.2 kHz PIT tag prior to release. Razorback sucker in 2014 averaged 459 mm TL and sizes ranged from 282 – 585 mm TL. Of the 1,198 individual fish measured, 75% (n = 900) were adult fish (> 400mm TL). Of these adult fish, 171 fish were > 500 mm TL. Various known age classes of razorback sucker were recaptured dating back to 1997 with the majority (80%) of recaptures composed of the 2008-2010 year classes (Table 5).

Table 5. Summary of razorback sucker by age class collected during nonnative fish removal; 2014.

Year class	N
1997	1
1999	6
2000	9
2001	22
2002	7
2003	5
2004	5
2005	1
2006	39
2007	66
2008	307
2009	312
2010	336
2012	73

Days in river since first encounter ranged from 1 – 5,045 days. Of the 1,189 razorback sucker that had a known stocking history, 31.9% (n=379) were recaptured < 1 year since first encounter and 10.4% (n=124) were recaptured > 5 years since first encounter. Twenty-one individuals were recaptured 10 years since first encounter.

DISCUSSION

Intensive nonnative removal was initiated in 2001 from PNM Weir to Hogback Diversion. Channel catfish catch rates in recent years leading up to 2014, remained relatively low and stable compared to years pre-intensive removal. In an effort to maximize our efficiency and target channel catfish in areas of higher abundance, funds and personnel for the two trips from PNM Weir to Hogback Diversion in 2014 were shifted in order to complete one 5-day trip from Shiprock Bridge to Montezuma Creek, Utah. Data from annual fall monitoring in 2014 failed to identify a channel catfish population rebound in the absence of nonnative fish removal. This was illustrated in that only eight channel catfish were collected in this section during 2014 fall monitoring.

In 2003, nonnative removal efforts were expanded to include the Hogback Diversion to Shiprock Bridge section. Due to low spring catch rates the March trip in 2014 was moved to August. Even with higher catch rates in summer sampling compared to spring sampling, the numbers of fish removed in 2014 were lower compared with the numbers removed in 2013. Channel catfish catch rates for juvenile and adult fish during 2014 fall monitoring were similar to recent years. The majority of channel catfish collected in this section in 2014 were large adults ranging from 350 to 450 mm TL. Twenty-two channel catfish were recaptured that were originally tagged downstream of Shiprock Bridge and Mexican Hat, Utah. These recaptures illustrate long range upstream movement and the potential to repopulate upstream removal reaches throughout the year. This long range movement and the absence of any impediments to upstream movement at Shiprock Bridge could be a main factor as to why we have not observed significant declines in catch rates this section. Although each section removal section is analyzed and presented independently, it is important to recognize the effect that high channel catfish abundance in other areas may have on removal sections through immigration.

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 2014, fall monitoring data showed that juvenile channel catfish catch rates were similar to 2013 but still lower than 2007, 2009 and 2011-2012 values. Catch rates for juvenile and adult fish during fall monitoring 2013 were the lowest observed catch rates since fall monitoring began in 1996. These low catch rates in 2013 may have been a result of poor sampling conditions due to high flows and increased turbidity. Catch rates for both life stages of channel catfish during fall monitoring in 2014 seemed to increase, although statistically only adult catch rates were significantly higher. Even with the increased effort and two passes per trip in this section, no declining trend has been observed for either life stage of channel catfish. Catch rates for juvenile channel catfish have actually increased since intensive removal began in this section. Similar increases in juvenile channel catfish catch rates were observed after the initial years of intensive removal in the uppermost section of our study area 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). Regardless, if increases in juvenile abundance are a response to exploitation, or other unknown factors, it may be critical to maintain or even increase intensive removal efforts to facilitate a declining population trend. Increased, or focused, removal efforts should concentrate on high priority areas that target the highest channel catfish abundances and size classes most susceptible to our gear type.

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 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 18.7% 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 28.6% of the adult fish population estimate. Similar to previous years, our exploitation rates for adults were much higher than for juveniles. As juvenile fish reach 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 holding seines below riffles after shocking boats pass by to collect channel catfish that are in tetany but slow to rise to the surface and missed by the electrofishing rafts and baiting areas prior to removal trips to concentrate channel catfish in known areas. 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 with the production of 41,500 eggs/fish at 380 mm TL. In 2012, in an attempt to disrupt channel catfish spawning, the summer trip from Shiprock Bridge to Mexican Hat that was typically completed in July was moved to June. This was an effort to target channel catfish either aggregating for spawning or disrupt males guarding egg nests. Although 2014 was the third consecutive year of this effort, no clear response can be quantified.

The majority of channel catfish captured in 2014 were juvenile, sub-adult, and newly recruited adult fish. Channel catfish greater than 400 mm TL comprised 17.5% of all catfish measured in 2014. A reduction in abundance of large channel catfish, greater than 400 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.

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 2014 were < 1.0 in all removal sections, and were < 1.0 fish/hour during fall monitoring for the 6th consecutive year. Mean CPUE for 2014 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 the upper two 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 of the two sections, common carp CPUE immediately declined. These declines may be a result of a combination of factors including intensive nonnative removal efforts, a regulated flow regime resulting in a lack of overbank flow and the waterfall at Clay Hills 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.

In 2014, we captured 33 individual adult Colorado pikeminnow. This represents the highest number of adult fish collected during one year of sampling. Additionally, the documented spawning aggregation of adult Colorado pikeminnow found in June for three consecutive years suggests that the numbers of sub-adult and adult fish in the San Juan River are reaching numbers that enable them to ‘find’ each other for spawning. The two submersible PIT tag readers deployed near the RM 119 in June were able to detect 13 adult Colorado pikeminnow in the same general area. While it is unknown if these fish were in spawning condition, it is assumed they were in the area in connection with the known spawning aggregation. Numbers of Colorado pikeminnow that had a PIT tags at time of capture were reduced in 2014 compared to previous years. It is 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 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 are missed with current sampling methodologies. Razorback sucker have shown long term persistence in the San Juan River. Twenty-one individual fish captured in 2014 had been in the river ten years or more. We continued to collect razorback sucker without PIT tags in 2014; however, fin rays were taken from untagged razorback sucker for a study using elemental analysis of fin rays to determine natal origin.

Under the framework of adaptive management, the SJRIP will continue to seek ways to improve the efficacy of nonnative fish removal. By using data collected from annual fall monitoring to assess long term trends, we have moved away from trying to maintain trips consistent in time and section each year to instead focus on areas of known higher channel catfish abundance. In 2014, we started this transition by shifting effort from areas of known lower channel catfish abundance, such as PNM Weir to Hogback Diversion, to areas of higher abundance. Utah Division of Wildlife Resources also shifted effort from downstream of Mexican Hat, UT to include four trips from Montezuma Creek to Mexican Hat, UT in 2014. We feel this shift in effort is needed to focus on the areas of highest abundance at certain times of the year when we can maximize our capture efficiency. Complete eradication of these species is not expected; however, using multiple pass sampling 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 Shiprock Bridge to Montezuma Creek, Utah, 2014. 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 7-11	857	52.7	105	128	769	8	2	17	0
Totals		**52.7**	**105**	**128**	**769**	**8**	**2**	**17**	**0**

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, 2014. [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 15-17	1,310	25.3	10	180	271	15	2	5	0
August 6-8	784	27.4	40	202	363	9	0	19	0
August 12-14	597	27.5	41	188	414	11	0	15	0
Totals		**80.2**	**91**	**570**	**1,048**	**35**	**2**	**39**	**0**

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; 2014. Endangered fishes 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 10-18									
Totals for trip	720	**90.6**	**30**	**136**	**2,333**	**10**	**1**	**12**	**9**
April 24 – May 2									
Downstream boats	1,074	80.4	30	215	1,974	12	0	1	0
Upstream boats		83.1	3	n/a	2,052	5	0	5	1
Totals for trip		**163.5**	**33**	**215**	**4,026**	**17**	**0**	**6**	**1**
June 19 - 27									
Downstream boats	1,081	89.8	95	243	3,131	11	1	10	2
Upstream boats		80.8	6	1	2,912	1	1	15	1
Totals for trip		**170.6**	**101**	**244**	**6,043**	**12**	**2**	**25**	**3**
August 28- Sept 5									
Downstream boats	577	93.9	128	159	1,502	5	0	16	0
Upstream boats		93.1	n/a	n/a	1,940	3	0	6	0
Totals for trip		**187**	**128**	**159**	**3,442**	**8**	**0**	**22**	**0**
****September 18 - 26**									
Downstream boats	906	63.5	206	134	2,033	6	0	22	0
Upstream boats		79.3	9	n/a	2,672	6	0	17	0
Totals for trip		**142.8**	**215**	**134**	**4,705**	**12**	**0**	**39**	**0**
Totals (excluding tagging trip)		**664.1**	**477**	**752**	**18,216**	**49**	**2**	**92**	**4**

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