Lower Yampa River Channel Catfish and Smallmouth Bass Control Program, Colorado, 2001-2006

Synthesis Report

Prepared for

Upper Colorado River Basin
Recovery Implementation Program
Project 110

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Acknowledgments

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EXECUTIVE SUMMARY

The Yampa River of northwestern Colorado is a major tributary within the upper Colorado River basin and provides direct (habitat) and indirect (flow and sediment) benefits for maintaining populations of four endangered fishes: Colorado pikeminnow *Ptychocheilus lucius*, humpback chub *Gila cypha*, bonytail *G. elegans*, and razorback sucker *Xyrauchen texanus*. Populations of native and endangered fishes are currently in decline. Electrofishing surveys conducted during this study compared with similar efforts in the early 1980's reveal a dramatic shift in the fish community. Native species have declined and nonnative species have increased. The number of introduced species (n = 20) now outnumber the natives (n = 13) and recent increases in the nonnative species and their populations have been associated with a concomitant decrease in the natives. During this study, populations of smallmouth bass *Micropterus dolomieu* increased from <1% of the total catch in 2001 to 19% in 2004. This study discusses the need for nonnative fish control and identifies the invasion of especially problematic species. Federal and state agencies are responding to this threat by evaluating potential fish control measures, but it is too early to tell whether ongoing efforts will be effective in reducing nonnative abundance or the sizes of predaceous fishes to a level compatible with endangered fish recovery needs.

The report will cover multiple years, different methods, and different target species. To assist the reader and to provide document clarity, each emphasized species will be reported separately by year.

KEY WORDS: smallmouth bass, channel catfish, roundtail chub, flannelmouth sucker, control, depletion, decline, mechanical, removal, electrofishing, fyke net

INTRODUCTION

The lower Yampa River of northwestern Colorado has long been recognized for its importance as habitat for endangered Colorado River fishes (Tyus and Karp 1989) and it was designated as critical habitat for the recovery of four endangered fishes: Colorado pikeminnow *Ptychocheilus lucius* (formerly Colorado squawfish), humpback chub *Gila cypha*, razorback sucker *Xyrauchen texanus* and bonytail chub G. *elegans* (Maddux et al. 1994). A review of the importance of tributary streams for endangered fish recovery in the upper Colorado River determined that the Yampa River was the most valuable tributary stream in the system, contributing habitat directly for three of the endangered fishes and indirectly supporting recovery of all four species by providing flow regulation and sediment inputs downstream (Tyus and Saunders 2000). Unlike other major Colorado River tributaries, peak flows, sediment transport, and associated physicochemical attributes of the Yampa River have not significantly changed from historic conditions (Tyus and Karp 1989, Roehm 2004). In addition, the Yampa River mitigates effects of Flaming Gorge Dam on the Green River by providing a natural shape to an otherwise regulated annual hydrograph, and, by providing sediment necessary for nursery habitats used by native fishes (Tyus and Karp 1989, Maddux et al. 1994).

Presently, in addition to 13 native fish species, the Yampa River basin supports populations of 20 or more nonnative fishes (Roehm 2004). Numbers of nonnative fishes have increased dramatically since 1975, when extensive surveys done by Holden and Stalnaker (1975) reported only 22 fish species in the Yampa River, indicating that there has been a 45% increase in the number of species since that time. The increasing number of nonnative fishes and increases in their population sizes has been of great concern to the Upper Colorado River Endangered Fish Recovery Program (Recovery Program), who identified the most problematic of these species to be: northern pike *Esox lucius*, smallmouth bass, and channel catfish *Ictalurus punctatus* (Roehm 2004).

Over the last 100 years, fish populations have not remained stable. Introductions of nonnative game fishes, principally by federal and state agencies have established large populations of potentially competitive and predaceous fishes (Tyus and Saunders 2000), these included common carp *Cyprinus carpio* and channel catfish which were firmly established by the early twentieth century (Tyus et al. 1982). Interactions of common carp and the native fishes are not well understood, but channel catfish have been implicated in the decline of humpback chub in Yampa Canyon (Tyus 1998). Northern pike and smallmouth bass, stocked in reservoirs by Colorado escaped into the Yampa River in the early 1980s and in 1992, respectively. Both species have established reproducing riverine populations, and both of these aggressive and highly predaceous species are a threat to various life stages of native fishes.

In 1999, the Recovery Program commissioned a study to control channel catfish abundance in the lower Yampa River. The channel catfish was believed to be the most invasive and abundant nonnative fish in the lower Yampa River. Sampling methods were mechanical, and selected in response to gear efficacy recommendations determined in Yampa Canyon in 1998. Channel catfish depletion in sub-reaches was between 50 and 80 percent using electrofishing and angling (Modde and Fuller 2002). This depletion suggested control feasibility, however, in years to come, the efficacy of control remained speculative as catfish catch rates remained high and river-wide depletion did not exceed 24%. Since this study nonnative fish control gained support but mainly because of an unprecedented increase and expansion of smallmouth bass into the study area. This study identifies the continued invasion of problematic nonnative fishes and describes mechanical nonnative control as an option for reducing channel catfish and smallmouth bass populations in Yampa Canyon.

Study Area

The study area included the lower Yampa River in northwestern Colorado between Deerlodge Park and Echo Park (Figure 1). This section of river flows through Yampa Canyon which is characterized by steep canyon walls, gravel to boulder substrate, and moderate to high gradient and meandering channel. The channel is fairly narrow with very little braiding. The canyon walls consist of red talus boulder fields and shear Weber sandstone walls. Flows in the lower Yampa River are highly variable, seasonally and annually with a 50% exceedence peak flow of approximately 13,000 cfs in May and average base flow of approximately 300 cfs in September. The entire study area, from Deerlodge Park to Echo Park, is located within Dinosaur National Monument.

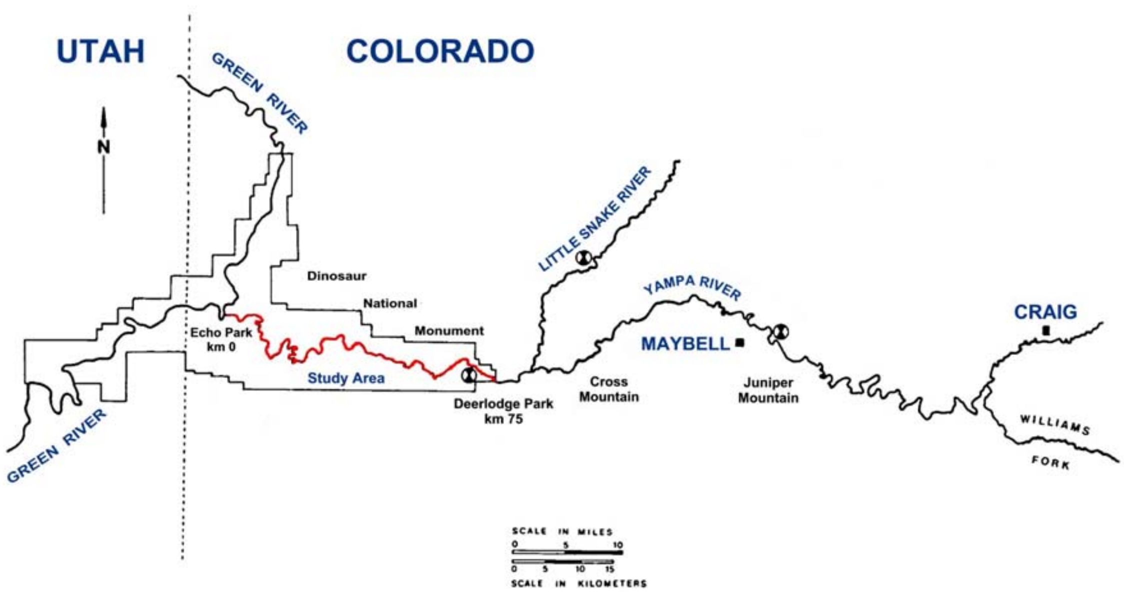

Figure 1. The Yampa River basin and study area in Dinosaur National Monument.

METHODS

Study Design

The Yampa River was sampled several times between 2001 and 2006 (Table 1). The study reach (0-46 river mile [rm]) was stratified longitudinally into ten sub-reaches (average length 4.8 rm) to determine fish movement and to make statistical comparisons. For continuity between years, the sub-reaches used in 1998-1999 were also used in 2001-2006 (Table 1). We used linear regression analysis to estimate population size (N) based on the x-intercept values using a removal estimator. From the abundance value and the number of fish collected, a measure of depletion (%) for that year (all passes combined) could be determined. Later in the study population estimates were used instead of a removal estimator because regressions in catch per effort (CPE) between passes did not occur.

In 2001-2003 the methods used were the same shown most effective in the feasibility study in 1998-1999 (Modde and Fuller 2000), *electrofishing* and *angling* as described below. The control strategy, recommended for centrarchids (Lentsch et al. 1996) and Ictalurids (Modde and Fuller 2002), was removal from the main river channel using mechanical techniques (i.e., electrofishing, trapping, angling, etc.). During that time the level of exploitation needed to reduce abundance was not specified, our intent was to reduce target nonnative fishes to the point where they would no longer impede endangered fish recovery. Exploitation levels needed to crash the smallmouth bass population were later implemented into the study design; see *modeling smallmouth bass exploitation* below. The only other method used was fyke netting at Deerlodge Park and Echo Park in 2003. Transport of nonnative fishes to public waters was to be coordinated with the Colorado Division of Wildlife (CDOW), but these proved unsuccessful due to difficulties communicating pick-up times from remote locations in Yampa Canyon, and because mid summer water temperatures stressed and caused mortality of captive fish. Channel catfish and smallmouth bass not translocated were to be euthanized and disposed of in isolated shorelines according to U.S. National Park Service recommendations. Minimum flow thresholds for the use of equipment were set by staff in regard to safety, safeguarding gear and species targeted and are as follows: 1,000 cfs for 16 foot [ft] electrofishing rafts, 500 cfs for regular rafting, and 300 cfs for canoeing.

Smallmouth bass were first collected in 2002 and because densities increased each year. . By 2004, the primary objective was to remove smallmouth bass; channel catfish removal was secondary. Methods remained the same initially, but because angling catch rates for bass were poor and varied with water clarity, the best and only method used the last two years of the study was electrofishing. Catch rates were not sufficient to produce population estimates, so, for more precise measures of depletion; population estimates and post removal estimates were implemented, see "*measuring depletion*" below.

Electrofishing-- We began electrofishing in late May or early June. Sampling earlier was ineffective for channel catfish because of cold water. We used two electroshocking rafts equipped with Smith Root systems of similar electrical output and capacity. One netter and operator per raft shocked both shorelines continuously along the entire reach. Prior to

2005, chase boats followed and collected targeted fish that drifted behind electroshocking rafts. Sampling time was kept in seconds and initiated when electrical current entered the water. The output pulse mode used was DC with 4 - 6 amps at about 60 pulses per second. All nonnative fish collected were measured (total length [TL]), and weighed (grams [g]). Marked fish (with color coded floy tags) were released immediately after being tagged and then removed from the river in the passes that followed.

Angling -- We solicited up to 30 volunteer anglers per trip. Five of the ten reaches were sampled per trip (half the study area). CPE angling was figured by minutes fishing per individual and then converted to fish per hour. Fishing time began at wetted fishing line and ended upon moving to a different fishing location. One employee per four anglers guided and assisted volunteers with data entry. Angling was discontinued the last two years of the study because bass collections by anglers were few and the emphasis of control switched from channel catfish to smallmouth bass removal.

Smallmouth Bass Aging--Otoliths were collected during the summer 2004 between Deerlodge Park and Echo Park (all reaches). Both electrofishing and angling were used to collect smallmouth bass from the full range of size classes. Whenever possible we removed both sagittal otoliths for aging. A digital image device was attached to the microscope, and any discrepancies found were resolved by viewing both otoliths simultaneously. Left and right otoliths were aged independently to ensure accuracy (Modde et al. 2006).

Fish Composition Monitoring-- Fish composition was evaluated by percent species captured electrofishing. Electrofishing data from the 1981 Yampa River Fishes Study (Miller et al. 1982) and the 2001-2006 nonnative fish control program were compared for changes in fish composition. In 1981, the lower Yampa River was stratified into two river sections (river miles 0-20 and 20-45). Two randomly selected sites per strata (2.5 river miles each) were sampled; this totaled five river miles per sampling occasion. A total of 5 sampling events were accomplished during April-September 1981.

In 2001, five one-mile monitor reaches were selected within river strata as delineated in 1981, and sampled twice during post-runoff. Likewise, in 2004 six sampling sites were selected for one-pass post-runoff sampling in June. Two electrofishing rafts per pass and two types of electrofishing systems were used; a Coffelt VVP-2C in 1981; and a Smith Root GPP 5.0 in 2001 and 2004. Both systems have similar frequency and voltage output pulse capacities. The output pulse mode used was DC. Slight departure from overall system specifications was assumed not to affect data comparability. Fish caught with chase boats were not used for monitoring analysis. All fishes >100 millimeter (mm) were netted using half inch mesh nets, measured (TL), weighed (g), and, except for smallmouth bass and channel catfish, released alive. Fish <100 mm TL were not included in abundance comparisons. Small bodied fish, i.e. mottled sculpin *Cottus bairdi*, speckled dace *Rhinichthys osculus*, fathead minnow *Pimephales promelas*, redside shiner *Richardsonius balteatus*, and red shiner Cyprinella *lutrensis*, were excluded from analysis. To classify abundance, we followed Tyus et al. 1982, e.g. abundant, common, rare, and incidental species. Statistical comparisons of CPE were made between years for all species using Chi-square.

Measuring Depletion – In 2001-2003 the removal estimator was not used because significant river-wide decreases in CPE between passes did not occur. So, to determine depletion, we implemented population estimates and post-removal estimates. Population estimates were determined using program Capture and Lincoln-Peterson protocols for both smallmouth bass and channel catfish in 2004 and for just smallmouth bass in 2005. Post-removal estimates were figured by deducting the number of fish removed from the point estimate. We discontinued the use of population estimates in 2006 due to the increase in smallmouth bass abundance and the need to increase exploitation. Limited duration of flows and short field seasons amplified the need to maximize removal. In 2006 all effort was dedicated to removal to reduce smallmouth bass abundance..

Additionally, in 2004 two reaches were randomly selected and designated as controls in which targeted species were marked and returned alive. Depletions of target species were to be determined from removal areas, and relative densities from both areas were compared with data from the final pass. These comparisons showed inconclusive results and were abandoned after 2004 after it was determined fish moved beyond control reach borders between sampling events. Lethal removal of channel catfish and smallmouth bass continued from all other areas.

Modeling Smallmouth Bass Exploitation – Simulation techniques were used to explore the effects on the smallmouth bass population of several different exploitation strategies (Haines and Modde 2007). The model was based on a riverine smallmouth bass model developed by Peterson and Kwak (1999). It was developed on a Microsoft Excel® spreadsheet and consisted of an age structured layout with survival rates, an overwinter survival rate that was a function of fluctuating flows, and recruitment rates that were functions of adult stock size and spring flows. The parameters were estimated in part from historical electrofishing data for the Yampa River and in part from the scientific literature. Parameters from historical data include population size, depletion from control efforts, growth rates, water flow and temperature. Because the model was very sensitive to the type of stock-recruitment relationship, and because we were highly uncertain about the nature of this relationship, we used three different stock-recruitment hypotheses that were consistent with historical data but implied differing population responses to exploitation. One hypothesis was that recruitment followed the Ricker stock-recruitment model (Hilborn and Walters 1992) that produced an equilibrium population size near the 2006 level (85 age 3+ fish per hectare); the second hypothesis was that recruitment followed the Beverton-Holt model (Hilborn and Walters 1992) with maximum recruitment also at the 2006 level; and the third was also a Beverton-Holt type recruitment but maximum recruitment at twice the 2006 level.

All capture data was submitted to the nonnative fish data base. Contact the Recovery Program for access to this data base.

RESULTS

Seasonal Sampling Variability

Electrofishing for channel catfish in early spring was ineffective at water temperatures less than 10 degrees Celsius, and sampling was best in late summer when water was warmer. Seasonal variables (warmer water, slower current and defined habitats) increased susceptibility of both channel catfish and smallmouth bass to capture and partially explains seasonal CPE increase with successive passes. The limiting factor for successful summer sampling was flow. In 2002, flows dropped to levels that denied access as early as mid June (Figure 2) and in 2003, 2004 and 2006 the study area was inaccessible by the second week in July. Seasonal conditions contributed to catch rate increases between passes and invalidated the use of regression analysis to predict population size.

Figure 2. 2002 lower Yampa River upstream of Harding Hole during record low flows.

Channel Catfish

Year 2001Channel Catfish Control

In 2001, 3,524 channel catfish in three electrofishing passes, and 1,446 in two angling trips (n=4,970 total). Mean total length of channel catfish captured by electrofishing was 294 mm (100 – 675 mm) TL, and mean TL of channel catfish caught angling was 267 mm (144 – 777mm) TL. For both methods the mean TL was 286 mm. CPE increased over passes and the CPE was 40.3 catfish per hour all passes combined (Figure 3 and 4).

Year 2002 Channel Catfish Control

In 2002, a total of 2,393 channel catfish were removed; 978 with electrofishing and 1,415 with angling. The lowest summer flows on record occurred in 2002. Canyon access was denied by mid June. Angling crews hiked into Harding Hole (rm 20) to continue collecting fish. One crew worked downstream to the Grand Overhang (14.5 rm); another crew sampled upstream past Big Joe Rapid (24 rm), which resulted in 519 catfish removed. Hiking into the canyon allowed us to observe the river at extremely low levels (<4 cfs), and water temperatures that reached 30 ˚C. Though we identified several mortalities, no large fish kills were observed (Figure 2). In 2002 mean total length of channel catfish captured by electrofishing was 302 mm, and the overall mean TL (both methods) was 279 mm. The combined electrofishing CPE was 23 catfish per hour (Figure 4).

Year 2003 Channel Catfish Control -- The scope of work was revised to include fyke netting near the upper and lower ends of the study area. Large fyke nets (4 x 4 ft diameter frame and 1 in mesh) were used in June near Deerlodge Park and Echo Park. During this effort 32 channel catfish (mean TL 294 mm) were collected and stocked into Kenney Reservoir near Rangely Colorado by CDOW. Other revision included using reach 2 and 7 as control reaches to make statistical comparisons and to monitor movement. In the first pass (electrofishing) 187 channel catfish from reach two received left pectoral fin clips and 200 channel catfish from reach seven had adipose fins clipped. After marking, channel catfish were returned to the river alive (n=387). In the second and final electrofishing pass 1,638 catfish were removed, only two were recaptures. One recapture was marked in reach seven between river miles 15 and 20 rm (left pectoral fin clip) and re-caught in reach one between 40.9 and 45 rm (the highest upstream reach). The second was marked and recaptured in the same reach (reach two). There were no size differences in catfish collected from control and removal reaches.

In 2003 we caught 3,982 channel catfish in two electrofishing passes, two angling trips and by fyke netting. During the two electrofishing passes 1,754 channel catfish were removed and 387 were released in control reaches; another 1,809 channel catfish were removed from the river by angling, and 32 were caught in fyke nets (n=3,982 total). Mean total length of channel catfish captured by electrofishing was 268 mm (97-750 mm TL), and mean total length of channel catfish caught angling was 231 mm (102-500 mm TL). The electrofishing CPE all passes combined was 36.7 per hour (Figure 4), and the angling CPE was 4.7 per hour (Figure 5). Collections within reaches did not show CPE reductions (Figure 6).

Year 2004 Channel Catfish Control -- The SOW was again revised to no longer set fyke nets at Deerlodge and Echo Parks, and to discontinue the use of control reach strategies. In 2004, we completed four electrofishing passes and four angling trips. We removed 3,464 channel catfish electrofishing, and by angling, volunteers and staff removed another 3,790 (n= 7,254). The electrofishing CPE increased each pass; reductions in CPE were not shown within reaches or by pass (Figure 3). Mean channel catfish length by electrofishing was 282 mm (105-782 mm TL), and by angling 204 mm. A decrease in mean total length between years was shown (Figure 7).

Year 2005 Channel Catfish Control -- The SOW was revised to focus on smallmouth due to their harvest by anglers in 2004. The volunteer angling program was discontinued for the remainder of the project. Other changes included measuring population abundance and depletion. Depletion was determined by the number removed (n) deducted from the population estimates point estimate, this figure, considering all removed (n) for the season is the post-removal estimate. Other changes in 2005 included the use of smaller boats which allowed access to the canyon in flows less than 700 cfs when catfish were more vulnerable to capture. In 2005, 4,006 catfish were removed during five electrofishing passes. The decreases in CPE in the fourth and fifth passes are partly attributed to the use of the smaller electrofishing rafts and generators however; CPE decreased between the last two passes using similar gear. The mean TL of channel catfish all passes combined was 274 mm.

2005 Channel Catfish Population Estimate-- In the first pass 261 catfish were tagged with blue floy-tags and released. The catfish population point estimate was 28,054 with standard error 8,259, coefficient of variation 0.29, and p-hat 0.039. Fish density estimates (95% C.I.) ranged from 350-1079 catfish/rm. The post-removal estimate is 24,048, and the removal density was 87 catfish per mile; this represents a population reduction somewhere between 8 and 25%, (Table 4).

Year 2006 Channel Catfish Control-- In 2006, 4,633 channel catfish were removed in six passes. The six-pass combined electrofishing CPE (all passes combined) was 38 catfish per hour, (Figure 4). The mean TL for combined passes was the same as in 2005, 274 mm. Once again, catfish at 225-250 mm were most common, and as in all years, very few catfish less than 200 mm were collected, (Figure 8). Since 2004 the catfish catch changed very little (size and CPE), and we haven't experienced significant river-wide depletions. Though mean TL decreased in beginning years, mean TL, and length frequencies have remained similar since 2003 (250-270 mm).

Smallmouth Bass

Year 2001-2002, *Incidental smallmouth Bass catch* -- In 2001 only two smallmouth bass were collected electrofishing. In 2002, thirteen smallmouth bass were caught in two electrofishing passes. By mid-June we couldn't access the river, and it was while hiking and angling that, for the first time, large numbers of smallmouth bass were caught. We caught 305 smallmouth bass representing 22% of the angling catch. This became a major concern to the Recovery Program.

Year 2003, *Incidental Smallmouth Bass Catch* -- In 2003 we collected 351 smallmouth bass in two electrofishing passes, and two angling trips, (mean TL 193 mm). Smallmouth bass were the second most abundant nonnative species. The number of smallmouth caught electrofishing (n=186) validated their proliferation as observed since 2002, and caused a sense of urgency. At a post-season nonnative fish control workshop, biologists considered smallmouth bass removal the primary study objective.

Year 2004 Smallmouth bass control -- Electrofishing catch rates escalated from 0.15 bass/hr in 2001 to greater than 21 bass/hour in 2004. In 2004, the sampling season started with a population estimate. During the first pass 360 smallmouth bass were tagged (with blue floy-tags), and released. Thereafter, 2,989 bass were removed in four electrofishing and two volunteer angling passes (two trips per angling pass). During the two angling passes (four trips) only 285 bass were caught.

Storm events and increased turbidity negatively affected angling catch rates. Conversely, the electrofishing catch rates appeared to be higher with increased turbidity

2004 Smallmouth Bass Population Estimate -- Population abundance was estimated using the program Capture (White et. al.1982). A population model with constant probability of capture M(o) was used for pass 1 and 2. The population point estimate was 14,861 with standard error 3894.89, and estimated probability of capture, p-hat 0.03. Fish density estimates with 95% confidence ranged from 197-538 bass/rm. The total number of smallmouth bass removed (n=2989) was 65 bass/rm. Based on the point estimate, 20.1 % of the population was reduced, or, considering the 95% confidence level, 33-59% of the population was removed.

2004 Smallmouth Bass Age, Size and CPE -- Mean smallmouth bass TL collected electrofishing was 185 mm (n=3066), and by angling was 204 mm (n=285). Based on otolith aging data, the majority of these fish were between three and six years (Figure 9). Most otoliths were clearly read using reflected light, but 12.7% of the otoliths had a degraded condition. Only fish over four years old had this condition. Most degraded otoliths could be aged, but not measured for annual otolith growth. This condition was suspected to be caused by parasites or some other stress to the fish that does not allow a proper annulus to form (Dr. Mark Belk, Brigham Young University, personal communication).

No young of the year smallmouth bass were collected, and the oldest fish collected was 10 years old (Figure 9). Mean total body length for each age class was: one year 90 mm, two year 140 mm, three year 176 mm, four year 195 mm, five year 230 mm, six year 250 mm, seven year 263 mm, eight year 193 mm (only one case), nine year 223 mm, 10 year 226 mm (only one case). The relation of otolith length to age was similar to the relation between body length and age. Each age group had a fairly wide range of body and otolith lengths (r^2 of 0.57 and 0.66, respectively) (Modde et al. 2006).

During the 2004 season, CPE increased with each successive electrofishing pass (Figure 10). Electrofishing CPE all passes combined was 21.6 smallmouth bass per hour. Angling catch rates for bass also increased each trip, but the increase was likely a result of angler experience and seasonal increases in water clarity.

2004 Smallmouth Bass Movement -- Movement was measured by distance between catches of tagged bass within the 10 stratified reaches; of 360 bass marked and released in the first pass 51 were recaptured over the field season. Twenty-six of the 51 recaptured did not leave the reach they were originally tagged. Twenty five (~50%) of the 51 recaptured did move; 18 moved upstream and seven moved downstream. Twenty one of the 25 fish that moved traveled a distance greater than about six river miles. The furthest distance moved within the study area was seven reaches upstream which is approximately 31.4 miles (two individuals). Of the seven that moved downstream only two moved more than one reach; the furthest distance moved downstream was nine miles. No tagged smallmouth bass were collected downstream in the Green River in the Whirlpool and Split Mountain reach later in the year. Thirteen marked bass left the study area, 10 were recaptured in 2004 - one in 2005, and two in 2006. The 10 re-caught in 2004 were recaptured upstream the study area between river mile 53 and 55. The furthest distance traveled upstream was by a bass recaptured at river mile 121, a distance of over 93 river miles.

Year 2005 Smallmouth Bass Control -- The SOW was again revised because few smallmouth bass were collected by anglers in 2004. The volunteer angling program was discontinued. More effort went into improving electrofishing techniques; we built smaller, lighter boats that improved maneuverability while sampling and allowed us to access the canyon during flows less than 1000 cfs (the previous minimal flow for larger electrofishing rafts). Sampling also improved as we worked against the current to shock slower. In 2005 we completed five passes and removed 2,671 smallmouth bass.

2005 Smallmouth Bass Population Estimate -- We tagged 498 smallmouth bass during the first pass (using blue floy-tags).. In 2004, a population model with constant probability of capture (M(o)) was used for pass 1 and 2. To standardize estimates per year this estimate was recalculated using M(t) and resulted in a change to 21,630 bass with probability of capture, (p-hat) 0.025 (Table 4). The 2005 two-pass population estimate was 24,893 bass with standard error 5,875, and p-hat 0.020 (Figure 11). Fish density estimates ranged from 345-858 bass per river mile, (Figure 12). The total number of smallmouth bass removed was 58 bass per river mile, (n=2,671). Using the point estimate 10.7% of the population was removed in 2005 (Figure 13).

2005 Smallmouth Bass Size and CPE -- Mean TL of smallmouth bass collected for all passes was 164 mm. The size most frequently caught was 150-175 mm comparatively, very few bass in the 150-175 mm size class were collected in 2004. This smaller cohort may represent younger bass displaced from upstream by fluctuations in spring flows. Flows were sustained above 7,000 cfs until 24 June. The median daily stream flow for this timeframe is less than 4,000 cfs based on 20 years of record. High flows have been shown to displace bass (Cleary 1956) and during this higher than normal flow event, nine bass tagged upstream of the study reach with yellow floy-tags were caught during routine sampling; seven of the nine were caught during a two week period. Bass tagged upstream from the study reach were also collected downstream in the Green River later in the year (Ron Brunson, Utah Division of Wildlife Resources, personal communication).

Length frequency shifted between passes. Within the first four passes the size most frequently collected was 150 mm TL, and by the last pass the most common size collected was 175 mm, the age-4 cohort (Modde et al. 2006). The median size for all passes combined was 200 mm.

Catch per effort increased between sampling events over the course of the season. Smallmouth bass became more vulnerable to electrofishing with receding flows; storm events and turbidity also caused increased catch rates. The number of smallmouth bass ($\geq$100mm TL) caught in clear water conditions was 462/ pass. During the third pass turbidity increased and 846 smallmouth bass were caught. The first measured reduction in CPE in the lower Yampa River occurred during this year's last pass (Figure 10). Lower catch rates were attributed in-part to a change in electrofishing technique. During pass four and five smaller rafts (catarafts) and generators were used. Despite this change, CPE was lower in the last pass using similar gear.

2005 Smallmouth Bass Movement – Of the 498 bass marked and released in the first pass, 16 were recaptured. Five displayed no movement; four moved upstream and seven moved downstream. Of the seven that move downstream, only three moved more than one reach. Mean upstream movement was 19.4 river miles compared to 8.3 river miles downstream. Though fewer individuals moved upstream, combined upstream movement was 14.3% greater than combined downstream movement. Three other tagged bass were caught upstream of the study area by other researchers (John Hawkins, Colorado State University, personal communication). The furthest movement upstream was to river mile 104, which is 58 river miles from the study's upstream boundary at Deerlodge Park. We collected nine yellow tagged smallmouth bass marked upstream outside the study area. No tagged smallmouth bass were collected downstream of our study area.

Year 2006 Smallmouth Bass Control -- The scope of work was revised to eliminate a population estimate, all effort was devoted to capture and removal. Again, electrofishing was the only method used; however, more effort went towards improving control strategies. Besides implementing techniques based on what we learned in the field, modeling was used to determine the percent exploitation needed to crash the population. Five removal passes were completed. After the fifth pass flows receded below 500 cfs (14 July), but storm events in September provided enough flow for another pass. During six passes, 1,914 smallmouth bass were removed from the study area (Table 3). In June, eight yellow floy-tagged bass that were tagged upstream of our study area were recaptured.

2006 Smallmouth Bass CPE and Size – In 2006 the highest CPE per pass for bass greater than 100 mm was ~10 per hour during the fourth pass, and the lowest was 5.2 in pass 3 (Figure 10).This year's CPE for all sizes of smallmouth was 10.3 per hour (all passes combined), 8.4 for bass >100 mm. (Figure 14). Comparatively, the highest CPE per pass last year was 29.7 per hour. The CPE, by reach, (all passes combined) was lower than those in the two previous years. We also observed lower catch rates in downstream reaches (Figure 15). Mean TL of smallmouth bass collected was 178 mm and the size most frequently caught was 200-225 mm (Figure 16).

***Sub Adult and Adult Fish Monitoring** (1981, 2001, and 2004)*

Nonnative Fishes -- Non-native fish species composition increased significantly since 1981 (Chi-square tests of independence (p= .0006). During the 2001-2004 surveys, 10 nonnative fish species (>100 mm total length) were collected and identified. Only two of the 10 were collected in 1981, channel catfish and common carp (Table 5). The 10 nonnative species collected in the recent study were categorized according to 1982 relative abundance classification of Tyus (1982). Five species were classified as rare (brown trout *Salmo trutta*, northern pike, rainbow trout *Oncorhynchus mykiss*, white sucker *Catostomus commersonii*, and a white sucker / flannelmouth *C. latipinnis* hybrid. Two species were classified as incidental (black bullhead *Ameiurus melas*, and green sunfish *Lepomis cyanellus*), while channel catfish, smallmouth bass, and common carp were classified common to abundant.

The greatest change in the nonnative fish community between years was the presence and expansion of smallmouth bass (Table 3 and 5). Smallmouth bass were absent previous to

2001 but represented 19% of the 2004 monitoring catch (Table 5). The second most notable change was the increase in the channel catfish catch in spite of channel catfish removal efforts (Table 5 and 6). The channel catfish catch within monitor sites increased between all years even with the removal of 26,860 catfish from the study area, however, the electrofishing CPE for all years and all passes combined do not show increase, (Figure 3). We did not monitor the fish community in 2005-06 but will continue in 2007.

Native Fishes -- During the 2001 and 2004 monitoring, seven native fishes (>100mm) were collected and identified. Too few endangered fish were caught to make comparisons, but decreases in native fishes were measured. Percent catch and catch per effort of bluehead sucker *Catostomus discobolus* and roundtail chub *Gila robusta* declined the most from 2001 to 2004. Bluehead sucker relative abundance was stable (Tyus 1982) until the period between 2001 and 2004 when the catch dropped from 38% in 1981 and 2001 to 19% in 2004, a decrease of 19% (Chi square; p=.02) (Table 7). In 1981 roundtail chub represented 12% of the catch but decreased in 2001 and 2004, to 7% and 2% respectfully (Chi square; p=.001) (Figure 17). This decrease occurred during the same time period that smallmouth bass density increased in all study sites.

Exploitation Modeling
The historical catch data and the three fitted recruitment hypotheses are in Figure 19. The 2004 and 2005 data were population estimates from the current removal study; the data prior to 2005 and the 2006 data were catch per hour electrofishing data scaled to population size using the 2004 and 2005 data as a reference. Simulation results show that at the present level of exploitation, there is minimal effect on the smallmouth bass population. Exploitation from removal efforts was much less than accepted levels of mortality known to sustain sports fisheries. For example, our exploitation (u) was u = 0.17, p = 0.03 for the lower Yampa River, and for maintaining smallmouth bass sports fisheries in the listed states the measures of exploitation were acceptable in Iowa, u = 0.33, (Paragamian 1984), in Wisconsin u = 0.45, (Hoff 1995), again in Wisconsin u = 0.53, (Newman and Hoff 2000) and in Ohio u = 0.56 (Coble and Marinac-Sanders 1981). According to this analysis, exploitation rates apparently need to be above u = 0.64 (and p > 0.10) to significantly reduce the smallmouth population over a 20 year period for all three recruitment hypotheses [Figure 18, (Haines and Modde 2007)]. This measure of exploitation is hoped to provide resolution to the level of control needed to reduce smallmouth bass populations.

DISCUSSION

Before smallmouth bass were introduced in the Yampa River, channel catfish ranked first among problematic species in the Colorado River system (Hawkins and Nesler 1991). Channel catfish were first introduced to the Yampa River in 1944, and have since been implicated as a causal factor in the decline of endangered humpback chub (Tyus 1998). In 1981, channel catfish catch rates using trammel nets and electrofishing “were usually higher than for other species except bluehead and flannelmouth suckers” (Miller et. al.

1982). In 2004 channel catfish catch rates exceeded those of bluehead and flannelmouth suckers.

Channel catfish abundance appeared so great that the likelihood of reducing their numbers seemed improbable, regardless; the urgency for nonnative fish control was acknowledged and considered crucial for endangered fish recovery (Tyus and Sanders 2000). Mechanical control of channel catfish was first implemented in 1998. That year, the most efficient channel catfish sampling gear was identified, and in 1999 channel catfish abundance was significantly reduced in several sub-reaches using electrofishing and angling (Modde and Fuller 2002). Optimism followed and larger mechanical control projects were inaugurated by the Recovery Program. The first attempt to reduce channel catfish abundance river-wide was under way by 2001 and though a strong effort resulted, significant depletions in CPE were not measured. The intensity that river-wide mechanical control required was recognized and posed pessimistic concern. Nevertheless, that winter, in the 2002 nonnative fish control workshop, nonnative fish control was defined "to reduce numbers of nonnative fishes to the point where they no longer impede recovery"; and the control strategy was to "remove nonnatives from main river channels using mechanical techniques". Though we couldn't show significant reduction in CPE per pass in 2001, the emphasis for control strengthened as did the importance to measure progress in terms of depletion.

The sub-adult and adult fish community was monitored for a native fish response to nonnative fish control. During the 2001-2004 surveys, 10 nonnative fish species (size >100 mm TL) were identified. Comparisons indicate that both channel catfish and smallmouth bass increased by 14% and 19% respectively between years 2001 and 2004. These findings are comparable to those found upstream in Lily Park by Anderson (2005) where channel catfish (200 to 300 mm TL) increased in abundance in 2003 and 2004, relative to 2000. An increased percentage of smallmouth bass was also observed at all river sites surveyed by Rick Anderson in 2004 (Anderson 2005).

Significant decreases in native fishes based on percent catch and CPE also occurred between years 2001 and 2004. The two species showing greatest decline are roundtail chub and bluehead sucker. The roundtail chub catch dropped from 12% in 1981 (Tyus 1982) to 2% in 2004. In 2001, the roundtail chub catch was 7% and noticeably lower than flannelmouth sucker and bluehead sucker which was 38% and 33% respectfully. This difference represents a significant change from 1981 when roundtail chub were said to be "as common as bluehead and flannelmouth sucker" and present in all strata in Yampa Canyon (Tyus 1982). Between 2001 and 2004 the bluehead sucker catch decreased 19% and the flannelmouth sucker decreased three percent. Similar comparisons upstream (outside the study) showed that flannelmouth sucker and bluehead sucker estimates were significantly lower in 2004 compared to 2000 and 2001 (Anderson 2005). Andersons' biomass estimates of total fish show that flannel mouth sucker and bluehead sucker progressively decreased and were lowest in 2004.

Decreases in native fishes occurred simultaneously with increases in smallmouth bass density. Smallmouth bass increased in catch per hour in 2001, 2002 and 2003 from .02, 0.19, and 3.19 respectfully and then increased to 24.45 in 2004. A similar increase was shown upstream from 2000 to 2004 when smallmouth bass increased from 0.8% to 21%. The northern limit of the native range of smallmouth bass occurs where the growing season is about 120 days (Robbins and MacCrimmon 1974). The Yampa River is near the highest elevation where successful smallmouth bass reproduction is know to occur (Mullner and Hubert 1993). Smallmouth bass growth is relatively slow in the Yampa River and average thermal conditions may limit their reproductive potential there. Smallmouth bass CPE has declined since 2004. Water temperatures during the summer of 2002 were much warmer than typical, and a longer growing season in 2002 appears to have facilitated recruitment of smallmouth bass in 2003 (Anderson 2005).

One of the most troubling observations of this study was the increase in the channel catfish catch rates despite channel catfish removal efforts. The only identifiable, and expected response to catfish removal was a decrease in mean total length, which could represent a decrease in channel catfish piscivory. Channel catfish in the Upper Colorado basin are not "fully piscivorous until they reach a length of 420 mm or more" (Tyus and Sanders 2000).

The most notable change in nonnative fish composition was the introduction and proliferation of smallmouth bass which as a species was basically absent prior to 2001, however the species was detected in 1989 (six fish in a collection of 5,349; catch = 0.11 fish per hour) (Karp and Tyus 1990). Subsequent bass introductions to the upper Yampa River, especially from Elkhead Reservoir in 1992, and favorable environmental conditions (early warm water temperatures and longer growing seasons) between 1998 and 2001 resulted in recruitment success and proliferation.

Naturalized populations of smallmouth bass are now established throughout the Yampa River. This shift in the fish community may present the greatest threat to native fish recovery yet identified. Smallmouth bass were first collected (since 1990) by electrofishing in 2002, and have since become the Recovery Program's primary target for nonnative fish control in Yampa canyon. This suggests a need to intensify efforts to reduce smallmouth bass stocks, yet the best known method remains unchanged.

The Recovery Program provides annual guidance on all recovery activities and projects and directs this and other nonnative fish control and removal programs. Their nonnative fish strategic plan to facilitate recovery of endangered fishes addresses the need to, "control introductions and proliferation of nonnative fishes". An important aspect of the control plan is "that the level of reduction should be specified to provide a measure of success" (Tyus and Sanders 1996). Since nonnative fish removal was developed and implemented in the Upper Colorado River basin, this level of reduction and reliable way to measure the depletion necessary to detect a native fish response (Workshop 2002) has been pursued but not fully understood.

In 2006 this concern was addressed with the question, "What does it take to impact and eventually crash the smallmouth bass population"? The exploitation level reached with our best methods and facilities was compared to the exploitation needed to negatively impact the population generated by modeling. Using three different models, and input from empirical data and from the literature, Haines and Modde (2007) generated exploitation levels and results that if applied should reduce smallmouth bass populations beyond natural recruitment. Seeing the time and immense effort required to crash a smallmouth bass population (by simulation) was sobering. Simulated results show that at the 2006 level of exploitation ($u = 0.17$, $p = 0.03$) our removal efforts are not high enough to adequately effect smallmouth bass abundance. According to all three recruitment hypotheses, at the beginning of a reduction plan that expands over a 20 year period, smallmouth bass exploitation rates need to be above $u = 0.64$ ($p > 0.10$). This was proposed and generally accepted at the 2006 nonnative control workshop.

So far, implementing mechanical control methods still continues to be the best known strategy, but higher levels of exploitation are needed. In this regard and in the pursuit of measurable success, a level of exploitation that is expected to reduce smallmouth bass abundance has been identified. Methods have been tailored to the species targeted and to environmental factors that effect catch rates, but levels of exploitation achieved to date are still sub-optimal.

CONCLUSIONS

Channel Catfish

1. Channel catfish mean TL (all passes combined) decreased from 1998 – 2003, but then stabilized.

2. Collections of channel catfish <150 mm were very rare.

3. Channel catfish are susceptible to angling over a wide range of turbidities. Angling for smallmouth bass was negatively influenced by turbidity.

4. Year to year reductions in annual channel catfish CPE (all passes combined) were not shown. Within years, catch per effort increased with warming water temperatures.

5. Channel catfish CPE also leveled or became more uniform between reaches in 2006.

Smallmouth bass

1. Annual smallmouth bass (> 100mm TL) CPE (fish / hour electrofishing) declined throughout the study.

2. Smallmouth bass (> 100mm TL) CPE (fish / hour electrofishing) generally declined in a downstream direction throughout our study area.

3. Based on exploitation modeling, our removal effort was not considered sufficient to negatively impact (reduce) the populations.

4. Young of year smallmouth bass become catchable by electrofishing in late summer and were considered quite susceptible to this method of sampling.

5. Prolonged exposure of smallmouth bass to electroshock increased catch efficiency, i.e. slow shocking worked better. Boat motors were an asset in this regard.

6. Movement of smallmouth bass into the study area from upstream reaches occurred during unstable, spring run-off.

RECOMMENDATIONS

1. Since the channel catfish population is well established and sustained by natural recruitment, control should continue but by removing catfish greater than 400 mm TL. Channel catfish of this size present a stronger predatory threat, and are highly fecund contributing considerably to yearly recruitment. Small catfish still present a negative threat to early life stages of native fishes, but unless an intensive basin wide effort is implemented, the emphasis should be to control smallmouth bass.

2. Expand smallmouth bass control by starting with passes earlier in the Spring before runoff flows limit access.

3. Conduct research to determine the effect of flow and temperature on the displacement of smallmouth bass.

4. Condunt research to determine how water temperature and growing season affect YOY over winter survival.

5. Continue to monitor the sub-adult and adult fish community with intent to identify native fish (composition) responses to control efforts.

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Table 1. The 2001 – 2006 Yampa River study sample dates and reaches by river mile. Monitor reaches are numbered as per the removal reach they fall in.

	Trip Days					
Date	1	2	3	4	5	6
2001	6/11-14	6/18-21	6/25-28	7/30-8/3	8/21-24	
2002	5/28-29	6/10-13	6/17-21	7/16-17	8/20-22	
2003	6/23-26	7/7-11				
2004	4/14-17	6/1-4	6/7-10	6/14-18		
2005	6/13-17	6/26-30	7/11-16	7/18-22	7/25-27	
2006	6/5-8	6/13-16	6/20-23	6/27-30	7/10-14	9/25-28

Reach	**Up stream RM**	**Down Stream RM**	**Distance (rms)**
Removal Reach 1	45	40.9	4.1
Monitoring (1)	39	38	1.0
Removal Reach 2	40.9	37	3.9
Monitoring (2)	38	37	1.0
Removal Reach 3	37	32.4	4.4
Removal Reach 4	32.4	28	4.4
Monitoring (4)	31	30	1.0
Removal Reach 5	28	24.5	3.5
Removal Reach 6	24.5	20	4.5
Monitoring (6)	24.5	23.5	1.0
Removal Reach 7	20	15	5.0
Removal Reach 8	15	10	5.0
Removal Reach 9	10	4.3	5.7
Removal Reach 10	4.3	0	4.3
Monitoring (10)	3	2	1.0

Table 2. 2001-2006 channel catfish numbers removed, CPE, and size.

Year	#Catfish Removed Electrofishing	Catch per Hour Electrofishing	# Catfish Removed Angling	Catch per Hour Angling	# Removed All Gear	Mean TL All Gear (mm)
2001	3524	40	1446	2.9	4970	286
2002	987	23	1415	4.4	2402	279
2003	1754	37	1809	4.7	3563	254

2004	3464	27	3790	2.8	7254	264
2005	4006	27	-	-	4006	257
2006	4633	38	-	-	4633	274
Total	18,368		8,456		28,860	

Table 3. Annual smallmouth bass numbers caught, total number removed and CPE for methods electrofishing and angling.

Year	# Bass Caught Electofishing (all passes)	Catch per Hour Electrofishing (all passes)	# Bass Removed Angling	# Removed All Gear
2001	2	.02	5	7
2002	13	.19	305	318
2003	186	3.19	164	351
2004	3066	24.45	283	2989
2005	3185	18.54	-	2671
2006	1914	10.31	-	1914
Total	8,364		752	8,243

Table 4. The 2004 and 2005 channel catfish and smallmouth bass population estimates.

Year	Type	Model	Sp	N	C.I.	SE	P-hat	CV	Removed	%
2005	MARK	M(t)	CC	28,054	16,100-49,634	8,259	.039	.29	4,006	**14**
2004	MARK	M(t)	SM	21,630	11,729-40,579	7,060	.025	.33	2,989	**14**
2005	MARK	M(t)	SM	24,893	15,890-39,460	5,875	.020	.24	2,671	**11**

Table 5. The 1981, 2001 and 2004 monitoring data, percent nonnative species caught (>1% total catch) electrofishing in the lower Yampa River.

Species	Status[a]	1981	2001	2004	% Increase	X^2 p-value
Channel catfish	Incidental	13	17	31	18	.0000

Smallmouth bass	Incidental	0	0	19	19	.0000

* An abundance classification change to abundant for both channel catfish and smallmouth bass would better represent recent population increase.

Table 6. The 2001 and 2004 nonnative fishes (>1% total catch) monitoring data, percent catch, and catch per hour electrofishing in the lower Yampa River.

Non-native Species	Year	Percent Catch	Catch/hour	N
	2001			
Channel Catfish		17	30.91	204
Common Carp		4	7.58	50
Brown trout		<1	.30	1
Northern Pike		<1	.30	2
White Sucker		<1	.30	2
Black Bullhead		<1	.15	1
Smallmouth bass		<1	.15	1
	2004			
Channel Catfish		31	59.40	237
Smallmouth bass		19	35.84	143
Common Carp		3	5.51	22
Brown trout		<1	.25	1
Rainbow trout		<1	.25	1
White/Flannelmouth sucker		<1	.50	2

Table 7. The 1981, 2001 and 2004 percent native fishes caught electrofishing (>1% total catch) in monitor reaches, percent decrease and the 1982 classification status.

Species	Status[a]	1981	2001	2004	% Decrease	X^2 p-value
Bluehead sucker	Common	38	38	19	19	.0213
Flannelmouth sucker	Abundant	28	33	25	3	.1594
Roundtail chub	Abundant	12	7	2	10	.0000

* An abundance classification change to common for roundtail chub would better represent recent sampling.

Table 8. The 2001 and 2004 native fishes monitoring data for percent catch, and catch per hour electrofishing in the lower Yampa River.

Native Species	Year	Percent Catch	Catch/hour	n
	2001			
Bluehead sucker		38	70.91	468
Flannelmouth sucker		33	62.73	414
Roundtail chub		7	12.12	80
Colorado pikeminnow		<1	1.06	7
Humpback chub		<1	.15	1
	2004			
Bluehead sucker		19	36.59	146
Flannelmouth sucker		25	46.62	186
Roundtail chub		2	4.51	18
Colorado pikeminnow		<1	.25	1
Mountain whitefish		<1	.25	1

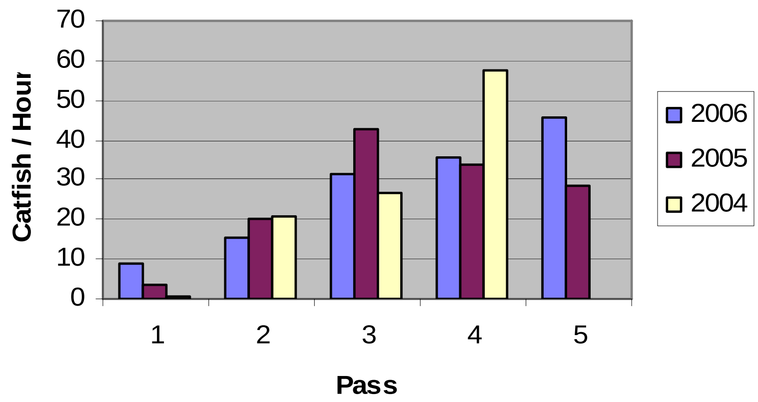

Figure 3. The 2004-2006 channel catfish CPE electrofishing by pass. The only decrease between passes was in 2005.

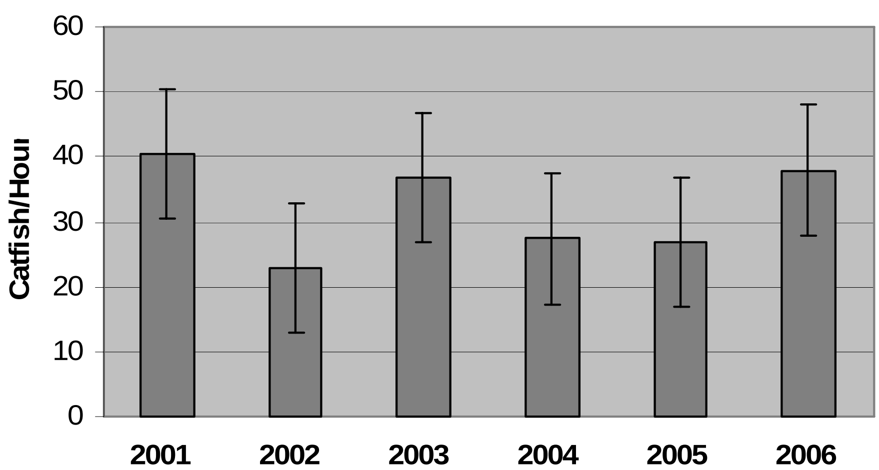

Figure 4. The 2001 – 2006 channel catfish CPE electrofishing all passes combined (with 95% confidence intervals).

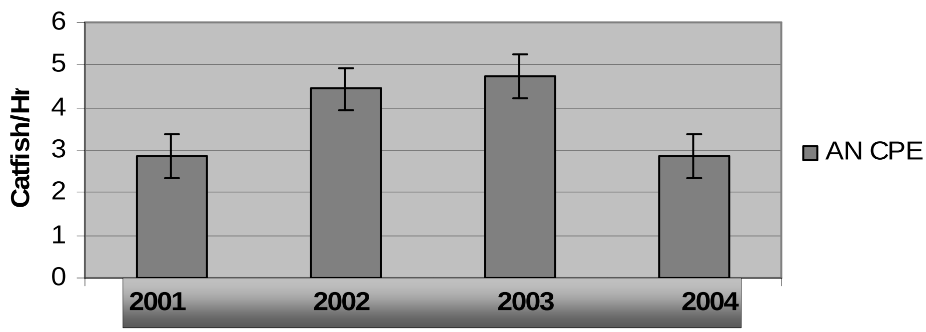

Figure 5. The 2001 – 2004 channel catfish CPE angling all passes combined.

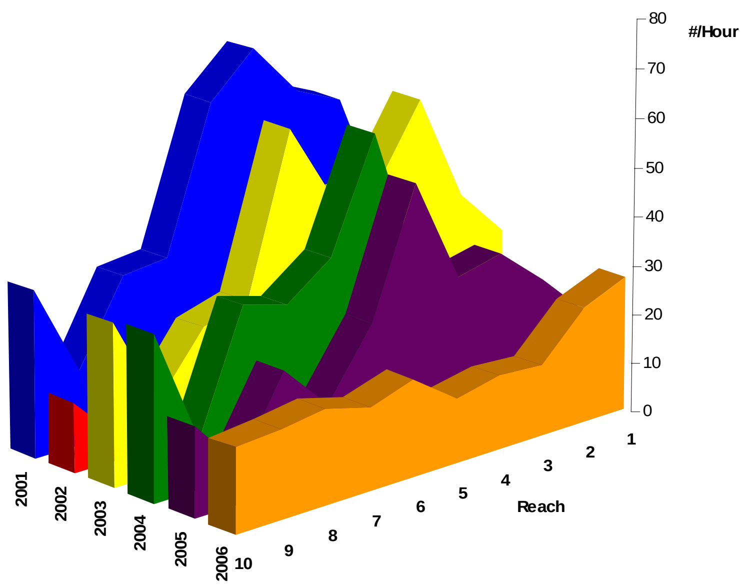

Figure 6. The 2001 – 2006 channel catfish CPE electrofishing by reach. Changes in catfish composition started to show in 2006.

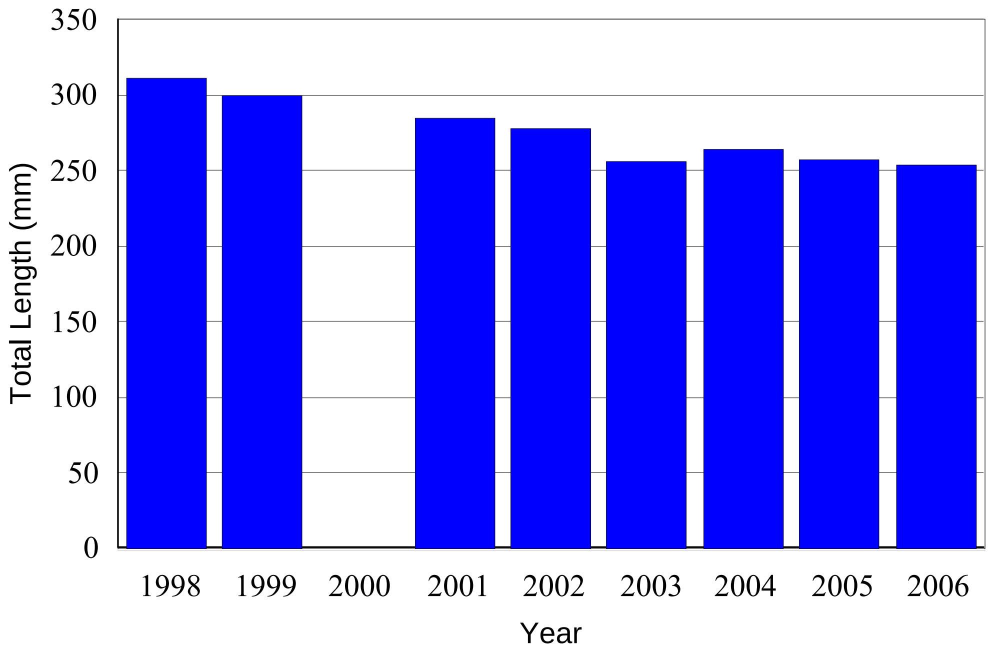

Figure 7. The mean total length for channel catfish from The 1998-2006.

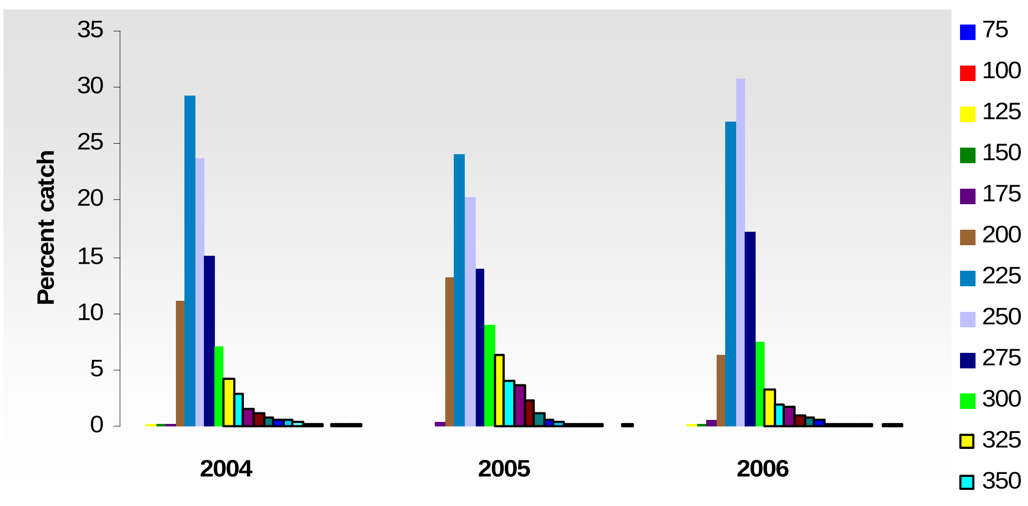

Figure 8. The 2004 – 2006 channel catfish length frequency in the lower Yampa River.

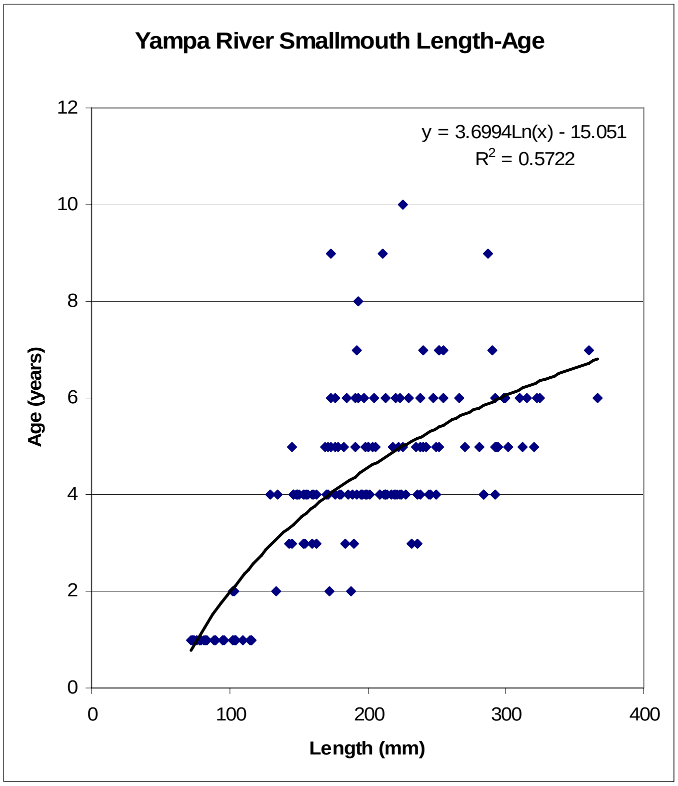

Figure 9. The 2004 smallmouth bass length and age data. Each mark represents an individual fish.

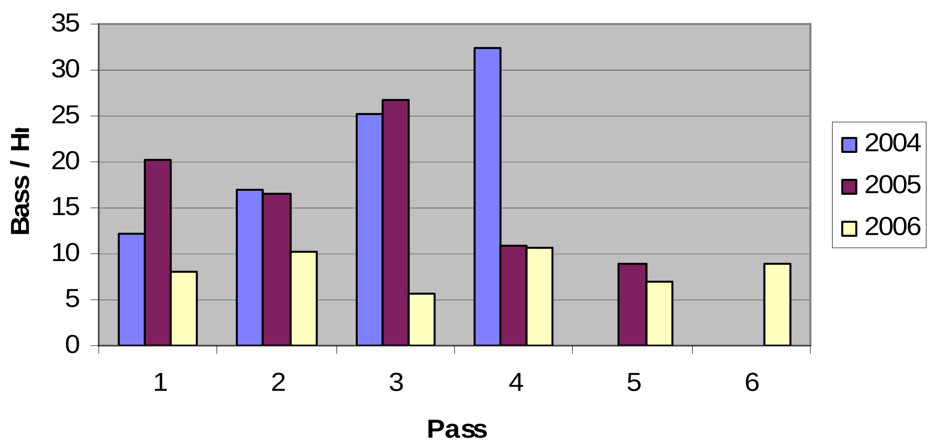

Figure 10. The 2004 – 2006 smallmouth bass catch per hour by pass in the lower Yampa River.

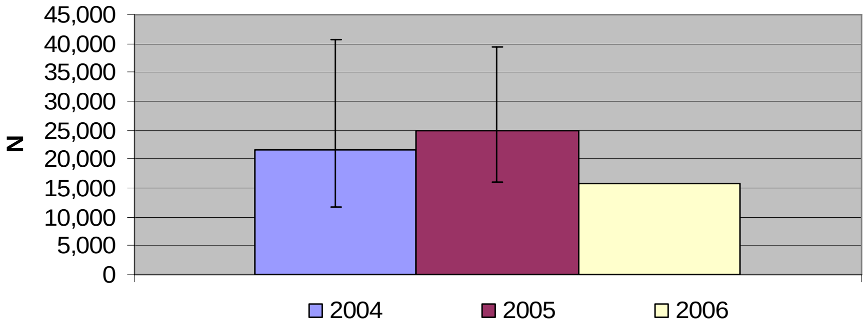

Figure 11. The 2004 and 2005 smallmouth bass population estimates for bass >100 mm between Deerlodge Park and the Green River confluence (46 miles). A proportional value based on CPE is shown for 2006.

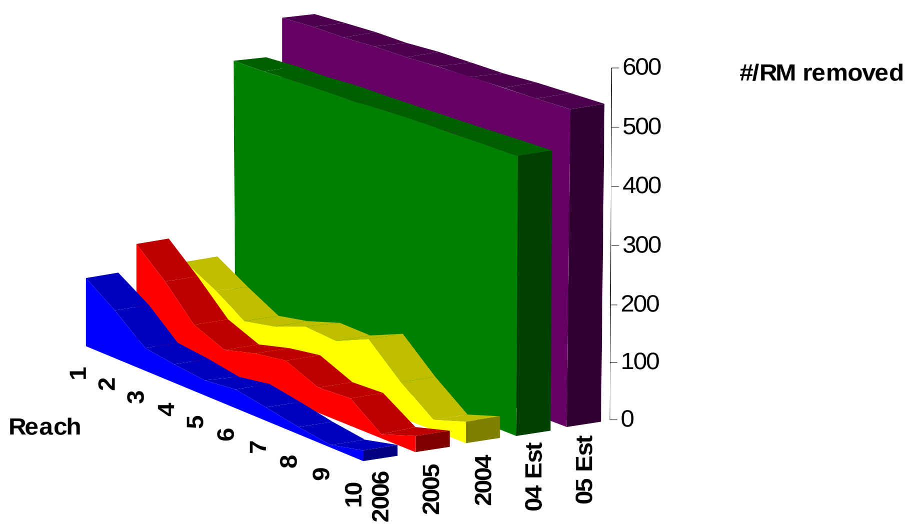

Figure 12. The number of smallmouth bass removed per river mile and the 2004 and 2005 smallmouth bass population estimates.

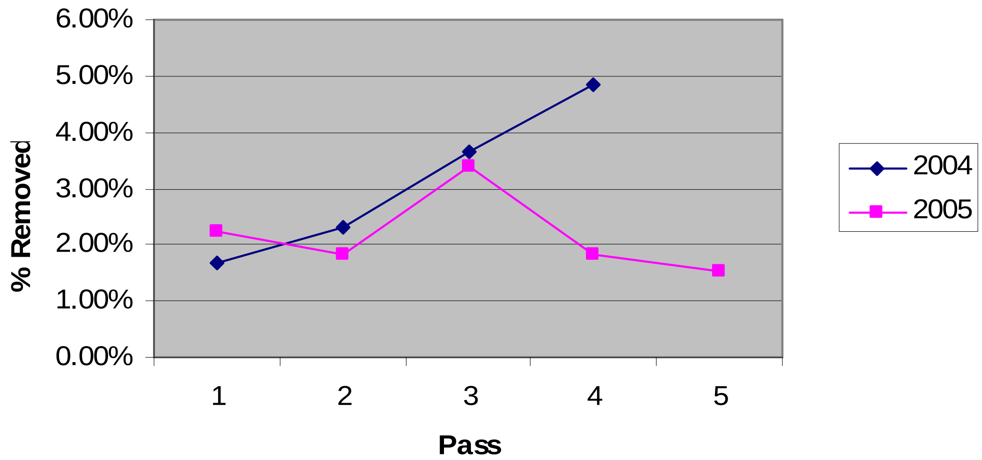

Figure 13. The smallmouth bass capture efficiency based on 2004 and 2005 population estimates.

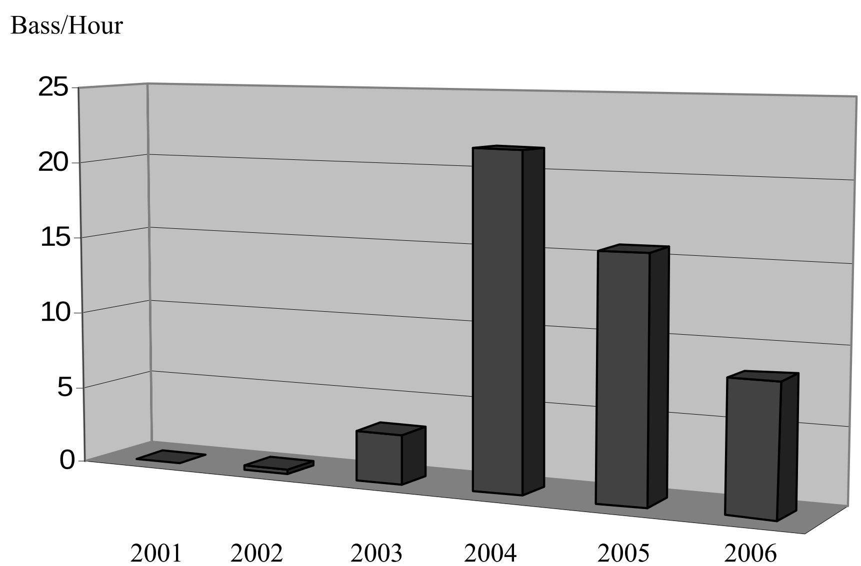

Figure 14. The 2001 – 2006 catch per effort, all passes combined for smallmouth bass >100 mm TL. A huge increase in density determined in 2004.

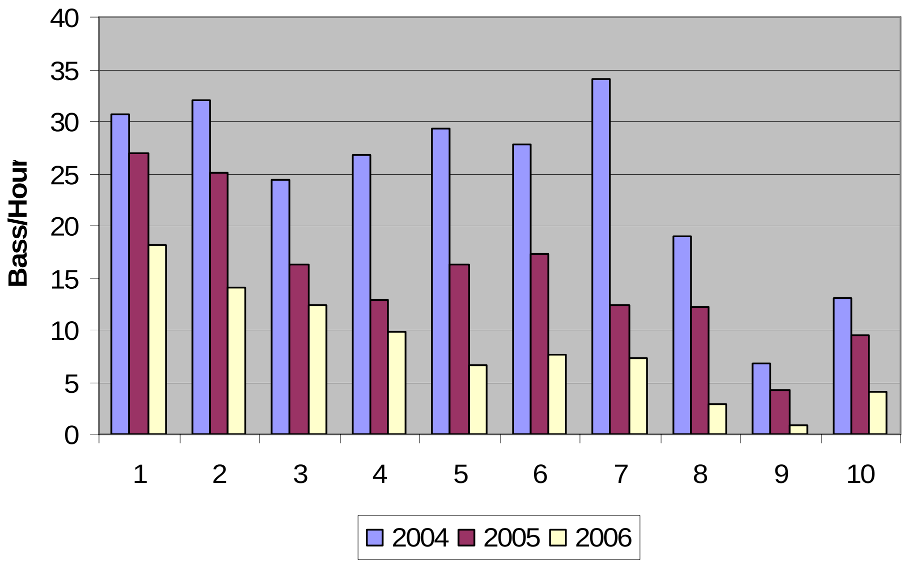

Figure 15. The 2004 – 2006 smallmouth bass CPE by reach [4-5 river miles per reach (see Table 1)]. Notice the gradual downstream decrease in showing in 2006.

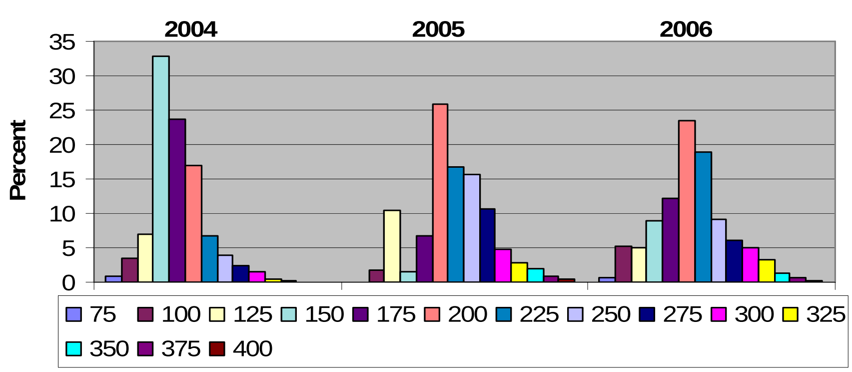

Figure 16. The 2004 – 2006 smallmouth bass length frequencies (total Length mm).

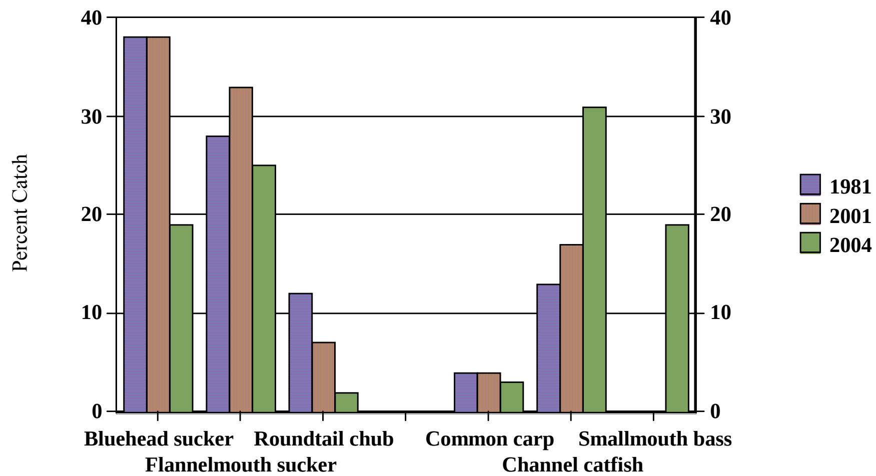

Figure 17. The 1981– 2004 comparison of native fishes and nonnative fishes in percent catch electrofishing (Tyus 1982 and Fuller 2004).

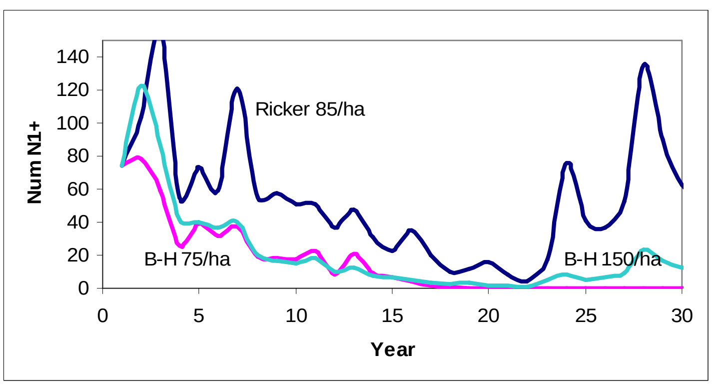

Figure 18. Exploit (u) at u = 0.64 for 20 years will bring *n* to 0 for all three recruitment hypotheses.

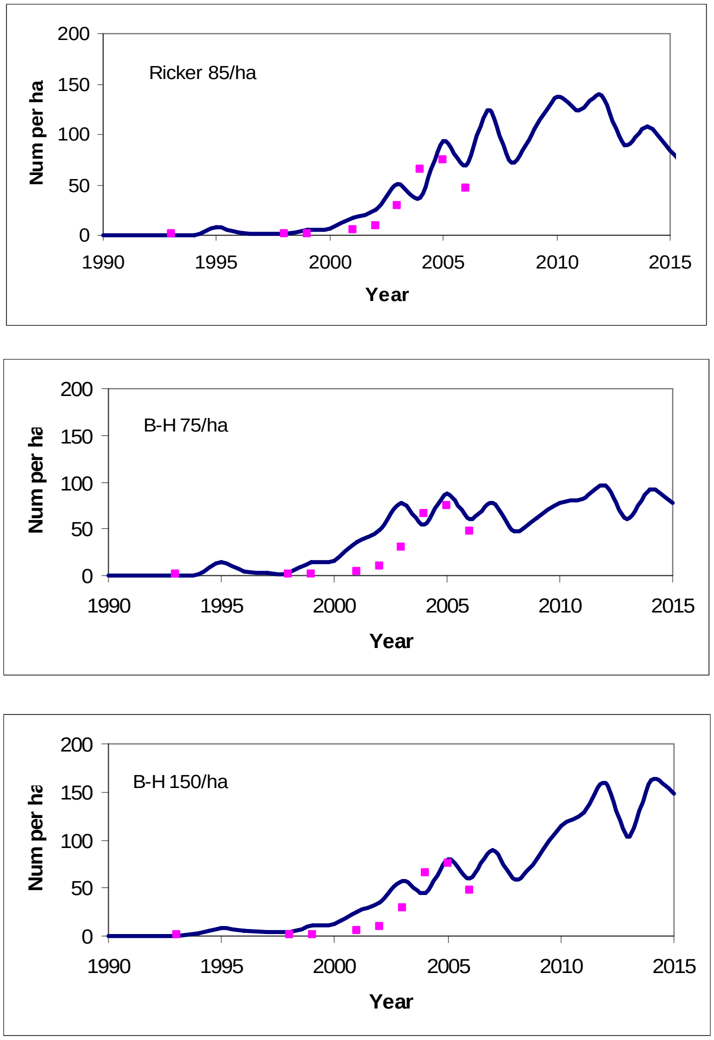

Figure 19. Historical catch data (dots) from smallmouth bass population estimates and CPE data scaled to population size and the three recruitment hypotheses (Ricker, Beverton-Holt 75 and Beverton-Holt 150). All three hypotheses show that the population size we calculated is congruent with the population sizes predicted by the models – regardless the removal effort.