Nonnative cyprinid removal in the lower Green and Colorado rivers, Utah

Prepared by

Melissa Trammel, Steve Meismer, and David Speas

for the

Upper Colorado River Endangered Fish Recovery Program

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Nonnative cyprinids, nonnative fish control, Green River, Colorado River, Colorado pikeminnow, razorback sucker, seining, red shiner, Upper Colorado River Basin, depletion, removal

EXECUTIVE SUMMARY

Controlling nonnative species of fish in the Upper Colorado River Basin has been a concern of the Upper Colorado River Endangered Fish Recovery Program (Program) for many years. Beginning in 1998, the Utah Division of Wildlife Resources (UDWR) was funded to examine the effectiveness and feasibility of removing nonnative cyprinids from the lower Green and Colorado rivers within Utah for the benefit of native endangered fish.

The study area included 50 consecutive miles on the Green River and three disjunct 10-mile sections of the Colorado River. Four or five removal trips were made each year in April and May on the Green River and July and August on the Colorado River. On each removal trip, all backwaters in the study area were seined multiple times to remove nonnative fishes.

Conclusions specific to our working hypotheses were:

1) Cyprinid removal by seining all backwaters in a river reach will deplete nonnative cyprinid abundance at a backwater level.

- Green River
    i. Depletion was observed within some individual backwaters within one-day sampling occasions.
    ii. No consistent or significant declines in catch or catch rate were observed in individual backwaters where fish were removed on consecutive removal trips.

- Colorado River
    i. Depletion was observed within some individual backwaters within one-day sampling occasions.
    ii. Backwaters were seldom available to be seined more than one trip so the trip removal effect could not be evaluated.

2) Cyprinid removal by seining all backwaters in a river reach will deplete cyprinid abundance at a reach level.

- Green River
    i. Significant differences were observed between treatment and control reaches in the Green River, but no decline in catch rate in treatment areas was observed relative to catch in control areas.
    ii. Temporary reductions in abundance of nonnative adults were observed at a reach level in the Green River.
    iii. In five unique backwaters sampled on each trip, declines in combined catch and catch rate were observed at a reach level in consecutive removal trips.
    iv. The net effect of removal was not significant due to increases in catch, which were likely a result of immigration, reproduction, and growth of larval nonnative fish.

- Colorado River
    1. No significant differences were observed between treatment and control reaches; no decline in catch rate in treatment areas was observed relative to catch in control areas.
    2. Temporary reductions in abundance of nonnative adults were observed at a reach level on the Colorado River within 1998 and 1999.
    3. Declines in catch and catch rate were observed in consecutive removal trips on the Colorado River in 1998 and 1999 until the final trip. But in 2000, catch increased on consecutive removal trips.
    4. The net effect of removal was not significant due to increases in catch, which were a result of immigration, reproduction, and growth of larval nonnative fish.

3) Cyprinid removal by seining all backwaters in a river reach will shift the species composition.

- No significant shifts in species composition were observed.

4) Fall YOY ISMP sampling will be able to detect changes in cyprinid abundance (backwater and reach levels) and species composition from cyprinid removal the previous spring.

- Fall YOY ISMP sampling was not able to detect changes in nonnative cyprinid abundance following removal periods.
- Fall YOY ISMP sampling was not able to detect changes in Colorado pikeminnow or razorback sucker abundance following nonnative cyprinid removal periods.
- Failure to detect changes in nonnative or endangered fish abundance may be due to the statistical power limitations of the ISMP sampling program.

5) Exclusion of nonnative cyprinid adults from portions of flooded tributaries will increase available area for larval native fishes and reduce area available for nonnative cyprinids.

- Blocks nets may reduce area available for nonnative cyprinids, but due to multiple block net failures due to adverse conditions, the usefulness of this technique could not be determined.

RECOMMENDATIONS

- Removal efforts should be pursued by the Program and additional methods evaluated to increase effectiveness, e.g.
    1. Investigate increasing effort by increasing number and frequency of removal passes.
    2. Investigate timing by beginning earlier in the spring and/or adding removal efforts in the fall to reduce over-winter competition and suppress nonnative abundance in the spring.
    3. Investigate additional methods e.g. alternate gear types or chemical treatment.
- Where possible, investigators should assess both depletion effects across removal efforts **and** differences between treatment and control areas; differences between treatment and control sections may not be due to nonnative fish removal efforts.

- Removal efforts should be accompanied by studies designed to evaluate subtle native fish responses.
- Consider additional study of the potential use of block nets to exclude nonnatives from productive off-channel habitats, particularly on the Green River.

1.0 INTRODUCTION

At least 40 nonnative fish species occur in the Upper Colorado River basin (UCRB) (Nesler 2003). Along with habitat modification, negative interactions of nonnative fishes are considered a major cause of the decline of native species in the UCRB (Behnke and Benson 1983; Stanford and Ward 1986; Carlson and Muth 1989; Bestgen 1990; Minckley 1991; Hawkins and Nesler 1991; Carlson and Muth 1993, Lentsch et al. 1996). Nonnative fishes that inhabit the UCRB include piscivorous gamefish species (e.g. northern pike *Esox lucius,* channel catfish *Ictalurus punctatus,* largemouth bass *Micropterus salmoides,* smallmouth bass *Micropterus dolomieu),* and smaller cyprinid species (e.g., red shiner *Cyprinella lutrensis*, sand shiner *Notropis stramineus*, and fathead minnow *Pimephales promelas)*. All nonnative species may negatively impact native populations through competition, predation, or both mechanisms (Hawkins and Nesler 1991, Lentsch et al. 1996, Tyus and Saunders 1996, Tyus and Saunders 2000).

It is likely that the nonnative cyprinid (NNC) species impact early life stages of native species due to their prevalence in habitats used by larval and young-of-year (YOY) native fishes (Tyus et al. 1982, McAda et al. 1994a, and Trammell et al. 1999a, and 1999c). Where distributions overlap, predation may be a significant cause of mortality in larval fishes (Pepin 1988, Bestgen 1997, Bestgen et al. 1998). Ruppert et al. (1993) established that red shiner preyed on fish larvae in the Yampa and Green rivers in Colorado. The susceptibility of early life stages of native fishes to predation and competition has thus been a concern to researchers and was the main impetus for nonnative cyprinid removal projects in the UCRB (Beyers et al. 1994, Muth and Snyder 1995).

The Upper Colorado River Endangered Fish Recovery Program (Program) has identified control of nonnative species as a necessary component of the recovery plan and has been conducting nonnative fish control experiments since 1993 (Pat Nelson, personal communication). Management primarily involves some form of active removal, a method suggested by Minckley (1991) as a means to enhance native fish survival in the UCRB. Lentsch et al. (1996) examined life histories of all nonnative species within the UCRB and proposed possible means for their control. The suggested control methodology for nonnative cyprinids included mechanical removal by seining in low-velocity habitats, blocking access of adults to portions of habitats, and manipulation of flow regimes. This study explored the mechanical control methodology for nonnative cyprinids proposed in Lentsch et al. (1996).

The goal of this study was to determine the feasibility of reducing the abundance of nonnative cyprinids from the lower Colorado and Green rivers in Utah to benefit native fishes, primarily Colorado pikeminnow and razorback sucker. Enhancement of growth and survival of native fishes was the desired outcome of removal efforts.

1.1 Objectives and Hypotheses

Our specific objective for this study was to remove nonnative cyprinids from habitats within a 50-mile river reach in the lower Green River in Utah, and from three, 10-mile reaches in the Colorado River in Utah. We sought to reduce cyprinid abundance from pre-runoff throughout summer months at two spatial scales, i.e., at backwater and river reach levels.

The working hypotheses of this study were:

1) *Cyprinid removal by seining all backwaters in a river reach will deplete cyprinid abundance at a backwater level.*

2) *Cyprinid removal by seining all backwaters in a river reach will deplete cyprinid abundance at a reach level.*

3) *Cyprinid removal by seining all backwaters in a river reach will shift the species composition.*

4) *Fall YOY ISMP sampling will be able to detect changes in cyprinid abundance (backwater and reach levels) and species composition from cyprinid removal the previous spring.*

5) *Exclusion of nonnative cyprinid adults from portions of flooded tributaries will increase available area for larval native fishes and reduce area available for nonnative cyprinids.*

2.0 METHODS

2.1 Study Area

Removal efforts were conducted in portions of the lower Green and Colorado rivers (Figure 1). On the Green River, habitats were treated within a 50-mile reach from the Dry Lake/School Bus Wash

(RM 102.0) to Mineral Bottom boat launch (RM 52.0). The Green River reach has mostly cobble substrate near the top of the reach that is gradually replaced by sand downstream. The San Rafael River enters the Green River at RM 97.0 and is the only major tributary flowing into the reach. Many other dry washes enter the reach, which are flooded at high water creating low-velocity habitat. The Green River was sampled during spring high flows; therefore, most of the available low-velocity habitats were flooded wash mouths, often in excess of 500 m long and 2 m deep. Frequently sampled habitats were referred to by name (Table 1).

On the Colorado River, habitats within three disjunct 10-mile reaches were treated. The Dewey reach (RM 97-87) contains mostly main-channel backwaters on the upstream or downstream ends of sandbars. The Dolores River enters the Colorado River in the upper part of this reach. The Moab reach (RM 65-55) is a slower reach of river with a few large flooded wash habitats and seasonally abundant main-channel backwater habitats. This reach includes Moab Wash, which flows seasonally beside and under the Atlas Uranium Mine tailings pile and contributes high levels of ammonia into the river (United States Geological Survey [USGS] 2002), and Mill Creek which is a small perennial tributary that flows into the Colorado River through The Nature Conservancy's Matheson Wetlands Preserve. The Lathrop reach (RM 30-20) contains primarily main-channel backwaters. The lower two reaches were chosen because they were extensively sampled during a nursery habitat study from 1992 to 1996 (Trammell and Chart 1999c).

2.2 Sampling

In each river reach, removal trips were conducted weekly for four or five weeks. All backwaters were sampled on each trip. In each sampled backwater for each one-day sampling occasion, several seine hauls were made to deplete the fish (removal passes). The number and physical configuration of seine hauls used to deplete the backwaters changed during the study as described in the river-specific sections. A 4.8 mm mesh seine was used to target fish greater than 25 mm TL to minimize capture of native sucker larvae. At each backwater, a seine was used to block the sampled habitat from the river, while the seinable portion of the backwater was depleted. The seinable portion of the habitat depended on the depth of the water, as depths greater than 1.2 m could not be effectively seined. Depletion was conducted with a series of seine hauls starting as close to the main-channel as possible and working towards the end. The length and width of the backwaters and the individual seine hauls were measured to calculate area seined and catch-per-unit-effort (CPE; #fish/m^2).

The first seine haul in each backwater was visually scanned for native fish. If native fishes appeared to comprise > 50% of the contents, all fish were immediately returned alive and the crew proceeded to the next habitat. This was intended to minimize mortalities of native fish. If the initial haul contained < 50% native fish, it and all other seine hauls were quickly examined for native fish which were identified by species, counted, measured, and returned to the habitat, or kept in buckets until the process was finished and then returned, while all nonnative fish were identified by species or classified as NNC, and counted. If seine hauls produced relatively few nonnative fish, all fish were identified and counted in the field. If seine hauls produced too many fish to identify individually, fish were collectively classified as NNC or identified to other nonnative species and split into subadult/adult categories (less than or greater than 40 mm TL, respectively). Nonnative cyprinids were usually grouped into one category (NNC) for processing so individual percent compositions are unavailable for red shiner, sand shiner and fathead minnow. In some cases, entire samples or subsamples were preserved (after identified native fish were released alive) to be enumerated later. Samples from approximately eight habitats per trip were preserved. Nonnative fish not preserved were buried on site.

Backwaters above and below the treatment reaches were sampled as controls. Control sites were sampled as described above except that all fish were returned alive to the backwater to compare CPE between treated and untreated areas. Only one seine pass was conducted.

2.2.1 Green River Methods

Nonnative cyprinid removal efforts on the Green River were primarily intended to benefit razorback sucker (*Xyrauchen texanus)* and Colorado pikeminnow (*Ptychocheilus lucius)*. From 1994-1999, razorback sucker larvae were found in the lower Green River during spring high flows, in large flooded washes (Muth et al. 1998, Chart et al. 1999). Razorback sucker spawn on the ascending limb of the hydrograph (Bestgen 1990; Muth 1995; Muth et al. 1998). Timing of depletion sampling on the Green

River was intended to coincide with the period before and during spawning of razorback sucker. Removal efforts were intended to reduce the abundance of nonnative cyprinids before native larvae began drifting into nursery area habitats.

Five sampling trips were conducted each year on the Green River. Sampling was conducted in 1998 from 11 May to 17 June, in 1999 from 26 April to 11 May and 31 May to 8 June, and in 2000 from 24 April to 24 May. This timing likely overlapped with native sucker spawning and drift, and preceded Colorado pikeminnow spawning (Bestgen et al. 1998). Sampling in 1998 and 1999 was suspended to wait for high spring runoff conditions. In reference to flow recommendations (Muth et al. 2000), peak discharge as measured at the USGS Green River at Green River gage (#090315000) in 1998 (24,100 cfs) was slightly above average, moderately wet in 1999 (30,000 cfs), and moderately dry (18,400 cfs) in 2000. The date of peak flow was 25 May in 1998, 23 June in 1999, and 3 June in 2000. The late peak in 1999 was a result of emergency bypass releases at Flaming Gorge Dam due to heavy late spring precipitation. Sampling in 1999 was suspended for two weeks after the first three trips so that sampling would occur nearer to the anticipated peak flow (Figure 2a). On the Green River, where habitats usually persisted throughout the sampling period each year, specific control sites above and below the study area were established during the first week of each year and were sampled on each trip.

There were changes in sampling methods among the three years of study. In 1998, sampling was conducted using an intensive block and seine technique with a three pass depletion to attempt complete removal of fish from the habitat (Trammell and Chart 1999b). However, only the portions of these habitats less than 1.2 m deep could be seined effectively. Some large washes were in excess of 500 m long, and only ½ to 1/3 of the length was less than 1.2 m in depth. Beginning where habitat depth was 1.2 m or less, a series of cells was established by stretching nets across the backwater. Each cell created was approximately five meters wide and was seined with three passes to remove fish. This methodology was very time consuming and the full 50-mile reach could not be treated in one seven-day sampling trip. Thus, focus of removal efforts narrowed through the five week season in 1998 to a series of habitats within a seven mile reach below the confluence with the San Rafael River in which razorback sucker larvae were comparatively abundant (Muth et al. 1998, Chart et al. 1999). The repeated seining within each cell produced few additional fish. The usefulness of the lengthy but more complete depletion effort was marginal compared to the untreated habitat area, suggesting modifications to the sampling protocol were necessary.

In 1999 sampling intensity was reduced in individual backwaters by eliminating individual cells and expanding removal efforts to cover the full 50-mile (80.5 km) reach. During the first three trips in 1999, at least two removal passes were made in each of these large flooded habitats. A series of seine hauls was made in each habitat until all seinable area was covered at least twice; however, during the final two weeks, the seinable area was covered only once with a series of hauls due to time constraints. In 1999 exclusion block nets were installed in three selected flooded wash habitats (School Bus Wash, White Wash, and Red Wash). These habitats were selected because they were too large and deep to be effectively seined, but could be easily blocked. Block nets were 6.4 mm plastic mesh suspended from 15.9 mm steel rebar and 6.4 mm shock cord by zipties. The block nets were 2 to 3 m high and 8 to 15 m wide, depending on the width of the habitat. Nets were installed inside the mouth of the washes while they were dry. When the washes became inundated at higher discharge, the block nets allowed larvae and smaller fishes to pass through the netting but excluded larger fishes, creating an area that had potentially fewer predators and less competition for resources. In 2000, the Program recommended discontinuation of the block nets; thus, all habitats were sampled similarly as in 1999, but no habitats were blocked.

2.2.2 Colorado River Methods

In the Colorado River, removal efforts were intended primarily to benefit Colorado pikeminnow and other native species. Colorado pikeminnow are known to spawn on the descending limb of the hydrograph in the Colorado River above Loma near RM 154 (Anderson 1999) and possibly just below the Colorado/Utah state line, or below Westwater Canyon (Trammell and Chart 1999d). Once hatched, larvae from these spawning sites drift downstream into the sampling reaches chosen for removal efforts.
Removal efforts were conducted after the spring peak flows for four weeks in 1998 and 1999, and for five weeks in 2000. The sampling periods generally began well after the peak flow because no backwater

habitats were available immediately after peak flows. Trammell and Chart (1999d) found that spawning and drift periods of Colorado pikeminnow ranged from early June to late August in the Colorado River in Utah. Thus, removal efforts conducted in July and August likely overlapped spawning and drift periods, particularly in 2000. Discharge usually fluctuated throughout the study period each year. Consequently, habitats sampled were smaller and shallower than on the Green River, and were much more ephemeral. Peak flows for the Colorado River as measured at the USGS Colorado River at Cisco gage (#09180500) were 28,500 in 1998 (moderately dry), 19,000 in 1999 (dry) and 17,500 in 2000 (dry). Discharges during the sampling period for all three years were below 12,000 cfs. Sampling flows in 1998 and 1999 (4000-12000 cfs) were distinctly higher than in 2000 when flows were consistently below 4,000 cfs (Figure 2b). Control sites were below and between the treatment areas. Due to their ephemeral nature, control sites on the Colorado River changed during each year.

Methods of sampling on the Colorado River differed slightly from those on the Green River and were also altered during the study. In 1998, the intensive block and seine technique was used only on the first two removal trips. The habitats were generally much smaller than on the Green River and seines could be easily pulled over the entire habitat area; therefore, for the remaining trips in 1998, and all trips in 1999 and 2000, three complete seine hauls were made in each habitat (three removal passes). In all years, at least one control habitat was sampled above or below each of the three study reaches. No exclusionary block nets were used in the Colorado River.

2.3 Data Analysis

Effort was calculated as area seined. The data are presented as total fish removed and as CPE (fish/10m^2). Only the first removal seine haul (if the entire backwater was seined in one haul) or the mean of the first seine haul in each cell of the backwater on each sampling occasion was used for CPE analysis because the ongoing removal artificially lowers the apparent CPE. To detect statistical differences in relative abundance, log transformed CPE data were analyzed using ANCOVA among years and between control and treatment areas. Sampling trips were treated as covariates in this analysis to control for effects of cumulative fish removal but not to assess effects of removal per se. Analysis of effects of removal within treatment reaches only was conducted separately (ANCOVA) using data from five unique backwaters (all flooded tributary mouths) sampled on most trips in each year in the Green River. Finally, we examined NNC CPE in each of four of these backwaters on consecutive removal seine hauls during each trip in 1998. All tests were considered significant if $P < 0.05$.

On the Colorado River, backwaters were ephemeral because decreasing flows during the sampling periods dried many habitats as others formed. Consequently few backwaters were sampled more than one time. Because CPE could not be directly compared for the same backwater between removal trips, mean CPE was calculated from all treated habitats in a reach for each of the three river reaches. A mean CPE was calculated separately for each of the control areas between treatment areas. Mean CPE was then compared among years, reaches and between treatment and control reaches using ANCOVA, and trips were specified as a covariate.

Young-of-year Colorado pikeminnow and other native and nonnative fish are monitored each fall by seining backwaters in the Green and Colorado rivers as a component of the ISMP. The ISMP seine data were used to evaluate native and nonnative fish response to the removal efforts. Mean CPE for 1998 to 2000 was compared graphically to the long-term mean CPE (ISMP) and associated 95% confidence intervals.

3.0 RESULTS

3.1 Green River

<u>NNC Removal</u>

Effort varied from year to year due to discharge, amount of available habitat, sampling protocols, and number of river miles sampled. Effort in 1998 was 88,149 m^2 seined over a seven-mile treatment reach, and 5,515 m^2 in the control reach. Effort in 1999 and 2000 was distributed over 50 river miles. In 1999, total area seined was 80,160 m^2 in the treatment reach, and 17,167 m^2 in the control reach. In 2000, area seined was 119,115 m^2 in the treatment reach and 15,620 m^2 in the control reach.

Since sampling preceded spawning of Colorado pikeminnow, all captured pikeminnow were at least age-1. In 1998, the Colorado pikeminnow were primarily 140-200 mm TL, and were likely of the

1996 year class or older (age-2+). The large numbers of Colorado pikeminnow captured in 1999 were primarily of the 1998 year class (age-1); ranging from 30 to 80 mm TL. In 2000, the Colorado pikeminnow were primarily of the 1999 year-class (age-1), although several age-2+ fish (140-200 mm TL) were also captured (Figure 3).

Total captures of fish were similar among years (Table 2). Effort in area seined was similar between 1998 and 1999, with a 48% increase between 1999 and 2000 (Table 3). From 1998 to 2000, 139,713 fish were removed. Nonnative cyprinids comprised the overwhelming majority (91%, 125,904) of all fish captured. An additional 27,917 fish were captured in control habitats and released. Of those, 93.4% (26,344) were nonnative cyprinids (Table 2, Figure 4). Nonnative cyprinids were grouped into one category (NNC) for processing so individual percent compositions are unavailable for red shiner, sand shiner and fathead minnow. No other nonnative species comprised more than 1% of the total catch in any single year. Captures and percentages of nonnative fish in treatment reaches were similar among years, with the fewest fish captured in 1998, and the most in 1999; in control reaches, captures were similar between 1998 and 2000, while double the numbers were captured in 1999. In treatment samples, native fish collectively comprised 12.2% of the total in 1998, 5.7% in 1999, and 8.6% in 2000 (Figure 4). Unidentified sucker larvae were the largest component in 1998; these fish were likely primarily native species. Colorado pikeminnow juveniles comprised 0.2% of the total in 1998, 2.6% in 1999, and 1.3% in 2000. No razorback sucker larvae or juveniles were identified during the project. Little change was observed in the composition of native and nonnative fishes among years, and little difference was observed between treatment and control reaches although the percentage of nonnative fishes was higher in the control reach (Figure 4).

Changes in age structure of nonnative cyprinids (subadults/adults) were observed between trips each year. The numbers and relative abundance of subadults (<40 mm TL) tended to increase during the year primarily due to reproduction (Figure 5). The relative abundance of subadult nonnative cyprinids likely was underestimated because seine mesh size was selected to exclude fish less than 25 mm. Although this assumption was not specifically evaluated, small fish were frequently observed to escape through the seine. However, sucker larvae greater than 20 mm were often captured. In 1998 and 1999, numbers of NNC adults (> 40 mm TL) declined on each trip until the final trip. No consistent decline in adult NNC in the control reaches was observed (Figure 5).

Results of the ANCOVA comparing NNC CPE indicated significant differences among years and between treatment and control reaches (Table 4). The three-year mean CPE in treatment and control reaches was 8.87 and 13.71 fish/m^2 (t-test, t = -2.82, df = 243, P = 0.005) respectively, although the difference was observed primarily in 1998 and 1999 (Figure 6). In both the treatment and control reaches, NNC CPE tended to increase from trip to trip in 1998, and was more variable in 1999 and 2000 (Figure 7).

Effects of removal efforts within a group of five unique backwaters that were treated on each trip and each year, and thus were treated more often than other habitats, were not significant (df = 98, F = 1.95, P = 0.17; Figure 8). The CPE generally declined on the first few consecutive trips, but increased on the final trip during 1998 and 2000. In 1998 at the smallest scale of removal (one-day sampling occasion) we observed a depletion effect in the first four seine hauls (Figure 9). However, this effect was short-lived as CPE tended to increase by the beginning of the next trip. This effect could not be examined in 1999 and 2000 due to changes in sampling protocol.

Colorado pikeminnow CPE did not appear to vary among years (Figure 6). Trends in CPE in both treatment and control reaches were similar and no differences were observed between treatment and control reaches in 1998 through 2000.

Block Nets

Of the habitats that were blocked with nets, only two (School Bus and White washes) were inundated for the entire study period. The third habitat, Red Wash, only had one week of inundation. Inundation refers to the period when nets had water in front of and behind them, water levels were shallow enough to allow for seining, and nets had not been breached or overtopped. Results were not consistent in these two habitats.

Generally, the percentage of adult nonnative cyprinids was lower inside the blocked section than outside. Percentage of adults inside the block nets in School Bus Wash averaged 31% compared to 49%

outside of the nets. However, 3,800 m^2 more habitat was seined inside the net due to our inability to seine in the deep water outside the nets. In White Wash, the percentage of adults was 18% inside and 10% outside the nets. No adult NNC were captured either inside or outside of the net on the single sample occasion when Red Wash was inundated. However, the significance of the block net experiment could not be adequately assessed due to the difficulties of seining the deep habitats, overtopping from high water levels, and breaching from beaver damage and flash floods.

<u>Comparison with ISMP</u>

The ISMP catch rates of Colorado pikeminnow in the lower Green River (ISMP reach 3) increased each year from 1997 to 2000 (Figure 10). However, catch rates remained below the long term mean, and well within the range of catch rates observed during ISMP sampling from 1986 to 1997. Colorado pikeminnow captures in the middle Green River (ISMP reach 4), where no removal efforts took place, were also slightly higher from 1998 to 2000 than in 1997, and were also lower than the long term mean.

In ISMP reach 3, catch rates for nonnative cyprinids in 1998 to 2000 were lower than the long term mean; however, catch rates were also very low in 1997 prior to removal efforts. Nonnative cyprinid catch rates in the middle Green River (ISMP reach 4) where no removal efforts were conducted were also lower than the long term mean and declined each year from 1997 to 1999. However, CPE increased to above the long-term mean in 2000.

3.2 Colorado River

<u>NNC Removal</u>

Most Colorado pikeminnow captured in 1998 and 2000 in both treatment and control reaches were age-0 (YOY), ranging from 16-52 mm TL; however, in 1999 the Colorado pikeminnow appeared to be age-1 (Figure 11). In 1999, 85 Colorado pikeminnow were captured, primarily on the first trip (July 5-9); ranging in size from 35 to 130 mm – larger than YOY Colorado pikeminnow caught on later trips in 1998 and 2000. These fish were likely part of the previous year class (age-1). In 1998, 60 Colorado pikeminnow were captured only on the fourth and final sampling trip (August 25-28); they ranged from 25 to 42 mm TL, and were all YOY with the exception of two large adults >500 mm TL. In 2000, a total of 1,489 YOY Colorado pikeminnow were captured, distributed among all trips from July 17-August 17. Lengths ranged from 16 to 52 mm TL, with average lengths increasing through the sampling period (Figure 11).

Numbers of fish captured and effort (area seined) varied from year to year due to discharge, amount of available habitat, and sampling protocols (Tables 5 and 6). During four trips in 1998, the area seined was 22,194 m^2 in treatment areas, and 5,082 m^2 in control areas. During four trips in 1999, the area seined was 34,400 m^2 in treatment areas and 4,548 m^2 in control areas. During five trips in 2000, the area seined was 131,580 m^2 in treatment areas, and 29,400 m^2 in control areas. Effort in 1998 was limited because sampling was discontinued in habitats with large numbers of sucker larvae in the first seine haul, as outlined in the methods. Incomplete records were kept of the habitats where sampling was discontinued. There are only three records indicating sampling was discontinued, but there were a few occurrences on each trip that were not recorded. In 2000, the low stable flows produced more available habitat than previous years.

The number of fish captured varied substantially among years (Table 5). In the three years of the study, 219,709 fish were captured in both treatment and control reaches. Nonnative cyprinid captures were lowest in 1998, with only 13,740 fish removed; however, native fish captures were very high (9,138), primarily larval suckers (8,829). Nonnative cyprinid captures were highest in 1999, with 84,598 nonnative fish removed; however, 1999 also had the lowest number of native fish (316). A total of 47,653 nonnative fish were removed in 2000. The highest number of Colorado pikeminnow (1,210) was captured in 2000; other native fish captures totaled 1,150 including larval suckers (Table 5).

Nonnative cyprinids comprised the overwhelming majority of all fish captured (Figure 12). No other nonnative species comprised more than 2.5% of the total catch in any single year. Percentages of nonnative fish in treatment reaches increased in 1999 and remained relatively high in 2000. The relatively high proportion of natives in 1998 was comprised of larval suckers, likely primarily native species. Colorado pikeminnow juveniles comprised 0.2% of the total in 1998, 0.1% in 1999, and 2.3% in

2000. No razorback sucker larvae or juveniles were identified during the project. Little change was observed in the composition of native and nonnative fishes among years, and little difference was observed between treatment and control reaches (Figure 12).

Nonnative fish captures were lowest in 1998 and highest in 1999 in both the treatment and control reaches (Figure 13). Nonnative cyprinids grew and reproduced during the sampling period. Changes in age structure (adults/subadults) were observed between trips each year. The numbers and relative abundance of subadults (<40 mm TL) tended to increase during the year in 1998 and 2000, but in 1999, the highest catch of subadults was observed on the first trip. The relative abundances of subadult nonnative cyprinids likely were underestimated because seine mesh size was selected to exclude fish less than 25 mm. Although this assumption was not specifically evaluated, small fish were frequently observed to escape through the seine. However, sucker larvae greater than 20 mm were often captured. In all years in the treatment reaches, numbers of adults (> 40 mm TL) declined on each trip until the final trip, which may indicate some short-lived impacts of removal on the adult population. In contrast, no consistent decline in adult NNC in the control reaches was observed (Figure 13).

Results of the ANCOVA comparisons of NNC CPE indicated a significant difference among years, removal trips, and river reaches (Table 4; Figure 14). Differences among years were attributed to the high CPE in 1999. Differences among removal trips reflected an overall upward trend in 1999 and 2000. In treatment reaches, NNC CPE decreased on the first three trips in 1998 and 1999, but increased on the final trip. In control reaches, NNC CPE tended to increase on all trips in all years, except for trip 3 in 1999 (Figure 15). Nonnative CPE was not statistically different between treatment and control reaches, although the significant interaction effect between treatment and control reaches (reach*TC effect [Table 4]) suggested that CPE in control sections were sometimes greater than those in treatment sections within specific river reaches (Figure 16). Colorado pikeminnow CPE was higher in 2000 than in 1998 or 1999, but this difference was likely not statistically significant, and similar increases were observed in both treatment and control reaches (Figure 14).

We examined NNC CPE in each of the two individual backwaters that were sampled on two consecutive trips in 1998 to test between-trip differences (Figure 17). In one backwater (RM 60.3), the initial CPE (pass 1) was lower on the second trip; however in the other backwater (RM 90.5), the initial CPE was higher on the second trip.

At the smallest scale of removal (one-day sampling occasion in one backwater) CPE declined on consecutive removal seine hauls during each trip in the RM 60.3 backwater, but the RM 90.5 backwater did not show a consistence decline in CPE. We frequently observed a depletion effect in the first four seine hauls in individual backwaters (Figure 17); however many backwaters did not show a consistent decline indicating depletion, similar to the RM 90.5 backwater.

Comparison with ISMP

The ISMP catch rates of Colorado pikeminnow in the lower Colorado River (ISMP reach 1) were lower than the long term mean in 1998 and 1999. CPE decreased from 1998 to 1999, but increased from 1999 to 2000 (Figure 18). However, catch rates remained within the range of catch rates observed during ISMP sampling from 1986 to 1997. There were no Colorado pikeminnow captures in the upper Colorado River (ISMP reach 2) where removal efforts were also conducted from 1999 to 2001 as part of another study (Trammell et al. 2002).

No Colorado pikeminnow YOY have been captured during ISMP in reach 2 since 1992. In the Colorado River ISMP (reach 1) catch rates for nonnative cyprinids in 1998 and 1999 were lower than the long term mean; however, catch rates were also very low in 1997. NNC CPE in 2000 was higher than the long term mean. Thus, the low catch rates of nonnative cyprinids during ISMP in 1998 and 1999 cannot conclusively be attributed to nonnative removal efforts.

4.0 DISCUSSION

Interpretation of these data is difficult due to the number of confounding factors influencing the abundance and catchability of nonnative cyprinids and native fishes, as well as changes in the sampling regime between years. Nonnative cyprinid species in this study are small bodied, extremely abundant, have high fecundity rates and are able to flourish in a wide variety of habitats range-wide (Lentsch et al. 1996). Nonnative cyprinids were frequently visually observed in many low-velocity shoreline habitats other than backwaters, particularly in flooded vegetation. Inherently high variation in NNC abundance and changing habitat conditions probably contribute to difficulties in data interpretation.

The results of this study suggest that depletion of NNC is attainable within individual backwaters on one-day sampling occasions (one trip), but depletion among sampling occasions (trips) is eventually offset by reproduction, recruitment, and immigration of NNC into newly depleted backwaters. Overall, treatment reaches in the Green River tended toward lower NNC relative densities than control reaches, but lack of depletion among trips and increases in NNC CPE during the final sampling trips suggest that removal did not cause these differences. Conversely, results from the Colorado River indicate that, while no treatment/control difference was detected, CPE did vary among removal trips, although not in the anticipated negative fashion. These findings suggest that effects of nonnative fish control may not be detectable by looking solely at results from removal efforts (i.e., for evidence of depletion over time) or treatment/control comparisons, but rather that results from the two approaches should be considered together as they may suggest conflicting interpretations.

Although some reduction in abundance of nonnative cyprinids was observed among the first few removal efforts in treatment reaches in 1998 and 1999 in the Green River, particularly of adult fish, the reduction was very temporary and was quickly offset by reproduction and growth of larval fishes into a size vulnerable to the sampling gear. Small fish were frequently observed to escape through the seine, which was selected to exclude fish less than 25 mm. As reproduction and growth occurred, the number and relative proportion of subadult fishes increased during the sampling period each year. Subadults less than 25 mm TL early in the spring likely recruited into the adult category and vulnerability to the gear type later in the season.

The effects of NNC reproduction on removal efforts are even more pronounced in the Colorado River during 1998 and 1999. Positive CPE trends were due primarily to increases in subadult fishes, but adult fish CPE increased as well. This latter could be a result of growth of subadults into adults as well as immigration, particularly in 1998 when the final trip was conducted four weeks after the previous trip. The four-week hiatus likely allowed subadult fish to grow to adult size and larval fish to become fully recruited to the gear. The increase in catch in 2000 was primarily composed of subadult fish. The low water and stable backwater conditions likely favored reproduction of the NNC, as well as enhanced the growth of larvae into catchable subadult fish. Any reproduction fundamentally compromises closure assumptions behind removal experiments at any spatial or temporal scale.

Lentsch et al. (1996) postulated that controlling nonnative cyprinids would be difficult because of their high abundance, ubiquity, adaptability, and reproductive potential. Red shiner, fathead minnow, and sand shiner are the most common species in the upper Colorado River basin, frequently comprising more than 80% of fishes captured in low velocity habitats (Valdez 1990; Muth and Nesler 1993; McAda et al. 1994a and 1994b, 1995, 1996, 1997; Trammell and Chart 1999a, 1999b, and 1999c). Minckley (1973), Scott and Crossman (1973), Cross and Collins (1975), Pflieger (1975) Carlander (1977), Matthews (1987), and Sublette et al. (1990) all report the tolerance of red shiner, sand shiner, and fathead minnow to various perturbations of "quality" habitats or conditions. All three of these species are classified as extremely tolerant of extremes in temperature, pollution, discharge, and siltation. Their small size and ability to persist in and re-colonize a variety of habitats makes removal difficult. Cross and Collins (1975) state that it will never be possible to completely remove red shiner and suggest they "will be with us until the end, no matter how badly we treat our water".

If reduction in abundance was possible, detection of the reduction may also prove difficult. For example, nonnative cyprinid data collected from 1986 to 1997 (McAda et al. 1994a, 1994b, 1995, 1996, 1997) during annual ISMP surveys in both the Green and Colorado rivers shows nonnative cyprinid numbers vary greatly from year to year despite the use of standard sampling protocols (Figures 10, 18 and 19). Furthermore, it appears that NNC density was at historically low levels in 1997, prior to removal efforts. Some studies have shown that nonnative cyprinid abundance is reduced in high water years (McAda et al. 1994a, McAda and Ryel 1998, Trammell et al. 1999, Lentsch et al. 1996); peak flows in 1997, 1998 and 1999 were all higher than average. Thus, due to inherent NNC population variability and NNC density antecedent to this study, attributing any changes in NNC abundance to removal efforts is difficult.

Fluctuating habitat availability (especially in the Colorado River) also contributed to difficulties in interpreting data. Most of the variation in area sampled was due to differences in discharge and accompanying changes in available habitat. In the Colorado River during NNC removal, flows in 1998 were between 5,000 and 11,000 cfs, and flows in 1999 were between 5,600 and 12,000 cfs, while flows in 2000 were consistently below 4,000 cfs. Trammell and Chart (1999c) found that flows below 4,000 cfs maximized backwater habitat area in the Colorado River, making sample size from that year disproportionately greater than previous years. Perhaps more importantly, the same control habitats were not available from one year to the next in the Colorado River and discharge-related changes in surface areas of individual treatment backwaters may have affected sampling efficiency. Similarly, area sampled and discharge was also variable in the Green River. Regardless of changing discharge, many individual backwaters could not be completely depleted due to depth of water and the abundance of vegetation, which allowed fish to avoid the seine. Variation in discharge probably exacerbated these components of sampling error.

In neither the Green nor the Colorado rivers was there a significant increase in the catch or catch rate of razorback sucker or Colorado pikeminnow as measured by the ISMP sampling programs. Thus, temporary reductions did not appear to result in increased recruitment of razorback sucker or Colorado pikeminnow, which may be the ultimate measure of success of the removal efforts. The lack of significance may be partly due to limitations of the statistical power of the ISMP to detect changes; however, other lines of evidence also suggest recruitment increases were not observed in these years.

In the Green River, no wild juvenile razorback sucker were observed during the intensive electrofishing conducted for the Colorado pikeminnow population estimate in the Lower Green River from 2000 to 2002 (Paul Badame, personal communication). Relatively large razorback sucker larvae (19 mm) were collected in the treatment areas during a related study in 1999, perhaps indicating improved growth, but no YOY or juvenile razorback sucker were captured in the fall or in subsequent years sampling in any of the concurrent sampling programs (including nonnative removal, fall ISMP, spring ISMP, razorback sucker evaluations, and bonytail monitoring.) During the fall YOY ISMP sampling for Colorado pikeminnow, the catch and catch rates of Colorado pikeminnow were not significantly greater during the removal years than the long term average (1986-1997), or of recent sampling years 1991-1997. Although the order-of-magnitude increase in age-1 Colorado pikeminnow in 1999 over 1998 in the treatment areas in the Green River is intriguing, the ISMP catch rates of pikeminnow in 1998 and 1999 were lower than the long-term average, with CPE in 1999 only slightly higher than in 1998. Colorado pikeminnow captured during removal efforts in 2000 was half that of 1999; however, ISMP catch rates for Colorado pikeminnow were higher than the previous three years of sampling.

In the Colorado River, during the fall YOY ISMP sampling for Colorado pikeminnow, the catch and catch rates of Colorado pikeminnow were not significantly greater during the NNC removal years than the long term average (1986-1997), or the recent pre-removal sampling years (1991-1997) (Figure 18). However, the large increase in captures of Colorado pikeminnow in the treatment areas in 2000 was followed by a rise in ISMP catch rate that fall.

Similar results were seen in a concurrent nonnative cyprinid removal study conducted in the Colorado River near Grand Junction, Colorado (ISMP reach 2). Trammell et al. (2002) found only temporary reductions in nonnative abundance in treated backwaters. They observed no positive response in native fish abundance during the study or during ISMP fall sampling.

Our ability to reduce nonnative cyprinid species appears to be limited to short-lived, site-specific reductions in abundance. However, the premise behind timing the removal to precede spawning of the endangered fishes was to provide a ‘window of opportunity’ for early growth and survival of the endangered fish by removing NNC just as the endangered fish begin to occupy the habitats. We may have provided a short window of opportunity; we were able to deplete individual backwaters on a single sampling occasion, although no long-term depletion was achieved of more than a few days. Although we could show little or no evidence of an immediate positive response on the part of native fish, this may be due to lack of appropriate sampling methods designed to test the response. Despite our inability to show either a reduction in abundance of NNC or a positive response from the native fishes, we should not abandon attempts to control these fishes.

The continuing presence of NNC in nursery habitats will remain a cause for concern for the long-term survival of the endangered fishes. The amount of effort expended on these studies was substantial, being both fiscally and labor intensive; several hundred thousand nonnative fishes were removed. But on a different scale the effort was only moderate. Five weeks of effort per 30 to 50 miles of river reach, involving four personnel and two seines does not appear as substantial an effort considering the hundreds of miles of river, adjacent ponds, and flooded bottomlands that are infested with NNC. Perhaps there is potential to lengthen the 'window of opportunity' by increasing the frequency of removal in selected habitats, adjusting the timing of removal to include additional removal in the fall, or by using different methods or gear types, such as the electric seine being built and evaluated by Colorado State University (Cameron Walford, personal communication). These methods should be explored along with more precise methods for evaluating native fish response to removal efforts. A response may be subtle and difficult to detect statistically with current ISMP methods, but nonetheless important to the endangered fishes.

5.0 CONCLUSIONS

Conclusions specific to our working hypotheses were:

1) Cyprinid removal by seining all backwaters in a river reach will deplete nonnative cyprinid abundance at a backwater level.

- Green River
    - i. Depletion was observed within some individual backwaters within one-day sampling occasions.
    - ii. No consistent or significant declines in catch or catch rate were observed in individual backwaters where fish were removed on consecutive removal trips.

- Colorado River
    - i. Depletion was observed within some individual backwaters within one-day sampling occasions.
    - ii. Backwaters were seldom available to be seined more than one trip so the trip removal effect could not be evaluated.

2) Cyprinid removal by seining all backwaters in a river reach will deplete cyprinid abundance at a reach level.

- *Green River*
    - i. Significant differences were observed between treatment and control reaches in the Green River, but no decline in catch rate in treatment areas was observed relative to catch in control areas.
    - ii. Temporary reductions in abundance of nonnative adults were observed at a reach level in the Green River.
    - iii. In five unique backwaters sampled on each trip, declines in combined catch and catch rate were observed at a reach level in consecutive removal trips.

iv. The net effect of removal was not significant due to increases in catch which were likely a result of immigration, reproduction, and growth of larval nonnative fish.

- *Colorado River*
    i. No significant differences were observed between treatment and control reaches; no decline in catch rate in treatment areas was observed relative to catch in control areas.
    ii. Temporary reductions in abundance of nonnative adults were observed at a reach level on the Colorado River within 1998 and 1999.
    iii. Declines in catch and catch rate were observed in consecutive removal trips on the Colorado River in 1998 and 1999 until the final trip, but in 2000 catch increased on consecutive removal trips.
    iv. The net effect of removal was not significant due to increases in catch which were a result of immigration, reproduction, and growth of larval nonnative fish.

3) Cyprinid removal by seining all backwaters in a river reach will shift the species composition.

- No significant shifts in species composition were observed.

4) Fall YOY ISMP sampling will be able to detect changes in cyprinid abundance (backwater and reach levels) and species composition from cyprinid removal the previous spring.

- Fall YOY ISMP sampling was not able to detect changes in nonnative cyprinid abundance following removal periods.
- Fall YOY ISMP sampling was not able to detect changes in Colorado pikeminnow or razorback sucker abundance following nonnative cyprinid removal periods.
- Failure to detect changes in nonnative or endangered fish abundance may be due to the statistical power limitations of the ISMP sampling program.

5) Exclusion of nonnative cyprinid adults from portions of flooded tributaries will increase available area for larval native fishes and reduce area available for nonnative cyprinids.

- Blocks nets may reduce area available for nonnative cyprinids, but due to multiple block net failures, the usefulness of this technique could not be determined.

6.0 RECOMMENDATIONS

- Removal efforts should be pursued by the Program and additional methods evaluated to increase effectiveness, e.g.
    i. Investigate increasing effort by increasing number and frequency of removal passes
    ii. Investigate timing by beginning earlier in the spring and/or adding removal efforts in fall to reduce over-winter competition and suppress nonnative abundance in the spring.
    iii. Investigate additional methods e.g. alternate gear types or chemical treatment.
- Where possible, investigators should assess both depletion effects across removal efforts

and differences between treatment and control areas; differences between treatment and control sections may not be due to nonnative fish removal efforts.

- Removal efforts should be accompanied by studies designed to evaluate subtle native fish responses.
- Consider additional study of the potential use of block nets to exclude nonnatives from productive off-channel habitats, particularly on the Green River.

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Table 1. Named habitats, reaches, and corresponding river miles (RM) sampled in treatment reaches on the Green and Colorado Rivers, 1998-2000.

Name	RIVER MILE
Green River	
SCHOOLBUS WASH	101.7
DELLENBAUGH WASH	99.5
WHITE WASH	95.5
RED WASH	95.0
BLUE WASH	94.5
TRIN ALCOVE	90.0
TEN MILE	80.2
Colorado River	
Lathrop	20-30
Moab	55-65
Dewey	87-97

Table 2. Numbers of fish captured in control and treatment reaches in the Green River from 1998 to 2000.

	Control			Treatment		
SPECIES	**1998**	**1999**	**2000**	**1998**	**1999**	**2000**
COLORADO PIKEMINNOW	4	333	70	95	1,286	629
BLUEHEAD SUCKER	0	15	1	12	107	70
BONYTAIL*	0	16	9	0	48	77
FLANNELMOUTH SUCKER	14	141	12	122	660	1,062
GILA SP.	0	6	0	0	8	15
SPECKLED DACE	0	288	43	29	483	199
SUCKER LARVAE	215	36	6	4,752	193	1,818
UNIDENTIFIED SUCKERS	13	29	1	24	86	261
Total Native Fish	246	864	142	5,034	2,871	4,131
NONNATIVE CYPRINIDS	6,715	12,347	7,282	35,145	47,196	43,563
BLACK CRAPPIE	0	0	0	11	0	3
BROOK STICKLEBACK	0	0	0	1	0	0
BULLHEAD CATFISH	0	0	2	15	4	11
CHANNEL CATFISH	48	20	143	450	106	175
COMMON CARP	63	3	15	485	6	282
GREEN SUNFISH	2	2	12	87	16	36
LARGEMOUTH BASS	0	0	0	0	0	1
MOSQUITO FISH	0	8	1	1	0	17
SOCKEYE SALMON	0	0	0	0	0	13
WALLEYE	0	0	0	1	0	1
WHITE SUCKER	0	2	0	34	11	7
Total Nonnative Fish	6,828	12,382	7,455	36,230	47,339	44,108

*** Bonytail were stocked**

Table 3. Area seined, numbers of Colorado pikeminnow (CS) and nonnative cyprinids (NNC) captured in treatment and control reaches in backwaters (BA) from 1998 to 2000 in the Green River.

Reach		Treatment Reaches				Control Reaches			
	Trip	No. of BAs	Area (m^2)	Number of CS	Number of NNC	No. of BAs	Area (m^2)	Number of CS	Number of NNC
1998	1	13	20,361	45	10,970	22	1,751	3	1,232
	2	11	19,085	36	6,635	12	1,114	0	1,107
	3	5	15,472	9	5,294	14	1,354	1	2,424
	4	8	18,122	3	3,428	8	570	0	547
	5	10	15,109	2	8,818	7	276	0	1,405
1998 Total		47	88,149	95	35,145	63	5,065	4	6,715
1999	1	14	11,050	348	12,017	15	1,809	6	936
	2	16	21,525	196	8,918	12	5,739	158	3,789
	3	11	19,810	191	6,952	11	5,219	74	2,434
	4	12	8,245	165	7,157	9	2,068	20	1,378
	5	16	19,530	386	12,152	6	2,332	75	3,810
1999 Total		69	80,160	1,286	47,196	53	17,167	333	12,347
2000	1	10	14,965	208	10,230	1	2,045	16	1,217
	2	12	27,940	165	9,921	3	4,970	23	1,913
	3	11	27,620	106	7,538	2	1,825	6	1,415
	4	9	26,185	90	9,840	2	3,180	18	1,744
	5	9	22,405	60	6,034	2	3,600	7	993
2000 Total		51	119,115	629	43,536	10	15,620	70	7,282
Grand Total		167	287,424	2,010	125,877	126	37,852	404	26,344

Table 4. Analysis of covariance on effects of NNC control trips (1-5/year; covariate), treatment and control reaches (TC), year (1998-2000), river reach (Colorado River only; N=3) and interactions for the Green and Colorado rivers.

River	Source of Variation	df	F	P
Green River	Trip	1	0.08	0.78
	Treatment/Control (TC)	1	4.78	0.03
	Year	2	11.91	< 0.01
	TC*Year	2	1.43	0.24
	Error	238		
	Total	245		
Colorado River	Trip	1	17.36	<0.01
	TC	1	1.75	0.19
	Year	2	32.09	<0.01
	Reach	2	3.44	0.03
	TC * Year	2	1.98	0.14
	TC * Reach	2	5.98	<0.01
	Year * Reach	4	1.80	0.13
	TC * Year * Reach	4	2.30	0.06
	Error	382		
	Total	401		

Table 5. Numbers of fish captured in control and treatment reaches in the Colorado River from 1998 to 2000.

	Control			Treatment		
SPECIES	**1998**	**1999**	**2000**	**1998**	**1999**	**2000**
COLORADO PIKEMINNOW	21	1	279	48	84	1,210
BLUEHEAD SUCKER	2	0	28	4	6	150
BONYTAIL*		0	2		5	1
FLANNELMOUTH SUCKER	16	3	23	37	12	23
GILA SP.	1	5	29	111	136	181
SPECKLED DACE	1	3	3	5	24	61
SUCKER LARVAE	1,494	0	500	8,829	38	619
UNIDENTIFIED SUCKERS	1	5	0	104	11	115
Total Native Fish	**1,536**	**17**	**864**	**9,138**	**316**	**2,360**
NONNATIVE CYPRINIDS	2,288	42,272	10,709	13,757	84,531	47,653
BLACK CRAPPIE	1	0	3	33	6	15
BULLHEAD CATFISH	6	0	474	38	40	1,175
CHANNEL CATFISH	3	9	245	133	102	152
COMMON CARP	32	15	98	339	426	88
GREEN SUNFISH	2	0	7	15	21	32
LARGEMOUTH BASS	0	5	25	28	48	93
SMALLMOUTH BASS	3	0	0	39	2	0
PLAINS KILLIFISH	0	0	1	18	6	90
MOSQUITOFISH	0	2	57	27	16	1,327
WHITE SUCKER	1	0	6	94	26	8
Total Nonnative Fish	**2,336**	**42,303**	**11,625**	**14,521**	**85,224**	**50,633**

*** Bonytail were stocked**

Table 6. Area seined, numbers of Colorado pikeminnow (CS) and nonnative cyprinids (NNC) captured in treatment and control reaches in backwaters (BA) from 1998 to 2000 in the Colorado River.

Reach		Treatment Reaches				Control Reaches			
	Trip	No. of BAs	Area (m^2)	Number of CS	Number of NNC	No. of BAs	Area (m^2)	Number of CS	Number of NNC
1998	1	12	6,846	1	4,709	5	346		37
	2	10	5,692		2,281	5	1,436		351
	3	8	4,356		889	2	468		241
	4	13	5,300	47	5,878	4	2,832	21	1,914
1998 Total		43	22,194	48	13,757	17	5,082	21	2,543
1999	1	18	15,696	78	43,777	5	1,812		26,896
	2	14	8,136	1	13,090	4	1,616	1	8,627
	3	18	5,268		9,602	3	736		3,091
	4	7	5,300	5	18,062	2	384		3,656
1999 Total		57	34,400	84	84,531	14	4,548	1	42,270
2000	1	22	29,930	8	4,199	5	7,035	1	412
	2	18	21,900	146	4,685	9	8,055	41	2,871
	3	22	25,695	343	9,133	6	3,990	33	1,707
	4	22	27,225	248	14,139	5	4,140	52	956
	5	19	26,830	465	15,497	6	6,180	152	4,763
2000 Total		103	131,580	1,210	47,653	31	29,400	279	10,709
Grand Total		203	188,174	1,342	145,941	62	39,030	301	55,522

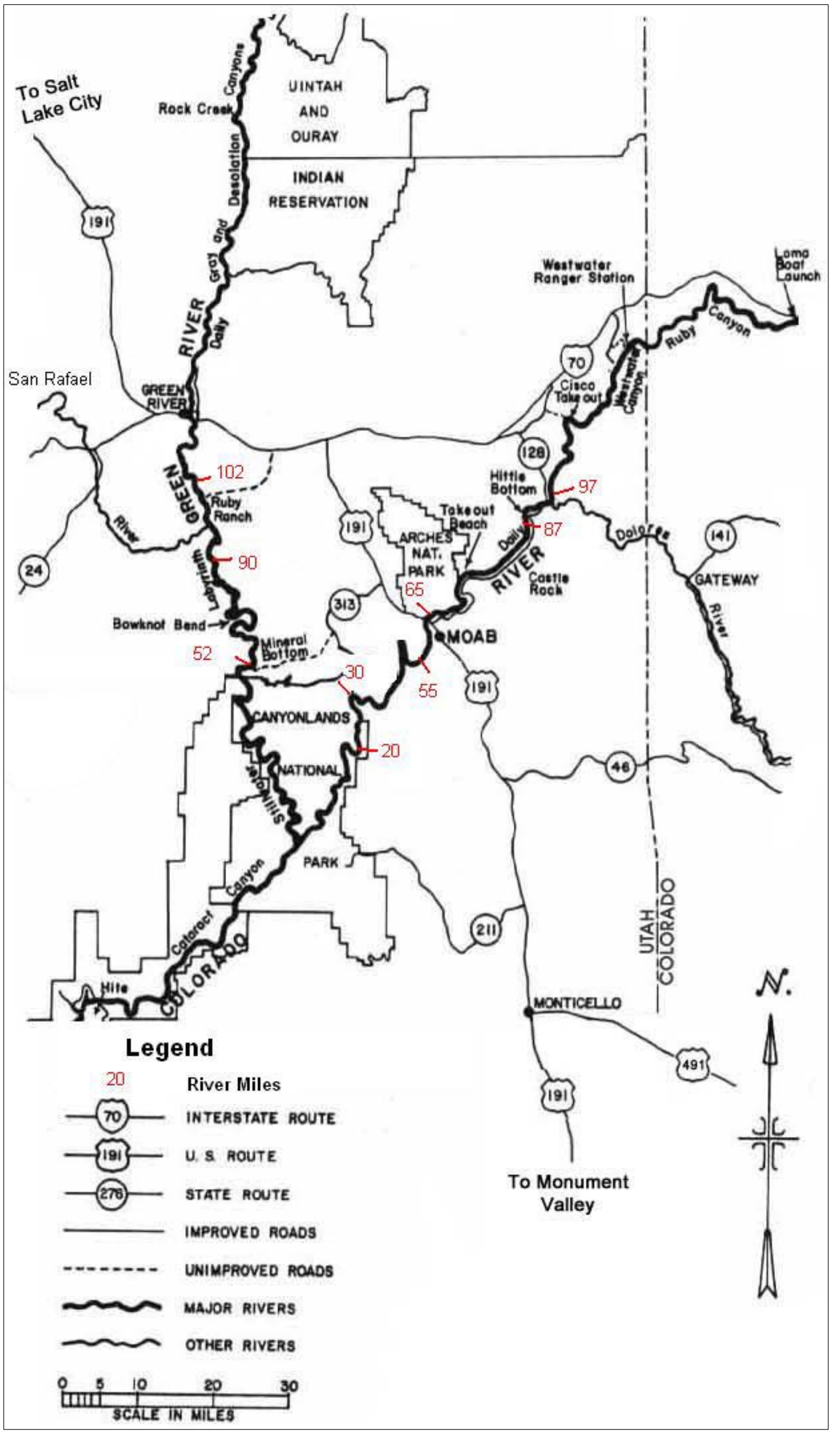


Figure 1. Study Area: Green River from above Ruby Ranch to Mineral Bottom (RM 102-50). Colorado River; Dewey Reach from above the Dolores River to near Hittle Bottom (RM 97-87), Moab Reach from above Moab Bridge downstream (RM 65-55), and Lathrop Reach from near upper border of Canyonlands NP downstream (RM 30 to 20).

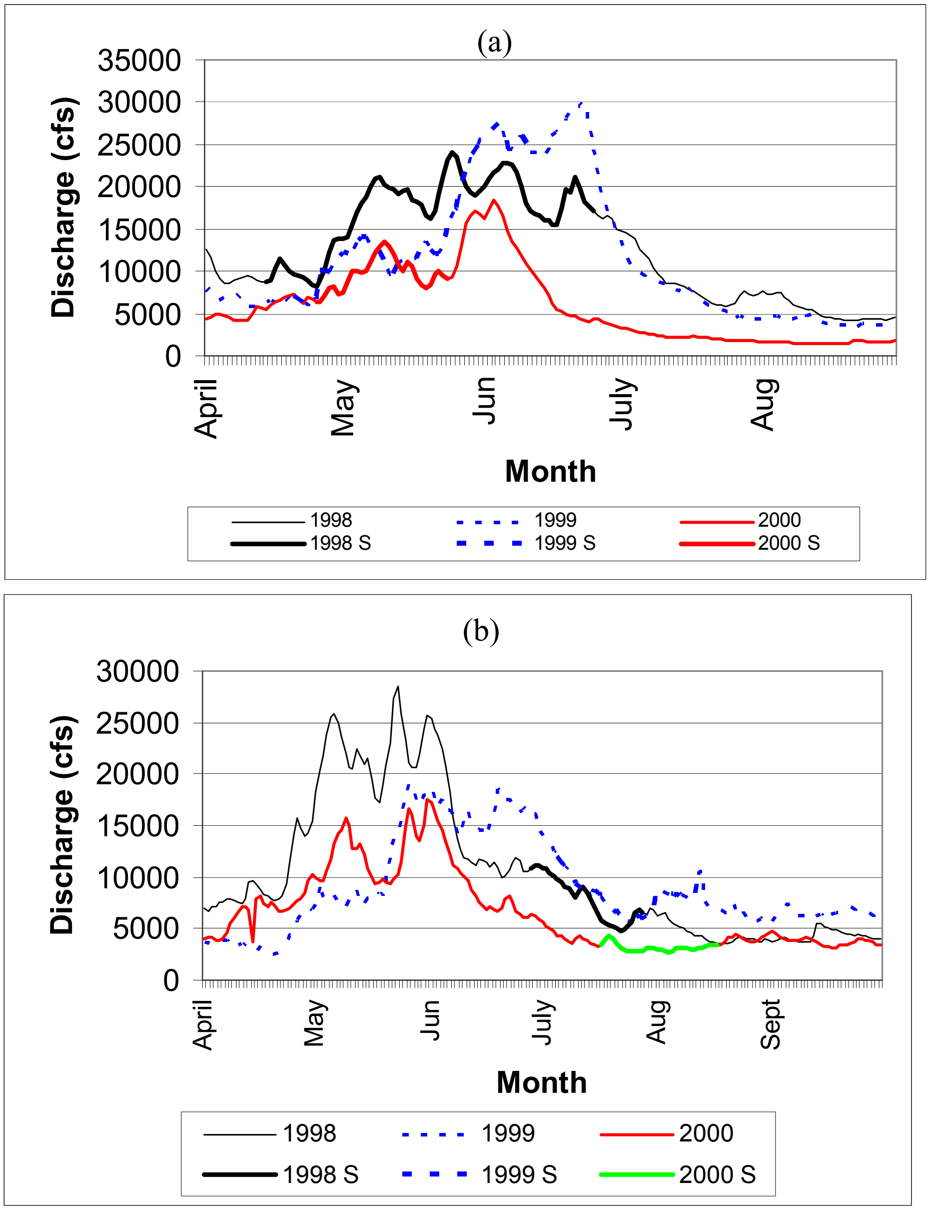
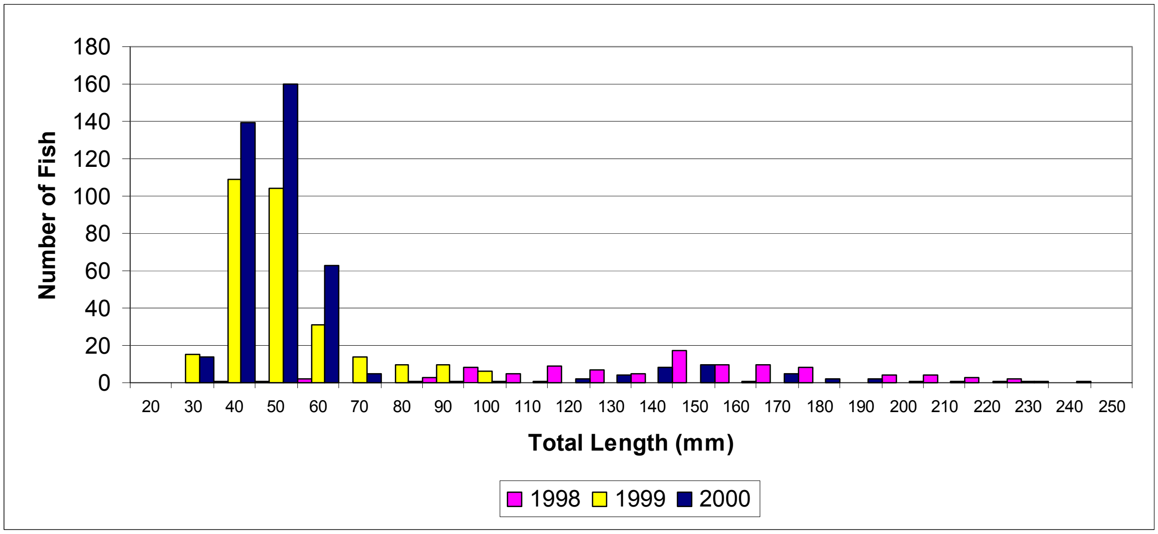


Figure 2. (a) Discharge as measured at the USGS Green River gage (#09315000) from 1998 to 2000. (b) Colorado River: Discharge as measured at the USGS Cisco gage (#09180500) from 1998 to 2000. Sample periods are indicated by thick lines.



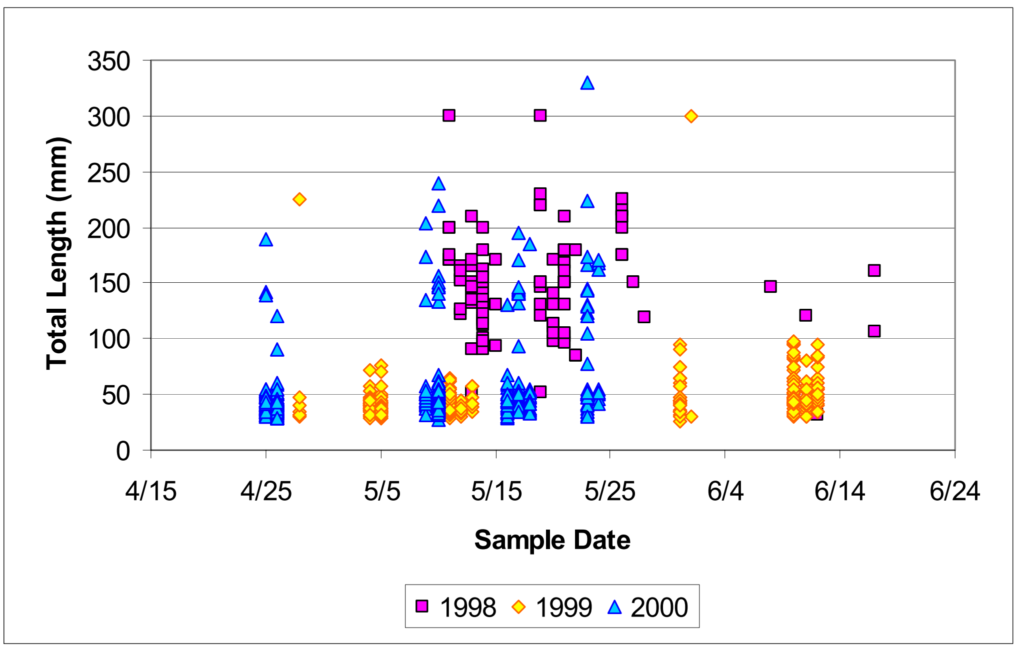
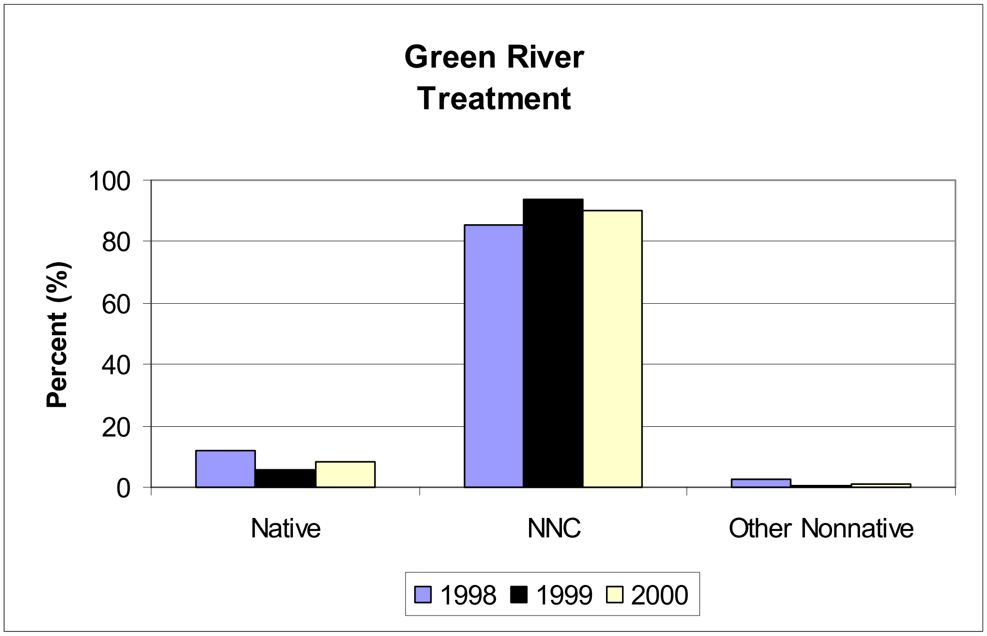


Figure 3. Green River: Length frequency distribution of Colorado pikeminnow captured in treatment and control reaches (combined) from 1998 to 2000.



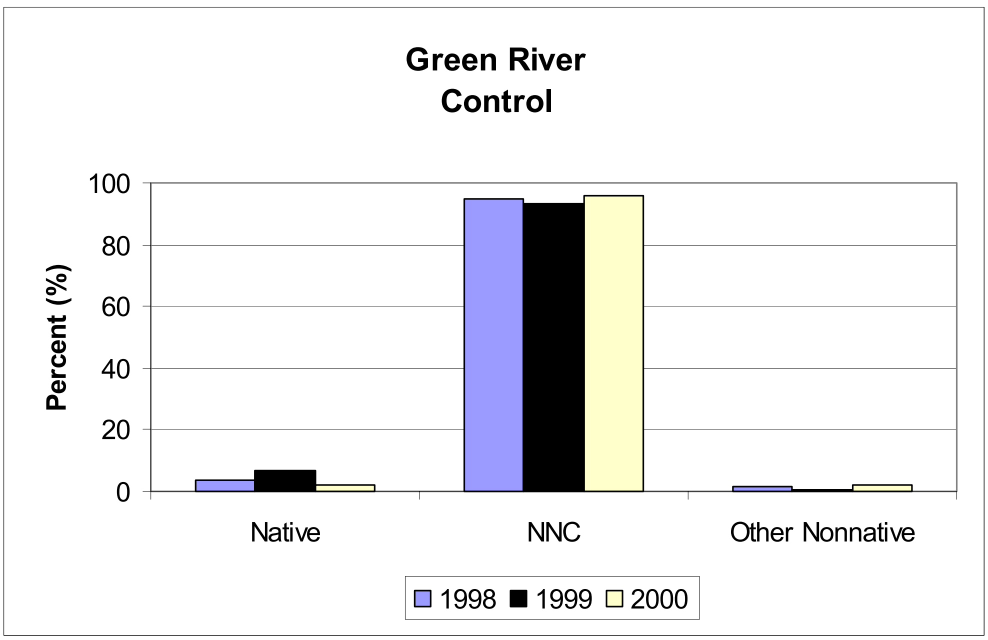


Figure 4. Green River: Percentages of native and nonnative fishes in treatment and control reaches, 1998 to 2000.

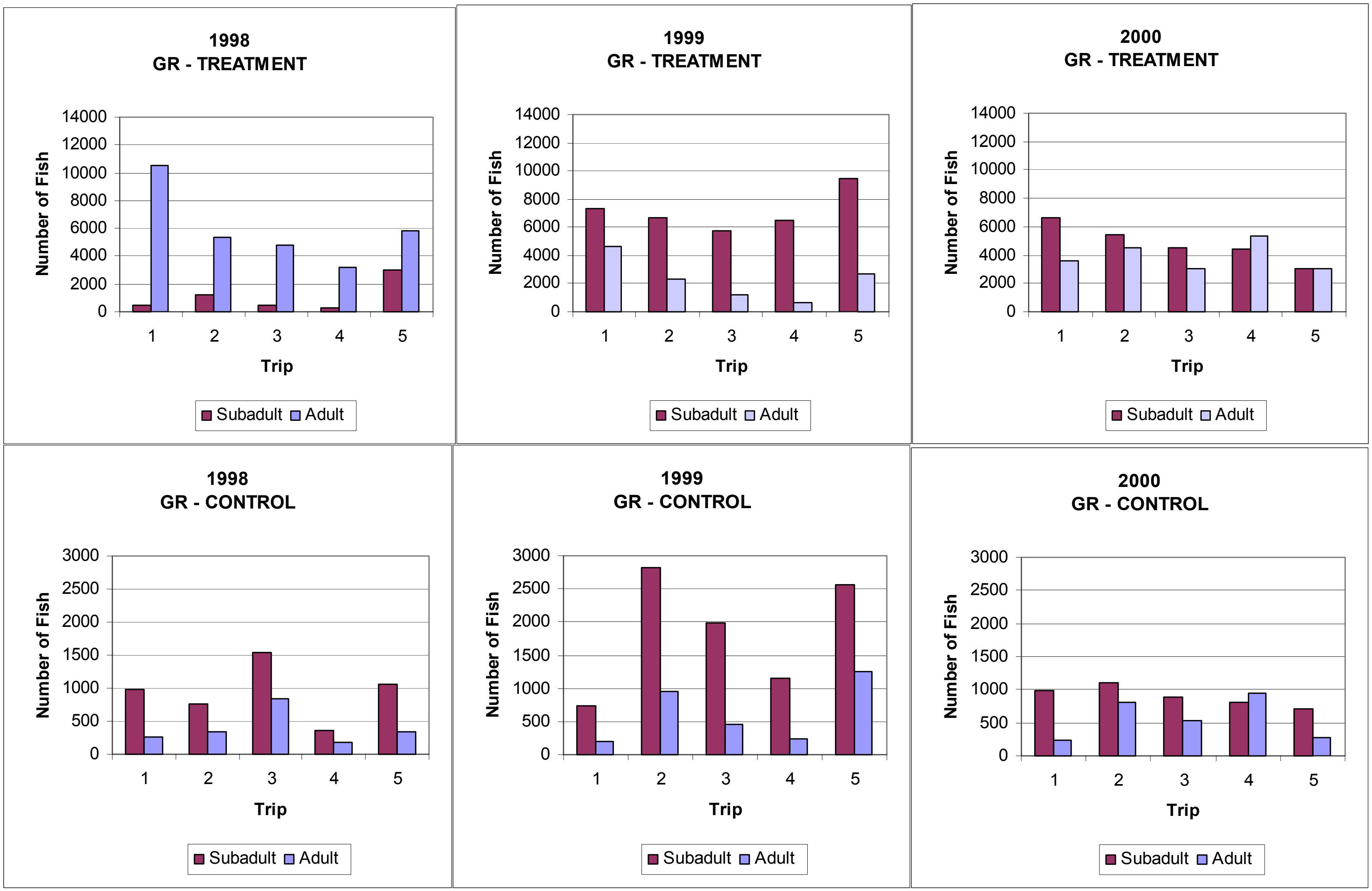
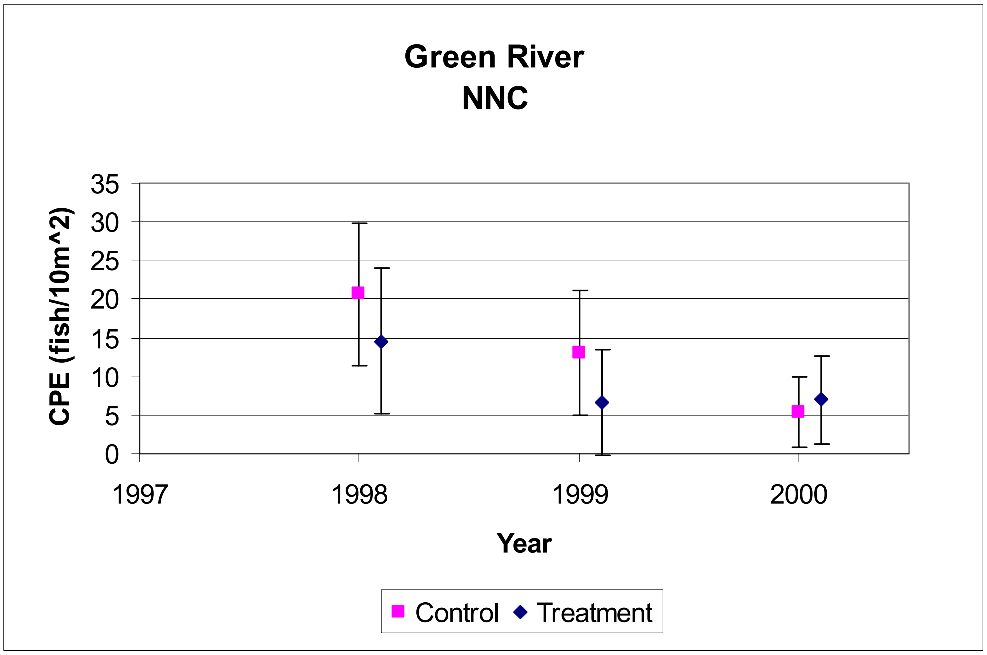


Figure 5. Green River: numbers of adult (>40 mm) and subadult (<40 mm) nonnative cyprinids in treatment and control reaches from 1998 to 2000.



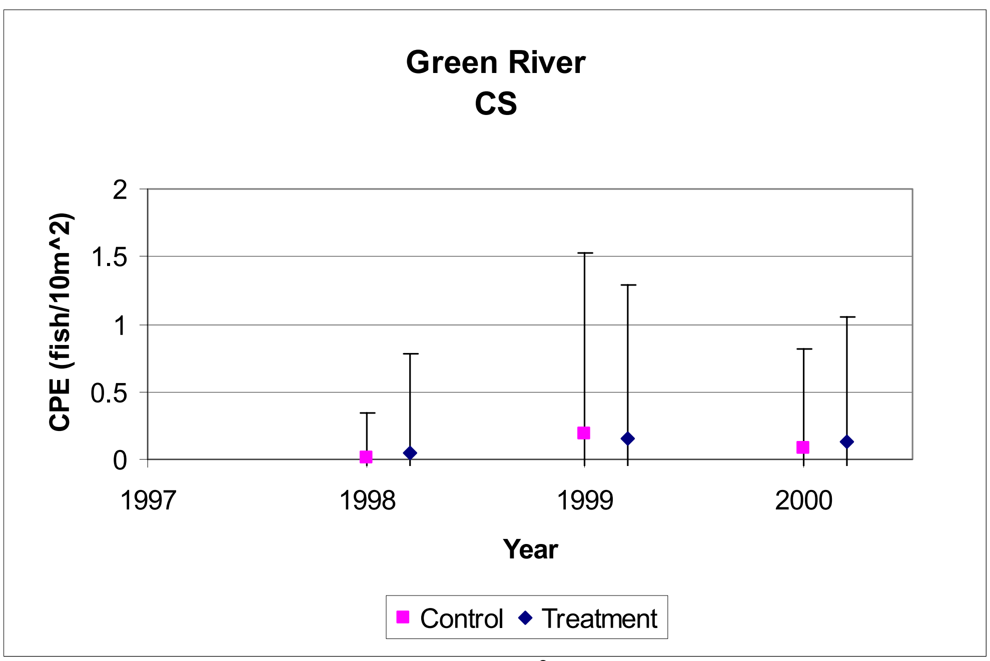
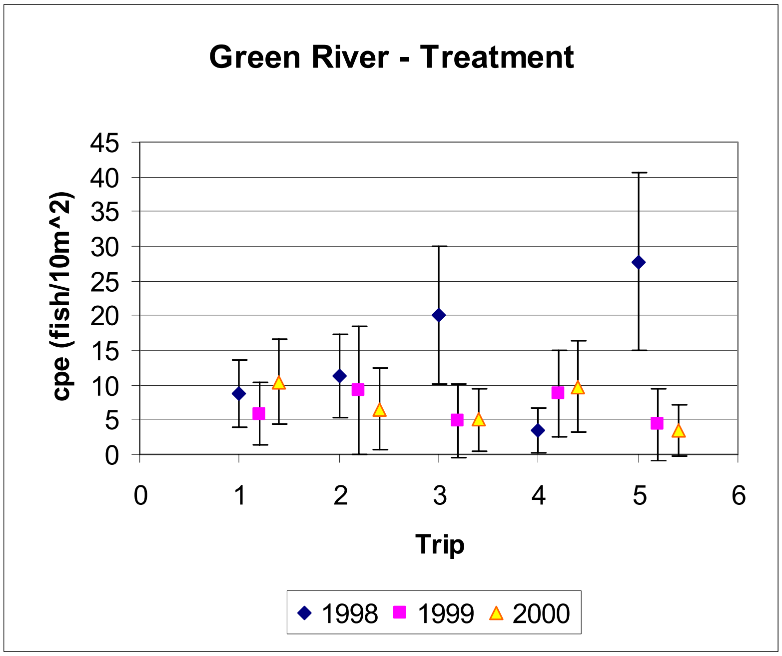


Figure 6. Green River: Mean CPE (fish/10m^2) of nonnative cyprinids (NNC) and Colorado pikeminnow (CS) captured in treatment and control reaches from 1998 to 2000. Error bars represent two standard errors.



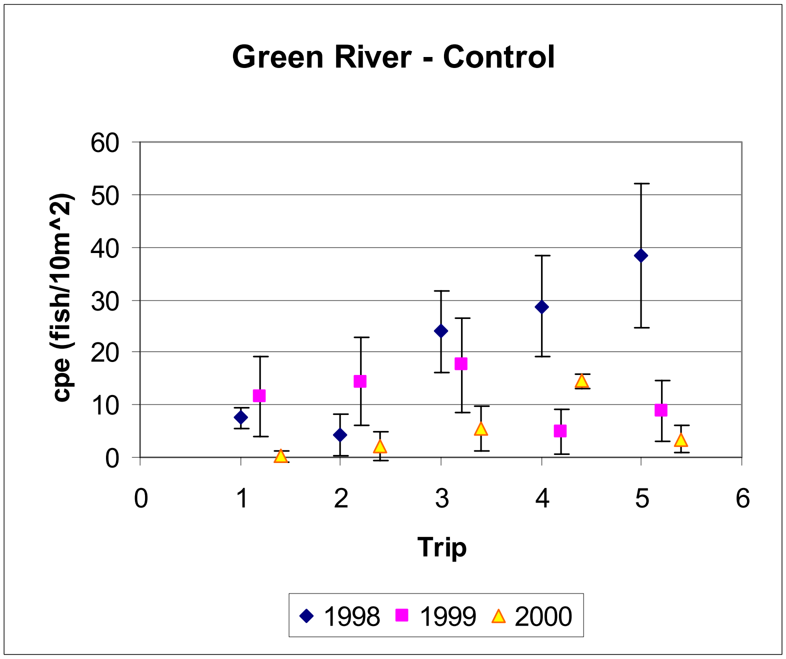
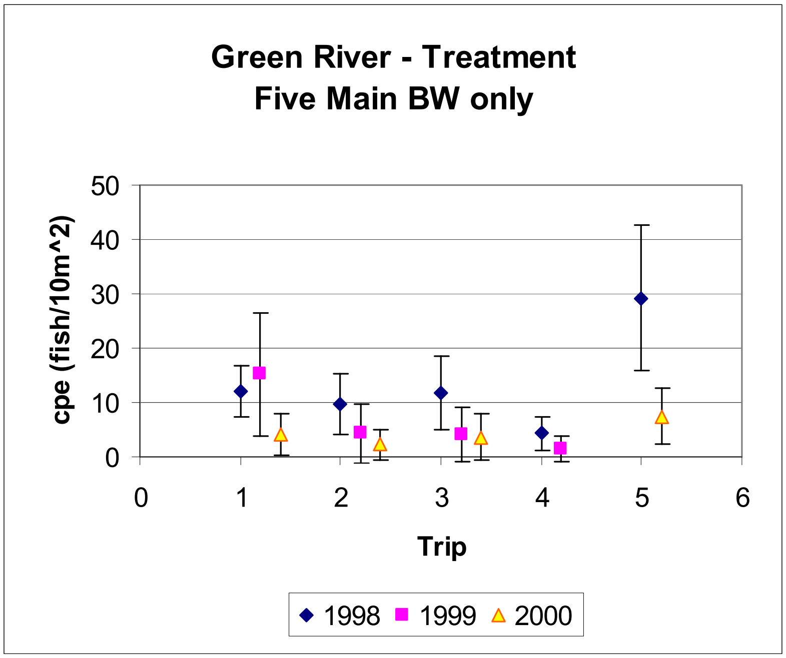


Figure 7. Green River: Mean CPE (fish/10m^2) of nonnative cyprinids captured on consecutive removal trips in treatment and control reaches from 1998 to 2000. Error bars represent two standard errors.



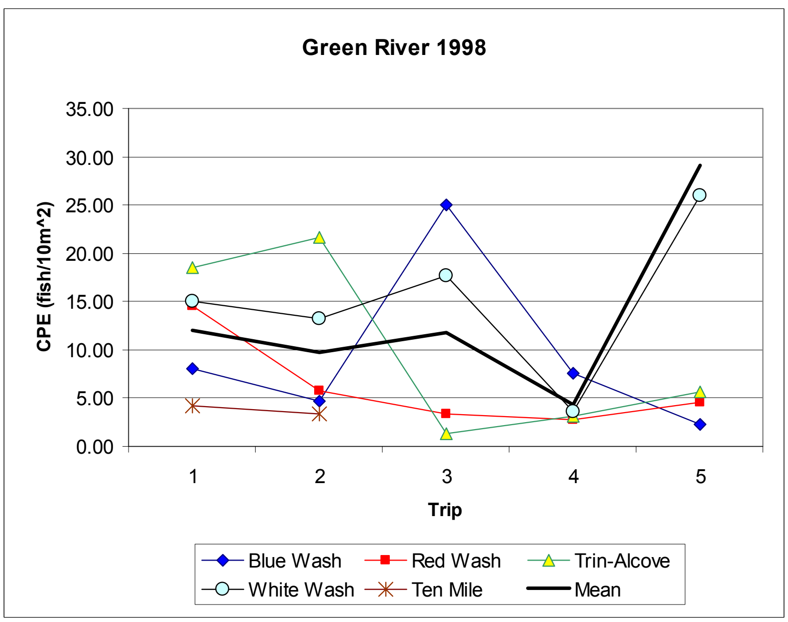


Figure 8. Green River: Mean CPE (fish/$10m^2$) of nonnative cyprinids captured in five unique treatment backwaters which were sampled on five consecutive removal trips each year from 1998 to 2000 (upper). CPE in five unique backwaters sampled in 1998 (lower).

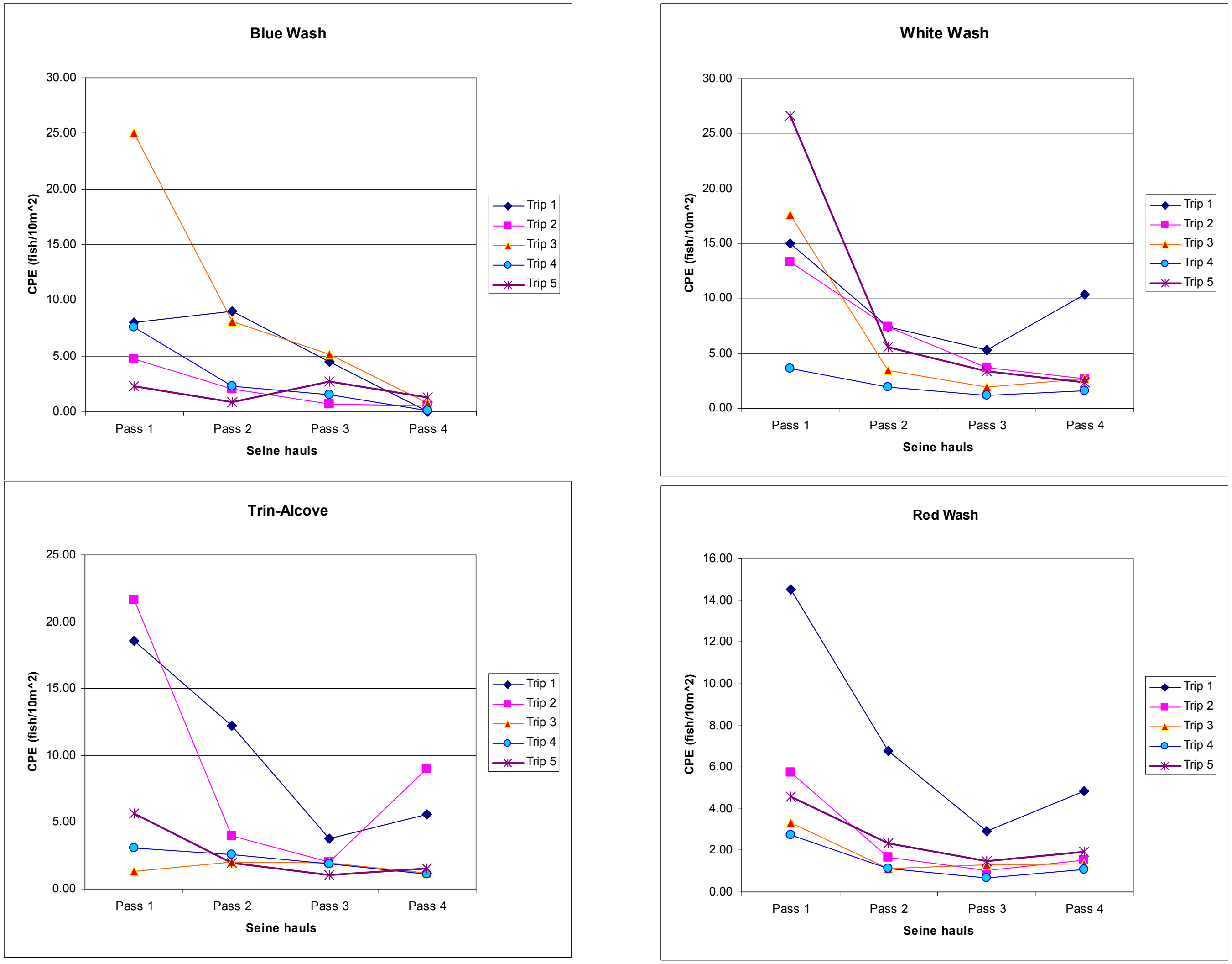


Figure 9. Green River: CPE (fish/10m^2) on four consecutive removal passes (seine hauls) in four unique backwaters sampled on five consecutive removal trips in 1998.

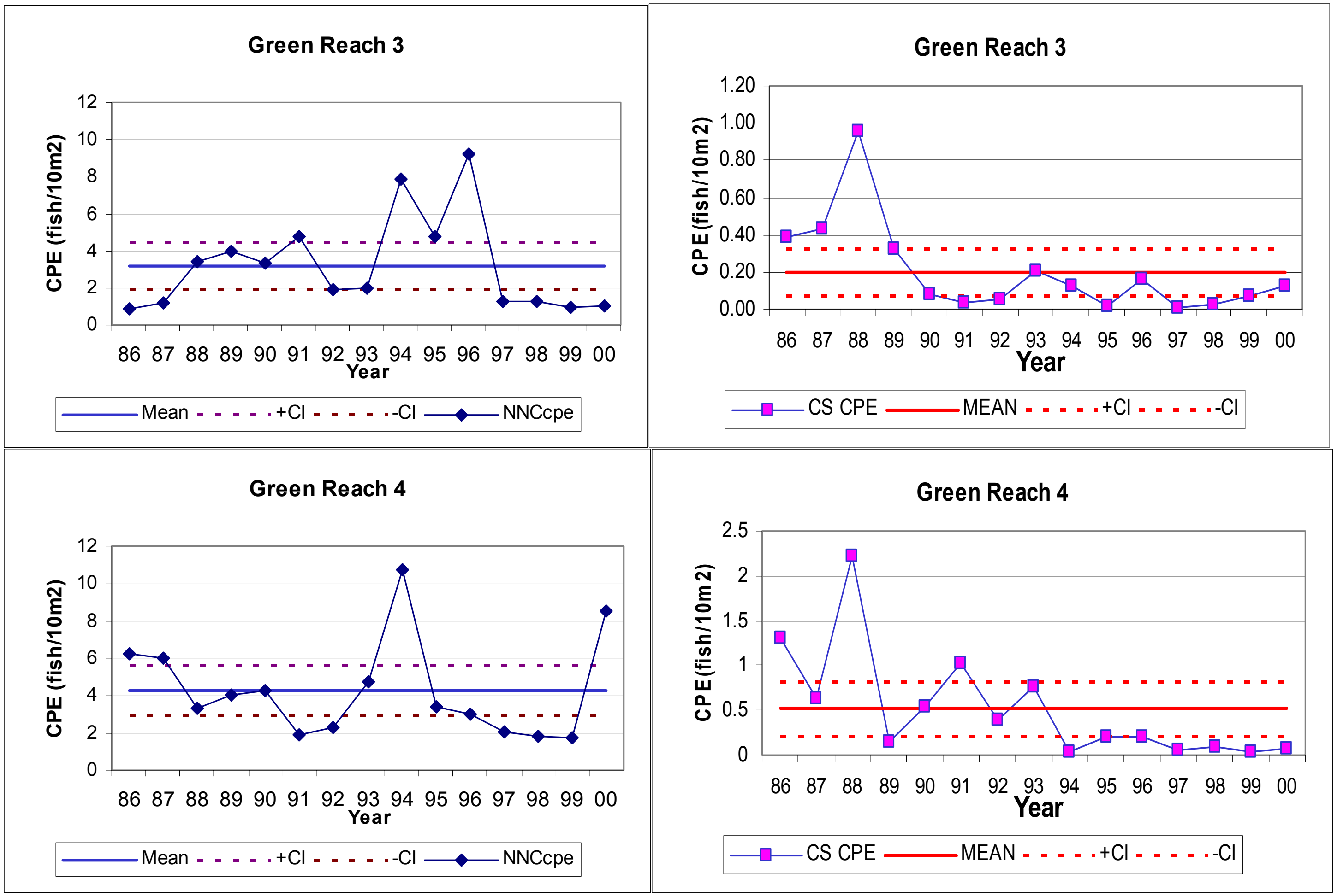
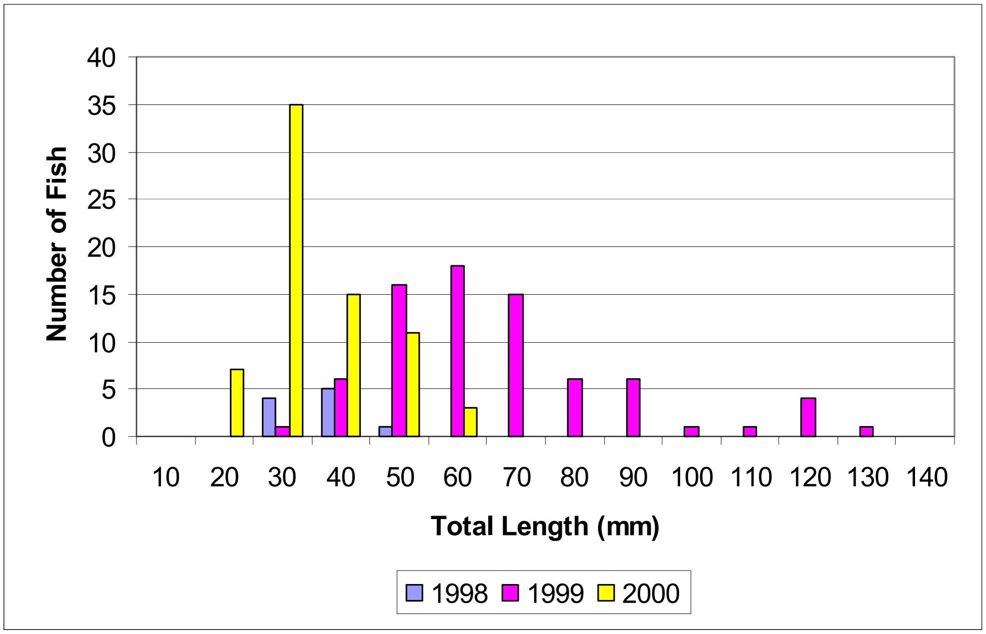


Figure 10. Green River: Comparison of long-term mean CPE (fish/10m^2) of ISMP from 1986 to 1997 to post-removal CPE (1998 to 2000) for nonnative cyprinids (NNC) and Colorado pikeminnow (CS). Solid line indicates long-term mean CPE, dashed lines indicate 95% confidence intervals.



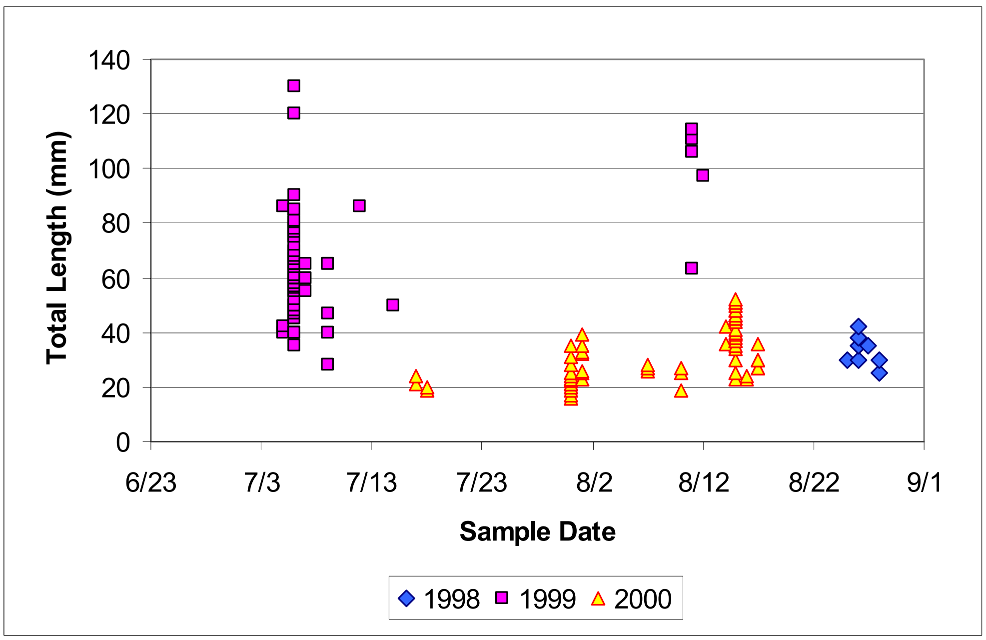
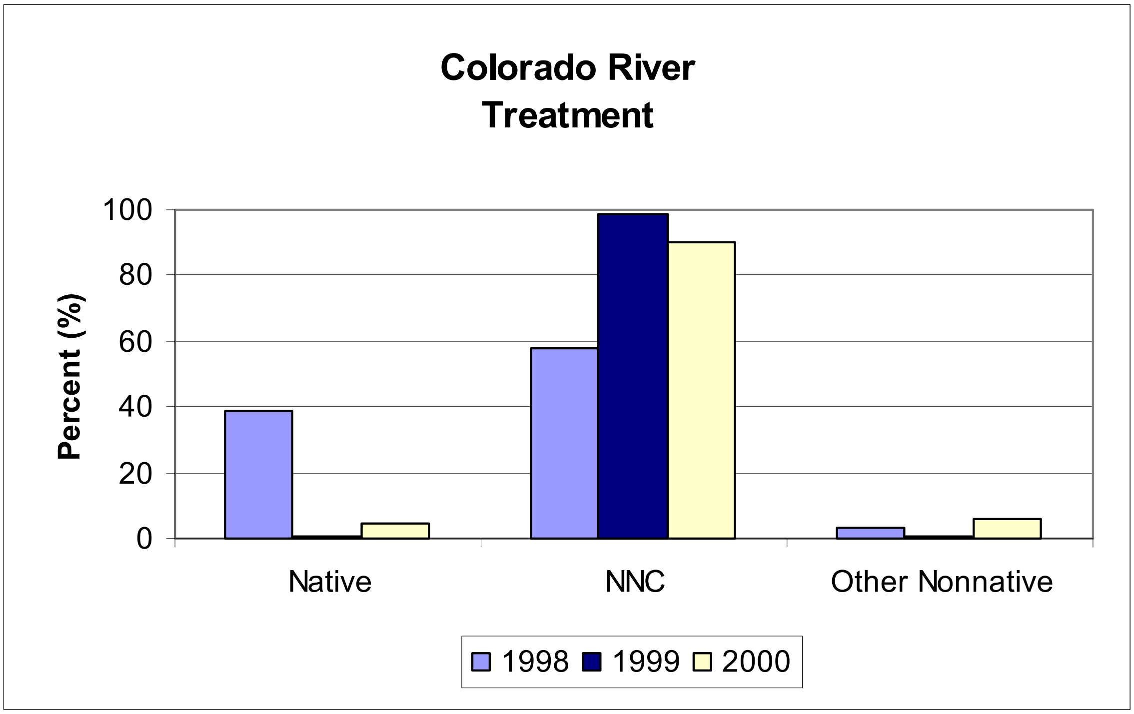


Figure 11. Colorado River: Length frequency distribution of Colorado pikeminnow captured in treatment and control reaches (combined) from 1998 to 2000.



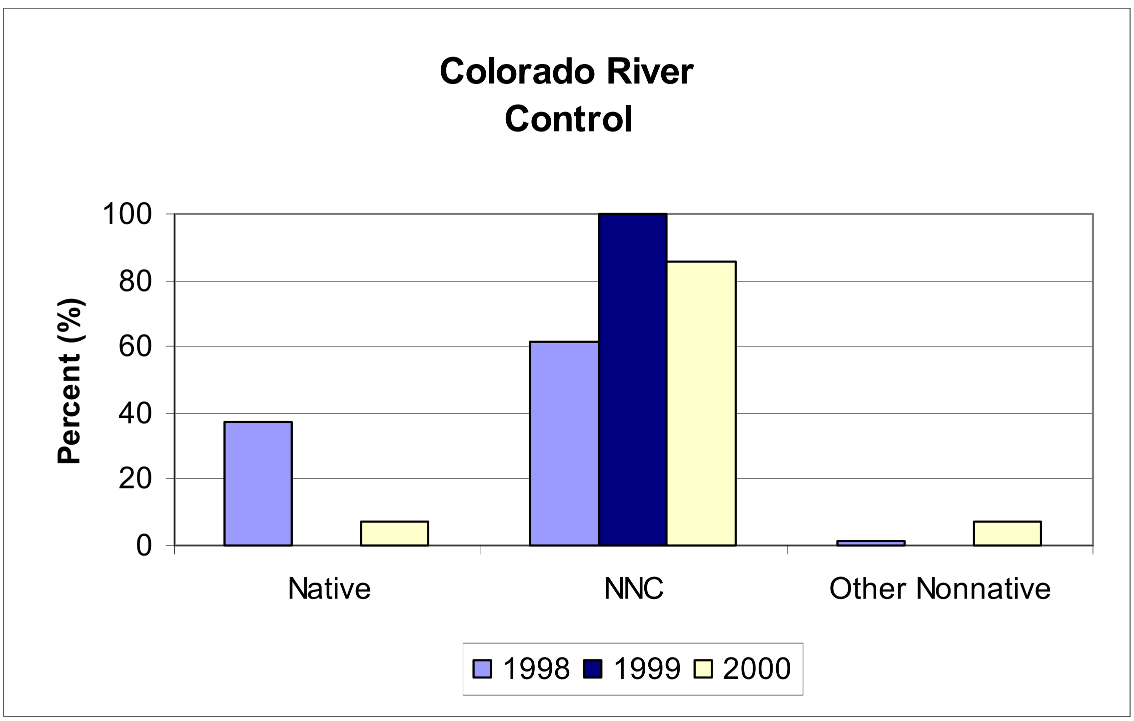


Figure 12. Colorado River: Percentages of native and nonnative fishes in treatment and control reaches, 1998 to 2000.

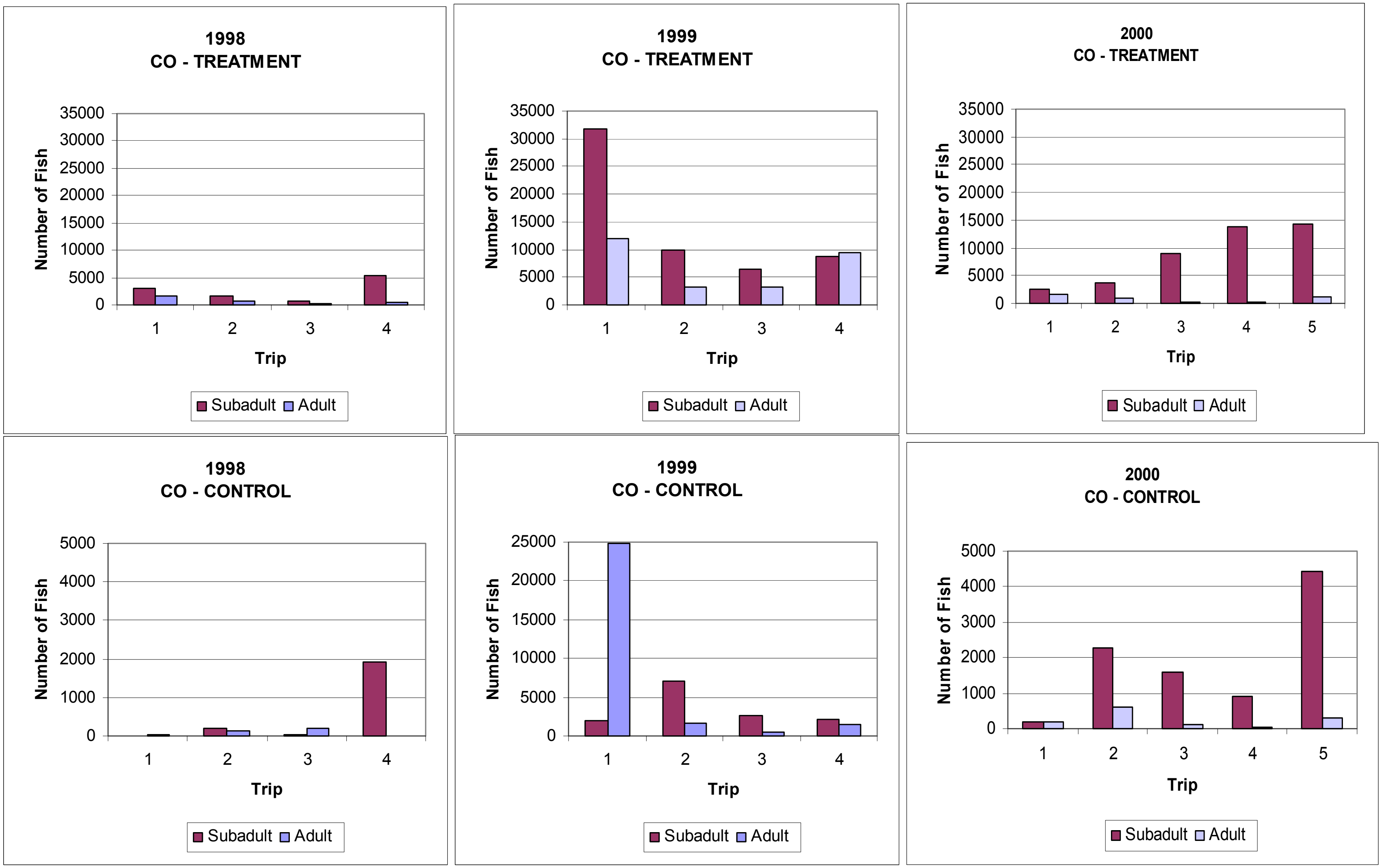


Figure 13. Colorado River: numbers of adult (>40 mm) and subadult (<40 mm) nonnative cyprinids in treatment and control reaches from 1998 to 2000

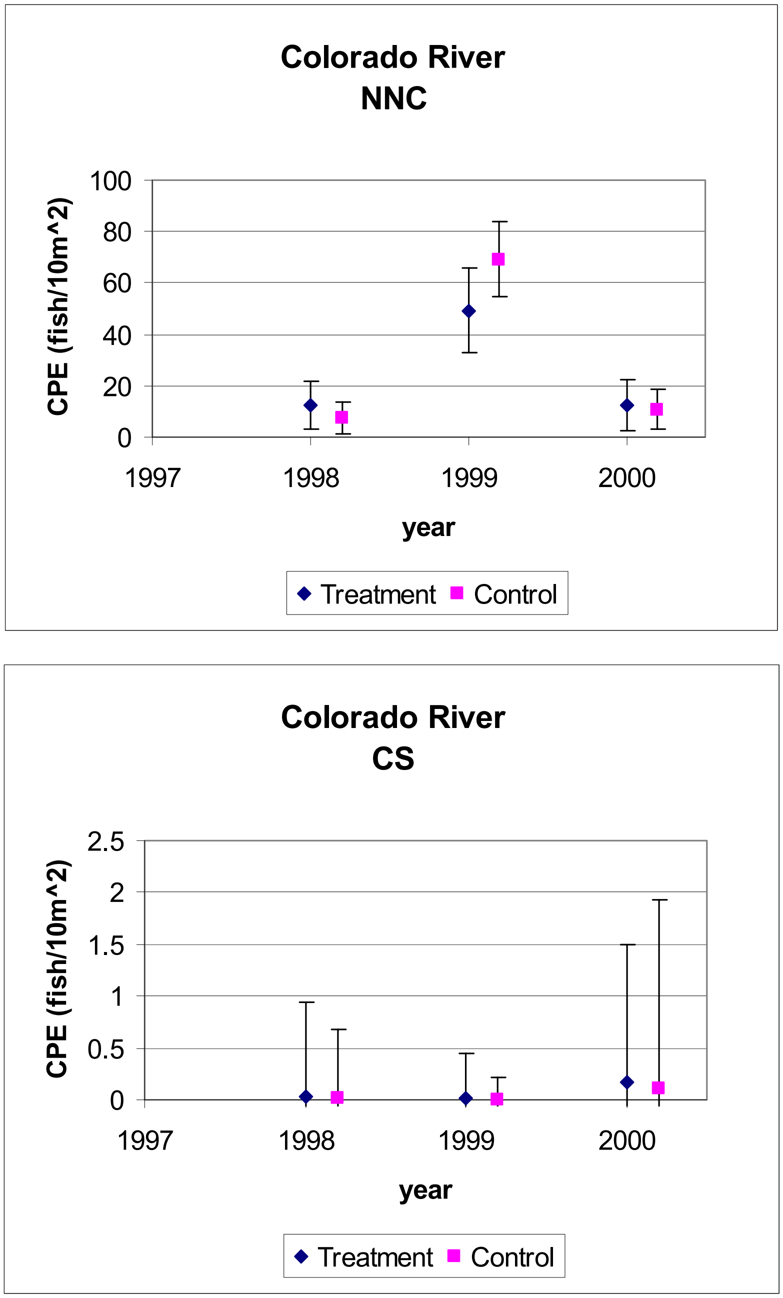
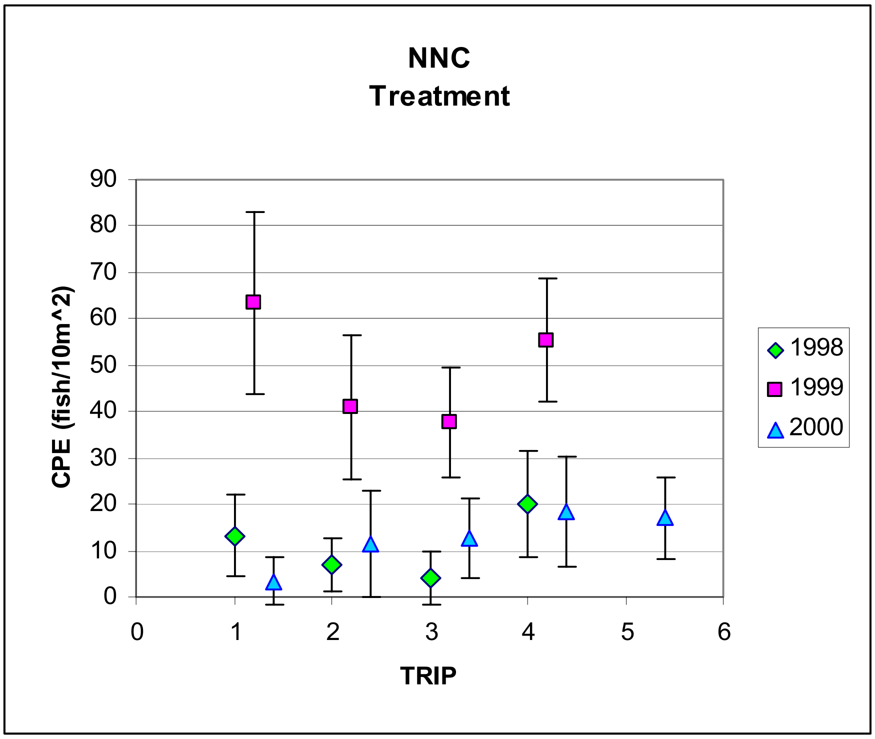


Figure 14. Colorado River: Mean CPE (fish/10m^2) of nonnative cyprinids (NNC) and Colorado pikeminnow (CS) captured in treatment and control reaches from 1998 to 2000. Error bars represent two standard errors.



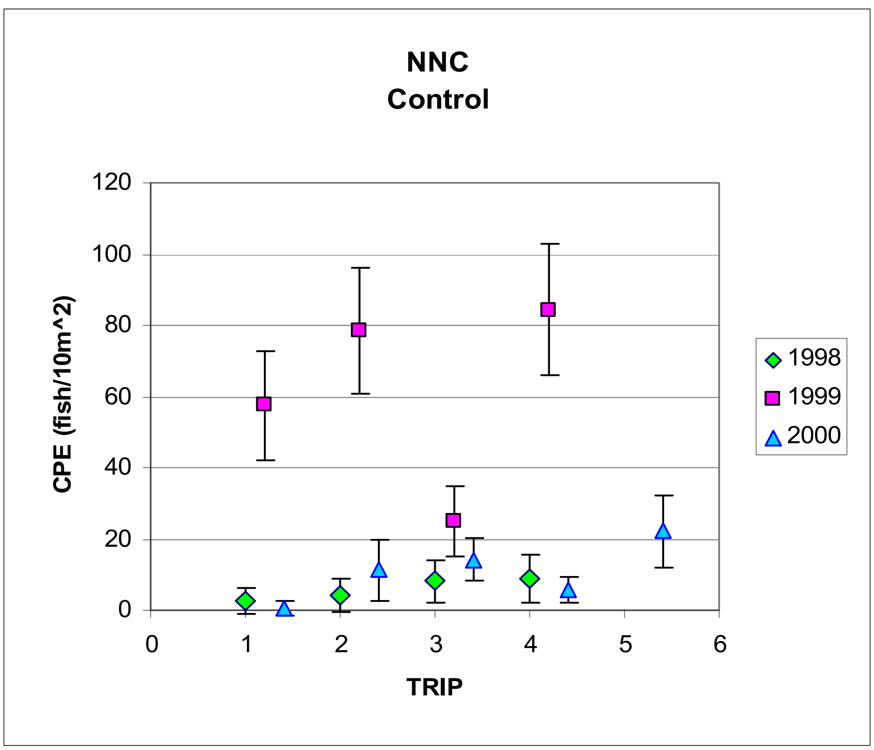


Figure 15. Colorado River: Mean CPE (fish/10m^2) of nonnative cyprinids captured on consecutive removal trips in treatment and control reaches from 1998 to 2000. Error bars represent two standard errors

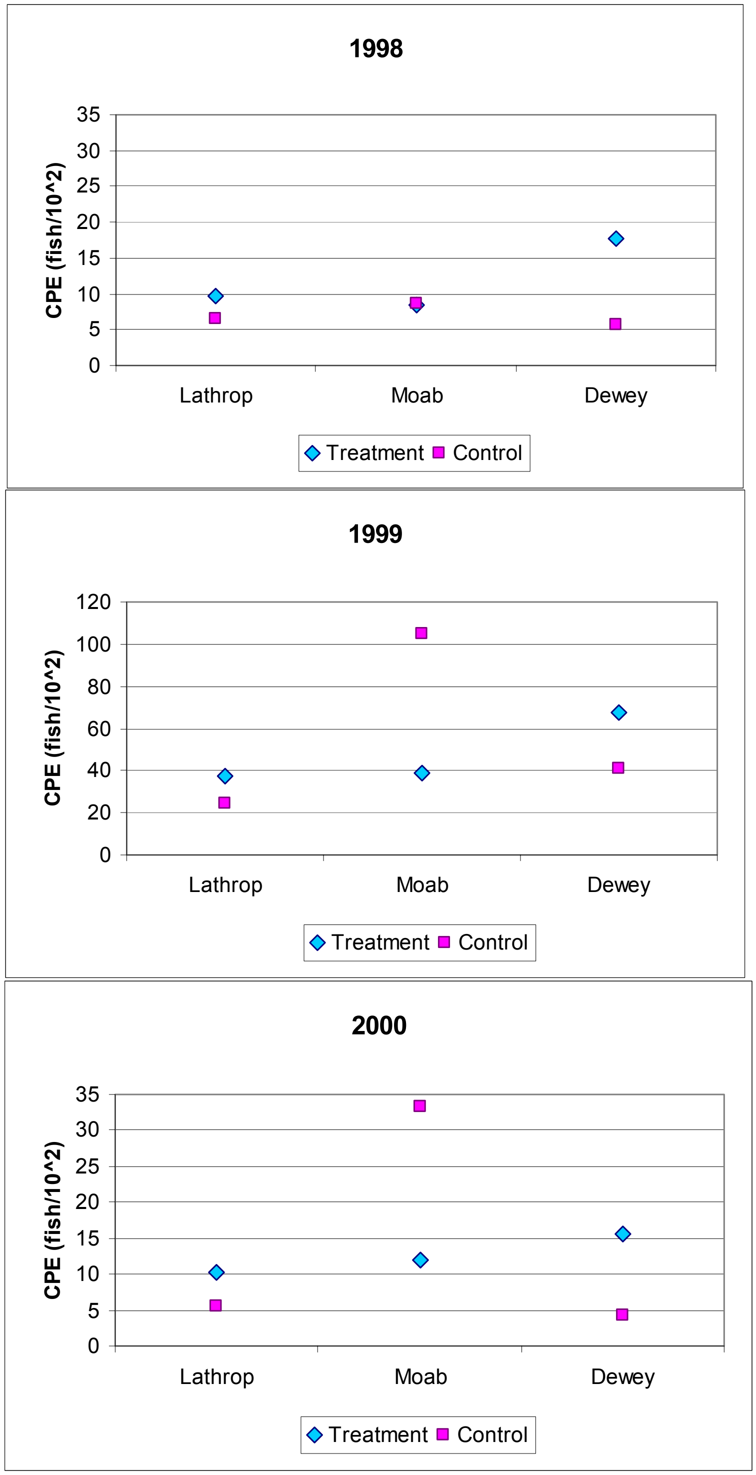


Figure 16. Colorado River: Mean CPE of nonnative cyprinids (fish/10m^2) in three distinct treatment and control reaches.

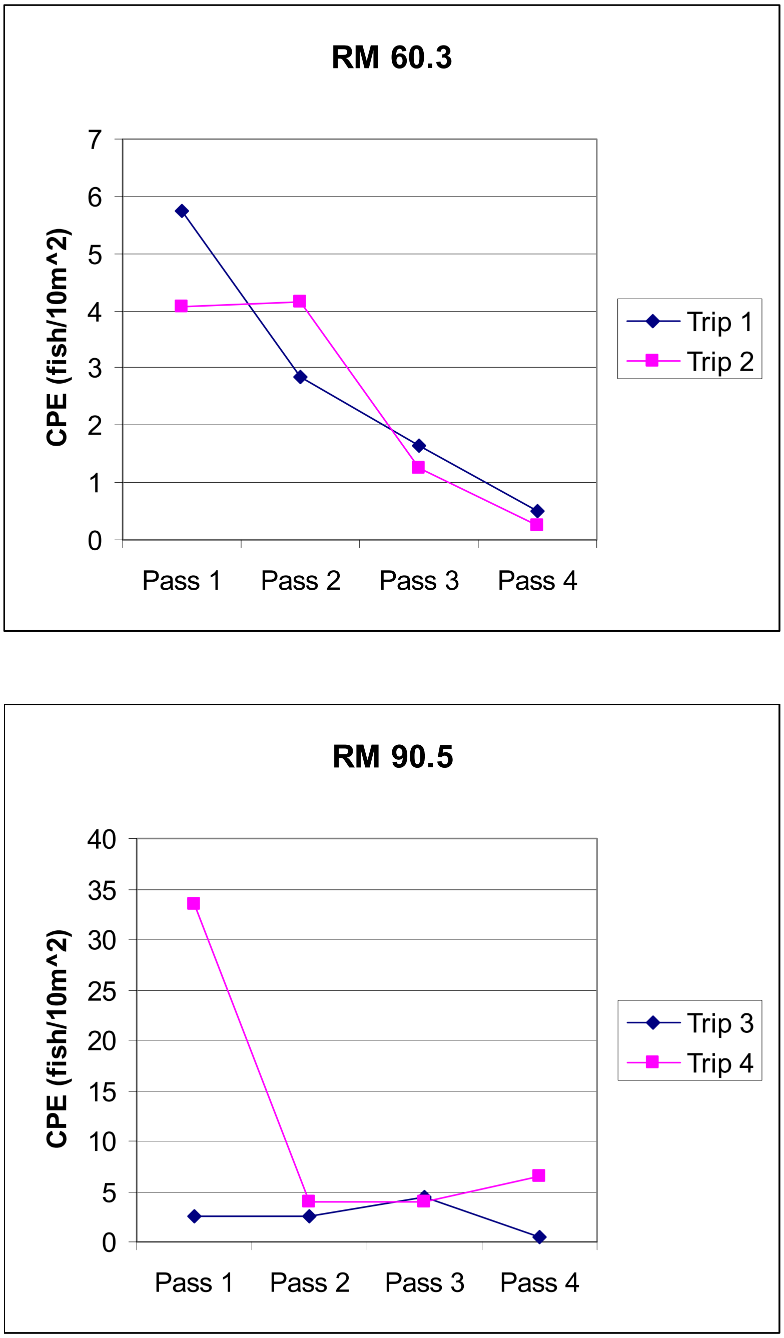
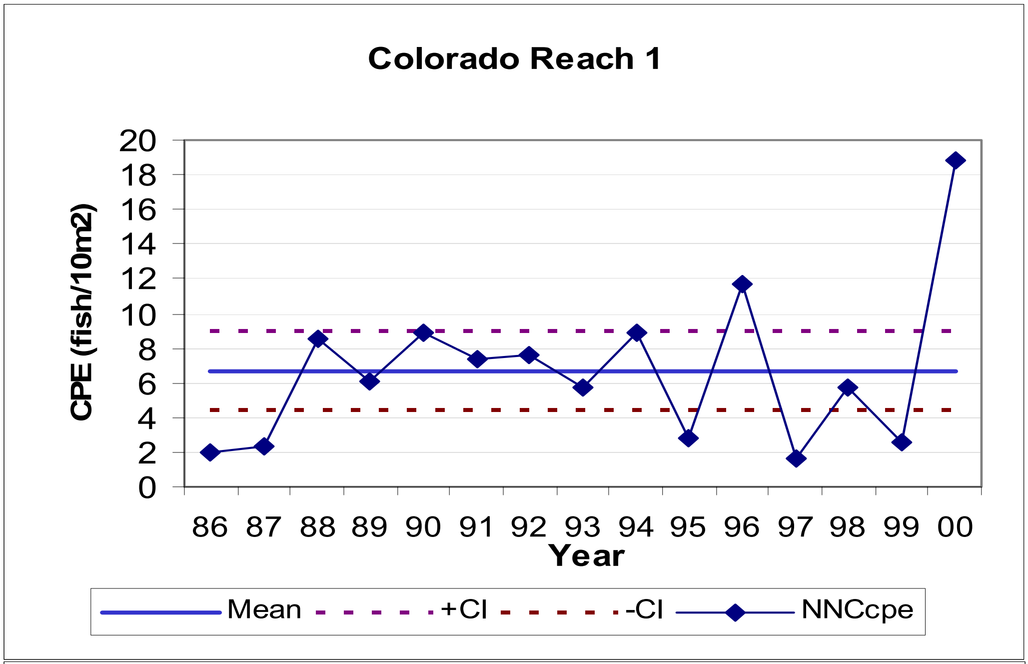


Figure 17. Colorado River: Mean CPE (fish/10m^2) of subsequent seine hauls (passes) in two individual backwaters (RM 60.3 and RM 90.5) sampled on two consecutive trips in 1998.



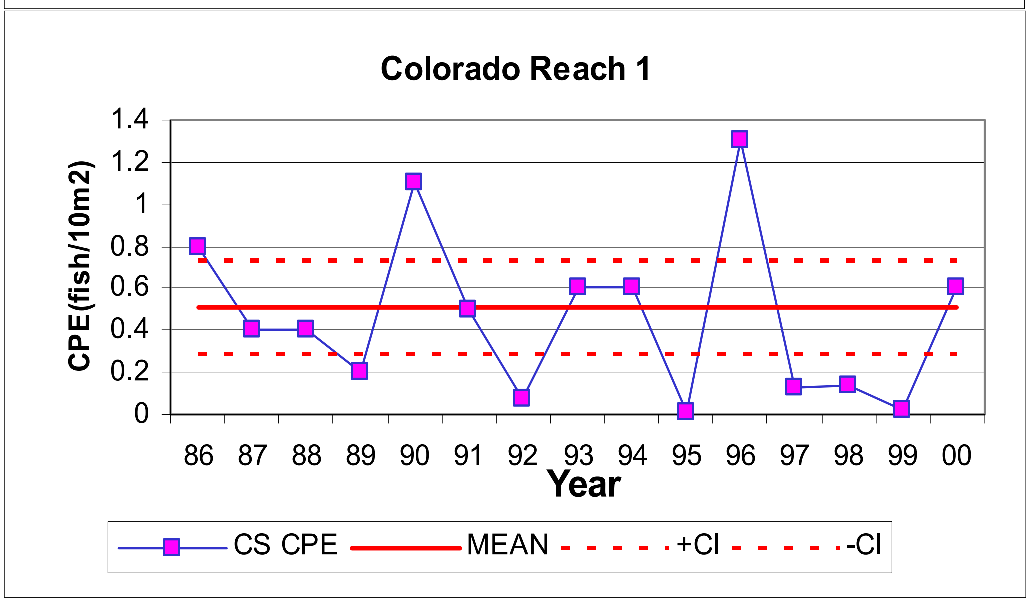


Figure 18. Colorado River: Comparison of long-term mean CPE (fish/10m^2) of ISMP from 1986 to 1997 to post-removal CPE (1998 to 2000) for nonnative cyprinids (NNC) and Colorado pikeminnow (CS).

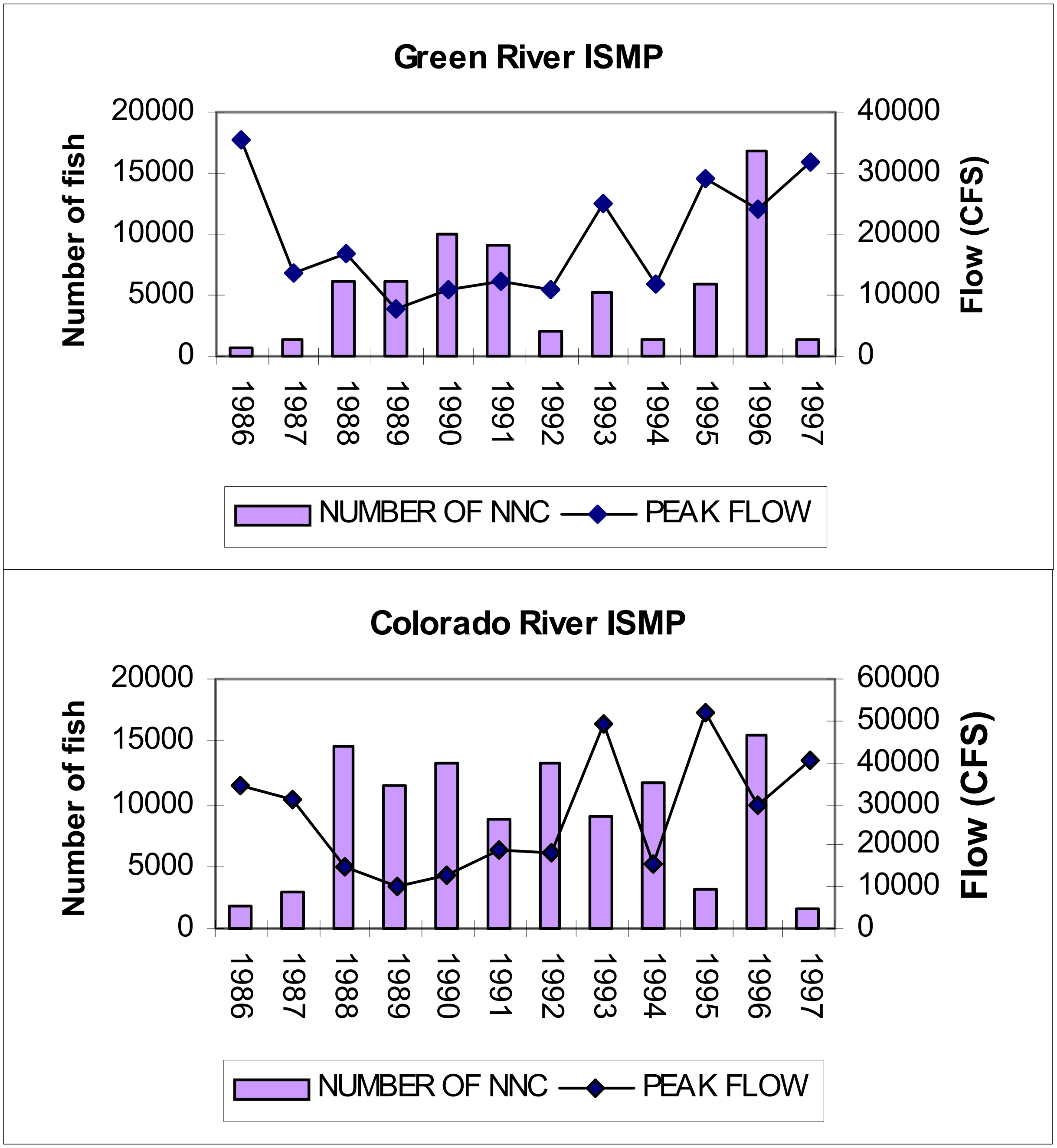


Figure 19. Captures of nonnative cyprinids in the Green and Colorado rivers during ISMP sampling 1986–1997 and annual peak discharge (USGS Green River at Green River, Utah Gage #09315000, and USGS Colorado River at Cisco, Utah Gage #09180500).