NORTHERN PIKE (*Esox lucius) C*ONTROL in the MIDDLE GREEN RIVER, UTAH 2001-2006

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS AND DISCLAIMER **2**
TABLE OF CONTENTS **3**
LIST OF TABLES **5**
LIST OF FIGURES **6**
LIST OF KEY WORDS **7**
EXECUTIVE SUMMARY **7**
INTRODUCTION **9**
GOALS AND OBJECTIVES **11**
STUDY AREA **12**
METHODS **13**
SAMPLING 13
CATCH PER UNIT EFFORT 14
AGE ANALYSIS 15
STOMACH CONTENT ANALYSIS 15
RESULTS **16**
SAMPLING 16
2001 ..... *16*
2002 ..... *16*
2003 ..... *17*
2004 ..... *17*
2005 ..... *18*
2006 ..... *18*
CATCH PER UNIT EFFORT 19
AGE ANALYSIS 20
STOMACH CONTENT ANALYSIS 21
DISCUSSION **22**
CATCH PER UNIT EFFORT 22
FACTORS AFFECTING CATCH RATES 22
Flows *23*
Net placement *23*
Equipment issues *24*
Crew turnover *24*
CATCH PER UNIT EFFORT SUMMARY 24
AGE ANALYSIS 266
STOMACH CONTENT ANALYSIS 288
CONCLUSIONS **29**

RECOMMENDATIONS..... 31
LITERATURE CITED 32

LIST OF TABLES

TABLE 1. CATCH RATES AND TOTAL NUMBER OF NORTHERN PIKE REMOVED DURING THE NORTHERN PIKE REMOVAL PROJECT (ONLY) FROM THE MIDDLE GREEN RIVER: 2001 – 2006. ..... **34**

TABLE 2. EFFORT EXPENDED BY GEAR TYPE DURING THE NORTHERN PIKE REMOVAL PROJECT (ONLY): 2001-2006. ..... **34**

TABLE 3. EFFORT AND NUMBER OF NORTHERN PIKE REMOVED DURING OTHER PROJECTS IN THE MIDDLE GREEN RIVER: 2001-2006. ..... **34**

TABLE 4. NORTHERN PIKE CAPTURES BY LOCATION: 2001-2006. ..... **35**

TABLE 5. NORTHERN PIKE CATCH RATES FROM THE UPPER AND MIDDLE YAMPA RIVER REMOVAL PROJECTS. **35**

TABLE 6. AGE GROUPINGS BY YEAR: 2001-2006. ..... **35**

TABLE 7. INFORMATION COLLECTED ON THE FOUR NORTHERN PIKE ORIGINALLY TAGGED IN THE YAMPA RIVER AND SUBSEQUENTLY REMOVED FROM THE GREEN RIVER. **35**

LIST OF FIGURES

FIGURE 1. THE UPPER COLORADO RIVER BASIN WITH THE NORTHERN PIKE CONTROL REACH HIGHLIGHTED. **36**

FIGURE 2. LENGTH FREQUENCY OF NORTHERN PIKE CAUGHT IN THE MIDDLE GREEN RIVER: 2001. ..... **37**

FIGURE 3. LENGTH FREQUENCY OF NORTHERN PIKE CAUGHT IN THE MIDDLE GREEN RIVER: 2002-2003. ..... **37**

FIGURE 4. LENGTH FREQUENCY OF NORTHERN PIKE CAUGHT IN THE MIDDLE GREEN RIVER: 2004-2006. ..... **38**

FIGURE 5. AVERAGE AND PEAK ANNUAL FLOW (CUBIC METERS PER SECOND) AS MEASURED AT THE GREEN RIVER GAUGE AT JENSEN, UT, COMPARED WITH THE NORTHERN PIKE CATCH-PER-UNIT-EFFORT (NUMBER OF NORTHERN PIKE/HOUR OR NUMBER OF NORTHERN PIKE/FYKE-NET NIGHT) IN THE MIDDLE GREEN RIVER FROM 2001 – 2006 (NORTHERN PIKE REMOVAL PROJECT ONLY). **38**

FIGURE 6. AVERAGE AND PEAK ANNUAL FLOW (CUBIC METERS PER SECOND) AS MEASURED AT THE GREEN RIVER GAUGE AT JENSEN, UT, COMPARED WITH THE NORTHERN PIKE CATCH-PER-UNIT-EFFORT (NUMBER OF NORTHERN PIKE/HOUR) IN THE MIDDLE GREEN RIVER FROM 2001 – 2006 (ALL OTHER PROJECTS). **39**

FIGURE 7. NORTHERN PIKE AGE ESTIMATES BY YEAR. **39**

FIGURE 8. NORTHERN PIKE AGE CLASS BY YEAR. **40**

FIGURE 9. AVERAGE AND PEAK ANNUAL FLOW (CUBIC METERS PER SECOND) AS MEASURED AT THE GREEN RIVER GAUGE AT JENSEN, UT, COMPARED WITH THE NUMBER OF NORTHERN PIKE OBSERVED (PRE-2001) OR REMOVED (2001 AND LATER) IN THE MIDDLE GREEN RIVER FROM: 1996 – 2006. ..... **40**

LIST OF KEY WORDS

Northern pike, *Esox lucius*, nonnative removal, cleithra, nonnative fish, middle Green River

EXECUTIVE SUMMARY

Beginning in 2001, researchers with the Utah Division of Wildlife Resources (Division) in Vernal, UT, began an intensive northern pike (*Esox lucius)* removal program in razorback sucker (*Xyrauchen texanus*) critical habitat of the middle Green River. Captures of northern pike during the Division's basin-wide surveys had increased from 1997 to 2000 and participants in the Upper Colorado River Endangered Fish Recovery Program (Program) were concerned that large numbers of pike would threaten recovery of native, endangered fishes in the Green River.

During this effort, crews were asked to capture and remove all northern pike encountered and to develop a northern pike control program or methodology, which could subsequently be evaluated for its effectiveness. They did this by utilizing multiple gear types: electrofishing, fyke netting, and trammel netting. Catch rates were highest for all gear types in 2001 and although catch rates varied over the course of this study, the overall trend was a gradual reduction (in both catch rates and numbers removed) from 2001 to 2006. Catch rates in this reach were low compared with the Yampa River.

From 2001 to 2005, researchers collected cleithra from northern pike and counted annuli to determine ages. Results of this analysis were grouped into young-of-year, juvenile, and adult age classes. Northern pike removed from the middle Green River from 2001 to 2003 were predominantly adult fish. In 2004, most fish were juvenile fish, and in 2005, pike were evenly distributed between juvenile and adult. Only three pike were identified as young-of-year over the

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study period. In comparison, researchers in the Yampa River see all size and age classes of pike, including young-of-year.

Researchers examined the stomach contents of all northern pike collected from 2002 to 2005. The overwhelming majority of stomachs were empty; only 13 of 144 pike stomachs contained fish remains. Of these, four pike had consumed native fish: three recently stocked razorback suckers and one bluehead sucker (*Catostomus discobolus:* total length (TL) 250mm). Lengths of pike that had consumed native fish ranged from 597 mm to 834 mm.

Based on decreasing catch rates and limited reproduction in the study area we were able to effectively reduce numbers of northern pike in the middle Green River. Available northern pike habitat within the study area appears to be limited and is easily sampled. We recommend a continuation of specific efforts to remove northern pike in the early spring. This coupled with opportunistic removal of northern pike throughout the year during other Program projects should effectively reduce their threat to the recovery of endangered fish in the middle Green River.

INTRODUCTION

Nonnative fishes have become established in rivers of the upper Colorado River basin, with certain species implicated in the reduction in distribution and abundance of native fishes, primarily through predation and competition (Hawkins and Nesler 1991; Lentsch et al. 1996; Tyus and Saunders 1996). The Upper Colorado River Endangered Fish Recovery Program (Program) has determined that control of nonnative fish in the upper Colorado River basin is essential to the recovery of the four endangered fish species: Colorado pikeminnow (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), humpback chub (*Gila cypha*), and bonytail (*Gila elegans*). Experts in the Upper Colorado River Basin have rated northern pike (*Esox lucius*) as one of the six nonnative species of greatest concern (Hawkins and Nesler 1991).

It is thought that northern pike were originally introduced as a game fish in Elkhead Reservoir, a small reservoir on Elkhead Creek (a tributary to the Yampa River in northern Colorado), in 1977 (Figure 1). The subsequent invasion of the Yampa River was likely due to this original introduction into Elkhead Reservoir (Tyus and Beard 1990). However, Hawkins et al. (2005) hypothesize that Elkhead Reservoir was not the original source of northern pike in the Yampa River due to discrepancies in stocking records from this period. Regardless, since the original invasion, northern pike have established a reproducing population in the upper Yampa River and have expanded their numbers and range throughout this river (Tyus and Beard 1990). Pike were not found in the Green River until after this initial invasion suggesting that the species moved downstream from the Yampa River into critical habitat of the Green River (Tyus and Beard 1990; Hawkins et al. 2005). Here, as in the Yampa River, they pose a competitive and predatory threat to the endangered fishes. Since 2001, Division of Wildlife Resources (Division) data show that four tagged northern pike ranging from 720 mm to 826 mm have moved from the

Yampa River downstream into the middle Green River, into critical habitat for razorback sucker. These fish moved down from between Yampa River Kilometer (RKM) 119.7 – 242.9 (River Mile (RM) 74.4 - 150.9) for total movements between 192.1 and 306.5 river kilometers (119.4 and 190.5 river miles).

Capture rates of northern pike in the Green River in the late 1990's indicated a rapid increase in the adult population: the number of northern pike captured during basin-wide monitoring increased from 48 collected in 1997 to 202 in 1999. In addition, in 2002, U.S. Fish and Wildlife Service crews observed numerous young-of-year (YOY) northern pike in Old Charley Wash on the Ouray National Wildlife Refuge (Green River RKM 401.0 (RM 249.2)) (K. Christopherson, pers. comm.) (Figure 1). This was dealt with through the use of Rotenone, a piscicide; however, the possibility of an established northern pike population was still quite alarming. Northern pike tend to prefer soft-rayed food fishes to pan fish or bullheads (Beyerle and Williams 1968) and because of the potential predatory threat to native, endangered species, the Program became very concerned and initiated a northern pike removal program in 2001. The Program was also concerned that northern pike would pose a predatory threat to all native fishes, including the non-endangered, "at risk" species such as roundtail chub (*Gila robusta*), flannelmouth sucker (*Catostomus latipinnis*) and bluehead sucker (*Catostomus discobolus*).

GOALS AND OBJECTIVES

At the beginning of this study, in 2001, crews were asked to develop an effective northern pike control program from Split Mountain in Dinosaur National Monument to Sand Wash (the study area will be discussed in further detail in the next section), focusing their removal efforts in areas of known northern pike concentrations. The goal of this control program was to sufficiently reduce the abundance of adults such that predatory and competitive impacts on growth, recruitment, and survival of endangered and other native fishes were minimized.

The study objectives were to:

1. Capture and remove (lethal) adult northern pike from reaches of the middle Green River.
2. Reduce the abundance of adult northern pike in the middle Green River. After 2003, this objective was changed to "Maintain low occurrence of adult northern pike in the middle Green River."
3. Determine the efficacy of removal efforts.
4. Identify the means and levels of northern pike control necessary to minimize the threat of predation/competition on endangered and other native fishes.

The end product included herein is an evaluation of the effectiveness of this northern pike removal program.

STUDY AREA

The Utah Division of Wildlife Resources (Division) Vernal office was tasked with conducting northern pike removal efforts in critical habitat of the middle Green River. This includes the Green River from the Split Mountain boat ramp in Dinosaur National Monument (RKM 513; RM 319) to the Sandwash boat ramp (RKM 346; RM 215), which is the staging location for rafting trips through Desolation Canyon (Figure 1). This reach and removal localities therein were selected based on northern pike observations from previous sampling activities. Known concentration areas for northern pike in this reach include the mouths of Brush Creek (RKM 490; RM 304.5), Cliff Creek (RKM 487; RM 302.9), Stewart Lake Drain (RKM 483; RM 300.0), Ashley Creek (RKM 481; RM 299.0) and Sportsman Drain (RKM 477; RM 296.6) (Figure 1). Each of these areas is characterized by slow water and submerged vegetation, similar to wetland habitat, which is ideal for northern pike and their spawning activities (Becker 1983; Bry 1996).

Higher gradients and an abundance of cobble, rubble, and gravel substrates characterize the uppermost section of the reach within Dinosaur National Monument. The lower section of this reach down to Sandwash boat ramp is a much lower gradient with primarily silt and/or sand substrates. Two major tributaries, the Duchesne and the White rivers flow into the Green River within this section.

METHODS

Sampling

In all years, sampling began in March, shortly after ice-off and continued through spring as river flows began to increase. This is the general time period when northern pike become active and move to shallow water areas including wetlands and flooded tributaries (Sigler and Sigler 1996). Selected reaches were sampled two to three times weekly. Crews mainly used three different methods for removal of northern pike: electrofishing, trammel netting, and fyke netting. Electrofishing was performed using 4.88 m aluminum welded jon boats equipped with 5.0 Smith-Root GPP electrofishers. This was done in locations such as Stewart Lake Drain, the mouth of Ashley Creek, and larger backwaters. Shoreline electrofishing was also effective for northern pike removal during other projects such as the Colorado pikeminnow abundance estimates, another spring project. Trammel nets were set at the mouth of tributaries and large backwaters to trap pike that might use these areas as refuge to escape increasing spring flows. Trammel nets were used mainly in conjunction with electrofishing to increase catch rates. Fyke nets were also set in tributary mouths and backwaters to trap fish as they went into these areas.

Sampling crews conducted removal activities in a manner that minimized potential negative impacts to endangered fish. For instance, sampling was curtailed or re-directed when Colorado pikeminnow were staging in tributary mouths or backwater habitats prior to spawning; when razorback sucker were congregated on and near the spawning bars; and following recent releases of hatchery reared endangered fish.

In 2001, gear was placed in a number of locations from Split Mountain to the Ouray Bridge (RKM 399; RM 248). By 2002, northern pike removal locations had become condensed mainly to the area from Split Mountain to Ashley Creek, though crews were still somewhat

successful at sampling lower in the sampling reach near Wyasket Bottom (RKM 410; RM 255) and the White River (RKM 396; RM 246). By 2004, however, the main concentration areas were Brush Creek, Cliff Creek, Stewart Lake inlet and drain, Ashley Creek, and the general Jensen area (Figure 1).

All northern pike captured from all middle Green River sampling projects were counted, weighed (g) and measured (mm) for total length (TL). All nonnative fish were euthanized and removed; native fish were released at the site of capture. Endangered fish species were scanned for a PIT (passive integrated transponder) tag, tagged if needed, and then released near the area of capture. Nonnative removal and evaluation efforts, which included tagging and marking native, endangered and target nonnative fishes, were also being conducted by other researchers and agencies in other areas of the middle Green River and Yampa River. Therefore, sampling crews examined all native, endangered and target nonnative fish for tags or marks and recorded pertinent information. This information was then reported to principal investigators as appropriate and included in annual reporting.

Catch Per Unit Effort

Catch-per-unit-effort (CPUE) was either calculated as fish/hour (electrofishing and trammel netting) or fish/fyke-net night (fyke-netting) (one fyke net set out for one night and usually left for a 24-hour period is equal to one fyke-net night). Fyke nets set for shorter periods of time were recorded in tenths of a fyke-net night for purposes of calculating CPUE. No statistical analyses were performed on CPUE over the study period because removal efforts were not done in a statistically consistent manner (removal efforts were not completed by pass, but rather by distinct sampling occasions). Catch rates from the middle Green River were compared

between years and to catch rates from the Yampa River, the likely source population, to discuss the effectiveness of the program.

Age Analysis

Cleithra were used to age northern pike (n=320) collected from 2001 through 2005. Cleithra were first cleansed in boiling water to remove soft tissue. Following accepted protocols (Campana 2001), crewmembers counted annuli under a microscope to determine age. To better make sense of the cleithra data, age results were lumped into three groups: young-of-year (YOY: 300 mm or less), juvenile (ages 1-3: 301-520 mm), and adult (4+: 521+mm). This length at age grouping was consistent with Brown (1971) who aged northern pike in streams in Montana, and Scott and Crossman (1973) who found that both male and female northern pike in the northern United States will be mature by age four (males will mature at two to three years and females at three to four, but all will be mature at age four).

Stomach Content Analysis

Stomach content analysis was conducted from 2002 through 2005. In the field, stomachs were individually preserved in 95% alcohol. In the laboratory, contents were identified to species, if possible. Lengths were taken on all native fish identified within the stomach. Crews did not attempt to identify partially digested materials.

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RESULTS

Sampling

2001

Electrofishing for northern pike removal began on 19 March 2001, ended on 08 May, and lasted 34 sampling days (Table 1). Crews fished for a total of 19.1 hours for this project (Table 2). The fyke netting effort began on 20 March and was completed on 01 June. This effort consisted of 421 fyke net nights. Crews also spent 37.7 hours electrofishing with a trammel net using the "block and shock" method where an area is closed off using a trammel net and fish are then chased into the trammel net as they try to escape the electrofishing equipment. This effort began on 20 March and ended on 29 June. Between the three efforts, 222 northern pike were removed from the Green River (Table 2). Crews also electrofished the middle Green River for the Colorado pikeminnow abundance estimates this year. This effort took 253 hours and removed an additional 29 pike from the reach for a grand total of 251 (Table 3). Mean total length of all pike captured was 613 mm (170 mm – 871 mm) (Table 1; Figure 2). Northern pike were predominantly removed between middle Green River RM 303 (Thunder Ranch) and RM 294 (Walker Hollow), though crews removed a few pike from the Split Mountain reach and around the town of Ouray and the Duchesne River (Table 4).

2002

Electrofishing for northern pike began on 02 April 2002, ended on 10 June, and took 20 sampling days to complete (Table 1). Crews fished for a total of 28.1 hours for this project (Table 2). Fyke netting began on 10 April and ended on 23 May. This effort consisted of 165 fyke net nights. Crews also spent 5.3 hours trammel netting between 16 April and 10 June.

Between all three efforts, a total of 32 northern pike were removed (Table 2). The Colorado pikeminnow abundance estimates continued in 2002 and crews removed an additional 10 northern pike during this effort (182 hours) (Table 3). Mean total length of all pike removed was 633 mm (295 mm – 815 mm) (Table 1; Figure 3). Concentration areas during 2002 remained the Thunder Ranch to Walker Hollow reach, though quite a few were still captured near the town of Ouray and the Duchesne River (Table 4).

2003

Electrofishing for northern pike began on 31 March 2003, ended on 27 June, and took 15 sampling days to complete (Table 1). Crews fished for a total of 65.5 hours for this project (Table 2). Fyke netting began on 12 March and ended on 20 June. This effort consisted of 103 fyke net nights. No trammel netting occurred this year for northern pike removal. Between the two efforts, a total of 7 northern pike were removed (Table 2). The Colorado pikeminnow abundance estimates continued in 2003 and crews removed an additional 16 northern pike during this effort (190 hours) (Table 3). Mean total length of all northern pike was 668 mm (423 mm – 984 mm) (Figure 3). Most pike were again removed from the Thunder Ranch to Walker Hollow reach and the Split Mountain reach (Table 4).

2004

Electrofishing began on 24 March 2004, ended on 14 June, and took 14 sampling days to complete (Table 1). Crews fished for a total of 14.7 hours for this project (Table 2). Fyke netting began on 22 March and ended on 14 June. This effort consisted of 93 fyke net nights. Crews returned to trammel netting between 23 April and 13 May and spent a total of 2.4 hours on this

activity in 2004. Between the three efforts, 18 northern pike were removed (Table 2). The Colorado pikeminnow abundance estimates did not occur in 2004; however, crews spent 147 hours electrofishing for another project, smallmouth bass removal, and removed an additional nine northern pike from the river (Table 3). Mean total length of all pike removed was 558 mm (371 mm – 834 mm) (Table 1; Figure 4). The greatest concentration of pike was again removed from the Thunder Ranch to Walker Hollow reach in 2004, though seven pike were removed between Razorback Bar (Green River RKM 500.5 (RM 311)) and Thunder Ranch (Green River RKM 487.6 (RM 303) as well (Table 4).

2005

Electrofishing for northern pike removal began on 11 April 2005, ended on 25 June, and took 32 sampling days to complete (Table 1). Crews fished for a total of 8.5 hours for this project (Table 2). Fyke netting began on 21 March and was completed on 16 June. This effort consisted of 227 fyke net nights. Crews continued to trammel net for northern pike between 24 March and 24 June and spent a total of 26 hours on this activity in 2005. Between the three efforts, 29 northern pike were removed (Table 2). Crews spent 80.4 hours electrofishing for smallmouth bass removal and removed an additional three northern pike from the river (Table 3). Mean total length of northern pike was 638 mm (388 mm – 870 mm) (Table 1; Figure 4). By far, the majority of pike were again removed from the Thunder Ranch to Walker Hollow reach of the middle Green River (Table 4).

2006

Electrofishing for northern pike began on 11 May 2006, ended on 12 May, and only lasted one sampling day (most electrofishing effort in 2006 was done during other projects) (Table 1). Crews fished for a total of 3.3 hours for this project (Table 2). Fyke netting began on 27 March and was completed on 31 May. This effort consisted of 52 fyke net nights. Crews continued to trammel net for northern pike between 27 March and 30 March and spent a total of two hours on this activity in 2006. Between the three efforts, a total of three northern pike were removed (Table 2). Crews returned to the Colorado pikeminnow abundance estimates (190.4 hours) and continued smallmouth bass removal (152.2 hours) and removed an additional 17 northern pike during these projects (Table 3). Mean total length of all pike removed was 549 mm (365 mm – 790 mm) (Table 1; Figure 4). Most pike were removed from the Split Mountain reach in 2006 (Table 4).

Catch Per Unit Effort

A total of 414 northern pike was removed over the six years of this removal effort. Total catch per effort over the six removal years by gear type was as follows: 0.60 fish/hour electrofishing, 0.16 fish/fyke-net night using fyke nets, and 0.76 fish/hour trammel netting and electrofishing. In general, following the removal of 251 northern pike and the highest catch rates in 2001, both numbers of pike removed and catch-per-effort have gradually declined and remained low through 2006 (Table 1; Figures 5 and 6).

This is also true for northern pike captured during other studies. Catch rates of pike during the Colorado pikeminnow abundance estimates (2001-2003; 2006) and smallmouth bass removal (2004-2006) started low (0.11 pike/hour and 0.06 pike/hour for each project respectively) and have remained low (0.08 pike/hour and 0.02 pike/hour in 2006 for each project

respectively) (Table 3). Catch rates over the entire period of pikeminnow abundance estimates were 0.08 fish/hour and 0.03 fish/hour for smallmouth bass removal.

No statistical analyses were performed on the data from the northern pike removal project because pike were not removed by pass. We can, however, qualitatively compare our catch rates with those from the Yampa River, a likely source of middle Green River pike. Reviewing annual reports and preliminary data from the northern pike removal projects there, catch rates are slightly higher, but have also been declining since the beginning of the projects. In the upper Yampa River, between Hayden and Craig, CO (RKM 275 – RKM 215.7 (RM 170.9 – RM 134)), electrofishing catch rates have gone from 8.0 pike/hour in 2004 down to 4.3 pike/hour in 2006 (Table 5). Electrofishing catch rates in the middle Yampa River (RKM 223.7 - RKM 95.0 (RM 139 – RM 59)) are also higher than in the middle Green River and have declined over the study period: 2.15 pike/hour in 2004 down to 1.43 pike/hour in 2006. Middle Yampa River removal crews did not set fyke nets until 2006. Catch rates for this gear type were low (0.12 fish/fyke-net night), which is similar to those seen in the middle Green River.

Age Analysis

In 2001, cleithra from 217 northern pike indicate age classes from young-of-year (YOY) through age 10 were present. Most pike collected were two to four years old and ranged from 400 to 800 mm in length. Only 12 pike were aged older than six years (Figure 7). All but one fish (a 295 mm YOY) captured in 2002 were identified as two to seven years old (Figure 7). The majority of these were actually in the four to five year-old range. In 2003, again, most fish were identified as four or five years old. Only three fish were identified as one- or two-year-old fish. The remaining fish were age-six or older. In 2004, the majority of fish were one-year-old fish,

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but the remaining fish seemed evenly distributed from age-two to age-seven. Finally, in 2005, fish were relatively evenly spread between age-one and age seven.

As explained earlier, fish were lumped into YOY, juvenile, and adult fish due to a great deal of overlap in the age-at-length estimates. Over the course of the study, only three young-of-year (YOY) fish were captured; this was in 2001 and 2002. These fish were 170, 295, and 390 mm. The 390 mm fish was captured early in 2000 and was likely an age-1 fish with no distinct cleithra markings. In 2002 and 2003, most fish were adult fish and ranged from 520 to 984 mm. In 2004, this shifted to most fish being predominantly juvenile fish, ranging in length from 371 to 480 mm. In 2005, pike numbers were low and juvenile/adult fish were evenly represented in the catch (Figure 8). Length ranges for all aged fish from 2001 to 2005 are included in Table 6.

Stomach Content Analysis

Over the course of the study, most extracted stomachs were empty. Only 13 of 144 fish had stomach contents recorded. Of these 13, five had minnows, shiners, and sunfish listed as their stomach contents. Four additional northern pike had potentially larger prey items in the stomachs (though prey size was rarely recorded for nonnative fish): channel catfish, black bullhead, white sucker, and one 178 mm smallmouth bass (this pike was 620 mm total length). Four northern pike had consumed native fish: three of which were hatchery reared razorback suckers (recently stocked in the Green River); the fourth native fish was a bluehead sucker. All native fish were near 250 mm in size and were eaten by northern pike ranging from 597 mm to 834 mm.

DISCUSSION

Catch Per Unit Effort

During the six years of the removal effort for northern pike, electrofishing and trammel netting catch rates decreased; fyke netting catch rates have varied, but essentially decreased over the years (Table 1). This is true also for northern pike catch rates during other projects in the middle Green River, such as the Colorado pikeminnow abundance estimates and smallmouth bass removal (Table 3). Among all gear types, electrofishing was the most efficient gear type throughout the entire study, although trammel netting was efficient at capturing northern pike in most years when used in conjunction with electrofishing (Table 1).

In comparison with catch rates in parts of the basin with established pike populations (i.e., the Yampa River), catch rates in the middle Green River are low and effort is considered to be at a preventative level (i.e., with minimal effort we are removing a similar number of northern pike each year and preventing the establishment of a reproducing northern pike population). Specific efforts to control northern pike in the middle Green River have decreased from 2001 (19.1 electrofishing hours; 421 fyke net nights; and 37.7 trammel netting hours) to 2006 (3.3 electrofishing hours; 52 fyke net nights; and 2 trammel netting hours).

Factors Affecting Catch Rates

Because this was a six-year study period, many things changed over the years that may have influenced these catch rates (besides a decrease in the number of northern pike in this reach): flows, net placement, equipment issues, and crew turnover.

Flows

Peak and average flows varied over the study period. Again, we did not do any statistical analyses on these data; however, by overlaying peak and average annual flows onto catch rates for northern pike in the middle Green River, some patterns do emerge (Figure 5). For the northern pike removal project, it initially appears that low flow may have been responsible for the decrease in catch rates between 2001 and 2002 for both electrofishing and fyke netting. It is difficult to conclude, however, that the decrease in catch rates were entirely a result of low flows because catch rates did not rebound with an increase in flows in 2003 or any subsequent year. Over the same low-flow period, however, there was no real decrease in trammel netting catch rates, suggesting that trammel netting may be a more consistent method of removal over varying hydrologies.

Flows may affect catch rates of northern pike during the Colorado pikeminnow abundance estimates (Figure 6), during which northern pike catch rates mirrored patterns in annual peak flow. Northern pike catch rates during smallmouth bass removal seem to show the opposite trend (Figure 6). It is important to realize, however, that these two projects are conducted at very different times of the year in terms of hydrology. The pikeminnow abundance estimate is completed in the spring before peak flows, whereas smallmouth bass removal is done after peak flows recede. In 2005 and 2006, most of the smallmouth bass removal was actually done during base flows. Therefore, the number of northern pike captured during these studies may instead be a result of the timing of the projects, not necessary flows.

Net placement

Specific net set locations varied little between 2001 and 2005, and only to improve catch rates. For example, if crews had set a net in the mouth of Ashley Creek that was not fishing well after one or two days, they moved it within this same general location to better catch fish as they

moved into or out of the creek. With a large scale turnover in personnel, net placement changed the most between 2005 and 2006, which may have affected catch rates. This potential complicating factor is discussed in the final paragraph of this subsection.

Equipment issues

River otters (*Lutra canadensis*) have been known to chew holes in nets and eat the captured fish. In addition, fyke nets can be washed away when flows rise quickly. From 2001 to 2005, complications associated with otters and river flow were considered infrequent and of little consequence. In 2006, river otters did compromise fyke-netting operations. Crews responded by shifting efforts from fyke-netting to more electrofishing and trammel netting. If this were a major factor influencing catch rates, however, one would predict a decrease in fyke-netting catch rates and a subsequent increase in catch rates for the other two gear types as effort is redistributed; however, this did not happen (Table 1).

Crew turnover

While project personnel remained consistent from 2001-2005; the entire crew was replaced in 2006. Changes in personnel in 2006 resulted in some minor changes in specific net set locations and a general decrease in overall sampling effort as the crew was not in place until late spring. This factor does not, however, explain the observed decrease in catch rates over the entire study period.

Catch Per Unit Effort Summary

It is not likely that the previous factors alone or even combined, are responsible for the observed reduction in northern pike catch rates. As mentioned, the two latter issues: equipment issues and crew turnover likely only affected catch rates (if at all) between pre-2006 and 2006. It does not explain the trend in decreasing catch rates between 2001 and 2005. Essentially, flows may have affected catch rates to a certain extent; however, from Figure 9, it appears that while spring peak flows decreased from 1997 to 2002, the numbers of northern pike increased (we do not have catch rates before 2001). In addition, regardless of what happened with flows between 2001 and 2006, numbers of pike essentially decreased or remained stable during this period. This essentially suggests that the removal effort has been the number one factor affecting catch rates in the middle Green River.

This project began in 2001 with the removal of 222 northern pike **(**2.77 fish/hour electrofishing; 0.31 fish/fyke net night; 1.03 fish/hour trammel netting) and an additional 29 pike captured during the Colorado pikeminnow abundance estimates (0.11 fish/hour). Based on catch rate data and absolute numbers of pike removed in subsequent years, the population never rebounded after this initial effort. Although we cannot say for certain why this species has not proliferated in this river reach as other nonnative species have over the same time period (i.e., smallmouth bass), it is likely because this reach of river is not a source of northern pike in the basin (i.e., pike have only limited capacity to spawn in this reach of river and we have thus far been effective at further limiting their spawning capability through this study). Other researchers in the Yampa River basin see higher catch rates of northern pike (Table 5). If the Yampa River is the source of the middle Green River population, reductions in catch rates, the lack of YOY fish in most years, and the observed size shifts between years can all be explained.

Age Analysis

Age results, even grouped into YOY, juvenile, and adult age classes, show an interesting shift from predominantly adults in 2001, 2002, and 2003 to predominantly juveniles in 2004 and an even number of both in 2005 (Figure 8). The inability to follow an age class through time suggests that in 2003 and 2004, removal efforts disturbed the population to the extent that most individuals are now removed each year and new individuals from other parts of the basin replace them. We do have definitive evidence of four individuals moving down from the Yampa River into critical habitat for razorback sucker in the middle Green River over the study period (Table 7). These fish moved between 192.1 and 306.5 river kilometers (119.4 and 190.5 river miles) downstream to get to the middle Green River near Jensen. We therefore know that downstream movement occurs; we can only assume it occurs to the extent that the majority of pike in the middle Green River were spawned in the Yampa River.

Beginning in 2006, northern pike captured in the middle Green River were sent to researchers at Colorado State University for analysis of stable isotopic signatures. If pike sources in the Yampa River drainage have a strong isotopic signature such that this signature imprints itself on the resident fish, we will eventually know the source of middle Green River pike.

The cleithra results suggest that northern pike may have successfully spawned in 2001 and 2002; however, because numbers of these younger fish in the river remained low (we detected only one YOY in both 2001 and 2002), it is more likely that these fish migrated down from the Yampa River, thus allowing us to keep this removal effort at a preventative level.

There are some issues to consider with the cleithra results. The researchers at the time certainly believed they were accurate in their age determinations; however, Quist et al. (2006) point to difficulties with aging catostomids of the upper Colorado River basin based on cleithra

analysis. Quist et al. (2006) evaluated between-reader precision of aging results for various catostomid species from analysis of fin rays, cleithra, opercular bones, and scales in comparison with age results from otolith analysis. They found that one reader was nearly accurate at identifying otolith age using the cleithra, but when this reader did err, he generally underestimated otolith age. The second reader consistently underestimated otolith age by two to three years, suggesting that it is quite easy to underestimate the age of catostomid species using cleithra aging techniques. In addition, Sharp and Bernard (1988) also point to difficulty in aging lake trout using cleithra techniques. A direct quote taken from their abstract exemplifies their concerns with using cleithra for aging lake trout in Alaska lakes, "Estimated ages from cleithra and whole vertebrae were, respectively, too imprecise and too low for these structures to be useful in age validation studies."

Even though these studies looked at accuracy of age analysis using cleithra from other species, their findings suggest that the use of cleithra in aging fish is not extremely accurate. Given these findings and the significant overlap of lengths at various ages (i.e., in 2001, a 980 mm fish was identified as an age-7 fish, but a 559 mm fish was identified as age-9), we felt more comfortable grouping pike into YOY, juvenile, and adult. It is possible, according to data from CDOW (unpublished) that the 980 mm fish could have come from Stagecoach Reservoir; this is within the observed range of normal growth for northern pike in this reservoir. However, the 559 mm fish shows extremely slow growth rates for an age-9 fish based on observations of Catamount and Stagecoach reservoirs and the Yampa River. Since we cannot be certain whether the observed variation is due to error in the aging results or to variation in growth rates, this age class grouping likely reduced much of that error (i.e., both of the fish mentioned above are adult

fish, thus removing any error that might exist between whether these are truly age-7 and age-9 fish).

Stomach Content Analysis

The stomach content analysis revealed very little new information. Clearly, northern pike eat native fish and can eat native fish that have recently been stocked in the river. A gape analysis of northern pike might be more informative as to the potential predatory danger of the species on native fish in the river.

Because catch rates have remained low from 2002 to 2006 and because it is likely a result of the removal effort, many members of the Program have recommended discontinuing specific northern pike removal efforts. While we agree that a reduction in effort is certainly warranted, we are hesitant to completely discontinue this project. Northern pike are known to spawn immediately after ice-off in early spring (Sigler and Sigler 1996 and references therein). They are known to have spawned in the middle Green River on one other occasion and their known concentration areas are ideal spawning habitat for this species (K. Christopherson, pers. comm.). Northern pike removal is the only project ongoing at this time of year and is highly efficient at removing other problematic nonnative species such as white sucker. Our recommendation is therefore to continue a preventative level of early spring nonnative fish removal.

CONCLUSIONS

We present one conclusion for each of our study goals and a few additional conclusions meant to help in making recommendations.

- *Capture and remove (lethal) adult northern pike from reaches of the middle Green River*. Over the course of the six years, we removed a total of 414 northern pike captured from this reach of river. Associated catch rates were 0.60 fish/hour electrofishing, 0.16 fish/fyke-net night fyke-netting, and 0.76 fish/hour trammel netting.
- *Reduce the abundance of adult northern pike in the middle Green River*. After 2003, this objective was changed to "Maintain low occurrence of adult northern pike in the middle Green River." In 2001, crews removed 251 northern pike; this number was reduced to 42 the following year, and remained around 20 individuals through 2006. Catch-per-unit-effort (CPUE) was also highest for all gear types in 2001 and although CPUE for electrofishing and fyke-netting varied over the course of the study period, the overall trend in all gear types was a decrease in catch rates between 2001 and 2006.
- *Determine the efficacy of removal efforts.* Electrofishing catch rates in the middle Green are consistently lower than those observed in the Yampa River. Catch rates in 2001 were comparable to those in the middle Yampa River in 2004; however, subsequent catch rates have decreased more in the Green River than in the Yampa River and did so immediately after the initial effort in 2001, pointing to a thus far effective removal effort.
- *Identify the means and levels of northern pike control necessary to minimize the threat of predation/competition on endangered and other native fishes*. If one concludes that the northern pike in the middle Green River are coming predominantly from the Yampa River, only a minimal (i.e., preventative) amount of effort is required to minimize the

threat of this predator to native fishes and that this minimal amount of effort will be required at least until northern pike removal has been successful in the Yampa River.

- The following lines of evidence indicate our removal efforts are successfully limiting the proliferation of northern pike in the middle Green River: a) declining trend in catch rates within the Green River, which does not appear to be influenced by extraneous factors (varying flows, net placement, equipment issues, or personnel turnover); and b) an age analysis that indicates that northern pike encountered in the middle Green River periodically immigrate from an upstream source as opposed to recruit from local reproduction.

Deleted:

- Based on pre-project sampling and the findings of this study, northern pike continue to concentrate in limited areas: the mouth of Brush Creek, Cliff Creek, Stewart Lake Drain, Ashley Creek and Sportsman Drain (Table 4). We presume these areas provide the best habitat for northern pike in the middle Green River. By focusing the majority of our removal effort in these specific locations in the early spring when fish congregate (presumably to spawn), we can successfully manage their densities.
- Catch rates tend to be higher with electrofishing and trammel netting; however, fyke nets can be set and left for many days at a time. Thus, in terms of man-hours, fyke-netting may be more cost effective in some years (when otters or variable flows are not a problem).

RECOMMENDATIONS

- Continue specific early spring removal efforts to effectively manage northern pike prior to their spawning period. More specifically, be ready to use electrofishing, trammel netting, and/or fyke netting to capture nonnative fish as soon as the river is navigable after ice-off.
- Discontinue age analysis using cleithra as northern pike numbers in the middle Green River are low and have been for a number of years**.** Given the uncertainties associated with this technique, if aging is still needed, fin rays or otoliths might be a more reliable method.
- Discontinue collection and analysis of stomach samples. If more information is desired on predatory effects of northern pike, initiate a gape analysis.
- Begin the season by using fyke nets to capture northern pike and set nets in both backwaters and tributary mouths. If problems are encountered with the nets or with either of these habitats, turn the focus more to electrofishing and trammel netting for northern pike. Our results show that these methods were the most effective in terms of catch rate over the course of the study and should therefore not limit our ability to capture northern pike if fyke-netting becomes problematic.

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Year	Electrofishing Dates	Electrofishing CPUE (Pike/ hour)	Fyke Netting Dates	Fyke Net CPUE (Pike/fyke net night)	Trammel Netting Dates	Trammel Net CPUE (Pike/ hours)	Mean Length all NP (mm)	Length Range all NP (mm)	Total Number Fish
2001	19 March - 08 May	2.77	20 March - 01 June	0.31	20 March - 29 June	1.03	613	170-871	251
2002	02 April - 10 June	0.60	10 April - 23 May	0.06	16 April - 10 June	0.94	633	295-815	42
2003	31 March - 27 June	0.08	12 March - 20 June	0.02	-	-	668	423-984	23
2004	24 March - 14 June	0.20	22 March - 14 June	0.15	26 April - 13 May	0.42	558	371-834	27
2005	11 April - 25 June	0.59	21 March - 16 June	0.06	24 March - 24 June	0.42	638	388-870	32
2006	11 May - 12 May	0.30	27 March - 31 May	0.04	27 March - 30 March	0.00	549	365-790	20

Table 1. Catch rates and total number of northern pike removed during the Northern Pike Removal project (only) from the middle Green River: 2001 – 2006.

Year	Electrofishing Hours	Number Pike Removed	Fyke Netting Nights	Number Pike Removed	Trammel Net/Electrofishing Hours	Number Pike Removed
2001	19.1	53	420.7	130	37.7	39
2002	28.1	17	165	10	5.3	5
2003	65.5	5	103	2	-	-
2004	14.7	3	93	14	2.4	1
2005	8.5	5	227	13	26	11
2006	3.3	1	52	2	2	0

Table 2. Effort expended by gear type during the Northern Pike Removal project (only): 2001-2006.

	Electrofishing					
	Pikeminnow Pop Est Hours	NP Removed	CPUE - CPM Pop Est	Smallmouth Bass Removal Hours	NP Removed	CPUE - SMB Removal
2001	253	29	0.11	-	-	-
2002	182.1	10	0.05	-	-	-
2003	190.4	16	0.08	-	-	-
2004	-	-	-	147	9	0.06
2005	-	-	-	80.4	3	0.04
2006	190.4	16	0.08	152.2	1	0.01

Table 3. Effort and number of northern pike removed during other projects in the middle Green River: 2001-2006.

	Island Park - Rainbow Park (RM334-326)	Split Mountain - Razorback Bar (RM319-311)	Razorback Bar - Thunder Ranch (RM311-303)	Thunder Ranch - Walker Hollow* (RM303-294)	Below Walker Hollow (<RM294)
2001**	0	18	0	155	49
2002	2	3	0	23	14
2003	4	5	2	8	4
2004	1	3	7	13	3
2005***	0	2	3	20	5
2006****	5	8	1	4	1

*Includes Brush Creek, Cliff Creek, Ashley Creek, Stewart Lake inlet/drain

**Does not include 29 NP from CPM abundance estimates

***2 records missing a location

****1 record missing a location

Table 4. Northern pike captures by location: 2001-2006.

Year	Upper Yampa EL	Middle Yampa EL	Middle Yampa FY
2004	8.00	2.15	-
2005	7.60	1.52	-
2006	4.30	1.43	0.12

Table 5. Northern pike catch rates from the upper and middle Yampa River removal projects.

2001		2002		2003		2004		2005	
Age	Length Range (mm)	Age	Length Range (mm)	Age	Length Range (mm)	Age	Length Range (mm)	Age	Length Range (mm)
YOY	170-390	YOY	295	YOY		YOY		YOY	
Juvenile	383-721	Juvenile	392-630	Juvenile	423-528	Juvenile	372-480	Juvenile	388-626
Adult	520-871	Adult	526-815	Adult	520-984	Adult	566-834	Adult	654-870

Table 6. Age groupings by year: 2001-2006.

Tag Number	Tagged By	Original Tag Date	Original Tag Location	Original Length (mm)	Original Weight (g)	Recaptured By	Recapture Date	Recapture Location	Recapture Length (mm)	Recapture Weight (g)	Distance Moved (km)
5126562616	Colorado State University	17-May-03	Yampa RKM 119.7	810	3250	UDWR, Vernal	22-Mar-04	Green RKM 481.2	820	-	192.1
5127175F66	Colorado State University	5-Jun-03	Yampa RKM 184.2	403	400	UDWR, Vernal	19-Sep-07	Green RKM 513.4	740	2473	224.4
425B654113	Colorado State University	18-Jun-03	Yampa RKM 166.2	808	4050	UDWR, Vernal	26-Mar-04	Green RKM 481.5	826	3744	238.3
FLOY45058	U.S. Fish and Wildlife Service	5-May-04	Yampa RKM 242.9	660	-	UDWR, Vernal	11-May-06	Green RKM 490.0	720	2232	306.5

Table 7. Information collected on the four northern pike originally tagged in the Yampa River and subsequently removed from the Green River.

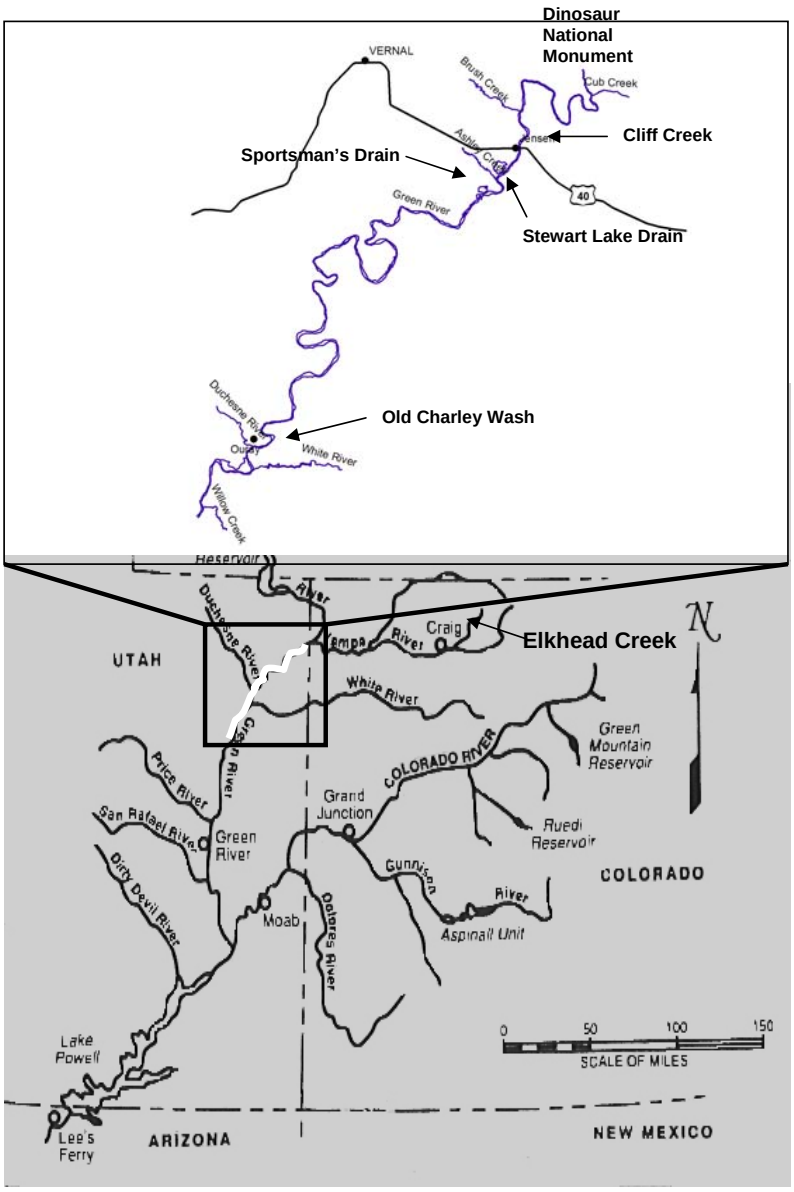

Figure 1. The Upper Colorado River Basin with the northern pike control reach highlighted. Brush Creek is RKM 490; Cliff Creek is not labeled but is just above Jensen at RKM 487; Stewart Lake is not labeled, but is just above Ashley Creek at RKM 483; and Ashley Creek is RKM 481.

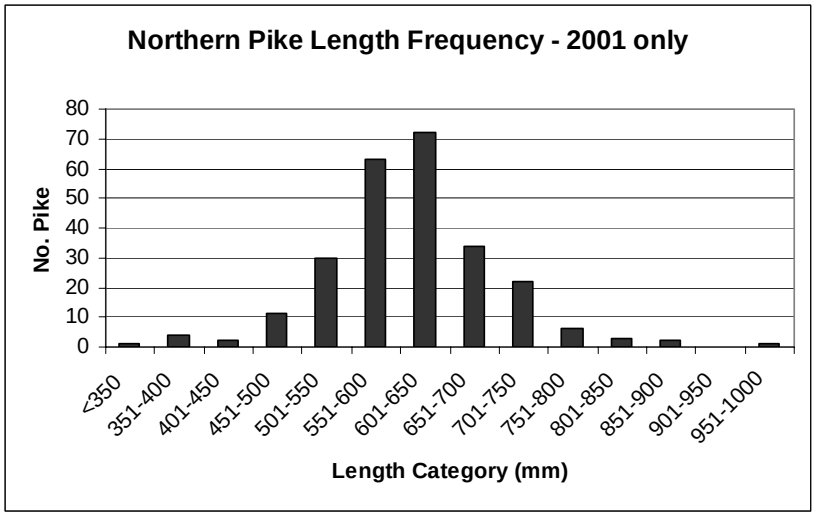

Figure 2. Length frequency of northern pike caught in the middle Green River: 2001.

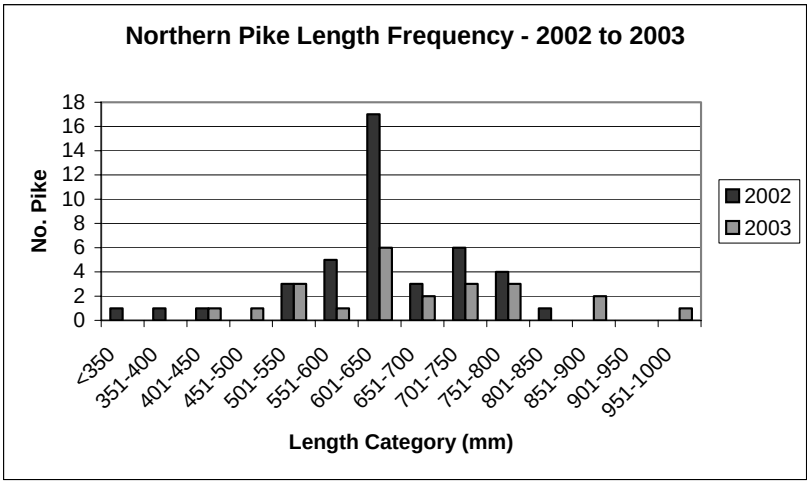

Figure 3. Length frequency of northern pike caught in the middle Green River: 2002-2003.

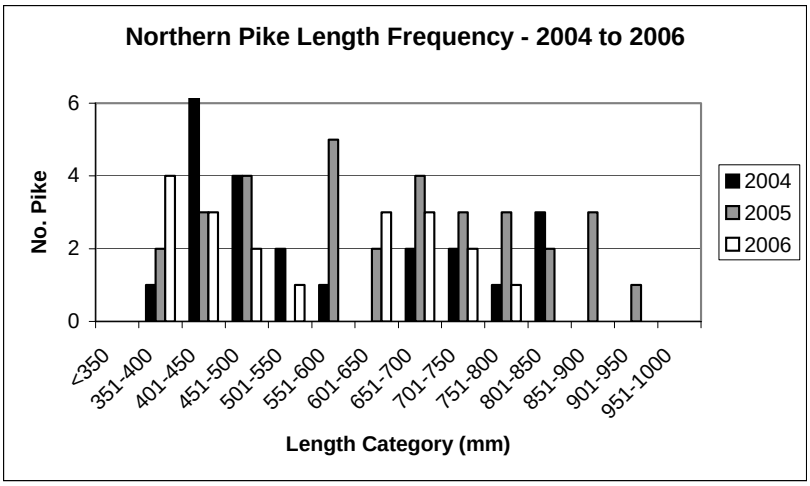

Figure 4. Length frequency of northern pike caught in the middle Green River: 2004-2006.

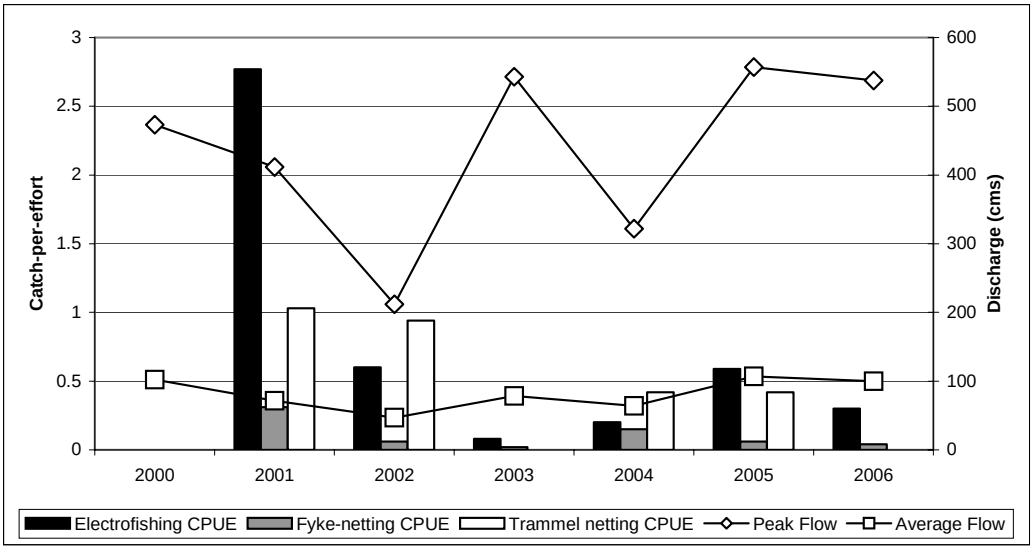

Figure 5. Average and peak annual flow (cubic meters per second) as measured at the Green River gauge at Jensen, UT, compared with the northern pike catch-per-unit-effort (number of northern pike/hour or number of northern pike/fyke-net night) in the middle Green River from 2001 – 2006 (northern pike removal project only).

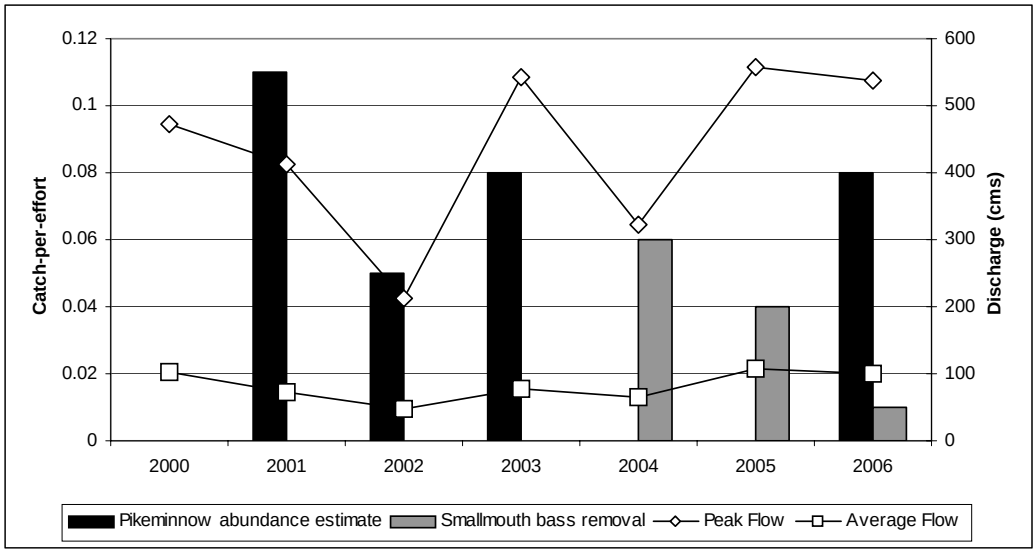

Figure 6. Average and peak annual flow (cubic meters per second) as measured at the Green River gauge at Jensen, UT, compared with the northern pike catch-per-unit-effort (number of northern pike/hour) in the middle Green River from 2001 – 2006 (all other projects).

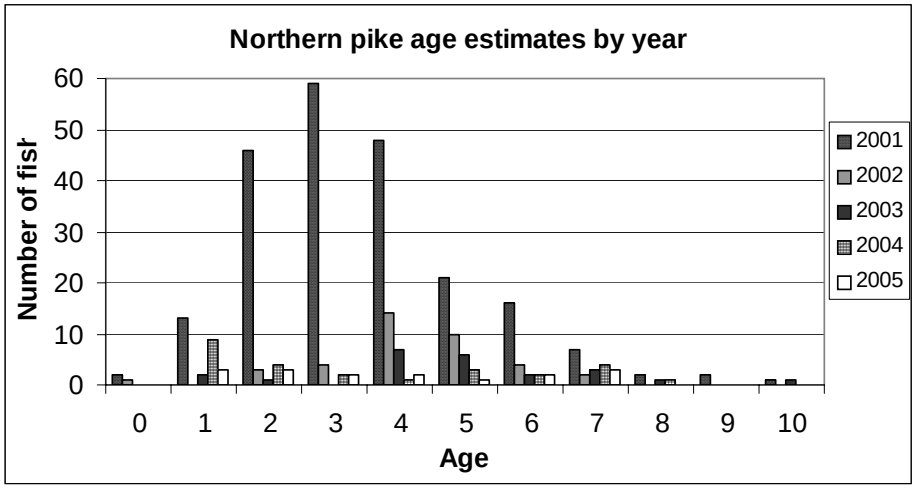

Figure 7. Northern pike age estimates by year.

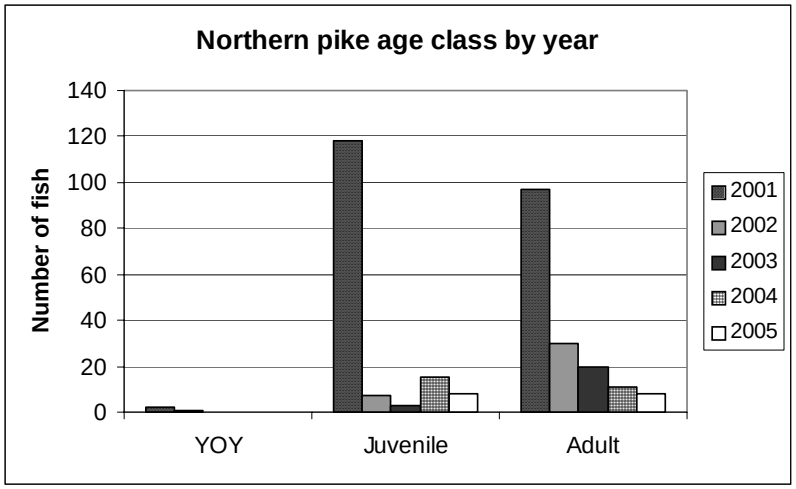

Figure 8. Northern pike age class by year.

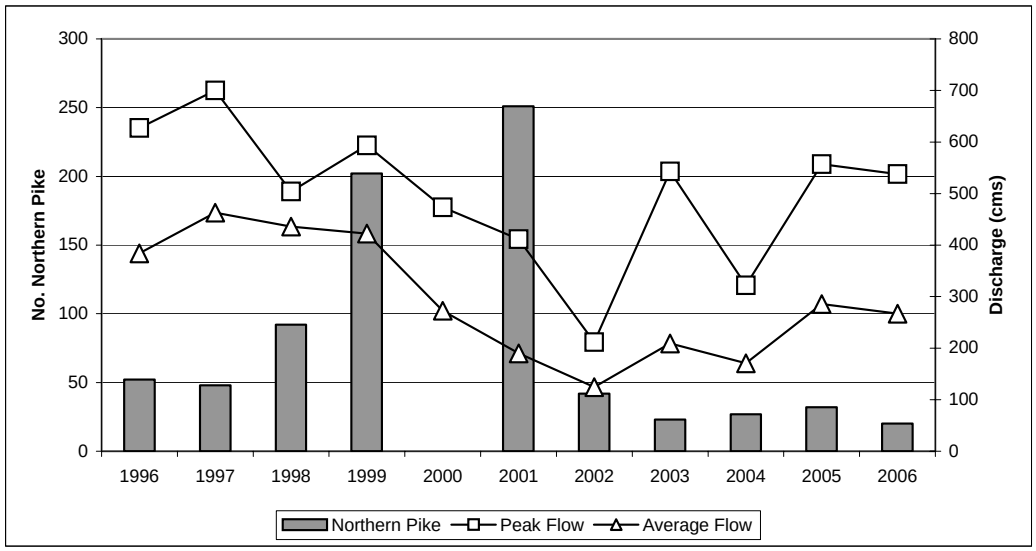

Figure 9. Average and peak annual flow (cubic meters per second) as measured at the Green River gauge at Jensen, UT, compared with the number of northern pike observed (pre-2001) or removed (2001 and later) in the middle Green River from: 1996 – 2006.