U.S. Fish & Wildlife Service

Northern Pike Removal, Smallmouth Bass Monitoring, and Native Fish Monitoring in the Yampa River, Hayden to Craig Reach, 2004-2006

March 2008

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Synthesis Report
Project No. 98b

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March 2008

Table of Contents

Acknowledgements

The authors wish to thank Dave Beers, Tim Modde, Mark Fuller, Frank Pfeiffer, Michael Caldwell, Clint Goode, Chris Smith, Tony Clark, Chad Huffaker, Jake Ney and Ryan Remington for their help in the field and Billy Atkinson, John Hawkins, Tom Nesler, Lori Martin and Chris Hill for providing additional data and support. We wish to thank many Upper Colorado River Basin researchers for valuable comments along the way that helped the sampling design decision-making process. Dolores Manning and Shirley Eksund provided invaluable administrative support. Anne Roy and the National Conservation Training Center library staff helped in retrieving literature. The Nature Conservancy's® Carpenter Ranch provided logistical support.

This study was funded by the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. The Recovery Program is a joint effort of the United States Fish and Wildlife Service, United States Bureau of Reclamation, 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.

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List of Figures

List of Tables

Executive Summary

Northern pike (*Esox lucius*) is a large aggressive, esocid native to many North American drainages that has been widely stocked outside of its natural range. Smallmouth bass (*Micropterus dolomieu*) is an exotic predatory fish present in the Yampa River. The Upper Colorado River Endangered Fish Recovery Program has established an active program to control nonnative fishes in the main rivers of the upper basin to assist in recovery of the endangered fishes. Objectives of this study are 1) to reduce numbers of the adult northern pike population in the study reach, 2) determine northern pike abundance and size structure in the study reach and the subsequent changes in the abundance and structure after removal, 3) determine if sampling (removal) concentration areas is effective, 4) maintain public support for the Recovery Program by providing off-channel angling opportunities, and 5) to monitor the native fish community and smallmouth bass population in the study area and 6) monitor movement of smallmouth bass and northern pike.

Adult northern pike abundance estimates declined after a total of 2267 northern pike were removed from the river. Catch rates also declined within all years although no significant trends were detected. Mean length of northern pike captured varied by year and pass. Northern pike moved upstream and more often downstream between and within years. Northern pike angling tag returns from water where they had been relocated were 25% in 2004, 5% in 2005 and were not estimable in 2006. Recapture rates of smallmouth bass tagged within the study area were very low making movement and abundance estimates difficult. The native fish community in the study area is poorly represented. Several other non native fishes were captured during the study.

Introduction

Northern pike (*Esox lucius*) is a large aggressive, esocid native in many North American drainages. The fish has been widely stocked outside of its native range for recreational sportfishing purposes. Stocking of northern pike outside of its natural range can have many negative effects on native and endangered fishes, existing sport fisheries or commercial fisheries such as salmon in the Pacific Northwest (Conover 1986). Specifically, negative effects may include altering entire communities through top down trophic effects (Colby et al. 1987), colonization of pike beyond the introduction point (McMahon and Bennett 1996), and competition with, and predation on, existing fish in the system (Findlay et al. 2000).

Northern pike occur in warm and cool water reaches of the Yampa River, Colorado. Northern pike escaped from Elkhead Reservoir (a reservoir on Elkhead Creek, a Yampa River tributary) where it was originally stocked in 1977 to provide public fishing opportunities. Northern pike have since established a reproducing population in the Yampa River (Nesler 1995; J. Hawkins, Colorado State University, personal communication). The population provides a source for continual movement of pike into the lower Yampa River and further downstream into the Green River where it occupies habitats of four endangered fishes — Colorado pikeminnow (*Ptychocheilus lucius)*, razorback sucker (*Xyrauchen texanus*), bonytail (*Gila elegans*) and humpback chub (*Gila cypha*). Northern pike provide a significant predatory risk to these species, especially juveniles and small adults of Colorado pikeminnow and razorback sucker and a significant predatory risk to other native species in the basin (Martinez 1995; Nesler 1995). Northern pike were identified as presenting a significant risk to the endangered fishes by a majority of upper basin researchers in surveys conducted during the late 1980's (Hawkins and Nesler 1991).

Smallmouth bass (*Micropterus dolomieu*) is an exotic predatory fish present to abundant in lower elevation reaches of the Yampa River. Smallmouth bass were introduced into Elkhead reservoir in the late 1970's. Smallmouth bass have been reported to be significant predators on Colorado pikeminnow in the middle Green River (Crowl 1995). Smallmouth bass in the Yampa River are nonnative predators and competitors in a significant portion of endangered fish spawning and nursery habitats in the Yampa and middle Green rivers.

Although non native fish are now in the majority in the upper Yampa River, native fish do occur. Colorado pikeminnow are at least seasonally present in the upper reaches (Finney 2006), flannelmouth sucker, bluehead sucker, roundtail chub, and mountain whitefish have also been collected (Finney and Haines 2005, Nesler 1995).

The Upper Colorado River Endangered Fish Recovery Program has established an active program to control nonnative fishes in the main rivers of the upper basin to assist in recovery of the endangered fishes found there. To date, the Recovery Program has initiated reduction efforts via mechanical removal for channel catfish, smallmouth bass, and northern pike in the Yampa and Green rivers, channel catfish and smallmouth bass in the Colorado River and small cyprinids in the Colorado and Green River drainages. In some cases, such as the Yampa River, northern pike have been removed from the main channel and stocked into off-channel impoundments to provide fishing opportunity for local anglers. Objectives of this study are as follows:

1) Reduce numbers of adult northern pike in the study reach
2) Determine population size and structure of northern pike in the study reach and the subsequent changes in the population size and structure after translocation
3) Determine if targeting northern pike concentration areas is an effective removal strategy
4) Maintain public support for the Recovery Program by providing off-channel angling opportunities
5) Monitor the native fish community and smallmouth bass population in the study area
6) Monitor movement of smallmouth bass and northern pike

Study Site

The Yampa River is a relatively free flowing river that originates west of the continental divide and flows 320 km to its confluence with the Green River. The 37-mile portion of the Yampa that makes up the study site (Figure 1) flows through low gradient agricultural lands. Seasonal flows in the study reach fluctuate between 100 and 13,000 ft^3/s and average 1232 ft^3/s (USGS; Craig, CO gauge), however in recent years flows have been lower due to prolonged drought.

The Elkhead Creek joins the Yampa River at river mile 148.1. Elkhead Reservoir impounds the Elkhead Creek 7.25 miles upstream of the Yampa River. Seasonal flows in the Elkhead Creek, since impoundment, have ranged from 9 to 2430 ft^3/s (USGS; Maynard Gulch, CO gauge).

Elkhead Reservoir was recently enlarged to provide municipal water for the city of Craig, Colorado and water for increased base flows in the Yampa River. In the winter of 2004-2005 a temporary fish screen was installed during enlargement construction on the reservoir outlet in an attempt to prevent non-native sport fish from escaping into the river. The screen failed on April 16, 2005 (prior to 2005 sampling; P. Nelson, pers. comm.) at a discharge of 500 cubic feet per second during the ascending limb of the hydrograph. Flows in the Elkhead Creek peaked at 1250 ft^3/s in 2005 and 1100 ft^3/s in 2006. Flows up to 480 ft^3/s were screened in 2006.

Methods

Fish Collection, Marking and Translocation

Sampling occurred in the spring of 2004, 2005, and 2006 coinciding with higher spring flows (between 2500 and 6500 CFS; below Craig gauge) which make the river accessible by boats and when backwaters were flooded. The entire study reach was broken into 2-mile subreaches (the furthest downstream reach is > 2miles) and sampled 6 times in 2004 and 7 times each in 2005 and 2006. Northern pike were collected using a combination of fyke nets and electrofishing. Northern pike were collected in all years using two pulsed DC electrofishing boats (22mm dip net mesh), each sampling opposite sides of the river except in large backwaters when both boats were used. Five fyke nets were continuously deployed during the 2004 sampling season (Figure 1) on public land.

During the first electrofishing pass in 2004 and 2005 and the 2nd electrofishing pass in 2006, all pike were marked and released. During all other electrofishing passes, and all fyke netting sampling, pike were removed and stocked into ponds accessible to the fishing public.

In 2005 on passes three and four, sampling was focused on concentration areas (reaches with a high number of backwaters) identified in 2004 and concentration areas identified below the Elkhead Creek confluence (due to perceived fish escapement). In 2006, concentration areas identified from previous sampling passes (again, reaches with a high number of backwaters) were targeted on pass 6. A large backwater at river mile 150 that contained numerous age-0 and age-1 "juvenile" pike (<300mm TL; Colorado Division of Wildlife, unpublished data) received additional effort.

Pike were marked using a T-bar tag with an individual number and were pelvic finclipped as a means of double tagging to assess tag retention for the purpose of meeting population estimation assumptions. All northern pike were scanned for the presence of passive integrated transponder (PIT) tags that are being used by other investigators studying pike in the basin. Total lengths (TL, mm) of northern pike, river discharge (ft^3/s; taken from USGS gauge), effort (seconds) sampling each 2-mile reach, and capture reach for each pike collected were recorded.

All smallmouth bass captured were tagged with T-bar tags, total length and capture reach recorded, and were released. Bluegill and crappie were counted, measured (TL), and released on pass 1 in 2005 and euthanized on all other sampling passes. The number and location of any unusual species encountered was recorded. The number of mountain whitefish encountered was recorded during passes 6 and 7 in 2005 and pass 7 in 2006. All other native fish were measured (TL), and released. Endangered species encountered were handled and processed according to Recovery Program protocol.

Movement Determination

To determine movement for northern pike, we used a formula (see Finney 2004) that incorporates the standardized two-mile reach system and the reach or exact location where a tagged fish was recaptured or released. Movement was analyzed both within the annual sampling period and between years. Within sampling period movement may be affected by our intensive sampling. Fish tagged and released in a lotic ecosystem may exhibit a "fallback response" to being captured and marked, wherein they drift downstream upon release (Moser and Ross 1993, Hughes 1998). Therefore, we consider between year movements to be without bias and more accurate and informative.

Abundance Estimation and Statistical Techniques

Abundance estimates and 95% confidence intervals for northern pike were obtained in 2004-2006 using Petersen mark-recapture estimates. Tagging and recapture passes for abundance estimation were done on consecutive passes to meet population closure assumptions. The final abundance estimates derived from electrofishing data in 2004 took into account the removal of pike through the fyke netting effort by adding the number of pike removed by fyke nets to the final point estimate. This method was similar to that used in 2006, adding the pike removed from pass 1 to the final total. This was

deemed accurate, as the number of pike removed by fyke nets or pass 1 is an absolute. To avoid error from multiple capture techniques, care was taken to remove any pike from the data set used to derive abundance estimates that were captured by fyke nets and removed before the possibility of recapture with electrofishing boats.

The abundance of smallmouth bass was estimated only in 2004. Low recapture rates in other years precluded mark recapture estimation. Due to anomalies in capture locations and efficiency by pass, the population of smallmouth bass in the removal reach was estimated only downstream of the Elkhead Creek using data only from passes 4, 5 and 6 when smallmouth bass immigrated into the study reach. The smallmouth bass population for this portion of the reach was estimated using standard multiple mark recapture methods and program CAPTURE closed population models (White et al. 1992).

Northern pike catch rates and changes in mean length of pike as sampling progressed within years were tested for differences using least squares linear regression analysis. Changes in mean length between different subreaches were tested using single factor analysis of variance.

Results

Northern Pike

Adult northern pike abundance estimates declined when 2267 northern pike were removed from the river (Table 1). Estimates were precise in 2004 and 2006 but the escapement of fish from Elkhead Reservoir in 2005 imposed bias. We removed 47-63% of the total adult population in each year. Numbers of pike decreased on all passes, all years, and capture probabilities typically declined as sampling progressed (Figure 2). As removal progressed during the study period, the presence of juvenile fish became more prevalent (Table 2). An increase in juvenile abundance was identified in 2005 and tapered off between 2005 and 2006. Northern pike captured in individual length classes was uniform in 2004 before major removal effects, shifting to a large number of smaller pike in 2005 and the subsequent small length class recruiting to larger length classes in 2006 (Figure 3).

Northern pike catch rates declined across the whole sampling period and were highly correlated with population size (Figure 4). Catch rates declined across the study period although no significant trends were detected (Figure 5). Based on changes in catch rates, the effectiveness of targeting concentration areas was supported in 2005 and 2006 (Figure 5). Catch rates varied by reach (Figure 6) and was indicative of habitat conditions in the reaches, reaches with backwaters having higher catch rates. Catch rates declined over time in reaches upstream of the Elkhead Creek confluence across all years, while typically remaining similar in reaches downstream of the Elkhead Creek confluence. Catch rates in the reach with the large backwater (RMI 149-151) increased between 2004 and 2005 due to a high abundance of juveniles (<300mm TL) in this reach but decreased in 2006.

Mean length of northern pike captured varied by year and pass (Figure 7). Mean length was different between passes in 2004 (d.f. = 5, $F= 30.932$, $P < 0.001$), 2005 (d.f. = 6, $F= 20.699$, $P < 0.001$) but not in 2006 (d.f. = 6, $F= 0.631$, $P = 0.710$). Mean length

declined in 2004 (d.f. = 5, F= 20.52, P = 0.01) but did not decline in 2005 (d.f. = 6, F= 0.18, P = 0.69) or 2006 (d.f. = 6, F= 2.14, P = 0.20).

Northern pike that we tagged moved upstream and downstream between and within years (Table 3). Movement tended to be downstream with dramatic movements as far as 86.4 miles. One tagged fish moved as far upstream as 32.4 miles. Downstream movement was more dramatic in 2005. In addition to pike from our study, a pike captured originally by the Colorado Cooperative Fish and Wildlife Research Unit was recaptured in Yampa Canyon during sampling for smallmouth bass that had moved downstream 100 miles over the course of one year and one month and two pike from our study were recaptured in the Green River near the mouth of the Yampa in July of 2005, having moved downstream over 125 miles in less than 4 months.

Northern pike captured in our study reach typically came from upstream areas (Table 4). A total of 81 NP that were tagged and released upstream of our study reach and were recaptured from 2004 to 2006. Twenty-two fish came from downstream reaches. Seven of the 15 pike of upstream origin captured in 2006 were from Catamount Reservoir, the first year in which tagged fish from this area were captured in our study area.

Angler Returns

Anglers were instructed by signs to return tags to a box located on the state wildlife area where pike were stocked. Northern pike tag returns were 25% in 2004, 5% in 2005 and inestimable in 2006. Previous years tag returns from pilot studies were 56% in 2002 and 41% in 2003. We captured thirteen, nine, and zero known pike in the river that were previously placed in state wildlife areas ponds in 2004, 2005 and 2006, respectively. Of the 22 escapees, 2 were recaptured before the river connected to the off channel ponds making these fish suspect of being moved by anglers.

Smallmouth Bass

Smallmouth bass were captured in significant numbers in 2004 making an abundance estimate possible. Fewer bass were captured in 2005 and 2006 (Table 5). Smallmouth bass were typically found in downstream reaches of the study area (Figure 9). Smallmouth bass encounters increased later in the sampling year.

Recapture rates of smallmouth bass tagged within the study area were very low making movement estimates difficult. Despite this we captured bass that had been tagged in downstream reaches by other investigators. Of the 40 smallmouth bass that had been previously tagged by other investigators, 11 of them had been previously captured in the river and re-released in the Elkhead reservoir, 0 in 2006, 9 in 2005 and 2 in 2004.

Native Fish

A total of 205 native fish were encountered between 2004 and 2006 (Table 6). The majority of the fish captured were mountain whitefish. No native fish that were captured and released alive in this study were recaptured (if tagged) to our knowledge.

Ancillary Fish Captures

Other than smallmouth bass, northern pike, and native fish, several other fishes were captured during the study. Few were captured in 2004, most were captured in 2005, and captures declined in 2006 (Table 7). All of these fish were euthanized, save 59 bluegill (*Lepomis macrochirus*) and 52 black crappie (*Pomoxis nigromaculatus*) captured on pass 1 in 2005. All ancillary fish with the exception of 12 bluegill were captured downstream of the Elkhead Creek confluence.

Discussion

Northern Pike

Northern pike abundance estimates derived in 2004, 2005, and 2006 allowed for quantification of our removal effectiveness. Within our constricted sampling period we feel all necessary population estimation assumptions were met. Although an estimate was possible in 2005, the immigration of fish into the system casts doubt on its precision. Although the possibility of using catch rates as an index of abundance in the reach has been discussed, the authors feel that the elimination of marked individuals would detract from precision and accuracy of abundance, eliminate the possibility of analyzing movement, and detract from the analysis of other population and individual based statistics such as survival rates and recruitment.

The presence of juvenile fish fluctuated greatly by year. Our impression was that adult abundance control in 2004 led to the large 2005 year class (due to lack of cannibalism) and the lack of a large age-1 size class in 2006 is indicative of a large effect on recruitment through our removal efforts. Two schools of thought in deterring pike year class are density dependent biotic factors (cannibalism) or abiotic factors (i.e. winter kill, discharge, backwater availability). For examples see Kipling and Frost (1970) Casselman and Lewis (1996) Franklin and Smith (1963), Johnson (1957), Clark (1950), Scott and Crossman (1973), and Kozmin (1981). Conflicts between these factors make analysis difficult due to our removal. Nesler (1995) and Hill (2004) previously identified backwaters as important sources of juvenile pike in the Yampa River. Backwaters with the highest abundance of juvenile pike are thought to be most important for spawning (Hawkins et al. 2005) and in our study area are prime spawning habitats and source populations (Nesler 1995). It remains that the increased year class may be due to our removal (and the subsequent decrease in intra-specific competition and cannibalism) thereby somewhat negating efforts, but with enough sustained effort, year class strength can be diminished. Lack of juvenile pike density throughout the study reach in 2005 eliminates blame from Elkhead escapement.

The above mentioned screen failure was cause for field investigators and the authors to suspect an escapement event of fishes (including pike) from Elkhead Reservoir and into the Yampa River. The following data and observations seem to support this event (see also Finney 2005):

1) Differences in catch rates both above and below the Yampa/Elkhead confluence between 2004 and 2005. The CPUE in 2-mile subreaches above the confluence decreased in all but one reach between 2004 and 2005. Conversely,

the CPUE in reaches below the confluence increased or remained analogous in 2005.

2) Several large pike (>1000mm) were captured in 2005 (n=5) despite a significant reduction in mean total length in 2004 when only 2 were captured. We feel it is very probable that some, if not all, of these fish came from Elkhead Reservoir where pike reach larger sizes than they do in the Yampa River (CDOW, unpublished data). In 2006 and 2007 only one pike greater than 1000mm was captured.

3) Crews also encountered pike that had numerous lacerations on their bodies different from those that would be expected from normal spawning behavior. We feel these lacerations may have come from swimming over the top of a dam, through a broken metal fish screen and into the plunge pool below the dam.

4) We (and others downstream) observed an increase in the presence of ancillary fishes [bluegill (*Lepomis macrochirus*), white crappie (*Pomoxis annularis*), green sunfish (*Lepomis cyanellus*), and largemouth bass (*Micropterus salmoides*)]. recorded in downstream areas from the Elkhead/Yampa confluence.

5) While sampling Elkhead Reservoir when the water level (pool elevation lower) was drawn down for reservoir enlargement construction, a lack of northern pike was noted (B. Elmblad, Colorado Division of Wildlife, Personal Communication)

6) Hawkins et al. (2005) reported similar phenomenon in the past relating Elkhead Reservoir drawdown to an increase in pike abundance in the Yampa River, "During the drawdown (1992), a large portion of the reservoir fishery including smallmouth bass and northern pike were transported in Elkhead Creek and Yampa River. The loss of gamefish from the reservoir into the river was significant enough to be noticed by reservoir anglers".

Catch rates varied between passes in all years, in part due to our removal efforts and in part due to varying sampling conditions between passes. The lack of a statistically significant decline in catch rates may be due to the increase catchability of northern pike at lower flows as sampling progressed. Over the three-year sampling period, more northern pike were taken out of the study area than were estimated within the study area for a given year. Our efforts caused a decline in CPUE and capture probability over time, similar to declines shown with increased effort by Mann (1980). We removed greater than 50 percent of the pike population in two of three years of sampling. Goeman and Spencer (1992) removed 3-15% of pike over a six-year period and noticed no difference in density. A more advanced statistical approach is necessary to obtain develop a strategy outlining the precise amount and type of effort needed to minimize reproduction and achieve a population crash.

Although our data are limited we feel targeting concentration areas may be a valid removal strategy. Our concentration areas were low velocity vegetated backwaters. Targeting concentration areas for increased yield or catch is a common practice in commercial pike fishing (Rosell and MacOscar 2002) and localized areas of pike concentration coincide with low velocity vegetated areas preferred by riverine pike (Desantos 1991). Holland and Huston (1984) caught 10 times more pike in vegetated backwaters,

With the amount of effort used and the gears employed, we removed larger individuals in the population and reduced individual mean length of the population. Size selectivity of gears, while a problem in fish surveys (Junge and Libsvarsky 1965; Thompson and Rahel 1996), may be used to advantage in removal projects by selectively removing large individuals, however, multiple removal passes begin to eliminate the effects of size selectivity (Kulp and Moore 2000). Electrofishing selects for larger individuals (Reynolds 1989). The size shift in the Yampa River northern pike populaion attributable to electrofishing was causal. Goeman et al. (1993) found trap netting ineffective in altering northern pike population structure. Selective removal of fish has been previously suggested for altering populations size structure (Evans et al. 1987; Walters 1987) and Dunning et al. (1982) found increases in harvest of larger fish caused a subsequent decrease in fishing yield. Broughton and Fisher (1981) found an increase in larger fish after removal, contrary to Kipling and Frost (1970) and Otto (1979) and our data. The differences in changes in size structure between studies is likely a function of the system in which they occur and the nature of pre removal population dynamics. The extensive examination of these variables is beyond the scope of this study.

Electrofishing and fyke nets employed were effective at capturing and removing northern pike. Fyke netting was effective at targeting and depleting populations in localized areas, whereas electrofishing was more effective in removing fish from a larger area and diverse habitats. Meronek et al. (1996) found fyke nets were useful in capturing northern pike. Like Moore et al. (1983) and Thompson and Rahel (1996), we also found electrofishing labor intensive. Electrofishing alone proves difficult in capturing riverine pike (Tyus and Beard 1990), but sampling in the spring, when pike were in spawning condition and known to be vulnerable to capture and exploitation (Paukert et al. 2001) helped our efforts. Using different gears, where appropriate, is an effective way of increasing removal efficiency by addressing factors such as habitat complexity (Grant and Noakes 1987), deep water (Riley and Fausch 1992) and fish size (Reynolds 1989). Like our study, the majority of previously successful mechanical fish control projects used a combination of methods, whereas unsuccessful ones typically did not (Meronek et al. 1996). Unfortunately, land access limited the use of fyke nets and they were consequently discontinued after depleting localized areas. Removal effectiveness would undoubtedly increase were we able to fish nets in other areas.

Recapture rates by anglers of tagged pike from floodplain ponds may be underestimated. There is some angler resentment to our current management of northern pike in removal area. Fish are being caught by anglers and kept or caught and released with the tags still in them in either the angler accessible ponds or into the river itself (B. Atkinson, Colorado Division of Wildlife, personal communication). In addition to angler animosity, natural factors play a role in underestimation of tag returns. Personnel that stock pike on a daily basis have noticed mortalities. Cannibalism is another natural occurrence that introduces bias into return estimates. We released a large number of pike into a small body of water and it is probable that pike preyed upon one another in the pond, especially considering the large size class differences of pike being released (range 93 –1022 mm). In addition, the smallest of size classes of pike released are probably not being harvested by anglers.

Northern pike in the removal area are generally moving downstream in the spring (see annual reports FY 2004-2006). There are several hypotheses reasons for this downstream

movement. One reason for this downstream movement may be competition for resources in the area is high and fish are seeking better foraging habitat downstream. Fish from downstream may be seeking quality spawning habitat in the spring before our sampling and consequently our data displays the post spawn movement back downstream. Pike may be moving in response to highly fluctuating seasonal flows and the subsequent effect on habitat availability. Northern pike in riverine environments may move to colonize new areas (Mann 1980) and migrate to spawning areas (Cassellman and Lewis 1996). Finally, fish from Elkhead Reservoir may be exhibiting a "fall back" response and drifting downstream after entering the Yampa.

The majority of NP that were tagged outside our study area and recaptured within the area came from upstream. The 81 NP that were recaptured that originated from upstream tagging studies represent an unknown percentage of the total number of fish that moved into our study area from upstream reaches. The immigration of NP into our study area from upstream reaches suggests a need to expand removal efforts to upstream areas to more effectively reduce the abundance of NP in our study area.

The proportion of tags collected from upstream and downstream areas, while somewhat a function of movement, may also be a function of the number of fish tagged. Tagging occurred in upstream areas of the Yampa River in 2004 and to a lesser degree 2005, and ceased in 2006. This may help explain the decline in tags collected from upstream areas as the study progressed. Similarly the number of northern pike tagged in Catamount Reservoir drastically increased (B. Atkinson, Colorado Division of Wildlife, pers. comm.), potentially explaining the increase in Catamount origin fish in 2006 (Finney and Haines 2006). Numbers of pike tagged in downstream reaches remained fairly constant across the study period.

Escapement of fish from off channel sources such as reservoirs impact downstream riverine fisheries. In our case, as similarly reported by Navarro and McCauley (1993), escapement from a water storage reservoir was the culprit. Additionally, Hawkins et al. (2005) found a historic escapement event in 1992 of northern pike from Elkhead Reservoir that was noticeable to Elkhead Reservoir anglers. This event was a reservoir drawdown similar to the 2005 drawdown. Although Miller et al. (2005) did not detect pike escaping from Elkhead Reservoir in 2003 or 2004, methods employed were not conducive to capturing large adults, spill was low compared to 2005, and the spillway was not altered at that time as it was during the 2005 runoff. To a lesser extent, escapement from stocked flood plain ponds negated our removal efforts, but the public relations benefits of restocking these fish may have mitigated for impacts. Nesler (1995) stated that gravel pit ponds in the Craig area were important sources of escapee pike but our sampling of these habitats did not support this (USFWS, unpublished data). Escapement of pike from Elkhead Reservoir not only added individuals to riverine population but also impacted our ability to detect our removal successes and failures. The addition of fish into the river from Elkhead Reservoir affected the validity of population estimates by violating closure assumptions, our ability to detect changes in catch rates, our ability to effectively reduce mean length, and our ability to target concentration areas.

Many valuable lessons about removing northern pike from a riverine environment have been learned or confirmed in this study and we recommend fishery managers implement them in future investigations. Despite some perceived successes we must caution against several common misconceptions. First, fish control may simply be

treating the symptom and not the problem. The question of whether successful invasion by non native fish is dependent upon habitat degradation or simply the act of the fish (and its life history attributes) being present through introduction, begs to be answered and fully understood. Second, despite our "success", managers must be careful when undertaking control projects and must take great care in how "success" is defined. Ultimately, success in our case would be an increase in the abundance of native and listed species in the study area or areas downstream. As Beamesderfer (2000) stated, "Real opportunities for impact [from non native fish removal] will remain difficult to discern from false cases which look good but accomplish nothing".

Smallmouth Bass

Smallmouth bass are seasonally present to abundant in the study area. Evidence points to an annual upstream migration of smallmouth bass in the Yampa River (though not detected in all years) during the warmer months as fish from downstream move up into warming, low velocity upstream areas. Coupled with our inability to sample the reach later in the year, these late year movements seemingly make downstream the study reach unimportant in the control of this species.

Native Fish

Three notable aspects of the native fish stand out. The first is that not a single chub was captured. Roundtail chub have been present in this area in the past (Nesler 1995). Second are the lack of pure strain native suckers and the high incidence of hybrid suckers and white suckers in the study area. Third, is the capture of 2 adult Colorado pikeminnow (see Finney 2006). These fish are the furthest upstream capture of a Colorado pikeminnow by scientists in the basin.

Ancillary Fish Captures

Ancillary fish captures were minimal in 2004, dramatically increasing in 2005 and decreasing in 2006. The trend of few fish in 2004, a large increase in 2005, and a dramatic decline in 2006 from the numbers seen in 2005 and is indicative of Elkhead Reservoir fish escaping in 2005. Because of their life history being poorly suited to a riverine environment, fewer fish were found in 2006.

Conclusions

- Northern pike were affected by our efforts in the study reach. Reductions in mean size, abundance, and catch rates were observed both within and among years.
- Northern pike exhibited a general upstream to downstream movement pattern when previously tagged fish were encountered.
- Presence and abundance of smallmouth bass in the study reach was highly variable between study years. Smallmouth bass were generally found in the downstream portions of the study area during sampling.
- Native fish fauna is depauperate in the study reach.

Management Recommendations

1. Continue with 7 passes until a more effective strategy can be defined. This strategy may include modeling exploitation in order to discover a population crash point, affecting recruitment in some way, and targeting pike in large backwaters exclusively.
2. Identify sites for fyke nets and obtain permission for access to set, maintain, and monitor their effectiveness.
3. Continue to monitor native fishes in the study area. Due to their rareness in the reach, and the intensive removal effort in the reach, this should be able to be accomplished with minimal effort.
4. Expand control efforts to upstream areas and explore escapement prevention measures on reservoir outlet structures.

Literature Cited

Beamesderfer, R. C. P. 2000. Deciding when intervention is appropriate. Fisheries 25 (6):18-23.

Broughton N. and K. Fisher. 1981. A comparison of three methods of pike (*Esox lucius*) removal from a lowland trout fishery. Fishery Management 12:101-106.

Casselman, J. M. and C. A. Lewis. 1996. Habitat requirements of northern pike (*Esox lucius*). Canadian Journal of Fisheries and Aquatic Science 52 (Suppl. 1): 161-174.

Clark, C. F. 1950. Observations on the spawning habits of northern pike, Esox lucius, in northwestern Ohio. Copeia 1950:285-288.

Colby, P. J., P. A. Ryan, D. H. Schupp, and S. L. Serns. 1987. Interactions in north-temperate lake fish communities. Canadian Journal of Fisheries and Aquatic Sciences 44:104-128

Conover, M. C. 1986. Stocking cool-water species to meet management needs. Pages 31-39 *in* R.H. Stroud, ed. Fish culture in fisheries management. American Fisheries Society, Bethesda, MD.

Crowl, T.W. 1995. Nonnative fish control report for the Green and Duchesne rivers. RIP Annual Report Meeting. Grand Junction, Colorado.

Desantos, J. M. 1991. Ecology of a riverine pike population. Warmwater Fisheries Symposium I, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-207.

Dunning, D. J., Q. Ross, and J. Gladden. 1982. Evaluation of minimum size limits for St Lawrence River northern pike. North American Journal of Fisheries Management 2:171-175.

Evans, D. O., B. A. Henderson, N. J. Box, T. R. Marshall, R. T. Oglesby, and W. J. Christie. 1987. Concepts and methods of community ecology applied to freshwater fisheries management. Canadian Journal of Fisheries and Aquatic Sciences 44 (Supplement 2):448-470.

Findlay, C. S., D. G. Bert, and L. Zheng. 2000. Effect of introduced piscivores on native minnow communities in Adirondack lakes. Canadian Journal of Fisheries and Aquatic Sciences Vol. 57, No. 3

Finney, S. T. and G. B. Haines. 2004. Translocation of northern pike from the Yampa River upstream of Craig, Colorado. Annual Report to the Recovery Program for the Endangered Fishes of the Upper Colorado River, Project 98b. U. S. Fish and Wildlife Service, Vernal, Utah.

Finney, S. T. 2005. Escapement of Northern Pike from Elkhead Reservoir. Memorandum to the Director's Office for the Recovery Program for the Endangered Fishes of the Upper Colorado River Basin.

Finney, S. T. and G. B. Haines. 2005. Translocation of northern pike from the Yampa River upstream of Craig, Colorado. Annual Report to the Recovery Program for the Endangered Fishes of the Upper Colorado River, Project 98b. U. S. Fish and Wildlife Service, Vernal, Utah.

Finney, S. T. and G. B. Haines. 2006. Translocation of northern pike from the Yampa River upstream of Craig, Colorado. Annual Report to the Recovery Program for the Endangered Fishes of the Upper Colorado River, Project 98b. U. S. Fish and Wildlife Service, Vernal, Utah.

Finney, S. T. 2006. Colorado pikeminnow (*Ptychocheilus lucius*) upstream of critical habitat in the Yampa River, Colorado. Southwestern Naturalist 50:262-263.

Franklin, D. R., and L. L. Smith, Jr. 1963. Early life history of the northern pike, Esox lucius L., with special reference to the factors influencing the numerical strength of year classes. Transactions of the American Fisheries Society 92:91-110.

Goemann, T. J. and P. D. Spencer. 1992. Fish community responses to manipulation of northern pike and yellow perch densities in a Minnesota lake. Minnesota Department of Natural Resources Completion Report, Investigation Report # 416, 20pp.

Goemann, T. J., P. D. Spencer, and R. B. Pierce. 1993. Effectiveness of liberalized bag limits as management tools for altering northern pike population size structure. North American Journal of Fisheries Management 13:621-624.

Grant, J. W. A., and D. L. G. Noakes. 1987. Escape behavior and use of cover by young-of-year brook trout, *Salvelinus fontinalis*. Canadian Journal of Fisheries and Aquatic Science 45:55-58.

Hawkins, J. A., and T. P. Nesler. 1991. Nonnative fishes in the upper Colorado River basin: an issue paper. Final Report. Colorado State University Larval Fish Laboratory and Colorado Division of Wildlife, Fort Collins.

Hawkins, J. C. Walford, and T. Sorenson. 2005. Northern pike management studies in the Yampa River, Colorado, 1999-2004. Final report. Contribution 137, Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado. 56pp.

Hill, C. G. 2004. Dynamics of northern pike spawning and nursery habitat in the Yampa River, Colorado. M. S. Thesis, Colorado State University, Fort Collins, Colorado.

Holland, L. E. and M. L. Hutson. 1984. Relationship of young-of the-year northern pike to aquatic vegetation types in backwaters of the upper Mississippi River. North American Journal of Fisheries Management 4:514-522.

Hughes, N. F. 1998. Reduction in growth and tagging may change interannual movement behavior of stream salmonids: evidence from arctic grayling in an interior Alaskan stream. Transactions of the American Fisheries Society 126:1072-1077.

Johnson, F. H. 1957. Northern pike year-class strength and spring water levels. Transactions of the American Fisheries Society 86:285-293.

Junge, C. O., and J. Libsvarsky. 1965. Effects of size selectivity on population estimates based on successive removals with electrofishing gear. Zoologicke listy 14:171-178.

Kipling, C. and Frost, W. E. 1970. A study of the mortality, population numbers, year class strengths, production and food consumption of pike, Esox lucius L., in Windmere from 1944 to 1962. Journal of Animal Ecology 39: 115-157.

Kozmin, A. K. 1981. The biology of the pike from Lake Lacha. Journal of Ichthyology 20:44-48.

Kulp, M. A. and S. E. Moore. 2000. Multiple electrofishing removals for eliminating rainbow trout in a small southern Appalachian stream. North American Journal of Fisheries Management 20:259-266.

Mann, R. H. K. 1980. The numbers and production of pike (Esox lucius) in two Dorset Rivers. Journal of Animal Ecology 49:899-915.

McMahon, T. E. and D. H. Bennett. 1996. Walleye and northern pike: boost or bane to northwest fisheries? Fisheries, Vol. 21 No. 8.

Martinez, P. J. 1995. Coldwater Reservoir Ecology. Colorado Division of Wildlife, Federal Aid in Fish and Wildlife Restoration Project F-242R-2, Job Final Report, Fort Collins.

Meronek, T. G., P. M. Bouchard, E. R. Buckner, T. M. Burri, K. K. Demmerly, D. C. Hatleli, R. A. Klumb, S. H. Schmidt, and D. W. Coble. 1996. A review of fish control projects. North American Journal of Fisheries Management 16:63-74.

Miller, W. J., D. E. Rees, and J. A. Ptacek. 2005. Elkhead Reservoir Escapement. Final Report to the Recovery Program for the Endangered Fishes of the Upper Colorado River. Project No. 118, Miller Ecological Consultants, Fort Collins, Colorado.

Moore, S. E., B. Ridley, and G. L. Larson. 1983. Standing crops of brook trout concurrent with removal of rainbow trout from selected streams in Great Smoky Mountains National Park. North American Journal of Fisheries Management 3:72-80.

Moser, M. L., and S. W. Ross. 1993. Distribution and movements of anadromous fishes of the lower Cape Fear River, North Carolina. Final Report to U.S. Army Corps of Engineers, Wilmington, North Carolina.

Navarro, J. E., and D. J. McCauley. 1993. Fish escapement from two storage reservoirs in Michigan. Rivers 4:36-47.

Nesler, T. P. 1995. Interactions between endangered fishes and introduced game fishes in the Yampa River, Colorado, 1987-1991. Final Report, Federal Aid Project SE-3. Colorado Division of Wildlife, Fort Collins.

Otto C. 1979. The effects on a pike (*Esox lucius*) population of intensive fishing in a south Swedish lake. Journal of Fish Biology 15:461-468

Paukert, C. P., J. A. Klammer, R. B. Pierce, and T. D. Simonson. 2001. An overview of northern pike regulations in North America. Fisheries 26(6):6-13.

Reynolds, J. B. 1989. Electrofishing. Pages 147-163 *in* L.A. Nielsen and D. L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Riley, S. C., and K. D. Fausch. 1992. Underestimation of trout population size by maximum-likelihood removal estimates in small streams. North American Journal of Fisheries Management 12:768-776.

Rosell, R. S. and K. C. MacOscar. 2002. Movements of pike, *Esox lucius*, in Lower Lough Erne, determined by mark-recapture between 1994 and 2000. Fisheries Management and Ecology 9:189-196.

Scott W. B. and E. J. Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada Bulletin 184. 966 pgs.

Thompson, P. D. and F. J. Rahel. 1996. Evaluation of depletion-removal electrofishing of brook trout in small rocky mountain stream. North American Journal of Fisheries Management 16:332-339.

Tyus, H. M and J. M. Beard. 1990. Esox lucius (esocidae) and Stizostedion vitreum (Percidae) in the Green River Basin, Colorado and Utah. Great Basin Naturalist 50:33-39.

Walters, C. J. 1987. Nonstationarity of production relationships in exploited populations. Canadian Journal of Fisheries and Aquatic Science 44(Supplement 2):156-165.

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.

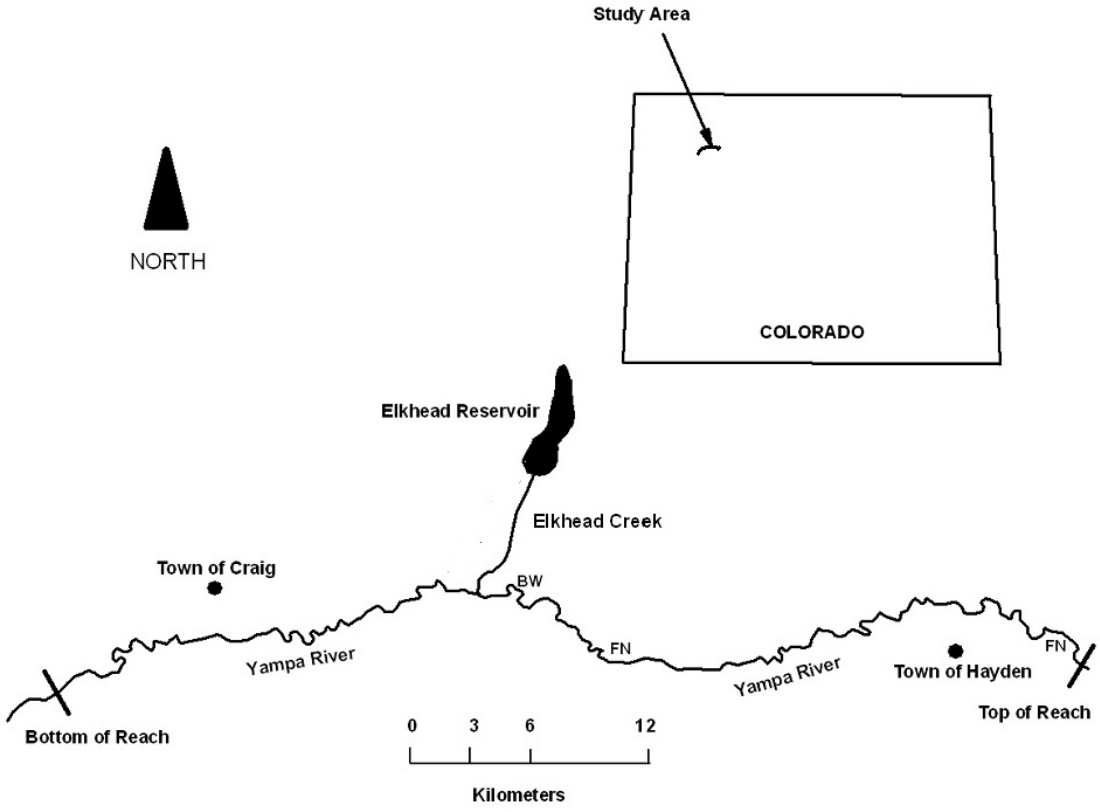

Figure 1. Upper Yampa River Study Site. Location of the largest backwater in the study site is noted with "BW" and fyke netting locations are noted with "FN".

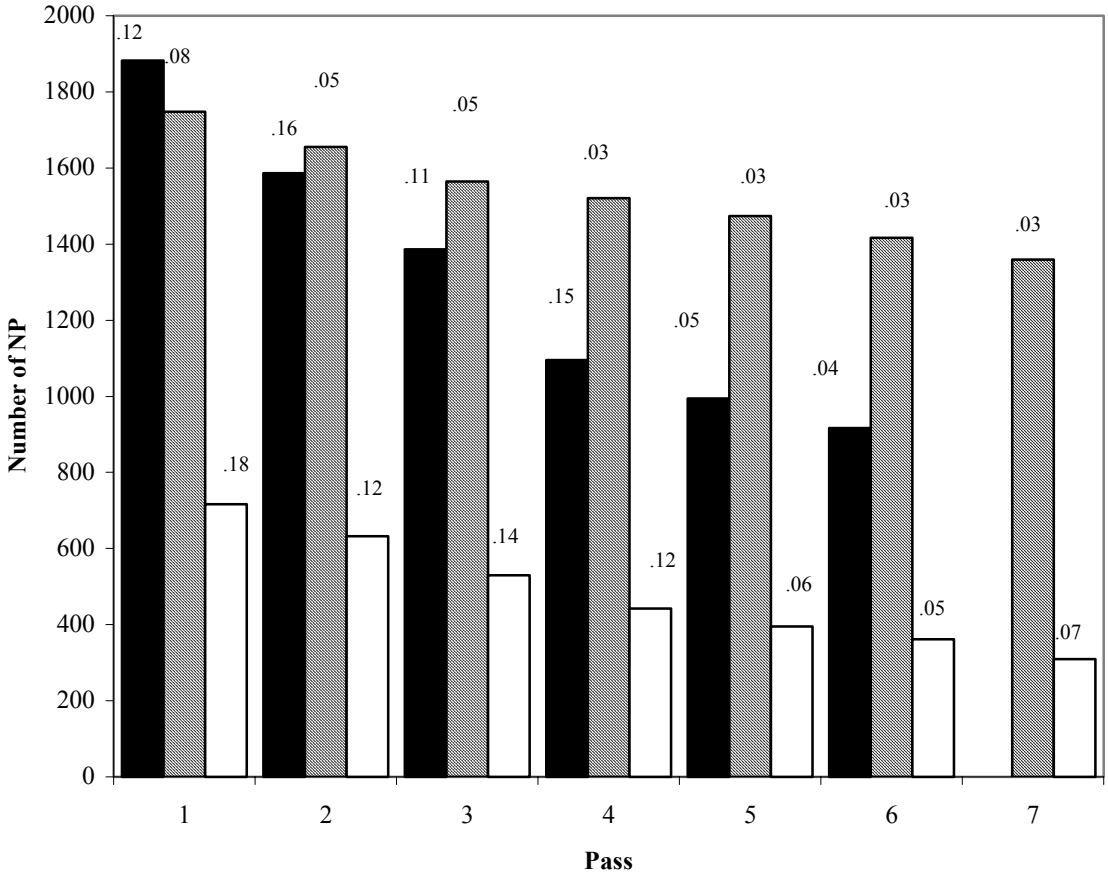

Figure 2. Northern pike (NP) remaining in the study reach after each pass based on population estimate and numbers removed. Dark bars represent 2004, slashed represent 2005 and open bars represent 2006. Adults only are represented in 2005 and 2006 data. Capture probabilities by pass are shown above the bars.

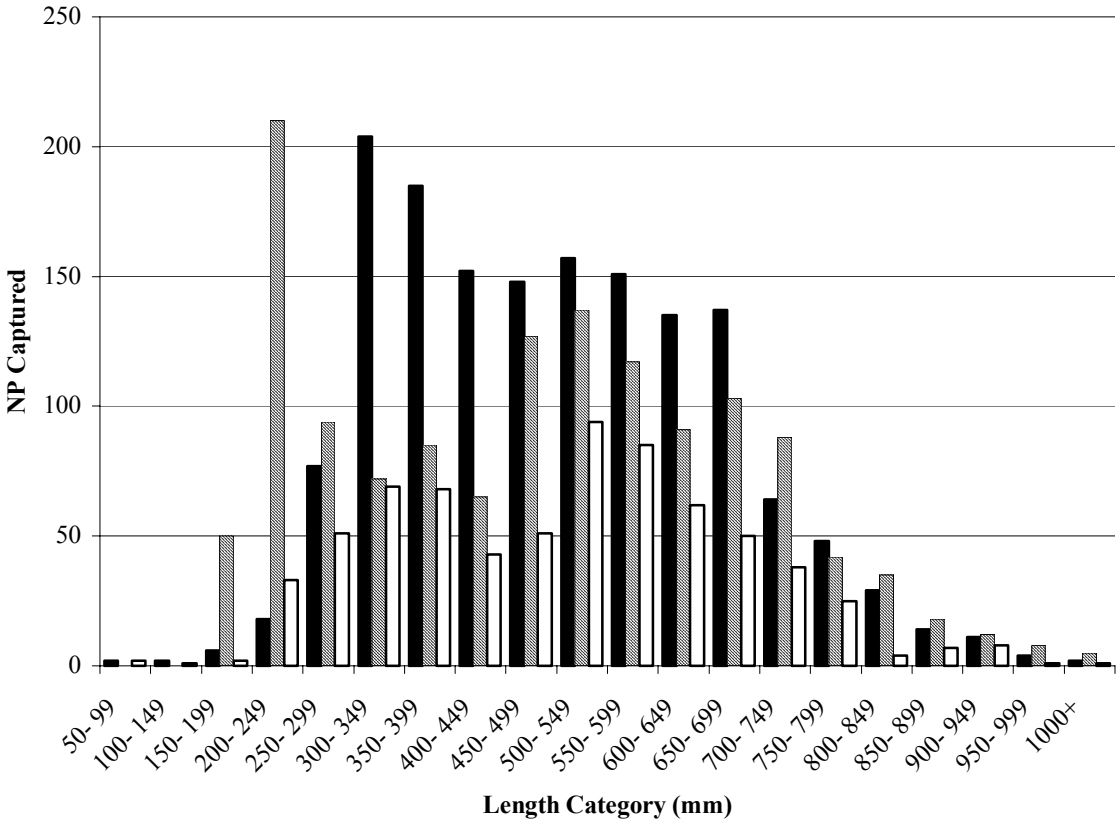

Figure 3. Number of northern pike (NP) captured in each length category, all sampling passes in 2004-2006 in the Yampa River. Dark bars represent 2004, slashed represent 2005 and open bars represent 2006.

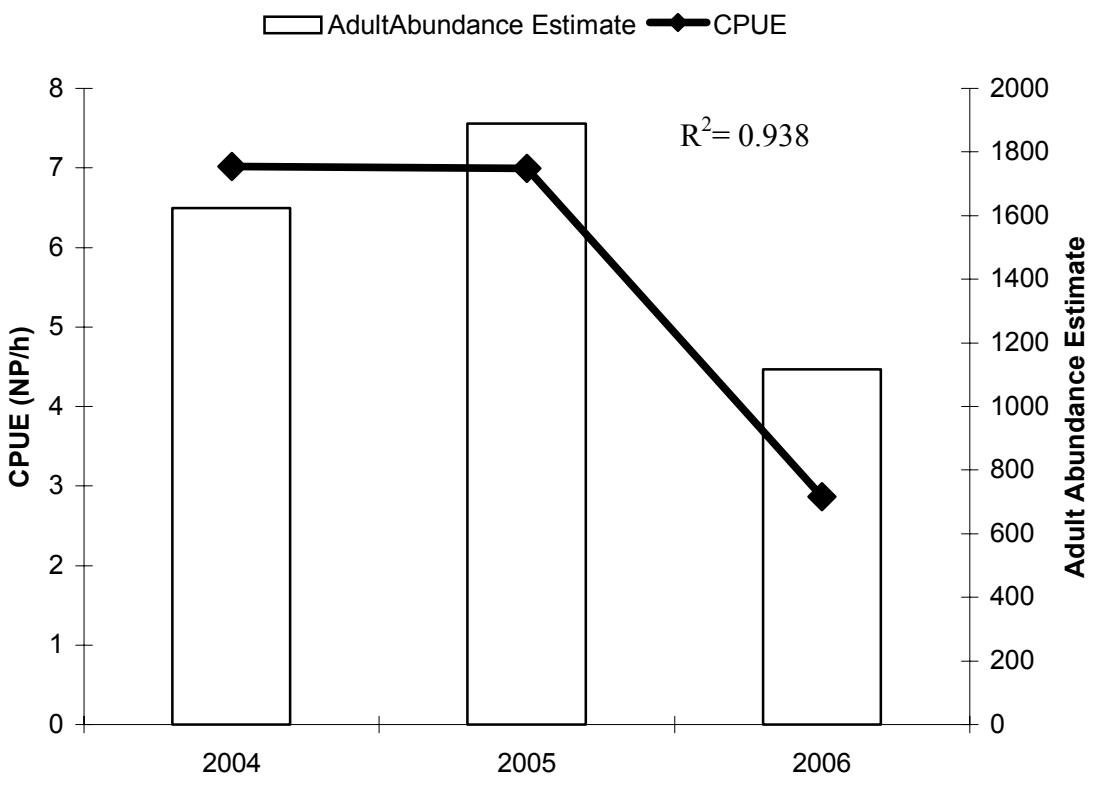

Figure 4. Catch per unit of effort (CPUE) and adult abundance estimates for northern pike (NP) during he spring of 2004, 2005, and 2006, Yampa River Colorado.

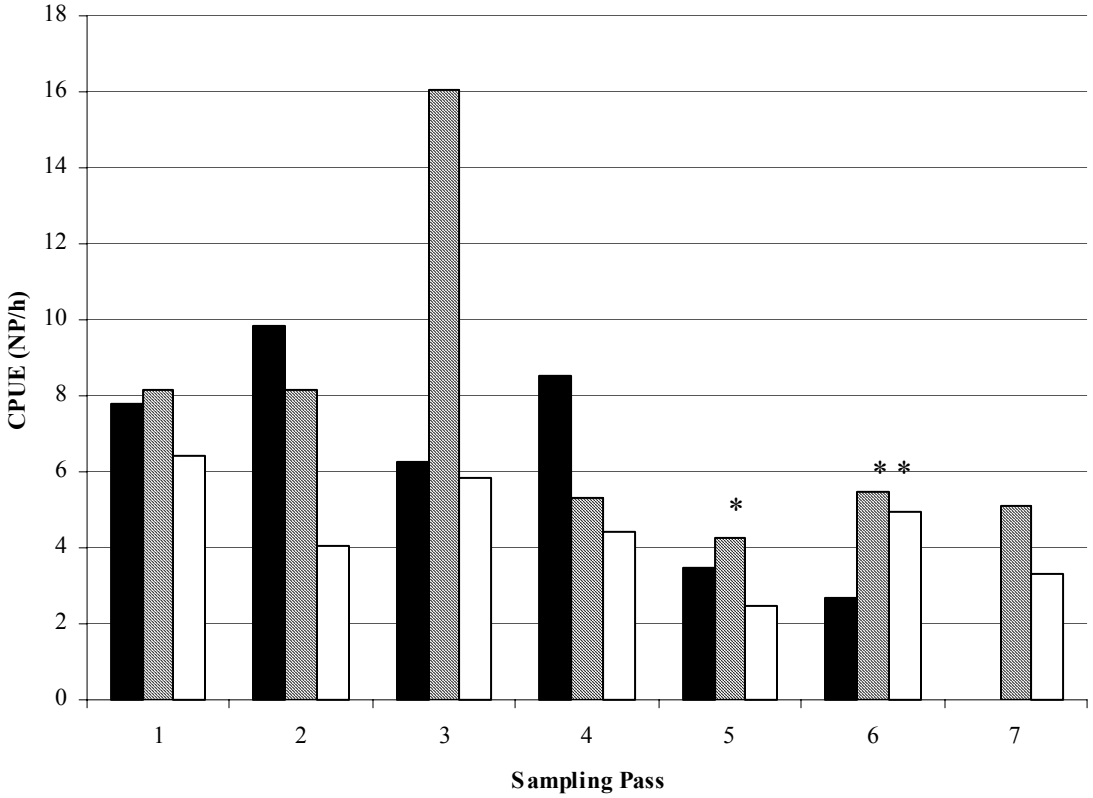

Figure 5. Northern pike (NP) catch rates (catch per unit of effort; CPUE) by sampling pass for 2004-2006 in the Yampa River. Dark bars represent 2004, slashed represent 2005 and open bars represent 2006. Declines in catch rates were not statistically significant for 2004 (*d.f.*=5, *F*=6.79, *p*=0.06), 2005 (*d.f.*=6, *F*=1.65, *p*=0.26), and 2006 (*d.f.*=6, *F*=3.04, *p*=0.14). * indicates concentration passes

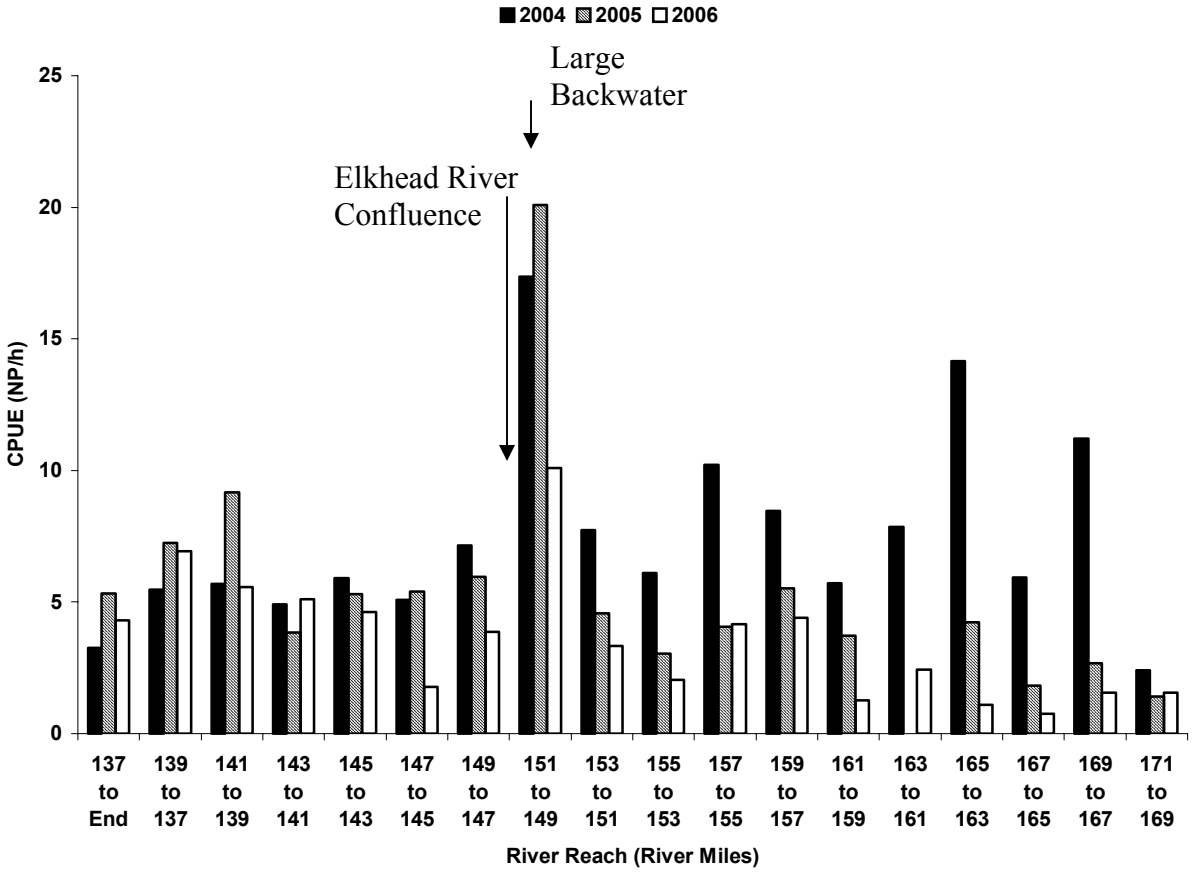

Figure 6. Northern pike (NP) catch rates (catch per unit of effort; CPUE) by reach for 2004-2006 in the Yampa River. Dark bars represent 2004, slashed represent 2005 and open bars represent 2006. Location of the large backwater and the Elkhead Creek confluence are shown with arrows

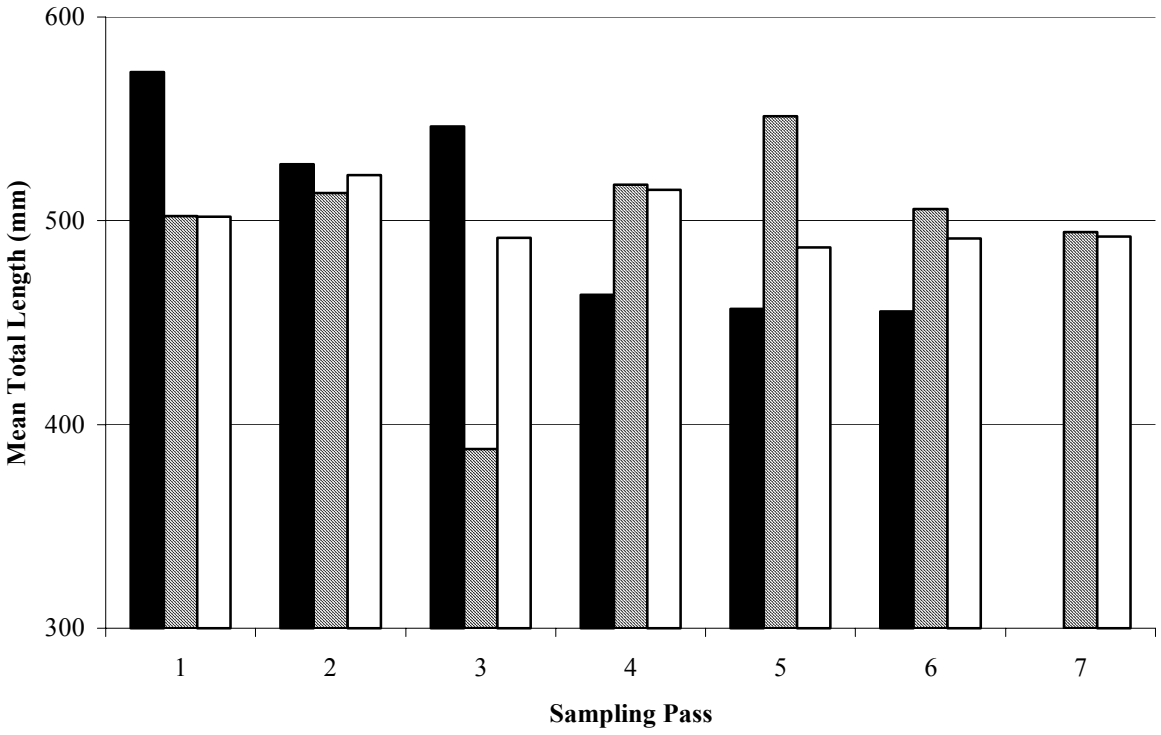

Figure 7. Mean total length of northern pike captured by pass in the Yampa River, 2004-2006. Dark bars represent 2004, slashed represent 2005 and open bars represent 2006.

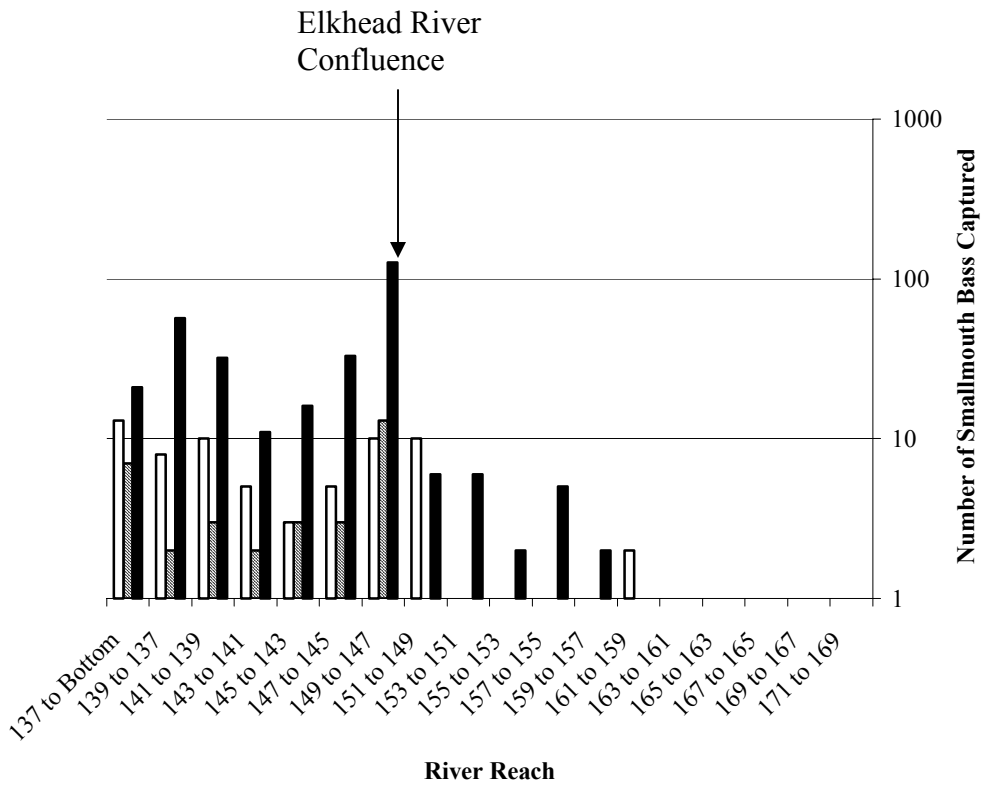

Figure 8. Smallmouth bass captured by reach during all study years. Dark bars represent 2004, slashed represent 2005 and open bars represent 2006. Scale is logarithmic.

Table 1. Adult pike population estimates (95% Confidence Intervals in Parentheses), adult pike per mile, number of adult pike captured (fyke net captures in parentheses), number of adult pike removed, percentage of adult pike removed, pike marked, pike recaptured, coefficient of variation (CV), and capture probability (p-hat) for the Yampa River, 2004-2006.

	Beginning Adult Population Estimate	Adult Pike/ Mile	Individuals Captured	Number Removed	Percentage Removed	Number Marked	Number Recaptured	CV	p-hat
2004	1755 (1289-2221)	47.4	1185 (130)	1002	57.0	207	34	0.46	0.12
2005	1748 (432-3064)	47.2	1053	813	46.5	114	19	0.38	0.08
2006	717 (338-839)	19.4	509	452	63.0	85	15	0.18	0.18

Table 2. Number of juvenile northern pike (<300mm total length) captured and removed from the Yampa River, 2004-2006.

	Number Captured	Number Removed
2004	55	52
2005	354	284
2006	159	135

Table 3. Northern pike movement summary in the Yampa River study reach 2004-2006. BW= between year movements, WI= within year movements. Measurements are in miles

	No. Moved Upstream	No. Moved Downstream	Range of Movement (upstream-downstream)	Mean Movement
2004 BW	21	51	32.4-86.4	1.8 downstream
2004 WI	36	40	13-17	2.5 downstream
2005 BW	10	35	7.5-77.7	16.7 downstream
2005 WI	19	74	13-82.5	12.7 downstream
2006 WI	11	10	3-21.4	3.6 downstream

Table 4. Origination of northern pike captured in the study reach, 2004-2006.

	2004	2005	2006	Total
Northern Pike Originally Released From Upstream	40	26	15	81
Northern Pike Originally Released From Downstream	6	10	6	22

Table 5. Smallmouth bass captured in the Yampa River study site 2004-2006

Year	Number Captured	Population Estimate (95% Confidence Interval)
2004	324	1469 (872-2621)
2005	34	N/A
2006	68	N/A

Table 6. Native fish captured or observed in 2004-2006 on the Yampa River. MWF= Mountain Whitefish, CP= Colorado Pikeminnow, FMS= Flannelmouth Sucker

	MWF	CP	FMS
2004	10*	1	1
2005	137**	1	0
2006	55***	0	0

* Captured during all 6 sampling passes
** observed on passes 6 and 7
*** observed on pass 7

Table 7. Number of ancillary fish captures in the Yampa River study reach 2004-2006

Species	2004	2005	2006
Black Crappie	4	322	20
Bluegill	0	422	12
Largemouth Bass	0	1	0
Black Bullhead	0	3	0
Channel Catfish	1	0	0
Green Sunfish	0	4	0

Cover Photo: Dave Beers holding a northern pike as Clint Goode looks on. Yampa River, Colorado

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March 2008