Non-native species monitoring and control in the upper San Juan River, New Mexico 2004

FINAL REPORT

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SAN JUAN RIVER RECOVERY IMPLEMENTATION PROGRAM

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prepared by:

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submitted to:

San Juan River Recovery Implementation Program
Biology Committee

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EXECUTIVE SUMMARY

Intensive non-native removal in 2004 on the upper San Juan River marked the fourth year of such efforts. A total of 6,925 channel catfish *Ictalurus punctatus* and 1,216 common carp *Cyprinus carpio* were removed from RM's 166.6 – 147.9 during 10 removal trips. Of the 10 trips, 6 were conducted from PNM Weir to Hogback Diversion (RM's 166.6 – 159.0) and four from Hogback Diversion to Shiprock Bridge, New Mexico (RM's 158.8 – 147.9). In addition to intensive removal efforts, opportunistic removal during riverwide monitoring trips continued in 2004.

PNM Weir to Hogback Diversion - SECTION 1

Channel catfish CPUE (fish / hour of electrofishing) varied among trip by trip comparisons with the highest CPUE occurring during June-August sampling trips. Among year comparisons revealed no apparent reduction in CPUE (all life stages combined), 2001-2004. However, there were continued reductions in adult CPUE and associated increases in juvenile ($p < 0.001$) CPUE. Channel catfish mean total length (mm) continued to decline since 1999 ($p < 0.001$). Juvenile channel catfish comprised < 1% of total catch in 1999 and > 45% in 2004 while channel catfish > 500 mm comprised 52.6% of the catch in 1999 compared to 3.5% in 2004. Common carp CPUE declined ($p< 0.001$) from 2001-2004 to a four year low CPUE of 5.07 fish / hour. There has been no apparent reduction in mean TL of common carp with adult fish still comprising over 90% of the catch.

Largemouth bass *Micropterus salmoides* were collected in this Section in 2004. The six trip CPUE of 3.69 fish / hour was the highest observed among 2001-2004 comparisons. Prior to 2004, collections of largemouth bass were incidental with CPUE < 0.3 fish / hour. The largest collection in 2004 occurred during the 17-19 August trip with 14.7 fish / hour collected. All largemouth bass collected ranged from 40 – 187 mm TL.

Hogback Diversion to Shiprock Bridge – SECTION 2

Similar to efforts upstream, channel catfish CPUE varied seasonally within this reach. Catch rates for all size classes combined did not decline between 2003-2004. Adult CPUE decreased ($p < 0.001$) from 46.4 to 27.1 fish / hour, 2003-2004, while juvenile CPUE increased ($p < 0.001$). Mean total length of channel catfish decreased between years (2003 Mean TL = 386.4 mm; 2004 Mean TL = 333.2). Common carp CPUE declined ($p < 0.001$) from 29.3 fish / hour in 2003 to 9.1 fish / hour in 2004. No apparent declines in mean TL of common carp were observed. Catch rates for channel catfish were higher ($p = 0.003$) within this Section compared to CPUE in the PNM Weir to Hogback Diversion Section.

Riverwide Removal

Decreasing trends in riverwide non-native CPUE continued in 2004 with both channel catfish and common carp CPUE at the second lowest levels observed among 1998-2004 comparisons. Adult channel catfish CPUE was at the lowest levels observed during riverwide monitoring among 1998-2004 comparisons. Juvenile channel catfish CPUE increased in 2004 ($p < 0.001$) but were still at levels lower than 2001, when intensive removal began. Large adult channel catfish continued to comprise less of the total channel catfish catch in 2004. Mean TL of channel catfish declined in 2004 and represented the smallest mean TL among 1998-2004 comparisons ($p < 0.001$). Common carp CPUE for all size classes combined was slightly up in 2004 but remained at levels below those observed in 1998. Adult common carp CPUE are at the lowest levels among 1998-2004 comparisons ($p < 0.001$). Declines in common carp are due to reductions in the number of adults removed with juvenile common carp continuing to comprise < 10% of the catch.

Removal efforts on the San Juan River, intensive and riverwide, has seen encouraging results in the control and monitoring of channel catfish and common carp since 2001. Fewer large, fecund adult channel catfish and continued declines in mean size have presumably reduced reproductive potential of channel catfish. Reductions in riverwide common carp abundance have likely limited negative interactions with native fish while greatly reducing the overall biomass of carp in the San Juan River.

Continued removal efforts may aid recovery actions for both razorback sucker and Colorado pikeminnow in the San Juan River. Augmentation is currently centered in upper portions of the San Juan River where intensive non-native removal occurs. Fewer non-native fish present may give rare fish a competitive edge and reduce overall negative interactions, including predation, resulting in higher retention rates further upstream in the system.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The presence of non-native fishes within the San Juan River may have deleterious effects on recovery efforts for Colorado pikeminnow *Ptychocheilus lucius* and razorback sucker *Xyrauchen texanus*. Channel catfish *Ictalurus punctatus* and common carp *Cyprinus carpio* may affect native aquatic communities through trophic interactions (direct predation, possible competition for food), spatial interactions (competition for habitat, spawning space or feeding areas), and by habitat alteration (Brooks et al. 2000; Minckley 1991; Sigler 1987; Tyus and Saunders 2000). Of these factors, only direct predation and aggressive behavior/harassment has been documented on the San Juan River (Brooks et al. 2000 and Ryden, personal communication). Opportunistic removal of non-native fishes began in 1996 and was formally adopted as a management tool in 1998. United States Fish and Wildlife Service (FWS), New Mexico Fishery Resources Office (NMFRO) evaluated numerous capture techniques and determined that raft mounted electrofishing was the most efficient method to remove large bodied non-native fish (Brooks and Smith 2005).

Removal efforts by NMFRO officially began in 1998 with intensified efforts beginning in 2001. Efforts focused on a 7.6 mile reach of river located near Fruitland, NM (Figure 1). Determination for location of concentrated removal efforts was influenced by information on adult fish distribution and abundance collected and reported on by FWS – Grand Junction (FWS-GJ) (Ryden 2000). Data suggested that distribution of channel catfish and common carp were limited upstream of PNM Weir (RM 166.6) and that the majority of non-native fishes within Geomorphic Reaches 6 and 5, as described by Bliesner and Lamarra (2000), were considered adult. Presence of water diversion structures that may serve as potential impediments to upstream fish movement and the propensity of large adult non-native fishes determined where intensive removal efforts would take place.

Efforts in 2004 marked the fourth consecutive year of removal from PNM Weir to Hogback Diversion (RM 166.6 - 159.0). Due to seasonal variance in catch rates (CPUE; fish/hour of electrofishing) of non-native fishes, efforts were expanded to include an additional 11.1 river miles immediately downsteam. Mark/recapture work conducted by NMFRO documented upstream movement into the study reach by channel catfish and common carp (Davis and Coleman 2004). These movement patterns correspond to the construction of a non-selective fish ladder completed in 2001 at RM 159.0. Hogback fish ladder allows for unobstructed movement by all fish species, including non-natives. In addition to intensive non-native removal trips, opportunistic removal riverwide during sub-adult and adult fish monitoring trips has occurred since 1996.

Study objectives were:

1. Continue data collection and mechanical removal of non-native species during main channel adult rare fish monitoring efforts.
2. Evaluate distribution and abundance patterns of non-native species to determine effects of mechanical removal on abundance and distribution patterns.
3. Continue transplantation of channel catfish to fishing impoundments isolated from the San Juan River.
4. Characterize the distribution and abundance of striped bass *Morone saxatilis* upstream of Lake Powell during removal efforts and determine predative impacts via stomach content analysis.
5. Develop catch per unit effort targets for use in evaluation of mechanical removal in discrete river reaches.

STUDY AREA

Non-native fish were removed from the San Juan River; Colorado, New Mexico, Utah; in all accessible habits from Farmington, New Mexico (Animas River confluence [RM 180.0]) downstream to Clay Hill's Landing (RM 2.9), Utah (Figure 1).

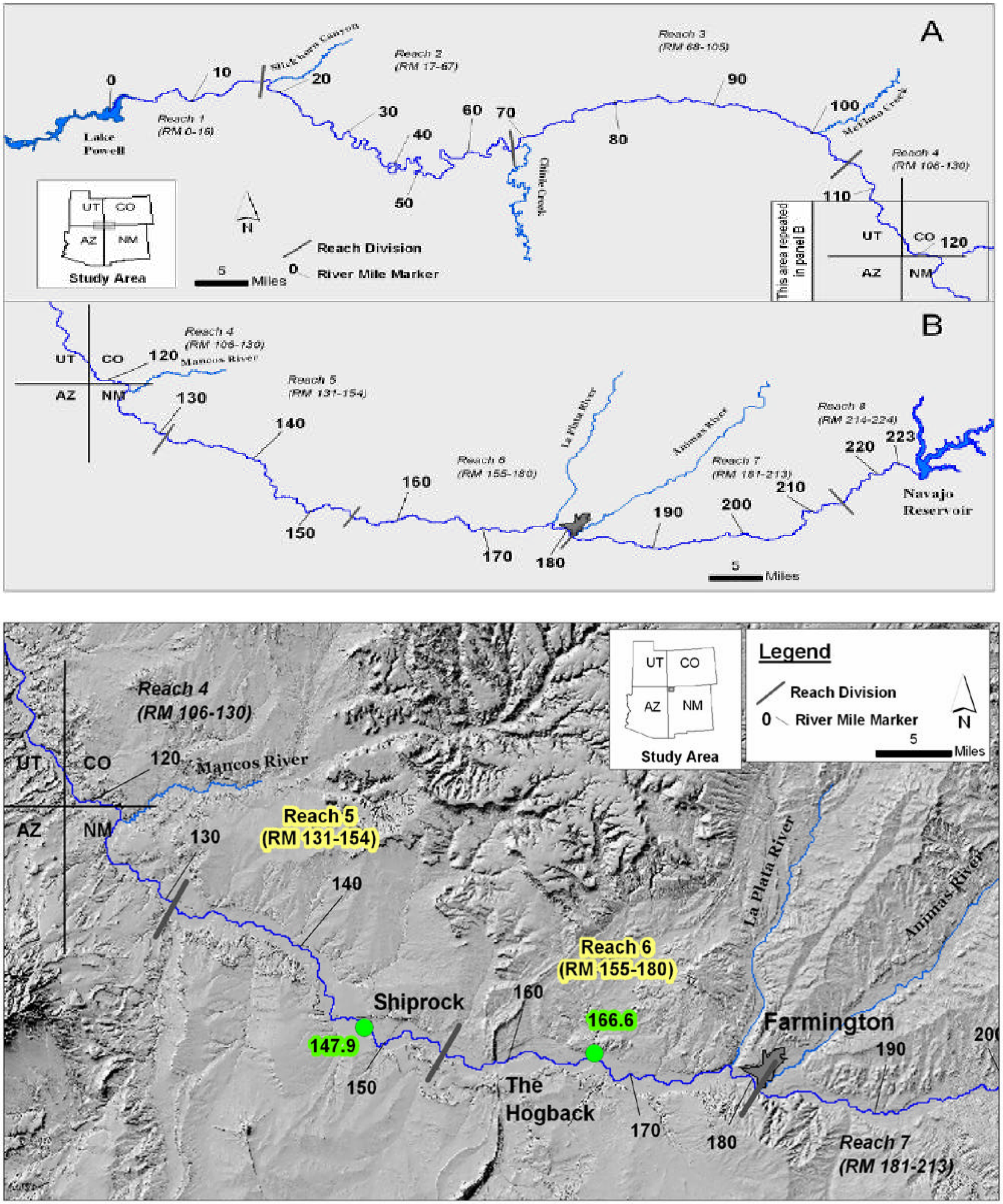

Figure 1. Map of study area including entire San Juan River basin (top) and a more detailed map of intensive removal reaches (green highlights; bottom). –map provided by Sara Gottleib, UNM MSB

Intensive non-native removal efforts were focused on 18.7 river miles of the San Juan River located in the northwestern portion of New Mexico near the towns of Fruitland and Shiprock (Figure 1.). Two removal Sections were sampled between RM's 166.6 – 147.9 and were located within Geomorphic Reaches 6 and 5. These separate Sections are delineated by a water diversion structure, Hogback Diversion. Throughout this report Section 1 will refer to PNM to Hogback Diversion (RM 166.6 – 159.0) while Section 2 refers to Hogback Diversion to Shiprock Bridge (RM 158.8 – 147.9).

METHODS

Sampling conducted during adult monitoring trips in 2004 followed similar protocols to previous years (Ryden 2000). Fishes were collected using raft mounted electrofishers. Rafts consisted of a rower and a netter and floated near the shoreline netting all fish seen. Sampling was conducted in one RM increments. At the end of each RM, all fish collected were enumerated by species and size class. At the end of every fifth mile, or designated mile, fish were measured to the nearest millimeter (mm) for total and standard lengths and weighed to the nearest 5 grams (g) for mass. All non-native fishes were removed from the river with exception of anchor tagged fish that were returned to the river.

Sampling conducted in Sections 1 and 2 followed similar protocol. In addition, a support raft was used both to collect any non-native fishes that surfaced behind the shocking rafts and to serve as a holding unit for transporting live fish. All non-native fishes or a representative sub-sample were measured (nearest 1 mm) for total and standard lengths and weighed (nearest 5 g) for mass. All non-native fishes were removed from the river. When possible, channel catfish were held for transplantation. Channel catfish were kept in live wells treated with salt and stress coat to alleviate stress caused by holding and transporting. A battery powered aeration system or compressed oxygen was used for circulation and aeration. Channel catfish were transported from the San Juan River in distribution trucks provided by New Mexico Department of Game and Fish and Navajo Nation Department of Fish and Wildlife to closed impoundments located within the drainage.

Analyses of all available capture data were divided between project types and were analyzed independently of each other. Catch rates among years from PNM to Hogback, Hogback to Shiprock and Riverwide sampling were compared independently.

To determine trends in distribution and abundance, CPUE (fish / hour of electrofishing) were calculated using software package SPSS 10.0. Species CPUE represents the total number of fish collected divided by the total effort of sampling (hours of electrofishing). Data were summarized by type of trip (i.e. intensive removal, riverwide), year, reaches and by individual trips. All CPUE data that was not normally distributed were first analyzed using non-parametric Kruskall-Wallis rank tests. If significant differences were observed, among year comparisons were conducted using a Mann-Whitney U test or Dunett T3 pairwise comparisons to obtain p-values.

Length (total length in millimeters) was used to determine changes in size class distributions of non-native fishes. When length data were normally distributed a one-way ANOVA was performed on unranked data to determine significant differences among years.

RESULTS

PNM Weir to Hogback Diversion (RM 166.6 – 159.0) – SECTION 1

A total of 2,902 channel catfish and 461 common carp were collected during six trips and 84.50 hours of electrofishing (Tables 1**)**. Of these fish, 26 channel catfish and 31 common carp were anchor tagged recaptures and were released back to the river. The remaining fish were removed from the river. In addition to channel catfish and common carp, other non-native fishes removed from Section 1 included rainbow trout *Oncorhynchus mykiss,* brown trout *Salmo trutta*, bullhead catfishes *Ameiurus spp*., largemouth bass *Micropterus salmoides,* green sunfish *Lepomis cyanellus*, bluegill *Lepomis macrochirus*, and white sucker *Catostomus commersoni* . No striped bass *Morone saxatilis* were collected or observed.

Table 1. Total count of major species collected during intensive non-native removal efforts from PNM Weir to Hogback Diversion, 2004.

Trip	*Ptyluc*	*Xyrtex*	*Ictpun*	*Cypcar*	*Micsal*	*Ameiurus spp*	*Saltru*
23-24 March	0	2	15	52	0	1	4
20-22 April	4	2	116	68	2	4	18
29 June – 01 July	8	9	854	95	4	3	9
20-22 July	5	3	1,082	54	46	16	3
17-19 August	5	3	831	104	269	8	3
8 November	5	2	4	88	4	0	7
Totals	**27**	**21**	**2,902**	**461**	**325**	**32**	**44**

Six trips were conducted from March to November (Table 1). Channel catfish CPUE was low initially ranging from 1.3 to 6.1 fish / hour of electrofishing. Trips conducted during June, July and August had increased CPUE ranging from 38.6 to 51.5 fish / hour (Figure 2). Channel catfish CPUE for all trips and all size classes combined was 28.8 fish / hour with the majority of fish collected during summer sampling (Table 1; Figure 2).

During the first two sampling trips, most channel catfish collected were adult fish with a juvenile CPUE of 0.0 and 0.2, respectively. During summer sampling, CPUE for both juvenile and adult channel catfish were nearly identical and ranged from 18.2 to 26.2 fish / hour (Figure 2).

Channel catfish CPUE among years has not declined since intensive non-native removal began in 2001 (Figure 3). Shifts in CPUE by size class has been observed with fewer, although not significantly, adult fish collected from 2003-2004. Juvenile CPUE did not change between 2003-2004 but remain higher ($p < 0.001$) than values observed 2001-2002.

Shifts towards smaller sized channel catfish has been documented since 1999 and this trend continued in 2004. Mean total length (TL) in 2004 was 334.5 mm compared to 487.1 in 1999. Juvenile channel catfish (< 300 mm TL) comprised 47.7% of the catch in 2004 and were absent from collections in 1999. In addition, large channel catfish > 500 mm TL comprised 52.6% of the catch in 1999 compared to 3.5 % in 2004 (Figure 4). Four individual catfish > 600 mm were collected in 2004.

Common carp CPUE in 2004 varied little with the majority of trips having rates < 10 fish / hour (Figure 5). Only the 8 November trip had CPUE > 10 fish / hour. Similar to previous years, majority (> 90%) of common carp removed in 2004 were adult fish with a mean TL of 485.8 mm.

Unlike channel catfish, common carp CPUE since 2001 significantly declined ($p < 0.001$) within this Section. Declines in CPUE has been observed with each subsequent year of removal, with a mean CPUE of 5.1 fish / hour in 2004, compared to 18.5 fish / hour in 2001 (Figure 5). Highest trip CPUE (14.7 fish / hour) in 2004 was lower than 60% of trips conducted in 2001.

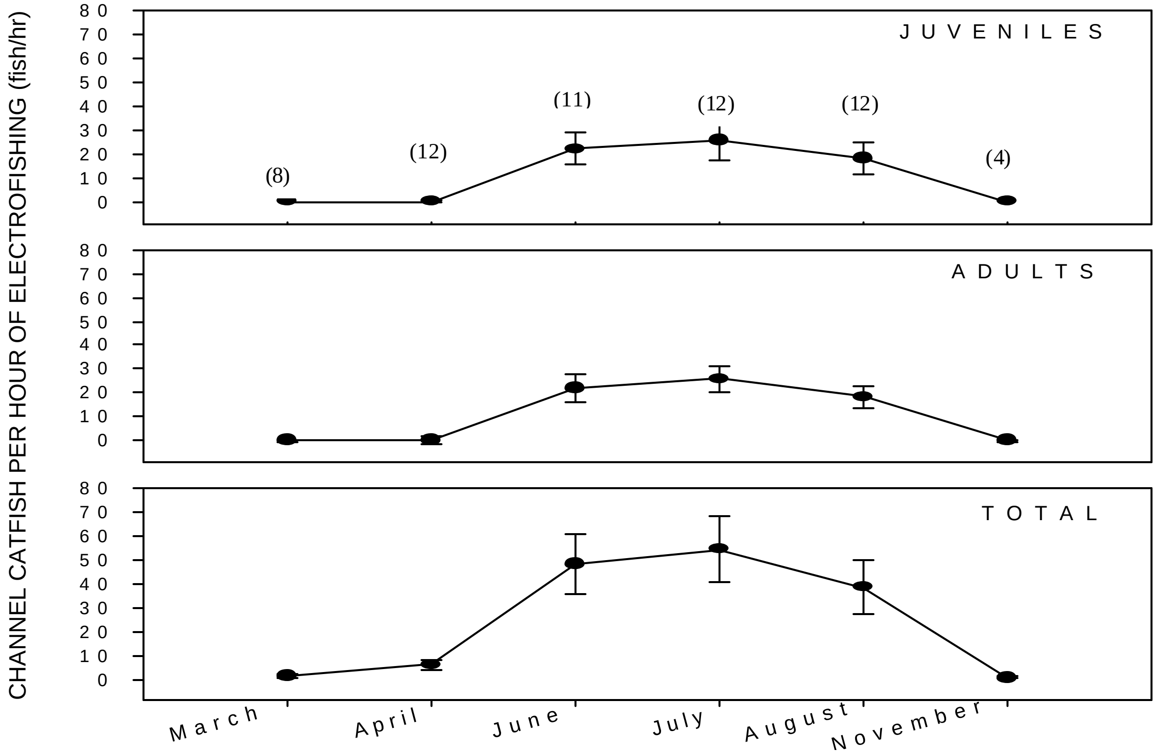

Figure 2. Channel catfish CPUE (fish / hour) by trip within the PNM Weir to Hogback Diversion Section. Sample size listed parenthetically and error bars represent + 1 SE.

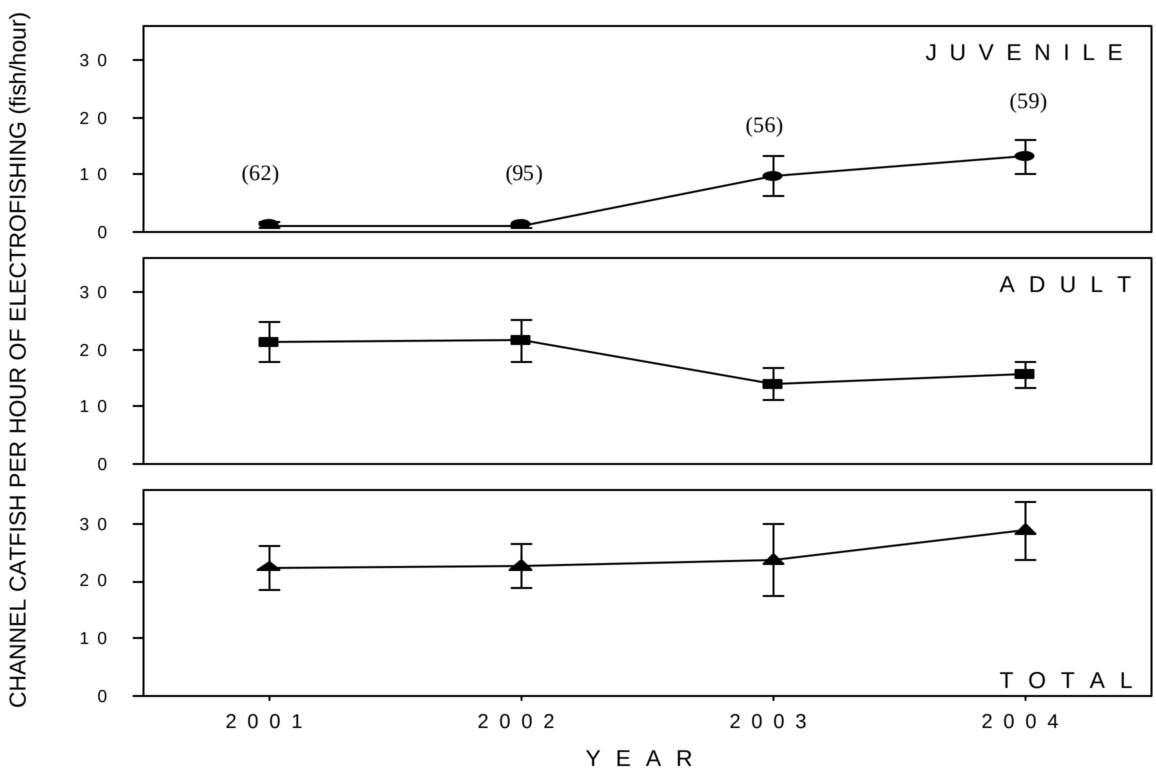

Figure 3. Channel catfish CPUE (fish / hour) by year within the PNM Weir to Hogback Diversion. Section. Sample size listed parenthetically and error bars represent + 1 SE

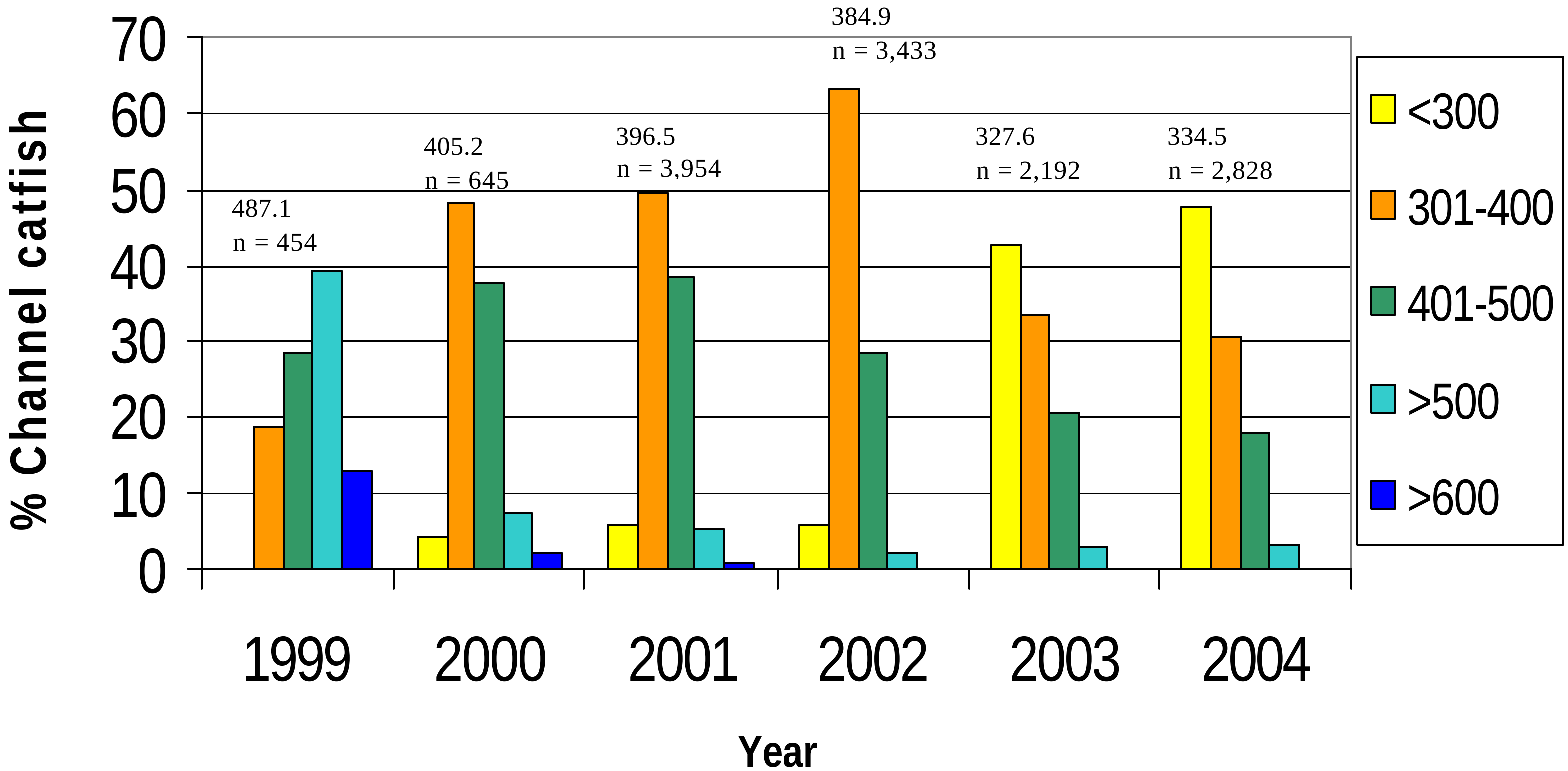

Figure 4. Size class distribution of channel catfish collected from PNM Weir to Hogback Diversion, 1999 – 2004. Mean total length (mm) and sample size above bars.

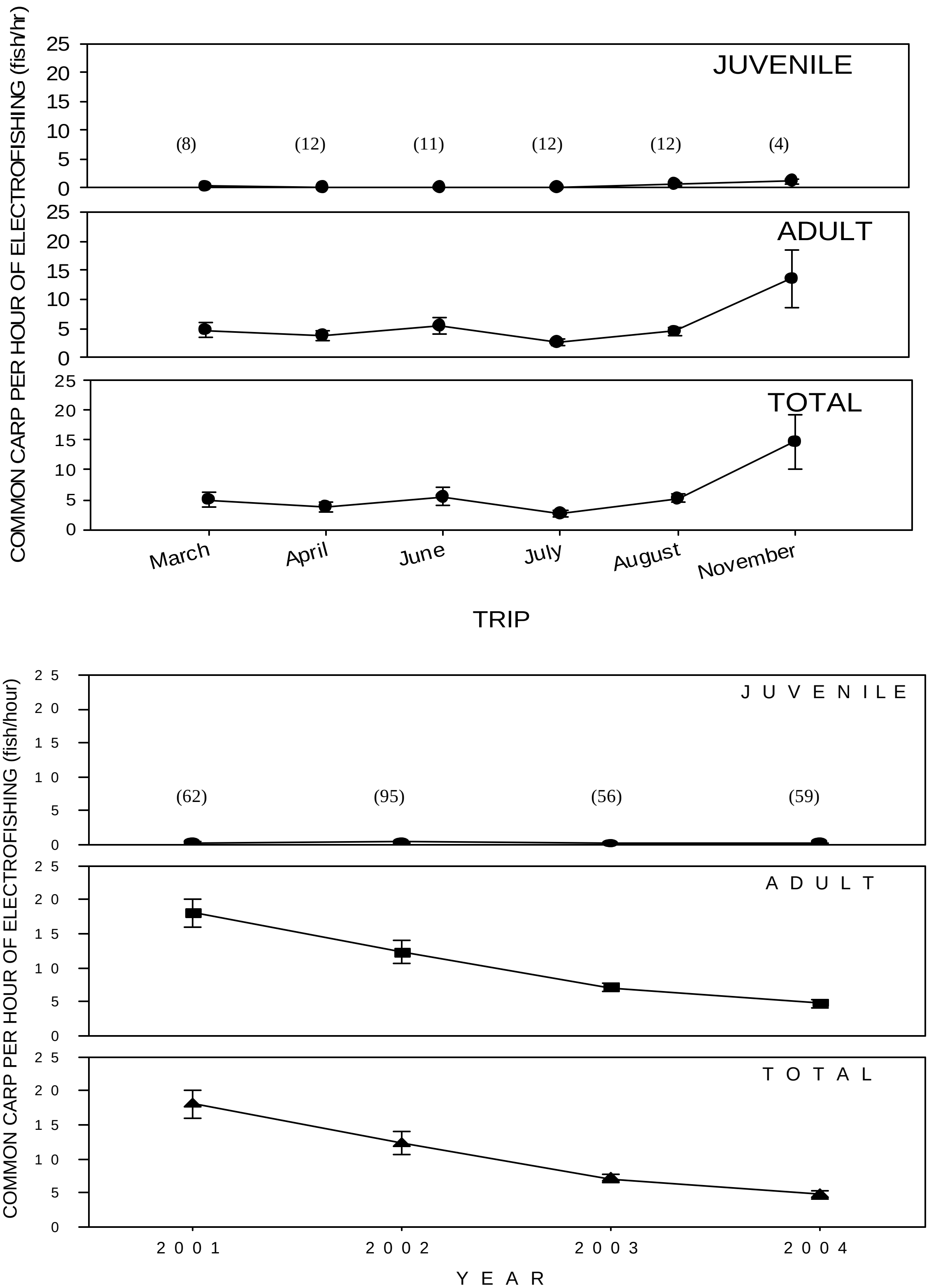

Figure 5. Common carp CPUE (fish / hour) by trip in 2004 (top) and by year (bottom); PNM Weir to Hogback Diversion. Sample size listed parenthetically and error bars represent ± 1 SE.

At RM 163.7, a rock and concrete weir operated by Arizona Public Service (APS) separates this intensive non-native removal Section into sub-sections. Channel catfish and common carp CPUE varied between sub-sections. A total of 309 channel catfish and 95 common carp (12.01% of catch) were collected upstream of APS Weir, while 2,593 and 366 (87.99%), respectively, were collected downstream. Differences in CPUE for both species between sub-sections has been evident since 2001. Channel catfish CPUE in 2001 was nearly identical between sub-sections (22.3 and 22.5 fish / hour). However, channel catfish CPUE was significantly lower ($p < 0.001$) upstream of APS Weir in 2004 with 8.7 fish / hour compared to 48.2 fish / hour downstream (Figure 6). Similar trends were observed for common carp with a 2004 CPUE of 2.7 fish / hour upstream of APS and 7.3 fish / hour below, $p < 0.001$ (Figure 6). These data demonstrate that APS Weir, under recent flow discharge conditions, has served as a partial impediment to upstream movement of non-native fishes.

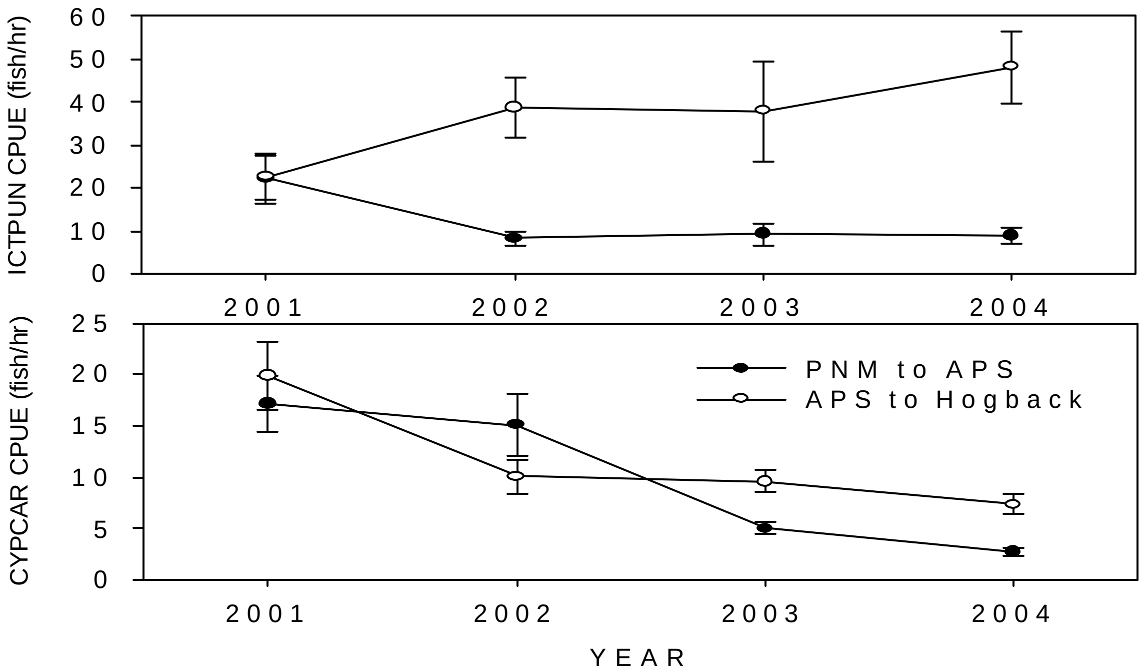

Figure 6. Comparison of channel catfish (ICTPUN) and common carp (CYPCAR) CPUE (fish / hour) between separate sub-sections of Section 1 (PNM Weir to Hogback Diversion), 2001-2004. Error bars represent ± 1 SE.

Total biomass (kilograms) of channel catfish and common carp removed has declined since 2001. Channel catfish biomass removed declined from 2,569 kg in 2001 to 1,262 kg in 2004. Some of this decline may be due to a reduction in number of trips conducted between years. However, although effort has not remained constant among years, it is important to note declines in overall numbers of fish removed and the amount of kg / channel catfish in 2001-2004 comparisons (Figure 7). Mean condition factor $K_{(f)}$ (Fulton type; (W / L^3)*100,000)) for channel catfish decreased from 0.97 in 2001 to 0.94 in 2004 ($p < 0.001$). Lower numbers of common carp removed have also resulted in less total kilograms removed among 2001-2004 comparisons. The amount of kg / common carp, however, has increased resulting in fewer but larger, more robust common carp (Figure 7). Mean condition factor $K_{(f)}$ for common carp increased from 1.37 in 2001 to 1.74 in 2004 ($p < 0.001$).

Relatively high numbers of largemouth bass were collected in Section 1 in 2004. Trip by trip CPUE ranged from 0.0 fish / hour during late March sampling to 14.7 fish / hour during August sampling (Figure 8). A six trip mean CPUE of 3.7 fish / hour represents the highest catch rates for largemouth bass among 2001-2004 comparisons (p = 0.03). Prior to 2004, highest yearly CPUE was 0.3 fish / hour. Due to difficulties encountered in netting these fish, CPUE effort metrics most likely under estimate largemouth bass abundance in this Section. All largemouth bass collected were juveniles and ranged from 40-187 mm TL.

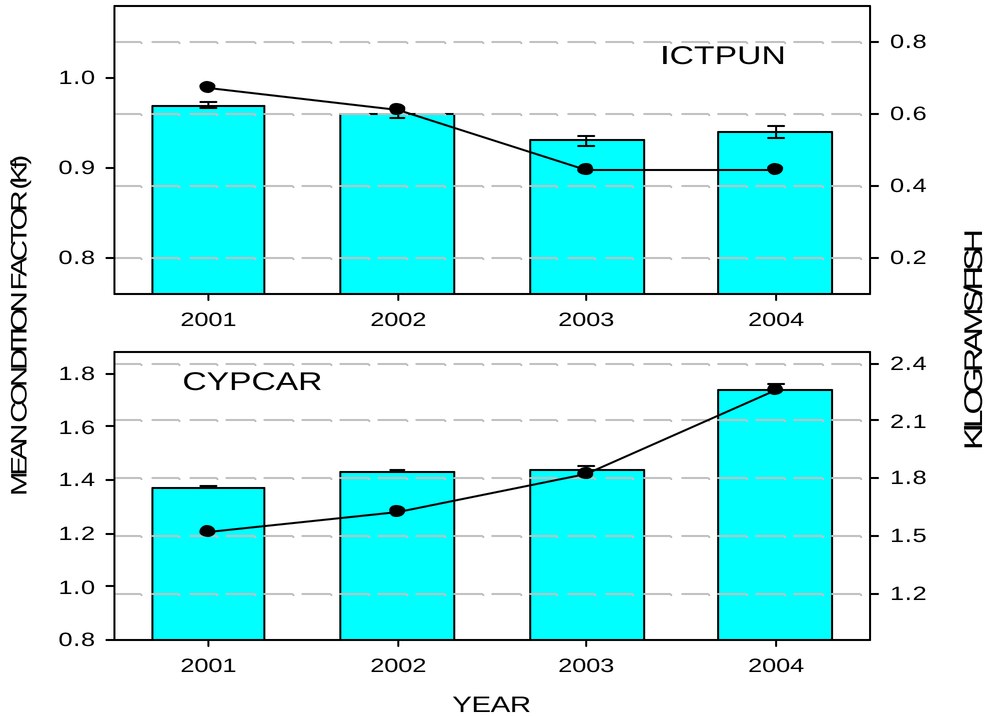

Figure 7. Mean condition factor $K_{(f)}$ and kilograms / fish of channel catfish [ICTPUN] and common carp [CYPCAR] collected from PNM Weir to Hogback Diversion, 2001-2004. Bars represent Mean $K_{(f)}$ and lines represent kilograms / fish.

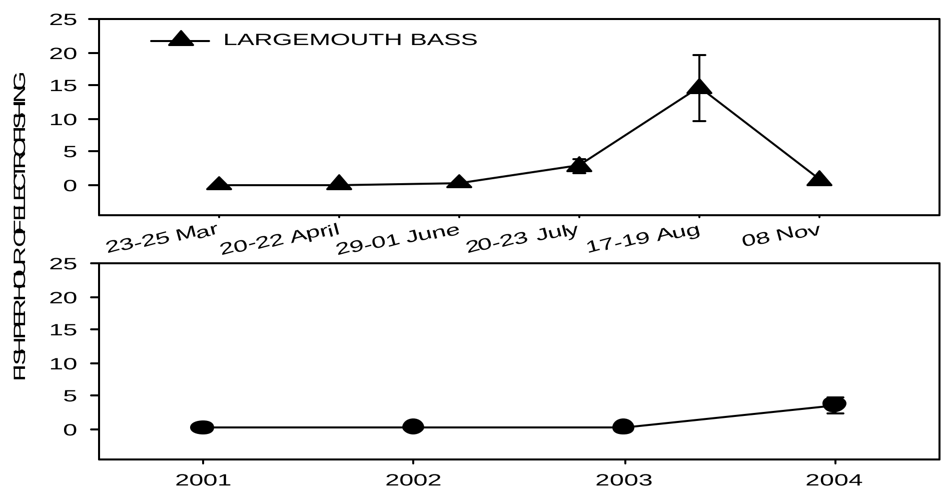

Figure 8. Largmouth bass CPUE (fish / hour of electrofishing) by trip and by year within the PNM Weir to Hogback Diversion Section, 2001-2004. Error bars represent $\pm$ 1 SE.

Hogback Diversion to Shiprock Bridge (RM 158.8 – 147.9) – SECTION 2

A total of 4,023 channel catfish and 755 common carp were collected within this Section during four trips and 76.6 hours of electrofishing (Table 2). All non-native fishes were removed from this Section. In addition to channel catfish and common carp, other non-native fishes removed from this Section in 2004 include rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, bullhead catfishes *Ameiurus spp*., largemouth bass *Micropterus salmoides*, green sunfish *Lepomis cyanellus*, and white sucker *Catostomus commersoni*. No striped bass *Morone saxatilis* were collected or observed.

Four trips were conducted from May to November (Table 2). Channel catfish CPUE was relatively high and ranged from 25.4 to 98.1 fish / hour. Trips conducted in June and September had overall CPUE > 80 fish / hour comprising 76.06% of the total channel catfish catch for the year (Figure 9). Channel catfish CPUE by size class varied among trips. May adult CPUE was 17.7 fish / hour and 7.8 fish / hour for juvenile fish. June CPUE varied with an adult CPUE of 31.9 and 52.7 fish / hour for juveniles (Figure 9) Adult CPUE in 2004 was 27.1 fish / hour and 29.1 for juveniles.

Table 2. Total count of major species collected during intensive non-native removal efforts from Hogback Diversion to Shiprock Bridge, 2004.

Trip	*Ptyluc*	*Xyrtex*	*Ictpun*	*Cypcar*	*Micsal*	*Ameiurus* spp	*Saltru*
11-13 May	3	46	497	86	0	4	5
15-17 June	47	28	1,791	219	0	3	6
14-15 September	25	71	1,269	143	46	2	2
16-18 November	9	58	466	307	1	6	4
Totals	**84**	**203**	**4,023**	**755**	**47**	**15**	**17**

Catch rates between years have not changed, 2003-2004, and channel catfish CPUE for all trips and all life stages combined in 2004 was 56.1 fish / hour (Figure 10). Changes in both adult and juvenile fish CPUE was significantly different than 2003 values. Adult CPUE decreased from 46.4 fish / hour ($p < 0.001$) in 2003 while juvenile CPUE increased from 10.9 fish / hour ($p < 0.001$).

Mean total length (TL) in 2004 was 333.23 mm compared to 386.4 mm in 2003 (Figure 11). Juvenile channel catfish (< 300 mm TL) comprised 50.5% of the catch in 2004 compared to 19.2% in 2003, while fish ranging from 401-500 mm comprised over 40.0% of the 2003 catch and < 25.0% in 2004 (Figure 11).

Common carp CPUE was relatively low in 2004. Mean CPUE of all trips in 2004 was < 15 fish / hour with the 8 November trip having the highest CPUE of 12.9 fish / hour (Figure 12). Catch rates by size class varied little with the majority of common carp collected classified as adult fish (> 250 mm). Juvenile CPUE was 0.6 fish / hour and comprised 7.3% of the total common carp catch.

In contrast to channel catfish, common carp CPUE declined from 29.1 fish / hour in 2003 to 9.1 fish / hour in 2004 ($p < 0.001$). Catch rates for juvenile common carp were < 4.0 fish / hour during all trips in 2004 (Figure 13). Significant differences between years are a result of declines ($p < 0.001$) in adult CPUE (Figure 13). No changes in mean TL of common carp occurred between years.

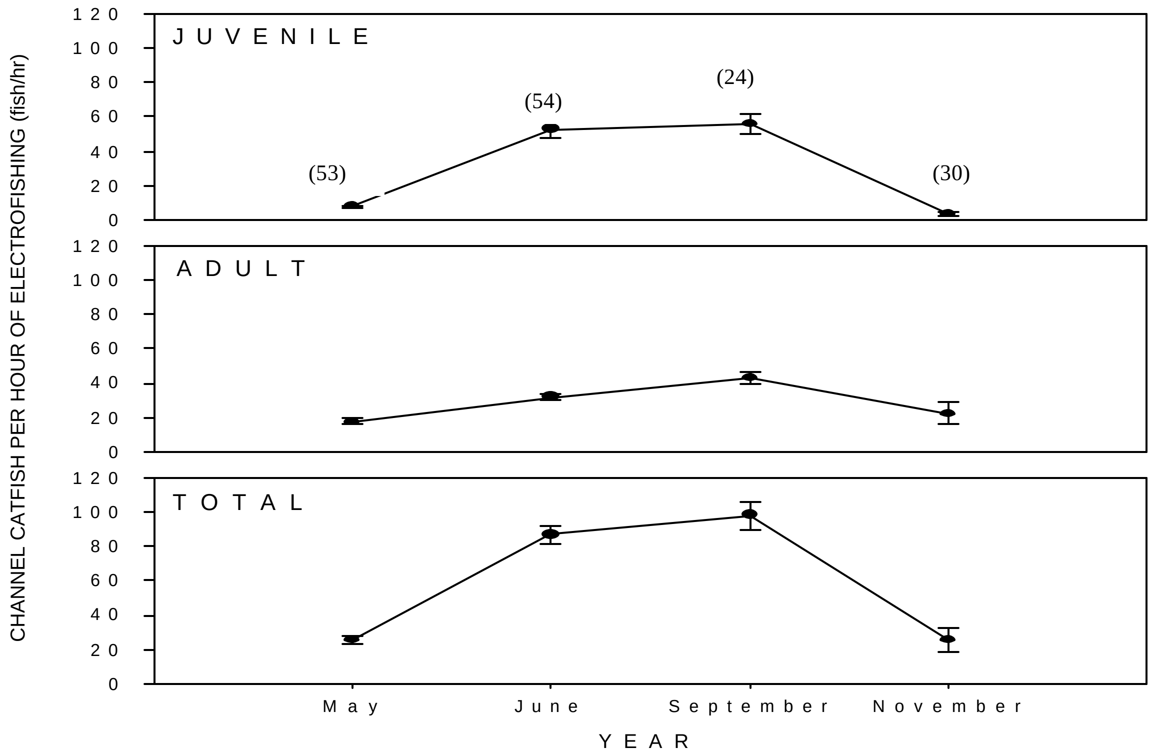

Figure 9. Channel catfish CPUE (fish / hour) by trip within the Hogback Diversion to Shiprock Bridge Section. Sample size listed parenthetically and error bars represent + 1 SE.

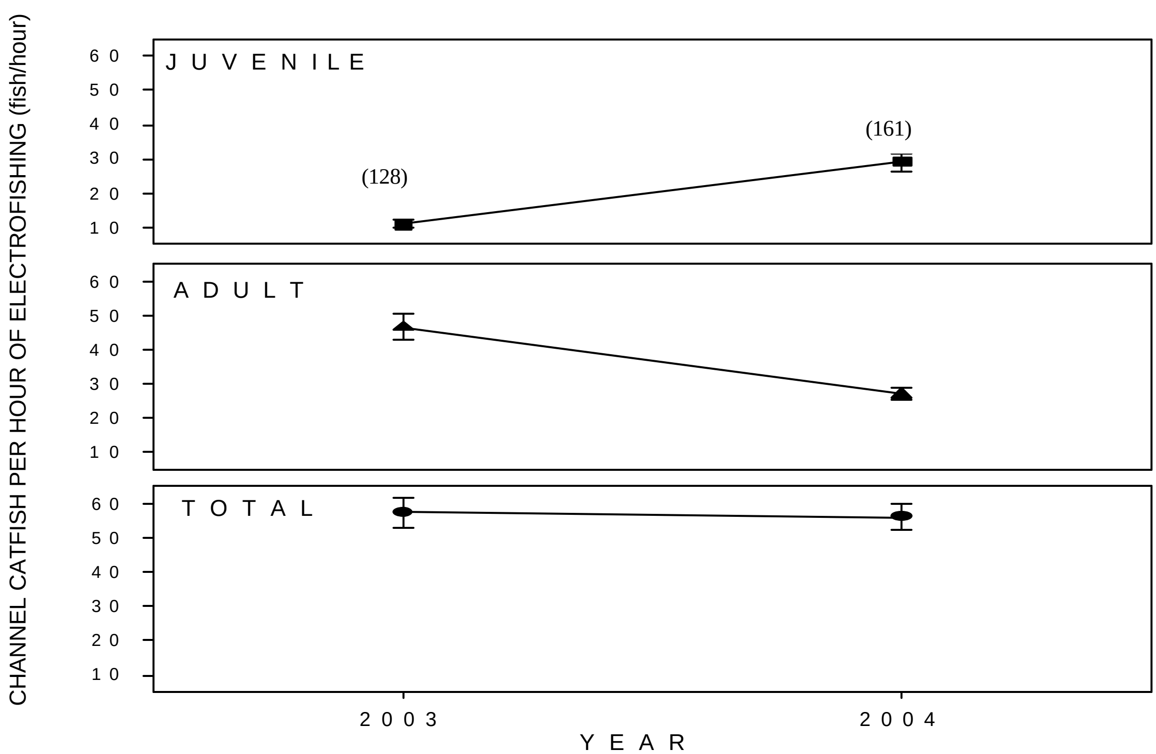

Figure 10. Channel catfish CPUE (fish / hour) by year within the Hogback Diversion to Shiprock Bridge Section. Sample size listed parenthetically and error bars represent + 1 SE.

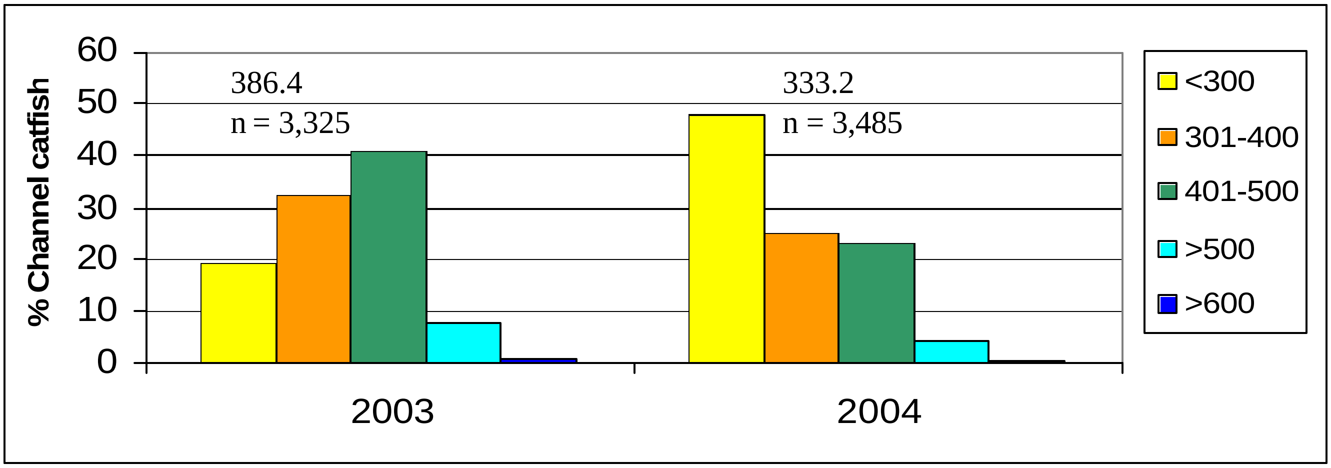

Figure 11. Size class distribution of channel catfish collected within the Hogback Diversion to Shiprock Bridge Section, 2003-2004. Mean total length (mm) and sample size above bars.

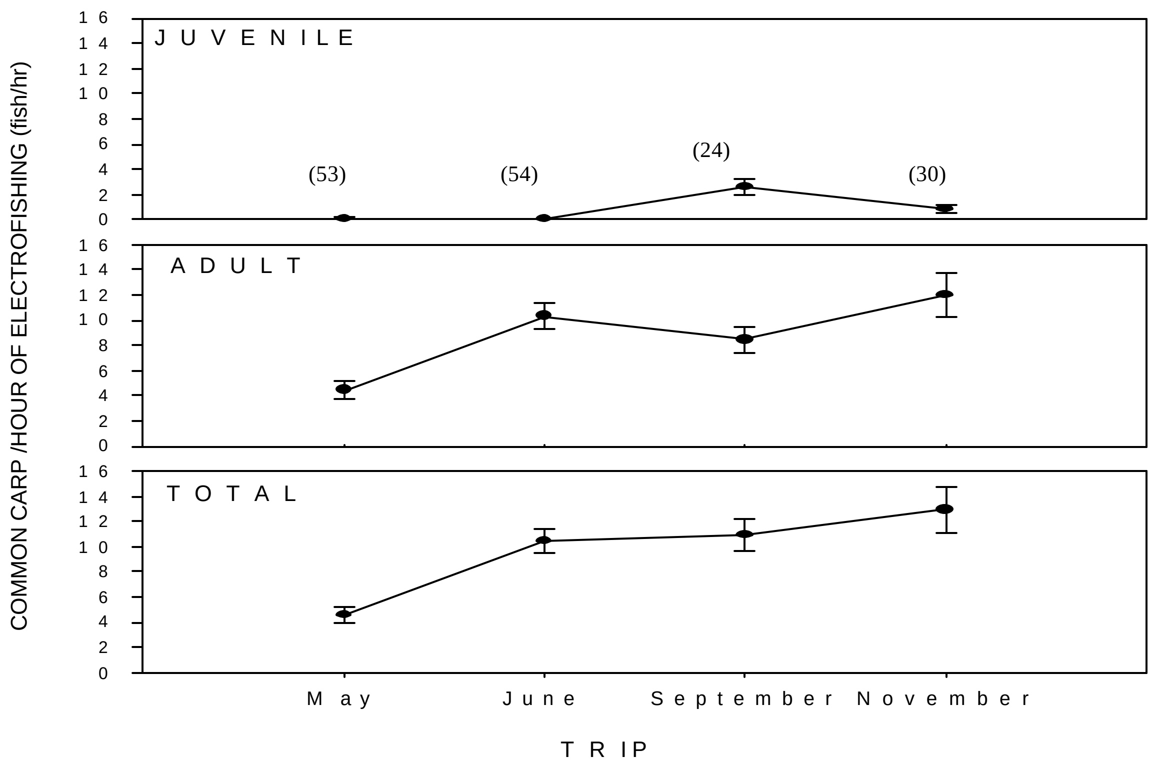

Figure 12. Common carp CPUE (fish / hour) by trip within the Hogback Diversion to Shiprock Bridge Section. Sample size listed parenthetically and error bars represent + 1 SE.

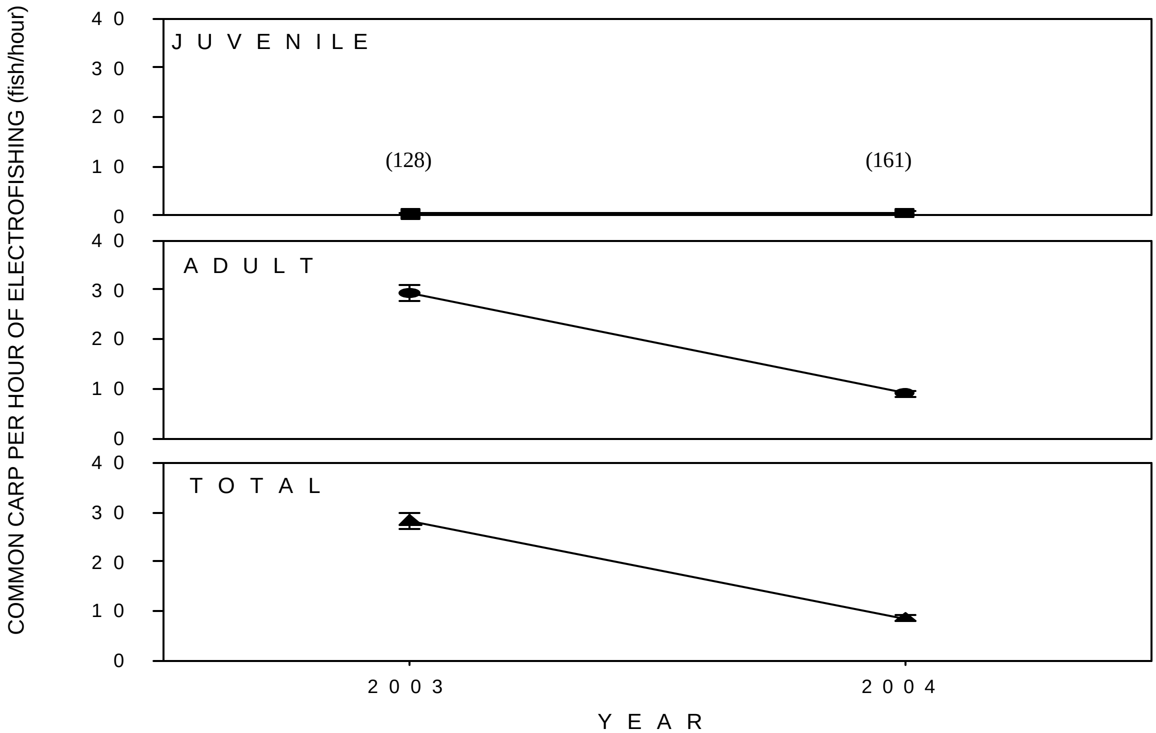

Figure 13. Common carp CPUE (fish / hour) by year within the Hogback Diversion to Shiprock Bridge Section. Sample size listed parenthetically and error bars represent + 1 SE.

Comparisons between Sections 1 and 2

Channel catfish CPUE varied between Sections and among years with typically much higher CPUE below Hogback Diversion. Within Section 1 (PNM Weir to Hogback), channel catfish CPUE in 2004 ranged from 0.6 to 54.5 fish / hour. These CPUE, although high, are relatively low in comparison with Section 2 (Hogback to Shiprock) CPUE. Lowest channel catfish CPUE in Section 2, in 2004, was 25.4 fish / hour and ranged to 98.1 fish / hour. Six trip mean CPUE in Section 1 was 28.8 fish / hour compared to a four trip mean CPUE of 56.1 fish / hour in Section 2, nearly twice that observed in Section 1 ($p < 0.001$).

To compare seasonal differences in channel catfish and common carp abundance between Sections, intensive non-native removal trips were conducted in December 2003 and November 2004. On each trip, Sections 1 and 2 were sampled within four days of each other so that water conditions (i.e. discharge, temperature, water clarity) were essentially the same.

Channel catfish CPUE within Section 1 during 2003 was 0.6 compared to 39.3 fish / hour ($p < 0.001$) immediately downstream in Section 2. Similar trends were observed during 2004 with 0.6 fish / hour collected in Section 1 compared to 25.5 fish / hr in Section 2 ($p = 0.003$) (Figure 14). Common carp CPUE also varied between reaches and years with values in 2003 of 6.8 fish / hour within Section 1 and 38.4 fish / hour in Section 2 ($p < 0.001$). Significant differences did not occur ($p = 0.708$) in 2004 CPUE of 14.7 fish / hour within Section 1 and 12.9 fish / hour within Section 2.

Native Fish Response to Intensive Non-native removal

To help determine native fishes response to intensive non-native removal efforts, we analyzed catch rates of both flannelmouth and bluehead suckers collected within removal reaches. Similar to non-native fishes analyses, sucker data were divided by life stages and mean CPUE was compared to determine trends.

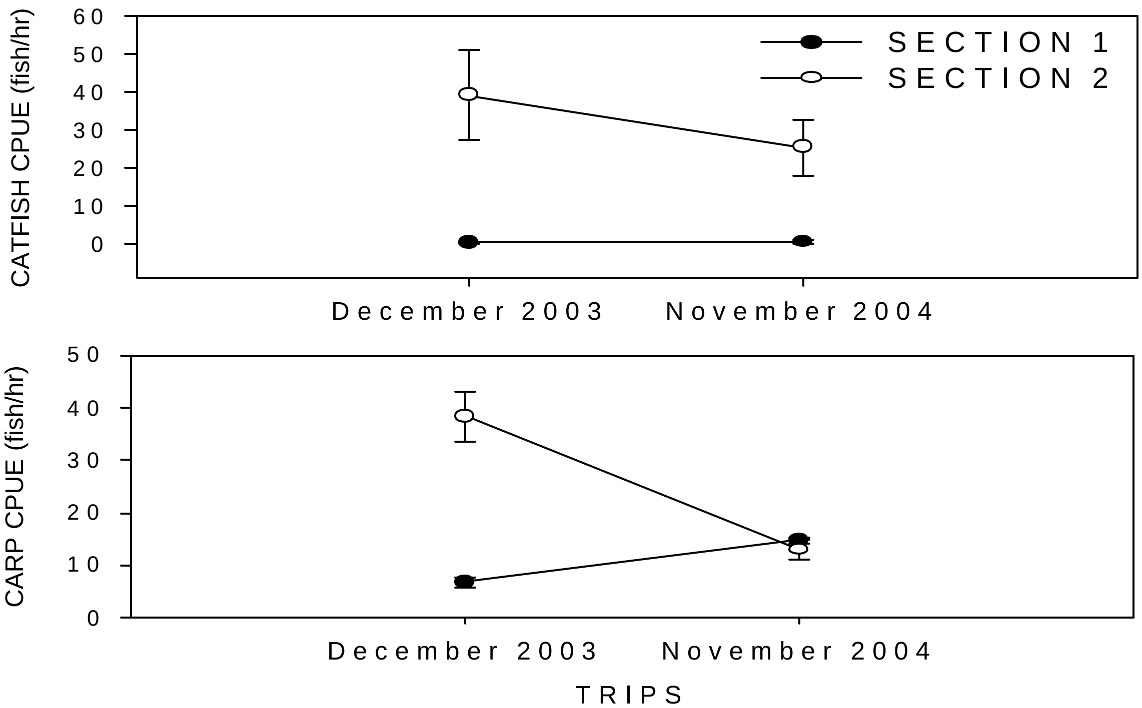

Figure 14. Comparison of channel catfish and common carp CPUE between two separate Sections where intensive non-native removal takes place (Section 1 = PNM Weir to Hogback Diversion; Section 2 = Hogback Diversion to Shiprock Bridge). Error bars represent ± 1 SE.

Flannelmouth sucker CPUE within Section 1 (PNM Weir to Hogback Diversion) has changed little since 2001. Among 1999-2004 comparisons, flannelmouth sucker CPUE has not significantly changed for individual size classes or for all life stages combined. Individual life stages exhibited increasing trends in 2004 but none of these increases were considered significant.

Bluehead sucker CPUE within Section 1 was similar to flannelmouth sucker CPUE trends and have changed little since 2001. Among 1999-2004 comparisons, bluehead sucker CPUE has not significantly changed for individual size classes or for all life stages combined. Bluehead sucker CPUE exhibited a general decrease for individual size classes, with exception of young-of-year, between 2003-2004 but these changes were not significantly different.

Analysis of native sucker CPUE may have failed to detect significant changes due to the completion and operation of the Nenahezad Fish Passage located at RM 166.6. This selective fish ladder is at the upper portion of the intensive non-native removal study area and has been in operation since 2003. Since operations began, a total of 39,822 flannelmouth and bluehead sucker have been moved upstream and out of the study area. Numbers of fish utilizing the fish passage show the importance of the passage itself in allowing fish to move upstream in presumably a similar way to what occurred prior to the barrier. However, the majority of native suckers utilized the fish passage prior to fall monitoring, and were may have been no longer available to electrofishing collections. This situation makes pre / post fish passage trend comparisons difficult to ascertain. In addition, flannelmouth sucker CPUE significantly increased (p = 0.004) immediately upstream, RM 180.0 – 168.0, of the fish passage between 2003 and 2004. However, significant increases did not occur among other year comparisons. This increase may not be indicative of an overall increasing trend in flannelmouth sucker abundance upstream of PNM Weir and may be resultant of sample variance among years.

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Table 3. Total number of channel catfish and common carp and mean CPUE (fish / hour; parenthetically) collected during main channel electrofishing surveys conducted in the spring and fall of each year, 1998-2004.

Species	Year	Young of Year	Juvenile	Adult	Total	Total Effort (Hours)
Channel catfish	1998	63 (.3)	2,738 (11.3)	1,994 (8.1)	4,795 (19.6)	241.78
	1999	114 (.7)	2,798 (19.6)	2,224 (13.5)	5,136 (33.9)	158.88
	2000	112 (.6)	4,305 (23.5)	1,907 (10.6)	6,320 (34.7)	178.06
	2001	110 (.4)	4,435 (21.3)	2,269 (12.0)	6,814 (33.6)	212.05
	2002	40 (.4)	1,193 (9.0)	1,166 (9.3)	2,409 (18.7)	243.45
	2003	52 (.4)	774 (5.6)	773 (6.4)	1,599 (12.7)	126.64
	2004	253 (2.1)	1,387 (10.2)	689 (4.2)	2,329 (16.5)	128.19
	Total	744 (.6)	17,630 (15.1)	11,022 (9.3)	29,402 (25.0)	1,289.05
	% of total catch	[2.53%]	[59.96%]	[37.49%]		
Common carp	1998	1 (<.0)	51 (.2)	3,308 (13.6)	3,360 (13.8)	235.12
	1999	0 (.0)	13 (.1)	3,075 (18.4)	3,088 (18.5)	158.88
	2000	99 (.6)	235 (1.4)	2,430 (14.1)	2,764 (16.1)	178.06
	2001	0 (.0)	98 (.6)	3,508 (15.4)	3,606 (16.0)	212.05
	2002	31 (.3)	154 (1.5)	1,082 (8.5)	1,268 (10.3)	235.90
	2003	3 (.2)	52 (.4)	757 (6.2)	812 (6.6)	126.64
	2004	29 (.3)	191 (1.8)	681 (4.6)	901 (6.6)	128.19
	Total	163 (.2)	794 (.8)	14,841 (12.4)	15,799 (13.3)	1,289.05
	% of total catch	[1.03%]	[5.03%]	[93.94%]		

Riverwide Removal Efforts (RM 180.0 – 0.00)

A total of 2,329 channel catfish and 901 common carp were opportunistically removed during monitoring trips in 128.19 hours of electrofishing (Table 3). Majority of channel catfish collected in 2004 were young-of-year or juvenile (n = 1,640; 70.42%). Number of adult channel catfish has decreased annually since 2001 with 689 adults removed in 2004 (Table 3). Common carp removed were primarily adult fish comprising 75.58% of total common carp catch. These numbers were similar to previous years but do represent the fewest number of adults in sampling conducted since 1998.

Channel catfish

Channel catfish CPUE for all Geomorphic Reaches and all life stages combined has varied since 1998 but generally exhibit a declining trend in abundance (Table 3, Figure 15). Catch rates increased in 2004 but remain significantly lower ($p < 0.001$) than values observed from 1999-2001 and are at levels similar to those observed in 1998. Increases in overall channel catfish CPUE are due in part to increased juvenile CPUE. Juvenile CPUE was similar to 1998 and 2002 values but remain significantly ($p < 0.001$) lower than values observed from 1999-2001. Adult channel catfish CPUE declined for the third consecutive year, although not significantly in 2003-2004 comparisons ($p = 0.17$), and are at the lowest levels in 1998-2004 comparisons (Figure 15).

Within Geomorphic Reach 6, portions of which intensive removal occurs, channel catfish CPUE for all life stages combined declined ($p = 0.04$) from 2003-2004 and were at the lowest values observed from 1998-2004 (Figure 16). Juvenile channel catfish CPUE has not seen declines in 1998-2004 comparisons Adult CPUE significantly ($p = 0.02$) declined since the highest CPUE was observed in 2001 and are at the lowest values observed among 1998-2004 comparisons.

Catch rates for all life stages combined within adjacent Geomorphic Reach 5 has declined ($p < 0.001$) since 2001 and are at the lowest levels observed among 1998-2004 comparisons (Figure 16). Juvenile channel catfish CPUE did not decrease while adult CPUE continued to decline ($p = 0.03$) in 2004. Adult CPUE has declined every year since 1999 to end with a mean CPUE of 7.9 fish / hour in 2004 compared to 28.2 fish / hour in 1999 (Figure 16).

All other Geomorphic Reaches had general increases in CPUE of channel catfish for all life stages combined (Figures 17 and 18). Observed increases in overall CPUE resulting from increases in juvenile CPUE were observed. No declining trends have been observed for adult channel catfish in Geomorphic Reaches 4-1.

Channel catfish mean total length (TL) for all Geomorphic Reaches combined declined from 301.8 mm in 2003 to 218.1 mm in 2004 ($p < 0.001$). This mean was the lowest among 1998-2004 comparisons and exhibit a decline for the first time since 1999 (Figure 19). Mean TL decreased in each of the six Geomorphic Reaches (Figure 20). Although a general decrease in mean TL occurred within in Geomorphic Reach 6, portions of which intensive removal occurs, the change was not significant ($p = 0.61$). A significant decrease ($p < 0.001$) occurred in adjacent Geomorphic Reach 5 but this decrease is resultant of the relatively small sample size (n = 12, of which 5 were < 100 mm) and should be interpreted carefully. Decreases ($p < 0.05$) occurred within Geomorphic Reaches 4 and 3 and declined for the second consecutive year. Additionally, means of 235.7 and 222.9 mm, respectively, are the lowest mean TL's in each Geomorphic Reach among 1998-2004 comparisons. Mean TL decreases as sampling moves downstream (Figure 20).

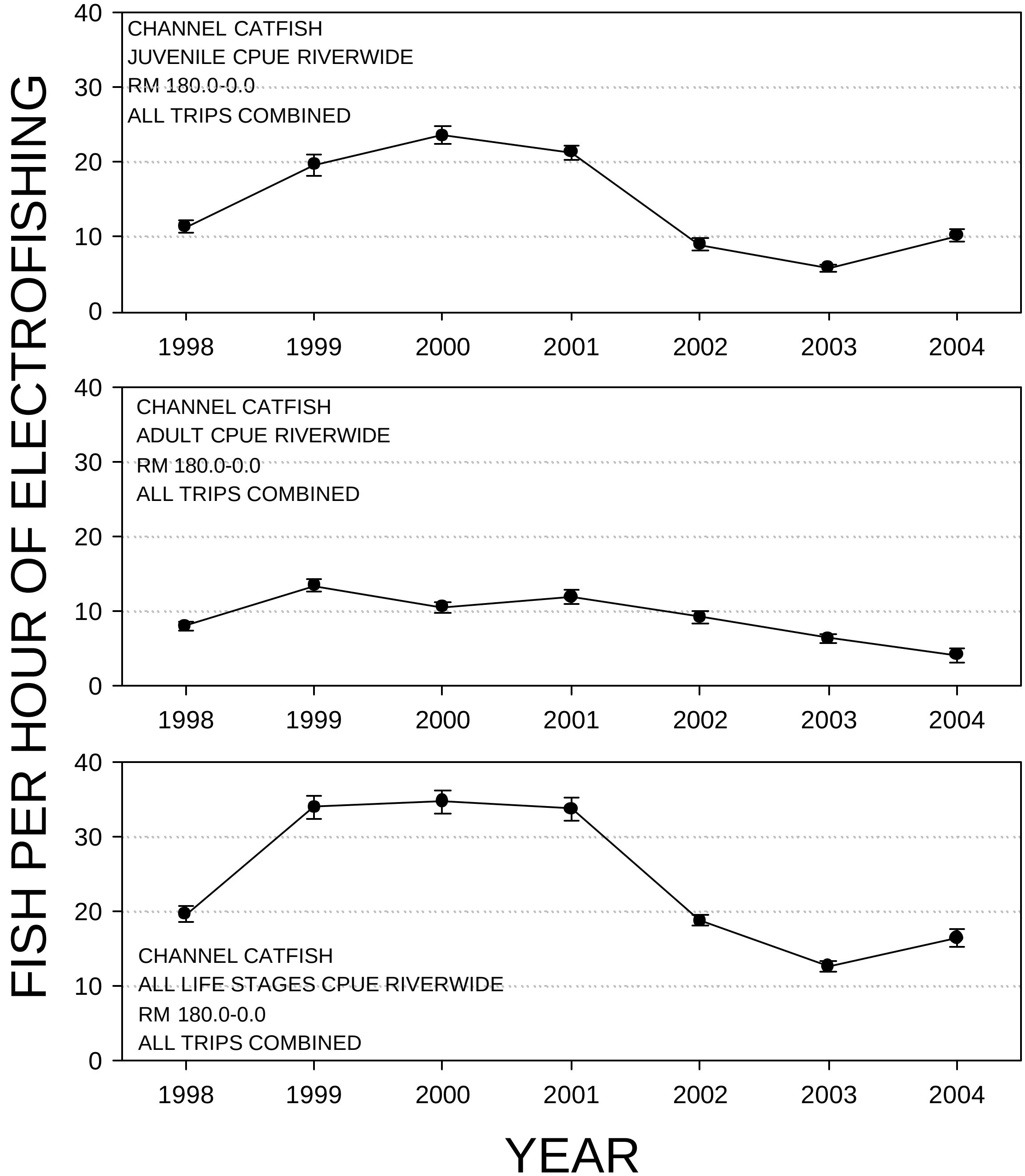

Figure 15 Channel catfish CPUE (fish / hour) by size class and by year, 1998-2004. Fish collected during riverwide monitoring efforts conducted by FWS-GJ in the spring and fall of each year. Error bars represent ± 1 SE.

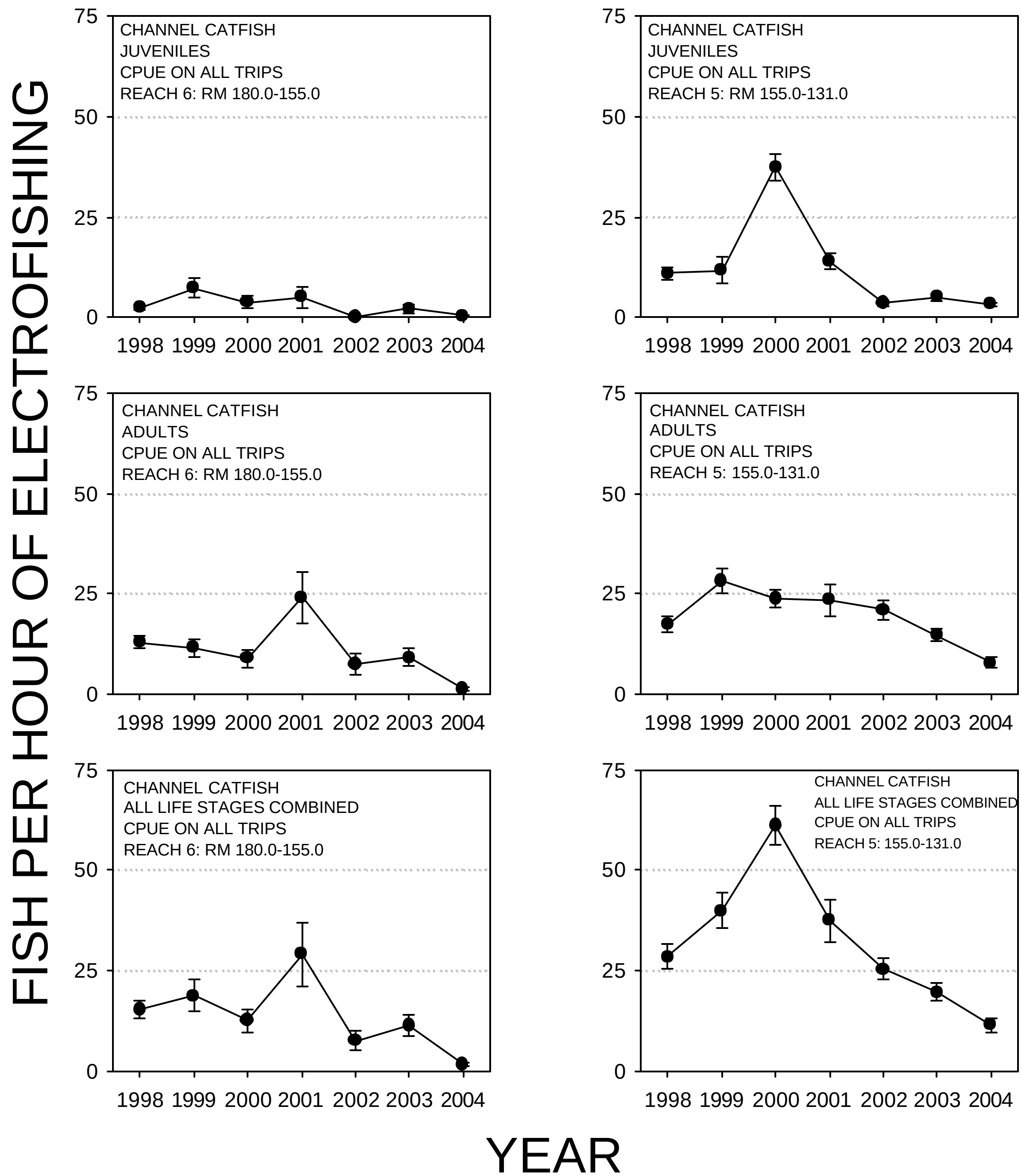

Figure 16. Channel catfish CPUE (fish / hour) in Geomorphic Reaches 6 and 5 by size class and by year, 1998-2004. Fish collected during riverwide monitoring efforts conducted by FWS-GJ in the spring and fall of each year. Error bars represent ± 1 SE.

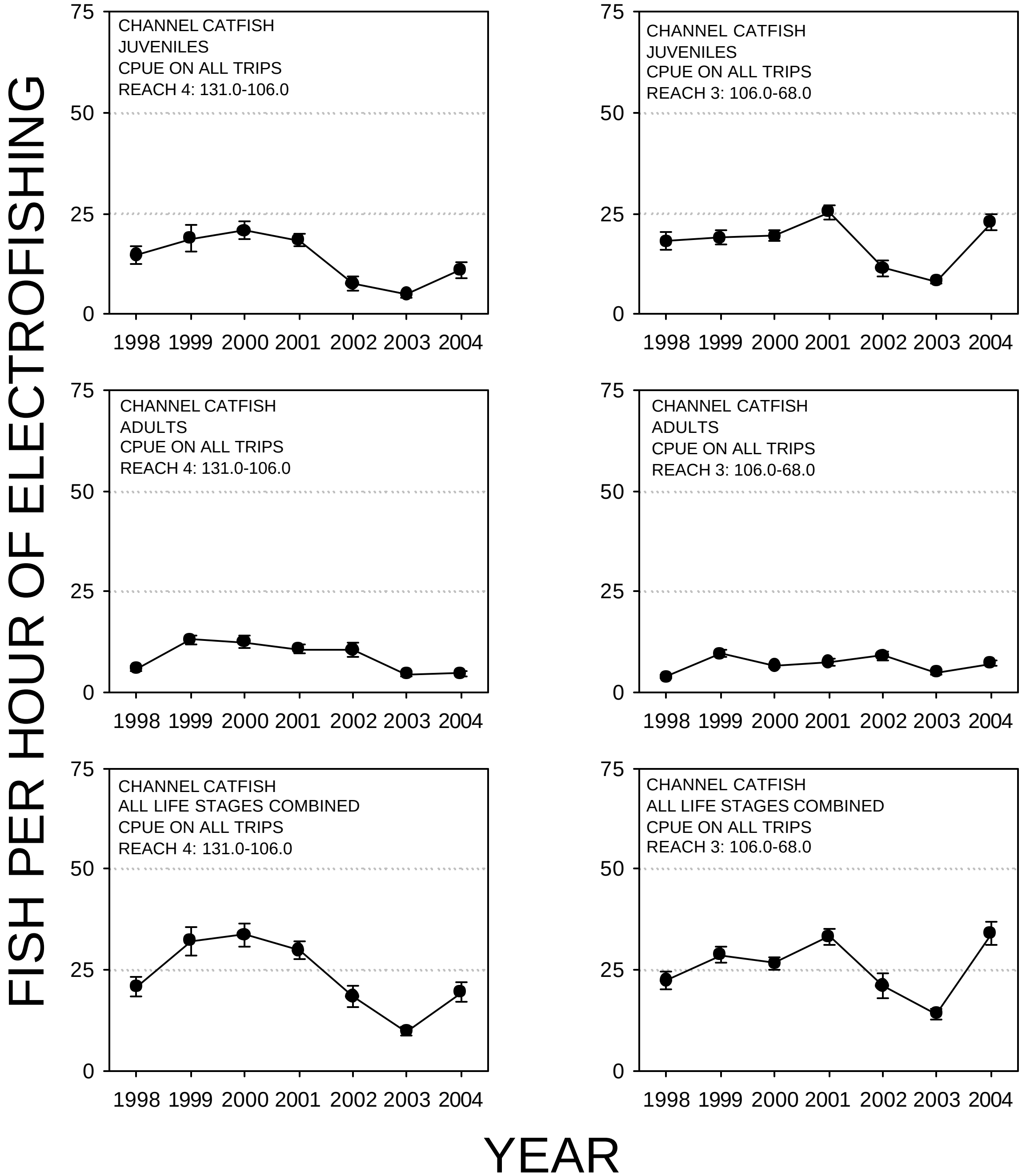

Figure 17. Channel catfish CPUE (fish / hour)in Geomorphic Reaches 4 and 3 by size class and by year, 1998-2004. Fish collected during riverwide monitoring efforts conducted by FWS-GJ in the spring and fall of each year. Error bars represent $\pm$ 1 SE.

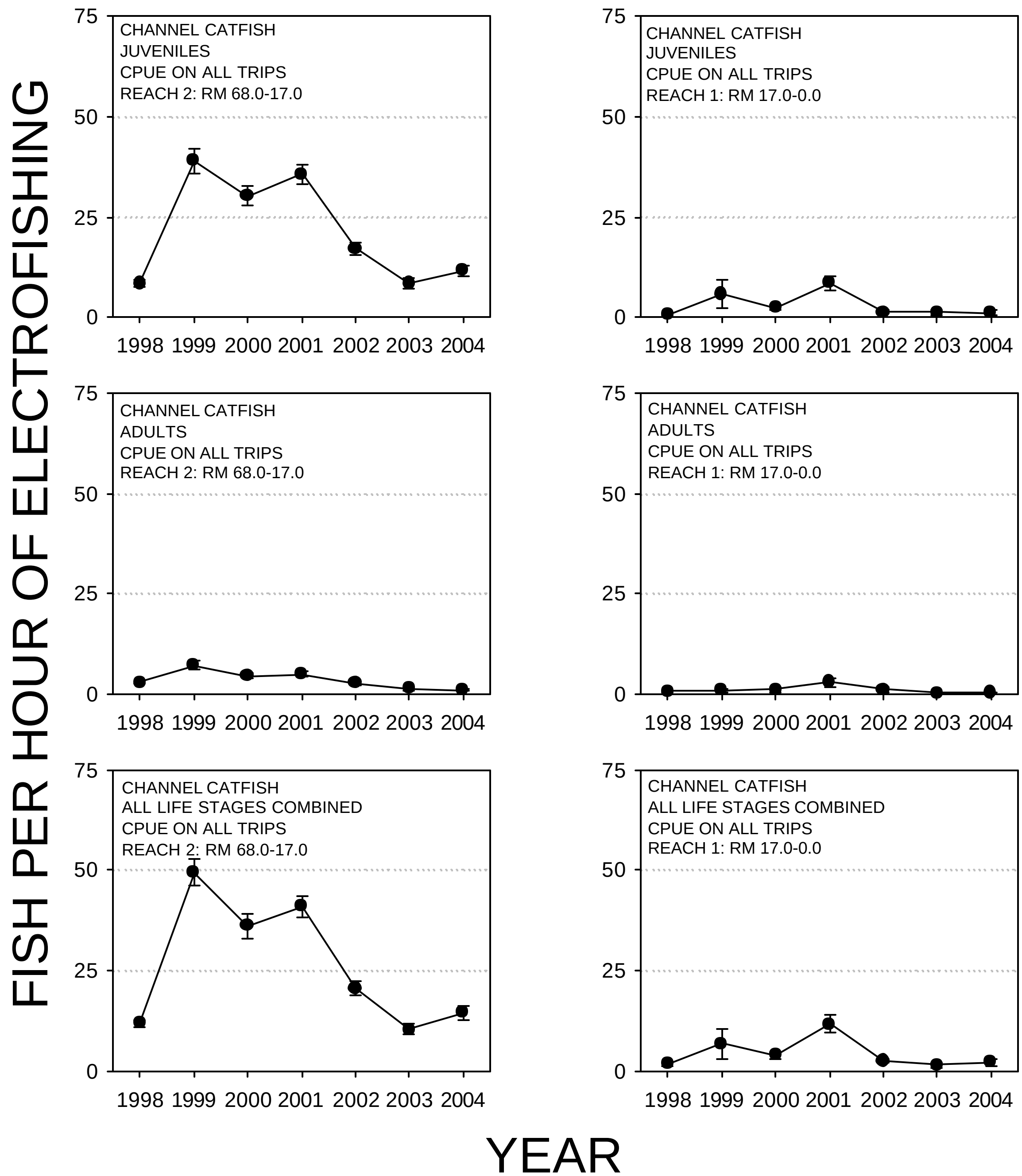

Figure 18. Channel catfish CPUE (fish / hour)in Geomorphic Reaches 2 and 1 by size class and by year, 1998-2004. Fish collected during riverwide monitoring efforts conducted by FWS-GJ in the spring and fall of each year. Error bars represent + 1 SE.

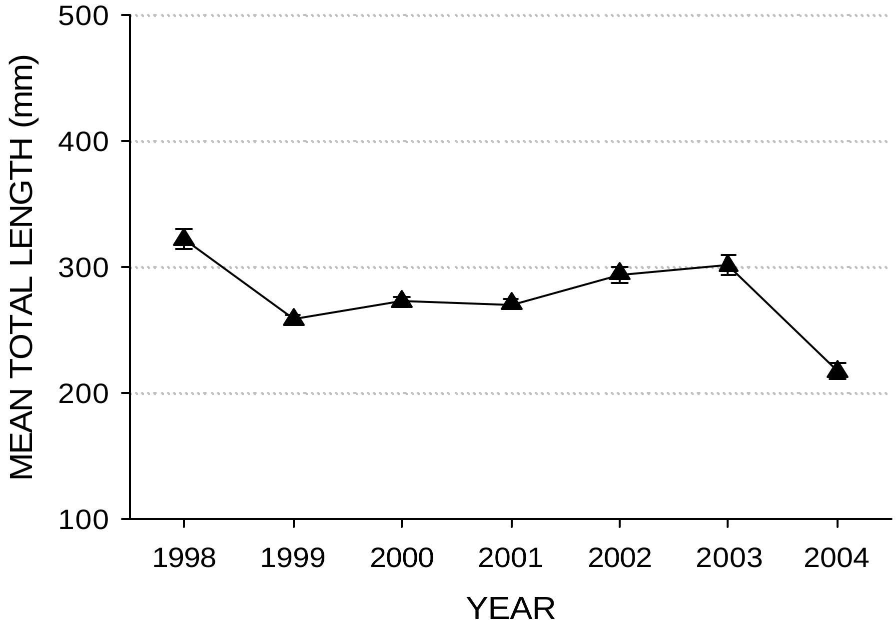

Figure 19. Mean total length (mm) of channel catfish collected in all Geomorphic Reaches during fall monitoring of each year 1998-2004. Error bars represent $\pm$ 1 SE

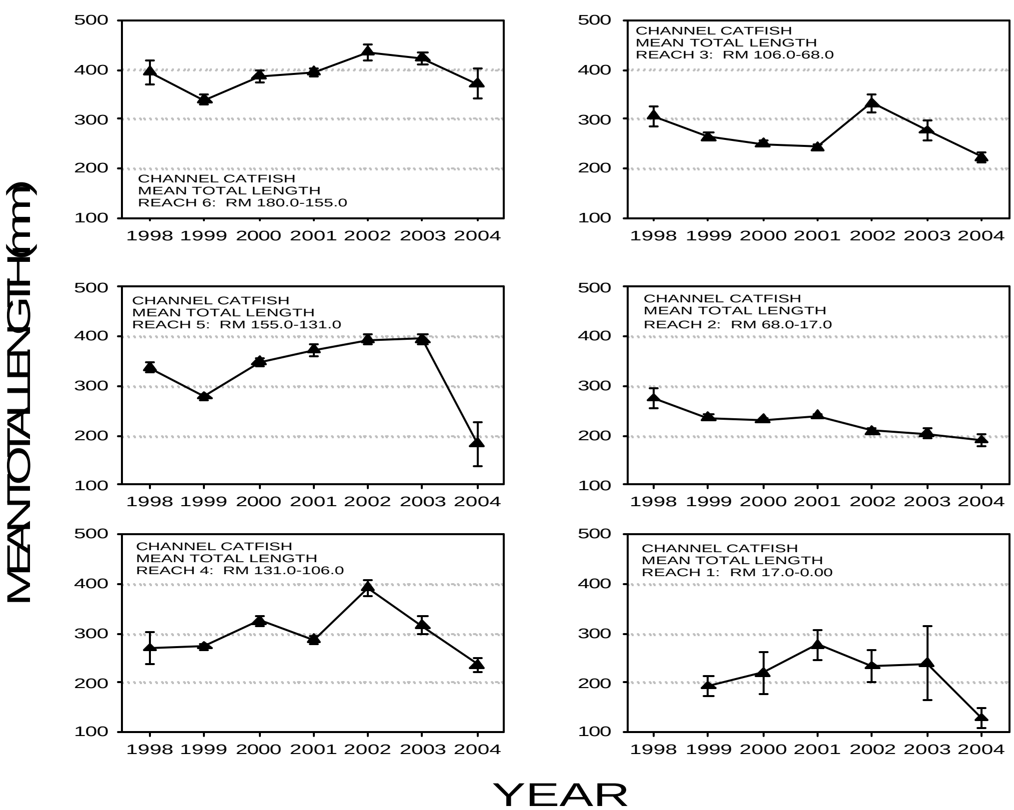

Figure 20. Mean total length (mm) of channel catfish by Geomorphic Reach and by year. Error bars represent $\pm$ 1 SE.

Common carp

Common carp CPUE for all Geomorphic Reaches and all life stages combined has varied since 1998 but generally exhibit a declining trend in abundance (Table 3, Figure 21). Catch rates have not changed since 2003 but remain lower ($p < 0.001$) than those observed in 2001. Catch rates in 2004 are the second lowest among 1998-2004 comparisons. Differences in common carp CPUE are resultant of changes in adult CPUE. Since 1998, adult CPUE declined ($p < 0.05$) each year with the exception of 2003-2004 ($p = 0.06$). Juvenile fish comprised 21% of the overall common carp catch at < 2 fish / hour (Figure 21). While adult CPUE was the lowest observed since 1998 (4.6 fish / hour), juvenile CPUE was the highest at 1.8 fish / hour.

Within Geomorphic Reach 6, portions of which intensive removal occurs, common carp CPUE for all life stages combined did not decline from 2003-2004. Although significant declines were not observed in 2004, CPUE values were the lowest (8.0 fish / hour) among 1998-2004 comparisons, $p < 0.001$ (Figure 22). Juvenile CPUE has not declined since 1998 and continue to comprise little of the overall common carp catch at 2.4 fish / hour. Adult CPUE did not decline in 2004, $p = 0.66$, but remains lower ($p = 0.001$) than values observed in 2001.

Catch rates for all life stages combined within adjacent Geomorphic Reach 5 did not decline in 2004 but remain lower ($p < 0.001$) than 2001 values (Figure 22). Juvenile CPUE has not changed since 1999 and continue to comprise a small percentage of the overall common carp catch in Geomorphic Reach 5. Adult CPUE of 10.0 fish / hour was similar to 2003 and was the lowest CPUE among 1998-2004 comparisons (Figure 22). No significant changes occurred for all life stages combined within Geomorphic Reaches 4-1 (Figures 23 and 24).

Common carp mean total length (TL) for all Geomorphic Reaches combined declined from 481.0 mm in 2003 to 360.8 in 2004 ($p < 0.001$). This is the lowest mean TL among 1998-2004 comparisons and is similar to the mean TL observed in 2000 (Figure 25). Similar to channel catfish, mean TL decreased in each of the six Geomorphic Reaches in 2004 (Figure 26). Although a general decrease in mean TL occurred within Geomorphic Reach 6, portions of which intensive removal occurs, the change was not significant ($p = 0.67$). Mean TL has not significantly declined for Geomorphic Reaches 3 and 1 and have not exhibited a declining trend among 1998-2004 comparisons. Mean TL in Geomorphic Reaches 5, 4, and 3 declined ($p < 0.05$) from 2003 and each are the lowest mean TL among 1998-2004 comparisons. Unlike channel catfish, mean TL does not decrease as sampling continues downstream. This hold true with the exception of Geomorphic Reach 6 which remains lower ($p <0.05$) than all other Geomorphic Reaches.

Rare Fish Collections

A total of 28 Colorado pikeminnow recaptures (24 individual fish) was collected in Section 1 in 2004. Of the 28 recapture events, 7 (25.0% of catch) occurred between PNM Weir and APS Diversion. Colorado pikeminnow were 79 – 530 mm TL and included age-0 to age-9 fish. A total of 15 Colorado pikeminnow were previously PIT tagged and 8 lacked a PIT tag. Due to size restrictions, (< 150 mm TL) these were released without implanting. A total of 21 razorback sucker were collected in Section 1. All fish were unique captures and ranged 334 – 540 mm TL. All fish were recaptures with the exception of one individual. Due to the size of the fish (438 mm TL; 359 mm SL) it is likely that this was a stocked individual whose prior PIT tag was expelled or was no longer readable. Two razorback sucker (9.52% of recaptures) were recaptured above APS Diversion.

A total of 84 Colorado pikeminnow representing 75 individual fish was collected in Section 2 in 2004. Fish were 62 – 362 mm TL. A total of 30 fish were considered new captures and did not have a PIT tag at time of capture. A total of 203 razorback sucker representing 181 individuals were recaptured in Section 2 in 2004. Of these, four did not indicate the presence of a PIT tag at time of capture but size of individuals suggest that these fish were recaptures (or stocked) fish that either expelled their tag or the tag was not longer readable.

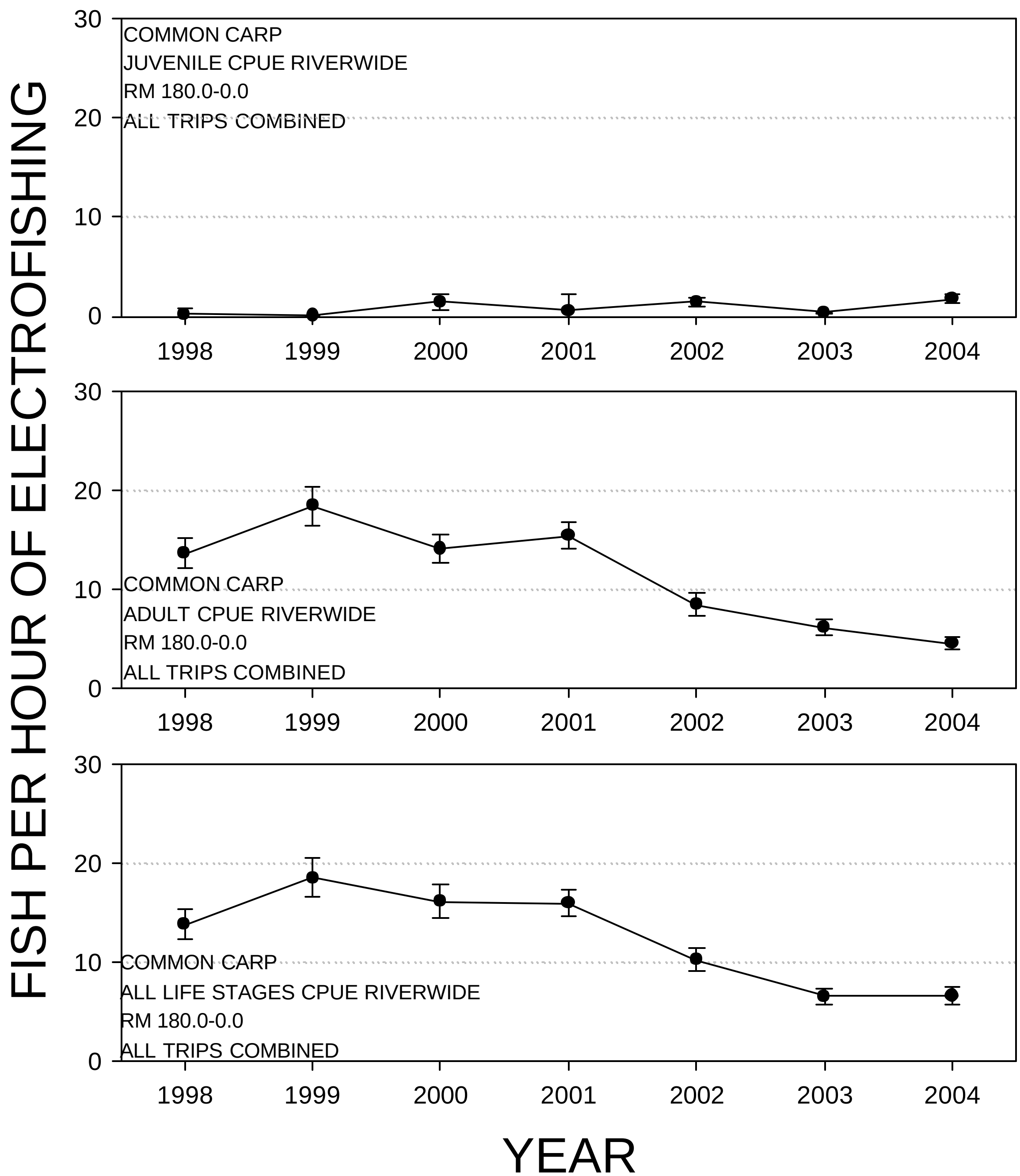

Figure 21. Common carp CPUE (fish / hour) by size class and by year, 1998-2004. Fish collected during riverwide monitoring efforts conducted by FWS-GJ in the spring and fall of each year. Error bars represent ± 1 SE.

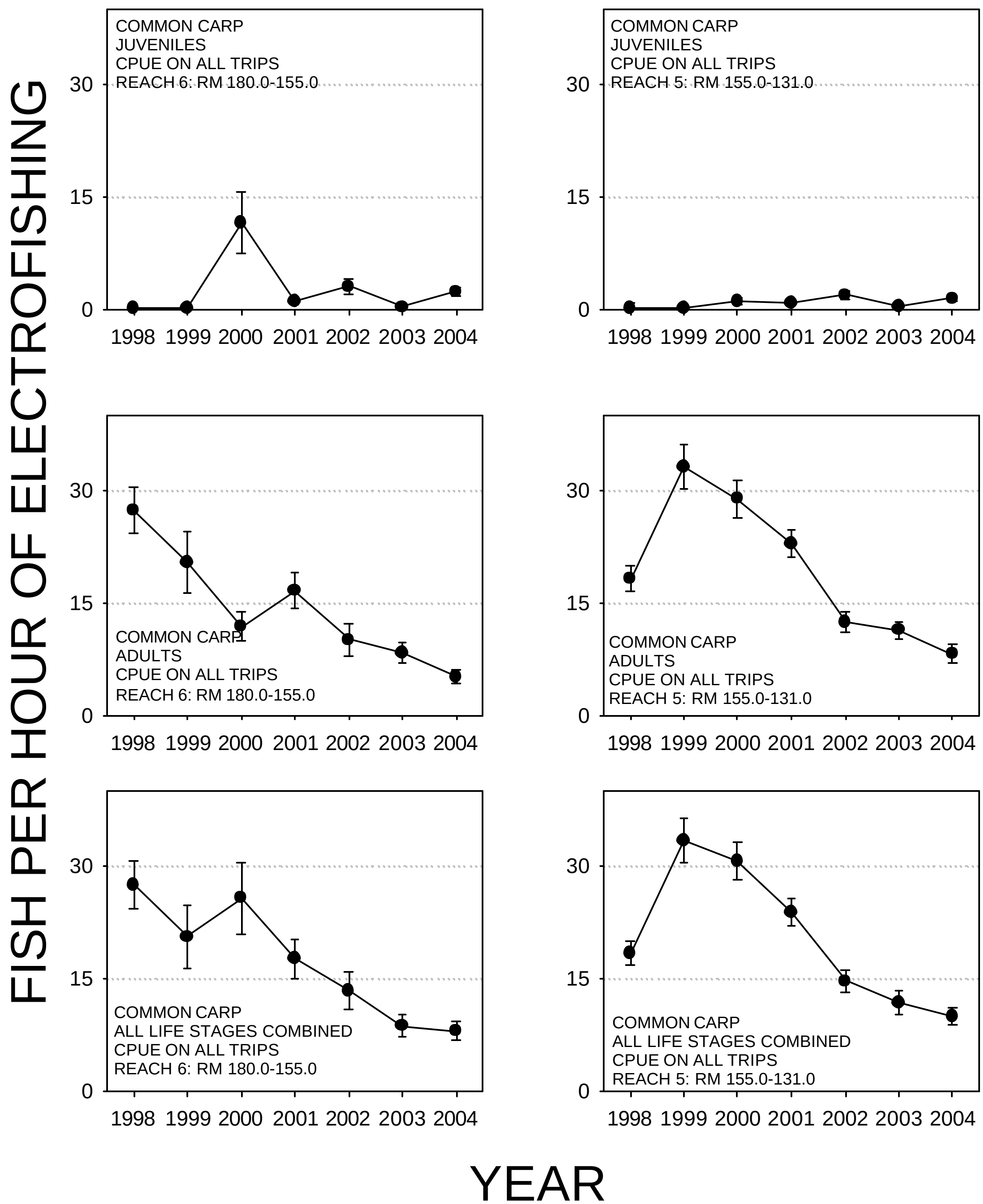

Figure 22. Common carp CPUE fish / hour in Geomorphic Reaches 6 and 5 by size class and by year, 1998-2004. Fish collected during riverwide monitoring efforts conducted by FWS-GJ in the spring and fall of each year. Error bars represent ± 1 SE.

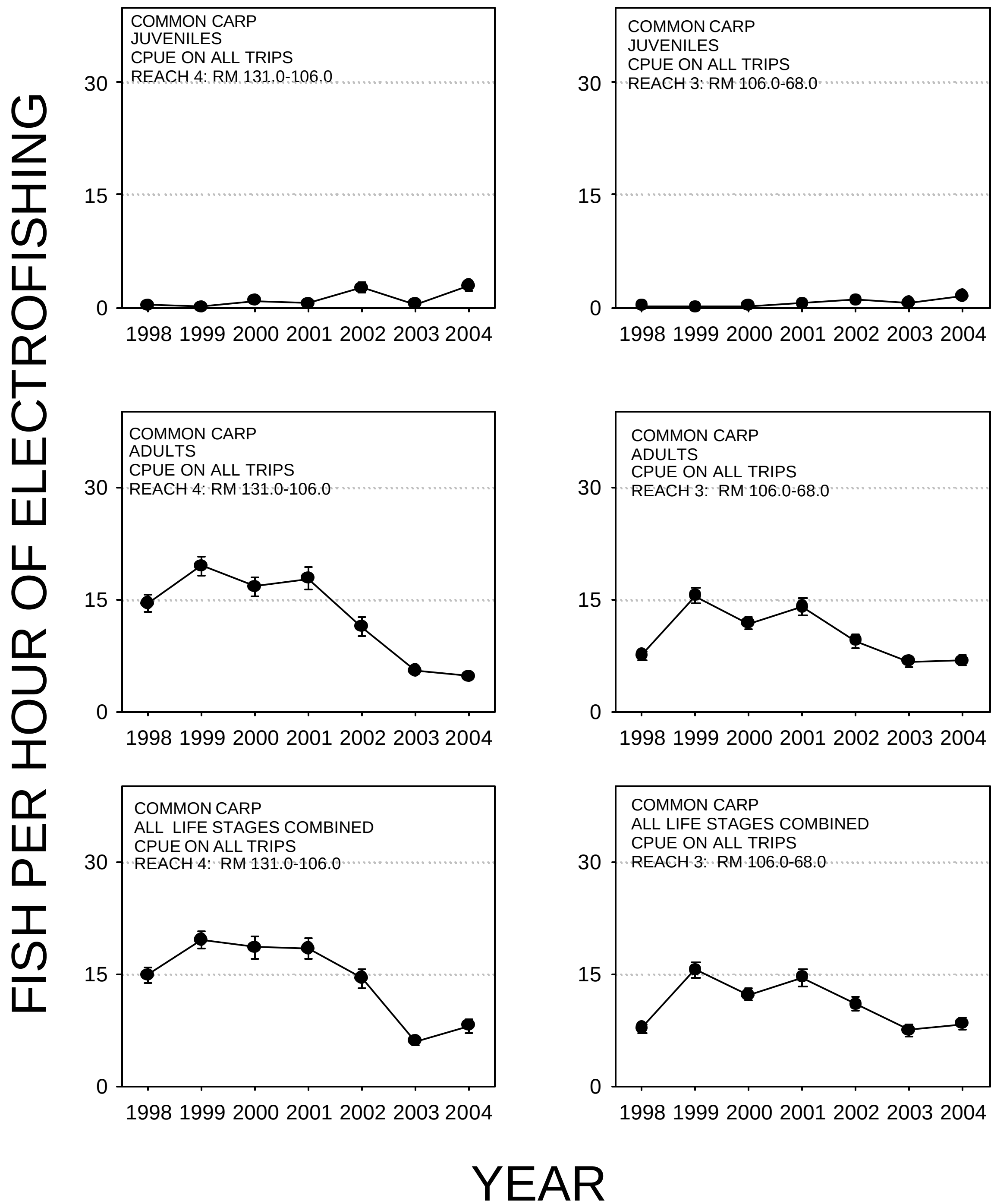

Figure 23. Common carp CPUE (fish / hour) in Geomorphic Reaches4 and 3 by size class and by year, 1998-2004. Fish collected during riverwide monitoring efforts conducted by FWS-GJ in the spring and fall of each year. Error bars represent ± 1 SE.

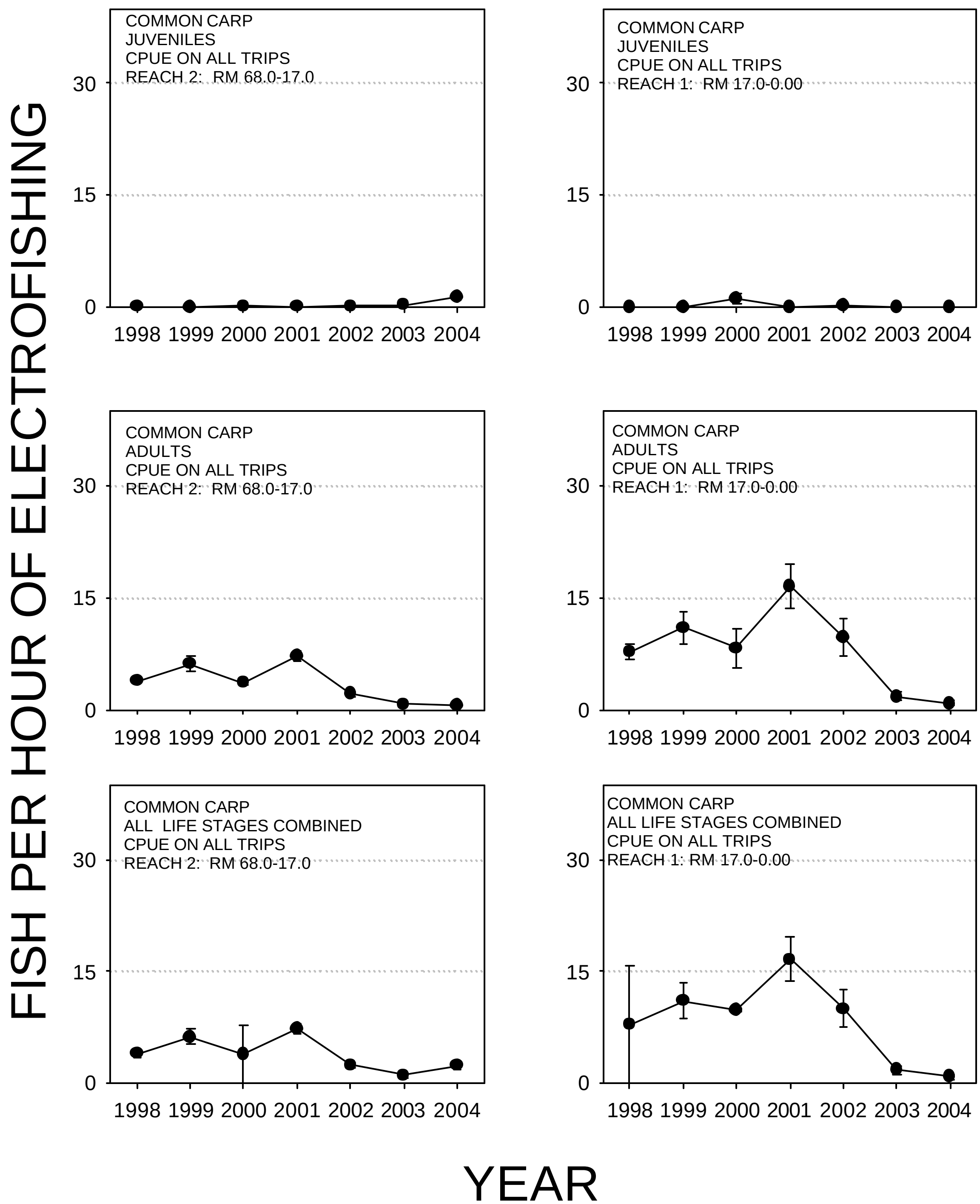

Figure 24. Common carp CPUE (fish / hour) in Geomorphic Reaches 2 and 1 by size class and by year, 1998-2004. Fish collected during riverwide monitoring efforts conducted by FWS-GJ in the spring and fall of each year. Error bars represent $\pm$ 1 SE.

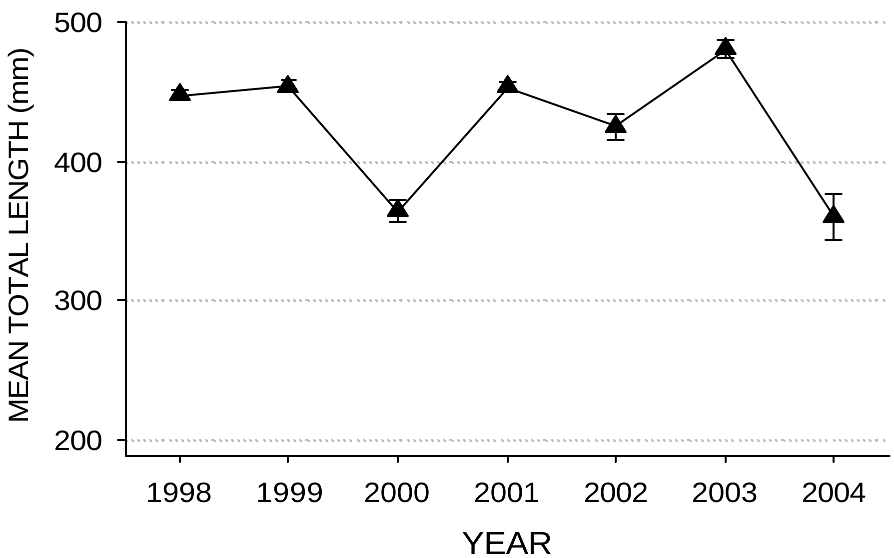

Figure 25. Mean total length (mm) of common carp collected in all Geomorphic Reaches during fall monitoring of each year 1998-2004. Error bars represent + 1 SE

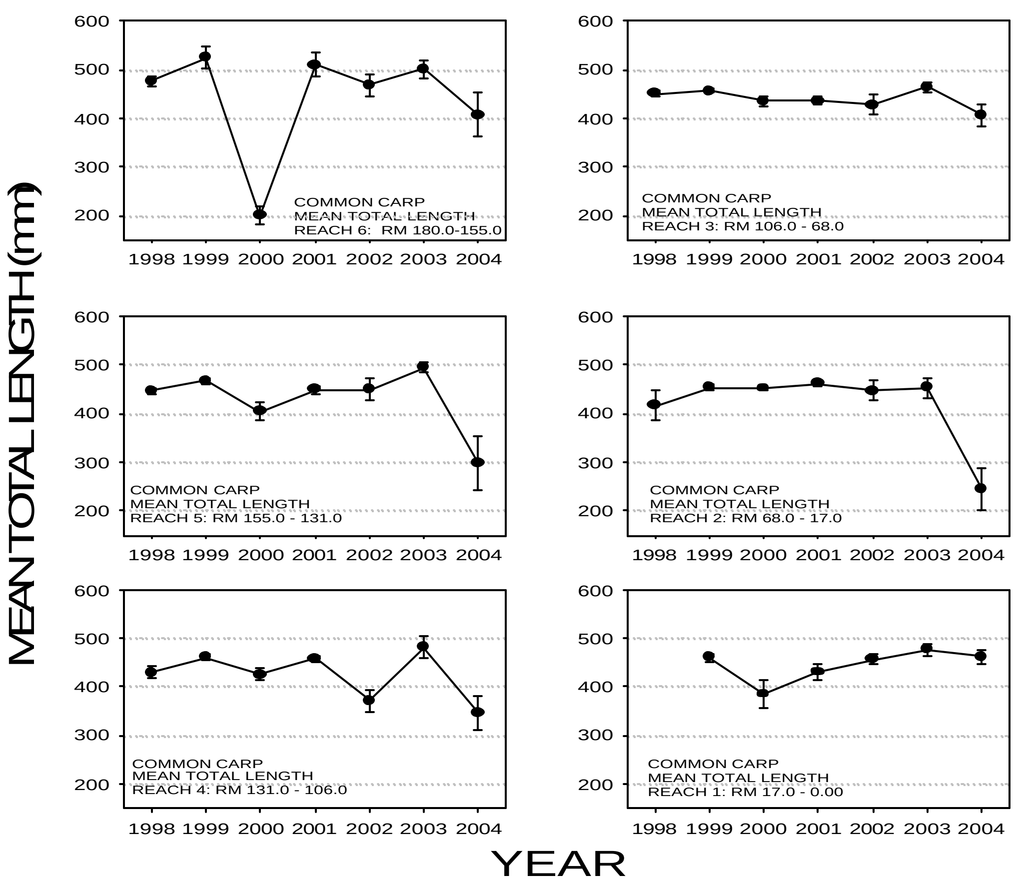

Figure 26. Mean total length (mm) of common carp by Geomorphic Reach and by year. Error bars represent + 1 SE.

DISCUSSSION

The majority of intensive non-native removal efforts were focused from PNM Weir to Hogback Diversion. However, due to seasonal variability in channel catfish CPUE, removal efforts were expanded in 2003 to include the Hogback Diversion to Shiprock Bridge Section.

Channel catfish CPUE from PNM Weir to Hogback Diversion (Section 1) has not declined among 2001-2004 comparisons. The lack of a clear decline in channel catfish CPUE is associated with increases in juvenile channel catfish CPUE. When non-native removal efforts first began, juvenile channel catfish were absent from collections within Section 1, while composing nearly 50% of the catch in 2004. Although CPUE for all life stages combined has remained similar since 2001 the shift to smaller fish is important

Declining trends in CPUE of large channel catfish and shift in size class distribution to smaller, less fecund size is encouraging. Shifts towards smaller fish may be important in long term suppression and reduction of channel catfish numbers in the San Juan River by reducing reproductive potential and recruitment. By removing large, more fecund channel catfish, mechanical removal has reduced numbers of sexually mature fish within intensive removal Sections. 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, it was determined that fish at 330 mm TL produced around 4,500 eggs / fish compared to the production of 41,500 eggs at 380 mm TL

A shift towards smaller channel catfish is also important for predation reasons. Brooks et al. (2000) found that San Juan River channel catfish < 300 mm TL consumed almost exclusively macroinvertebrates and Russian olive fruits with piscivory occurring most frequently in fish > 450 mm TL. Documentation of predation on endangered fish during their study was not observed due to the relatively low numbers of rare fish in the San Juan River at the time of their study, but has been documented elsewhere in SJRIP work (Jackson 2005). As augmentation efforts continue and numbers of rare fish increase, predation on rare fish by channel catfish will undoubtedly increase.

For example, in 2004 a 690 mm TL channel catfish collected by UDWR crews consumed a 325 mm TL razorback sucker, along with another 280 mm unidentifiable sucker in its stomach. These crews also documented a ~210 mm PIT tagged pikeminnow that was consumed by a 416 mm channel catfish (Jackson 2005). Aggressive behavior by channel catfish on native fishes has also been observed. Individual native suckers as larger as 510 mm have been collected with apparent channel catfish bite marks across the dorsal region (Ryden, personnel communication; personal observations). Instances of predation and other negative interactions with native fishes may be reduced with continued shifts to smaller channel catfish. Food habits studies suggest channel catfish of this size are not piscivorous with gape limitations possibly preventing predation.

Common carp are ubiquitous and during 1991-1997 SJRIP studies were found to be the fourth most abundant fish in electrofishing collections (Ryden 2000). In addition to widespread abundance, majority of common carp collected were large adult fish > 400 mm TL, weighing up to or exceeding 1,800 grams. Within intensive removal reaches, total biomass of common carp removed has declined since 2001. It appears that removal efforts have been successful in decreasing common carp abundance, possibly limiting 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). Although overall biomass of common carp has declined, average mass has increased since 2001 resulting in a higher mean condition factor $K_{(f)}$. It appears that common carp are becoming less common in collections but fish that are collected are generally larger, more robust fish than in previous years.

Seasonal variations in channel catfish and common carp CPUE may be attributed to sampling conditions, but most likely are due to localized movement patterns. Tagged non-native fishes have been documented to move upstream of Hogback Diversion and reoccupy Section 1 during summer months (Davis and Coleman 2004). In addition to this movement, CPUE between sub-sections of Section 1 (PNM Weir to Hogback Diversion) differ between each other. Both channel catfish and common carp CPUE were significantly lower upstream of APS Diversion than downstream. Due to flow conditions and operational requirements of APS Diversion, it appears that upstream movement of non-native fishes was limited, but possible. Although this sub-section (PNM-APS) is not a true closed population, both mark / recapture data and intensive non-native removal CPUE data suggest that movement into this sub-reach has been limited. These data suggest that if given a true closed population, or a section of river where emigration is limited, mechanical removal by electrofishing can be successful in the San Juan River.

Largemouth bass collections in Section 1 during 2004 are interesting due to the relatively high number observed. However, pulses in juvenile largemouth bass CPUE have been observed in previous years with fish failing to recruit into adult size classes (Dale Ryden, personal communication). It is unknown where these fish originate from but it is unlikely that they are year round residents actively reproducing in the San Juan River. The San Juan River lacks quiet, warm waters with low turbidity preferred by largemouth bass (Pflieger 1997, Robison and Buchanan 1988) . A more likely source would be from off channel ponds and associated irrigation returns that are common in this Section. The majority of largemouth bass collections in 2004 occurred at or nearby irrigation returns (Davis, personal observation). Concern about largemouth bass in the San Juan River and active mechanical removal efforts geared specifically towards this species does not need to be considered unless recruitment to adult size classes are observed.

Ascertaining native fishes response exclusively to mechanical removal efforts has proven to be difficult. Trends in native sucker distribution and abundance are dependant on multiple factors including discharge, temperature, habitat suitability and mechanical removal. Trends in native sucker CPUE from PNM Weir to Hogback Diversion show little change since 2001, when removal efforts began. Catch rates for native suckers in this Section may have been even higher before completion of the Nenahezad Fish Passage at RM 166.6. Since 2003, a total of 39,822 flannelmouth and bluehead suckers have been processed and transferred upstream of our study reach (Lapahie 2003, 2004) and may have influenced CPUE trend comparison. Lack of apparent declines in native sucker abundance related to repeated exposure to electrofishing is encouraging. These data suggest that management tools and methodology like intensive non-native removal by electrofishing are not having deleterious affects on native fish abundance. Further research into the affects repeated exposure to electrofishing has on native fishes is encouraged.

Decreasing trends in both channel catfish and common carp CPUE riverwide continued to be observed and were at the second lowest levels among 1998-2004 comparisons. Adult channel catfish CPUE in 2004 was at the lowest level observed during riverwide monitoring since 1998. Juvenile channel catfish CPUE increased in 2004, but was still at levels lower than 2001when intensive removal began. Large, more fecund channel catfish continued to comprise a small proportion of the catch. Mean TL of channel catfish in 2004 was the lowest observed since 1998.

Observed reductions in channel catfish CPUE since 1998 are likely a result of both intensive and opportunistic removal efforts conducted riverwide. However, other factors such as discharge, habitat quality and availability, and temperature may have influenced decreases as well. Decreased abundance riverwide is likely reducing potential negative interactions with native fish. Continued reduction in mean TL and shifts to smaller size class distributions of channel catfish are important indicators of successful removal and exploitation efforts. Results are similar to those Pitlo (1997) observed as evidence of overexploitation of channel catfish in the Mississippi River. It was observed that as the numbers of large fish decline, the population became highly dependent on newly recruited fish, resulting in large fluctuations in catch and dependence on the strength of individual year-classes. Shift towards smaller fish in the San Juan River with fewer large individuals results in a possible reduced reproductive potential and may influence recruitment in subsequent years.

Common carp abundance, based of CPUE, appears to have decreased since 1998 and is primarily a result of fewer large adult fish in electrofishing collections. With recent flow conditions in the San Juan River lacking out of bank flow, available low flow or slackwater, spawing and nursery habitats for common carp has likely been limited. Lack of available nursery habitat may have influenced recent common carp abundance trends as much as mechanical removal has and close watch on trends post high spring discharge is necessary

Intensive non-native removal efforts by NMFRO continued to work with both state and tribal partners in transplanting channel catfish from the San Juan River to closed impoundments in the area. These efforts were initiated to address negative concerns by citizens about removal of game fish from the river. By transplanting channel catfish, anglers in the Four Corners region still have the opportunity of fishing for quality sized fish. To date, over 9,000 channel catfish have been transferred to closed impoundments with the assistance of Navajo Nation Department of Fish and Wildlife and New Mexico Department of Game and Fish. Fish transferred continue to be larger than those produced by federal and private hatcheries and average 356-406 mm TL and .31 fish / kg (14-16" and 0.68 fish / lb).

Intensive removal efforts will continue in 2005 with trips distributed between each of the two Sections. These data will continue to track changes in distribution and abundance trends and will help researchers in evaluating overall effectiveness of removal efforts. Important information on movement and retention of augmented rare fish will also be collected and will aid researchers in evaluation of augmentation efforts.

CONCLUSIONS

PNM Weir to Hogback Diversion (RM 166.6 – 159.0)

- Overall CPUE for channel catfish has not declined, 2001-2004 ($p = 0.894$).
- General declines of adult channel catfish and associated increases in juvenile CPUE ($p = 0.019$); typical of an over-harvested fish population.
- Juvenile channel catfish comprised > 45% of total catch in 2004 and were absent from collections in 2001. Channel catfish > 500 mm comprised > 50% of the catch in 1999 and only 3.5% in 2004
- Reductions in overall common carp CPUE have been observed 2001-2004 ($p < 0.001$).
- No apparent reduction in size class distribution of common carp.
- Increased CPUE of largemouth bass during August 2004 trip (15 fish / hr) and highest CPUE ($p = 0.033$) among 1998-2004 comparisons.

Hogback Diversion to Shiprock Bridge (RM 158.8 – 147.9)

- Overall CPUE for channel catfish has not declined, 2003-2004 ($p = 0.800$)
- Observed decreases ($p < 0.001$) in adult channel catfish and associated increases in juvenile CPUE ($p < 0.001$); typical of an over-harvested fish population.
- Mean TL and CPUE higher within this reach compared to the adjacent upstream reach.
- Reductions in overall common carp CPUE (p , 0.001) have been observed 2003-2004.
- No apparent reduction in size class distribution of common carp.

Riverwide Removal Efforts (RM 180.0 – 0.00)

- Channel catfish CPUE for all Geomorphic Reaches combined was slightly higher than 2003 but still lower than 1998 values.
- Third consecutive year of declining CPUE for adult channel catfish.
- Geomorphic Reaches 6 and 5, portions of which intensive non-native removal takes place, had the lowest channel catfish CPUE among 1998-2004 comparisons.
- Common carp CPUE for all Geomorphic Reaches combined was slightly higher than 2003 but still lower than 1998 values.
- Third consecutive year of declining CPUE for adult common carp and 2004 values was the lowest among 1998-2004 comparisons.
- Geomorphic Reaches 6 and 5, portions of which intensive non-native removal takes place, had the lowest common carp CPUE among 1998-2004 comparisons.
- Both channel catfish and common carp saw marked declines in average size with mean total lengths the lowest among 1998-2004 comparisons.
-

Channel catfish transplantation efforts 2001-2004

- Over 9,000 channel catfish have been removed from the San Juan River and transplanted to off channel reservoirs by the New Mexico Department of Game and Fish and the Navajo Nation Department of Fish and Wildlife.
- Transplanted San Juan River channel catfish were larger than fish provided by U.S. Fish and Wildlife Service National Fish Hatcheries.

Future removal efforts on the upper San Juan River

- Continue intensive removal efforts from RM 166.6 to 147.9.
- Expansion of removal trips to include at least two trips from Shiprock Bridge to Montezuma Creek, Utah (RM 147.9 – 93.6).

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APPENDIX

Appendix A. Colorado pikeminnow collected during intensive removal trips from PNM Weir to Hogback Diversion, 2004.

Date	RM or Section	PIT tag	Recapture	Total Length (mm)	Standard Length (mm)	Weight (grams)	Comments
4/20/2004	163.4-159.0	NO TAG	N	137	117	15	
	163.4-159.0	5229795601	Y	189	157	44	
4/21/2004	163.4-159.0	7F7B1B0B31	Y	530	452	1250	
4/22/2004	163.4-159.0	NO TAG	N	132	111	16	
6/29/2004	163.4-159.0	441E2C7F17	Y	225	183	95	
	163.4-159.0	522A1E427F	N	226	193	--	
	166.6-163.4	522A2F6B76	N*	230	195	90	
6/30/2004	163.4-159.0	441E767F2A	Y	251	206	125	
	166.6-163.4	NO TAG	N	79	-	-	
7/01/2004	163.4-159.0	141F1D621D	Y	240	190	95	
	163.4-159.0	441E2F3341	Y	229	185	90	
	163.4-159.0	NO TAG	N	80	65	-	
7/20/2004	163.4-159.0	522A54130A	N	224	184	60	
	166.6-163.4	NO TAG	N	230	186	82	TAG NOT READ
7/21/2004	166.6-163.4	7F7B1BOB31	Y	529	450	980	
	163.4-159.0	NO TAG	N	131	105	-	
7/22/2004	163.4-159.0	441C504C4B	Y	280	220	155	
8/17/2004	163.4-159.0	441F1F7861	Y	283	229	168	
	166.6-163.4	512D5F2B33	Y	397	321	620	
8/18/2004	163.4-159.0	7F7B1BOB31	Y	530	450	1010	
8/19/2004	163.4-159.0	423C757921	N	165	133	38	
	163.4-159.0	NO TAG	N	135	115	-	

Appendix B. Razorback sucker collected during intensive removal trips from PNM Weir to Hogback Diversion, 2004.

Date	RM or Section	PIT tag	Recapture	Total Length (mm)	Standard Length (mm)	Weight (grams)	Comments
3/23/2004	163.4-159.0	522A616543	Y	450	374	902	
3/24/2004	163.4-159.0	423E654D5D	N	540	458	1950	
4/20/2004	163.4-159.0	5229193946	N	438	359	1850	FEMALE
4/20/2004	163.4-159.0	522A58157F	Y	401	366	890	
6/29/2004	166.6-163.4	4240012C53	Y	445	374	1300	
	163.4-159.0	423F0F3B2F	Y	457	393	1000	
	163.4-159.0	423E307573	Y	442	377	950	
	163.4-159.0	441D52671A	Y	371	305	630	
	163.4-159.0	423E734C79	Y	450	370	1140	
	163.4-159.0	4419071C06	Y	355	294	540	
	163.4-159.0	441D530C25	Y	381	320	610	
6/30/2004	163.4-159.0	441B186760	Y	352	280	410	
7/01/2004	163.4-159.0	52283D0C7D	Y	334	270	445	
7/20/2004	163.4-159.0	53244B047C	Y	473	400	1800	
	163.4-159.0	44796E6D3E	Y	382	320	560	
	163.4-159.0	5228710138	Y	452	381	850	
8/17/2004	163.4-159.0	4507082A1A	Y	382	230	460	LERNIA
8/18/2004	166.6-163.4	441D5A7B6F	Y	345	290	525	
8/18/2004	163.4-159.0	4473520A14	Y	390	340	780	LERNIA
11/08/2004	163.4-159.0	44152D1512	Y	377	305	795	LERNIA
	163.4-159.0	423E2A0977	Y	461	385	1400	

Appendix C. Colorado pikeminnow collected during intensive removal trips from Hogback Diversion to Shiprock Bridge, 2004.

Date	RM	TL	SL	Wt	Recap	PIT tag
5/11/04	155.0	172	139	35	N	
5/12/04	148.0	87	68	N/A	N	
5/13/04	151.0	62	53	N/A	N	
6/15/04	151.0	259	215	130	Y	#441E617834
	152.0	209	170	64	Y	#441E3F3C66
	152.0	220	178	80	Y	#441E4A0352
	152.0	245	198	120	Y	#441E6E0567
	154.0	210	160	75	Y	#441E273538
	154.0	221	175	130	Y	#441E3C6F05
	155.0	233	185	100	Y	#441C29392F
	155.0	220	175	82	Y	#441E3C6F05
	155.0	225	180	90	Y	#441F173C42
	156.0	247	190	120	Y	#441F0A695F
	157.0	210	168	53	Y	#441E5F335B
6/16/04	149.0	223	170	85	Y	#441E371474
	149.0	219	167	70	Y	#441E4A0352
	149.0	222	173	80	Y	#441E77577B
	150.0	221	173	90	Y	#441E371474
	150.0	218	175	70	Y	#441E4A0352
	150.0	362	224	125	Y	#441E617834
	150.0	239	198	75	Y	#441F130B3E
	151.0	208	166	75	Y	#441E0B1E26
	151.0	248	205	105	Y	#441E472530
	152.0	185	147	50	Y	#441E303B43
	152.0	75	59	5	N	
	152.0	260	N/A	N/A	N	
	153.0	212	170	75	Y	#441E5A3D2B
	154.0	194	161	60	Y	#441E591E4C
	154.0	212	170	72	Y	#441E5A3D2B
	154.0				Y	#441E6F004A
	155.0	180	140	48	N	#522A544139
	156.0	233	190	90	Y	#441E5A7219
	156.0	N/A	N/A	N/A		
	157.0	226	188	80	Y	#441C660A0C
	157.0	236	190	115	Y	#441E610658
6/17/04	150.0	233	195	90	Y	#441F130B3E
	150.0	250	207	115	Y	#441F130D10
	151.0	232	190	80	Y	#441E3C135
	151.0	246	203	110	Y	#441E60567
	151.0	136	107	N/A	N	
	152.0	255	210	140	Y	#441E2A1803
	154.0	234	190	100	Y	#441E304973
	154.0	220	117	70	Y	#441F113E1D
	154.0	213	170	65	Y	#441F172E08
	155.0	232	185	90	Y	#441D1144E01
	155.0	216	173	60	Y	#441F113E1D

	155.0	214	170	60	Y	#441F172E08
	156.0	244	190	110	Y	#441E754B3E
	156.0	235	192	95	Y	#441F144E01
	157.0	243	195	105	Y	#441F173E76
	157.0	76	61	N / A	N	
9 / 14 / 04	152.0	200	170	60	N	
	153.0	180	150	51	N	
	153.0	190	160	52	N	
9 / 14 / 04	155.0	175	140	42	N	
	156.0	174	142	40	N	#42447E4716
	156.0	305	256	180	Y	#441E3A651C
	156.0	185	155	70	N	#5229210072
	156.0	170	145	N / A	N	
	157.0	160	135	28	N	
	157.0	148	125	25	N	
9 / 15 / 04	151.0	151	124	30	N	
	152.0	182	150	54	Y	#423C653568
	152.0	165	134	50	Y	#424159116F
	153.0	191	156	54	N	#423D040E42
	153.0	185	155	50	N	#42417C720D
	153.0	181	136	37	N	#42446A5843
	155.0	165	134	30	N	#522A264F2C
	155.0	190	156	51	N	#522A2A2E2E
	156.0	180	146	45	N	#4244421A4E
	156.0	175	147	31	N	#52291A794C
	157.0	177	144	50		#42400E193F
	157.0	171	141	35	N	#4242064E15
	157.0	205	171	70		#424470705A
	157.0	158	122	32		#4244724806
	157.0	184	150	48		#42453B0465
	157.0	155	129	N / A	N	#522A500556
11 / 16 / 04	148.8	85	64	4	N	
	154.5	162	133	32	N	
	157.0	149	120	22	N	
	157.0	162	130	32	N	
11 / 17 / 04	149.0	85	66	6	N	
	154.0	167	135	26	N	
	154.0	93	74	7	N	
	156.0	153	122	27	N	
11 / 18 / 04	149.0	162	131	27	N	#4244453579

Appendix D. Colorado pikeminnow collected during intensive removal trips from PNM Weir to Hogback Diversion, 2004.

5/11/04	151.0	378	328	610	Y	#44210C7E33
	151.0	357	294	500	Y	#5229711D7E
	152.0	297	245	240	Y	#441D4F161E
	154.0	405	332	850	Y	#44147B494B34
	154.0	433	367	750	Y	#522A58157F
	155.0	343	284	500	Y	#44170D6809
	155.0	304	245	390	Y	#441D4F161E
	155.0	479	403	1450	Y	#507E6B455A
	155.0	351	286	450	Y	#5228367538
	155.0	354	285	620	Y	#52283A5C05
	155.0				N	
	156.0	485	412	1450	Y	#423F6A4379
	156.0	337	276	490	Y	#441B052114
	156.0	321	270	550	Y	#441B29707C
	157.0	449	385	950	Y	#4240017E60
	157.0	367	305	560	Y	#441A794646
	157.0	370	311	615	Y	#441D607075
	157.0	375	315	760	Y	#5228371D10
	157.0	473	406	1300	Y	#5324594E7C
5/12/04	148.0	342	281	510	N	#423D090D1A
	148.0	452	384	1120	Y	#424004437A
	148.0	354	292	540	Y	#5228367538
	149.0	315	260	440	Y	#441D2E1F19
	150.0	437	356	950	Y	#52283A1B71
	152.0	490	419	1000	Y	#4242312966
	152.0	340	275	520	Y	#5229763A0F
	152.0	385	324	630	Y	#522A505F23
	153.0	350	293	340	Y	#4415291942
	153.0	410	349	500	Y	#522860564A
	154.0	450	385	990	Y	#423F170161
	154.0	340	275	510	Y	#5229763A0F
	155.0	342	278	500	Y	#44167F4930
	156.0	460	384	1055	Y	#423F0D5520
	157.0	394	338	700	Y	#522A575300
5/13/04	149.0	376	310	410	Y	#5228446967
	151.0	460	393	980	Y	#423F7E0831
	151.0	348	295	340	Y	#5228453011
	152.0	447	360	820	Y	#423C7A6305
	152.0	360	292	381	Y	#441D282749
	152.0	381	317	470	Y	#5229171632
	154.0	426	362	820	N	#522A251013
	155.0	354	289	390	Y	#441D59592B
	155.0	337	272	320	N	#52290B194E
	156.0	435	370	775	Y	#423F7E7469
	157.0	425	352	850	Y	#423E5ED7C
	157.0	459	380	675	Y	#4240017E60

6 / 15 / 04	151.0	376	312	540	Y	#441D56076C
	154.0	490	410	1000	Y	#424015340B
	154.0	462	295	500	Y	#441B275D3C
	154.0	441	360	920	Y	#441E273538
	155.0	436	365	940	Y	#423E714355
	155.0	442	355	800	Y	#423F742F0F
	155.0	458	375	820	Y	#52283F3118
	156.0	338	274	450	Y	#441D462F45
	157.0	457	381	850	Y	#423F0D5520
	157.0	435	372	900	Y	#423F7E7469
	157.0	406	329	750	Y	#522A575300
6 / 16 / 04	150.0	375	308	530	Y	#441D56076C
	151.0	430	346	760	Y	#423E7F419
	154.0	430	356	870	Y	#423D1D0A77
	154.0	366	299	480	Y	#441737015D
	157.0	354	287	475	Y	#441E610658
	157.0	355	287	480	Y	#52282D173E
	157.0					
6 / 17 / 04	151.0	435	365	1120	Y	#423E717425
	153.0	477	380	1200	Y	#4240105835
	154.0	431	362	810	Y	#423C6E6151
	154.0	436	365	820	Y	#4240166146
	154.0	425	350	825	Y	#424218610D
	154.0	363	302	470	Y	#441737015D
	155.0	453	375	1200	Y	#53257A7764
	156.0	431	355	850	Y	#423F7E7469
	157.0	444	367	775	Y	#423F083F31
	157.0	435	362	850	Y	#423F7E7469
9 / 14 / 04	151.0	450	390	810	Y	#423E751E21
	152.0	385	330	550	Y	#4364293F35
	155.0	345	295	430	Y	#42415C1E3C
	155.0	385	330	600	Y	#43636C1451
	155.0	400	350	630	Y	#45035D4D24
	155.0	409	340	690	Y	#450950482F
	155.0	445	375	910	Y	#45127B2405
	156.0	482	412	1240	Y	#4471571E1F
	156.0	410	355	670	Y	#4474193528
	156.0	375	305	555	Y	#45063C3843
	156.0	385	320	610	Y	#450711695B
	156.0	412	347	690	Y	#45073F2258
	156.0	363	303	620		#5229736141
	156.0	402	343	810		
	157.0	479	395	1280	Y	#423E761E52
	157.0	435	355	1000	Y	#423F7E7469
	157.0	394	325	525	Y	#434F016C0F
	157.0	403	330	575	Y	#43644B0226
	157.0	407	325	680	Y	#43655D7910
	157.0	406	333	725	Y	#4369053E68
	157.0	405	350	620	Y	#4369256A62
	157.0	361	300	560	Y	#4369332E06
	157.0	368	297	600	Y	#44741B7F44

9/14/2004	157.0	396	323	600	Y	#447A73677C
	157.0	400	350	690	Y	#447C2F1008
	157.0	372	303	480	Y	#447C551F69
	157.0	370	315	520	Y	#4502785577
	157.0	410	350	650	Y	#4509032D12
9/15/04	152.0	493	419	1300	Y	#43655A0319
	152.0	410	338	520	Y	#43687D256E
	152.0	390	318	640	Y	#441D3C043D
	152.0	407	348	820	Y	#450B460B31
	153.0	405	330	610	Y	#43687D256E
	153.0	427	355	640	Y	#44720F3D42
	155.0	383	330	570	Y	#434F333745
	155.0	382	321	640	Y	#4364495151
	155.0	394	330	740	Y	#44747E3067
	155.0	415	355	800	Y	#447E172339
	155.0	378	321	460	Y	#45032E3953
9/15/04	155.0	422	360	890	Y	#45065B5658
	155.0	345	290	310	Y	#45071F2D04
	155.0	450	390	N/A	Y	#4507492C41
	156.0	400	330	560	Y	#434F201054
	156.0	425	350	725	Y	#4365727573
	156.0	290	237	200	Y	#43670F7F23
	156.0	345	278	N/A	Y	#44172C7874
	156.0	395	335	580	Y	#4472325150
	156.0	384	303	625	Y	#4479714311
	156.0	N/A	N/A	830	Y	#447B551F26
	156.0	411	340	575	Y	#447E151E5C
	156.0	377	320	410	Y	#45065C4154
	156.0	425	364	790	Y	#4507462116
	156.0	510	435	1510	Y	#53245D7146
	157.0	375	315	390	N	#4244555175
	157.0	360	306	380	N	#42447B6965
	157.0	411	350	640	Y	#434F110352
	157.0	285	241	225	Y	#434F2C412B
	157.0	415	355	750	Y	#434F336E27
	157.0	356	305	400	Y	#43653F1713
	157.0	400	335	610	Y	#4365425C6E
	157.0	422	360	800	Y	#4365556268
	157.0	392	333	490	Y	#436572173D
	157.0	415	350	750	Y	#43685E1C12
	157.0	340	284	360	Y	#43685E435E
	157.0	340	280	290	Y	#43685E435E
	157.0	384	332	540	Y	#43692B686A
	157.0	386	322	800	Y	#441A734755
	157.0	378	321	560	Y	#44711B0B62
	157.0	423	357	910	Y	#44717D2D52
	157.0	402	340	670	Y	#4473775C52
	157.0	372	319	500	Y	#447910597F
	157.0	404	348	760	Y	#44795E557E
	157.0	339	286	380	Y	#45043D6827
	157.0	335	280	330	Y	#4507112273
	157.0	320	264	340	Y	#450A660976

11/16/04	148.8	390	332	575	Y	#43642C164B
	148.8	416	358	860	Y	#45065F4F4F
	149.8	415	355	800	Y	#4477184012
	149.8	410	340	750	Y	#447B246144
	149.8	379	310	650	Y	#447B570911
	149.8	466	382	1060	Y	#4509273412
	153.0	385	325	480	Y	#45065C4154
	154.5	509	415	1250	Y	#423F625669
	154.5	457	366	950	Y	#4240012C53
	154.5	462	380	1000	Y	#42421B7D5C
	154.5	486	397	1350	Y	#44103C2024
	154.5	462	383	1080	Y	#4467081E05
	154.5	377	302	600	Y	#4473365138
	154.5	503	428	2100	Y	#4479736824
	154.5	407	338	920	Y	#4504223F69
	154.5	404	332	550	Y	#45073B4400
	156.0	405	345	700	Y	#4504223F69
	157.0	276	220	220	Y	#4368795176
11/17/04	149.0	460	381	980	Y	#423F746427
	149.0	395	327	500	Y	#4364293F35
	149.0	400	330	600	Y	#52290F1213
11/17/04	150.0	410	352	820	Y	#4471201D6D
	152.0	462	383	980	Y	#423E751E21
	152.0	375	310	440		
	154.0	425	352	800	Y	#4240005A6D
	154.0	415	352	800	Y	#4369185754
	154.0	437	352	710	Y	#43693F0C6A
	154.0	395	330	740	Y	#44737F1663E
	154.0	476	390	1340	Y	#507E6B455A
	156.0	430	355	950	N	#4249544B5F
	156.0	399	330	610	Y	#43654E782C
	156.0	376	311	560	Y	#4365702513
	156.0	420	351	705	Y	#4368491D22
	156.0	399	328	890	Y	#441A6D7833
	156.0	412	339	750	Y	#44711E2606
	156.0	412	336	690	Y	#4472004E79
	156.0	411	345	750	Y	#4472443B29
	156.0	378	302	560	Y	#4506603E3B
	156.0	412	351	700	Y	#450B127823
	156.0	430	359	960	Y	#4519012410
	156.0	394	326	620	Y	#5229192938
11/18/04	149.0	384	330	610	Y	#447C300A40
	150.0	457	379	1300	Y	#423E771339
	150.0	416	352	1000	Y	#4471201D6D
	150.0	378	305	660	Y	#447C300A40
	152.0	423	355	700	Y	#4369185754
	154.0	465	387	1320	Y	#423F633E41
	154.0	409	344	810	Y	#4364301266
	154.0	272	212	300	Y	#436879517C
	154.0	402	328	780	Y	#4473403307
	154.0	470	400	1450	Y	#44796B4E32

154.0	410	354	950	Y	#447D3C1247
154.0	405	335	800	Y	#450B16225A
156.0	397	332	800	Y	#434F307927
156.0	398	325	700	Y	#4368550D6B
156.0	280	231	230	Y	#436879517C
156.0	458	393	1400	Y	#4502791865
156.0	350	288	625	Y	#52283D0C7D
156.0	479	408	1300	Y	#522A47736F