Smallmouth bass control in the middle Yampa River, 2003–2007

February 2009

John Hawkins
Cameron Walford
Angela Hill

Larval Fish Laboratory
Colorado State University
Fort Collins, Colorado 80523

Project No. 125
Final Report for the

Upper Colorado River Endangered
Fish Recovery Program
U. S. Department of Interior, Fish and Wildlife Service
Lakewood, Colorado 80225

Contribution 154 of the Larval Fish Laboratory, Colorado State University

ACKNOWLEDGMENTS

This study was funded by the Recovery Implementation Program for Endangered Fishes of the Upper Colorado River Basin. The Recovery Program is a joint effort of the U. S. Fish and Wildlife Service, U. S. Bureau of Reclamation, U. S. National Park Service, Western Area Power Administration, states of Colorado, Utah, and Wyoming, Upper Basin water users, environmental organizations, and the Colorado River Energy Distributors Association. Project administration was administered by T. Chart, D. Speas, V. Romero, M. Olivas, J. Frantz, and C. Morales. We thank landowners in the Yampa Valley that allowed access to the river through private property. We especially thank the many people that assisted with field sampling. Colorado Division of Parks provided access at Yampa River State Park facilities. We thank the following reviewers: K. Bestgen, S. Capron, T. Chart, B. Dillon, P. Martinez, C. Mellon, T. Nesler, D, Speas, M. Trammel, R. Valdez, and K. Zelasko. Colorado Division of Wildlife and U.S. Fish and Wildlife Service provided collecting permits. This is Larval Fish Laboratory Contribution 154.

Disclaimer
Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the authors, the Fish and Wildlife Service, U. S. Department of Interior, or the Recovery Implementation Program.

Key Words: Colorado pikeminnow, endangered species, invasive nonnative fish control, northern pike, smallmouth bass, Upper Colorado River Basin, Yampa River.

Suggested Citation: Hawkins, J., C. Walford, and A. Hill. 2009. Smallmouth bass control in the middle Yampa River, 2003–2007. Final report, Larval Fish Laboratory Contribution 154, Colorado State University, Fort Collins to Upper Colorado River Endangered Fish Recovery Program, U.S. Fish and Wildlife Service, Denver, Colorado.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

EXECUTIVE SUMMARY

We implemented removal of invasive nonnative smallmouth bass in the Yampa River from 2003 to 2007 with a goal of decreasing smallmouth bass abundance to increase survival and abundance of native and endangered fishes. In 2003, we used mark-recapture data to estimate smallmouth bass distribution, density, capture probability, and movement. From 2004 through 2007, we estimated abundance of adult smallmouth bass (>150 mm) at the beginning of each year prior to removal using mark-recapture methods at two study sites: a 24-mile (39 km) site at Little Yampa Canyon and a 5-mile (8-km) site at Lily Park. Abundance estimates were used to gauge subsequent removal efficiency in each year. From 2003 through 2007, we removed 15,190 smallmouth bass (2,441 kg) of all sizes with boat electrofishing and from 2005 through 2007 we removed 18,166 small, young-of-year smallmouth bass (126.5 kg) with electric seine. Of the bass removed, 5,448 (1,805 kg) were translocated to either Elkhead Reservoir or the Justice Center Pond in Craig for future fishing opportunities.

Abundance of adult smallmouth bass declined after mechanical removal at each study site. At Little Yampa Canyon we removed 3,879 adult smallmouth bass from 2004 through 2006 and abundance declined 17% from 2,888 fish in 2004 to 2,394 fish in 2007. At Lily Park we removed 2,545 adult smallmouth bass from 2004 through 2006 and abundance declined 19% from 1,519 fish in 2004 to 1,233 fish in 2007. We achieved annual removal rates of 40–64% of the bass in Little Yampa Canyon and 40–83% of the bass in Lily Park. Although we observed declines in abundance that we attributed to our annual removals, compensatory mechanisms (e.g., recruitment and immigration) likely off-set some of our removal effort. Recruitment appeared robust based on abundant young-of-year smallmouth bass captured with electric seine and the wide distribution and high abundance of yearlings captured by boat electrofishing. Immigration of smallmouth bass into our study sites was documented based on the movement of fish between our two study sites, invasion of escapees from Elkhead Reservoir, and movement of tagged fish from other reaches such as South Beach,

Maybell, and Yampa Canyon. The potential for smallmouth bass movement among reaches was shown by movements of up to 50 miles (80 km) in less than a year and up to 100 miles (161 km) after periods of more than a year. Documenting the rate of immigration into our study sites and improving our knowledge of movement dynamics in the Yampa River will require increased tagging effort in the Craig, South Beach, and Maybell reaches. Long-range movements of smallmouth bass throughout the Yampa River suggest that expanded and higher removal rates are needed river wide if we are to sustain removals in our study reaches.

We observed biological and environmental differences between Little Yampa Canyon and Lily Park study sites that may provide insight into the interactions and population dynamics of smallmouth bass and native fish populations. For example, density of smallmouth bass ranged from 100 to 143 fish per mile (62–89 fish/km) at Little Yampa Canyon and from 247 to 393 fish per mile (153–244 fish/km) at Lily Park. Smallmouth bass larger than 250 mm comprised 11% of the bass at Lily Park and 43% of the bass at Little Yampa Canyon. Smallmouth bass were extremely rare at both sites 23 years ago when native fishes were a dominant part of the fish community. Smallmouth bass numbers have increased from near zero to 51% of the fish community from 1984 to 2007 at Little Yampa Canyon and from zero to 25% of the fish community at Lily Park during the same period. In 1983 and 1984, native fish comprised 91% of the fish community at Lily Park and 67% of the fish community at Little Yampa Canyon. In 2007, native fish comprised no more than 8% of the fish community at Little Yampa Canyon and 56% of the fish community at Lily Park. Smallmouth bass are now the dominant predator in the middle Yampa River and their rise in abundance was concurrent with the decline of native fish in the Yampa River. Higher removal rates, both within the study area and at other study areas may be needed to adequately reduce the predatory threat of smallmouth bass in the Yampa River and to restore the native fish community.

Conclusions

- Smallmouth bass are the most abundant nonnative predator in the middle Yampa River.
- Little Yampa Canyon and particularly Lily Park, contained high densities of smallmouth bass.
- Abundance of smallmouth bass declined after intensive removal but it was unknown whether the reduction was caused by removal, environmental factors, or a combination of both.
- Smallmouth bass moved long distances in both up and downstream directions in the Yampa River.
- Some smallmouth bass that were translocated into Elkhead Reservoir escaped and dispersed downstream to the Yampa River, including into our study sites.
- Mechanical removal effectiveness was partially offset by immigration and recruitment of fish into each study site.
- Floy tag loss was not detected during the short mark-recapture period required to estimate abundance.
- Diversity and abundance of most native fishes has declined in the study reaches compared to twenty years ago.

Recommendations

- Continue intensive removal of smallmouth bass in high density areas such as Little Yampa Canyon and Lily Park
- Remove smallmouth bass from other reaches in conjunction with other on-going studies.
- Continue annual abundance estimates of smallmouth bass to monitor changes in smallmouth bass abundance.
- Continue to monitor escapement of translocated fish.
- Due to the invasive nature of smallmouth bass we highly recommend not translocating them to novel locations within the Yampa River basin or to other basins.

- Maintain fish community sampling at study sites to monitor changes in species composition.
- Increase number of removal occasions by starting earlier in the year.
- Provide field crews with technical assistance in testing and maintaining electrofishing equipment to insure that it operates at maximum potential.
- Increase angler education to encourage anglers not to remove tags and to explain the benefits that tagged fish provide for reservoir management.
- Study the biology and ecology of smallmouth bass in the Yampa River and examine why there are differences between Little Yampa Canyon and Lily Park.

INTRODUCTION

Project background—Nonnative smallmouth bass *Micropterus dolomieu* currently occupy portions of the Yampa and Green rivers in Colorado and Utah that are designated as critical habitat for four federally endangered fishes: Colorado pikeminnow *Ptychocheilus lucius*, razorback sucker *Xyrauchen texanus*, humpback chub *Gila cypha*, and bonytail *G. elegans*. Smallmouth bass are a predatory and competitive threat to these endangered fishes. Participants of the Upper Colorado River Endangered Fish Recovery Program (Recovery Program) determined that control of nonnative fishes was necessary for recovery of endangered fishes in the Upper Colorado River Basin and the Colorado Division of Wildlife (CDOW), a Recovery Program participant, developed an Aquatic Wildlife Management Plan for the Yampa River Basin that recommended managing the river reach downstream of Craig, Colorado to enhance survival of native and endangered fishes. The management plan recommended removal of some nonnative predators from sections of the Yampa River but also acknowledged the importance of providing fishing opportunities for local anglers and recommended that when practical gamefish removed from the river should be translocated to nearby waters that are isolated from the Yampa River. Specifically, the management plan recommended removal and translocation of smallmouth bass, northern pike *Esox lucius* and channel catfish *Ictalurus punctatus* and lethal removal of white sucker *Catostomus commersonii* (CDOW 1998). Potential benefits of reducing nonnative predator abundance in the Yampa River include reduced predation and competition with native fish, increased forage for endangered Colorado pikeminnow, and reduced recruitment of predators to endangered fish nursery areas downstream.

This project implemented a portion of the management plan's recommendations by removing invasive smallmouth bass from two sections of the Yampa River and was one of several similar projects conducted concurrently in the Green River Basin with a common goal of improving the survival of endangered fishes. The objective of this project was to determine if the number of smallmouth bass in our study sites could be reduced to a level that would improve survival and recruitment of native fishes, to identify the level of effort required, and to determine movement patterns of smallmouth bass. Based on knowledge gained during the preceding years we refined our tasks (Scope of Work objectives) each year resulting in the following:

1. Obtain an estimate of the number of smallmouth bass in the 24-mile treatment reach in Little Yampa Canyon and a 5-mile reach in Lily Park using a mark–recapture abundance estimator.
2. Remove a large portion of the estimated population of smallmouth bass from the 24-mile treatment reach in Little Yampa Canyon and the 5-mile concentration area in Lily Park.
3. Calculate the proportion of smallmouth bass removed from each study area based on initial population size.
4. Remove large numbers of age-0 and age-1 smallmouth bass from the 12-mile treatment reach in Little Yampa Canyon (This is the lower section of the 24-mile study reach and corresponds with the treatment reach for the Native Fish Evaluation Study # 140).
5. Understand movement of recaptured smallmouth bass.

Historical background of smallmouth bass invasion in the Yampa River—Smallmouth bass were first introduced to the Yampa River basin in 1978 when the Colorado Division of Wildlife stocked the species in Elkhead Reservoir. This 450-acre mainstem reservoir was built in 1974, 5 miles upstream from the Yampa River confluence on Elkhead Creek, a Yampa River tributary located 148 miles upstream from the Green River confluence. Prior to reservoir stocking, smallmouth bass did not occur in the Yampa River based on their absence from fish collections in 1951, 1967–1971, and 1976–1977 (Bailey and Alberti 1952; Holden and Stalnaker 1975; Carlson et al. 1979). Although both the spillway and the outlet structure at Elkhead Reservoir were unscreened, fish escapement was not initially considered a problem by resource managers because smallmouth bass were very rare in the Yampa River for several years after stocking. For example during extensive boat electrofishing in 1981 and

1982, only one smallmouth bass was captured among the almost 4,000 juvenile and adult fish collected and additional boat electrofishing from 1986 through 1988 produced none (Wick et al. 1985; McAda et al. 1994). There was no detectible reproduction of smallmouth bass in the river based on the absence of young bass in seine and dipnet collections of approximately 35,000 small-bodied fish from the lower 121 miles of the Yampa River in 1981 and 1982 (Wick et al. 1985). Absence of smallmouth bass through 1988 suggested that escapement was minimal even after high peak-flows in 1983 and 1984.

Fish sampling in several Yampa River reaches downstream of Craig first detected the species 45 miles downstream of Elkhead Reservoir in 1981, then 70 miles downstream of the reservoir in 1990 and 1991, and 95 miles downstream of the reservoir in 1992 (McAda et al. 1994). Although relative abundance of smallmouth bass remained low, the number captured increased from two in 1989, to five in 1990, 14 in 1991, and 49 in 1992 (McAda et al. 1994). Because of their rarity, smallmouth bass were not considered a problem by Colorado River Basin biologists and managers surveyed about problematic nonnative fishes in 1990 (Hawkins and Nesler 1991). However, smallmouth bass abundance increased dramatically in the Yampa River in late summer 1992 after rapid draining of Elkhead Reservoir through the unscreened outlet structure (Nesler 1995). By 2003, the riverine population of adult smallmouth bass comprised 18% of the fish collected at Little Yampa Canyon, 13% of the fish at Maybell, and 5% of the fish at Lily Park (Anderson 2004). Riverine reproduction was confirmed in 2001 when sub-adult smallmouth bass (< 150 mm TL) comprised 98% of the fish seined at Little Yampa Canyon and 58% of the fish seined at Maybell (Anderson 2004). In 2005, Elkhead Reservoir dam construction included a screened notched spillway to reduce escapement of reservoir fishes. However, on May 17th the screen clogged with debris and failed allowing unscreened discharge into Elkhead Creek. Construction on the reservoir was completed in 2006 with a 6.4 mm screened outlet structure to reduce fish escapement during draw-down events and a redesigned unscreened spillway.

METHODS

Study area— The Yampa River is located in arid, northwestern Colorado and drains portions of the southern Rocky Mountains, Wyoming Basin, and Colorado Plateau to the Green River. It remains one of the last relatively unregulated rivers in the Upper Colorado River Basin and has an average annual discharge of 1.2 million acre feet and a snow-melt discharge that peaks in spring. This study focused on the area downstream of Craig, Colorado, where the Yampa River meanders primarily through low-gradient alluvial floodplain except for four high-gradient canyons of varying length. Canyon-bound reaches include Little Yampa Canyon (RM 129.9–103.4), Juniper Canyon (RM 91.1–89.1), Cross Mountain Canyon (RM 58.9–55.5) and Yampa Canyon (RM 45–0). We selected two study areas based on high concentrations of smallmouth bass observed during previous sampling for northern pike (Hawkins et al. 2005). The two areas were Little Yampa Canyon, from Roundbottom to 1-mile upstream of Government Bridge near Lay, Colorado (RM 124–100) and Lily Park between Cross Mountain Canyon and the Little Snake River confluence (RM 55.5–50.5; Figure 1). River reaches downstream of RM 177 and outside of our study sites were sampled by either us or other agencies. These included Craig (RM 177–135), South Beach (RM 135–124), Lower Juniper (RM 100–89), Maybell / Sunbeam (RM 89–59), and Yampa Canyon (RM 45–0; Figure 1).

Sampling protocol— Sampling began in 2003 with a single study site at Little Yampa Canyon and our study design divided the site into equal-sized control and treatment reaches with the intent of determining whether abundance of adult smallmouth bass ($\geq$150 mm total length; TL) declined in the treatment reach after smallmouth bass removal. Beginning in 2004, at the start of each annual sampling season, we estimated abundance of adult smallmouth bass in each study site. On subsequent sampling occasions in the same year we removed smallmouth bass from the treatment reach and marked and returned them to the river in the control reach. In 2003, each reach was 6-miles long with the treatment (RM 111.2–117.2) upstream of the control (RM

105.2–111.2; Table 1). In 2004, we added Lily Park (RM 50.5 – 55.5) as another treatment reach, switched locations of Little Yampa Canyon control and treatment reaches, and increased the length of those reaches to 12-miles (control, RM 124.0–112.0; treatment RM 112.0–100.0). Reach length was increased because of extensive movement of smallmouth bass observed between shorter 6-mile reaches in the previous year. Those reach lengths remained the same in 2005. However, continued high rates of movement between control and treatment reaches in 2004 and 2005 resulted in the elimination of the control reach and expansion of the treatment reach to 24-miles in Little Yampa Canyon in 2006 and 2007.

Boat electrofishing occurred from April through mid-July when flow was sufficient (>1000 cfs) to navigate the river with 17-ft. aluminum, Jon-boats fitted with outboard jet motors. We sampled both shorelines concurrently with two electrofishing boats in a downstream direction and covered about 6 miles per day until the entire reach was sampled. Each boat used pulsed-DC current, one boat with a Coffelt and the other with a Smith-Root electrofishing unit. Duration of electrofishing effort was obtained from a timer on each electrofishing unit. Each reach was sampled on four to ten occasions per year with an interval of 4–10 days between occasions. Fish marked and released on the first one or two sample occasions each year served as the mark for annual abundance estimates. Study reaches were divided into ½-mile sections and we electrofished to the lower terminus of each section before processing fish. Fish that were returned to the river were Floy tagged and released within the ½-mile section from which they were captured. Backwater and flooded tributary mouth areas were sampled by electrofishing boat, fyke net, or block-and-shock techniques described by Nesler (1995). To determine spawning locations and timing of smallmouth bass reproduction, we noted guarding males moving off nests and reproductive condition of fish. Adult smallmouth bass were also captured occasionally by angling during periods of low stream discharge. Other nonnative species captured and euthanized included black crappie *Pomoxis nigromaculatus*, bluegill *Lepomis macrochirus*, green sunfish *L. cyanellus*, pumpkinseed *L. gibbosus*, black bullhead *Ameiurus exile*, and walleye

Stizostedion vitreum.

From 2005 through 2007, during periods of low stream discharge in July and August, we focused on removing young (age-0 and age-1) smallmouth bass from the lower 12-mile section of the Little Yampa Canyon study site (i.e. the original treatment reach designated in 2004; Table 2). Fish removal from this reach maintained consistency with the control–treatment design of the native fish evaluation study (Bestgen et al. 2007). The reach was accessed by canoe or truck and fish were captured with a 10 m-long electric seine powered by a 2000-watt generator. We sampled primarily shallow, low-velocity shorelines associated with backwaters, embayments, or boulders deposited from talus slopes. Electrofishing time of each sample was recorded with a stop watch.

Fish handling— Fish captured with boat electrofishing were placed in a live well, measured to the nearest mm TL, and weighed to the nearest 50 gr with 5- or 10-kg, Pesola® spring scale. Fish captured with electric seine were weighed to the nearest 0.1 gr with an electronic scale. We examined all fish for tags, fin clips, pike bites, gametes, and wear along the ventral medial fins indicating nest cleaning. Smallmouth bass were tagged at the start of each year so that recaptured fish could be used to determine abundance, monitor movement, and monitor potential escapement from translocated waters. In 2003 we tagged smallmouth bass larger than 100 mm and in later years we tagged bass larger than 150 mm. Beginning in 2005 during removal from the treatment reaches, smallmouth bass < 250 mm were euthanized with an overdose of Tricaine methanesulfonate (MS-222) and bass $\geq$ 250–mm TL were translocated (Table 1). In prior years, bass were not euthanized and all sizes were translocated from treatment reaches. If not previously tagged, smallmouth bass were tagged with a numbered, blue or yellow, Floy® t-bar anchor tag (model FD-94) inserted through the left musculature between pterygiophores near the posterior base of the dorsal fin. Fish held for transport off site were maintained in a recirculating live well (150-gallon poly stock tank) with compressed oxygen. Smallmouth bass that were translocated were Floy tagged and placed in an oxygenated live well and transported to either Elkhead Reservoir or

Craig Justice Center Pond.

To determine if there was tag loss between mark and recapture sample occasions that could affect abundance estimation, smallmouth bass at Little Yampa Canyon were double marked with a yellow Floy–tag and a partial, lower caudal-lobe clip on the first sample occasion in 2007. All smallmouth bass captured on the second sample occasion were examined for both marks.

Removal effort— We attempted to maximize the number of removal occasions each year based on time and resources. To assist our planning and sampling design we estimated removal rate with the formula:

$R = 1-(1-p)^n$; where

R = percent of fish handled (annual rate of removal)

p = capture probability (estimated from prior year)

n = number of sample (removal) occasions.

Conversely, the number of sample occasions necessary to obtain a given level of removal (removal rate) can be estimated by solving for n:

$n = \log(1-R)/\log(1-p)$.

Removal evaluation— We estimated abundance and capture probability from tag recaptures of smallmouth bass with a Huggins estimator using program MARK based on two to three sample passes each year (White et al.1982; White 2008). Capture probability is the probability that an individual fish will be captured on a sampling occasion. We calculated catch per unit effort (CPUE) for adult smallmouth bass on each sample occasion and obtained an average CPUE for all sample occasions each year. To determine whether CPUE was a predictor of abundance we compared CPUE with density (# adult fish / mile) which was derived from abundance point estimates standardized for reach length. We determined removal effectiveness primarily by examining changes in annual abundance of adult smallmouth bass ($\geq$150 mm TL) in each reach starting with an initial abundance estimate in 2004 and ending with an abundance estimate in 2007. The 2007 abundance reflected fish removal that occurred from 2004 through 2006. Fish removal done in 2007 will be evaluated with the 2008 abundance estimate. Two other annual measures of removal effectiveness were removal rate and recapture rate. Removal rate measured the proportion of fish removed in relation to the abundance estimate. Recapture rate measured the percent of tagged fish recaptured during removal. Comparison of the two rates provides insight into how we gauge success. If we tagged a proportion of a population of fish in a closed system with no loss of tags or change in the number of fish through immigration, recruitment, emigration, or mortality and all fish behaved similarly to the sampling gear, then we would expect recapture rate to equal removal rate. For example, if we tag and release 100 fish from a population of 1000 fish (i.e. 10% of the fish are tagged) and later we remove 400 fish from the system, then our removal rate is 40% (400/1000 = 40%). If recapture rate equals removal rate then we would expect that 40 of those 400 individuals would be recaptured tagged fish. If so, then recapture rate would equal 40% (40/100 = 40%).

Movement of tagged fish— Recaptures of tagged smallmouth bass were examined to determine the extent of movement within and between study sites. To determine if smallmouth bass remained within each control and treatment reach, we examined the proportion of smallmouth bass that moved out of each reach after they were tagged and released on the first sampling occasion. High rates of movement between the two reaches during the year would reduce our ability to compare control and treatment reaches. We also examined movement of all smallmouth bass that we tagged in all years, including fish initially tagged by us that were recaptured by another agency or fish initially tagged by another agency that were recaptured by us. Distance moved was the distance between the initial tagging location and the last capture location. We excluded fish recaptured less than 7 days after initial tagging to reduce the immediate effects of capture and examined movement of recaptured fish that were at large for two time intervals: less than one year and greater than or equal one year. We also excluded fish recaptured after escaping from Elkhead Reservoir in the above analysis, but we did examine how far downstream they moved after escaping. In addition to movement of all fish, we report the percent of recaptured fish that immigrated to or emigrated from each study site (Little Yampa Canyon or Lily Park), what percentage of each group moved up or downstream, and their distance.

Fish Community (1-mile) sampling— Relative abundance of the fish community was monitored at four, 1–mile sites in Little Yampa Canyon from 2004 to 2007 and one 1–mile site at Lily Park in 2007. These locations included RM 118.0–119.0 near Milk Creek, RM 112.5–113.5 near Sand Spring Gulch, RM 108.0–109.0 near Duffy Tunnel inlet, RM 103.2–104.2 near Morgan Gulch and RM 52.0–53.0 near Lily Park Bridge. Each site was sampled on two to six occasions with boat electrofishing concurrently with smallmouth bass sampling. At each site we netted, counted, and measured lengths and weights of all fish.

RESULTS

Study site abundance— Abundance of adult smallmouth bass in the 24-mile study site at Little Yampa Canyon declined 17% from 2,888 (SE = 597) fish in 2004 to 2,394 (SE = 566) fish in 2007 after 3 years (2004–2006) of fish removal (Table 3). There was a negative relationship of abundance as a function of time ($\log_e$ [abundance] = 167.01 – 0.0793 * year; $r^2 = 0.48$). However, overlapping 95% confidence intervals among all years suggested no significant differences in estimates. Precision was highest (CV = 7%) in 2006 when abundance was estimated after two marking occasions that year and was moderately good (CV = 13–24%) in other years when abundance was estimated after one marking occasion (Table 3). Capture probability of smallmouth bass at Little Yampa Canyon averaged 11% (Table 3).

Density of smallmouth bass derived from annual point estimates of abundance ranged from 100 to 143 fish per mile at Little Yampa Canyon (Table 4). CPUE of adult smallmouth bass captured by boat electrofishing was positively correlated with bass density when CPUE was based on either the first marking occasion or the average of all sample occasions each year (Figure 2). CPUE on the first sample occasion provided the best predictor of density (CPUE [1^{st} occasion] = 0.07 * density – 2.62; $r^2 = 0.81$). CPUE of smallmouth bass captured at Little Yampa Canyon declined 22% from 10.4 fish/hour in 2004 to 8.1 fish/hour in 2007 (Table 4; Figure 3).

Abundance of adult smallmouth bass in the 5-mile treatment reach at Lily Park declined 19% from 1,519 (SE = 1,479) fish in 2004 to 1,233 (SE = 268) fish in 2007 after 3 years (2004–2006) of removal (Table 3). There was a negative relationship of abundance as a function of time ($\log_e$ [abundance] = 152.73 – 0.0728 * year; $r^2 = 0.21$). However, overlapping 95% confidence intervals among all years suggested no significant difference in estimates. Abundance estimates at Lily Park were moderately good (CV = 13–25%) in all years except 2004 when the point estimate was very imprecise (CV = 97%). As with Little Yampa Canyon, precision was best at Lily Park in 2006 when abundance was estimated after two marking occasions (CV = 13%) compared to other years when abundance was estimated after one marking occasion. Capture probability of smallmouth bass at Lily Park was lowest in 2004 and among all years averaged 9% (Table 3). Based on point estimates, density of smallmouth bass at Lily Park ranged 247 to 393 fish per mile, over 2.5 times higher in all years than the density of smallmouth bass at Little Yampa Canyon (Table 4). Boat electrofishing CPUE at Lily Park declined 33% from 39.6 in 2004 to 26.4 fish/hour in 2007 (Figure 3).

Tag loss— We observed no tag loss that would bias abundance estimates based on short-term tag loss studies. Of 131 smallmouth bass double-tagged in 2007, all 19 recaptures retained both marks, 11–19 days later. Longer-term tag loss was detected on 40 smallmouth bass during the study including: 11 fish with remnants of tags that appeared to have been cut by fishermen, 28 fish with an injury or scar at the tagging location indicating possible natural tag loss, and one incidence of tag failure where the numbered vinyl tubing had detached from the monofilament anchor.

Sampling effort— We electrofished 957 hours with boat electrofishing and 91 hours with electric seine at the two study sites from 2003 through 2007 (Tables 1 and 2). In 2004 and 2005, we estimated that it would require ten removal occasions to remove 45% of the adult smallmouth bass in Little Yampa Canyon based on a 6% capture probability measured in 2003. We actually completed eight removal occasions in each of those two years. Capture probability improved to 12% and in 2006 we estimated it would require nine removal occasions to reach our goal of removing 70% of the smallmouth bass in Little Yampa Canyon. We completed five removal occasions in 2006 and seven in 2007. At Lily Park, removal occasions were tied to northern pike removal and we targeted five removal occasions per year. We completed five removal occasions in all but one year at Lily Park. On average, boat electrofishing sampled 6 miles per day and each mile required 1.2 hours of applied electrofishing time to complete. At each site the number of hours spent to complete one sample occasion with boat electrofishing was similar within and among years. Because boat electrofishing effort was consistent among sample occasions, greater total effort for fish removal in any year was primarily due to more sample occasions. However, in 2006 and 2007 removal effort also increased due to the expansion of the treatment reach to 24 miles.

Effort expended to remove smallmouth bass from the Little Yampa Canyon treatment reach using boat electrofishing increased over time from 15 hours in 2003 to 156 hours in 2007 (Table 1). In 2003 at Little Yampa Canyon, we sampled the control and treatment reaches equally and removed smallmouth bass on two occasions. In 2004 and 2005, we sampled the treatment reach twice as often as the control reach and removed smallmouth bass on eight occasions each year. We completed five removal occasions in 2006, a low water- year and seven occasions in 2007, a normal water-year. In those two years, extra effort was required to remove bass from a larger treatment area. Effort expended to remove smallmouth bass from Little Yampa Canyon with electric seine ranged from 21 to 42 hours (Table 2).

Effort expended to remove smallmouth bass from Lily Park was relatively consistent among years with four to five sample occasions each year and 24 to 30 hours of boat electrofishing each year (Table 1). Length of the reach remained constant at 5 miles in all years. Smallmouth bass were removed from Lily Park with 2 hours of electric seine in 2007 (Table 3).

Fish captured with boat electrofishing— Using boat electrofishing we removed 15,190 smallmouth bass with a biomass of 2,441 kg and tagged and released 4,876 smallmouth bass (1,801 kg) in 5 years at our two study sites (Table 5). We captured and released another 88 smallmouth bass (51 kg) in areas outside of our study sites.

At Little Yampa Canyon, 8,883 smallmouth bass (1,923 kg) were removed from the river with boat electrofishing; 5,677 (1,878 kg) of those fish were adults (Table 5). Generally, we removed increasing numbers of both adult and sub-adult smallmouth bass each year from Little Yampa Canyon, with the most bass (n = 2,785) removed in

2007 (Table 1).

Our capture efficiency, measured by removal rate, was 40 to 64% of the point estimate at Little Yampa Canyon. Our highest removal rate was in 2007 when we had many removal occasions (n = 7) and removed fish from the entire 24-mile reach (Table 4). Capture probability was moderately good at 8% that year (Table 3). Removal rates of 40% and 41%, in 2004 and 2005, respectively, for the 24-mile reach were low but actually very good considering that fish were only removed from 50% of the reach from which we determined abundance. We removed 48% of the estimated abundance of smallmouth bass in 2005. Removal rate was low in 2006 due to few removal occasions. Recapture rate, the percent of tagged fish recaptured, ranged 31–47% and in most years was lower than removal rate (Table 4).

At Little Yampa Canyon, smallmouth bass ranged from 22 to 495 mm, average length of adult bass was 272 mm (SD = 77) and their average weight was 463 grams. Large adults (≥250 mm) comprised from 32 to 50% of the size structure of the smallmouth bass community at Little Yampa Canyon each year (Figure 4).

Of the 8,883 smallmouth bass removed from Little Yampa Canyon 3,848 (1,558 kg) were translocated. More smallmouth bass (n =1,480) were translocated in 2004 than in any other year because bass of all sizes were translocated in that year; in other years, only bass ≥250 mm TL were translocated and their numbers ranged from 240 to 792 fish per year (Table 5). We removed seven other nonnative species besides smallmouth bass from Little Yampa Canyon, including 250 black crappie, 172 bluegill, 111 black bullhead, 66 green sunfish, four pumpkinseed, and one largemouth bass (Table 6). We also removed and northern pike which were reported in Martin and Wright (2008). Many of the centrarchid species were most abundant in 2005 and 2006 after the temporary construction screen at Elkhead Reservoir failed during runoff.

At Lily Park, 6,307 smallmouth bass (518 kg) were removed from the river with boat electrofishing and 3,569 (462 kg) of those fish were adults (Table 5). The number of smallmouth bass removed at Lily Park was only 26% less than the number removed from Little Yampa Canyon, a reach almost five times larger than Lily Park. We removed the most adults (n = 1,024) in 2007 and the most sub-adults (n = 1,065) in 2005 (Table 5). Removal rates at Lily Park were similar to those observed at Little Yampa Canyon and ranged 40–83% with the highest occurring in 2007 (Table 4). Recapture rates at Lily Park were lower than removal rate and in every year they were lower than those observed in Little Yampa Canyon (Table 4).

At Lily Park, smallmouth bass ranged from 22 to 510 mm, average length of adult bass was 206 mm (SD = 45), 66-mm shorter than the average length at Little Yampa Canyon and their average weight was 188 grams. Large adults (≥250 mm) were much less common at Lily Park than they were at Little Yampa Canyon and comprised 6 to 16% of the smallmouth bass community each year (Figure 5).

Of the smallmouth bass removed from Lily Park, 1,600 (247 kg) were translocated. As with Little Yampa Canyon, the number of smallmouth bass translocated was highest in 2004 (n = 1,285) when fish of all sizes were translocated; in other years, the number of bass translocated ranged from 67 to 167 fish per year (Table 5). Starting in 2004, the number of smallmouth bass translocated each year from Lily Park was much lower than the number translocated from Little Yampa Canyon primarily because there were few adult bass over the acceptable 250 mm length at Lily Park (Table 5). We removed five other nonnative species from Lily Park, including 36 black crappie, 22 bluegill, four black bullhead, seven green sunfish, and five walleye (Table 7). We also removed northern pike which were reported in Martin and Wright (2008). These species were much less common than they were at Little Yampa Canyon.

Fish captured with electric seine — We removed 18,166 small, mostly young-of-year smallmouth bass with a biomass of 126.5 kg from the lower 12 miles of Little Yampa Canyon with an electric seine in July and August from 2005 through 2007 (Table 8).

Average length was 76 mm (SD = 40.9). More smallmouth bass were removed in 2005 (n = 7,642) when effort was highest of all three years (Tables 2 and 8). Annual CPUE of smallmouth bass removed with electric seine at Little Yampa Canyon was 182 fish per hour in 2005, 262 fish per hour in 2006, and 193 fish per hour 2007. At Lily Park, we removed 239 smallmouth bass (5.2 kg) or 159 fish/hour from Lily Park with electric seine on one sample occasion in 2007.

With electric seine we removed seven other nonnative species and one hybrid from Little Yampa Canyon, including: 112 northern pike, 2,187 black bullhead 82 black crappie, 102 bluegill, 26 green sunfish, one Iowa darter, and two largemouth bass (Table 9). No other nonnative species except smallmouth bass were removed from Lily Park with electric seine. At Little Yampa Canyon, the number of young northern pike that we removed each year declined over time and the number of black bullhead that we removed increased dramatically, although the increase was primarily due to catching many small YOY that had little biomass in 2007. In 2005 we captured the highest number of young centrarchids of any year, including two largemouth bass which most likely escaped from Elkhead Reservoir.

Spawning observations— Ripe smallmouth bass were observed only at Little Yampa Canyon where we captured four ripe males and 12 ripe females from mid-June through early July in all years. Morning temperatures ranged from 16 to 21^{0}C. During that period we also captured males with abraded ventral median fins in the process of building nests and observed males guarding nests in 2006 and 2007. We increased effort at locations that contained nests in an effort to remove both guarding males and young from nests. Average length of ripe females was 397 mm (SD = 56) and ripe males was 251 mm (SD = 137). Ripe fish or nests were observed between river mile 108 and 123.

Nest were located in areas with no noticeable velocity, usually side-channel backwaters with gravel and sand substrates. Nest were also observed in the main channel along shoreline areas usually downstream of debris fans or other velocity breaks. Depth of nests that we could see were 2–3 feet but some male bass were caught in probable nesting areas at depths to 4 feet. No ripe smallmouth bass, spawning behavior, or nests were observed at Lily Park.

Longitudinal distribution of smallmouth bass— Both Little Yampa Canyon and Lily Park had high concentrations of bass and within each site there were some 1-mile sections that contained larger aggregations of smallmouth bass than others. We provide 2007 data as an example of smallmouth bass distribution because in that year we sampled all 1-mile sections at each site equally. Data reported show the number of fish captured on all sample occasions. The highest catch per mile was at Lily Park where after six sample occasions we handled between 200 and 400 adult smallmouth bass per mile in 3 of the 5 miles (Figure 6). At Little Yampa Canyon, after eight sample occasions, we captured as many as 234 smallmouth bass in one section (RM 112–113) and otherwise captured over 100 bass in two other sections at RM 104–105 and RM 108–109. High relative densities of sub-adult smallmouth bass were often associated with high densities of adult smallmouth bass, except at RM 119–120 where large numbers of YOY and yearlings were captured along a 1/4 mile long area of railroad rip rap just upstream of Milk Creek. Concentration areas remained consistent within and among years and were associated with complex habitat composed of islands with associated riffles, deep eddies associated with boulder debris fans, and in the case of Little Yampa Canyon, abundant cover from large boulders that eroded from steep talus canyon slopes.

Movement of tagged smallmouth bass— We released 3,601 tagged smallmouth bass including 3061 fish at Little Yampa Canyon and 540 fish at Lily Park during our study period. A large proportion of tagged fish were never seen again including 58% of the fish tagged at Little Yampa Canyon and 70% of the fish tagged at Lily Park. The lower rate of recapture at Lily Park is presumed due to the smaller size of that reach compared to the size of Little Yampa Canyon. Tagged fish were recaptured from one to eight times and time at large spanned one day to 4 years after their release.

Movement of smallmouth bass between the control and treatment reaches of Little Yampa Canyon in 2004 and 2005 reduced our ability to compare results from the two reaches. In 2004, 15% of the tagged smallmouth bass left the treatment reach and 8% left the control reach. In 2005, 9% of the tagged smallmouth bass left the treatment reach and 24% left the control reach (Table 10). On average, fish moved 11.1 miles with a range from 0.7 to 50.5 miles. These emigration rates were considered high enough to negate the control and treatment approach and starting in 2006 the control reach was eliminated and the treatment reach was expanded to cover the entire 24-mile Little Yampa Canyon study site. For consistency with later years (2006 and 2007), we combined mark-recapture data from control and treatment reaches in 2004 and 2005 and estimated abundance for the 24-mile study site.

Movement of recaptured smallmouth bass based on the distance they moved from the first to the last capture occasion for all years combined showed that 10% remained stationary and were recaptured in the same ½ mile section of their release. A fairly high proportion of fish remained within ± 5 miles of their release location, including 31% of bass recaptured less than a year later and 22% of bass recaptured more than a year after release. Range of movement was farther after longer time at large. Smallmouth bass at large less than a year were recaptured up to 38 miles downstream and 51 miles upstream of their release location; bass at large more than a year were recaptured up to 99 miles downstream and up to 95 miles upstream of their release location (Figure 7). For bass recaptured within a year of initial tagging (n=735), 46% were recaptured downstream and 41% were recaptured upstream of their release location (Figure 7). Movement direction of smallmouth bass at large more than 1 year (n=637) was similar with 45% and 48% of fish recaptured downstream or upstream, respectively (Figure 7).

Of the smallmouth bass recaptured after release in Little Yampa Canyon, most remained there and were recaptured in Little Yampa Canyon, including 93% of 581 bass recaptured less than one year after release and 84% of 588 bass recaptured more than one year after release. The remaining recaptured smallmouth bass that emigrated out of Little Yampa Canyon moved in both up and downstream directions (Table 11). The majority of emigrants moved upstream but emigrants moved the farthest distances downstream. Emigrants recaptured in the same year as their release moved a maximum of 40 miles and those recaptured more than a year after their release moved a maximum of 90 miles. Smallmouth bass that immigrated into Little Yampa Canyon came from both upstream and downstream reaches (Table 11). Immigrants recaptured in the same year as their release moved a maximum of 47 miles from their original release location and those recaptured more than a year after their release moved a maximum of 100 miles to reach Little Yampa Canyon. The majority of immigrants came from downstream reaches and moved upstream to reach Little Yampa Canyon. (Table 11).

Of the smallmouth bass recaptured after release at Lily Park, most remained there at recapture, including 87% of 88 bass recaptured less than one year after release and 41% of 32 bass recaptured more than one year after release. The remaining recaptured smallmouth bass that emigrated out of Lily Park moved out in both up and downstream directions (Table 12). Emigrants recaptured in the same year as their release moved a maximum of 30 miles and those recaptured more than a year after their release moved a maximum of 70 miles. Smallmouth bass that immigrated into Lily Park came from both upstream and downstream reaches. Immigrants recaptured in the same year as their release moved a maximum of 30 miles from their original release location and those recaptured more than a year after their release moved a maximum of 71 miles to reach Lily Park (Table 11).

Recapture of tagged Elkhead Reservoir escapees— Of 3,484 tagged smallmouth bass translocated to Elkhead Reservoir during the study period, 5% escaped and were recaptured either in the Yampa River (n=184) or at the dam spillway (n=2; Tables 13 and 14). Escapees were recaptured from 2 days to 4 years after stocking and escapement was documented for fish translocated in all years except 2007. The failure of a temporary spillway screen during dam renovation in 2005 increased escapement based on two tagged smallmouth bass that were caught by net on the unscreened dam spillway in 2005 . One of those fish (423 mm) was caught on the spillway on 19 May 2005, two days after it was stocked and the other (251 mm) was caught on 16 May 2005, one year after it was originally stocked (W. J. Miller, personal communication). In addition, smallmouth bass stocked in 2005 had the highest rate of escapement of all subsequent years. Of the 647 smallmouth bass stocked in 2005, 83 (13%) were later recaptured in the river. Captures of escaped fish in 2006 further support high escapement rates in 2005. In 2006 we captured 111 escapees, the highest number of escaped bass seen in any year (Table 13). Smallmouth bass that escaped Elkhead Reservoir dispersed distances from 0.1 to 109 miles downstream of Elkhead Creek (RM 148.1). Most escapees were recaptured in Little Yampa Canyon, South Beach, and Craig reaches, although one was recaptured downstream at Yampa Canyon, over 100 miles away (Table 14).

Of the 791 smallmouth bass translocated to the Justice Center pond, one fish placed there in 2006 was recaptured in the Yampa River at RM 92.9 in 2007, and although it seems highly unlikely due to the distance from the river, we attribute this escapee to someone that relocated the fish back to the river.

One-mile fish community sampling— At Little Yampa Canyon, nonnative fish species dominated the community, comprising 92–97% of the individuals collected each year (Table 15). Smallmouth bass were the dominant nonnative species comprising 49–60% of the fish community and flannelmouth sucker *Catostomus latipinnis* were the dominant native fish species comprising 1–5% of the fish community. We captured seven native species, 16 nonnative species, and three hybrids (Table 15). Three centrarchid species, bluegill, green sunfish, and black crappie were seen at Little Yampa Canyon and not at Lily Park.

At Lily Park, nonnative fishes comprised 44% of the fish community in 2007, the only year that Lily Park was sampled. Smallmouth bass were the dominant nonnative species, comprising 25% of the fish community and flannelmouth sucker were the most dominant native species, comprising 47% of the fish community. In 2007, abundance of all fish as measured by CPUE, was four times higher at Lily Park compared to abundance at Little Yampa Canyon indicating higher production at Lily Park.

Comparisons of our 1-mile samples from 2007, our most recent data, with similar electrofishing samples collected 23 years earlier (Wick et al. 1985) revealed substantial increases in diversity and abundance of nonnative fishes and declines in native fishes. At Little Yampa Canyon, relative abundance of native species declined dramatically from 68 to 3% of the fish community from the earlier sampling to present and at Lily Park, native fishes declined from 91 to 57% during the same period (Table 16). Smallmouth bass had the most dramatic increase in abundance between the two time periods increasing from 0.3 to 51% of the fish community at Little Yampa Canyon and from zero to 25% of the fish community at Lily Park. Increases were also observed for nonnative white sucker and northern pike and minor declines were observed for nonnative common carp and channel catfish. Native roundtail chub *Gila robusta*, flannelmouth sucker, and bluehead sucker *Catostomus discobolus* which together comprised 66% of the Little Yampa Canyon fish community in 1983–1984 declined to only 3% of all fish collected in 2007. At Lily Park, each of those three natives also declined in abundance between the two time periods, but flannelmouth sucker still comprised 47% of the fish community at Lily Park. Flannelmouth sucker and to some extent bluehead sucker were apparently persisting at Lily Park in the presence of large numbers of smallmouth bass. Recent sampling in 2007 also collected four piscivorous nonnative species not observed by Wick et al. (1985) including: bluegill, creek chub *Semotilus atromaculatus*, brown trout *Salmo trutta*, and brook trout *Salvelinus fontinalis*. Overall abundance of fish, as measured by CPUE, declined from 1983 and 1984 to 2007. Assuming catch efficiency was similar between periods, at Little Yampa Canyon 4.5 times more fish were collected in 1983–1984 (148 fish/hour) than in 2007 (33 fish/hour) and at Lily Park twice as many fish were collected during the earlier sampling period in 1983–1984 (305 fish/hour) as were collected in 2007 (141 fish/hour). During both periods, abundance of fish at Lily Park was higher than at Little Yampa Canyon, indicating better production of fish in the Lily Park reach.

DISCUSSION

We found that abundance of adult nonnative smallmouth bass declined after mechanical removal at two study sites in the Yampa River. We propose that our annual removal rates of 40–48% at Little Yampa Canyon and 44–65% at Lily Park from 2004 through 2006 assisted with the decline in abundance. At Little Yampa Canyon we removed 3,879 adult smallmouth bass from 2004 through 2006 and abundance declined 17% from 2,888 fish in 2004 to 2,394 fish in 2007. At Lily Park we removed 2,588 adult smallmouth bass from 2004 through 2006 and abundance declined 19% from 1,519 fish in 2004 to 1,233 fish in 2007. Additional evidence of a decline of smallmouth bass numbers from 2004 to 2007 included declining CPUE at both sites during the study period. CPUE was well correlated with density and CPUE may serve as an occasional substitute for annual abundance estimates; however, abundance estimation using mark-recapture methods is superior for measuring changes in smallmouth bass populations in the Yampa River and we encourage its continued use.

Removal rates improved with increased effort. In Little Yampa Canyon in 2004 and 2005, removal rates were not very high because our treatment (removal) area at the time was only 12 miles long or 50% of the 24-mile study site for which abundance was estimated. In 2006 even though smallmouth bass were removed from the entire 24-mile reach, removal rate was low because we only completed five removal occasions that year due to a short-duration water year. We achieved the highest removal rates at Little Yampa Canyon (64%) and Lily Park (83%) in 2007; however, those removals did not affect the observed decline in abundance because removals in 2007 were done after abundance was estimated. Increasing the rate of removal will require applying removal at a geographic scale that matches the distribution and home-range of the targeted species, increasing effort, or increasing capture efficiency. Removal rate could be improved with more effort such as increasing the number of electrofishing boats operating concurrently. However, we suggest increasing effort by adding one or two more removal occasions earlier in the year. Capture efficiency also affects removal rate and we suggest continuing efforts started by Martinez (2007) to standardize electrofishing gear by providing field crews with technical assistance in testing and maintaining electrofishing equipment to insure that it operates at maximum potential.

Although we observed declines in abundance that we attributed to our annual removals, compensatory mechanisms (e.g., recruitment and immigration) likely off-set some of our removal effort. This is to be expected in any fish removal program based on stock-recruitment dynamics and the meta-population structure we observed in this particular system. For example, throughout our study period, recruitment appeared robust based on abundant young-of-year smallmouth bass captured with electric seine and the wide distribution and high abundance of yearlings captured by boat electrofishing. Immigration of smallmouth bass into our study sites was documented based on the movement of fish between our two study sites, invasion of escapees from Elkhead Reservoir, and movement of tagged fish from other reaches such as South Beach, Maybell, and Yampa Canyon. The potential for smallmouth bass movement among reaches was shown by movements of up to 50 miles in less than a year and up to 100 miles after periods of more than a year. Documenting the rate of immigration into our study sites and improving our knowledge of movement dynamics in the Yampa River will require increased tagging effort in the Craig, South Beach, and Maybell reaches. Long-range movements of smallmouth bass throughout the Yampa River suggest that expanded and higher removal rates are needed river wide if we are to sustain removals in our study reaches.

We documented that recapture rate (the proportion of tagged fish recaptured at least once) was lower than removal rate in almost all years. A large portion of tagged smallmouth bass (58% at Little Yampa Canyon and 70% at Lily Park) were never seen again after their release, suggesting that the proportion of tagged fish in the population was reduced by some combination of emigration, tagging mortality, or tag loss. And that these rates were higher at the shorter (5 mile) Lily Park reach than at Little Yampa Canyon which was 24 miles long. Smallmouth bass moved equally in upstream and downstream directions and distance between release site and final capture site increased with time. Emigration was observed from both study sites, but the detection probability of marked fish was lower in reaches outside of our two study sites because smallmouth bass were not consistently netted in those reaches, especially during the first three years. We did not observe tag loss during the short (11–19 days) mark-recapture period based on double tagging of fish in 2007. This suggests that Floy tags were adequate for mark-recapture methods used to estimate abundance. Mortality of fish to anglers was also not a concern during the short time interval of mark-recapture sampling because environmental conditions (high, cold, turbid flow) were unsuitable for fishing and we never observed fishermen during that time. Tagging mortality was not studied, although there were no apparent deaths attributed to tagging during 12 hour holding periods before translocation. Long-term tag loss is a well documented problem for smallmouth bass in streams (Walsh and Winkelman 2002). However, we observed minimal tag loss (40 fish) during the study period, but we probably underestimated long-term tag loss because it was based on observations such as injury or scar tissue at the tag site. A more reliable evaluation will require a durable second mark.

Although we documented escapement from Elkhead Reservoir using Floy-tagged fish, the number of fish that escaped could be biased low if fish are losing tags or if anglers at the reservoir are intentionally removing tags. If more refined estimates of escapement are needed then a tamper resistant tag (e.g. PIT tag) is required to prevent angler removal that could confound results. Because those types of tags typically require additional handling time and could reduce the time that field crews spend doing fish removal, we recommend a reassessment of our tagging objectives to determine whether current tags are suitable. To reduce the potential for unintentional removal of tags we suggest signs at reservoirs to encourage anglers not to remove tags and to explain the benefits that tagged fish provide for reservoir management.

We observed biological and environmental differences between Little Yampa Canyon and Lily Park that may provide insight into the interactions and population dynamics of smallmouth bass and native fish populations. For example, density of smallmouth bass ranged from 100 to 143 fish per mile at Little Yampa Canyon and from 247 to 393 fish per mile at Lily Park. Smallmouth bass larger than 250 mm comprised 11% of the bass at Lily Park and 43% of the bass at Little Yampa Canyon. Lily Park also had little angling pressure, fewer recaptures of tagged fish, lower abundance of other centrarchids, and higher abundance of native species.

Smallmouth bass were extremely rare at both sites 23 years ago when native fishes were a dominant part of the fish community. Bioenergetics modeling supports that invasive smallmouth bass at their current levels are highly capable of consuming large quantities of native fishes and therefore present the greatest predatory threat to native fishes in the Yampa River (Johnson et al. 2008). Smallmouth bass numbers increased from near zero to 51% of the fish community from 1984 to 2007 at Little Yampa Canyon and from zero to 25% of the fish community at Lily Park during the same period. Smallmouth bass are now the dominant predator in the middle Yampa River and their rise in abundance was concurrent with the decline of native fish in the Yampa River. Concurrently, catch rates of all other fishes declined 77% at Little Yampa Canyon and 54% at Lily Park from 1984 to 2007. In 2007, native fish comprised no more than 8% of the fish community at Little Yampa Canyon and 56% of the fish community at Lily Park. Although our removal efforts were associated with a decline in abundance of smallmouth bass in our study area, those removals were not sufficient to effect a native fish response (Bestgen et al 2007). Higher removal rates, both within the study area and at other study areas may be needed to adequately reduce the predatory threat of smallmouth bass in the Yampa River and to restore the native fish community.

CONCLUSIONS

- Smallmouth bass are the most abundant nonnative predator in the middle Yampa River.
- Little Yampa Canyon and particularly Lily Park, contained high densities of smallmouth bass.
- Abundance of smallmouth bass declined after intensive removal but it was unknown whether the reduction was caused by removal, environmental factors, or a combination of both.
- Smallmouth bass moved long distances in both up and downstream directions in the Yampa River.
- Some smallmouth bass that were translocated into Elkhead Reservoir escaped and dispersed downstream to the Yampa River, including into our study sites.
- Mechanical removal effectiveness was partially offset by immigration and recruitment of fish into each study site.
- Floy tag loss was not detected during the short mark-recapture period required to estimate abundance.
- Diversity and abundance of most native fishes has declined in the study reaches compared to twenty years ago.

RECOMMENDATIONS

- Continue intensive removal of smallmouth bass in high density areas such as Little Yampa Canyon and Lily Park
- Remove smallmouth bass from other reaches in conjunction with other on-going studies.
- Continue annual abundance estimates of smallmouth bass to monitor changes in smallmouth bass abundance.
- Continue to monitor escapement of translocated fish.
- Due to the invasive nature of smallmouth bass we highly recommend not translocating them to novel locations within the Yampa River basin or to other basins.
- Maintain fish community sampling at study sites to monitor changes in species composition.
- Increase number of removal occasions by starting earlier in the year.
- Provide field crews with technical assistance in testing and maintaining electrofishing equipment to insure that it operates at maximum potential.
- Increase angler education to encourage anglers not to remove tags and to explain the benefits that tagged fish provide for reservoir management.
- Study the biology and ecology of smallmouth bass in the Yampa River and examine why there are differences between Little Yampa Canyon and Lily Park.

LITERATURE CITED

Anderson, R. and G. Stewart. 1999. Riverine fish flow investigations. Federal Aid Project F-289, Study SE-3-22. Colorado Division of Wildlife, Fort Collins.

Anderson, R. 2004. Riverine fish flow investigations. Federal Aid Project F-289-R7. Job Progress Report. Colorado Division of Wildlife, Fort Collins.

Baily, C. And R. Alberti 1952. Lower Yampa River and tributaries study, Job 4. Job Completion Report F-3-R-1. Federal Aid Division, The Colorado Game and Fish Department, Denver.

Bestgen, K. R., Walford, C. D, and A. A. Hill. 2007. Native fish response to removal of non-native predator fish in the Yampa River, Colorado. Final Report Upper Colorado River Basin Recovery Implementation Program Project Number 140. Larval Fish Laboratory Contribution 150. Colorado State University.

CDOW (Colorado Division of Wildlife). 1998. Aquatic Wildlife Management Plan: Yampa River Basin, Colorado Division of Wildlife, Aquatic Wildlife Section, Denver.

Dowling, D. C., R. W. Weldon, and P. B. Bayley. 1990. Assembling an electric seine: a technical reference. Aquatic Ecology Technical Report 90/2. Illinois Natural History Survey.

Hawkins, J. A. and T. P. Nesler. 1991 Nonnative fishes of the Upper Colorado River Basin: an issue paper. Contribution 48 of the Larval Fish Laboratory, Colorado State, University, Fort Collins.

Hawkins, J., C. Walford, and T. Sorensen. 2005. Northern pike management studies in the Yampa River, Colorado, 1999–2002. Final report to the Upper Colorado River Endangered fish Recovery Program, Contribution 137 of the Larval Fish Laboratory, Colorado State University.

Holden, P. B. And C. B. Stalnaker. 1975. Distribution and abundance of mainstream fishes of the middle and upper Colorado River basins, 1967–1973. Transactions of the American Fisheries Society 104:217–231.

Johnson, B. M. P. J. Martinez, John A. Hawkins, and K. R. Bestgen. IN PRESS. Ranking predatory threats by nonnative fishes in the Yampa River, Colorado via bioenergetics modeling. North American Journal of Fisheries Management.

Martin, L. M. and F. B. Wright. 2008. 2004–2007 middle Yampa River northern pike and smallmouth bass removal and evaluation. Project 98a, Draft Report. Colorado Division of Wildlife, Denver, CO.

Martinez, P. J. 2007. Westslope warmwater. Colorado Division of Wildlife, Great Outdoors Colorado Progress Report, Fort Collins.134 pp.

McAda, C. W., J. W. Bates, J. S. Cranney, T. E. Chart, W. R. Elmblad, and T. P. Nesler. 1994. Interagency standardized monitoring program: summary of results, 1986–1992. Final Report. Recovery Implementation Program for the endangered fishes of the upper Colorado River Basin. U. S. Fish and Wildlife Service.

Nesler, T. P. 1995. Interactions between endangered fishes and introduced game fishes in the Yampa River, Colorado, 1987–1991. Colorado Division of Wildlife, Fort Collins.

Walsh, M. G. and D. L. Winkelman. 2002. Short-term retention of Floy anchor tags by stream-dwelling smallmouth bass. Proceedings of the annual conference of the

Southeastern Association of Fish and Wildlife Agencies 56:38–43.

Wick, E. J., J. A. Hawkins, and C. A. Carlson. 1985. Colorado squawfish and humpback chub population and habitat monitoring 1981-1982. Division of Wildlife, Denver, CO Endangered Wildlife Investigations Job Progress Report SE 3-6.

White, G. C. 2008. Closed population estimation models and their extensions in program MARK. Environmental and Ecological Statistics 15:89–99.

White, G. C., D. A. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, LA-8787-NERP, Los Alamos, New Mexico.

Table 1— Summary of sample design for smallmouth bass removal using boat electrofishing at Little Yampa Canyon (LYC) and Lily Park (LP) study sites in the middle Yampa River, Colorado, 2003–2007.

	2003	2004	2005	2006	2007
Dates Sampled	12 Apr – 2 Jul	21 Apr – 8 Jul	22 Apr – 21 Jul	20 Apr – 4 Jul	17 Apr – 30 Jun
Site Length					
LYC Control	6 miles	12 miles	12 miles	–	–
LYC Treatment	6 miles	12 miles	12 miles	24 miles	24 miles
LP	–	5 miles	5 miles	5 miles	5 miles
Location (river mile)					
LYC Control	105.2–111.2	112–124	112–124	–	–
LYC Treatment	111.2-117.2	100–112	100–112	100–124	100–124
LP	–	50.3–55.3	50.3–55.3	50.3–55.3	50.3–55.3
# mark / # removal occasions					
LYC Control	5 / 0	5 / 0	4 / 0	–	–
LYC Treatment	3 / 2	1 / 8	1 / 8	2 / 5	1 / 7
LP	–	1 / 5	1 / 5	2 /4	1 / 5
Effort (hours)					
LYC mark & release	55	73	84	59	25
LYC removal	15	105	116	136	156
Total	70	178	200	195	181
LP mark & release	–	3	5	10	5
LP removal	–	24	30	26	30
Total	–	27	35	36	35
Length of bass (mm)					
Tagged on mark pass	100	150	150	150	150
Translocated	all sizes	all sizes	≥250	≥250	≥250
Euthanized [1]	none	none	<250	<250	<250
Translocation site	Elkhead Reservoir	Elkhead Reservoir	Elkhead Reservoir	Justice Center pond, Elkhead Res	Justice Center pond, Elkhead Res
Significant Information	Primary purpose was to determine bass density and catch rates, partial removal on last 2 passes	Removal begins; sites expand to 12-miles; Lily Park added as study site; began 1-mile community sampling.	Elkhead Reservoir dam construction begins, start lethal removal of small bass <250 mm TL; start low-flow young bass removal.	Elkhead Reservoir dam construction active with unscreened releases, bass escapees documented	Second year of removal from entire study sites.

[1] From 2005 to 2007 bass <150 mm captured on the marking pass were euthanized and those ≥150 mm were tagged; on subsequent removal passes each year bass <250 mm were euthanized.

Table 2— Summary of sample design for smallmouth bass removal using electric seine at Little Yampa Canyon (LYC) and Lily Park (LP) study sites in the middle Yampa River, Colorado, 2005–2007.

	2005	2006	2007
Dates Sampled	20 Jul – 30 Aug	25 Jul – 17 Aug	10 Jul – 14 Aug
Site Length			
LYC Treatment	12 miles	12 miles	12 miles
LP	–	–	5 miles
Location (river mile)			
LYC Treatment	100 – 112	100 – 112	100 – 112
LP	–	–	50.3 – 55.3
EL Seine effort (hours)			
LYC removal	42	21	26
LP removal	–	–	2
Length of bass (mm)			
Translocated	≥250	≥250	≥250
Euthanized	<250	<250	<250
Translocation Site	Elkhead Reservoir	Justice Center pond, Elkhead Reservoir	Justice Center pond, Elkhead Reservoir
Significant Information	Start of young smallmouth bass removal at Little Yampa Canyon.		Start of young smallmouth bass removal at Lily Park

Table 3— Abundance estimates for smallmouth bass ≥150 mm TL at two study sites in the middle Yampa River, 2004–2007. Abundance estimates derived from the Huggins estimator which is similar to model M(t). Coefficient of variation (CV) = Standard Error (SE) / mean x 100. CI = Confidence Interval. Capture probability was average of all mark-recapture sample occasions.

Little Yampa Canyon (24-miles long)

Length	Year	Abundance	95% CI	SE	CV (%)	Sample occasions	Capture probability (%)
24 miles	2004	2,888	1,977–4,375	597	21	2-pass	10
24 miles	2005	3,422	2,683–4,446	445	13	2-pass	12
24 miles	2006	2,718	2,372–3,148	197	7	3-pass	13
24 miles	2007	2,394	1,554–3,837	566	24	2-pass	8
							mean = 11

Lily Park (5-miles long)

Length	Year	Abundance	95% CI	SE	CV (%)	Sample occasions	Capture probability (%)
5 miles	2004	1,519	352–7,678	1,479	97	2-pass	3
5 miles	2005	1,963	1,235–3,262	500	25	2-pass	9
5 miles	2006	1,778	1,386–2,333	239	13	3-pass	9
5 miles	2007	1,233	846–1,932	268	22	2-pass	16
							mean = 9

Table 4— Annual capture efficiency of smallmouth bass ≥ 150–mm TL at two study sites in the middle Yampa River, 2004–2007. Percent of bass removed is the proportion of the abundance estimate.

Little Yampa Canyon (24-miles long)

Year	Abundance for 24-mile reach	Density (# fish/mile)	Length of removal area	# bass removed	% bass removed	% of tagged fish recaptured	CPUE (95% CI)
2004	2,888	120	12 miles	1,169	40	47	10 (7–14)
2005	3,422	143	12 miles	1,402	41	38	12 (10–14)
2006	2,718	113	24 miles	1,308	48	31	9 (5–13)
2007	2,394	100	24 miles	1,534	64	34	8 (6–10)

Lily Park (5-miles long)

Year	Abundance for 5-mile reach	Density (# fish/mile)	Length of removal area	# bass removed	% bass removed	% of tagged fish recaptured	CPUE (95% CI)
2004	1,519	304	5 miles	981	65	23	40 (14–66)
2005	1,963	393	5 miles	786	40	18	27 (21–34)
2006	1,778	356	5 miles	778	44	16	30 (22–39)
2007	1,233	247	5 miles	1,024	83	29	26 (10–43)

Table 5— Number, biomass (kg), and disposition of smallmouth bass captured by boat electrofishing and angling, Yampa River, Colorado, 2003–2007.

Little Yampa Canyon (24-miles long)

	Number of fish		Subsets of fish removed from river: by disposition			Subsets of fish removed from river: by size	
Year	returned to river	removed from river	Elkhead Reservoir	Justice Center pond	euthanized	sub-adult (<150 mm)	adult (≥150 mm)
2003	1,374 (423)	308 (75)	240 (54)	–	68 (20)	44 (1)	264 (73)
2004	951 (418)	1,577 (365)	1,480 (353)	–	97 (12)	408 (5)	1,169 (360)
2005	1,183 (471)	2,250 (408)	567 (274)	–	1,683 (134)	848 (20)	1,402 (388)
2006	554 (320)	1,963 (541)	307 (185)	462 (270)	1,194 (86)	655 (10)	1,308 (531)
2007	133 (81)	2,785 (535)	593 (300)	199 (123)	1,993 (111)	1,251 (9)	1,534 (525)
Total	4,195 (1,712)	8,883 (1,923)	3,187 (1,166)	661 (392)	5,035 (364)	3,206 (45)	5,677 (1,878)

Lily Park (5-miles long)

	Number of fish		Subsets of fish removed from river: by disposition			Subsets of fish removed from river: by size	
Year	returned to river	removed from river	Elkhead Reservoir	Justice Center pond	euthanized	sub-adult (<150 mm)	adult (≥150 mm)
2004	32 (9)	1,324 (139)	1,285 (138)	–	39 (1)	343 (5)	981 (135)
2005	264 (23)	1,851 (125)	81 (29)	–	1,770 (96)	1,065 (28)	786 (98)
2006	320 (43)	1,402 (104)	–	67 (24)	1,335 (80)	624 (16)	778 (89)
2007	65 (14)	1,730 (150)	104 (34)	63 (21)	1,563 (94)	706 (8)	1,024 (141)
Total	681 (89)	6,307 (518)	1,470 (202)	130 (45)	4,707 (272)	2,738 (56)	3,569 (462)

Table 6— Number and disposition of selected nonnative fish captured with boat electrofishing and fyke nets at Little Yampa Canyon in the Yampa River, 2003–2007.

	2003	2004	2005	2006	2007	Total
euthanized						
black crappie	122	4	72	42	10	250
bluegill	9	1	49	27	86	172
black bullhead	30	1	29	18	33	111
green sunfish	1	–	41	20	4	66
pumpkin seed	–	–	1	–	2	3
creek chub	–	–	–	3	–	3
largemouth bass	–	–	1	–	–	1
bluegill x pumpkinseed	1	–	–	–	–	1
sand shiner	–	1	–	–	–	1
released						
white sucker	165	20	10	63	9	267
white x flannelmouth sucker	4	1	12	13	14	44
white x bluehead sucker	9	–	–	–	–	9
rainbow trout	–	3	36	47	12	98
common carp	24	7	5	5	2	43
channel catfish	–	5	2	5	1	13
brown trout	–	–	1	9	–	10
mountain whitefish	–	1	2	1	3	7

Table 7— Number and disposition of selected nonnative fish captured with boat electrofishing and fyke nets at Lilly Park in the Yampa River, 2003–2007.

	2003	2004	2005	2006	2007	Total
euthanized						
black crappie	7	1	3	24	1	36
bluegill	–	–	17	2	3	22
green sunfish	–	1	–	3	3	7
walleye	2	2	1	–	–	5
black bullhead	–	–	–	3	1	4
released						
common carp	39	–	–	–	–	39
channel catfish	–	1	9	16	–	26
rainbow trout	3	–	–	1	1	5
brown trout	–	–	–	–	3	3

Table 8— Number, biomass (kg), and disposition of smallmouth bass captured by electric seine, Yampa River, Colorado, 2005–2007.

Little Yampa Canyon treatment (12-miles long)

	Number of fish		Breakdown of fish removed from river				
			by disposition			by size	
Year	returned to river	removed from river	Elkhead Reservoir	Justice Center pond	euthanized	sub-adult (<150 mm)	adult (≥150 mm)
2005	32 (2.8)	7,642 (53) [a]	–	–	7,642 (53) [a]	7,569 –	73 –
2006	4 (1.2)	5,503 (29.3)	–	–	5,503 (29.3)	5,404 (20.2)	99 (9)
2007	–	5,021 (44.2)	2 (0.6)	–	5,019 (43.6)	4,871 (30.3)	150 (13.9)
Total	36 (4)	18,166 (126.5)	2 (0.6)	–	18,164 (125.9)	17,844	322

Lily Park (5-miles long)

	Number of fish		Breakdown of fish removed from river				
			by disposition			by size	
Year	returned to river	removed from river	Elkhead Reservoir	Justice Center pond	euthanized	sub-adult (<150 mm)	adult (≥150 mm)
2007	–	239 (5.2)	–	–	239 (5.2)	226 (4.1)	13 (1.2)

[a] Weights were not taken from fish in 2005 so biomass was estimated for that year based on the average weight of fish in 2006 and 2007.

Table 9— Number and biomass (kg) of species collected with electric seine in the Yampa River, 2005–2007.

	Little Yampa Canyon				Lily Park
	2005	2006	2007	Total	2007
smallmouth bass	7,642 (14.1)	5,503 (29.3)	5,021 (44.2)	18,166 (87.6)	239 (5.2)
northern pike	63 (5.4)	37 (3.1)	12 (4.3)	112 (12.9)	–
black bullhead	7 (0.4)	331 (0.5)	1,846 (0.7)	2,184 (1.6)	–
black crappie	75 (0.02)	3 (0.1)	4 (0.1)	82 (0.1)	–
bluegill	53 0.6	32 0.3	17 (0.5)	102 (1.4)	–
green sunfish	9 0.1	14 0.2	3 (0.05)	26 (0.3)	–
green sunfish x bluegill	–	6 (0.1)	–	6 (0.1)	–
Iowa darter	1	–	–	1	–
largemouth bass	2	–	–	2	–
Total all species	7,852 (20.5)	5,926 (33.7)	6,903 (49.8)	20,681 (104.1)	239 (5.2)

Table 10— Proportion of recaptured smallmouth bass that either left or remained in control and treatment reaches in Little Yampa Canyon in the middle Yampa River, 2004 and 2005.

released location	number of fish released	fish not recaptured	fish that remained in each reach	fish that moved out of each reach
2004				
Treatment	53	42%	43%	15%
Control	74	65%	27%	8%
2005				
Treatment	183	51%	40%	9%
Control	147	58%	18%	24%

Table 11— Percent of recaptured smallmouth bass that immigrated into or emigrated out of Little Yampa Canyon and distance moved based on tag recaptures in the middle Yampa River, 2003–2007.

<1 year after release	emigrants (n=39)		immigrants (n=51)	
movement direction	% of fish	mean distance (miles)	% of fish	mean distance (miles)
upstream	82%	16	86%	22
downstream	18%	15	14%	7

≥1 year after release	emigrants (n=96)		immigrants (n=28)	
movement direction	% of fish	mean distance (miles)	% of fish	mean distance (miles)
upstream	72%	15	75%	63
downstream	28%	34	25%	22

Table 12— Percent of recaptured smallmouth bass that immigrated into or emigrated out of Lily Park and distance moved based on tag recaptures in the middle Yampa River, 2003–2007.

<1 year after release	emigrants (n=11)		immigrants (n=10)	
movement direction	% of fish	mean distance (miles)	% of fish	mean distance (miles)
upstream	0	--	100%	20
downstream	100%	14	0	--

≥1 year after release	emigrants (n=19)		immigrants (n=11)	
movement direction	% of fish	mean distance (miles)	% of fish	mean distance (miles)
upstream	100%	55	18%	14
downstream	0	--	82%	58

Table 13— Number and percent of translocated smallmouth bass that escaped from Elkhead Reservoir and were recaptured each year in the Yampa River.

Year translocated	# fish translocated	Year recaptured in river 2003	2004	2005	2006	2007	Total
2003	231	--	--	2 (1%)	7 (3%)	2 (1%)	11 (5%)
2004	1601	--	4 (0.2%)	24 (1%)	50 (3%)	13 (1%)	91 (6%)
2005	648	--	--	5 (1%)	54 (8%)	24 (4%)	83 (13%)
2006	307	--	--	--	--	1 (0.3%)	1 (0.3%)
2007	697	–	–	–	–	–	–
Total	3,484	--	4 (0.1%)	31 (1%)	111 (3%)	40 (1%)	186 (5%)

Table 14– Recapture location of tagged smallmouth bass in the Yampa River after escaping from Elkhead Reservoir. Elkhead Creek confluence is located at Yampa River mile 148.1.

Capture location	distance from Elkhead Creek confluence(miles)	number of fish
Elkhead Creek	*caught at dam spillway*	2
Craig Reach	0–13	20
South Beach	13–24	39
Little Yampa Canyon	24–48	113
Juniper	48–59	6
Maybell	59–88	3
Lily Park	88–103	2
Yampa Canyon	103–148	1
Total		186

Table 15— Relative abundance of fish collected by boat electrofishing at 1-mile study sites in the Yampa River, 2004-2007.

	Little Yampa Canyon (4 sites)				Lily Park (1 site)
	2004	2005	2006	2007	2007
nonnative species					
smallmouth bass	49.2	54.3	60.3	51	24.9
white sucker	23	18.2	15.9	31.9	6.6
white x flannelmouth sucker	7.9	7.5	5.8	4.3	0.5
northern pike	2.1	4.3	3.0	3.3	0.3
common carp	2.4	1.1	1.6	1.4	4.7
rainbow trout	0.6	4.5	1.2	–	0.2
channel catfish	2.7	0.6	1.4	1	5.2
black bullhead	1.7	0.6	–	1.4	–
white x bluehead sucker	1.7	0.3	0.7	0.4	–
creek chub	0.2	0.3	0.9	0.8	–
bluegill	–	0.4	0.9	0.8	–
green sunfish	0.5	0.3	0.5	–	–
black crappie	0.1	0.8	–	–	–
sand shiner	0.2	0.1	–	0.2	0.3
brook trout	–	–	–	0.2	–
brown trout	–	–	–	0.2	0.5
fathead minnow	0.1	–	–	–	–
red shiner	–	–	–	–	0.5
native species					
flannelmouth sucker	4.8	3.1	2.5	1.0	47.3
bluehead sucker	1.5	0.8	3.0	1.6	8.2
roundtail chub	0.7	2.6	1.8	0.8	0.6
speckled dace	–	–	–	–	0.2
Colorado pikeminnow	–	–	–	–	0.2
mountain whitefish	–	–	0.2	–	–
flannelmouth x bluehead sucker	0.1	–	–	–	–
mottled sculpin	0.1	–	–	–	–
% non-native fish	93	93	92	97	44
% native fish	7	7	8	3	56
Total number of fish	807	718	433	514	655
Total electrofishing effort (hours)	19.1	19.6	17.2	15.6	4.6
CPUE for all fish handled	42	36.6	25.2	32.9	142.4

Table 16— Comparison of relative abundance of fish captured by boat electrofishing at Little Yampa Canyon and Lily Park reaches of the Yampa River in 1983-1984 and 2007. The 1983–1984 data were from Wick et al. 1985 and 2007 data from 1-mile fish-community sampling.

	Little Yampa Canyon		Lily Park	
	1983 & 1984	2007	1983 & 1984	2007
nonnative species				
smallmouth bass	0.3	51.0	–	24.9
white sucker	24.4	31.9	0.5	6.6
white x flannelmouth sucker	2.2	4.3	–	0.5
northern pike	0.3	3.3	0.2	0.3
common carp	3.4	1.4	5.4	4.7
rainbow trout	–	–	–	0.20
channel catfish	1.8	1.0	3.0	5.2
black bullhead	–	1.4	0.2	–
white x bluehead sucker	–	0.4	–	–
creek chub	–	0.8	–	–
bluegill	–	0.8	–	–
sand shiner	–	0.2	–	0.3
brook trout	–	0.2	–	–
brown trout	–	0.2	–	0.5
red shiner	–	–	–	0.5
native species				
flannelmouth sucker	25.5	1.0	65.4	47.3
bluehead sucker	25.7	1.6	20.6	8.2
roundtail chub	14.8	0.8	3.9	0.6
speckled dace	–	–	–	0.2
Colorado pikeminnow	0.5	–	0.8	0.2
mountain whitefish	0.9	–	–	–
flannelmouth x bluehead sucker	0.2	–	–	–
% non-native fish	33	97	9	44
% native fish	67	3	91	56
Total number of fish	784	514	854	655
Total electrofishing effort (hours)	5.3	15.6	2.8	4.6
CPUE for all fish handled	148	33	305	141

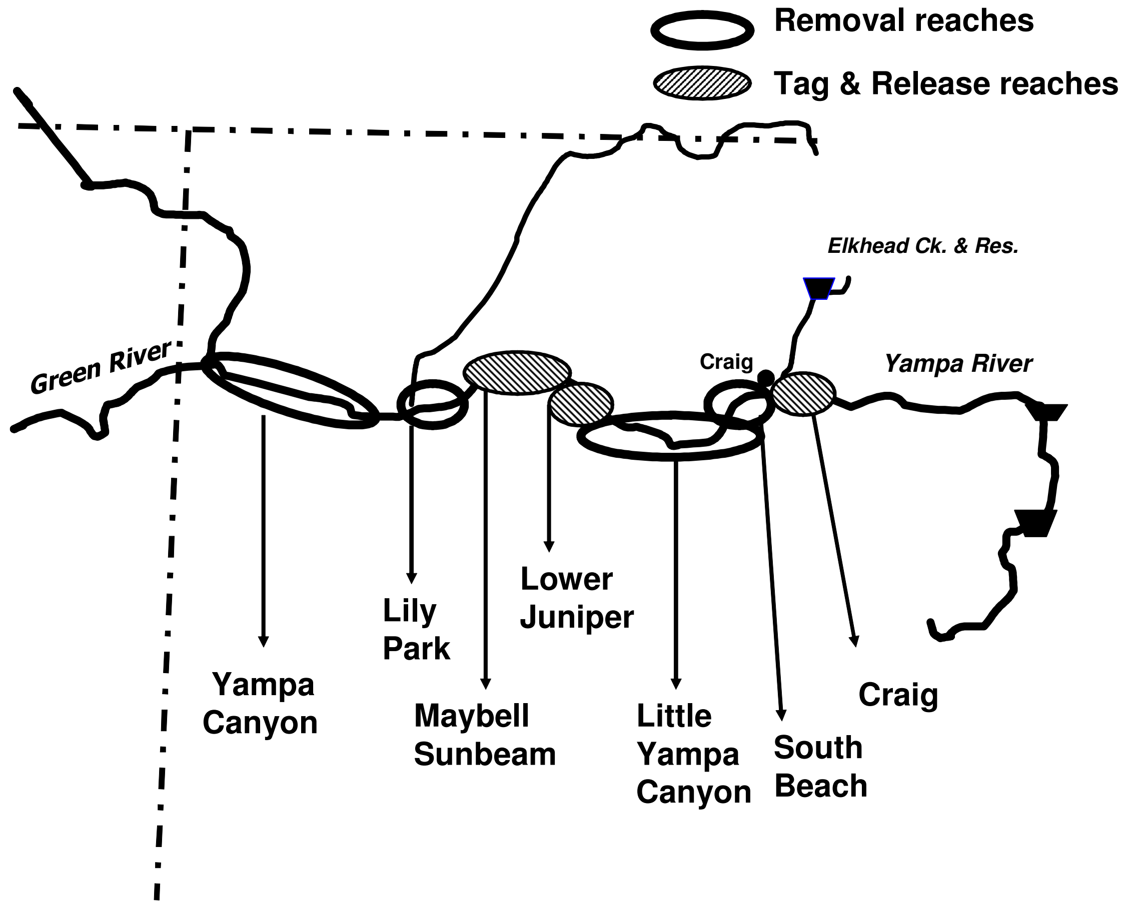


Figure 1— Map of Little Yampa Canyon and Lily Park study sites in the Yampa River, Colorado, 2003–2007. Other labeled reaches were sampled by other agencies.

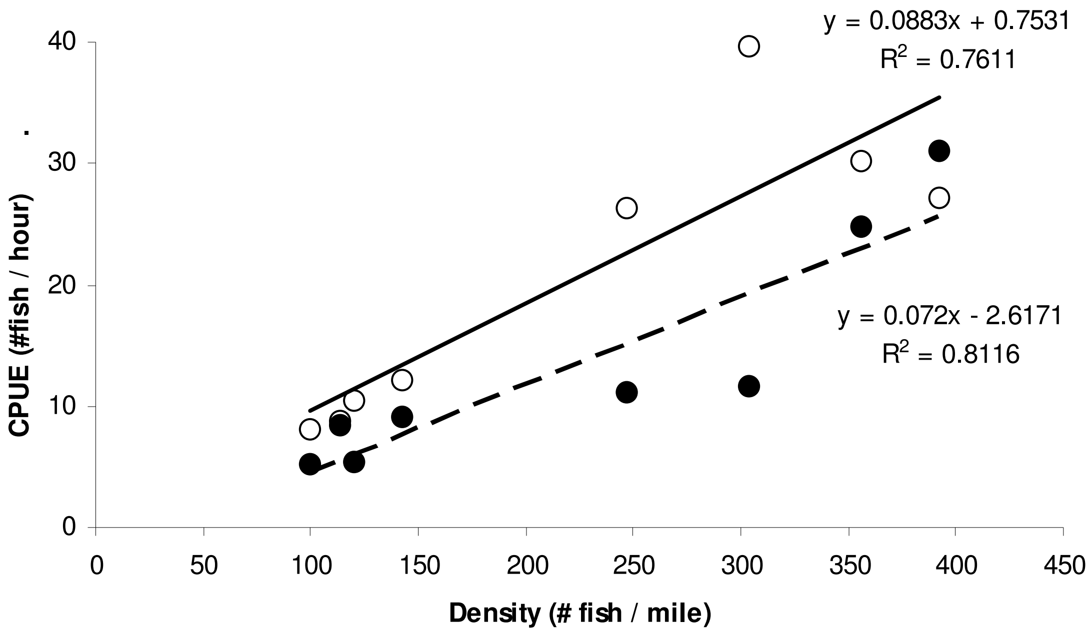


Figure 2— Catch per unit effort (CPUE) as a function of density of adult smallmouth bass (≥ 150–mm TL) captured by boat electrofishing at Little Yampa Canyon and Lily Park in the Yampa River, 2004–2007. Density was derived from point estimates of abundance. Open circles and solid regression line indicate CPUE derived from average number of fish captured on all sample occasions each year and solid circles and dashed line indicate CPUE derived from number of fish captured on the first sample occasion each year.

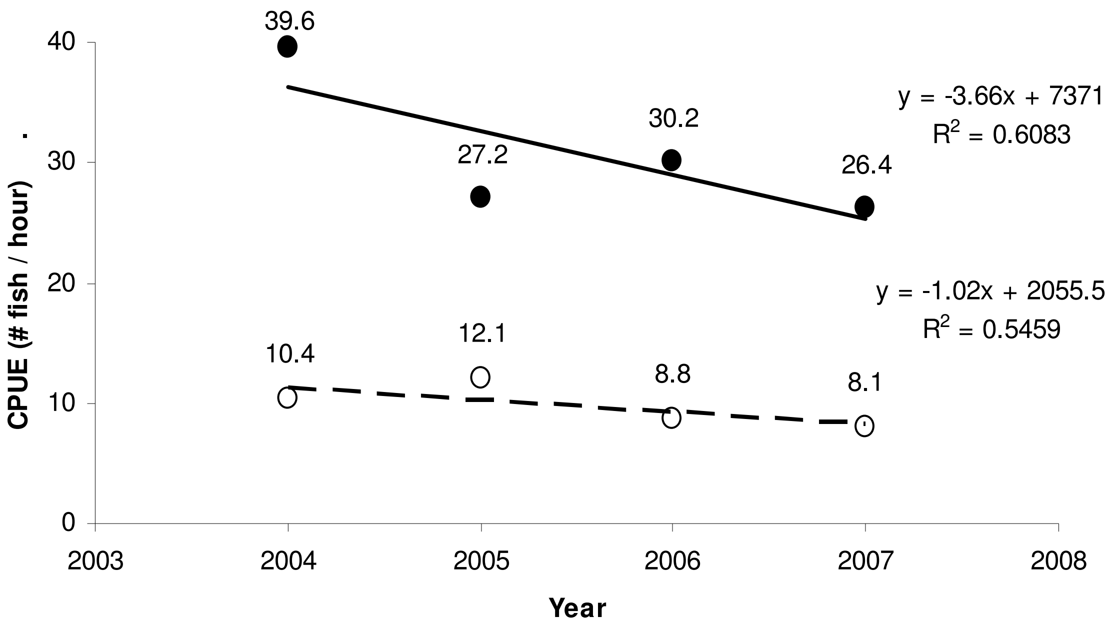


Figure 3— Catch per unit effort (CPUE, # fish/hour) of adult smallmouth bass ($\geq$150–mm TL) captured by boat electrofishing in the Yampa River, 2004–2007. CPUE was derived from average number of fish captured on all sample occasions each year. Solid circles and regression line represent Lily Park and open circles and dashed line represent Little Yampa Canyon.

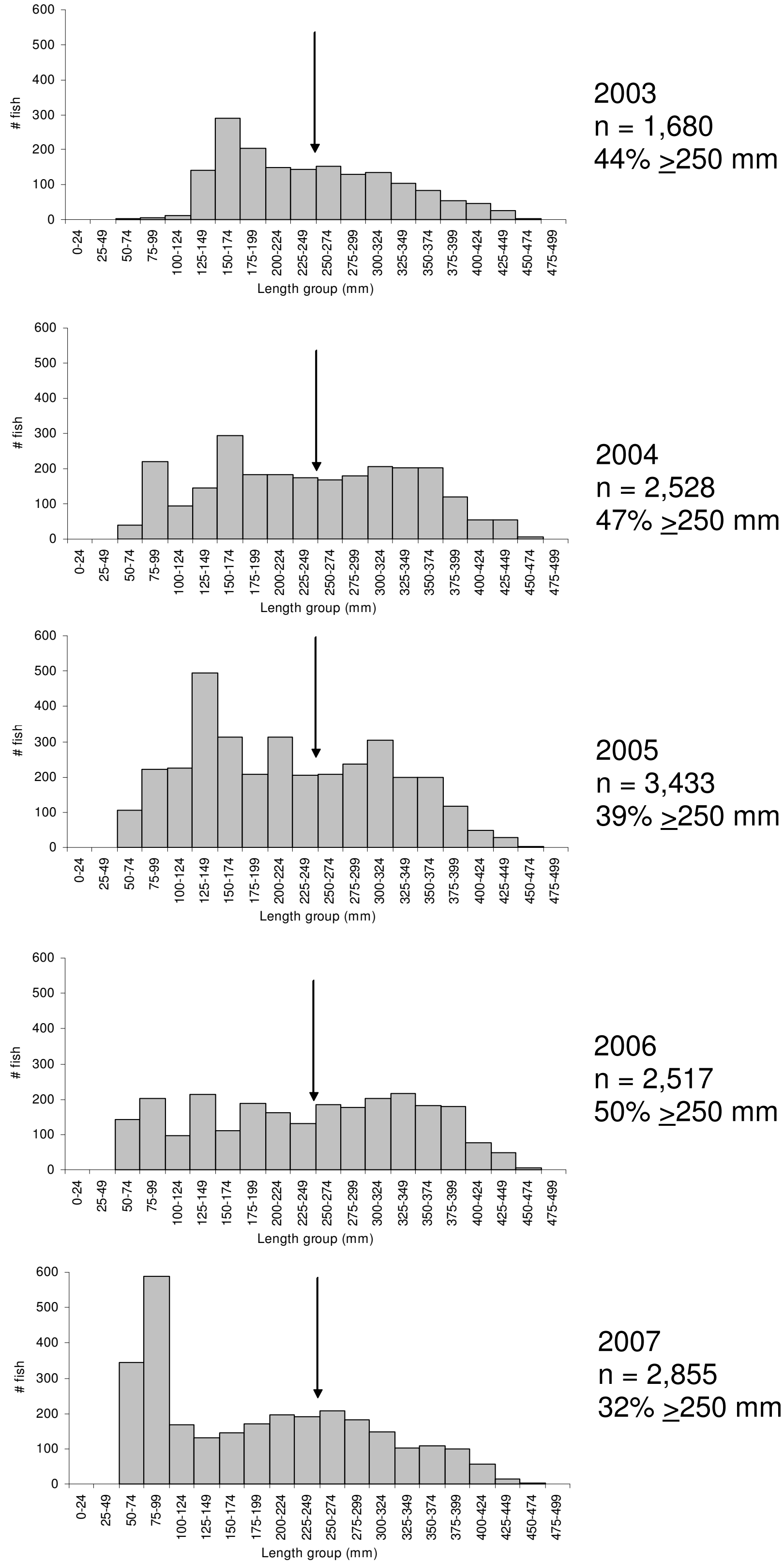


Figure 4— Length-frequency of smallmouth bass captured by boat electrofishing each year in the Little Yampa Canyon study site in the middle Yampa River, Colorado, 2003–2007. Vertical arrow demarcates length groups ≥250 mm and the percentage of all fish ≥250 mm is provided for each year.

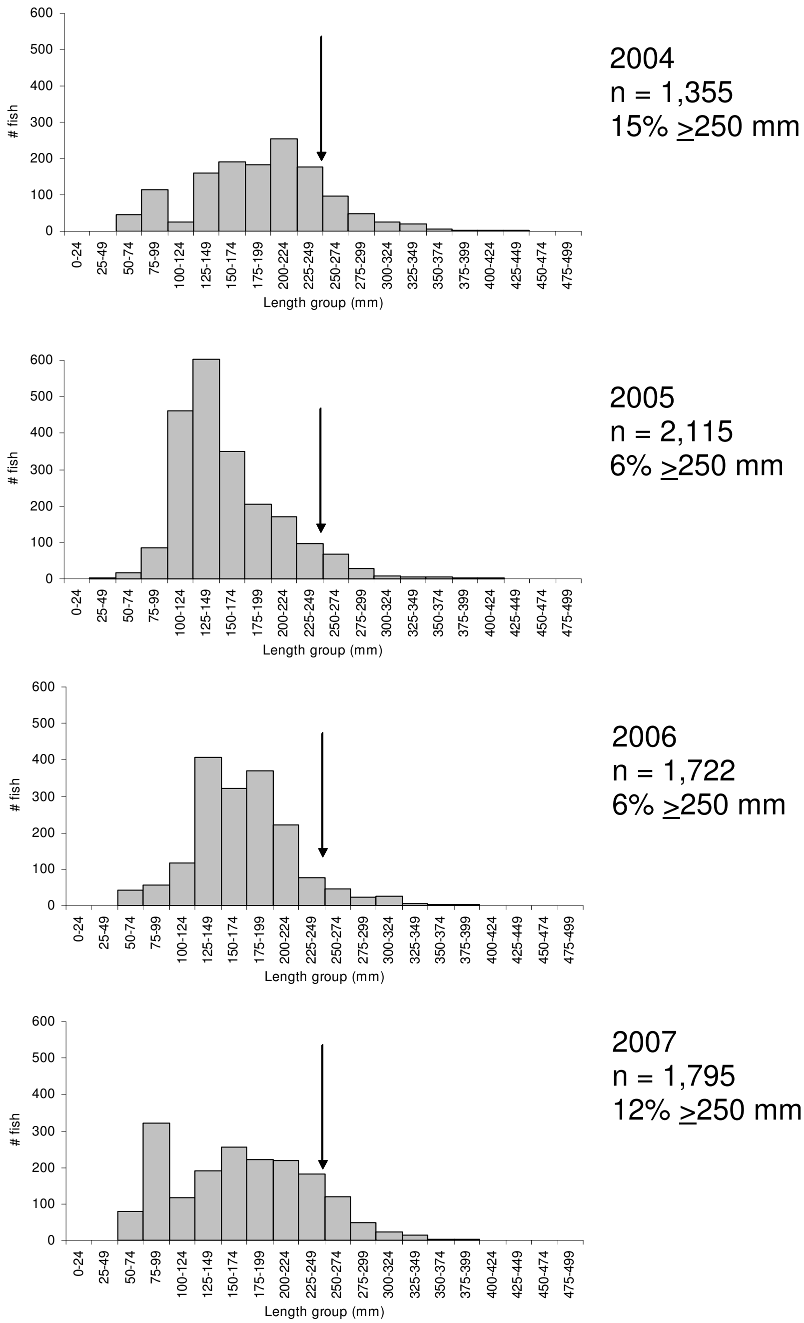


Figure 5— Length-frequency of smallmouth bass captured by boat electrofishing each year in the Lily Park study site in the middle Yampa River, Colorado, 2003–2007. Vertical arrow demarcates length groups >250 mm and the percentage of all fish >250 mm is provided for each year.

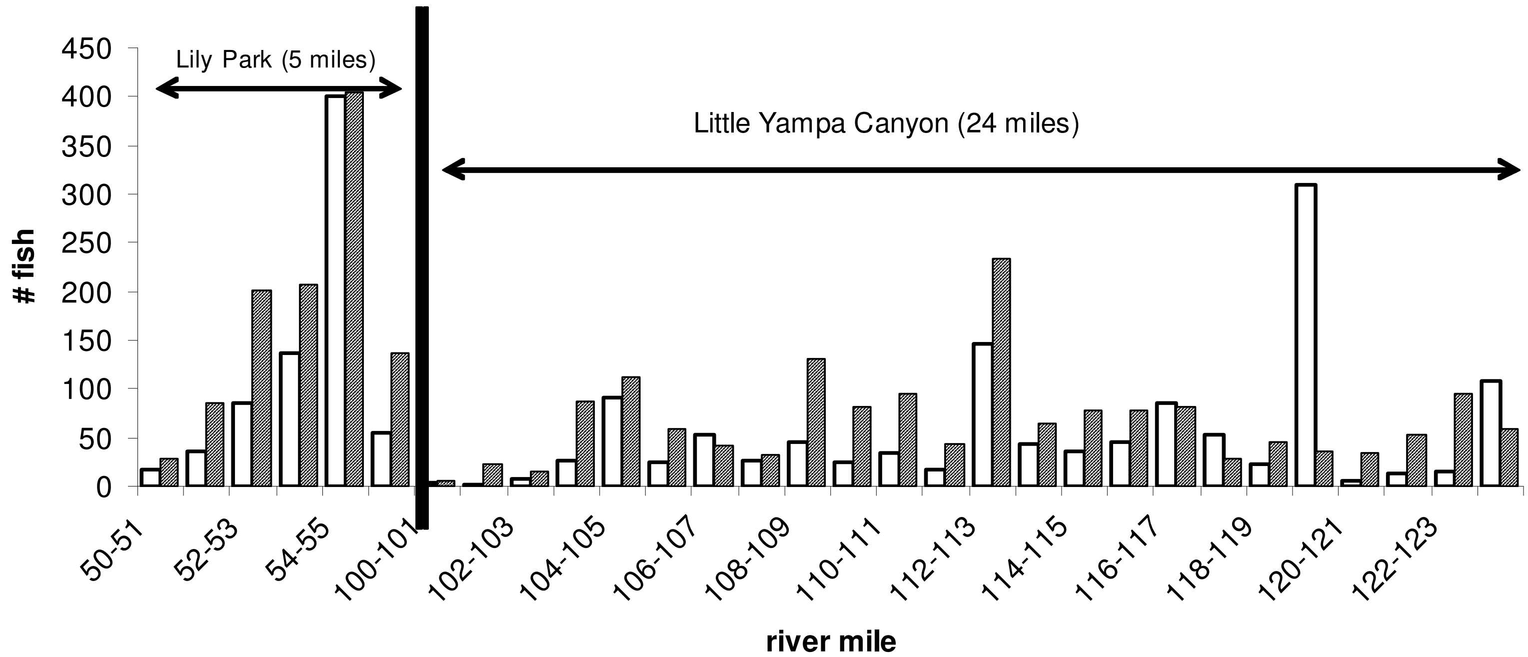
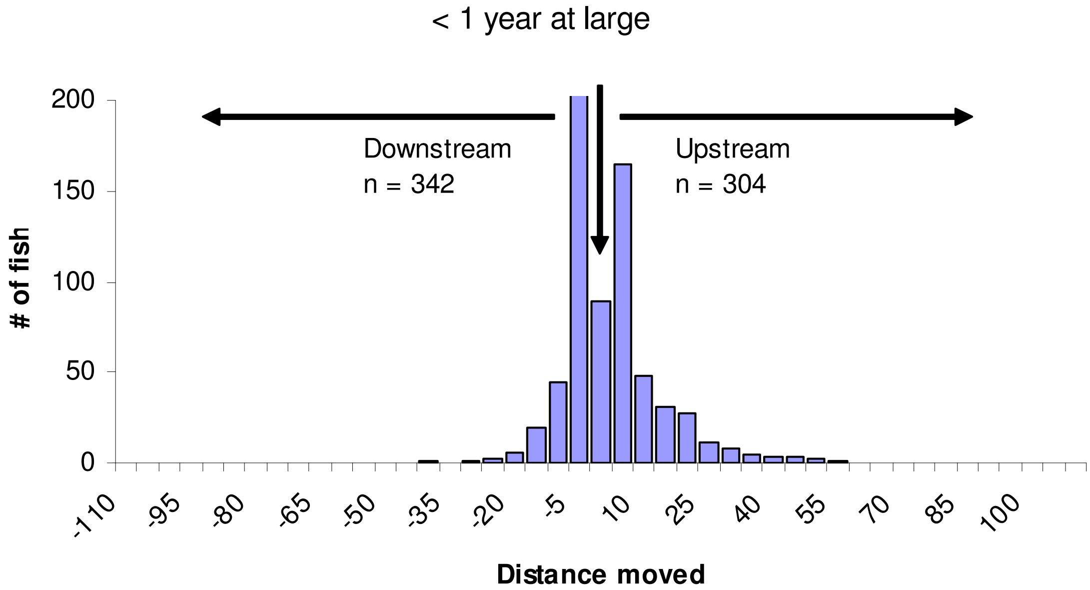


Figure 6—Number of smallmouth bass captured in each mile on all sample occasions in the Yampa River 2007. There were six sample occasions at Lily Park and eight sample occasions at Little Yampa Canyon. Open bars are smallmouth bass < 150 mm and solid bars are smallmouth bass $\geq$ 150 mm total length.



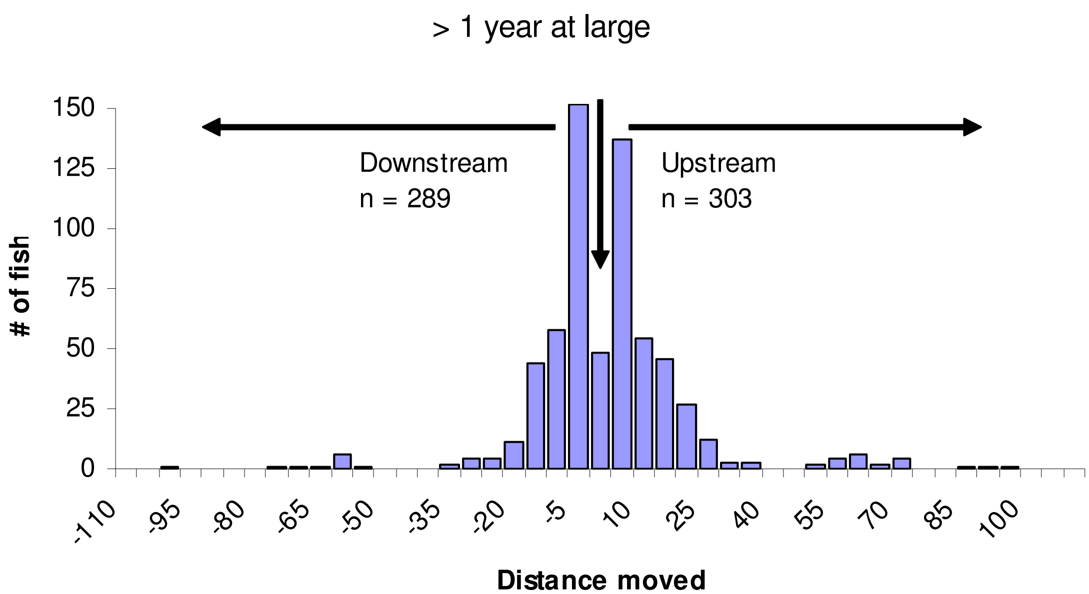


Figure 7— Distances moved by recaptured smallmouth bass after either <1 year (n=735) or ≥1 year (n=637) at large in the middle Yampa River, 2003--2007. Vertical arrow indicates no movement. Highest bar value of 268 for the group -0.1 to -5.0 was truncated in upper figure.