Middle Yampa River
Northern Pike and Smallmouth Bass Removal and Evaluation;
Colorado Pikeminnow and Roundtail Chub Evaluation:
2004 - 2007

Upper Colorado River Basin Recovery Implementation Program
Project No. 98a
October 10, 2010

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Northern Pike and Smallmouth Bass Removal and Evaluation;
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Synthesis Report
Project No. 98a
October 10, 2010

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Table of Contents

Section	*Page*
Acknowledgements	3
List of Tables	7
List of Figures	11
List of Key Words	15
Executive Summary	16
Introduction	22
Study Area Description	26
Field Methods/Approach	27
Overview of Fish Collection	27
Northern Pike	29
Field Collection-Passive Gear and “Block-and-Shock” Technique	29
Mark-Recapture and Removal	30
Smallmouth Bass	31
Mark-Recapture and Removal	31
Colorado Pikeminnow and Roundtail Chub	33
Incidental Non-Native Fish Species	33
Data Analyses	34
Northern Pike	34
Population Estimate, Capture Probability, and Capture Efficiency	34
Catch Per Unit Effort (CPUE)	35
Movement	37
Growth	39
Smallmouth Bass	39
Population Estimate	39
Catch Per Unit Effort (CPUE)	40
Movement	41
Results	42
Northern Pike	42
Population Estimate, Capture Probability, and Capture Efficiency	42
Catch Per Unit Effort	43
Population Dynamics	44

Table of Contents (continued)

Section	*Page*
Movement	46
Within Years	46
Among Years	47
Growth	49
Among Years	49
Movement	49
Emigration From Our Study Area	49
Immigration Into Our Study Area	50
Escapement	51
Smallmouth Bass	52
Population Estimate	52
Catch Per Unit Effort	54
Population Dynamics	55
Movement	56
Among Years 2006 and 2007	56
Within Year 2007	56
Colorado Pikeminnow	57
Roundtail Chub	58
Incidental Non-Native Fish Species	59
Discussion	59
Northern Pike	59
Smallmouth Bass	67
Colorado Pikeminnow	73
Roundtail Chub	74
Incidental Non-Native Fish Species	75
Conclusions	75
Northern Pike	75
Smallmouth Bass	76
Colorado Pikeminnow	78
Roundtail Chub	78
Incidental Non-Native Fish Species	78
Recommendations	79
Northern Pike	79
Smallmouth Bass	80
Colorado Pikeminnow and Roundtail Chub	81
Incidental Non-Native Fish Species	81

Table of Contents (continued)

Section	*Page*
Literature Cited	82
List of Appendices	85

List of Tables

Table *Page*

1. Middle Yampa River reaches, river sections, reach descriptions, river miles, and agency responsible by year, 2004-2007 86

2. Actions taken for smallmouth bass by reach, for the middle Yampa River downstream of Craig, 2004-2007 87

3. Northern pike encountered, number of northern pike marked, and number of northern pike removed, from the middle Yampa River downstream of Craig, 2004-2007 88

4. Northern pike adult population estimates with 95% confidence intervals and percentage of adult northern pike population estimate removed, from the middle Yampa River downstream of Craig, 2004-2007 89

5. Northern pike capture efficiencies by pass and by year, for the middle Yampa River downstream of Craig, 2004-2007 90

6. Northern pike capture events and catch per unit effort for different sampling methods used, in the middle Yampa River downstream of Craig, 2004-2007 91

7. Northern pike catch per unit effort by pass and by year, for the middle Yampa River downstream of Craig, 2004-2007 92

8. Number of northern pike handled, number of northern pike removed, and percentage of northern pike handled that were removed, from the middle Yampa River downstream of Craig, 2004-2007 93

9. Number of northern pike captured by pass and by year, for the middle Yampa River downstream of Craig, 2004-2007 94

10. Number of marked adult northern pike recovered on each pass by year, for the middle Yampa River downstream of Craig, 2004-2007 95

11. Number of adult northern pike marked, percentage of adult northern pike not recaptured within the same year, and percentage of adult northern pike population estimate of adult northern pike marked not recaptured within the same year by year, for the middle Yampa River downstream of Craig, 2004-2007 96

12. Number of adult northern pike marked by year and recovered within years and across years for the middle Yampa River downstream of Craig, 2004-2007 97

List of Tables (continued)

Table *Page*

13. Direction of movement for northern pike recaptured by year, for the middle Yampa River downstream of Craig, 2004-2007 98

14. Distance traveled by northern pike recaptured by year, for the middle Yampa River downstream of Craig, 2004–2007 99

15. Movement of northern pike by river section and by year, for the middle Yampa River downstream of Craig, 2004-2007 100

16. Number of northern pike that traveled certain distances in river miles and the range of their total length (in millimeters) at initial capture by year, for the middle Yampa River downstream of Craig, 2004-2007 101

17. Direction of movement for northern pike recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, 2004-2007 102

18. Distance traveled by northern pike recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, 2004-2007 103

19. Movement of northern pike by river section for individuals recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, 2004-2007 104

20. Number of northern pike that traveled certain distances in river miles and the range of their total length (in millimeters) at initial capture for individuals recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, 2004-2007 105

21. Northern pike increase in growth (in millimeters) by total length of size groups for individuals recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, 2004-2007 106

22. Number of northern pike marked in our study area of the middle Yampa River downstream of Craig that emigrated to other projects in the Yampa River and Green River, 2004-2007 107

23. Number of northern pike marked in other projects in the Yampa River that immigrated to our study area in the middle Yampa River downstream of Craig, 2004-2007 108

List of Tables (continued)

Table *Page*

24. Smallmouth bass capture events. Smallmouth bass encountered, marked, and released or removed, for the middle Yampa River downstream of Craig, 2006-2007 109

25. Smallmouth bass capture events by size and overall catch per unit effort, for the middle Yampa River downstream of Craig and Reach 1 only in 2006 and 2007 110

26. Smallmouth bass population estimates by reach and pass number, for the middle Yampa River downstream of Craig, 2006-2007 111

27. Catch per unit effort for smallmouth bass by pass, for the middle Yampa River downstream of Craig, 2006–2007 112

28. Capture efficiencies for adult smallmouth bass across removal efforts for Reach 1, South Beach to Round Bottom, for the middle Yampa River downstream of Craig, 2006–2007 113

29. Smallmouth bass handled, removed, and percentage handled that were removed in Reach 1, South Beach to Round Bottom, for the middle Yampa River downstream of Craig, 2006-2007 114

30. Number of smallmouth bass marked and percentage of bass marked and not recovered in Reach 1, South Beach to Round Bottom, for the middle Yampa River downstream of Craig, 2006-2007 115

31. Number of smallmouth bass marked and recovered within the same year or on subsequent years in Reach 1, South Beach to Round Bottom, for the middle Yampa River downstream of Craig, 2006-2007 116

32. Smallmouth bass among year movement summary, for the middle Yampa River downstream of Craig, 2006-2007 117

33. Movement of smallmouth bass during 2007, for the middle Yampa River downstream of Craig 118

34. Characteristics of Colorado pikeminnow individuals collected, for the middle Yampa River downstream of Craig, 2004-2007 119

35. Characteristics of Colorado pikeminnow individuals recaptured, for the middle Yampa River downstream of Craig, 2004-2007 120

List of Tables (continued)

Table *Page*

36. Characteristics of roundtail chub individuals collected, for the middle Yampa River downstream of Craig, 2005-2007 121

37. Characteristics of roundtail chub individuals recaptured, for the middle Yampa River downstream of Craig, 2005-2007 122

38. Number and total length range (in millimeters) of incidental non-native species collected by year, for the middle Yampa River downstream of Craig, 2004-2007 123

List of Figures

Figure *Page*

1. River reaches of the middle Yampa River sampled by the Colorado Division of Wildlife (CDOW) and Colorado State University (CSU), 2004-2007. 124

2. Average daily Yampa River discharge near Maybell (U.S. Geological Survey gage 09251000) April 1 through July 31, 2004 with agency initial marking, initial removal, and final removal dates for Projects 98a and 98b. 125

3. Average daily Yampa River discharge near Maybell (U.S. Geological Survey gage 09251000) April 1 through July 31, 2005 with agency initial marking, initial removal, and final removal dates for Projects 98a and 98b. 126

4. Average daily Yampa River discharge near Maybell (U.S. Geological Survey gage 09251000) April 1 through July 31, 2006 with agency initial marking, initial removal, and final removal dates for Projects 98a and 98b. 127

5. Average daily Yampa River discharge near Maybell (U.S. Geological Survey gage 09251000) April 1 through July 31, 2007 with agency initial marking, initial removal, and final removal dates for Projects 98a and 98b. 128

6. Minimum daily Yampa River temperatures near Maybell (U.S. Geological Survey gage 09251000), March 1 through July 31, 2004-2007 with initial marking dates for Project 98a. 129

7. Northern pike (≥200 millimeters in total length) population estimates with 95% confidence intervals, and number of northern pike removed by year, for the middle Yampa River downstream of Craig, 2004–2007. 130

8. Number of northern pike (≥200 millimeters in total length) capture events per hour (catch per unit effort) for the Juniper, Maybell, and Lily Park sections of the middle Yampa River downstream of Craig, 2004-2007. 131

9. Number of northern pike (≥200 millimeters in total length) capture events per hour (mean catch per unit effort) with 95% confidence intervals, for the middle Yampa River downstream of Craig, 2004-2007. 132

List of Figures (continued)

Figure *Page*

10a. Northern pike total length (in millimeters) frequency distribution by combined passes for the Juniper Springs section of the middle Yampa River downstream of Craig, 2004. 133

10b. Northern pike total length (in millimeters) frequency distribution by combined passes for the Juniper Springs section of the middle Yampa River downstream of Craig, 2005. 133

10c. Northern pike total length (in millimeters) frequency distribution by combined passes for the Juniper Springs section of the middle Yampa River downstream of Craig, 2006. 133

10d. Northern pike total length (in millimeters) frequency distribution by combined passes for the Juniper Springs section of the middle Yampa River downstream of Craig, 2007. 133

11a. Northern pike total length (in millimeters) frequency distribution by combined passes for the Maybell section of the middle Yampa River downstream of Craig, 2004. 134

11b. Northern pike total length (in millimeters) frequency distribution by combined passes for the Maybell section of the middle Yampa River downstream of Craig, 2005. 134

11c. Northern pike total length (in millimeters) frequency distribution by combined passes for the Maybell section of the middle Yampa River downstream of Craig, 2006. 134

11d. Northern pike total length (in millimeters) frequency distribution by combined passes for the Maybell section of the middle Yampa River downstream of Craig, 2007. 134

12a. Northern pike total length (in millimeters) frequency distribution by combined passes for the Lily Park section of the middle Yampa River downstream of Craig, 2004. 135

12b. Northern pike total length (in millimeters) frequency distribution by combined passes for the Lily Park section of the middle Yampa River, 2005. 135

12c. Northern pike total length (in millimeters) frequency distribution by combined passes for the Lily Park section of the middle Yampa River, 2006. 135

12d. Northern pike total length (in millimeters) frequency distribution by combined passes for the Lily Park section of the middle Yampa River, 2007. 135

List of Figures (continued)

Figure *Page*

13. Smallmouth bass (≥150 millimeters in total length) population estimates with 95% confidence intervals, and number of smallmouth bass removed by year, for the middle Yampa River for South Beach to Round Bottom (Reach 1), 2006 and 2007. 136

14a. Smallmouth bass total length (in millimeters) frequency distribution by Pass 1 and Pass 2 combined and Pass 3 and Pass 4 combined, for the middle Yampa River downstream of Craig, 2006. 137

14b. Smallmouth bass total length (in millimeters) frequency distribution by Pass 1 and Pass 2 combined and Pass 3 and Pass 4 combined, for the middle Yampa River downstream of Craig, 2007. 137

15a. Smallmouth bass total length (in millimeters) frequency distribution by pass, for the middle Yampa River downstream of Craig, 2006. 138

15b. Smallmouth bass total length (in millimeters) frequency distribution by pass, for the middle Yampa River downstream of Craig, 2007. 138

16. Number of smallmouth bass capture events per hour (catch per unit effort) for each reach by pass, for the middle Yampa River downstream of Craig, 2004-2007. 139

17. Catch per unit effort (number of smallmouth bass capture events per hour) normalized as a percentage of mean catch per unit effort for respective reaches plotted against mean daily stream flow in cubic feet per second (cfs) for all passes that occurred on the ascending limb of the hydrograph, for the middle Yampa River downstream of Craig, 2007. 140

18. Catch per unit effort (number of smallmouth bass capture events per hour) normalized as a percentage of mean catch per unit effort for respective reaches plotted against mean daily water temperature in degrees Celsius for all passes that occurred on the ascending limb of the hydrograph, for the middle Yampa River downstream of Craig, 2007. 141

19. Longitudinal distribution of smallmouth bass from river mile 135 to river mile 60, excluding river miles 124-100, for the middle Yampa River downstream of Craig, 2006 and 2007. 142

20a. Smallmouth bass total length (in millimeters) frequency distribution by reach, for the middle Yampa River downstream of Craig, 2006. 143

List of Figures (continued)

Figure *Page*

20b. Smallmouth bass total length (in millimeters) frequency distribution by reach, for the middle Yampa River downstream of Craig, 2007. 143

21. Colorado pikeminnow capture events by river mile and reach, for the middle Yampa River downstream of Craig, 2004–2007. 144

22. Colorado pikeminnow total length (in millimeters) frequency distribution, for the middle Yampa River downstream of Craig, 2004–2007. 145

23. Roundtail chub capture events by river mile and reach, for the middle Yampa River downstream of Craig, 2005-2007. 146

24. Roundtail chub total length frequency (in millimeters) distribution, for the middle Yampa River downstream of Craig, 2005-2007. 147

25a. Number of black bullhead collected by river mile and reach, for the middle Yampa River downstream of Craig, 2004-2007. 148

25b. Number of black crappie collected by river mile and reach, for the middle Yampa River downstream of Craig, 2004-2007. 148

25c. Number of bluegill collected by river mile and reach, for the middle Yampa River downstream of Craig, 2004-2007. 148

25d. Number of green sunfish collected by river mile and reach, for the middle Yampa River downstream of Craig, 2004-2007. 148

List of Key Words

Yampa River, northern pike, smallmouth bass, roundtail chub, Colorado pikeminnow, boat electrofishing, mark recapture, fyke nets, gill nets, trammel nets, population/abundance estimates, catch per unit effort (CPUE), exploitation rates, movement, escapement, sportfishing opportunities

Executive Summary

Northern pike (*Esox lucius*) and smallmouth bass (*Micropterus dolomieu*) are two of 40 introduced fish species to Colorado currently found in the Colorado River basin (Nesler 2003). Northern pike and smallmouth bass were introduced to Elkhead Reservoir of the Yampa River basin, a sub-basin of the Colorado River basin, from the late 1970's to early 1980's (CDOW 2004). Both non-native species have since escaped the reservoir via Elkhead Creek, and moved downstream into the Yampa River. Northern pike and smallmouth bass have established reproducing, self-sustaining populations in the mainstem, middle Yampa River (Fuller 2009).

Negative influences of such introductions on native fish fauna are cause for concern, especially in areas occupied by endangered species. The middle Yampa River downstream of Craig, Colorado, has been designated by the U.S. Fish and Wildlife Service (USFWS) as critical habitat for the federal- and state-listed Colorado pikeminnow (*Ptychocheilus lucius*). Primary threats to this native species include competition and predation from non-native fish species (USFWS 2002).

This project was designed to evaluate removal of northern pike and smallmouth bass populations within approximately 76 river miles (RMs) of the Yampa River. The Colorado Division of Wildlife (CDOW) completed the northern pike portion of this study in conjunction with Colorado State University (CSU). CDOW and CSU northern pike information in this report applies to the entire study area, whereas CDOW smallmouth bass information is presented only for specific reaches of the study area sampled by the CDOW. The CDOW and CSU study area included the middle Yampa River from the upper terminus at Craig (RM 134.2-South Beach boat launch) to the lower terminus in

Lily Park, (RM 50.5-downstream of Cross Mountain Canyon). Main channel shorelines and tributary streams/backwater areas were sampled from mid-April through late-July, 2004 through 2007. Fish capture methods included active (electrofishing and angling) and passive (gill, trammel, and modified fyke net sets) sampling techniques.

Project goals included: 1) reducing the number of northern pike within the study area and reducing the number of smallmouth bass occupying the South Beach reach (RM 134.2-RM 124.0), thereby benefiting native fishes of the Yampa River Basin, as well as native fish communities downstream within the Green River Basin; 2) transporting live northern pike collected from the study area for release in Loudy Simpson pond (Craig) and Rio Blanco Lake (White River Basin, near Meeker, Colorado); and 3) transporting live smallmouth bass ($\geq$250 millimeters (mm) in total length (TL)) collected from the South Beach reach for release in Elkhead Reservoir and Craig Justice Center pond, thereby providing angler opportunities to harvest northern pike and smallmouth bass.

Study objectives included: 1) removing and translocating as many live northern pike as possible within the study area, and removing and translocating as many live smallmouth bass ($\geq$250 mm TL) as possible within the South Beach reach; 2) estimating the number of northern pike occupying the study area, and estimating the number of smallmouth bass occupying the South Beach reach; and 3) estimating the proportion of the northern pike and smallmouth bass populations that were removed. These objectives were also accomplished.

Boat electrofishing and use of modified fyke nets proved feasible for capture of northern pike. Numbers of individual northern pike collected and total catch rates declined from 2004 through 2006, only to increase in 2007. Northern pike adult population estimates

(≥200 mm TL) and mean electrofishing catch rates decreased from 2004 through 2006, although these differences were not statistically significant based on comparison of 95% confidence intervals. Values for both metrics increased in 2007.

Overall, 2,234 northern pike (84% of those handled) were removed by the CDOW and CSU from 2004 through 2007. Ninety percent of northern pike removed were stocked in Loudy Simpson pond and Rio Blanco Lake to provide sportfishing opportunities for anglers. Numbers of northern pike decreased overall in a downstream direction from the Juniper section to the Lily Park section. Northern pike removal was the most effective in the most downstream section, Lily Park where catch rates declined across all four years. Reduction of the number of larger northern pike (≥700 mm TL) across the project was offset by the increase in small-to intermediate-sized northern pike (251 mm TL-450 mm TL). Alternatively, few presumptive juvenile northern pike (<200 mm TL) were collected from 2004 through 2007.

The majority (83%) of northern pike recaptured moved in a downstream direction regardless of time spent at large. Distance moved by northern pike varied. Some northern pike were sedentary; other northern pike moved short distances (<1 RM), while some northern pike moved more than 40 RMs. In general, fish that were at large for a shorter period of time (three months) moved shorter distances between recaptures than those northern pike that were at large for at least 11 months.

Field results indicated immigration and emigration of northern pike were too extensive to achieve the proposed 65% exploitation rate (Modde and Haines, unpublished) for marked northern pike. Mark-recapture population estimates remain problematic in accurately assessing northern pike densities as the assumption of a closed-system was violated. The

use of multiple metrics, both quantitative and qualitative, may yield the best results when assessing northern pike populations in the middle Yampa River.

Our northern pike removal efforts within critical habitat of the middle Yampa River suggested the criterion of less than three adult northern pike per RM will not be achievable until upstream northern pike spawning and nursery habitats are reduced, and sources and recruitment of northern pike are minimized. We concur with Hawkins et al. (2005) and Finney and Haines (2008) who indicated that for northern pike removal to be the most effective, a basin-wide approach must be implemented.

Smallmouth bass removal efforts by the CDOW began in 2006, when marking and removal was initiated for the 10.2 RM South Beach reach (Reach 1). Additionally, in 2006, smallmouth bass handled by the CDOW across the remaining study reaches were captured, examined for external tags, measured for TL in mm, weighed, and released alive. CDOW smallmouth bass efforts increased in 2007 when marking was initiated for all CDOW project reaches, although Reach 1 remained the only reach in which smallmouth bass were removed.

Smallmouth bass numbers and adult population estimates ($\geq$150 mm TL) in Reach 1 (South Beach) did not change significantly between the years of 2006 and 2007, and catch rates for smallmouth bass were consistent between 2006 and 2007 for all CDOW project reaches. Overall, 894 smallmouth bass were removed by the CDOW between 2006 and 2007. Four hundred and ninety nine of these fish were $\geq$250 mm TL (equal to or greater than 10 inches), and were translocated to either Elkhead Reservoir or Craig Justice Center pond for recreational fishing opportunities; the remaining 395 smallmouth bass that were <250 mm TL were euthanized.

Smallmouth bass concentration areas in the middle Yampa River occurred in Reach 1 and Reach 3 (Upper Maybell), and were generally associated with canyon-type river reaches. The greatest concentration of adult smallmouth bass was found in the downstream end of Reach 1 which borders CSU's 24-mile study reach in Little Yampa Canyon. The greatest concentration of sub-adult (<150 mm TL) smallmouth bass occurred at the upstream end of Reach 3, immediately downstream of Juniper Canyon. Further, a greater proportion of sub-adult smallmouth bass was captured later in the study season. Smallmouth bass CPUE was also affected by interrelated environmental variables, including turbidity, water temperature, and river discharge. Smallmouth bass catch rates correlated with water temperature and to a greater extent with river discharge on the ascending limb of the hydrograph. The majority (73%) of recaptured smallmouth bass moved in an upstream direction regardless of time spent at large. Upstream movement of smallmouth bass varied from 1 to 56 RMs and downstream movement varied from 1 to 10 RMs.

Our removal efforts indicated the recommended target exploitation rate for smallmouth bass of 65% (Modde and Haines, unpublished) was not achieved in Reach 1, suggesting that greater removal effort is necessary. Further, field results demonstrated smallmouth bass numbers are great enough in Reach 3 to warrant removal in future years, and the presence of sub-adults within this reach suggested that reproduction occurs there or nearby.

Smallmouth bass presumably moved extensive distances during the short study periods, confounding adult smallmouth bass population estimates calculated for relatively small reaches of river. Additionally, estimated capture probabilities for adult smallmouth bass were low. Therefore, we provide recommendations for improving smallmouth bass

mark-recapture methodologies, as well as suggest methods for improving the statistical reliability of adult smallmouth bass population estimates, including marking smallmouth bass later in the field season when catch rates are higher, and conducting estimates for greater lengths of the river to account for the vast movement exhibited.

Introduction

Northern pike (*Esox lucius*) and smallmouth bass (*Micropterus dolomieu*) are two of 40 fish species introduced to Colorado and currently found in the Colorado River basin (Nesler 2003). Northern pike were first introduced to the Yampa River basin in Elkhead Reservoir in 1977. This species was introduced to reduce numbers of nonnative suckers in the reservoir (Roehm 2004). Smallmouth bass were also stocked in Elkhead Reservoir in the late 1970's or early 1980's (CDOW 2004). Elkhead Creek flows into and out of Elkhead Reservoir, and has served as a conduit for downstream movement of northern pike and smallmouth bass into the Yampa River. Movement of northern pike into the Yampa River downstream of Elkhead Reservoir was demonstrated as early as 1979 (Tyus and Beard 1990). Prior to 1992, capture of smallmouth bass in the Yampa River was considered an incidental occurrence (Nesler 1995). Large draw-down events of Elkhead Reservoir in 1992 and 1994 may have resulted in the greatest escape of smallmouth bass into the Yampa River (CDOW 2004). Both non-native species have established reproducing, self-sustaining populations in the mainstem, middle Yampa River (Fuller 2009).

Negative influences of such introductions on the native fish fauna are cause for concern, especially in areas occupied by endangered species. The middle Yampa River downstream from Craig, Colorado, has been designated by the U.S. Fish and Wildlife Service (USFWS) as critical habitat for the federal- and state-listed Colorado pikeminnow (*Ptychocheilus lucius*). Primary threats to this native species include competition and predation from non-native fish species (USFWS 2002). Warmwater sportfishes, in particular, have been recognized as negatively influencing native fishes.

The northern pike has been identified as one of two principal, non-native fish species that pose threats to juvenile and adult Colorado pikeminnow (USFWS 2002). Northern pike and Colorado pikeminnow utilize similar habitat in the spring and early summer during the spawning season. Both species also rely on native sympatric species as prey, including the roundtail chub (*Gila robusta*), flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*Catostomus discobolus*), and speckled dace (*Rhinichthys osculus*) (Tyus and Beard 1990; Nesler 1995). Resource exploitation may also increase the likelihood of northern pike predation on young and adult endangered fishes (Tyus and Beard 1990; Nesler 1995). Johnson et al. (2008) categorized northern pike as "potent piscivores, capable of ingesting adults of even large-bodied native species." Thus, northern pike may potentially impact native fish species through competition and predation.

The smallmouth bass has also been designated as a non-native fish species of interest (Hawkins and Nesler 1991) due to increased abundance, habitat preferences, and piscivorous habits (USFWS 2002). Smallmouth bass may negatively affect all endemic fishes in the Gila River basin of Arizona (Hawkins and Nesler 1991), and were identified as a major predator in Arizona, impeding successful reintroduction of Colorado pikeminnow (AGFD 2002). Further, Valdez and Muth (2005) noted that smallmouth bass "pose significant threats to the survival of endangered fish" because smallmouth bass "prey upon them and compete for food and space." Most recently, Johnson et al. (2008) identified the smallmouth bass as the "greatest predatory threat to native fishes of the Yampa River" based upon level of piscivory. Therefore, smallmouth bass may also impact native fish species through predation and competition.

Potential negative interaction between introduced, non-native sportfish and native fishes prompted the development of management plans including control of non-native fishes.

A strategic plan for non-native fish control was developed for the upper Colorado River basin by 1997 (Tyus and Saunders 1996), and implemented by the Upper Colorado River Endangered Fish Recovery Program (UCRP) (USFWS 2002). The two basic strategies recommended for non-native fish control within the plan include removal and exclusion. The Colorado Division of Wildlife (CDOW) developed and implemented an Aquatic Wildlife Management plan (CDOW 1998) specific to the Yampa River basin in 1998 for recovery of endangered fishes. This plan includes reduction of northern pike and smallmouth bass numbers in riverine habitats, and evaluation of such actions through monitoring for significant temporal and spatial depletion of target species. The UCRP adopted a Non-Native Fish Management Policy (UCRRIP 2004) in 2004. This policy states that the overall goals of non-native fish management are to: 1) attain and maintain fish communities where populations of the endangered and other native fish species can persist and thrive, and 2) achieve recovery goals for the endangered species. Successful implementation of such non-native fish management projects is expected to benefit endangered fishes, as well as sympatric, native non-listed fish species.`

This project was designed to evaluate removal of northern pike and smallmouth bass from populations within approximately 76 river miles (RMs) of the middle Yampa River from 2004 through 2007. Project goals included: 1) reducing the number of northern pike within the study area and reducing the number of smallmouth bass occupying the South Beach reach (RM 134.2-RM 124.0), thereby benefiting native fishes of the Yampa River Basin, as well as native fish communities downstream within the Green River Basin; 2) transporting live northern pike collected from the study area for release in Loudy Simpson pond (Craig) and Rio Blanco Lake (White River Basin, near Meeker, Colorado), and transporting live smallmouth bass ($\geq$250 millimeters (mm) total length (TL)) collected from the South Beach reach for release in Elkhead Reservoir and Craig

Justice Center pond, thereby providing angler opportunities to harvest northern pike and smallmouth bass.

Study objectives included: 1) removing and translocating as many live northern pike as possible within the study area, and removing and translocating as many live smallmouth bass (≥250 mm TL) as possible within the South Beach reach; 2) estimating the number of northern pike occupying the study area, and estimating the number of smallmouth bass occupying the South Beach reach; and 3) estimating the proportion of the northern pike and smallmouth bass populations that were removed.

The CDOW completed the northern pike portion of this study in conjunction with Colorado State University (CSU). Roles of the two agencies and level of effort, as well as goals and objectives occasionally changed from year to year. The entire study area, however, has remained the same. Specific information detailing lead-agency involvement by species of interest, and agency-specific project goals and objectives are provided in Appendix A and Table 1. Actions taken for smallmouth bass by CDOW and CSU are included in Table 2.

The objective of this report is to synthesize the goals, objectives, methods, and results of fish sampling completed primarily by the CDOW from 2004 through 2007. Recommendations are also provided for future sampling based on our field results and observations. Further, the authors include additional analyses specifically requested by the UCRP Biology Committee (BC) within the Nonnative Fish Management Draft Synthesis Report Guidance (Pat Nelson email, 01/23/2007).

CDOW and CSU northern pike information in this report applies to the entire study area, whereas CDOW smallmouth bass information is presented only for specific reaches of the study area sampled by the CDOW in 2006 and 2007. CDOW data are also presented for roundtail chub (2005-2007), Colorado pikeminnow (2004-2007), and incidental non-native fish species captured (i.e., ictalurids, centrarchids, and cyprinids) (2004-2007). Data collected by CSU for smallmouth bass and species other than northern pike are presented elsewhere (Hawkins 2004, 2005, 2006, and 2007). CSU is considered the lead agency for smallmouth bass in RMs 124.0-100.0 (Little Yampa Canyon) and RMs 55.5-50.5 (Lily Park). The CDOW has been considered the lead agency for northern pike in the entire study area (RM 134.2-RM 50.5) since 2005.

Study Area Description

The Yampa River basin (3,410 square miles) is located in the northwestern portion of Colorado, west of the Continental Divide (Figure 1). The Yampa River originates at the confluence of three waters draining the Flat Tops Wilderness Area and Routt National Forest. The river then flows to the north and eventually west, joining the Green River in Dinosaur National Monument in Colorado, near the Utah border.

The study area includes approximately 76 RMs within critical habitat of the middle Yampa River from the upper terminus downstream of Craig (RM 134.2-South Beach boat launch) to the lower terminus in Lily Park, (RM 50.5-downstream of Cross Mountain Canyon) (Figure 1 and Table 1). Major tributaries within the study area include: the Williams Fork River (RM 129.9), Milk Creek (RM 119.2), Lay Creek (RM 88.2), Spring Creek (RM 81.6), Sand Creek (RM 72.9), and the Little Snake River (RM 51.0). Other, smaller tributaries (occasionally ephemeral) include: Fuhr Gulch (RM 117.1), Sand Spring Gulch (RM 113.2), Horse Gulch (RM 106.7), Morgan Gulch (RM

103.4), Maudlin Gulch (RM 97.9), Jesse Gulch (RM 97.7), Temple Gulch (RM 91.2), and Overholt Draw (RM 76.1). The CDOW and CSU divided the area into several sampling reaches (Figure 1 and Table 1). These reaches were part of three larger sections: the Juniper section includes Reach 1, Reach CSU 1, Reach CSU 2, Reach 2; the Maybell section includes Reach 3 through Reach 5; and the Lily Park section includes Reach CSU 3. Northern pike data were analyzed by reach and section, whereas smallmouth bass data were examined by reach.

The Juniper section is approximately 43 RMs and flows from a higher, steeper gradient to a lower, flatter gradient through Duffy Mountain/Little Yampa Canyon and Juniper Canyon. The river then traverses irrigated, agricultural land in between the canyons. The Maybell section begins just downstream of the whitewater in Juniper Canyon, where the river meanders for 28.1 RMs through irrigated, agricultural land before descending into Cross Mountain Canyon. The five RM section in Lily Park originates just downstream of Cross Mountain Canyon, and flows through irrigated, agricultural land before the confluence with the Little Snake River at RM 51.0. Approximately seven RMs associated with Juniper Canyon and Cross Mountain Canyon were not sampled due to un-navigable river conditions related to a large, instream water diversion.

Field Methods/Approach

Overview of Fish Collection

Most fish capture methods were selected based on success of prior investigators (Hawkins et al. 2005). These methods included active (electrofishing and angling) and passive sampling (trammel and modified fyke net sets) techniques. Gill nets were also used to capture northern pike by entangling their teeth. This nontraditional use of gill nets was developed and implemented by other state wildlife management agencies,

including Montana Fish, Wildlife, and Parks (D. Schmetterling, personal communication). Smallmouth bass and roundtail chub were collected by electrofishing, while passive techniques were used additionally to capture northern pike and Colorado pikeminnow. Angling for northern pike and smallmouth bass was also conducted by CSU on several passes in 2006 and 2007.

Fish were sampled from mid-April through late-July. Main channel shorelines and tributary streams/backwater areas were sampled each year with boat mounted electrofishing gear (Smith-Root 5.0 GPP, Smith-Root VVP-15B, and Coffelt VVP-15). Electrofishing effort and electrofishing settings were recorded by reach and habitat (main channel or tributary stream/backwater) sampled, and by date. Water conductivity and temperature measurements were taken in the main channel, as well as tributary streams/backwaters.

River discharge (Figures 2, 3, 4, and 5) and river temperature (Figure 6) conditions were evaluated to determine start and stop dates for fish collection based on previous CDOW and CSU fish sampling experience. Data for river discharge and river temperature were obtained from the United States Geological Survey (USGS) gage on the Yampa River near Maybell (USGS Station 09251000) (USGS 2009). In general, river discharge greater than 1,500 cubic feet per second (cfs) was sufficient to navigate most sections of the river safely. Alternatively, fish sampling of main channel and tributary streams/backwaters was ineffective as river discharge increased to greater than 8,000 cfs. Electrofishing and modified fyke net sets were generally most effective in tributary stream/backwater areas at intermediate flows (4,000 cfs-6,000 cfs). Sampling was less efficient in tributary stream/backwater habitats when these areas were inundated from high discharge (>6,000 cfs) associated with spring snowmelt conditions. Electrofishing

conditions were generally the most effective once river temperatures reached at least seven degrees Celsius (J. Hawkins, personal communication).

CDOW and CSU crews initiated sampling during the third week of April each year (Figure 2, Figure 3, Figure 4, and Figure 5). Sampling typically was completed by the end of July. Information regarding the initial marking day, the initial removal day, and the final removal day in relation to river discharge is provided for each year. Further, this same information is included for the USFWS sampling effort in Project 98b (RM 171.0 to RM 134.2) working immediately upstream of the CDOW and CSU personnel.

Northern Pike

Field Collection-Passive Gear and "Block-and-Shock" Technique

Passive techniques including modified fyke nets, trammel nets, and gill nets were utilized to target northern pike in tributary stream/backwater habitats when river discharge was elevated. Cotton/linen fyke nets were only used in 2006 and 2007. Specifications of these nets included the following: bar measure-diamond mesh ranged from 6.4 mm-38.1 mm; nets were modified with rectangular frame throats which measured 1.2 meters (m) in height and ranged from 1.5 m-2.0 m in width; and single leads ranged from 7.6 m-30.5 m in length. An early season fyke net and pheromone experimental study as well as a high water discharge fyke net study were undertaken in 2006 by the CDOW. Specific methodology applied during the early season fyke net and pheromone experimental study, as well as results specific to this study are presented in Appendix B. The high water discharge fyke net study involved placing modified fyke nets in tributary stream/backwater habitats for a 24-hour period when river discharge was elevated in May, 2006. The "block-and-shock" (Nesler 1995) technique was utilized with temporary placement of gill or trammel nets in the mouths of tributary stream/backwater habitats.

These nets blocked the mouth of tributary stream/backwater habitats and captured fish while crews electrofished the enclosed tributary stream/backwater habitats. All nets were removed from these habitats following the completion of electrofishing. Clear, monofilament gill nets and cotton/linen trammel nets were typically a minimum of 15.2 m in length. Bar measure mesh size was 25.4 mm for gill nets and the inside panel of trammel nets. Outer panels of the trammel nets measured 279.4 mm.

Mark-Recapture and Removal

Northern pike population estimates were determined using a mark-recapture methodology for the entire study area (RM 134.2-RM 50.5). Typically, a single marking pass was followed within two weeks by the first recapture/removal pass. A minimum of two additional removal passes were performed. River reaches did not all receive the same level of removal effort due to low flow conditions and equipment malfunction. In 2006, two marking passes were conducted by CSU with the objective of marking a larger number of individuals to increase recapture probability.

Northern pike were examined for the presence of t-bar FLOY tags, fin clips, and in some cases, Passive Integrated Transponder (PIT) tags. Historically, northern pike were PIT tagged by other research projects to determine tag suitability and retention (J. Hawkins, personal communication). Total length ($\pm$ 1 mm) and weight ($\pm$ 1 gram (g)) were recorded for each northern pike. All northern pike not previously FLOY tagged were tagged in the dorsal fin region with a unique, numbered and colored t-bar FLOY tag. Minimum length for FLOY tagged northern pike varied between years, ranging from $\geq$150 mm TL to $\geq$200 mm TL, as tagging protocols changed from year to year. FLOY tag number and tag color, fin clips, and PIT tag number were recorded for each northern pike. Capture locations for northern pike were recorded to the nearest tenth of a RM.

Northern pike collected on marking passes were returned to the river alive near the capture location. Northern pike captured on removal passes were tagged, transported, and stocked in Loudy Simpson pond (2004-2007) and Rio Blanco Lake (2004-2006) to provide sportfishing opportunities for anglers as per CDOW policy. Subsets of northern pike were also removed from the river, euthanized, and provided to three agencies: 1) the CDOW and CSU for determination of age, and bioenergetics analyses, and 2) the Colorado Department of Public Health and Environment (CDPHE) for mercury composition analyses. Results of the age, bioenergetics, and mercury analyses are not provided in this report.

Smallmouth Bass

Mark-Recapture and Removal

In 2005, the CDOW only collected data from smallmouth bass that had been previously FLOY tagged by other investigators. These data are not included in this report, but have been previously summarized by Martin (2005).

In 2006, the CDOW initiated a mark-recapture methodology for smallmouth bass collected within the South Beach reach (Reach 1) (RM 134.2-RM 124.0). The marking pass was followed within two weeks by the first recapture/removal pass. Two additional removal passes were performed in Reach 1. Smallmouth bass were examined for the presence of FLOY tags and fin clips, measured for TL ($\pm$ 1 mm), and weighed ($\pm$ 1 g). Smallmouth bass $\geq$150 mm TL that were captured and not previously FLOY tagged, were tagged in the dorsal fin region with a unique, numbered and colored t-bar FLOY tag. FLOY tag number and tag color, fin clips, TL, and weight were recorded for each

smallmouth bass. Capture locations for smallmouth bass were recorded to the nearest tenth of a RM.

Smallmouth bass collected outside of the South Beach reach were not tagged in 2006. All smallmouth bass netted were examined for the presence of FLOY tags and fin clips. FLOY tag number and tag color, fin clips, TL, and weight were recorded for each smallmouth bass. Capture locations for smallmouth bass were recorded to the nearest tenth of a RM. Smallmouth bass captured outside of the South Beach reach were released alive near the capture location.

In 2007, the CDOW initiated a mark-recapture methodology for smallmouth bass in all five reaches of the study area. Smallmouth bass were tagged and released in Reach 2 through Reach 5 during four passes. Smallmouth bass were removed only from the South Beach reach (Reach 1). A total of five removal passes were completed within Reach 1. Smallmouth bass were examined for the presence of FLOY tags and fin clips, measured for TL ($\pm$ 1 mm), and weighed ($\pm$ 1 g). Smallmouth bass not previously FLOY tagged, were tagged in the dorsal fin region with a unique, numbered and colored t-bar FLOY tag. Minimum length of smallmouth bass tagged varied, ranging from $\geq$150 mm TL to $\geq$250 mm TL, as tagging protocols changed from year to year. FLOY tag number and tag color, fin clips, TL, and weight were recorded for each smallmouth bass. Capture locations for smallmouth bass were recorded to the nearest tenth of a RM.

In 2006 and 2007, smallmouth bass ($\geq$250 mm TL) captured within the South Beach reach (Reach 1) (RM 134.2-RM 124.0) on removal passes were tagged, transported, and stocked in two locations to provide sportfishing opportunities for anglers as per CDOW policy. In 2006 and 2007, the Craig Justice Center pond was stocked with tagged

smallmouth bass. Elkhead Reservoir was stocked with tagged smallmouth bass in 2007. Smallmouth bass <250 mm TL collected from the South Beach reach were euthanized in both years. Subsets of smallmouth bass were also removed from the river, euthanized, and provided to three agencies: 1) the CDOW and CSU for determination of age, and bioenergetics analyses, and 2) the CDPHE for mercury composition analyses. Results of the age, bioenergetics, and mercury analyses are not provided in this report.

Colorado Pikeminnow and Roundtail Chub

All Colorado pikeminnow and roundtail chub captured were measured for TL (± 1 mm) and weighed (± 1 g). Both species were scanned for the presence of PIT tags. Roundtail chub were not scanned and implanted with PIT tags until 2005. Thus, even though the CDOW handled roundtail chub in 2004, these data are not included in this report. Colorado pikeminnow and roundtail chub without 134.2 kHz PIT tags were implanted with new 134.2 kHz PIT tags following the guidance of previous investigators (J. Hawkins, personal communication). All Colorado pikeminnow and roundtail chub captured were released back to the river alive immediately following data collection. PIT tag number, TL, and weight were recorded for each Colorado pikeminnow and roundtail chub. Capture locations for both species were recorded to the nearest tenth of a RM. External lacerations on individuals were attributed as presumptive northern pike attacks, and recorded.

Incidental Non-Native Fish Species

Incidental, non-native fish species were also encountered, including ictalurids, centrarchids, and cyprinids. All individuals of these fish species were measured for TL (± 1 mm), euthanized, and provided to the CDOW and CSU, as well as the CDPHE to assist in determination of age and bioenergetics analyses, as well as mercury composition

analyses, respectively. Results of the age, bioenergetics, and mercury analyses are not provided in this report.

Data Analyses

Northern Pike

Population Estimate, Capture Probability, and Capture Efficiency

A combined CDOW and CSU dataset was utilized to calculate northern pike population estimates for the middle Yampa River downstream of Craig (RM 134.2) to near the confluence with the Little Snake River (RM 50.5) (approximately 76 RMs) from 2004 through 2007. Hawkins et al. (2005) used the Program CAPTURE Model (t) of Chao (White et al. 1982) to generate northern pike population estimates in the middle Yampa River prior to 2004. This same model was used in the current analyses to facilitate data comparison to previous years. Northern pike individuals <200 mm in TL were excluded from the analysis. Adult population estimates were determined for northern pike ≥200 mm TL and ≥300 mm TL; the minimum size considered for northern pike juveniles and adults varied between projects. All northern pike ≥200 mm TL were considered to be adult fish. All northern pike collected on the first pass that had been previously tagged by other investigators were also utilized as "marked" fish for purposes of determining population estimates. Additionally, northern pike captured during the early season fyke net and pheromone experimental study in 2006 were included in the 2006 point estimate. Duplicate catches of the same fish within the same pass by CSU and CDOW were accounted for once.

Capture probabilities and efficiencies were determined for northern pike ≥200 mm TL for each year of the project. Capture probabilities were expressed as the percentage of Pass 1-marked northern pike recovered on Pass 2. Northern pike capture efficiencies by pass

were calculated for each year. Total northern pike capture efficiencies across all passes combined were also calculated for each year. Capture efficiencies were expressed as the total number of northern pike ≥200 mm TL removed per pass relative to the respective population estimate. Northern pike removed on each pass were accounted for cumulatively, by subtracting these fish from the population estimate for each subsequent pass. For example, the population estimate for northern pike ≥200 mm TL for 2004 was estimated at 981 individuals. On the first removal pass (Pass 2), 227 northern pike ≥200 mm TL were removed. The capture efficiency for this pass was 227 divided by 981 (23%). One hundred and three northern pike ≥200 mm TL were removed on Pass 3. The capture efficiency for this pass was determined by dividing 103 by 754 (227 northern pike had been removed from the estimated population of 981 on Pass 2).

Catch Per Unit Effort (CPUE)

Catch per unit effort (CPUE) was determined for each year of the project (2004-2007), and reported as the number of northern pike capture events per hour. Often, the CDOW and CSU performed additional passes subsequent to Pass 2. These additional passes were completed at varying times during the course of each year, usually two to three weeks apart. This temporal variation created difficulty when combining both of the agencies' data by pass number. Agency data for northern pike were combined by pass based upon the total number of trips through the study reach of interest. For example, in 2005, the CDOW sampled the South Beach reach (Reach 1) on two occasions subsequent to Pass 2. CSU also sampled this reach, completing two additional northern pike removal passes. A total of five northern pike removal passes were performed through Reach 1. The CDOW's third northern pike removal pass through Reach 1 was actually the fifth northern pike removal pass overall because CSU completed two northern pike removal

passes through Reach 1 between the CDOW's second and third northern pike removal passes.

Catch rates were determined for the three gear types used, as well as the sum of all gears used. CPUE was determined for each of these categories:

1) the number of northern pike capture events by electrofishing, including "block-and-shock" electrofishing associated with tributary stream/backwater sampling;

2) the number of northern pike capture events during modified fyke net sets and electrofishing ("block-and-shock") during modified fyke net sets; modified fyke net sets and electrofishing during modified fyke net sets were considered a unique sampling protocol due to the brevity of the electrofishing component, accounting for 1.3% of the total 589 hours of effort

3) the number of northern pike capture events during angling; and

4) the total of 1), 2), and 3).

Total CPUE for all gear types was also presented by size classes (<200 mm TL, ≥200 mm TL, ≥300 mm TL, and ≥700 mm TL) for northern pike captured. All capture events were independent of one another, and all individuals that were recaptured, were included in total capture events. All northern pike could have been captured on multiple occasions, and each occasion was considered as a capture event.

Mean CPUE was also determined for each gear type used, as well as the sum of all gears used for northern pike. Mean CPUE was determined for the same methodology categories (see above) as was calculated for total CPUE. Catch rates were generated by river section (Juniper, Maybell, and Lily Park) by category. These catch rates for the river sections were then summed, and a mean CPUE calculated for each year and for each category.

Movement

Northern pike movement was examined throughout the project. Movement analysis involved calculating the distance traveled by subtracting the farthest downstream RM of capture from the farthest upstream RM of capture. Three requirements had to be met before northern pike were included in movement analysis. Individuals had to: 1) be captured more than once, 2) be captured on different days; i.e., individuals recaptured on the same day were excluded, and 3) travel more than one RM from the initial capture location upon recapture. Northern pike that were sedentary or that did not travel more than one RM from the initial capture were not analyzed due to the potential for error in estimating capture location within a relatively small distance. Several individuals were recaptured on more than one occasion. Greatest distance traveled across all recaptures was recorded for these fish.

Movement distance for northern pike included the following categories:

1) >1.0 to 5.0 RMs,
2) >5.0 to 10.0 RMs,
3) >10.0 to 20.0 RMs,
4) >20.0 to 30.0 RMs,
5) >30.0 to 40.0 RMs, and

6) >40.0 RMs.

Movement direction (upstream or downstream) for northern pike was also identified and determined by comparing the first capture location to the second capture location. Several northern pike were captured on three occasions. Movement direction for these individuals was determined by comparing the first capture location to the second capture location, and the second capture location to the third capture location. If the movement direction was the same for both recapture events, then the direction was counted once toward either upstream or downstream movement. Movement data were not used if northern pike moved ≤ one RM between recapture events. For example, a fish could have moved 0.8 RM upstream from the initial capture location, and then moved downstream 2.0 RMs to the third capture location. The movement direction for this fish would have been recorded as "downstream," since the first movement would have been excluded.

Movement direction categories for northern pike included the following: 1) downstream movement, 2) upstream movement, 3) downstream movement then upstream movement, and 4) upstream movement then downstream movement. Fish from these four categories were grouped together to determine overall movement direction, either upstream or downstream. Total numbers of fish in categories one and three were summed to determine the total number of northern pike that moved downstream. Total numbers of fish in categories two and four were summed to determine the total number of northern pike that moved upstream.

Movement in and out of river sections was also determined for northern pike. River section was identified by comparing the first capture location to the second capture location. Greatest distance traveled was used to determine movement by sections for

northern pike that were recaptured on two or more occasions within the same year. Greatest distance traveled was also used to determine movement by sections for northern pike that were recaptured from 11 to 15 months at large.

Growth

Northern pike recaptured after being at large for 11 to 15 months were used for growth analysis. Total growth for an individual was calculated as the difference in TL between the initial and subsequent capture events within this time period. Total growth for each fish was evaluated by size class. The greatest TL recorded within seasons was used to calculate growth for a fish recaptured on multiple occasions within the 11 to 15 month period.

Smallmouth Bass

Population Estimate

Chapman's (1951) modification of the Lincoln-Petersen formula was used to generate smallmouth bass population estimates for the middle Yampa River. Capture probability was calculated by dividing the number of recaptured fish on the recapture pass by the point estimate. Although using an open model as was used with northern pike may have been more appropriate, in 2006 and 2007 the smallmouth bass portion of this study was in a pilot phase, thus the closed Chapman model was deemed sufficient for exploring methods for calculating abundance. CDOW data from 2006 and 2007 were utilized to calculate smallmouth bass population estimates for Reach 1 (South Beach reach), approximately 10.2 RMs. Analyses were based upon an initial mark pass followed by the recapture pass. Smallmouth bass population estimates were determined for Reach 2 (RMs 100.0-91.0), Reach 3 (RMs 88.7-79.2), Reach 4 (RMs 79.2-71.0), and Reach 5 (RMs 71.0-60.6) in 2007.

Smallmouth bass individuals <150 mm TL were excluded from the population estimate analysis in all reaches except Reach 3. All smallmouth bass <200 mm TL were excluded from population estimate analysis in Reach 3. Ideally, 150 mm TL would have been the minimum length for determination of population estimates in all five reaches. However, tagging protocols changed from year to year. All smallmouth bass collected on the first pass that had been previously tagged by other investigators were utilized as "marked" fish for purposes of determining population estimates. Duplicate catches of the same fish within the same pass were accounted for once.

Catch Per Unit Effort (CPUE)

CPUE for smallmouth bass was generated only for boat electrofishing, and was reported as the number of smallmouth bass capture events per hour of electrofishing. All smallmouth bass could have been captured on multiple occasions, and each occasion was considered as a capture event. Total CPUE was calculated by dividing the number of smallmouth bass capture events across all sampling passes by the total amount of electrofishing effort across all sampling passes in Reach 1, for 2006 and 2007. Total CPUE was also calculated for Reaches 2, 3, 4, and 5 combined, in 2006 and 2007. Total CPUE was generated across the entire study area for each sampling pass in 2006 and 2007, and was calculated by dividing the total number of smallmouth bass capture events in each sampling pass by the corresponding amount of electrofishing effort. In 2007, the authors chose to begin examining CPUE for each individual reach to identify concentration areas and observe any trends in future years. Thus, in 2007 only, total CPUE was calculated for each individual reach by dividing the total number of smallmouth bass capture events across all passes for each reach by the corresponding amount of electrofishing effort. In addition to reporting CPUE for unique reaches and for

discrete sampling passes, relative daily CPUE (total number of smallmouth capture events per hour/mean CPUE) was plotted against mean daily discharge (cfs) and water temperature (degrees Celsius) for all sampling passes that occurred on the ascending limb of the hydrograph.

Movement

Smallmouth bass movement was examined within 2007 (i.e. initial and recapture both occurred in 2007) and between 2006 and 2007 (i.e. initial capture occurred in 2006 and recapture occurred in 2007). Movement analysis for smallmouth bass followed similar methodology as the analysis for northern pike. However, movement distance for smallmouth bass included the following categories:

1) >1.0 to 2.0 RMs,
2) >2.0 to 4.0 RMs,
3) >4.0 to 6.0 RMs,
4) >6.0 to 8.0 RMs,
5) >8.0 to 10.0 RMs,
6) >10.0 to 20.0 RMs,
7) >20.0 to 30.0 RMs,
8) >30.0 to 40.0 RMs,
9) >40.0 to 50.0 RMs, and
10) >50.0 to 60.0 RMs.

Movement direction (upstream or downstream) for smallmouth bass was also identified and determined by comparing the first capture location to the final capture location. Movement calculations for fish that were recaptured more than once were based on the initial capture location and final capture location. Proportions of smallmouth bass that

moved downstream versus upstream greater than one mile were calculated to describe the overall trend of smallmouth bass movement direction (i.e. upstream or downstream). Further, frequencies of smallmouth bass per movement category and by direction were calculated to determine range and frequency of movement. Movement data were not used if smallmouth bass moved ≤ one RM between capture events.

Results

Northern Pike

Population Estimate, Capture Probability, and Capture Efficiency

Numbers of individual northern pike captured by the CDOW and CSU decreased from 2004 through 2006 (Table 3), and then increased 69% in 2007. Population estimates for adult fish (≥200 mm TL) decreased from 2004 through 2006, although this decrease was not statistically significant based on comparison of 95% confidence intervals) (Figure 7; Table 4). The northern pike population estimate for adult fish (≥200 mm TL) in 2007 was twice the 2006 estimate for fish of the same size. Northern pike capture probabilities (percentage of Pass 1-marked northern pike recovered on Pass 2) remained relatively unchanged ranging from 22% to 23%, from 2004 through 2007 (Table 4). Northern pike capture efficiencies (numbers of northern pike removed compared to the respective population estimates) also varied from year to year (Table 5). Capture efficiencies decreased from Pass 2 through Pass 4, from 2004 through 2007. Overall, northern pike capture efficiencies remained relatively unchanged ranging from 52% to 57% throughout the project.

Overall, 2,234 northern pike were removed by the CDOW and CSU from 2004 through 2007 (Table 3). Approximately 84% of the northern pike handled (n=2,666) were removed during the project. From 53% to 57% of the adult northern pike population

estimate (≥200 mm TL) was removed each year (Table 4). A total of 90% (n=2,012) of northern pike removed were stocked in Loudy Simpson pond (n=1,661) and Rio Blanco Lake (n=351) to provide sportfishing opportunities for anglers (Table 3). Ten percent of northern pike removed were used for research purposes.

Catch Per Unit Effort

Total CPUE decreased for all electrofishing capture events from 2004 through 2006, and increased in 2007, for adult northern pike (≥200 mm TL) (Table 6). Total effort (excluding effort associated with angling) increased from 2004 (386 hours) to 2006 (991 hours), and decreased in 2007 to 521 hours. The substantial increase in effort in 2006 was attributable to the early season fyke net and experimental pheromone study, as well as the high discharge fyke net study. Total catch rates for adult northern pike (excluding capture events and effort associated with angling) varied within years and sections, as well as between years and sections (Figure 8). Lily Park was the only section where total CPUE declined from 2004 through 2007. Northern pike electrofishing total catch rates were the highest in 2007 (2.33 northern pike capture events/hour) and in 2004 (2.15 northern pike capture events/hour), and the lowest in 2006 (1.43 northern pike capture events/hour) and in 2005 (1.52 northern pike capture events/hour) (Table 6).

Mean CPUE for adult northern pike (≥200 mm TL) followed the same pattern (Figure 9) as total CPUE for adult northern pike by year for each gear type used. Mean electrofishing CPUE decreased for all capture events from 2004 through 2006, and increased in 2007. Further, mean catch rates for northern pike captured with fyke nets slightly decreased from 2006 to 2007. However, none of these differences were statistically significant based on comparison of 95% confidence intervals.

Catch rates for all northern pike capture events also varied by pass, with the highest catch rates generally occurring on Pass 1, Pass 2, and/or Pass 3 for each year (Table 7). In only one year (2005) did catch rates decline from Pass 1 (2.54 northern pike capture events/hour) through Pass 6 (0.63 northern pike capture events/hour).

Numbers of northern pike collected per river mile followed the same pattern as population estimates and catch rates from 2004 through 2007. Adult northern pike (≥200 mm TL) decreased from 12.9 northern pike/RM in 2004 to 8.5 northern pike/RM in 2006 (Table 4). The number of adult northern pike collected per RM increased to 17.8 in 2007, more than twice the number of adult fish per RM in 2006.

Population Dynamics

Numbers of northern pike collected of different size classes varied from year to year (Table 8). Numbers of northern pike <200 mm TL decreased from 102 individuals in 2004 to three individuals in 2007. However, numbers of northern pike ranging from 201 mm TL to 299 mm TL increased from eight individuals in 2004 to 94 individuals in 2007. Numbers of northern pike between 301 mm TL and 699 mm TL decreased from 464 individuals in 2004 to 285 individuals in 2006. The number of northern pike between 301 mm TL and 699 mm TL (n=667) in 2007 more than doubled the number of individuals in 2006. Numbers of northern pike ≥700 mm TL decreased from 91 individuals in 2004 to 11 individuals in 2007.

Numbers and size classes of northern pike collected by year varied within and among sections (Figures 10a-10d, Figures 11a-11d, and Figures 12a-12d). More juvenile northern pike were collected in the Juniper section in 2004 compared to all other years and all other sections. Numbers of northern pike from 251 mm TL to 450 mm TL

increased in the Juniper section in 2007. In a similar pattern, numbers of northern pike from 301 mm TL to 400 mm TL increased in 2006 and 2007 in the Maybell section compared to previous years. Young northern pike (≤250 mm TL) were collected in the Juniper and Maybell sections each year. Only two northern pike of this same size class were collected in the Lily Park section in one year, 2006. Conversely, numbers of larger, adult northern pike (≥700 mm TL) decreased from 2005 to 2007 in all three sections. Overall, number of northern pike decreased in a downstream direction from the Juniper section to the Lily Park section. Northern pike were concentrated in the Juniper and Maybell sections. Few northern pike were captured in Lily Park from 2004 through 2007.

Numbers of individual northern pike ≥200 mm TL captured by pass varied from year to year (Table 9). In 2004 and 2007, numbers of northern pike increased from the marking pass to the second pass (first removal). Numbers of northern pike decreased from the marking pass to the second pass in 2005 and 2006. Numbers of northern pike captured from Pass 2 through Pass 4 decreased in all years.

The percentage of northern pike marked on the first pass and recovered on subsequent passes in the same year declined from 2004 (48%) through 2006 (37%) (Table 10). In 2007, approximately half (49%) of the northern pike marked on the first pass were recaptured on subsequent passes in 2007. Overall, less than 50% of the northern pike marked on the first pass of each year were recovered within the same year.

Conversely, the percentage of northern pike marked on the first pass and not recovered on subsequent passes in the same year increased from 2004 to 2006 (Table 11). A maximum of 63% of northern pike marked on the first pass in 2006 were not recaptured

on subsequent passes in 2006. In 2007, slightly more than half (51%) of the northern pike marked on the first pass were not recaptured on subsequent passes.

The number of marked northern pike that were not recovered in the same year as the initial mark can also be expressed as a percentage of the population estimate for the respective year. These percentages varied from year to year, increasing from 2004 (8%) through 2006 (21%), and decreasing in 2007 (7%) (Table 11).

Northern pike marked in one year were recaptured in subsequent years throughout the project (Table 12). Overall, 10% (57/568) of northern pike marked in 2004 through 2006 were recovered after approximately one year at large. Three additional northern pike initially marked in 2004 or 2005 were recaptured in 2006 and 2007, respectively, after two years at large. One northern pike marked in 2004 was recovered in 2007 after three years at large. Fifty-two percent (392/759) of northern pike marked from 2004 through 2007 have been recaptured to date.

Four northern pike were recaptured after being at large for more than two years. These fish ranged in size at initial capture from 409 mm TL to 672 mm TL. All four northern pike moved five RMs or less from each of the initial capture locations, and were recaptured within the same sections the fish were initially marked in.

Movement-Within Years

Two hundred and forty-three northern pike that moved more than one RM between capture events were used to characterize short-term movement of this species in the middle Yampa River (Tables 13 and 14). Another 145 northern pike were excluded from the analysis because these fish were either sedentary or moved less than one RM from the

initial capture location. The 243 northern pike analyzed were marked and recaptured within a three month time period of each year, from 2004 through 2007.

Direction and distance traveled by these 243 northern pike varied. Eighty-five percent (207/243) of northern pike recaptured moved in a downstream direction, while 15% (36/243) of northern pike recaptured moved in an upstream direction. One hundred and fifty-one of 243 (62%) northern pike moved up to 10 RMs, while 32% (77/243) of northern pike moved between 10 RMs and 30 RMs. Fifteen of 243 northern pike (6%) moved more than 30 RMs.

Ninety percent (219/243) of northern pike were recovered in the same section as the initial capture (Table 15). The majority of these northern pike (80%) (176/219) were collected in the Juniper section. Overall, 24 of 243 northern pike (10%) were recovered in a different section than the initial capture section. All 24 of these northern pike were initially marked in the Juniper section and recaptured in the adjacent Maybell section.

Distance moved by northern pike was not related to the total length of individual fish (Table 16). Fish ranging from 269 mm TL to 1075 mm TL moved up to 5 RMs. Northern pike that moved 20 RMs or more ranged in TL from 249 mm to 915 mm.

Movement-Among Years

Fifty northern pike were used to characterize long-term movement of this species in the middle Yampa River. These northern pike were marked and recaptured within an 11 to 15 month time period from one year to the next year, from 2004 through 2007. Direction of movement of these 50 northern pike (Table 17) was similar to those northern pike recaptured in a shorter time frame (three months). Seventy-two percent (36/50) of

northern pike recaptured moved in a downstream direction, while 28% of northern pike (14/50) recaptured moved in an upstream direction.

The 50 northern pike at large for at least 11 months (Table 18) moved farther than those northern pike recaptured within three months. Twenty-one of 50 (42%) northern pike at large for at least 11 months moved up to 10 RMs, compared to 62% of those that moved up to 10 RMs in three months. Conversely, 46% (23/50) of northern pike at large for at least 11 months moved between 10 RMs and 30 RMs, while 32% of northern pike (77/243) recaptured within three months moved between 10 RMs and 30 RMs. Six of 50 northern pike (12%) moved more than 30 RMs, twice the percentage (6%) of those fish that moved more than 30 RMs in three months.

Northern pike movement by section during the 11 to 15 month time frame (Table 19) was similar to the movement of northern pike recaptured within three months. Seventy-eight percent (39/50) of northern pike were recovered in the same section as the initial capture. The majority of these northern pike (64%) (25/39) were collected in the Juniper section, while 33% (13/39) were collected in the Maybell section. One fish was captured in Lily Park. Overall, 11 of 50 northern pike (22%) were recovered in a different section than the initial capture section. Eight of these northern pike initially marked in the Juniper section were recaptured in the Maybell section. Three northern pike initially marked in the Maybell section were recaptured in the Lily Park section.

Several size classes of northern pike were recaptured after 11 to 15 months at large and no relationship was observed between total length and distance moved (Table 20). Northern pike that were <332 mm TL at initial capture were not recaptured after 11

months at large. In contrast, only 31 northern pike <332 mm TL at initial capture were recaptured after three months at large.

Growth-Among Years

Northern pike growth varied significantly for different size classes of fish recaptured after 11 to 15 months at large based on comparison of 95% confidence intervals (Table 21). Smaller, adult northern pike had greater growth than larger, adult northern pike. Growth for 26 smaller, adult northern pike (301 mm TL-500 mm TL) ranged between 63 mm and 290 mm. Growth for 22 larger, adult northern pike (501 mm TL-700 mm TL) ranged between 16 mm and 137 mm.

Movement-Emigration From Our Study Area

Thirty-three northern pike initially marked within our study area were recovered in other project study areas of the Yampa and Green rivers (Table 22). Fifteen of these 33 fish were originally marked within our study area by J. Hawkins in 2000 and 2003 (J. Hawkins, personal communication). We marked the remaining 18 northern pike within our study area between 2004 and 2007. These 18 fish accounted for 2.4% of the total number of northern pike we marked during this time.

Twenty-three of the 33 northern pike initially marked in our study area moved upstream or downstream to project areas of other investigators within the Yampa River, from 2004 through 2007. Twenty-one of these 23 fish moved into an adjacent upstream section sampled by the USFWS (RM 171.0 to RM 134.2) (S. Finney, personal communication). One of the 21 fish we marked was released at RM 112.0, in 2005. This northern pike was recaptured and released in our study area approximately 36 RMs downstream at RM 76.1, in 2006, and was recaptured almost a year later in 2007 at RM 137.9, nearly 62

RMs upstream of the 2006 release location in our study area (S. Finney, personal communication). Two of the 23 northern pike from our project moved downstream into another section in 2005 sampled by the USFWS (RM 46.0-RM 0.0) (M. Fuller, personal communication). These two fish were marked in June 2003 at RM 77.0 and RM 49.5 (J. Hawkins, personal communication), and later recovered in July 2005 (M. Fuller, personal communication). Northern pike that moved from our study area to other projects within the Yampa River were at large from less than one month to more than five years.

Ten of 33 northern pike initially marked in our study area were also collected by other investigators in the Green River between 2004 and 2007 (Table 22). Seven of the 10 fish moved into a section within five RMs of the confluence of the Yampa and Green Rivers (RM 345.1) (K. Bestgen, personal communication). One of these northern pike moved approximately 82 RMs from the Yampa River to the Green River in almost three months, at a rate of almost one RM per day. Three northern pike were recaptured in another section sampled by Utah Division of Wildlife Resources (RM 319.0-RM 299.0) (T. Hedrick, personal communication). One of these northern pike moved approximately 149 RMs from the Yampa River to the Green River in slightly more than nine months. Northern pike that moved from our study area to the Green River were at large from three months to more than four years.

Movement-Immigration Into Our Study Area

Northern pike from upstream Yampa River projects also moved into our study area (Table 23). One hundred and eight northern pike moved into our project from upstream locations, from 2004 through 2007. Ninety-three (86%) of these fish were marked by Finney (2007). Forty-eight of the 93 northern pike marked by Finney (some were marked in previous years as well as 2005) were collected in our study area in 2005. In

2005, Finney marked 114 northern pike, and recovered 19 on his first removal pass (Finney 2007). In 2005, we recaptured 42 of Finney's 114 marked fish (37%), 31 of which were recaptured on our Pass 1 (n=23) and Pass 2 (n=8). In 2006 and 2007, we recaptured 12 of 85 (14%) of Finney's 2006 marked fish, and 11 of 118 (9%) of Finney's 2007 marked fish, across all passes, respectively. Ten of the 108 northern pike that moved into our study area between 2004 and 2007 were marked by Finney and Atkinson in 2004 and 2005 between RM 198.8-RM 170.8. Three northern pike recaptured in our study area in 2005 and 2006 were initially marked in April 2002 by Hill (2004) at RM 163.9 and RM 163.3. In 2006, we recaptured a northern pike in our study area at RM 97.9 that was originally tagged in Catamount Reservoir (RM 205.0) in the spring of 2003 (B. Atkinson, personal communication). This was the first northern pike tagged in Catamount Reservoir that was recaptured in our study area. We recaptured a second northern pike from Catamount Reservoir in 2007.

Escapement

The majority of northern pike captured in this project as well as those collected from 2004-2007 by Finney upstream were removed and stocked in local waters of the Yampa River drainage (Loudy Simpson and Yampa River State Wildlife Area (YRSWA) ponds, respectively). We also stocked northern pike removed from the Yampa River into Rio Blanco Lake of the White River drainage. Transplanting northern pike into these waters provided sportfishing opportunities for anglers. Neither location in the Yampa River drainage is completely isolated from the river during high river discharge, and therefore northern pike have the opportunity to escape to the river. Anglers may also have harvested northern pike from these ponds and released these fish back into the river. A northern pike stocked in the YRSWA ponds in the spring of 1999 was recaptured in the Yampa River in 2000 (Hawkins et al. 2005). One northern pike stocked in Loudy

Simpson pond in July of 2005 was recovered in the Green River in July of 2006 (K. Bestgen, personal communication). Another northern pike we stocked in Loudy Simpson pond in May of 2005 was recovered by Finney in the Yampa River one month later, in June of 2005 (S. Finney, personal communication). An additional 25 northern pike stocked in YRSWA ponds (by Finney and Atkinson) or Loudy Simpson pond (by Finney and us) were recovered in the Yampa River by us and Finney (Finney and Haines 2008; S. Finney and B. Atkinson, personal communication), between 2004 and 2007. The numbers of northern pike stocked in YRSWA and Loudy Simpson ponds by various investigators were not recorded. Therefore, the total number of northern pike recovered in the Yampa River cannot be calculated. However, we stocked 1,661 northern pike in Loudy Simpson pond from 2004 through 2007. Northern pike were released in YRSWA and Loudy Simpson ponds any where from less than one month to approximately one year from when the fish were recaptured in the Yampa and Green rivers.

Smallmouth Bass

Population Estimate

The total number of smallmouth bass captured across the entire study area increased from 1,199 (CPUE = 6.96 SBM/hour) in 2006 to 1,346 (CPUE = 6.98 SMB/hour) in 2007 (Table 24). Total effort, however, increased in 2007, with two additional removal passes in Reach 1 (RM 134.2-124.0). These two passes accounted for an additional 259 smallmouth bass collected.

Overall, the total number of individual smallmouth bass captured in Reach 1, the only reach where smallmouth bass removal occurred, increased from 469 to 583 in 2006 and 2007, respectively (Table 25). Across all other reaches combined (Reach 2–Reach 5), where smallmouth bass removal had not occurred, 463 bass were marked and released

across all four passes in 2007. In 2007 across Reach 2 through Reach 5, the greatest numbers of tagged and released bass occurred in Reach 2 and Reach 3, while nearly half the number of bass were tagged and released in Reach 4 and Reach 5.

Population estimates that were determined in 2006 and 2007 for Reach 1, yielded extremely broad confidence intervals, leaving little certainty for analyzing trends (Table 26). For Reach 1 the Lincoln-Petersen point estimate was 1139 (409-1869=95% confidence interval, SE=372, p-hat =0.06) in 2006 and 516 (101-931=95% confidence interval, SE=212, p-hat= 0.07) in 2007 (Figure 13).

In 2007, population estimates were conducted in Reaches 2 through 5 for the first time.These estimates also yielded broad confidence intervals that in several cases suggested numbers of bass ranged as low a zero (Table 26), making trend analysis difficult if not impossible. In Reach 2 the estimate was 241 (0-482=95% confidence interval, SE=123, p-hat=0.21). In Reach 3, the point estimate was 71 (0-161=95% confidence interval, SE= 46, p-hat=0.84). In Reach 4, there were no recaptures in the second pass and a Lincoln-Petersen estimate was not conducted. In Reach 5 the point estimate was 76 (7-145=95% confidence interval, SE=35, p-hat=0.23)

Increased effort in 2007 also resulted in an increase in the number of smallmouth bass removed (Table 24). However, given the amount of uncertainty in population estimates, it was impossible to confidently estimate the proportion of the population that was removed (i.e. exploitation rate). In Reach 1, where smallmouth bass removal occurred in 2006 and 2007, the total number of fish removed increased by 58%. In 2006, 54% of the smallmouth bass removed were >250 mm TL and were translocated to Craig Justice Center pond, while 46% were less <250 mm TL and were euthanized. In 2007, 27% of

all smallmouth bass removed were relocated to Craig Justice Center ponds, while 32% were relocated to Elkhead Reservoir. Forty-one percent of all smallmouth bass removed were euthanized (Table 24).

Catch Per Unit Effort

Overall, catch rates generally increased as the field season progressed (Table 27). In particular, the proportion of small fish increased as pass number increased (Figure 14, Figure 15) in both 2006 and 2007. Generally, in 2006 the mean size of smallmouth bass decreased from 331 mm, to 312 mm, to 201 mm, to 195 mm in passes 1, 2, 3, and 4, respectively. A similar trend was observed in 2007, as mean size changed from 336 mm, to 296 mm, to 321 mm, to 225 mm, to 204 mm, and finally to192 mm in passes 1, 2, 3, 4, 5, and 6, respectively.

Figure 16 summarizes CPUE for all sizes of smallmouth bass across each reach for each pass in 2007. In general, CPUE for smallmouth bass increased with each additional pass, particularly in high concentration reaches (e.g. reach 1, 2, and 3), and exhibited a strong correlation with river discharge (Figure 17) A power function yielded the best fit for these data ($r^2 = 0.765$). However, the regression lacks data for flows ranging from 2400 cfs to 4200 cfs. A correlation also existed between water temperature and CPUE, though not as significant (Figure 18). An exponential function yielded the best fit for these data ($r^2 = 0.491$) Regardless, low catch rates early in the study resulted in low capture probability during the mark-recapture passes.

CPUE was very similar in 2006 and 2007, averaging between 8 and 9 fish/hour, respectively. CPUE was generated only in 2007 for individual reaches (Table 28). Figure 19 shows the longitudinal distribution of bass captured in our entire study area in

increments of two river miles; calculating CPUE for each reach reflected the trends depicted in the longitudinal distribution In Reach 1 CPUE was 9.2 fish/hour, in Reach 2 CPUE was 5.1 fish/hour, in Reach 3 CPUE was 10.9 fish/hour, in Reach 4 CPUE was 3.4 fish/hour, and in Reach 5 CPUE was 3.5 fish/hour. At this stage of smallmouth bass investigation, CPUE appears to be a more reliable index of smallmouth bass abundance than population estimates, since CPUE information is collected across a range capture rates, including relatively low capture rates early in the season and relatively high capture rates later in the season. Conversely, population estimates are conducted early in the season, when capture rates are lowest, and too few fish are tagged to produce a reliable estimate.

Population Dynamics

Total length frequency histograms of smallmouth bass for each of 5 reaches in 2006 and 2007 are displayed in Figure 20. Over two years, little change in size distribution of smallmouth bass occurred, though statistical significance was not tested. Most notable was the difference in size distribution of smallmouth bass between each reach, which was consistent in both years. Reach 1 and Reach 3 had the greatest relative abundance of juvenile bass (<200 mm); whereas, Reach 1 and Reach 2 had a greater relative abundance of adult bass (>200 mm) and Reach 1 had an abundance of bass in all size classes, relative to the other four reaches. Conversely, Reach 4 and Reach 5 had relatively few bass in all size classes, with more juvenile bass than adult bass.

The proportions of smallmouth bass in different size classes that were removed from Reach 1 were reflective of the length frequency distribution observed for bass in Reach 1. Further these proportions were similar in 2006 and 2007.(Table 29). Of all fish handled in 2006, 74% were removed, and in 2007, 94% of smallmouth bass handled were

removed. In both years a large proportion of bass that were tagged were not captured on subsequent passes. In 2006 that proportion was 92% and in 2007 it was 76% (Table 30).

Eight percent of smallmouth bass marked in 2006 were recovered across all subsequent passes in the same year, and 9% of bass marked in 2006 were recovered in 2007. Twenty-three percent of smallmouth bass marked in 2007 were recovered in 2007 (Table 31).

Movement-Among Years 2006 and 2007

We recaptured 19 smallmouth bass in 2007 that were initially tagged in 2006. Of those 19 fish, 16 (84%) had moved more than one mile from their initial tagging location (Table 32). Of the16 fish that moved more than one mile, nine were tagged by CSU in 2006 and were recaptured by CDOW in 2007. Eleven (69%) fish demonstrated upstream movement, while 5 (32%) moved downstream. Distance traveled by fish that moved upstream ranged as high as nine miles, and there does not appear to be a clear trend for upstream distance traveled. Distance traveled by those fish that moved downstream ranged as high as 25 miles, with four fish traveling in the 10 to 20 mile range.

Movement-Within Year 2007

In 2007, 57 smallmouth bass initially tagged were recaptured. Of those 57 fish, 36 moved more than one mile from the point of initial capture. Of those 36 fish that moved more than one mile, five were initially tagged by CSU (Table 33). Twenty seven (77%) fish demonstrated upstream movement, while eight (23%) moved downstream (Table 33). Distance traveled by fish that moved upstream ranged to a maximum of 57 miles, with 23 fish traveling in the one to 20 mile range. Distance traveled by those fish that moved downstream ranged to a maximum of 10 miles.

Colorado Pikeminnow

The total number of Colorado pikeminnow individuals collected each year increased from 16 in 2004 to 25 in 2006 (Table 34). Only 11 individual Colorado pikeminnow, however, were captured in 2007. Colorado pikeminnow were collected in all five reaches sampled by the CDOW in 2005 and 2007 (Figure 21). Reach 2 through Reach 4 (Juniper to Maybell) were the most productive for Colorado pikeminnow. Colorado pikeminnow were collected in both main channel and tributary stream habitats (Table 34). A total of 46 capture events occurred in the main channel, while 37 capture events occurred in tributary streams. Colorado pikeminnow collected during the project ranged from 449 mm TL to 806 mm TL (Figure 22). Numbers of Colorado pikeminnow individuals bearing marks presumably attributable to northern pike attacks decreased from six individuals in 2004 to zero individuals in 2007 (Table 34). Three Colorado pikeminnow mortalities occurred related to sampling and handling during the project.

A total of 59 individual Colorado pikeminnow were collected among all years, 2004 through 2007. Eleven Colorado pikeminnow were handled on multiple occasions from 2004 through 2007 (Table 35). Six Colorado pikeminnow were recaptured after an approximate 12 month interval. Recapture locations were an average of 10.6 RMs from initial capture locations. Half of these fish were recaptured upstream of their initial capture locations, while two fish were recaptured downstream of their initial capture locations. One Colorado pikeminnow was recaptured in the same location as the initial capture location (Sand Creek at RM 72.9). Three Colorado pikeminnow were recaptured after approximately 24 months at large, an average of 4.4 RMs from initial capture locations. One of these fish was recaptured upstream of the initial capture location, while the other two fish were recaptured downstream of their initial capture locations. One

Colorado pikeminnow was captured in 2004, 2005, and 2006. This fish was recaptured in the same location in 2005 and 2006 (Sand Creek), and 2.1 RMs downstream of the 2004 capture location. One Colorado pikeminnow was captured in all four years of the project. This fish was recaptured in the same location in 2005 and 2006 (Spring Creek at RM 81.6), 4.6 RMs downstream from the initial capture location in 2004. In 2007, this Colorado pikeminnow was collected 1.1 RMs upstream of the capture location in 2005 and 2006.

Roundtail Chub

From 48 to 69 roundtail chub individuals were collected each year between 2005 and 2007 (Table 36). Roundtail chub were collected each year in Reach 2, Reach 4, and Reach 5 (Figure 23). In 2007, the first roundtail chub was collected in Reach 1. Reach 5 was the most productive for roundtail chub captures from 2005 through 2007. In 2006 and 2007, 90% of roundtail chub capture events occurred in the main channel and 10% in tributary streams (Table 36). Roundtail chub collected ranged from 68 mm TL to 542 mm TL overall (Figure 24). A presumptive age-0 (68 mm TL) roundtail chub was collected for the first time in 2007. Nine roundtail chub were documented with marks presumably attributable to northern pike (Table 36). No known roundtail chub mortalities occurred during the project that were related to our actions

A total of 166 individual roundtail chub were collected across all years of the project. Seven roundtail chub were handled on multiple occasions from 2005 through 2007 (Table 37). Five roundtail chub were recaptured after approximately 12 months at large, moving an average of 2.2 RMs from their initial capture locations. Eighty percent (4/5) of these fish were recaptured downstream of their initial capture location. Two roundtail chub were recaptured after approximately two years at large. One fish moved 28 RMs

upstream of the initial capture location, while the other roundtail chub moved 4.1 RMs downstream of the initial capture location.

Incidental Non-Native Fish Species

Non-targeted, non-native fish species were also collected each year of the project (Table 38). All black bullhead, black crappie, bluegill, brook stickleback, creek chub, and green sunfish collected were lethally removed. Black bullhead were collected from 2005 through 2007, in Reach 1 through Reach 4 (Figure 25a). Black crappie and bluegill were collected from 2004 through 2007, with the most individuals of each species captured in 2005. Black crappie and bluegill were collected in all reaches, with the most individuals of each species captured in Reach 1 (Figure 25b and Figure 25c, respectively). Green sunfish were only collected in 2006 and 2007. This species was captured in Reach 2 through Reach 4 (Figure 25d). Presumptive age-0 black crappie, bluegill, and green sunfish were collected between 2006 and 2007. One brook stickleback and one creek chub were collected in 2005 and 2006, respectively.

Discussion

Northern Pike

Agencies participating in northern pike removal in the Yampa River Basin have been evaluating the effectiveness of northern pike removal since 1999. Active and passive sampling techniques have been assessed in different habitats during the intervening time. Nearly nine years later, investigators are still determining if their efforts were successful in 1) reducing northern pike numbers, and/or 2) accurately estimating abundance of the northern pike population inhabiting the middle Yampa River.

Boat electrofishing and use of modified fyke nets both proved feasible for capture of northern pike, consistent with findings of others (Hawkins et al. 2005; Finney and Haines 2008). We were able to exploit and suppress large, adult northern pike (≥700 mm TL) throughout the study area. Nesler (1995) and Hawkins et al. (2005) observed large northern pike to be commonly distributed throughout the middle Yampa River, from 1987-1991 and 1999-2002, respectively. Reduction of the number of larger northern pike across the project was offset by the increase in generally, small- to intermediate-sized northern pike (251 mm TL-450 mm TL) observed in Maybell in 2006 and 2007, and in Juniper in 2007. Northern pike of this size class may be increasing as a compensatory response due to the reduction of larger northern pike, or other environmental variables may have increased spawning success and therefore recruitment of these small fish from upstream areas.

Northern pike removal was the most effective in the most downstream section, Lily Park. Lily Park was the only section where catch rates declined across all four years. Hawkins et al. (2005) observed the same trend from 1999 through 2002, attributing their success to fish being removed at a greater rate than the rate of immigration and recruitment from upstream. Upstream removals reduced immigration by "relieving competitive pressures that would increase downstream dispersal" (Hawkins et al. 2005). Diminished recruitment was credited to the "absence of a local source of small fish, and the distant source of potential recruits far upstream" (Hawkins et al. 2005). Our results support conclusions reached by Hawkins et al. (2005).

We concur with Nesler (1995) that the middle Yampa River downstream of Craig does not provide suitable spawning habitat for northern pike. Northern pike reproduction was not evident, or relatively unsuccessful in critical habitat of the Yampa River.

Presumptive juvenile northern pike (<200 mm TL) were collected from 2004 through 2007, with the greatest number of juveniles caught in 2004 (n=102) and the fewest captured in 2007 (n=3). More juvenile northern pike were observed in the Juniper section (our most upstream sampling section) than any other section. Further, fish <200 mm TL were also collected in the Maybell section, but never within Lily Park. These observations suggest that upstream sources for smaller northern pike exist, and that these fish are dispersing into critical habitat from upstream spawning areas, confirming results of Hawkins et al. (2005). Nesler (1995) noted that the riverine population of northern pike is dependent on an influx of fish from off-channel ponds and sloughs, and that such habitats were the primary sources of successful reproduction for northern pike, occurring most commonly in the river from upstream of Craig.

The lowest number of presumptive juvenile northern pike (<200 mm TL) was collected in the Juniper section in 2007, compared to all other sections and years. Such results suggest that removal efforts upstream of critical habitat may have had a positive impact in limiting successful reproduction upstream and/or recruitment of northern pike into our study area. Additionally, the average monthly discharges in April and May of 2006, 4,717 cfs and 7,115 cfs, respectively, were higher than the average discharges for these months (2,614 cfs and 6,225 cfs, respectively) over the period of record, 1916-2006 (USGS 2007). Such conditions may have limited the reproductive and recruitment success of northern pike, although this observation would need to be examined. Removal efforts upstream, environmental conditions, or a combination of both may have influenced the reduction of presumptive juvenile northern pike numbers within our study area over time.

Several patterns were observed related to movement of recaptured northern pike. Overall, the majority (83%) of northern pike recaptured moved in a downstream direction regardless of time spent at large. Eighty-eight percent (258/293) of northern pike were recovered in the same section as the initial capture. The majority of these 258 northern pike (78%) remained in the Juniper section in the time period following the initial mark. Fish that were at large for a shorter period of time (three months) moved shorter distances between recaptures than those northern pike that were at large for at least 11 months.

Distance moved by northern pike varied. Some northern pike were sedentary; other northern pike moved short distances (<1 RM) while some northern pike moved more than 40 RMs. Northern pike moved great distances in a month, while others moved one RM or less after being at large for more than one year. The total length of northern pike was not correlated to distance moved, regardless of the time interval between recapture events. Survival of fish at large for a period of 11 or more months was limited to northern pike ≥332 mm TL at initial capture. Smaller northern pike (<332 mm TL) were recaptured after three months at large, but not after at least 11 months at large. These smaller northern pike may not have been recaptured due to mortality, predation by larger northern pike, and/or movement occurring without our detection (capture).

Our results support Nesler's (1995) statement that the Yampa River is "a chronic source of adult northern pike in the middle Green River." Ten northern pike initially marked in our study area migrated downstream to the Green River. These northern pike ranged in total length at initial capture from 403 mm to 825 mm, and were at large from approximately three months to more than four years. The total number of northern pike captured in the middle Green River decreased from 251 fish in 2001 to 24 fish in 2003,

and 19 fish in 2007 (T. Hedrick, personal communication). Large-scale northern pike removal efforts began in critical habitat of the Yampa River in 2000, and have continued through 2007. Such northern pike removal efforts in the middle Yampa River may be contributing to a decrease in number of northern pike in the middle Green River.

Northern pike immigrated into our study area. The extent of northern pike movement into our study area from downstream projects remains unclear as Projects 110, FR115, and 123b/109 lethally remove all northern pike collected (M. Fuller; K. Bestgen; and T. Hedrick, personal communication, respectively). Fish moved into our study area from as far upstream as Catamount Reservoir near Steamboat Springs. The majority of northern pike (86%) (93/108), however, immigrated into our project from Finney's study area, located immediately upstream (RM 171.0-134.2) of our project area. In 2005, we recaptured more of Finney's marked fish on our first pass than he recaptured on his first pass. Immigration rates from Finney's study area into our study area decreased from 2005 through 2007. Such short term immigration of northern pike from upstream project areas during the first marking and first recapture passes demonstrated that the assumptions necessary for mark-recapture population estimation were violated.

Population estimates generated for the middle Yampa River from mark-recapture methodology remain problematic in accurately assessing northern pike densities. Mark-recapture studies assume closed systems, with no immigration, emigration, mortality, and/or reproduction. The middle Yampa River is not a closed system. We recaptured 20% (23/114) of Finney's first pass-marked fish anywhere from five to 19 days after the initial mark, in 2005. Such movements help explain the relatively wide confidence intervals, high standard errors associated with our mark-recapture abundance estimators, and rapidly declining capture efficiencies during our subsequent removal passes.

Other metrics to evaluate northern pike populations and their abundance exist, but should be utilized with equal caution. In our project, for example, northern pike mean catch rates and densities (number of fish/RM) followed the same trend as population estimates for all four years of the project. Catch rates can be quite variable, though, with fluctuations in environmental conditions and crew capture ability influencing results. Shifts in length frequencies as well as relative abundance of specific size classes of populations might also be useful in conjunction with other metrics to describe northern pike population structure. The use of multiple metrics, both quantitative and qualitative, may yield the best results when assessing northern pike populations.

Another quantitative tool to evaluate non-native fish control efforts was proposed by Modde and Haines (2006, unpublished) at the December 2006 Non-Native Fish Control Workshop. These investigators used exploitation models to determine that a 65% exploitation rate would be required to "crash" populations of smallmouth bass in the Yampa River basin. We applied this benchmark to the estimated northern pike population in our study area in 2007. We determined that four to five removal passes would be necessary to achieve 65% exploitation of northern pike in critical habitat when a 23% capture efficiency is applied to every removal pass, and closed-model assumptions are met. In 2007, northern pike actual capture efficiencies for the entire study area fluctuated from pass to pass, ranging from 23% between the first mark and first removal pass to 18%, 12%, 0%, 3%, and 5% for each removal pass thereafter. We still had 51% of marked northern pike at large after six removal passes. Capture efficiencies on removal passes were comparable from 2004 through 2007. Emigration of marked northern pike likely resulted in decreased capture efficiencies. Our field results indicated

that immigration and emigration of northern pike is too extensive to obtain the 65% exploitation rate for marked northern pike.

The Yampa River Nonnative Fish Control Strategy (UCREFRP 2008) established other criteria to evaluate removal efforts. One such criterion is the total number of adult fish present per RM. The interim benchmark for northern pike of the middle Yampa River, based upon population estimates, is less than three adult northern pike per RM. The 2007 northern pike density estimate in critical habitat of the middle Yampa River was 12.9 northern pike per RM, more than four times the interim density criterion. Our results suggest that this goal will not be achievable until northern pike sources upstream of critical habitat are controlled, and recruitment into critical habitat from upstream riverine areas is further reduced.

Several investigators have indicated that for northern pike removal to be the most effective, a basin-level approach must be followed. We agree with Nesler (1995) that "escapement of northern pike from off-channel pond habitat and access to suitable riverine spawning habitat would have to be reduced on the same widespread scale to be effective in reducing the abundance of the riverine population." We also concur with Hawkins et al. (2005) and Finney and Haines (2008) who provide two recommendations: 1) that northern pike removal efforts be expanded upstream of critical habitat, and 2) that escapement prevention be further considered on outlet structures of northern pike sources.

Multiple agencies have acted upon these recommendations upstream of critical habitat, attempting to reduce further impacts of northern pike to the Yampa River. The CDOW has recently increased efforts to reduce northern pike riverine spawning habitat, as well

as eliminate Catamount Reservoir as a source of northern pike to the Yampa River. Modifications to potential northern pike spawning habitat have been underway at Chuck Lewis State Wildlife Area near Steamboat Springs. Further, northern pike are actively being removed from Catamount Reservoir, (a private water upstream of Steamboat Springs) (B. Atkinson, personal communication). The UCRP recently partnered with others to install a permanent fish screen on the outlet of Elkhead Reservoir as part of the Elkhead Dam and Reservoir Enlargement project. Managing water releases by minimizing spillway flows from Elkhead Reservoir, as well as controlling escapement of non-native fishes from the reservoir will likely benefit native fishes of the Yampa River.

Efforts to minimize northern pike escapement from Loudy Simpson and YRSWA ponds must also be considered. Escapement potential from both of these waters is high, particularly during elevated river discharge. Additionally, disgruntled anglers not supportive of our project may have harvested northern pike from the stocked ponds, and then released these fish back into the river. Two northern pike "escapees" from YRSWA ponds were recaptured by Finney before rising spring river flows connected the river to the ponds, "making these fish suspect of being moved by anglers" (Finney and Haines 2008). Further, evaluation of potential reproduction of northern pike in these waters should also be undertaken since age-0 northern pike were collected from YRSWA ponds (D. Winkelman and R. Fitzpatrick, personal communication). Thus, Loudy Simpson and YRSWA ponds may provide suitable spawning habitat for northern pike.

Implementation of these activities upstream of critical habitat may well result in more effective northern pike removal efforts downstream in the middle Yampa River. However, as Hawkins et al. (2005) suggested, "fish must be removed at a rate greater than the rate of replacement from immigration or recruitment for removal to be effective.

Effective removal was further clarified by Hawkins et al. (2005) as requiring "increased effort (more sampling occasions) and removal in areas upstream of critical habitat to reduce immigration into downstream critical habitat reaches." Completing additional electrofishing passes to remove northern pike, however, increases the likelihood of injuring native fishes within critical habitat. Further, in 2007, removal efforts were increased in the South Beach reach by two passes. An additional 83 northern pike were removed on these two passes, accounting for 11% of the total number of northern pike removed in the entire study area.

Our northern pike removal efforts exploited and suppressed large, adult northern pike in critical habitat of the middle Yampa River. Further, these efforts may be decreasing the number of northern pike collected farther downstream in critical habitat of the Yampa and Green rivers. However, until actions are addressed upstream of critical habitat, including the reduction of northern pike spawning and nursery habitats, and the minimization of northern pike sources and recruitment, our removal efforts within critical habitat of the middle Yampa River will not achieve the criterion of less than three adult northern pike per RM. We support Finney and Haines' (2008) statement that we may "simply be treating the symptom and not the problem."

Smallmouth Bass

Our investigation of smallmouth bass in the middle Yampa River, from Craig to Cross Mountain Canyon, has just begun. We completed the following tasks, beginning in 2006: 1) handled smallmouth bass across our entire study area, 2) determined population estimates in Reach 1, and 3) removed smallmouth bass in Reach 1. Population estimates were determined across the entire study area in 2007, which was also the second consecutive year for smallmouth bass removal in Reach 1. After two years of

investigating smallmouth bass in the middle Yampa River downstream of Craig (Reach 1 through Reach 5), we recognize that the smallmouth bass population is dynamic, and abundance is therefore difficult to estimate. Population estimates generated in two consecutive years for Reach 1 have been confounded with uncertainty, resulting from poor capture efficiencies during the mark and first removal pass. However, other less scientifically rigorous measurements, such as catch per unit effort, suggest that in certain reaches the smallmouth bass population is robust, indicating a persistent abundance of the species. We have documented consistent areas of smallmouth bass concentration. Given such high concentration of smallmouth bass in our study area and that smallmouth bass are implicated in hampering native fish restoration efforts, we have demonstrated the need for more extensive smallmouth bass control in our study area.

A significant reduction in abundance of smallmouth bass was not observed from 2006-2007, despite the 2007 point estimate being half the estimate of 2006, with wide 95% confidence intervals both years. Such population estimates may have been confounded by environmental variables which impacted capture efficiency during the mark and first removal pass in both years. Moreover, the point-estimate for smallmouth bass in 2007 may have been a gross underestimation of the actual population size, particularly since our removal numbers were higher than the point estimate. Regardless of the accuracy of these estimates, smallmouth bass inhabiting Reach 1 exceeded the target population criteria of 30 smallmouth bass > 150mm/mile (UCREFRP 2008). We estimated approximately 114 smallmouth bass/mile and 50 smallmouth bass/mile in 2006 and 2007, respectively, using the point estimates generated.

In 2007, the same uncertainty in population estimates was observed in Reach 2-Reach 5 as discussed for Reach 1 (South Beach). Capture efficiencies were relatively low during

the mark and first recapture passes, compared to all subsequent passes. In these reaches we marked and released smallmouth bass alive on every pass. Multiple marking and release passes allowed us to generate several iterations of the Lincoln-Petersen estimate, using different combinations of passes as the marking effort. Our methods generally resulted in an increase in number of tagged fish at large, as well as the total number of fish caught in the recapture effort by orders of magnitude; however, capture probabilities remained low. Such increases of tagged fish at large resulted in higher smallmouth bass population estimates, but also resulted in increased uncertainty, due to the low percentage of recaptured fish.

Smallmouth bass population estimates were negatively influenced by varying capture probabilities. A strong positive relationship existed between smallmouth bass catch rates and river discharge. CPUE (number of smallmouth bass capture events/hour) increases with discharge on the ascending limb of the hydrograph, but stabilizes once peak flows have been reached and discharge begins to decline. However, it is likely that multiple variables in addition to streamflow are driving factors in smallmouth bass CPUE. Several of these variables, such as turbidity and water temperature, are closely linked to streamflow during the timeframe for which this analysis was conducted. For example, a correlation exists between water temperature and CPUE on the ascending limb of the hydrograph, though not strong (r^2=0.49). As water temperature warms, smallmouth bass may become more mobile and active and, thus, more susceptible to our electrofishing gear. Increased turbidity, as a result of elevated discharge, may also be positively influencing smallmouth bass CPUE in our study. It has been suggested that turbidity serves as cover, enabling smallmouth bass to move into shallow water that they otherwise would not utilize. Though one could construct a model that incorporates these

factors as covariates, during this study CPUE was correlated with discharge, which could influence water temperature and turbidity.

In 2007, river discharge ranged from 2000 cfs to 2400 cfs during our marking and first removal passes. Total numbers of fish collected during this time also were lower than subsequent passes when river discharge had increased. Such information suggested that our population estimates were likely biased low, with false precision. For example, in Reach 1 40 smallmouth bass were tagged during Pass 1, when CPUE was 1.81 SMB/hour, and 4 of those fish were recaptured during Pass 2, when CPUE was 4.17 SMB/hour. By Pass 3, CPUE was 8.99 SMB/hour, twofold higher than Pass 2 and eightfold higher than Pass 1. Thus, it should not be assumed that the ratio of recaptures and the population estimate based on our Pass 1 and Pass 2 effort is representative of the population, since the majority of fish were not susceptible to our sampling gear at that time.

Smallmouth bass population estimates in our study were likely further confounded by movement among different reaches. As discussed for northern pike, mark-recapture population estimates assume closed systems, without immigration, emigration, reproduction, and/or mortality. Our analysis provided limited insight into patterns of smallmouth bass movement in the middle Yampa River due to few recaptures, and it is recommended that further synthesis of movement information be conducted combining CSU and CDOW's efforts. However, our data suggest that smallmouth bass exhibit pronounced movement patterns in the middle Yampa River, moving appreciable distances in very short time periods. We suspect that this movement was significant enough to confound our abundance estimates, and warrants the need for open models in estimating abundance in future years Furthermore, we conclude that these migratory

behaviors warrant the need for researchers in the middle Yampa River to re-examine how geographic boundaries of the smallmouth bass population are defined. Generating estimates for individual 10 RM reaches, as was done in this study, does not account for the long-distance movement exhibited by these fish.

More accurate and precise population estimates for smallmouth bass in the CDOW study area are needed. Currently, the success of non-native fish control in the Yampa River is evaluated based on exploitation rate, or the proportion of the population that is removed in a given year. However, reliable population estimates for smallmouth bass must be generated for such evaluation to occur. Therefore, methods used for generating these estimates must be re-examined. We recommend conducting mark and recapture passes at higher flows, as more fish are susceptible to sampling gear. The need for tagging a greater proportion of the actual population size to generate reliable mark-recapture estimates has long been recognized by fishery biologists (Robson and Reiger 1964); tagging a greater number of fish will increase confidence in the estimator. Furthermore, smallmouth bass researchers in the Yampa River need to give greater consideration to smallmouth bass movement when defining longitudinal population boundaries in the Yampa River. With knowledge of the long-distance movements exhibited by this species, the current approach of partitioning the Yampa River for population estimates violates one of the assumptions of the estimator.

Due to the varied concerns over the population point estimators, we believe that catch rates more accurately depicted smallmouth bass prevalence and abundance in 2006 and 2007 in the middle Yampa River below Craig. CPUE fluctuated minimally between 2006 and 2007, overall. CPUE was strikingly similar between passes among 2006 and 2007, and demonstrated almost the exact same trend with respect to pass number. The

total number of smallmouth bass handled in Reach 1 varied minimally between years. Moreover, overall CPUE across the entire study area illustrated a minute change at 6.96 and 6.98 smallmouth bass capture events per hour in 2006 and 2007, respectively.

CPUE provides an acceptable indicator of smallmouth bass concentration areas. In 2007, CPUE for the Upper Maybell Reach (Reach 3) was elevated at 10.9 smallmouth bass capture events per hour. This catch rate was higher than the 9.2 catch rate within the smallmouth bass removal reach (South Beach). Catch rates for the remaining three reaches were comparatively low, with the next highest concentration occurring in Juniper (Reach 2), at 5.1 smallmouth bass capture events per hour.

Reaches of the middle Yampa River flowing through canyons, or that are immediately downstream of canyons, provide rocky habitat favorable to smallmouth bass. The greatest density of smallmouth bass within Reach 1 occurred along the most downstream end of the reach, just upstream of Hawkins' upper study area terminus. Smallmouth bass were also concentrated downstream of Juniper Canyon, in Reach 3. This concentration area consisted predominately of early life-stage smallmouth bass and could be a result of reproduction occurring in Juniper Canyon, a short section of river that we were unable to sample with our methods.

We recommend future smallmouth bass control not be limited entirely to Reach 1. Reach 3 was identified as a high concentration area for smallmouth bass in 2006 and 2007. As such, smallmouth bass removal efforts should be extended into this reach of the middle Yampa River. Further, control efforts should be considered in Reach 2 (Juniper), the reach just upstream of Juniper Canyon. This reach had the third greatest CPUE with 75% of bass captured greater than 250 mm in total length. Control efforts within the Juniper

reach would reduce the number of adult smallmouth bass entering and potentially reproducing in Juniper Canyon, where removal does not occur. With the high densities of juvenile smallmouth bass documented immediately below Juniper Canyon, in Reach 3, it is likely that reproduction in Juniper Canyon is replenishing smallmouth bass numbers immediately downstream.

The potential impacts to smallmouth bass density within Reach 1 resulting from our removal efforts are difficult to discern and quantify. Across our entire study area, we removed 346 smallmouth bass, but released 869 fish alive in 2006. In 2007, we removed 548 smallmouth bass, but released 850 alive. The target exploitation rate required for a "crash" of the smallmouth bass population is 65%, as recommended by Modde and Haines (2006). Six to seven removal passes (capture probability of 15%) would be necessary in Reach 1 to achieve the 65% criterion. However, based on our assumption that the 2007 smallmouth bass population estimate was likely an underestimate, we suspect more removal passes would be required to obtain the 65% benchmark. We conducted three and five removal passes in Reach 1 in 2006 and 2007, respectively. Exploitation of smallmouth bass within this reach at the necessary rate has not occurred, based on our efforts in 2006 and 2007. Increasing removal effort and/or capture probability is essential in eliciting large-scale decline of the smallmouth bass population within the middle Yampa River. Therefore, increased removal effort in Reach 1 is warranted to effectively control the smallmouth bass population.

Colorado Pikeminnow

Two observations support that our removal efforts may be benefiting Colorado pikeminnow. Finney (2006) reported captures of two Colorado pikeminnow, just upstream of critical habitat in the Yampa River; this is the only published account of

Colorado pikeminnow upstream of critical habitat. In 2007, we collected a Colorado pikeminnow at RM 132.0 in the South Beach reach (Reach 1). This is the farthest upstream in critical habitat that we collected a Colorado pikeminnow. Further, numbers of Colorado pikeminnow individuals bearing marks presumably attributable to northern pike attacks decreased during the project.

We remain concerned about the potential chronic and/or acute impacts/effects that increased electrofishing efforts may have on Colorado pikeminnow. Almost 20% (11 of 59) of the Colorado pikeminnow we captured were handled on multiple occasions throughout the project. Further, one Colorado pikeminnow was collected in all four years of the study.

Roundtail Chub

Two observations support that our removal efforts may be benefiting roundtail chub. First, a roundtail chub was collected in the upper most reach, South Beach (Reach 1) for the first time in 2007. Second, a presumptive age-0 (68 mm TL) roundtail chub was collected for the first time in 2007.

Nesler (1995) identified the roundtail chub as "the native fish species most adversely affected by, and vulnerable to northern pike predation." In 2005, we collected a northern pike (681 mm TL) with a roundtail chub (estimated at 335 mm TL) in its abdomen (Martin 2005). The roundtail chub was approximately 49% of the northern pike's total length, supporting Hawkins et al. (2005) observation that "northern pike consumed prey that were up to 72% of the northern pike's body length. Roundtail chub with presumed attacks from northern pike were collected throughout our project. This result was unlike our observations with Colorado pikeminnow where evidence of northern pike attacks

decreased over time. This finding may be explained by the size and vulnerability of roundtail chub to northern pike predation in relation to Colorado pikeminnow. Alternatively, our roundtail chub observations may be a function of sample size; we collected more roundtail chub individuals (166) in three years than Colorado pikeminnow (59) in four years.

Incidental Non-Native Fish Species

Numbers of black crappie and bluegill were the greatest in 2005. The temporary, outlet screen failure at Elkhead Reservoir in 2005 may explain the increase in abundance of black crappie and bluegill. However, number of black crappie in 2006 and number of bluegill in 2007 were relatively high, as well. Further, presumptive age-0 black crappie and green sunfish were both collected in 2006 and 2007, while presumptive age-0 bluegill were collected in 2007. Collection of these juvenile fish suggests that either young-of-the-year are entering the middle Yampa River from lacustrine sources, or adults of these species are successfully reproducing within the riverine environment.

Conclusions

Northern Pike

- Boat electrofishing and use of modified fyke nets both proved feasible for capture of northern pike within critical habitat of the middle Yampa River.

- Our removal efforts suppressed large, adult northern pike ($\geq$ 700 mm TL) within critical habitat of the middle Yampa River. Thus, the predatory impact of northern pike has been reduced as evidenced in the decrease of presumptive northern pike attacks on Colorado pikeminnow.

- Northern pike reproduction was not evident, or relatively unsuccessful in critical habitat of the middle Yampa River. Presumptive juvenile northern pike (<200 mm TL) were rare. These younger northern pike may be originating from upstream nursery habitats, and recruiting into critical habitat.

- Northern pike immigrated into our study area, with 86% of fish immigrating from Finney's study area immediately upstream. Northern pike also immigrated at least 70 RMs from Catamount Reservoir downstream into our study area.

- Short term and relatively large scale immigration of northern pike from upstream project areas during the first marking and first recapture passes demonstrated assumptions for closed population estimation were violated within critical habitat of the middle Yampa River.

- Northern pike immigration and emigration is too extensive to achieve a 65% exploitation rate for marked northern pike, and sustain a declining trend in northern pike abundance within critical habitat of the middle Yampa River.

- Northern pike continually immigrated into our study area, and thus the interim removal criterion of less than three adult northern pike per RM was not obtained. This criterion will not be achievable until upstream northern pike spawning and nursery habitats are reduced, and sources and recruitment of northern pike are minimized.

<u>Smallmouth Bass</u>

- Boat electrofishing proved feasible for capture of smallmouth bass.

- Smallmouth bass CPUE was affected by interrelated environmental variables: water temperature, turbidity, and river discharge.

- Smallmouth investigations in the CDOW study area are in the beginning stages and study methodology continues to change substantially from year to year, making trend analysis difficult.

- The population estimate for smallmouth bass in Reach 1 did not change significantly between 2006 and 2007.

- CPUE of smallmouth bass across the entire CDOW study area remained stable between 2006 and 2007.

- Smallmouth bass concentration areas in the middle Yampa River were generally associated with canyon type river sections. Reach 1, Reach 2, and Reach 3 feature canyon sections, or are immediately adjacent to canyon sections, and have relatively high smallmouth bass densities. Highest densities of sub-adult (<150 mm) smallmouth bass were found in the upstream end of Reach 3, immediately downstream of Juniper Canyon.

- Smallmouth bass in the middle Yampa River exhibit extensive movement both upstream and downstream, and move great distances in a relatively short time period.

- CPUE of smallmouth bass generally increases with each pass, with a greater proportion of sub-adult bass being captured later in the study.

- CPUE of smallmouth bass correlates with water temperature, and to a greater extent with river discharge, on the ascending limb of the hydrograph. CPUE increases with increasing discharge during the spring runoff.

- Population estimates for smallmouth bass in the CDOW study area are based on low capture probabilities.

Colorado Pikeminnow

- Collection of a Colorado pikeminnow in the upper most reach (South Beach) for the first time, and decreased numbers of presumed northern pike attacks on Colorado pikeminnow are encouraging results associated with our removal efforts.

Roundtail Chub

- Collection of one presumptive age-0 (68 mm TL) roundtail chub, and upstream movement of a roundtail chub into the upper most reach (South Beach) for the first time are encouraging results associated with our removal efforts in 2007.

Incidental Non-Native Fish Species

- Presence and survival of black bullhead, black crappie, bluegill, and green sunfish within critical habitat of the middle Yampa River continued despite our removal efforts. Collection of presumptive age-0 black crappie, bluegill, and green sunfish suggests that these juveniles are either entering the middle Yampa River

from lacustrine sources, or adults of these species are successfully reproducing within the riverine environment.

Recommendations

Northern Pike

- Implement upstream control of northern pike to reduce upstream reproduction, and downstream recruitment into critical habitat of the middle Yampa River. Efforts should include reducing northern pike spawning and nursery habitats, and minimizing sources and recruitment of northern pike. Long term benefits to native fishes of the middle Yampa River may not be achievable until such efforts are implemented.

- Continue removing northern pike from critical habitat of the middle Yampa River.

- Coordinate timing of marking and first recapture passes with upstream investigators to determine an overall population estimate from the most upstream removal reach to the most downstream removal reach. Synchronizing marking passes and first removal passes between projects, and coordination of subsequent removal passes should provide more accurate and reliable northern pike abundance estimates for the middle Yampa River.

- Mark-recapture abundance estimators for northern pike should be used with caution due to immigration of northern pike from upstream into our study area, and emigration of marked northern pike out of our study area. Combine mark-recapture efforts on a larger scale to remove immigration and emigration as

violations of the closure assumption for northern pike population abundance estimation.

- Continue to assess the efficacy of mark-recapture abundance estimators every year to evaluate northern pike removal efforts.

- Evaluate alternative metrics as abundance estimators and explore the use of such to more effectively evaluate northern pike removal efforts.

- Control northern pike escapement from YRSWA and Loudy Simpson ponds by screening pond-river connectivity points and pond inlets/outlets to further increase isolation potential.

- Continue efforts to secure other suitable receiving waters with public access for translocation of northern pike.

Smallmouth Bass

- Coordinate initial mark and first removal effort with CSU (J. Hawkins) so that mark recapture data may be combined to produce an estimate over a larger landscape.

- Consider postponing the population estimate until later in the sampling season when catch rates for smallmouth bass have been demonstrated to be higher.

- Continue to assess the efficacy of abundance estimators every year to evaluate smallmouth bass removal efforts.

- Increase the number of removal passes in South Beach (Reach 1) from five to at least six. Our findings suggest that we are not currently exploiting smallmouth bass at a rate necessary to induce large-scale population decline.

- Extend smallmouth bass removal to include at least Reach 3 (RM 90–80). In 2007, out of the five reaches we sampled, Reach 3 had the highest CPUE for smallmouth bass. Reach 3 has proven to be a concentration area for smallmouth bass two years in a row. Increase sampling effort in new removal reaches commensurate with that recommended for Reach 1.

Colorado Pikeminnow and Roundtail Chub

- Continue same methodology as 2007 for handling and evaluating Colorado pikeminnow and roundtail chub collected.

Incidental Non-Native Fish Species

- Continue observation, measurement, and lethal removal of incidental non-native fish species.

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List of Appendices

Appendix		*Page*
A.	Colorado State University and Colorado Division of Wildlife goals and objectives for northern pike and smallmouth bass, 2004-2007	149
B.	Field methods/approach, results/discussion, and literature cited for the Colorado Division of Wildlife's 2006 early fyke net and pheromone experimental study	152

Table 1. Middle Yampa River reaches, river sections, reach descriptions, river miles, and agency responsible by year across the project, from 2004-2007. *CSU=Colorado State University. **CDOW=Colorado Division of Wildlife. *** River Mile 58.5 is a backwater on river left that was sampled downstream of the lower terminus of Reach 5.

River Reach	River Section	Reach Description	River Miles	Agency Responsible
1	Juniper	South Beach launch to Round Bottom	134.2-124.0	*CSU (2004-2005); **CDOW (2005-2007)
CSU 1	Juniper	Little Yampa Canyon	124.0-112.0	CSU (2004-2007)
CSU 2	Juniper	Little Yampa Canyon	112.0-100.0	CSU (2004-2007)
2	Juniper	Ups. Government bridge to mouth of Juniper Canyon	100.0-91.0	CSU (2004-2005); CDOW (2004-2007)
3	Maybell	Dwn. Juniper Canyon to Old Maybell launch	88.7-79.2	CSU (2004); CDOW (2004-2007)
4	Maybell	Old Maybell launch to Sunbeam launch	79.2-71.0	CSU (2004); CDOW (2004-2007)
5	Maybell	Sunbeam launch to ups. Cross Mountain launch	71.0-60.6; ***(58.5)	CDOW (2005-2007)
CSU 3	Lily Park	Lily Park	55.5-50.5	CSU (2004-2007); CDOW (2004)

Table 2. Actions taken for smallmouth bass (SMB) by reach, for the middle Yampa River downstream of Craig, from 2004-2007. Northern pike were marked and removed in all reaches from 2004 through 2007. *Mark-Removal=fish were marked on the first pass(es) and removed on subsequent passes. **CSU=Colorado State University. ***Mark-Release=fish were marked on the first pass(es) and released on subsequent passes.

Reach Number and Reach Name	2004 SMB Action	2005 SMB Action	2006 SMB Action	2007 SMB Action
Reach 1- South Beach	None	None	*Mark-Removal	Mark-Removal
Reach **CSU 1- Little Yampa Canyon	***Mark-Release	Mark-Release	Mark-Removal	Mark-Removal
Reach CSU 2- Little Yampa Canyon	Mark-Removal	Mark-Removal	Mark-Removal	Mark-Removal
Reach 2- Juniper	None	None	None	Mark-Release
Reach 3- Upper Maybell	None	None	None	Mark-Release
Reach 4- Lower Maybell	None	None	None	Mark-Release
Reach 5- Sunbeam	None	None	None	Mark-Release
Reach CSU 3- Lily Park	Mark-Removal	Mark-Removal	Mark-Removal	Mark-Removal

Table 3. Number of individual northern pike (NPK) captured, number of individual NPK not marked (too small), number of individual NPK marked on all passes, number of NPK marked on the first pass by the Colorado Division of Wildlife (CDOW) and Colorado State University (CSU), number of NPK marked on the first pass by other agencies (foreign recaptures), number of NPK removed, number of NPK removed on all passes per the number of NPK captured, number of NPK stocked in Rio Blanco Lake and Loudy Simpson ponds, and number of NPK mortalities and number of NPK used for research by year, for the middle Yampa River downstream of Craig, from 2004-2007. ∑=Summation by columns where applicable.

Year	# NPK Individuals Captured	# NPK Not Marked (too small)	# NPK Marked on All Passes	# NPK Marked on First Pass by CDOW and CSU	# NPK Marked on First Pass by Other Agencies (Foreign Recaptures)	# NPK Removed	# NPK Removed/ # NPK Captured	# NPK Stocked in Rio Blanco and Loudy Simpson	# NPK Mortalities and # NPK Used for Research
2004	742	104	638	137	22	665	665/742 (90%)	633	32
2005	526	17	509	156	39	410	410/526 (78%)	367	43
2006	520	17	503	202	12	384	384/520 (74%)	284	100
2007	878	9	869	187	4	775	775/878 (88%)	728	47
∑	2,666	147	2,519	682	77	2,234	2,234/2,666 (84%)	2,012	222

Table 4. Northern pike (NPK) population estimates (Program CAPTURE Model (t) of Chao) with 95% confidence intervals, standard error, coefficient of variation, capture probability from Pass 1 to Pass 2, percentage of NPK (≥ 200 millimeters (mm) total length (TL)) point estimate removed, and number of NPK ≥ 200 mm TL per river mile by year, for the middle Yampa River downstream of Craig, from 2004-2007. Numbers based upon a mark/release and recapture/removal effort for NPK ≥ 200 mm TL and NPK ≥ 300 mm TL. *=Numbers of NPK removed include NPK removed on all passes, including those few removed on the first pass due to mortality, or for research purposes.

Year	Point Estimate (N-hat) for NPK ≥ 200mm with 95% Confidence Interval	Point Estimate (N-hat) for NPK ≥ 300mm with 95% Confidence Interval	Standard Error	Coefficient of Variation	Capture Probability (p-hat)	% of NPK (≥ 200mm) Point Estimate Removed	# NPK ≥ 200mm/ River Mile
2004	981 (774-1288)	981 (774-1288)	129.4	0.132	0.23	57 (563*/981)	12.9
2005	701 (573-891)	678 (555-861)	80.3	0.115	0.22	56 (391/701)	9.2
2006	649 (539-811)	623 (517-780)	68.5	0.106	0.22	53 (344*/649)	8.5
2007	1360 (1092-1744)	1073 (825-1321)	164.5	0.120	0.23	57 (772*/1360)	17.8

Table 5. Northern pike (NPK) capture efficiencies (numbers of NPK ≥200 millimeters total length removed compared to the respective population estimates) expressed as percentages for Pass 2-Pass 9 by year, for the middle Yampa River downstream of Craig, from 2004-2007. *NC=Not Completed (pass not attempted). **NPK caught by angling. ***Number includes one NPK caught by angling. ****=Numbers of NPK removed only include NPK removed on pass 2-pass 9; several NPK were removed on the first pass (see Table 4 description) in 2004, 2006, and 2007 due to mortality, or for research purposes.

Year	NPK Capture Efficiency on Pass 2	NPK Capture Efficiency on Pass 3	NPK Capture Efficiency on Pass 4	NPK Capture Efficiency on Pass 5	NPK Capture Efficiency on Pass 6	NPK Capture Efficiency on Pass 7	NPK Capture Efficiency on Pass 8	NPK Capture Efficiency on Pass 9	Total NPK Capture Efficiency Pass 2-Pass 9
2004	23.1%	13.7%	12.1%	20.5%	6.8%	*NC	NC	NC	57% (557****/981)
2005	22.0%	15.9%	16.5%	9.4%	5.2%	2.7%	2.8%	0.6%	56% (391/701)
2006	21.7%	21.3%	17.3%	3.0%	2.8%	0.6%	NC	NC	52% (339****/649)
2007	23.5%	21.3%	17.0%	4.0%	5.7%	2.9%	0.8%	0.3%	57% (770****/1360)

Table 6. Number of northern pike (NPK) (<200 millimeters (mm) in total length (TL)) capture events, number of NPK (≥200 mm TL) capture events, number of NPK (≥300 mm TL) capture events, number of NPK (≥700 mm TL) capture events, total number of NPK capture events, total NPK Catch Per Unit Effort (CPUE) (# of NPK capture events per hour) by electrofishing (EL), total NPK CPUE by fyke netting (FN), total NPK CPUE by angling (AN), and total NPK CPUE for all gear types by year, for the middle Yampa River downstream of Craig, from 2004-2007. FN also included electrofishing (block-and-shock) associated with fyke net sets. *NA=Not Applicable. **ND=Not Determined (effort not recorded). ***One northern pike was not measured for TL. ∑=Summation by columns where applicable.

Year	# NPK (< 200mm) Capture Events	# NPK (≥ 200mm) Capture Events	# NPK (≥ 300mm) Capture Events	# NPK (≥ 700mm) Capture Events	Total # NPK Capture Events	NPK CPUE by EL	NPK CPUE by FN	NPK CPUE by AN	Total NPK CPUE (Sum of All Gear Types)
2004	102	729	717	106	831	2.15	*NA	NA	2.15
2005	22	609	593	101	631	1.52	NA	NA	1.52
2006	40	605	579	50	645	1.43	0.12	**ND	0.65
2007	3	974	857	11	***978	2.33	0.10	0.01	1.38
∑	167	2,917	2,746	268	3,085				

Table 7. Total northern pike (NPK) catch per unit effort (CPUE) (number of northern pike capture events per hour) by pass and by year, for the middle Yampa River downstream of Craig, from 2004-2007. CPUE included capture events and effort only associated with electrofishing and fyke net setting (fyke net setting included electrofishing (block-and-shock) associated with fyke net sets). *NC=Not Completed (pass not attempted). **AN only=Angling Only.

Year	NPK CPUE Pass 1	NPK CPUE Pass 2	NPK CPUE Pass 3	NPK CPUE Pass 4	NPK CPUE Pass 5	NPK CPUE Pass 6	NPK CPUE Pass 7	NPK CPUE Pass 8	NPK CPUE Pass 9
2004	2.96	3.08	1.68	0.99	1.72	0.70	*NC	NC	NC
2005	2.54	1.92	1.20	1.04	0.94	0.63	0.58	0.59	0.37
2006	0.55	0.89	0.51	0.92	0.31	0.39	**AN only	NC	NC
2007	2.79	3.64	2.02	0.94	0.99	0.88	1.10	0.34	AN only

Table 8. Total number of northern pike (NPK) individuals handled, number of NPK (<200 millimeters (mm) total length (TL)) removed, number of NPK (≥200 mm TL) removed, number of NPK (201 mm TL-299 mm TL) removed, number of NPK (≥300 mm TL) removed, number of NPK (301 mm TL-699 mm TL) removed, number of NPK (≥700 mm TL) removed, and percent of NPK individuals handled that were removed by year, for the middle Yampa River downstream of Craig, from 2004-2007. ∑=Summation by columns where applicable.

Year	Total # NPK Individuals Handled	# NPK (<200mm) Removed	# NPK (≥200mm) Removed	# NPK (201mm-299mm) Removed	# NPK (≥300mm) Removed	# NPK (301mm-699mm) Removed	# NPK (≥700mm) Removed	% of NPK Individuals Handled That Were Removed
2004	742	102	563	8	555	464	91	90 (665/742)
2005	526	19	391	12	379	297	82	78 (410/526)
2006	520	40	344	15	329	285	44	74 (384/520)
2007	878	3	772	94	678	667	11	88 (775/878)
∑	2,666	164	2,070	129	1,941	1,713	228	84 (2,234/2,666)

Table 9. Number of northern pike (NPK) individuals ≥200 millimeters (mm) total length (TL) marked on the first pass and number of NPK ≥200 mm TL captured on subsequent passes (Pass 2-Pass 9) by year, for the middle Yampa River downstream of Craig, from 2004-2007. *NC=Not Completed (pass not attempted). **NPK caught by angling. ***Number includes one NPK caught by angling. ∑=Summation by columns where applicable.

Year	# NPK Marked on Pass 1	# NPK Captured on Pass 2	# NPK Captured on Pass 3	# NPK Captured on Pass 4	# NPK Captured on Pass 5	# NPK Captured on Pass 6	# NPK Captured on Pass 7	# NPK Captured on Pass 8	# NPK Captured on Pass 9
2004	159	227	103	79	117	31	*NC	NC	NC
2005	195	154	87	76	36	18	9	9	2
2006	214	141	108	69	10	9	**2	NC	NC
2007	191	320	222	139	27	37	***18	5	**2
∑	759	842	520	363	190	95	29	14	4

Table 10. Number of northern pike (NPK) marked on the first pass, number of marked NPK recovered on Pass 2-Pass 9, and percentage of total marked NPK recovered on Pass 2-Pass 9 by year, for the middle Yampa River downstream of Craig, from 2004-2007. All marked NPK were ≥200 millimeters in total length. *NC=Not Completed (pass not attempted). ∑=Summation by columns where applicable.

Year	# NPK Marked on Pass 1	# Marked NPK Recov. on Pass 2	# Marked NPK Recov. on Pass 3	# Marked NPK Recov. on Pass 4	# Marked NPK Recov. on Pass 5	# Marked NPK Recov. on Pass 6	# Marked NPK Recov. on Pass 7	# Marked NPK Recov. on Pass 8	# Marked NPK Recov. on Pass 9	% Total Marked NPK Recov. on Pass 2-Pass 9
2004	159	36	14	7	13	6	*NC	NC	NC	48 (76/159)
2005	195	42	18	15	7	0	0	1	0	43 (83/195)
2006	214	46	21	7	2	3	0	NC	NC	37 (79/214)
2007	191	44	27	14	0	3	5	0	0	49 (93/191)
∑	759	168	80	43	22	12	5	1	0	44 (331/759)

Table 11. Number of northern pike (NPK) marked on the first pass, percentage of marked NPK not recovered on all subsequent passes of the same year, percentage of NPK point estimate (fish were ≥200 millimeters (mm) total length (TL)) of marked NPK not recovered within the same year as the initial mark by year, for the middle Yampa River downstream of Craig, from 2004-2007. All marked NPK were ≥200 mm TL. ∑=Summation by columns where applicable.

Year	# NPK Marked on Pass 1	% Marked NPK Not Recovered on All Subsequent Passes of the Same Year	% of NPK Point Estimate (≥ 200mm) of Marked NPK Not Recovered Within the Same Year as the Initial Mark
2004	159	52 (83/159)	8 (83/981)
2005	195	57 (112/195)	16 (112/701)
2006	214	63 (135/214)	21 (135/649)
2007	191	51 (98/191)	7 (98/1360)
∑	759	56 (428/759)	

Table 12. Number of northern pike (NPK) marked on the first pass, number of marked NPK recovered in 2004, 2005, 2006, and 2007, and total number of marked NPK recovered for all years combined (2004-2007) by year, for the middle Yampa River downstream of Craig, from 2004-2007. All marked NPK were ≥200 millimeters total length. *NA=Not Applicable. ∑=Summation by columns where applicable.

Year	# NPK Marked on Pass 1	# Marked NPK Recovered in 2004	# Marked NPK Recovered in 2005	# Marked NPK Recovered in 2006	# Marked NPK Recovered in 2007	Total # Marked NPK Recovered to Date (2004-2007)
2004	159	76	20	2	1	99
2005	195	*NA	83	14	1	98
2006	214	NA	NA	79	23	102
2007	191	NA	NA	NA	93	93
∑	759	76	103	95	118	392

Table 13. Direction of movement for northern pike (NPK) recaptured on all passes (including the marking pass, Pass 1) by year, for the middle Yampa River downstream of Craig, from 2004-2007, as a result of certain criteria. Direction was determined by comparing the first capture location to the second capture location. Several individuals were captured on three occasions. Movement direction for these individuals was determined by comparing the first capture location to the second capture location, and the second capture location to the third capture location. If the movement direction was the same for both recapture events, then the direction was counted once toward either upstream or downstream movement. If fish were recaptured on the same day and/or moved less than or equal to one river mile during the recapture events, then these movement events were excluded. Numbers of NPK individuals recaptured by year in this table are different than the numbers of NPK individuals recovered on removal passes and presented by year in Table 10. For example, the 97 NPK individuals recaptured in 2005 include: 83 fish marked on Pass 1 and recaptured on all subsequent removal passes (this is the total number of recovered NPK individuals presented in Table 10); 8 fish that were marked and recaptured on Pass 1 that moved more than one river mile; and 6 fish that were recaptured on the same day. Only 71 of these fish, however, were included in the movement analysis. This process was also used for NPK recaptured in 2004, 2006, and 2007. ∑=Summation by columns where applicable.

Year	# NPK Individuals Recaptured	# NPK Individuals Included in Analysis	# NPK Moved Downstream	# NPK Moved Upstream	# NPK with Downstream Movement Followed by Upstream Movement	# NPK with Upstream Movement Followed by Downstream Movement
2004	84	50	41	9	0	0
2005	97	71	67	3	0	1
2006	108	58	50	6	1	1
2007	99	64	48	16	0	0
∑	388	243	206	34	1	2

Table 14. Distance traveled (calculated by subtracting the farthest downstream river mile (RM) of capture from the farthest upstream RM of capture) by northern pike (NPK) recaptured by year, for the middle Yampa River downstream of Craig, from 2004-2007, as a result of certain criteria. Individuals had to: 1) be captured more than once, 2) be captured on different days, i.e. individuals recaptured on the same day were excluded, and 3) travel more than one RM from the initial capture location upon recapture to be included in the analysis. Several individuals were captured on more than one occasion. Greatest distance traveled across all recaptures was recorded for these fish. Total numbers of NPK individuals recaptured by year do not agree with numbers of NPK individuals recaptured on removal passes presented by year in Table 10. See explanation in Table 13. ∑=Summation by columns where applicable.

Year	# NPK Individuals Recaptured	# NPK Individuals Included in Analysis	# of NPK Individuals that Traveled Certain Distances					
			> 1 to 5 RMs	> 5 to 10 RMs	> 10 to 20 RMs	> 20 to 30 RMs	> 30 to 40 RMs	> 40 RMs
2004	84	50	21	11	12	4	1	1
2005	97	71	18	20	18	9	4	2
2006	108	58	16	21	13	5	2	1
2007	99	64	28	16	13	3	3	1
∑	388	243	83	68	56	21	10	5

Table 15. Movement of northern pike (NPK) by river section and by year, for the middle Yampa River downstream of Craig, from 2004-2007, as a result of certain criteria. Individuals had to: 1) be captured more than once, 2) be captured on different days, i.e. individuals recaptured on the same day were excluded, and 3) travel more than one river mile (RM) from the initial capture location upon recapture to be included in the analysis. Several individuals were captured on more than one occasion. River section was identified by comparing the first capture location to the second capture location. Greatest distance traveled was used to determine movement by sections for NPK that were recaptured on more than two occasions within the same year. Total numbers of NPK individuals recaptured by year do not agree with numbers of NPK individuals recaptured on removal passes presented by year in Table 10. See explanation in Table 13. ∑=Summation by columns where applicable.

Year	# NPK Individuals Recaptured	# NPK Individuals Included in Analysis	Same Section	Different Section	Juniper to Juniper	Maybell to Maybell	Lily Park to Lily Park	Juniper to Maybell	Maybell to Lily Park
2004	84	50	47	3	35	10	2	3	0
2005	97	71	62	9	55	6	1	9	0
2006	108	58	51	7	32	17	2	7	0
2007	99	64	59	5	54	5	0	5	0
∑	388	243	219	24	176	38	5	24	0

Table 16. Number of northern pike (NPK) individuals that traveled certain distances in river miles (RMs) and the range of their total length (TL) in millimeters (mm) at initial capture by year, for the middle Yampa River downstream of Craig, from 2004-2007, as a result of certain criteria. Individuals had to: 1) be captured more than once, 2) be captured on different days, i.e. individuals recaptured on the same day were excluded, and 3) travel more than one RM from the initial capture location upon recapture to be included in the analysis. n=number of NPK individuals and R=range of NPK individuals TL (mm) at initial capture. Total numbers of NPK individuals recaptured by year do not agree with numbers of NPK individuals recaptured on removal passes presented by year in Table 10. See explanation in Table 13. ∑=Summation by columns where applicable.

Year	# NPK Individuals Recaptured	# NPK Individuals Included in Analysis	# of NPK Individuals that Traveled Certain Distances					
			> 1 to 5 RMs	> 5 to 10 RMs	> 10 to 20 RMs	> 20 to 30 RMs	> 30 to 40 RMs	> 40 RMs
2004	84	50	n=21 R=340-990	n=11 R=419-665	n=12 R=400-1030	n=4 R=507-840	n=1 R=537	n=1 R=915
2005	97	71	n=18 R=323-1075	n=20 R=327-894	n=18 R=269-755	n=9 R=443-875	n=4 R=270-764	n=2 R=278-545
2006	108	58	n=16 R=314-697	n=21 R=334-965	n=13 R=283-800	n=5 R=474-697	n=2 R=505-549	n=1 R=314
2007	99	64	n=28 R=269-550	n=16 R=278-590	n=13 R=274-423	n=3 R=270-286	n=3 R=249-569	n=1 R=285
∑	388	243	n=83 R=269-1075	n=68 R=278-965	n=56 R=269-1030	n=21 R=270-875	n=10 R=249-764	n=5 R=278-915

Table 17. Direction of movement for northern pike (NPK) recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, from 2004-2007, as a result of certain criteria. Direction was determined by comparing the first capture location to the second capture location. Several individuals were captured on three occasions. Movement direction for these individuals was determined by comparing the first capture location to the second capture location, and the second capture location to the third capture location. If the movement direction was the same for both recapture events, then the direction was counted once toward either upstream or downstream movement. If fish were recaptured on the same day and/or moved less than or equal to one river mile during the recapture events, then these movement events were excluded. ∑=Summation by columns where applicable.

Year	# NPK Individuals Recaptured	# NPK Individuals Included in Analysis	# NPK Moved Downstream	# NPK Moved Upstream	# NPK with Downstream Movement Followed by Upstream Movement	# NPK with Upstream Movement Followed By Downstream Movement
2004-2005	20	19	17	2	0	0
2005-2006	14	12	8	4	0	0
2006-2007	23	19	11	8	0	0
∑	57	50	36	14	0	0

Table 18. Distance traveled (calculated by subtracting the farthest downstream river mile (RM) of capture from the farthest upstream RM of capture) by northern pike (NPK) recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, from 2004-2007, as a result of certain criteria. Individuals had to: 1) be captured more than once, 2) be captured on different days, i.e. individuals recaptured on the same day were excluded, and 3) travel more than one RM from the initial capture location upon recapture to be included in the analysis. Several individuals were captured on more than one occasion. Greatest distance traveled across all recaptures was recorded for these fish. ∑=Summation by columns where applicable.

Year	# NPK Individuals Recaptured	# NPK Individuals Included in Analysis	# of NPK Individuals that Traveled Certain Distances					
			> 1 to 5 RMs	> 5 to 10 RMs	> 10 to 20 RMs	> 20 to 30 RMs	> 30 to 40 RMs	> 40 RMs
2004-2005	20	19	5	3	4	5	2	0
2005-2006	14	12	4	2	4	0	2	0
2006-2007	23	19	5	2	7	3	0	2
∑	57	50	14	7	15	8	4	2

Table 19. Movement of northern pike (NPK) by river section for individuals recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, from 2004-2007, as a result of certain criteria. Individuals had to: 1) be captured more than once, 2) be captured on different days, i.e. individuals recaptured on the same day were excluded, and 3) travel more than one RM from the initial capture location upon recapture to be included in the analysis. River section was identified by comparing the first capture location to the second capture location. Greatest time at large was used to determine movement by sections for northern pike that were recaptured on multiple occasions during the 11 to 15 month time period. ∑=Summation by columns where applicable.

Year	# NPK Individuals Recaptured	# NPK Individuals Included in Analysis	Same Section	Different Section	Juniper to Juniper	Maybell to Maybell	Lily Park to Lily Park	Juniper to Maybell	Maybell to Lily Park
2004-2005	20	19	16	3	11	5	0	1	2
2005-2006	14	12	9	3	5	4	0	3	0
2006-2007	23	19	14	5	9	4	1	4	1
∑	57	50	39	11	25	13	1	8	3

Table 20. Number of northern pike (NPK) individuals that traveled certain distances in river miles (RMs) and the range of their total length (TL) in millimeters (mm) at initial capture for individuals recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, from 2004-2007, as a result of certain criteria. Individuals had to: 1) be captured more than once, 2) be captured on different days, i.e. individuals recaptured on the same day were excluded, and 3) travel more than one RM from the initial capture location upon recapture to be included in the analysis. n=number of NPK individuals and R=range of NPK individuals TL (mm) at initial capture. *NA=Not Applicable. ∑=Summation by columns where applicable.

Year	# NPK Individuals Recaptured	# NPK Individuals Included in Analysis	# of NPK Individuals that Traveled Certain Distances					
			> 1 to 5 RMs	> 5 to 10 RMs	> 10 to 20 RMs	> 20 to 30 RMs	> 30 to 40 RMs	> 40 RMs
2004-2005	20	19	n=5 R=385-574	n=3 R=618-644	n=4 R=568-907	n=5 R=508-687	n=2 R=456-577	n=0 R=*NA
2005-2006	14	12	n=4 R=390-680	n=2 R=365-451	n=4 R=380-920	n=0 R=NA	n=2 R=405-465	n=0 R=NA
2006-2007	23	19	n=5 R=359-527	n=2 R=342-569	n=7 R=332-404	n=3 R=395-569	n=0 R=NA	n=2 R=524-556
∑	57	50	n=14 R=359-680	n=7 R=342-644	n=15 R=332-920	n=8 R=395-687	n=4 R=405-577	n=2 R=524-556

Table 21. Northern pike (NPK) increase in growth in millimeters (mm) by total length (TL) size group for individuals recaptured after 11 to 15 months at large, for the middle Yampa River downstream of Craig, from 2004-2007. n=number of NPK individuals, x=average increase in growth (mm), R=range of increase in growth (mm), 95 CI=95% Confidence Interval. *NA=Not Applicable. ∑=Summation by columns where applicable.

Year	NPK Increase in Growth (mm) by TL Size Group (mm)								
	101-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-1000
2004-2005	n=0 x=*NA R=NA	n=0 x=NA R=NA	n=1 x=211 R=211	n=3 x=76 R=63-84	n=6 x=61 R=36-98	n=8 x=56 R=16-137	n=0 x=NA R=NA	n=0 x=NA R=NA	n=1 x=33 R=33
2005-2006	n=0 x=NA R=NA	n=0 x=NA R=NA	n=4 x=211 R=155-290	n=4 x=146 R=126-173	n=2 x=64 R=52-75	n=1 x=49 R=49	n=0 x=NA R=NA	n=0 x=NA R=NA	n=1 x=22 R=22
2006-2007	n=0 x=NA R=NA	n=0 x=NA R=NA	n=11 x=160 R=72-226	n=3 x=163 R=144-183	n=5 x=67 R=35-123	n=0 x=NA R=NA	n=0 x=NA R=NA	n=0 x=NA R=NA	n=0 x=NA R=NA
∑	n=0 x=NA R=NA 95 CI=NA	n=0 x=NA R=NA 95 CI=NA	n=16 x=176 R=72-290 95 CI=150-202	n=10 x=130 R=63-183 95 CI=100-160	n=13 x=64 R=35-123 95 CI=48-80	n=9 x=55 R=16-137 95 CI=26-84	n=0 x=NA R=NA 95 CI=NA	n=0 x=NA R=NA 95 CI=NA	n=2 x=28 R=22-33 95 CI=0-98

Table 22. Number of individual northern pike (NPK) marked in our study area of the middle Yampa River downstream of Craig that emigrated to other projects in the Yampa River and Green River, from 2004-2007. Principal investigator, project number, and project river miles (RM) are also presented. NPK recaptured each year may have been marked that same year or in a previous year. Data provided via personal communication with principal investigators.
∑=Summation by columns where applicable.

	# NPK Individuals Recaptured in 2004	# NPK Individuals Recaptured in 2005	# NPK Individuals Recaptured in 2006	# NPK Individuals Recaptured in 2007	Sum of NPK Individuals Recaptured 2004-2007
Yampa River					
Finney Project 98b RM 171.0-RM 134.2	4	6	4	7	21
Fuller Project 110 RM 46.0-RM 0.0	0	2	0	0	2
Green River					
Bestgen Project FR115 RM 351.3-RM 344.1	4	1	2	0	7
Hedrick Project 144 RM 319.0-RM 299.0	2	0	0	1	3
∑	10	9	6	8	33

Table 23. Number of individual northern pike (NPK) marked in other projects in the Yampa River that immigrated to our study area in the middle Yampa River downstream of Craig, from 2004-2007. Principal investigator, project number, and project river miles (RM) are also presented. NPK recaptured each year may have been marked that same year or in a previous year. Data provided via personal communication with principal investigators. ∑=Summation by columns where applicable.

	# NPK Individuals Recaptured in 2004	# NPK Individuals Recaptured in 2005	# NPK Individuals Recaptured in 2006	# NPK Individuals Recaptured in 2007	Sum of NPK Individuals Recaptured 2004-2007
Yampa River					
Atkinson Catamount Project RM 205.0	0	0	1	1	2
Finney/Atkinson Project 98c RM 198.8-RM 170.8	2	3	4	1	10
Finney Project 98b RM 171.0-RM 134.2	15	48	16	14	93
Hill Project C31 RM 192.0-RM 139.0	0	2	1	0	3
∑	17	53	22	16	10

Table 24. Smallmouth bass (SMB) total capture events (i.e. includes recaptures), number of SMB individuals captured (i.e. recapture events not included), number of SMB marked, number of SMB not marked (due to size), number of SMB recaptured within the same year tagged by the Colorado Division of Wildlife (CDOW) and Colorado State University (CSU), number of foreign SMB recaptures: [CDOW06=recaptures tagged by CDOW in 2006, CSU=CSU recaptures from previous years, FWSR = U.S. Fish and Wildlife Service red tag recaptures, UNK=unknown tag identification], number of SMB released, number of SMB removed and final disposition: [CJC=Craig Justice Center pond, PM/Morts=Provided to Pat Martinez, CDOW Aquatic Researcher, including mortalities], number of SMB transported to Elkhead Reservoir [EH] and total number of SMB removed, for the middle Yampa River downstream of Craig in 2006 and 2007. Data included for CDOW Pass 1 through Pass 4, Reach 1 through Reach 5, as well as two additional passes for Reach 1.

					SMB Recaptures from Same Year		SMB Recaptures from Prior Years					# SMB Removed			
Year	# SMB Capture Events	# SMB Individuals Captured	# SMB Marked by CDOW	# SMB Not Marked	CSU	CDOW	CDOW	CSU	USFWS	UNK	# SMB Released	CJC	PM/Morts	EH	Total
2006	1215	1199	117*	885	12*	10	NA	51	0	1	869	186	160	0	346
2007	1398	1346	515**	831	52**	2	10	49	1	0	803	148	221	174	548

* Numbers are based on effort for Reach 1 (South Beach) only
** Numbers are based on effort for all reaches, with two additional passes for Reach 1

Table 25. A summary of total number of capture events (i.e. all fish captured during the project, including recaptures) in 2006 and 2007 for smallmouth in various total length categories . Total length categories include smallmouth bass (SMB) < 150 millimeters (mm) in total length, capture events of SMB ≥ 150 mm in total length, capture events of SMB ≥ 250 mm in total length, capture events of SMB ≥ 350 mm in total length, capture events of SMB ≥ 450 mm in total length, total capture event of SMB, and SMB Catch Per Unit Effort (CPUE) (# of SMB captured/hour by electrofishing).

Year	# of SMB (<150 mm) Capture Events	# of SMB (≥150 mm) Capture Events	# of SMB (≥250 mm) Capture Events	# of SMB (≥350 mm) Capture Events	# of SMB (≥450mm) Capture Events	Total # SMB Capture Events	Overall SMB CPUE (# of SMB /hour)
Reach 1 through Reach 5 Combined							
2006	367	847	527	274	2	1215	6.96
2007	403	993	678	301	4	1398	6.98
South Beach (Reach 1) Only							
2006	116	315	301	173	0	469	NA
2007	155	428	357	206	3	583	9.24

Table 26. Smallmouth bass (SMB) population estimates, based on the Lincoln-Petersen method, for 5 sample reaches within in the middle Yampa River, downstream of Craig. Population estimates are for all reaches for SMB > 150 mm in total length. In reach 2 through 5 population estimates are for 2007 only, as it was the first year for mark-recapture studies. Multiple iterations of the Lincoln-Petersen appear for reaches 2 - 5: Pass 1 = the first pass was used as the Marking effort (M) and pass 2 was used as the recapture effort; Pass 1, 2 combined = Pass 1 and 2 were combined as the marking effort (M) and pass 3 was used as the Recapture effort (R); Pass 1,2, 3 combined = Pass 1, 2, and 3 were combined and used as the marking effort (M) and pass 4 was used as the Recapture effort (R). These do not apply to South Beach (Reach 1), as SMB were removed in all passes subsequent to the initial marking pass.

	# SMB Marked on Marking Pass(es)	# SMB Tagged and Recaptured "R" During the Recapture Occasion	Total # SMB Captured "C" During the Recapture Occasion	Point Estimate (N-hat)	95% Confidence Interval	Standard Error (SE)	Coefficient of Variation (CV)	Capture Probability (p-hat)
Reach 1								
2006	119	17	75	1139	409 - 1869	372.2	0.327	0.06
2007	40	4	62	516	101 - 931	212	0.411	0.07
Reach 2								
2008	10	2	65	241	0 - 482	123	0.51	0.21
Reach 3								
2008	8	1	15	71	0 - 161	46	0.65	0.84
Reach 4	NA	NA	NA	NA	NA	NA	NA	NA
Reach 5								
2008	6	2	32	76	7 - 145	35	0.461	0.23

Table 27. Smallmouth bass (SMB) catch per unit effort (CPUE) (number of smallmouth bass capture events, including recaptures per hour) by pass and year, for the middle Yampa River downstream of Craig, from 2004-2007. CPUE include capture events (i.e. all fish captured including recaptures) and effort associated only with electrofishing).

Year	SMB CPUE Pass 1	SMB CPUE Pass 2	SMB CPUE Pass 3	SMB CPUE Pass 4	SMB CPUE Pass 5	SMB CPUE Pass 6
2006	4.38	4.19	8.86	10.38	NA	NA
2007	1.81	4.17	8.99	9.68	5.67	21.82

Table 28. Catch per unit effort (CPUE; # smallmouth bass/hour) for all sizes of smallmouth bass, broken down by individual reach within in the middle Yampa River downstream of Craig for 2007.

Reach	# of SMB Bass Handled	Total Electrofishing Effort (Hours)	CPUE (# of fish/hour)
Reach 1 (South Beach)	583	63.12	9.2
Reach 2 (Juniper)	188	36.59	5.1
Reach 3 (Upper Maybell)	408	37.33	10.9
Reach 4 (Lower Maybell)	105	30.9	3.4
Reach 5 (Sunbeam)	113	32.04	3.5

Table 29. Total number of smallmouth bass (SMB), number of SMB < 150 mm removed, number of SMB 150-249 mm removed, number of SMB 250-349 mm removed, number of SMB 350mm-449 mm removed, number of SMB ≥ 450 mm removed, and the percentage of SMB handled that were handled removed for the South Beach to Round Bottom Reach (Reach 1) in 2006 and 2007.

Year	Total # of SMB Individuals Handled	# of SMB Removed (< 150 mm)	# of SMB Removed (150 mm–249 mm)	# SMB Removed (250 mm–349 mm)	# SMB Removed (350 mm–449 mm)	# SMB Removed (≥ 450 mm)	% of SMB Handled Removed
2006	469	112	49	77	104	0	74% (346/469)
2007	583	153	70	142	173	3	94% (548/583)

Table 30. Number of smallmouth bass (SMB) marked on the first pass, percentage of SMB marked on the first pass and not recovered on all subsequent passes during the same year, and the number of tagged and un-recovered SMB expressed as a percentage of the population point estimate for SMB for the South Beach to Round Bottom Reach (Reach 1) of the Middle Yampa River, downstream of Craig in 2006 and 2007.

Year	# of SMB Marked on Pass 1	% of Marked SMB Not Recovered on Subsequent Passes	% of SMB Point Estimate of Marked SMB Not Recovered Within the Same Year of Marking
2006	117	92% (108/117)	9% (108/1139)
2007	40	76% (31/40)	6% (31/516)

Table 31. Number of smallmouth bass (SMB) marked in 2006 and the number recovered on subsequent passes within the same year, and during all passes completed in 2007 for the South Beach to Round Bottom (Reach 1) of the Middle Yampa River downstream of Craig. Also the number of SMB marked in 2007 and recovered in subsequent passes of the same year.

Year	# of SMB Marked on Pass 1	# of Marked SMB Recovered in 2006	# of Marked SMB Recovered in 2007
2006	117	9 (8%)	10 (9%)
2007	40	NA	9 (23%)

Table 32. Distance traveled (calculated by subtracting the furthest downstream river mile (RM) of capture from the furthest upstream RM of capture) by smallmouth bass (SMB) marked in 2006 and recaptured in 2007 for the middle Yampa River downstream of Craig. Only SMB that traveled ≥ 1 mile were included. This analysis includes seven fish that were tagged by CSU in 2006 and recaptured by the CDOW in 2007; all other SMB were initially tagged by CDOW and recaptured by CDOW.

Direction of Movement (2006 – 2007)	Percentage of SMB that Moved	# of SMB Individuals that Traveled Certain Distances						
		>1 – 2 RM	>2 – 4 RM	>4 – 6 RM	>6 – 8 RM	>8 – 10 RM	>10 – 20 RM	>20 – 30 RM
Upstream	69% (11/16)	0	2	1	4	1	3	0
Downstream	32% (5/16)	0	0	0	1	0	3	1

Table 33. Distance traveled (calculated by subtracting the furthest downstream river mile (RM) of capture from the furthest upstream RM of capture) by smallmouth bass (SMB) within 2007 for the middle Yampa River downstream of Craig. Only SMB that traveled ≥ 1 mile were included. This analysis includes six fish that were tagged by CSU and recaptured by the CDOW.

		# of SMB Individuals that Traveled Certain Distances									
Direction of Movement (2006 – 2007)	Percentage of SMB that Moved	>1–2 RM	>2–4 RM	>4–6 RM	>6–8 RM	>8–10 RM	>10–20 RM	>20–30 RM	>30–40 RM	>40-50 RM	>50-60 RM
Upstream	77% (27/36)	4	3	4	4	4	4	2	1	0	1
Downstream	23% (8/36)	1	3	2	1	1	0	0	0	0	0

Table 34. Number of Colorado pikeminnow (CPM) individuals collected, total length (TL) range in millimeters (mm), number of main channel habitat collections, number of tributary stream/backwater (BW) habitat collections, number of CPM with presumed northern pike (NPK) attacks, and number of CPM mortalities by year, for the middle Yampa River downstream of Craig, from 2004-2007.

Year	# of CPM Individuals Collected	CPM TL Range (mm)	Main Channel Habitat Collections	Tributary Stream/BW Habitat Collections	# of CPM with Presumed NPK Attacks	# CPM Mortalities
2004	16	512-806	12	4	6	2
2005	22	500-730	13	13	5	1
2006	25	449-805	14	16	2	0
2007	11	525-747	7	4	0	0
∑	74	449-806	46	37	13	3

Table 35. Colorado pikeminnow (CPM) capture and recapture events for individuals recaptured after at least 11 months at large, including date of initial capture, initial capture location by river mile (RM), total length (TL) in millimeters (mm) at initial capture, date of recapture event, recapture location by RM, and TL at recapture, for the middle Yampa River downstream of Craig, from 2004-2007.

Initial Date of CPM Capture	CPM Individual	CPM Initial Capture Location by RM	CPM TL (mm) at Initial Capture	CPM Recapture Event	CPM Recapture Location by RM	CPM TL (mm) at Recapture
5/5/04	351F	78.3	512	5/23/06	72.9	538
5/5/04	5123	76.5	536	6/14/05	72.9	540
5/5/04	1461	75.0	578	6/14/05	72.9	605
				4/18/06	72.9	628
5/6/04	405E-54C9	86.2	600	5/24/05	81.6	610
				4/19/06	81.6	639
				4/26/07	82.7	653
5/18/04	305D	76.1	806	5/24/06	72.9	805
6/4/04	0A4D	81.6	600	5/19/05	72.1	598
4/28/05	056F	91.5	730	5/16/07	96.0	747
5/5/05	5C65	82.0	500	4/26/06	93.7	552
6/10/05	D8A3	62.3	608	4/26/06	94.2	636
5/5/06	2D87	99.3	625	5/16/07	92.5	643
5/25/06	32BD	72.9	488	5/15/07	72.9	537

Table 36. Number of roundtail chub (RTC) individuals collected, total length (TL) range in millimeters (mm), number of main channel habitat collections, number of tributary stream/backwater (BW) habitat collections, number of RTC with presumed northern pike (NPK) attacks, and number of RTC mortalities by year, for the middle Yampa River downstream of Craig, from 2005-2007. *ND=Not Determined.

Year	# of RTC Individuals Collected	RTC TL Range (mm)	# of Main Channel Habitat Collections	# of Tributary Stream/BW Habitat Collections	# of RTC with Presumed NPK attacks	# of RTC Mortalities
2005	69	310-542	*ND	ND	3	0
2006	48	323-490	47	6	1	0
2007	49	68-505	47	4	5	0
∑	166	68-542	94	10	9	0

Table 37. Roundtail chub (RTC) capture and recapture events for individuals recaptured after at least 11 months at large, including date of initial capture, initial capture location by river mile (RM), total length (TL) in millimeters (mm) at initial capture, date of recapture event, recapture location by RM, and TL at recapture, for the middle Yampa River downstream of Craig, from 2005-2007.

Initial Date of of RTC Capture	RTC Individual	RTC Initial Capture Location by RM	RTC TL (mm) at Initial Capture	RTC Recapture Event	RTC Recapture Location by RM	RTC TL (mm) at Recapture
5/19/05	1728	71.4	453	6/13/06	77.4	472
6/7/05	7070	69.7	399	5/1/07	97.7	440
6/7/05	09F0	69.7	352	6/14/07	65.6	440
6/7/05	ED25	68.0	364	5/2/06	66.5	397
7/5/05	359E	65.7	410	6/17/06	65.3	424
5/2/06	9448	65.6	388	4/24/07	65.3	408
6/7/06	12D9	94.0	436	5/1/07	91.2	439

Table 38. Number and total length (TL) range in millimeters (mm) of incidental non-native species collected by year, for the middle Yampa River downstream of Craig, 2004-2007. BBH=Black bullhead; BCR=Black crappie; BGL=Bluegill; BST=Brook stickleback; CRC=Creek chub; SNF=Green sunfish. *NA=Not Applicable. **ND=Not Determined.

Year	# BBH (TL range in mm)	# BCR (TL range in mm)	# BGL (TL range in mm)	# BST (TL range in mm)	# CRC (TL range in mm)	# SNF (TL range in mm)
2004	0 (*NA)	1 (**ND)	2 (119-197)	0 (NA)	0 (NA)	0 (NA)
2005	3 (204-223)	77 (113-292)	68 (80-218)	1 (ND)	0 (NA)	0 (NA)
2006	7 (146-249)	48 (54-289)	10 (103-190)	0 (NA)	1 (129)	8 (52-97)
2007	11 (87-209)	11 (68-172)	40 (53-206)	0 (NA)	0 (NA)	7 (70-147)
∑	21 (87-249)	137 (54-292)	120 (53-218)	1 (NA)	1 (129)	15 (52-147)

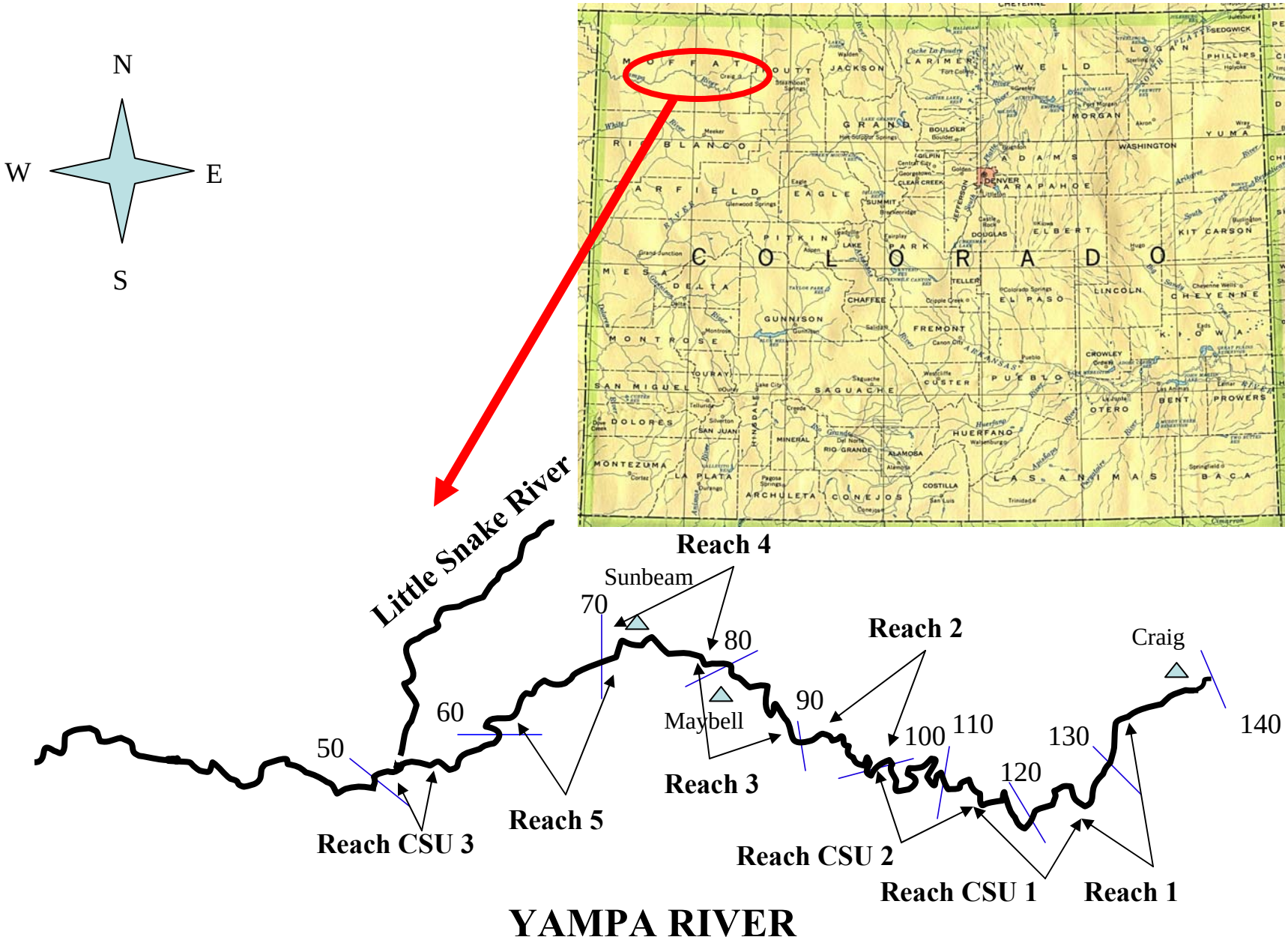

Figure 1. River reaches of the middle Yampa River sampled by the Colorado Division of Wildlife and Colorado State University (CSU), 2004-2007. See Table 1 for river reach descriptions. Graphics courtesy of P. Martinez and R. Anderson.

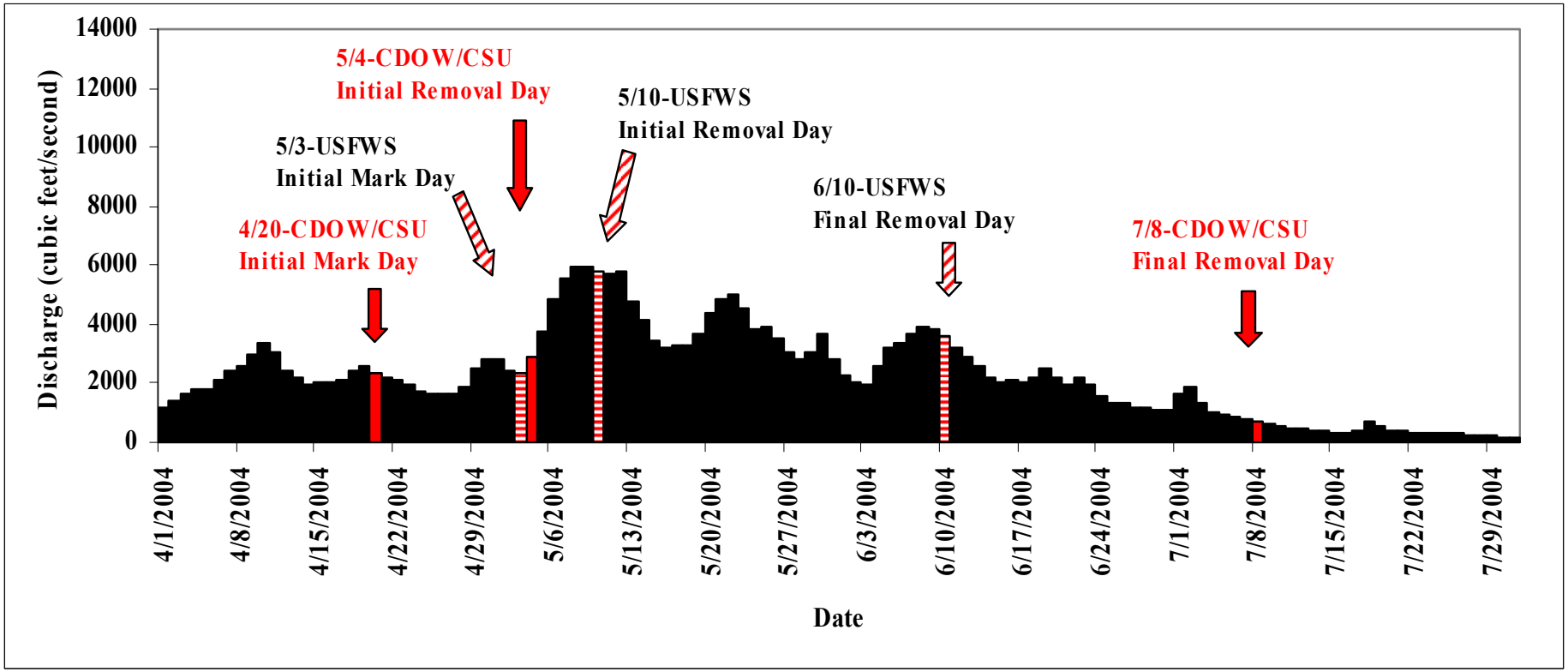

Figure 2. Average daily Yampa River discharge near Maybell (U.S. Geological Survey gage 09251000) April 1 through July 31, 2004. Colorado Division of Wildlife (CDOW), Colorado State University (CSU), and U.S. Fish and Wildlife Service (USFWS) initial marking days, initial removal days, and final removal days for Projects 98a and 98b.

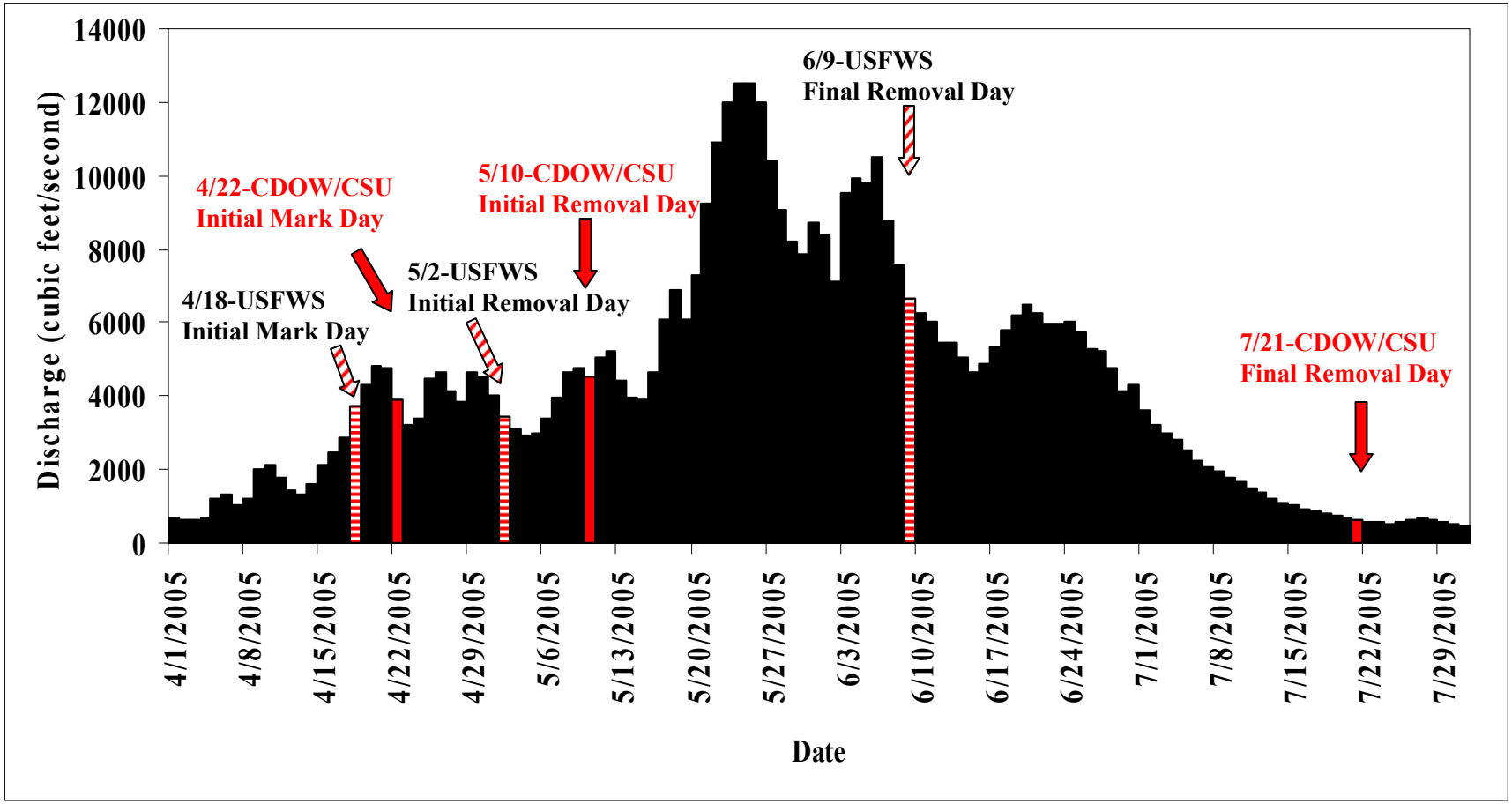

Figure 3. Average daily Yampa River discharge near Maybell (U.S. Geological Survey gage 09251000) April 1 through July 31, 2005. Colorado Division of Wildlife (CDOW), Colorado State University (CSU), and U.S. Fish and Wildlife Service (USFWS) initial marking days, initial removal days, and final removal days for Projects 98a and 98b.

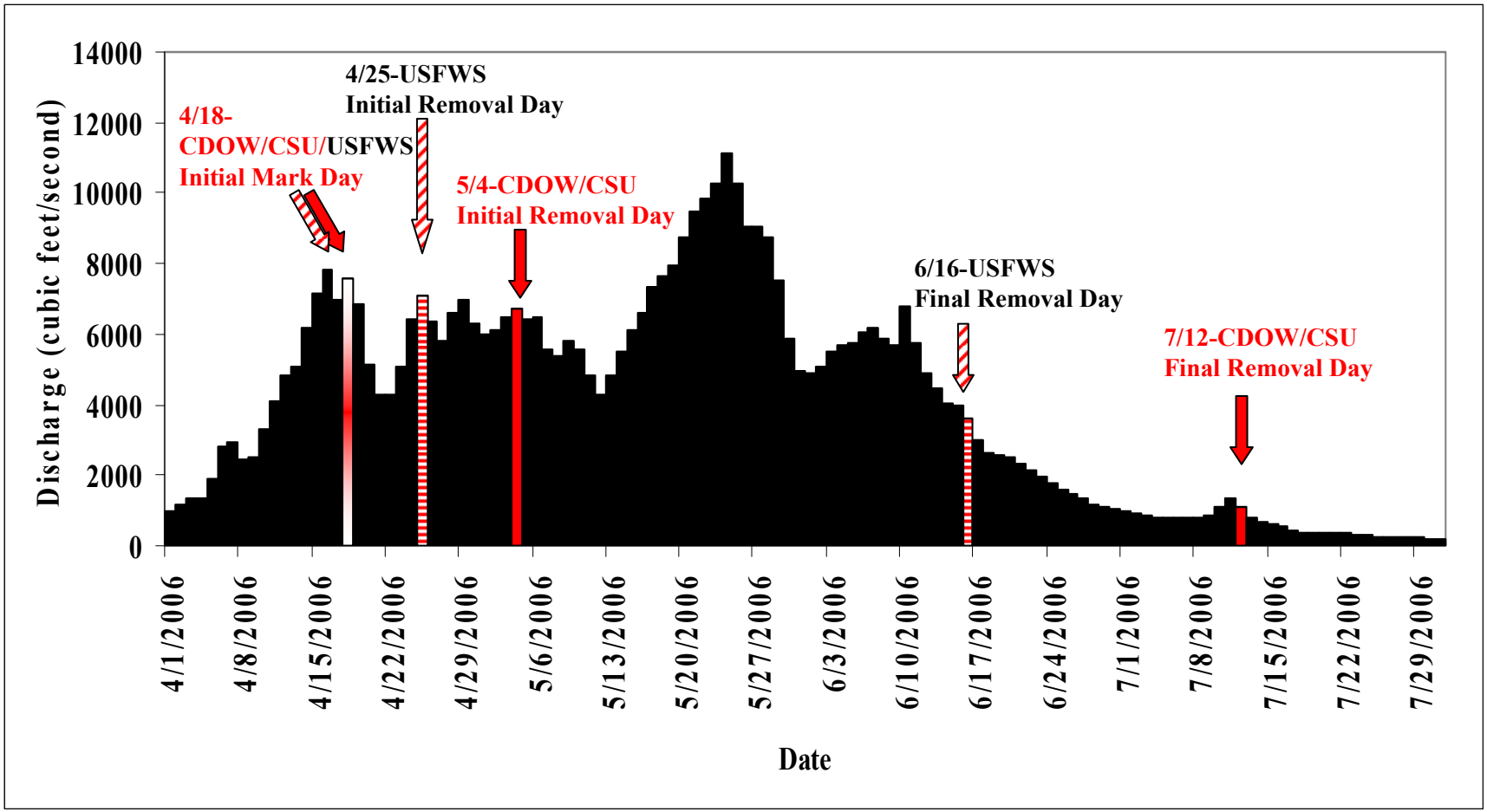

Figure 4. Average daily Yampa River discharge near Maybell (U.S. Geological Survey gage 09251000) April 1 through July 31, 2006. Colorado Division of Wildlife (CDOW), Colorado State University (CSU), and U.S. Fish and Wildlife Service (USFWS) initial marking days, initial removal days, and final removal days for Projects 98a and 98b.

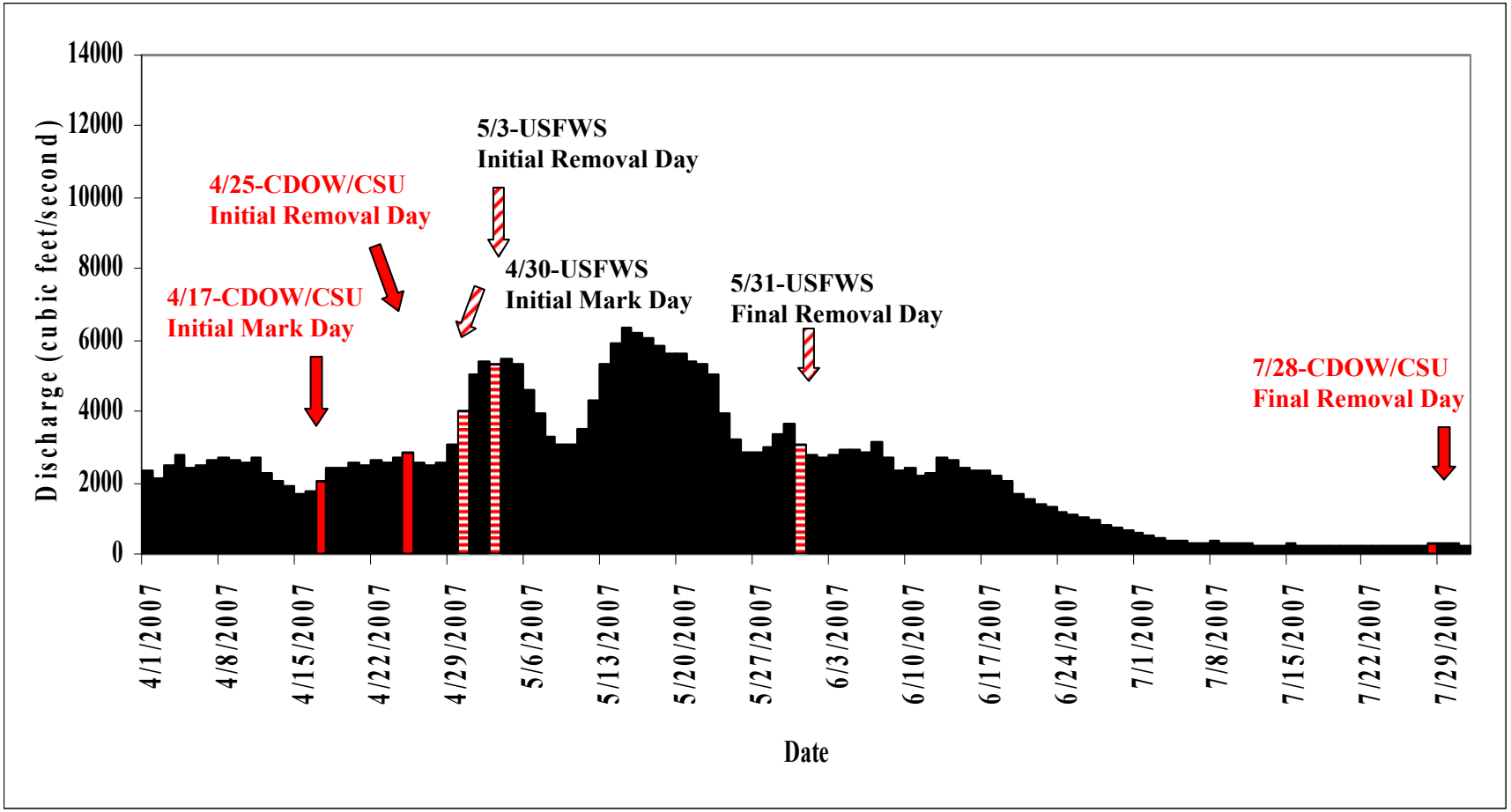

Figure 5. Average daily Yampa River discharge near Maybell (U.S. Geological Survey gage 09251000) April 1 through July 31, 2007. Colorado Division of Wildlife (CDOW), Colorado State University (CSU), and U.S. Fish and Wildlife Service (USFWS) initial marking days, initial removal days, and final removal days for Projects 98a and 98b.

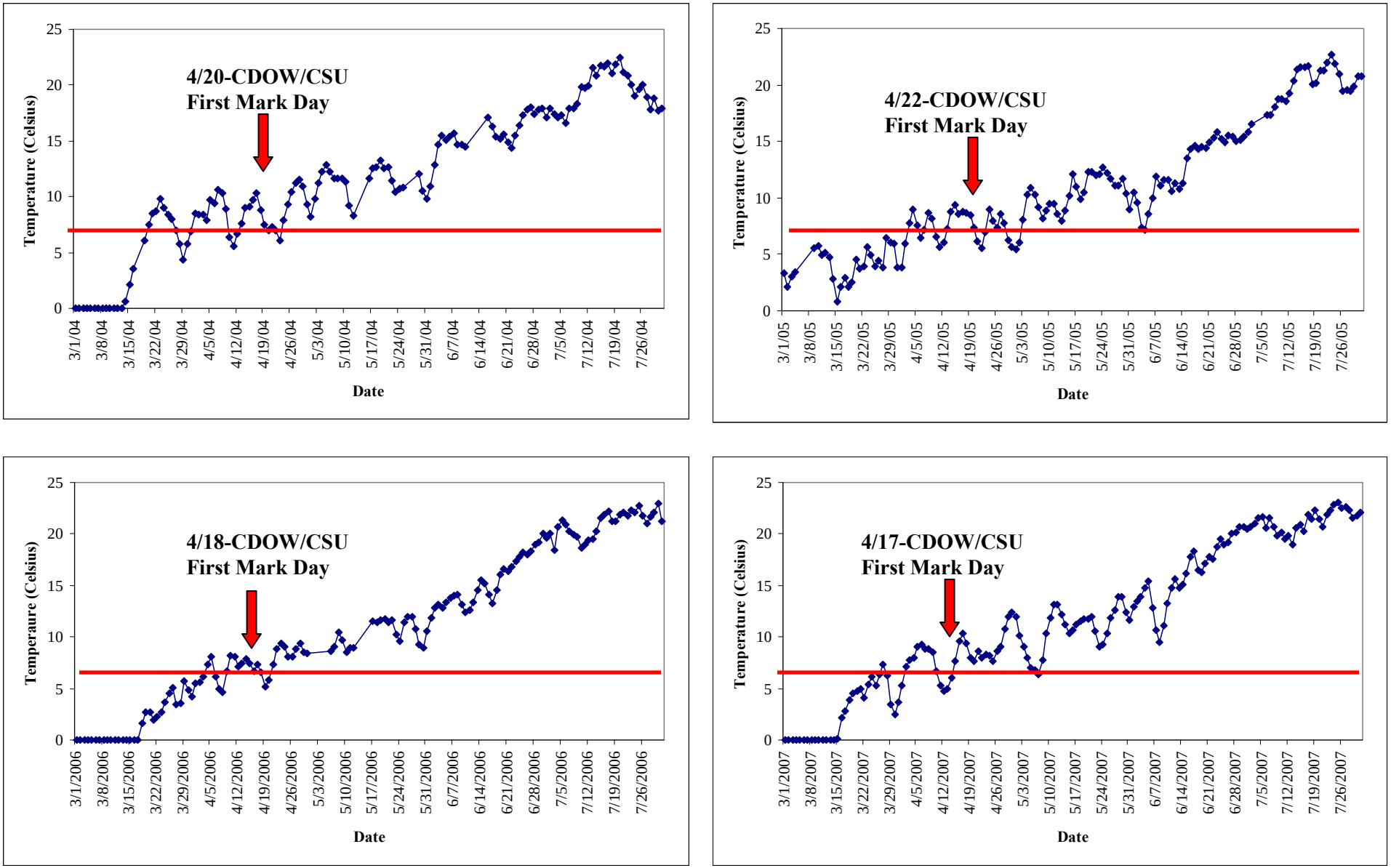

Figure 6. Minimum daily Yampa River temperatures near Maybell (U.S. Geological Survey gage 09251000), March 1 through July 31, 2004-2007. Colorado Division of Wildlife (CDOW) and Colorado State University (CSU) initial marking dates for Project 98a. Horizontal line denotes seven degrees Celsius; the minimum river temperature required for effective electrofishing.

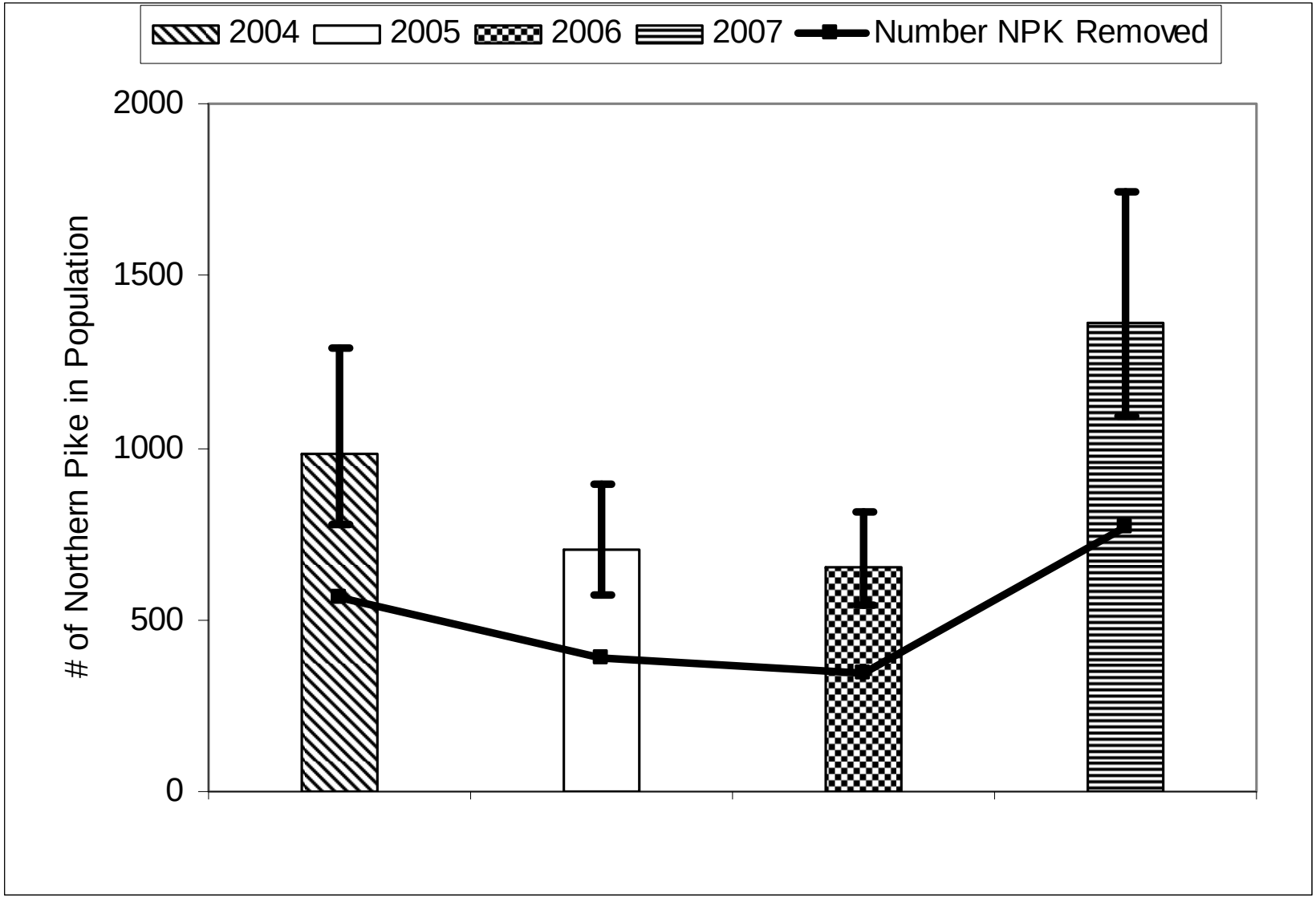

Figure 7. Northern pike population estimates with 95% Confidence Intervals for the middle Yampa River downstream of Craig, South Beach through Lily Park (approx. 76.3 river miles) in 2004, 2005, 2006, and 2007 for fish ≥200 millimeters in total length. Total numbers of northern pike removed by year are indicated with the solid line.

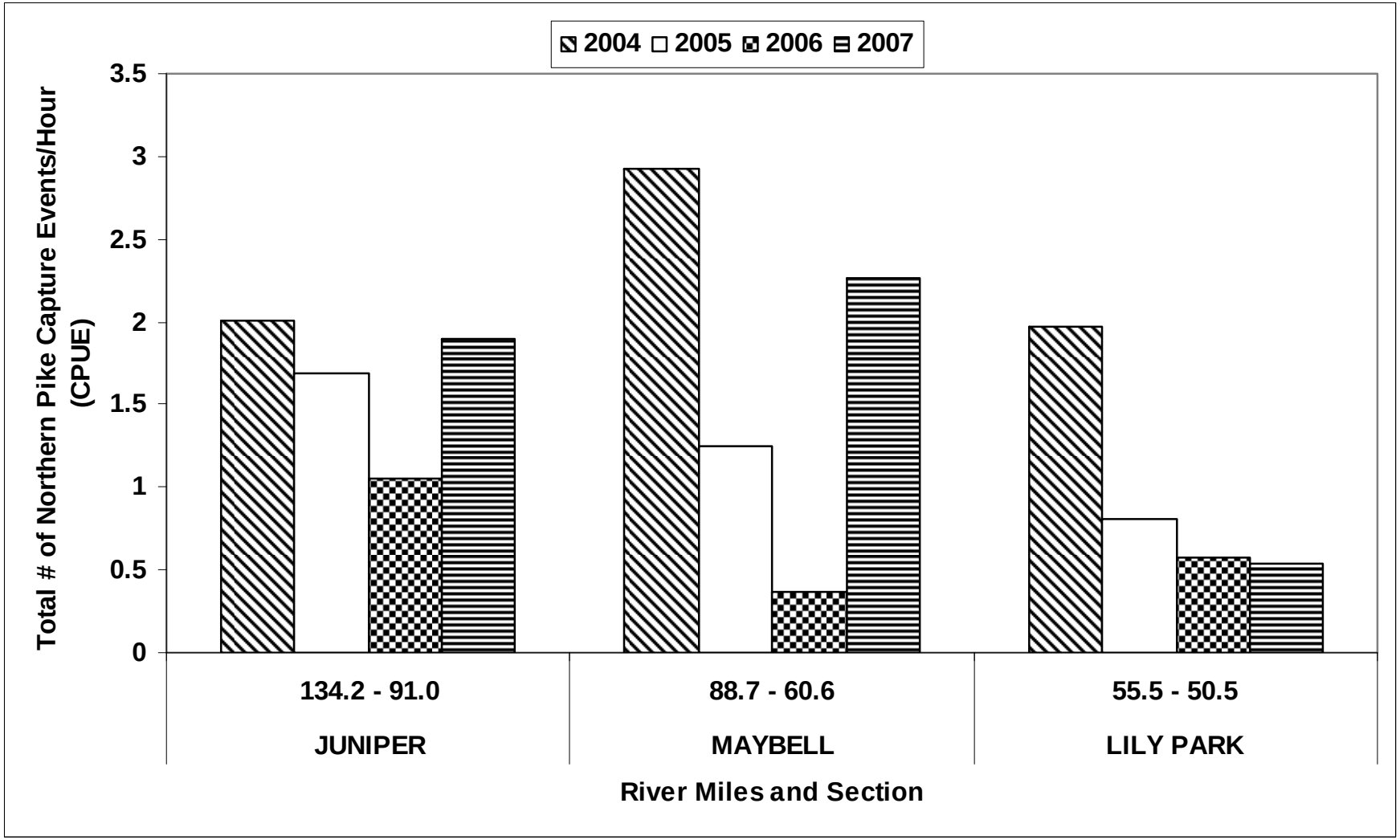

Figure 8. Number of northern pike capture events per hour (CPUE) for the Juniper, Maybell, and Lily Park sections of the middle Yampa River downstream of Craig, South Beach through Lily Park (approx. 76.3 river miles) in 2004, 2005, 2006, and 2007 for all capture events by electrofishing and fyke netting. Capture events and effort associated with angling in 2006 and 2007 are excluded.

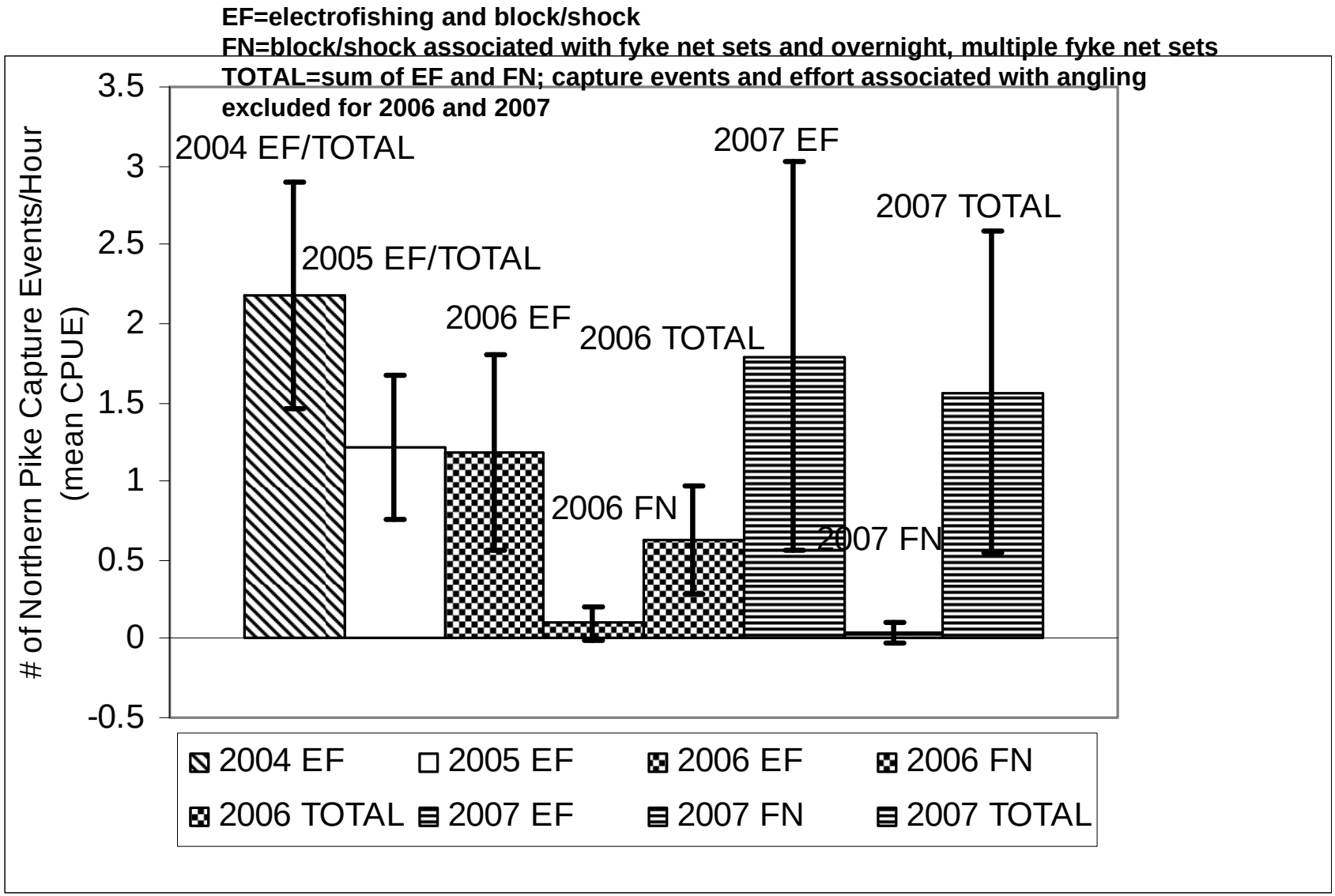

Figure 9. Number of northern pike (≥200 millimeters in total length) capture events per hour (mean CPUE) with 95% Confidence Intervals for the middle Yampa River downstream of Craig, South Beach through Lily Park (approx. 76.3 river miles) in 2004, 2005, 2006, and 2007 for all capture events. Fyke netting (FN) was not completed in 2004 and 2005. Therefore, 2004 EF also equals 2004 TOTAL, and 2005 EF equals 2005 TOTAL.

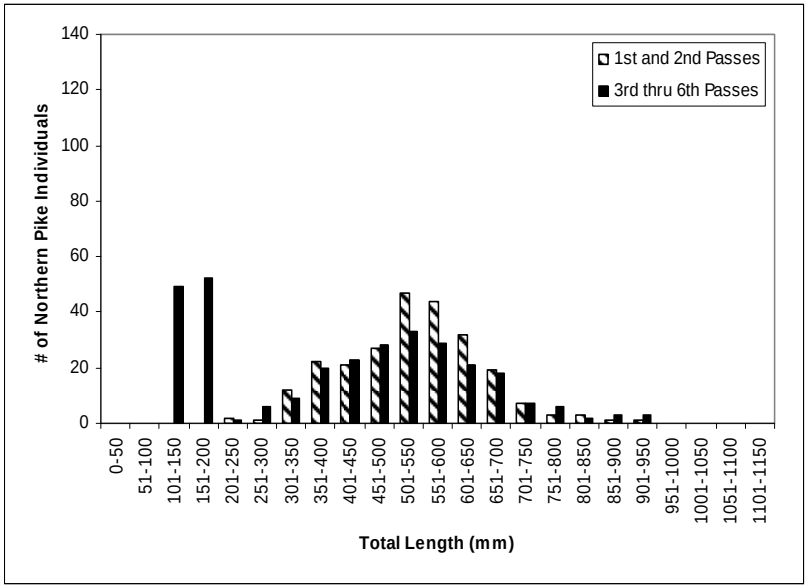

Figure 10a. Northern pike total length frequency for the Juniper section (includes river reaches 1, CSU 1, CSU 2, and 2) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 6 combined, 2004. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

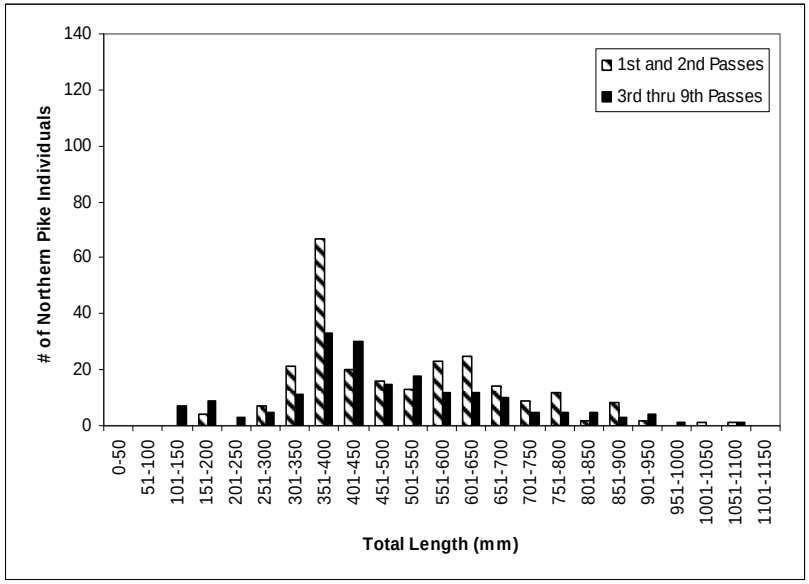

Figure 10b. Northern pike total length frequency for the Juniper section (includes river reaches 1, CSU 1, CSU 2, and 2) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 9 combined, 2005. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

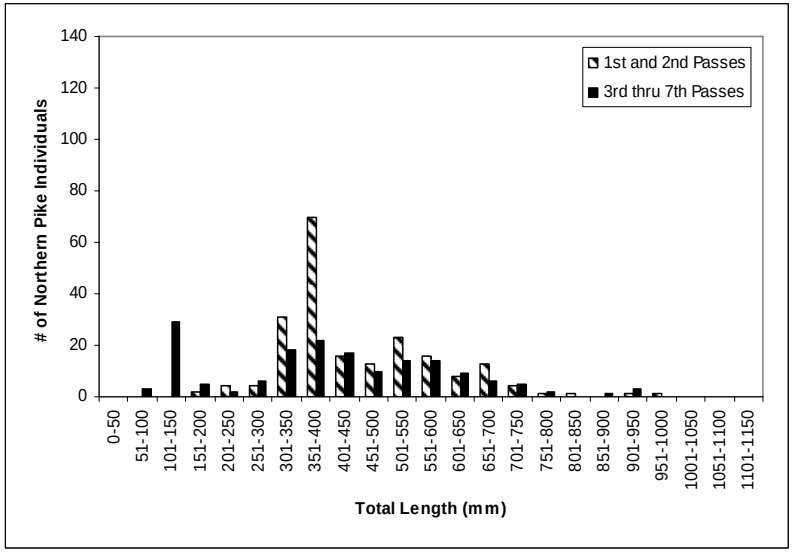

Figure 10c. Northern pike total length frequency for the Juniper section (includes river reaches 1, CSU 1, CSU 2, and 2) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 7 combined, 2006. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

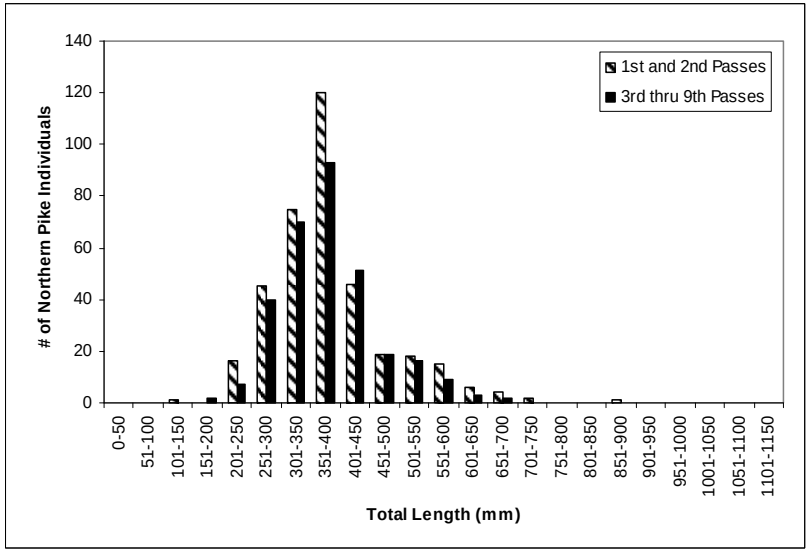

Figure 10d. Northern pike total length frequency for the Juniper section (includes river reaches 1, CSU 1, CSU 2, and 2) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 9 combined, 2007. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

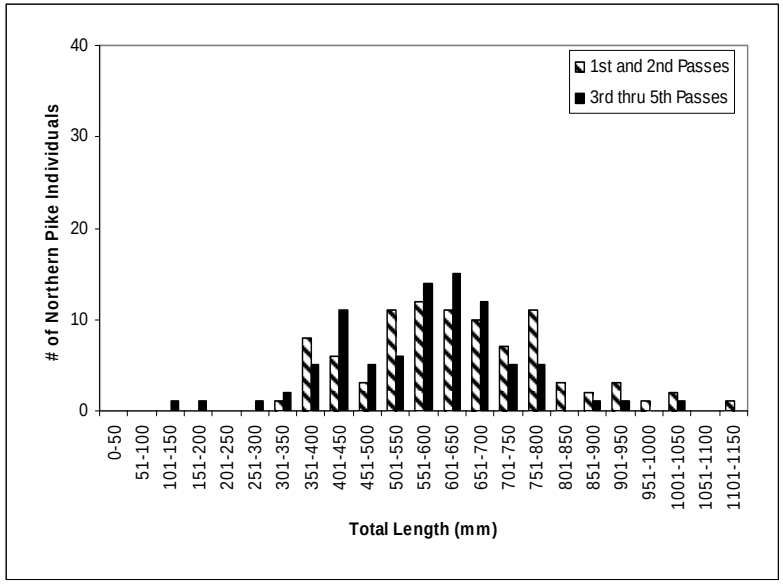

Figure 11a. Northern pike total length frequency for the Maybell section (includes river reaches 3-5) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 5 combined, 2004. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

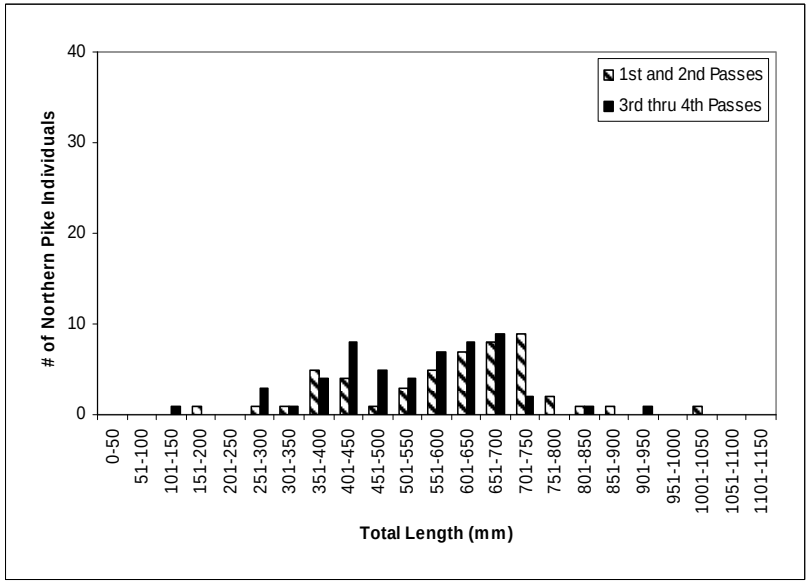

Figure 11b. Northern pike total length frequency for the Maybell section (includes river reaches 3-5) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 4 combined, 2005. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

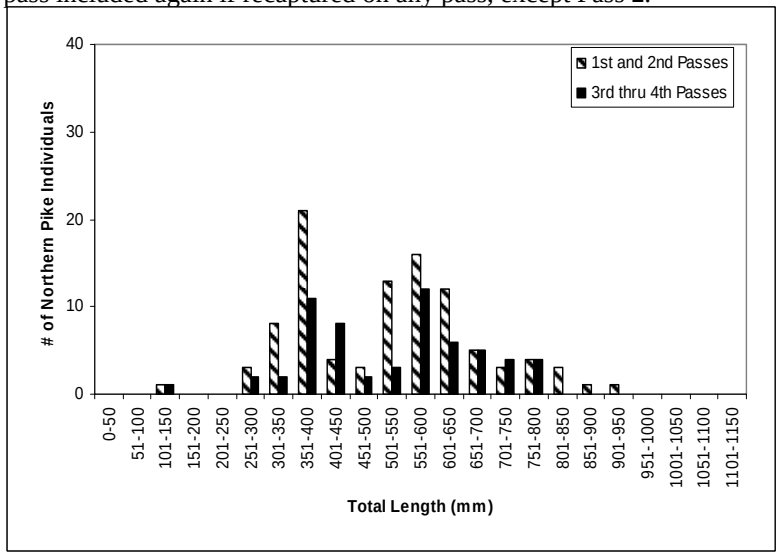

Figure 11c. Northern pike total length frequency for the Maybell section (includes river reaches 3-5) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 4 combined, 2006. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

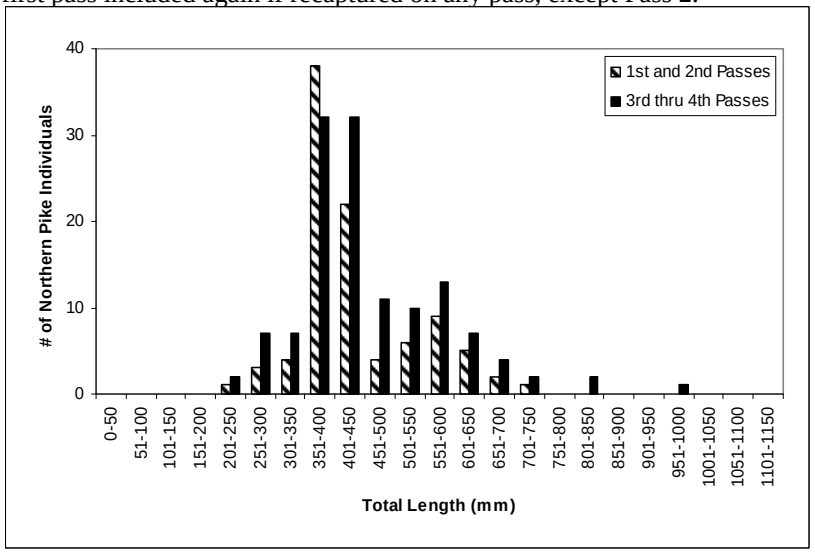

Figure 11d. Northern pike total length frequency for the Maybell section (includes river reaches 3-5) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 4 combined, 2007. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

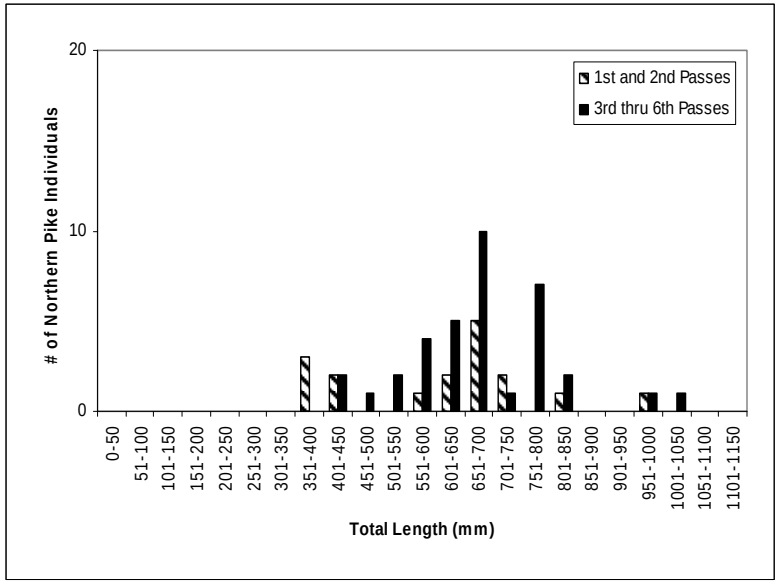

Figure 12a. Northern pike total length frequency for the Lily Park section (river reach CSU 3) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 6 combined, 2004. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

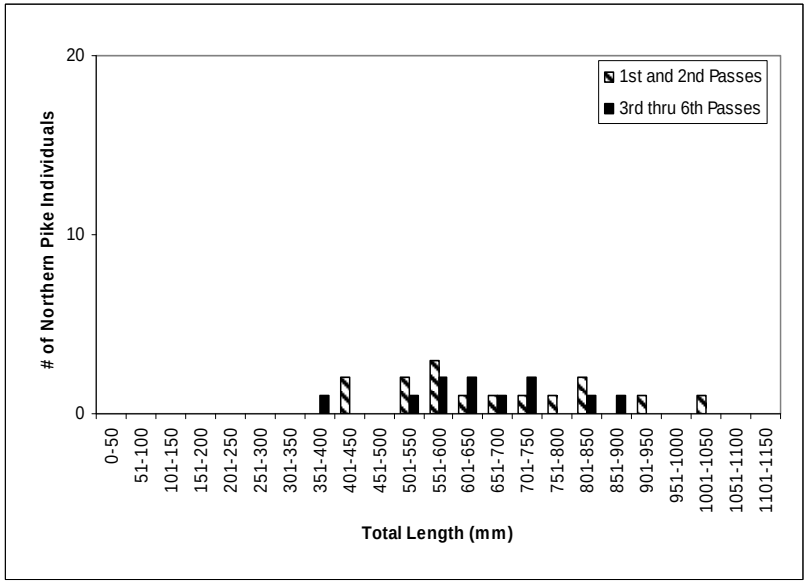

Figure 12b. Northern pike total length frequency for the Lily Park section (river reach CSU 3) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 6 combined, 2005. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

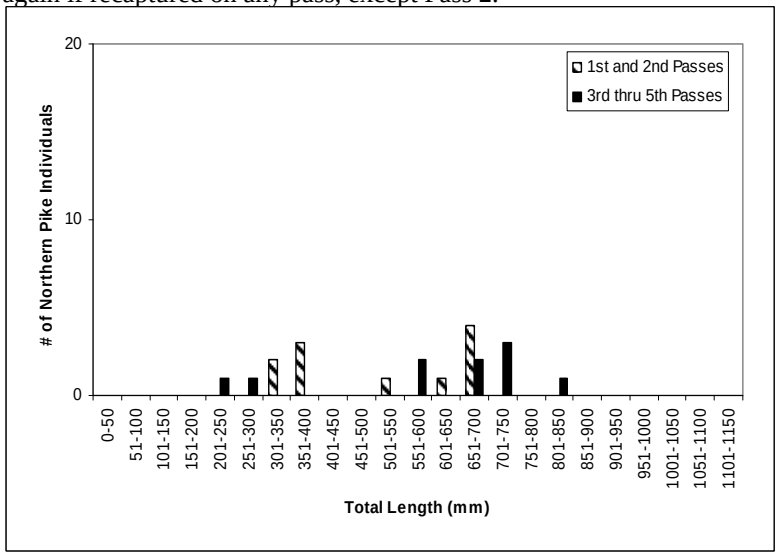

Figure 12c. Northern pike total length frequency for the Lily Park section (river reach CSU 3) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 5 combined, 2006. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

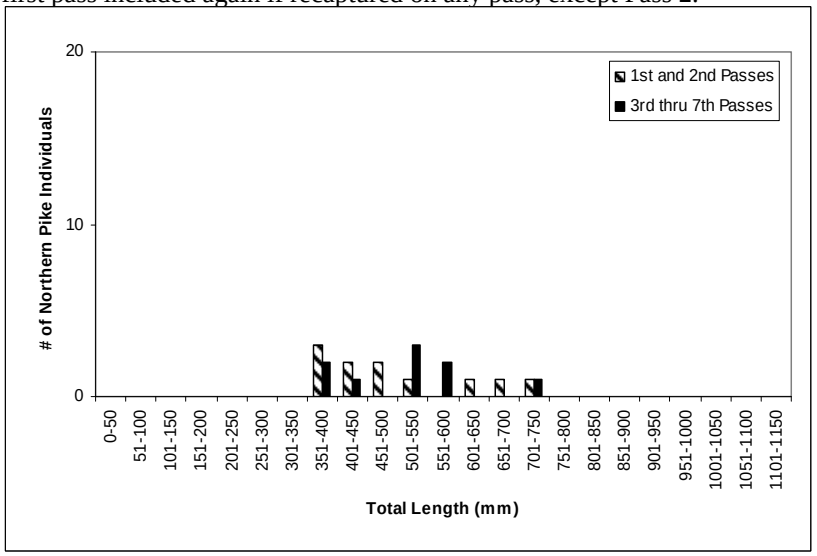

Figure 12d. Northern pike total length frequency for the Lily Park section (river reach CSU 3) of the middle Yampa River by Pass 1 and Pass 2 combined, and Pass 3 through Pass 7 combined, 2007. Recaptures from the first pass included again if recaptured on any pass, except Pass 2.

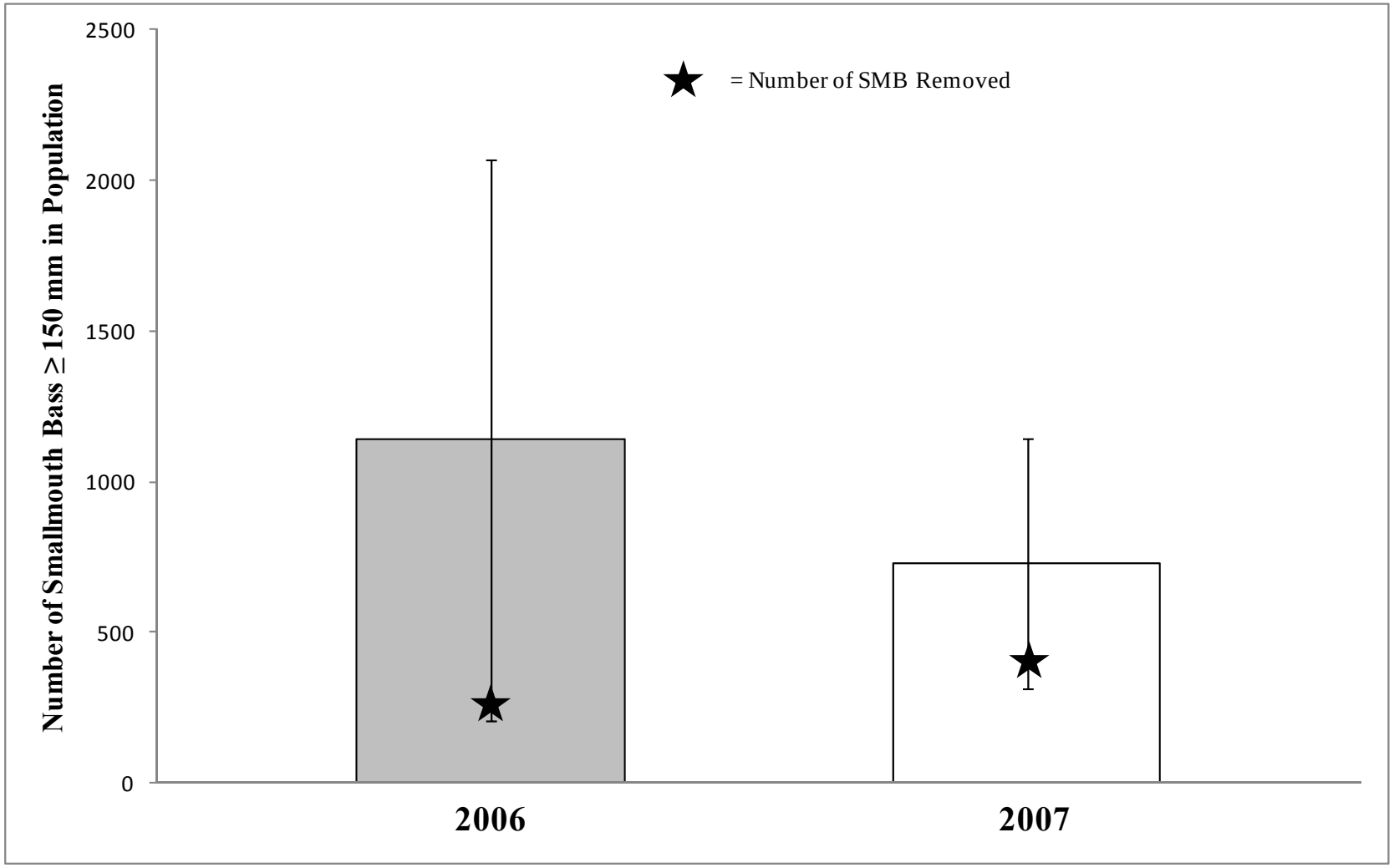

Figure 13. Lincoln-Petersen smallmouth bass population estimates for South Beach (Reach 1), including the associated 95% confidence intervals and a solid line indicating the number of fish removed for each respective year, in 2006 and 2007.

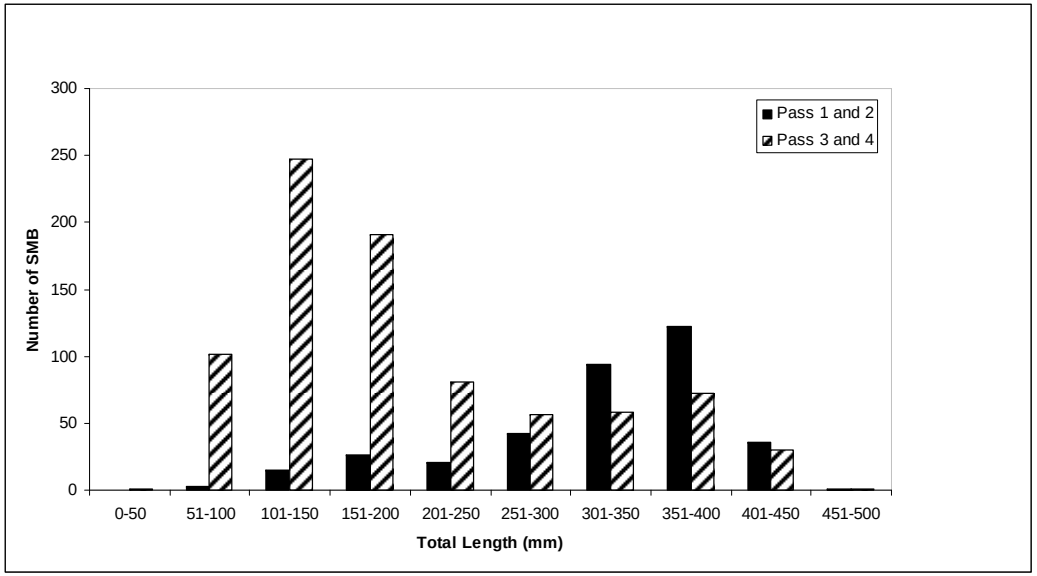

Figure 14a. Smallmouth bass total length (mm) frequency distribution during passes 1 and 2 combined and 3 and 4 combined across the study reach for the middle Yampa River, downstream of Craig, in 2006.

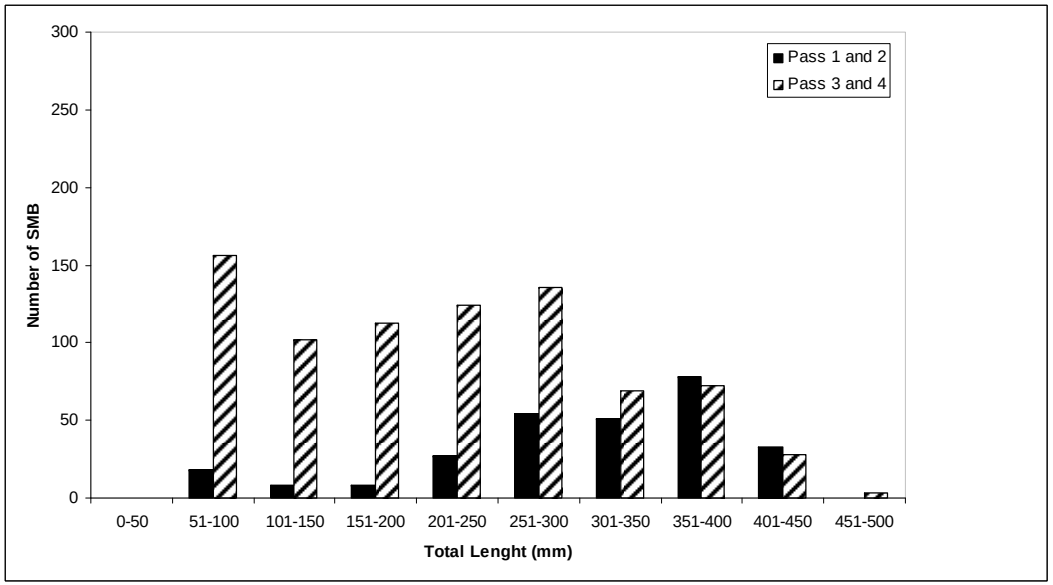

Figure 14b. Smallmouth bass total length (mm) frequency distribution during passes 1 and 2 combined and 3 and 4 combined across the entire study reach for the middle Yampa River, downstream of Craig, in 2007.

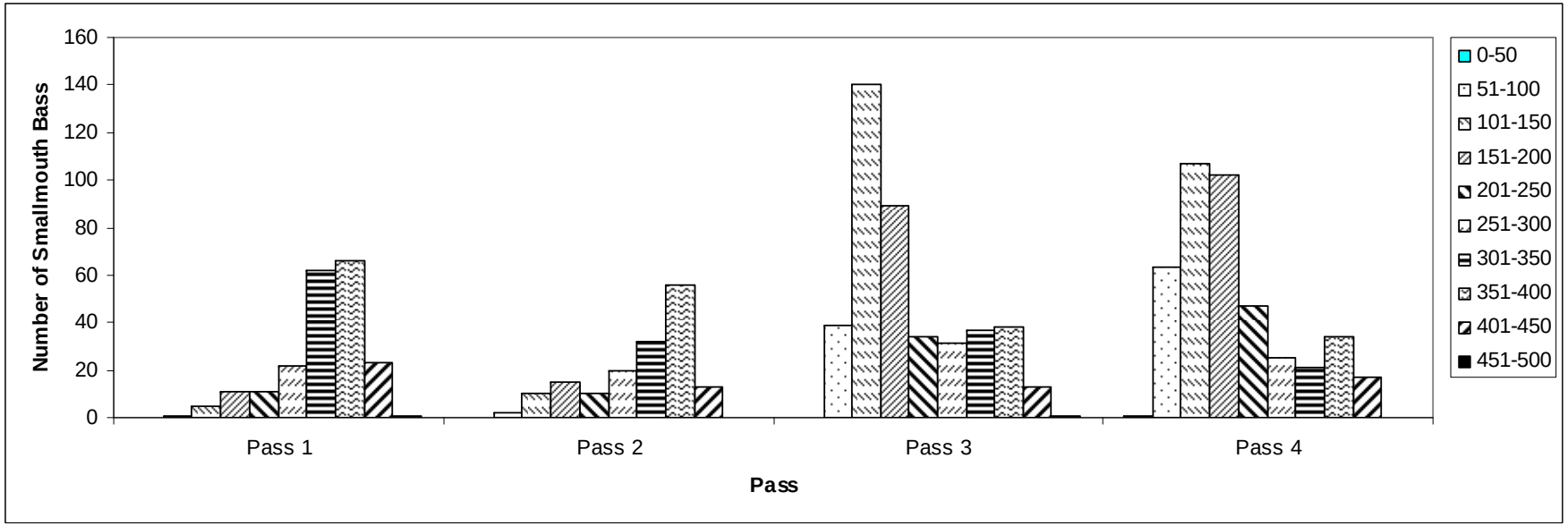

Figure 15a. Total length (mm) frequency distribution for smallmouth bass across 4 passes in the middle Yampa River, downstream of Craig, in 2006.

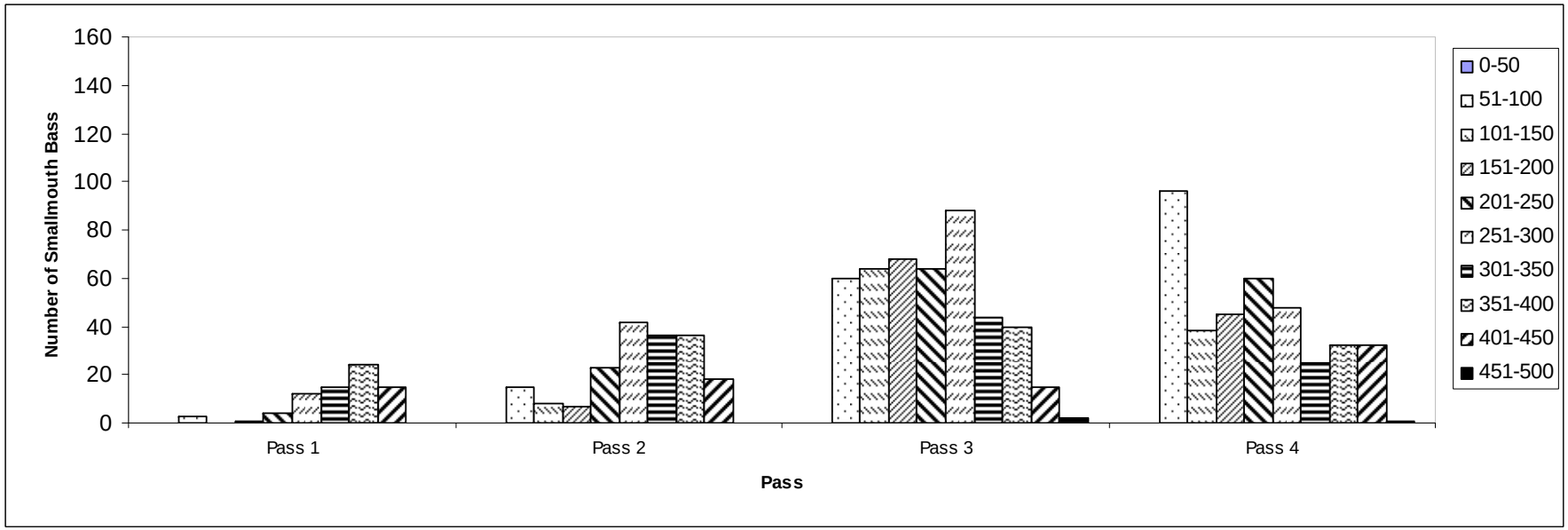

Figure 15b. Total length (mm) frequency distribution for smallmouth bass across 4 passes in the middle Yampa River, downstream of Craig, in 2007.

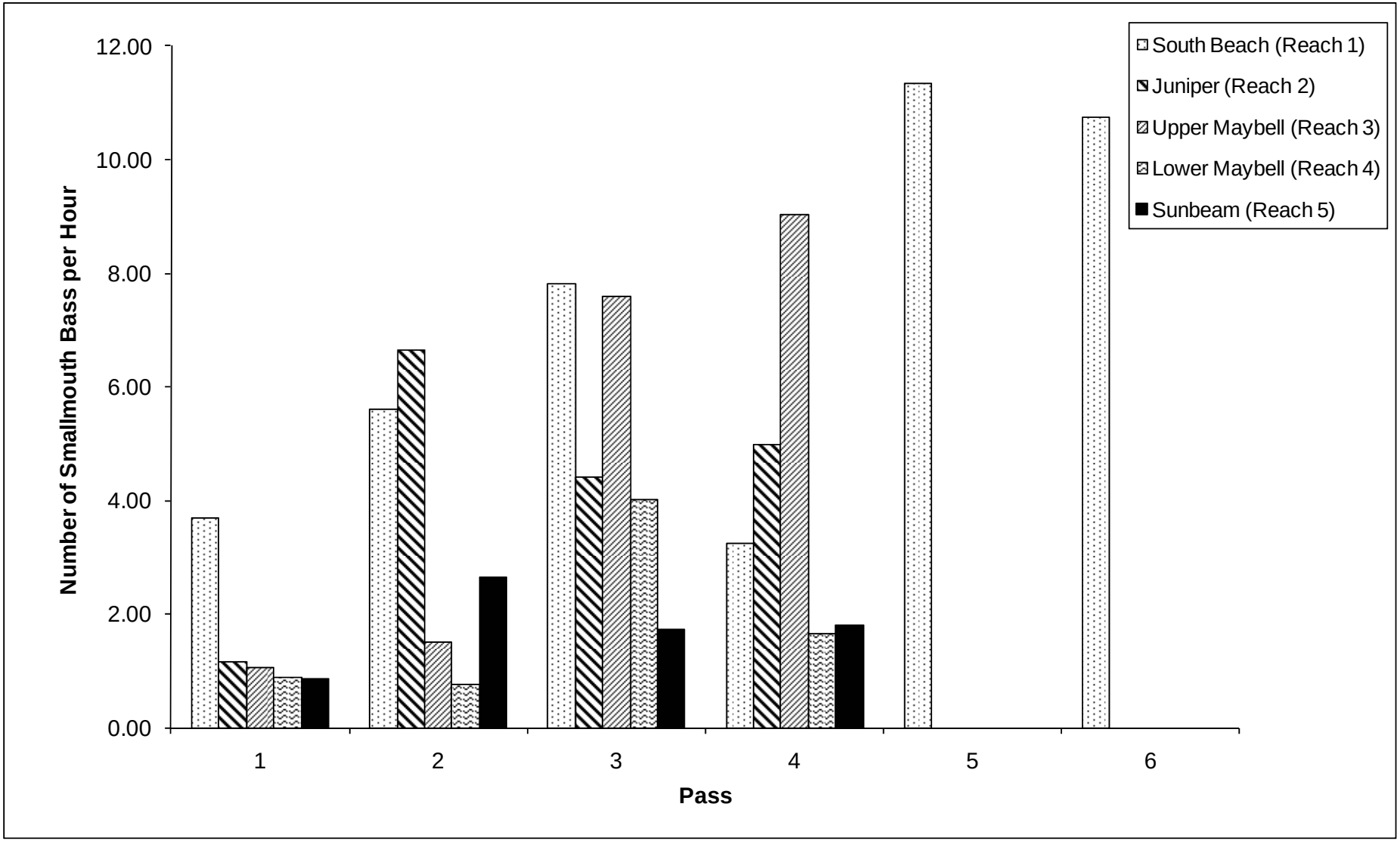

Figure 16. Catch Per Unit Effort (CPUE; number of smallmouth bass/hour) for each of 5 sample reaches across all passes conducted in the middle Yampa River downstream of Craig.

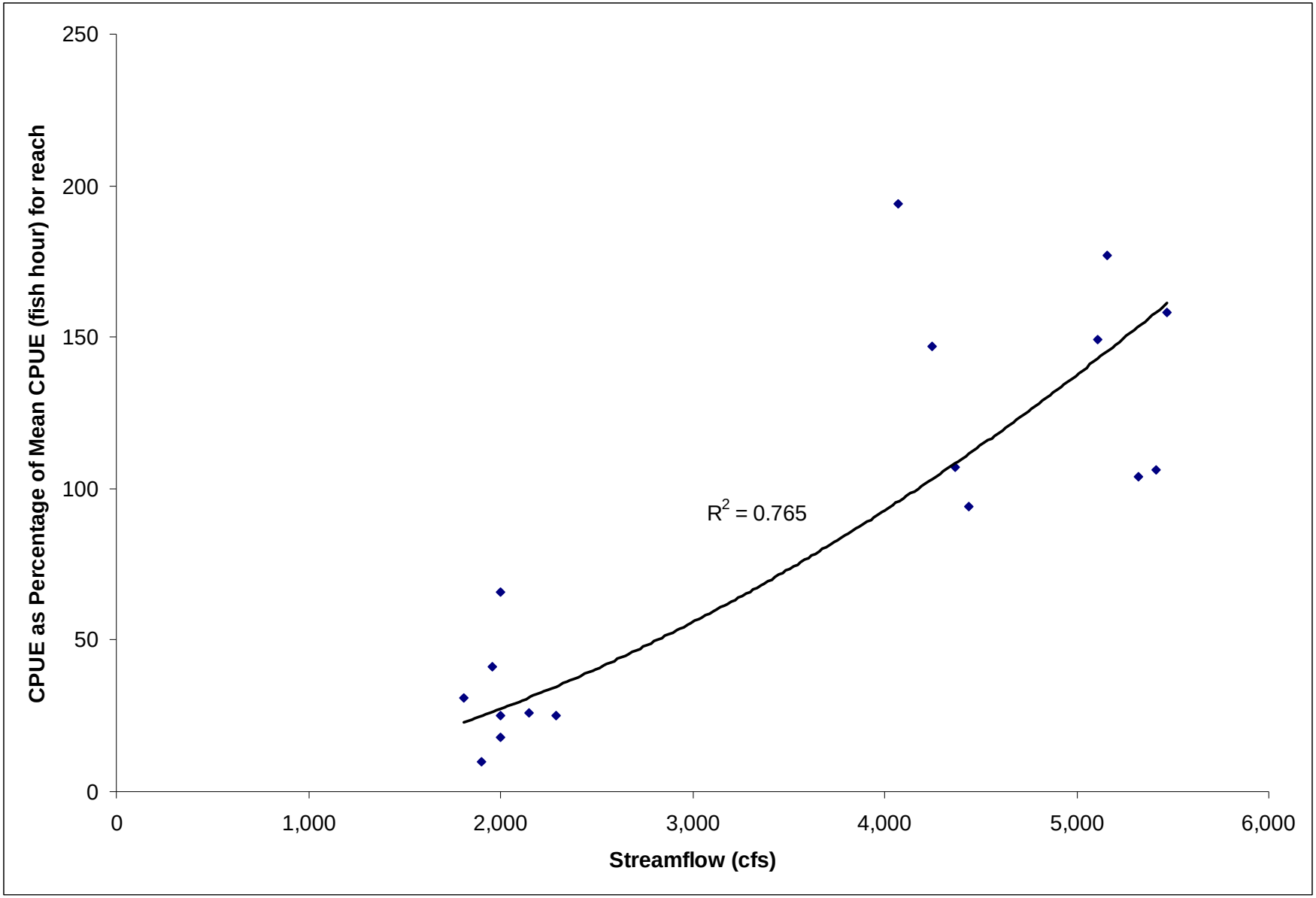

Figure 17. Catch Per Unit Effort (CPUE; number of smallmouth bass/hour) normalized as a percentage of mean CPUE for the respective reach, plotted against mean daily streamflow (Cubic Feet Per Second) for all passes that occurred on the ascending limb of the hydrograph. The data were fitted with a power curve (r^2=0.765).

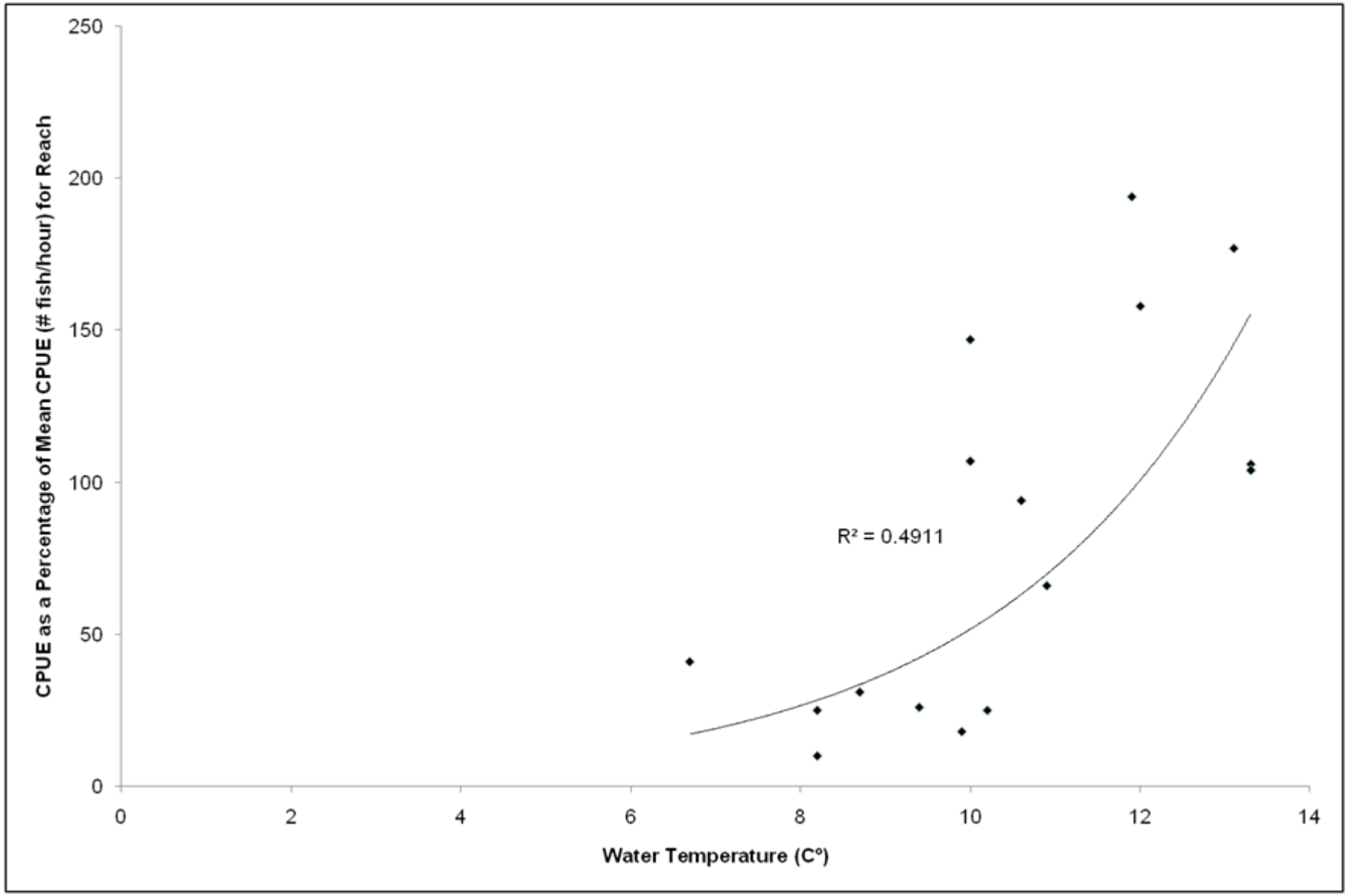

Figure 18. Catch Per Unit Effort (CPUE; number of smallmouth bass/hour) normalized as a percentage of mean CPUE for the respective reach, plotted against mean daily water temperature (Celsius) for all passes that occurred on the ascending limb of the hydrograph. The data best fit with an exponential curve (r^2=0.4911).

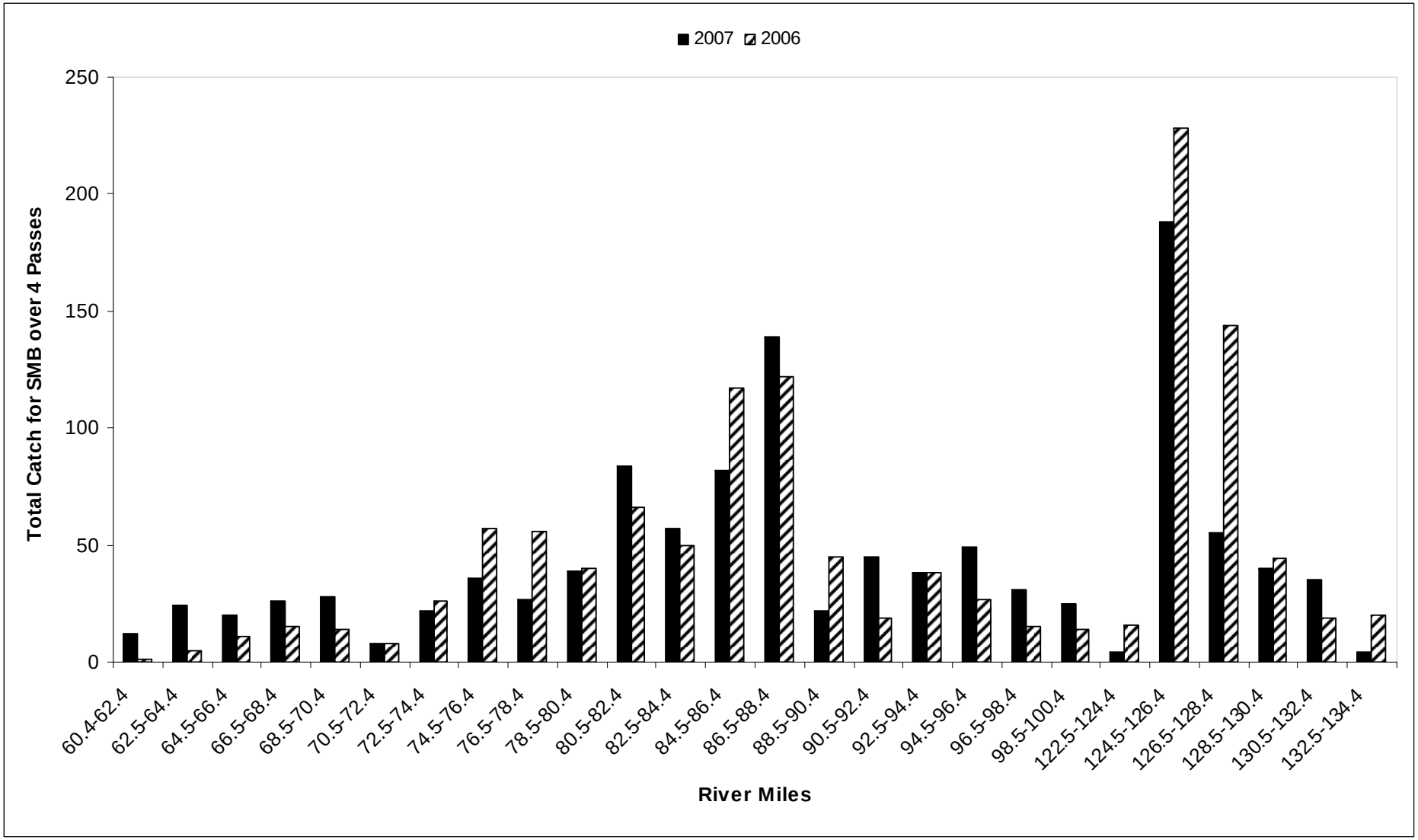

Figure 19. Linear distribution of smallmouth bass in 2007 and 2006 in the Yampa River form river mile 135 to 60, excluding river mile 124 to 100, which was covered by Hawkins (CSU).

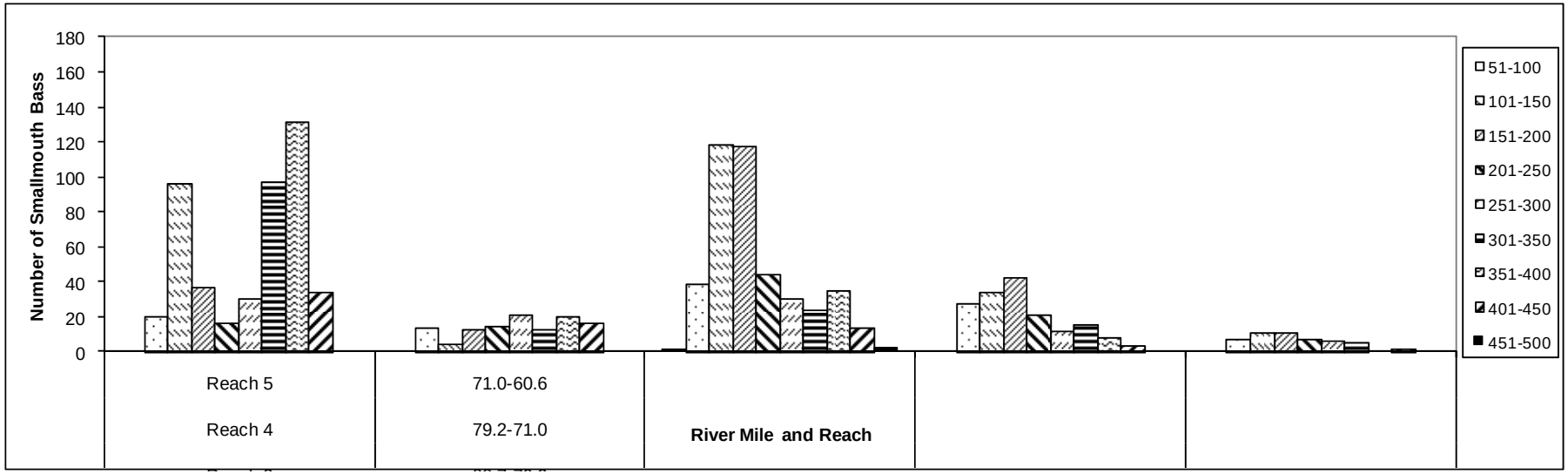

Figure 20a. Smallmouth bass total length (mm) frequency distribution for the five sampling reaches within in the middle Yampa River, downstream of Craig, in 2006. Length categories are in increments of 50 and range from 51 to 500 mm.

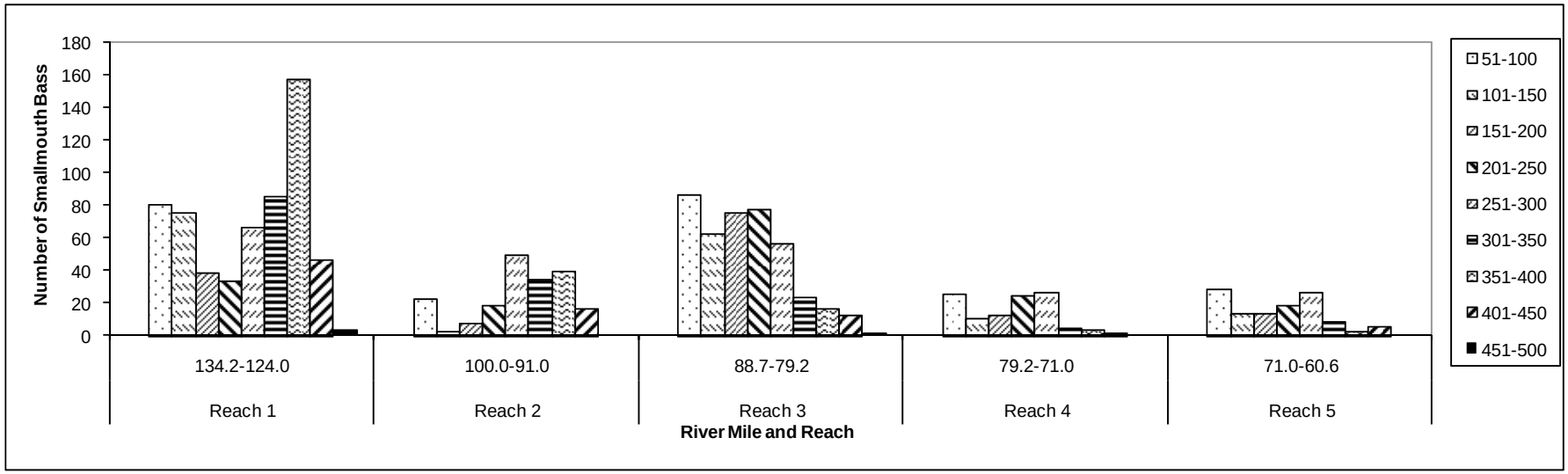

Figure 20b. Smallmouth bass total length (mm) frequency distribution for the five sampling reaches within the middle Yampa River, downstream of Craig, in 2007. Length categories are in increments of 50 mm and range from 51 to 500 mm.

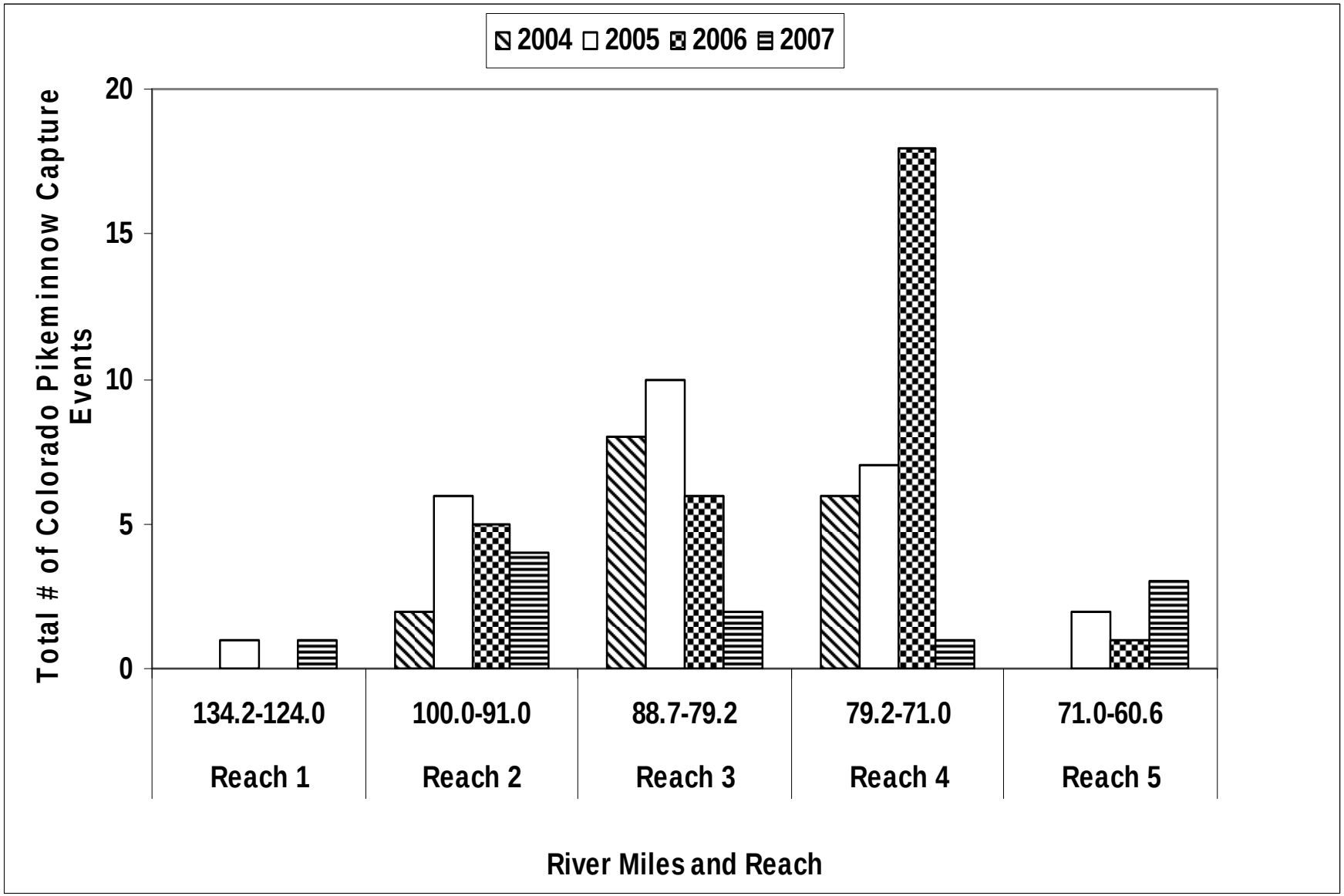

Figure 21. Colorado pikeminnow capture events by river mile and reach for the middle Yampa River, 2004-2007. Reach 1 and Reach 5 were not sampled in 2004.

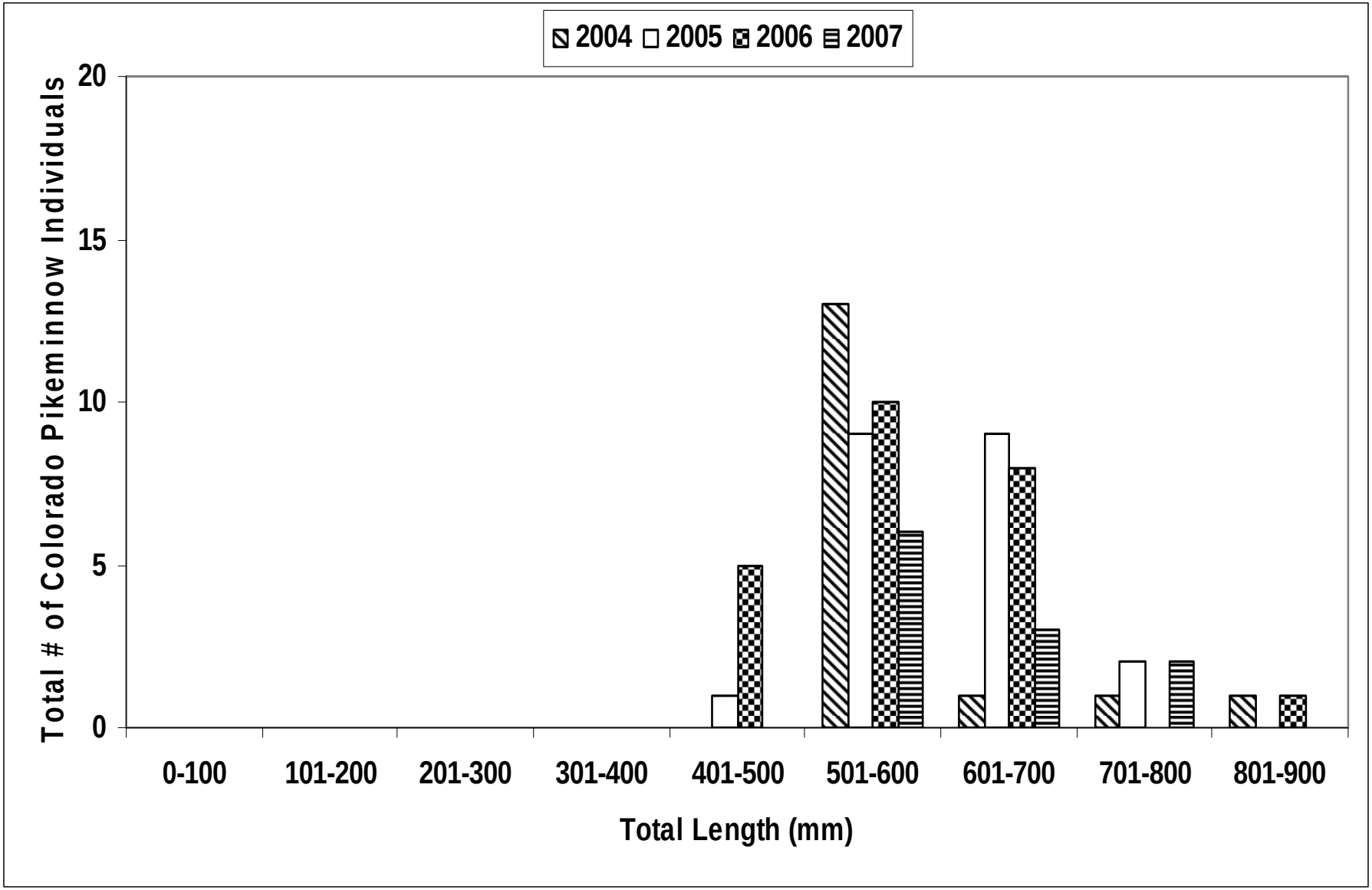

Figure 22. Colorado pikeminnow total length frequency for all individuals collected in the middle Yampa River, 2004-2007.

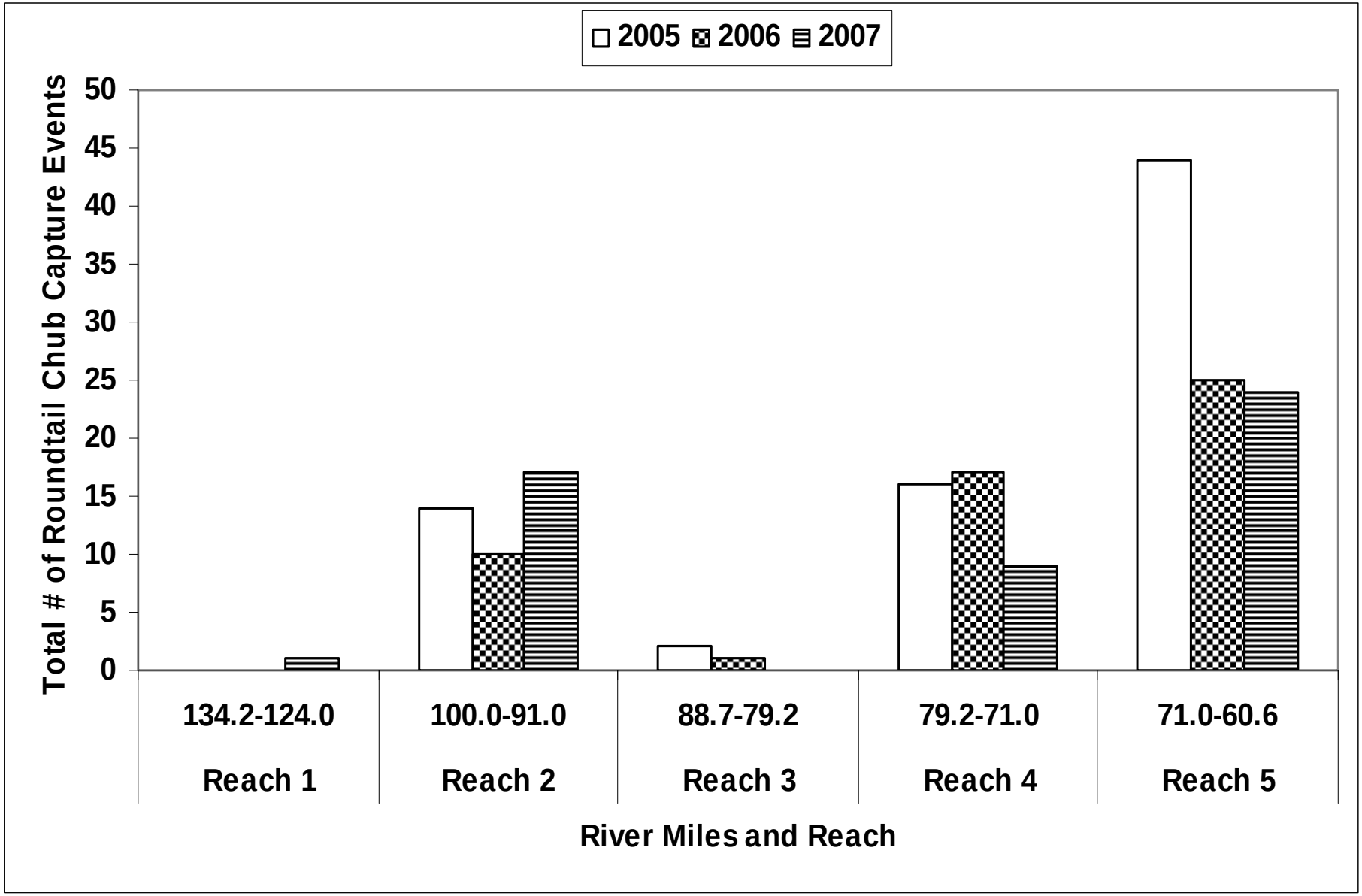

Figure 23. Roundtail chub capture events by river mile and reach for the middle Yampa River, 2005-2007.

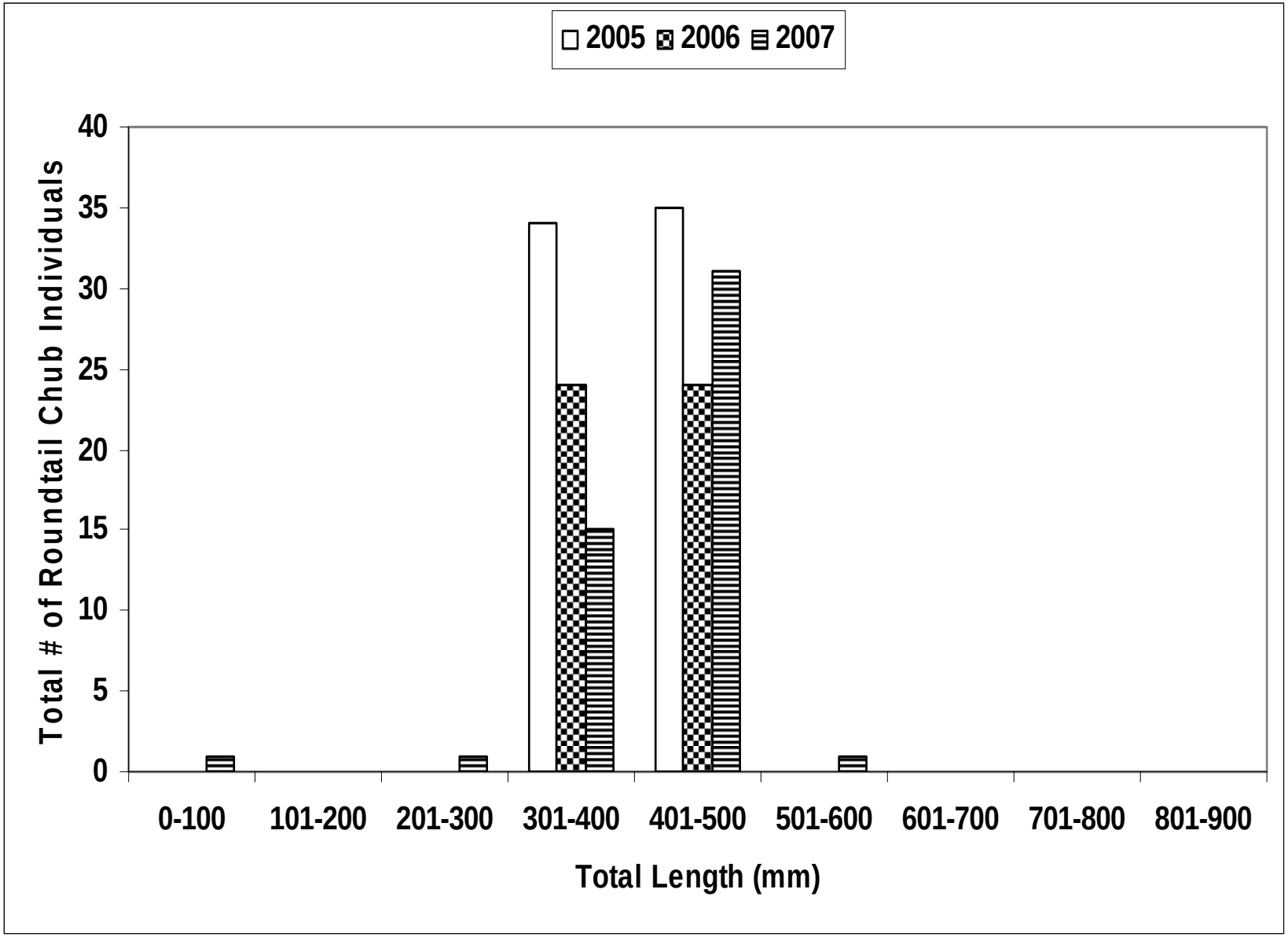

Figure 24. Roundtail chub total length frequency for all individuals collected in the middle Yampa River, 2005-2007.

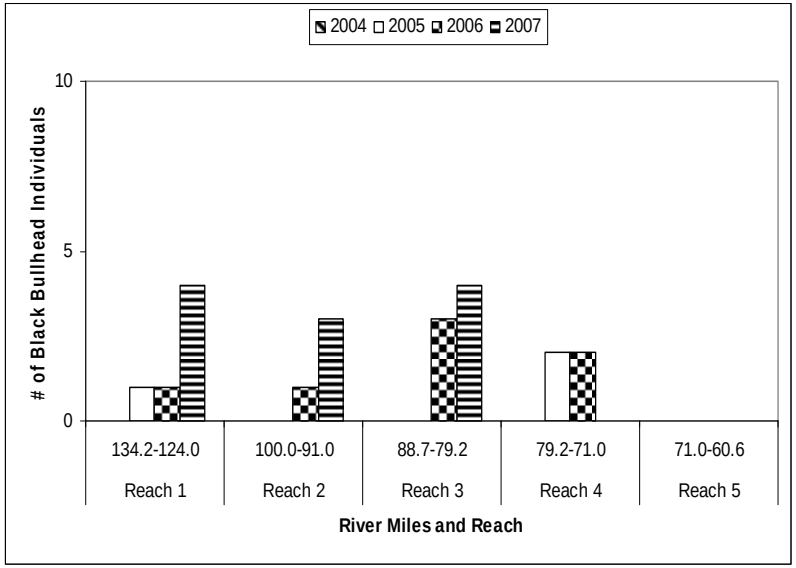

Figure 25a. Number of black bullhead individuals collected by river mile and reach for the middle Yampa River, 2004-2007.

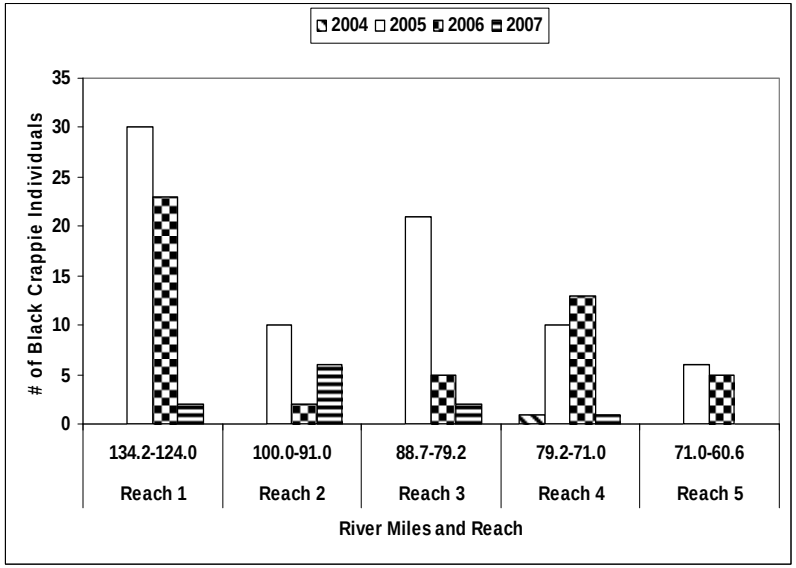

Figure 25b. Number of black crappie individuals collected by river mile and reach for the middle Yampa River, 2004-2007.

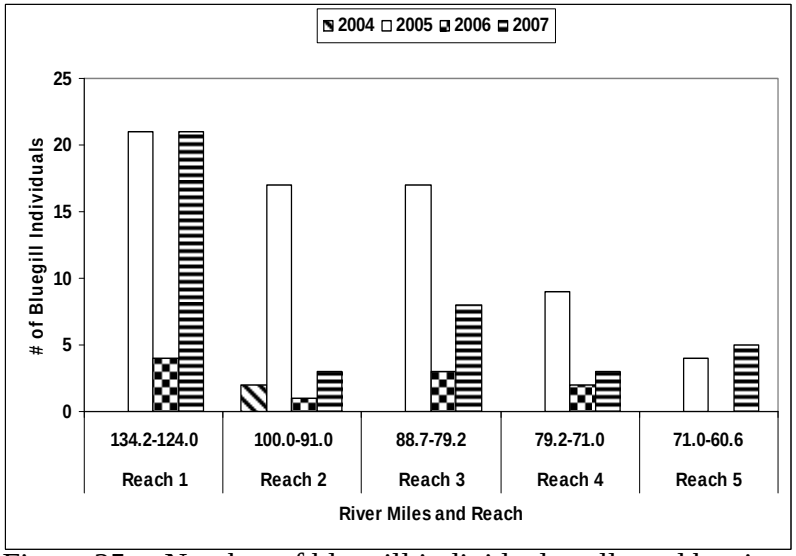

Figure 25c. Number of bluegill individuals collected by river mile and reach for the middle Yampa River, 2004-2007.

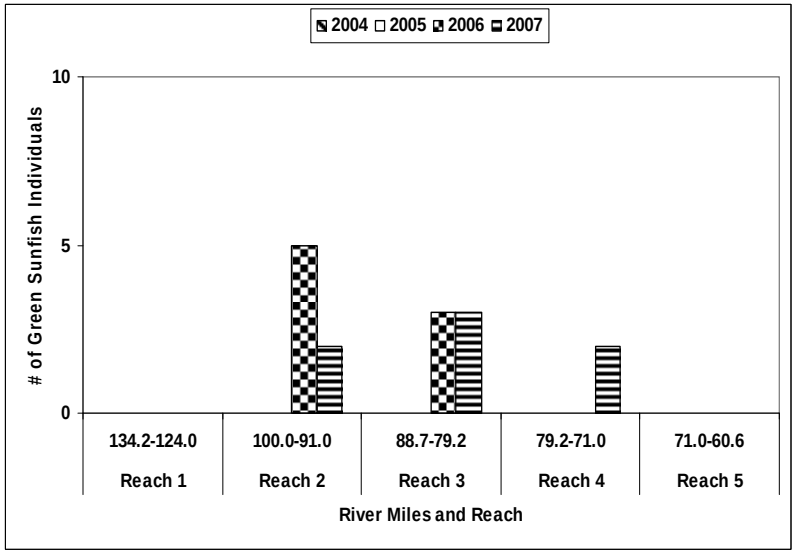

Figure 25d. Number of green sunfish individuals collected by river mile and reach for the middle Yampa River, 2004-2007.

Appendix A: Colorado State University and Colorado Division of Wildlife Goals and Objectives for Northern Pike and Smallmouth Bass, 2004-2007

Please refer to Table 1 for information regarding river reaches, river sections, reach descriptions, and river miles sampled by year and agency. Please refer to Table 2 for actions taken for northern pike and smallmouth bass from 2004 through 2007.

2004

Colorado State University (CSU) was the lead agency for removal of northern pike and smallmouth bass from critical habitat of the middle Yampa River, and evaluation of such removal efforts. The Colorado Division of Wildlife (CDOW) complimented the efforts of CSU by assisting in removal and translocation of northern pike and smallmouth bass from specific river reaches. All 2004 northern pike and smallmouth bass data and information provided are excerpted from Hawkins 2004.

CSU Goal and Objectives for Northern Pike:

The goal of CSU was to remove as many northern pike as possible from critical habitat, and estimate the fraction of the population removed.

The objectives for northern pike included the following: 1) to obtain an estimate of the number of northern pike that reside in the 95-mile study reach in the Yampa River using a mark-recapture abundance estimator, 2) to remove a large portion of the estimated population of northern pike from the study reach during five removal passes, and 3) to calculate the proportion of northern pike removed based on the initial population size.

CSU Goal and Objectives for Smallmouth Bass:

The goal of CSU was to remove as many smallmouth bass as possible from a 12-mile treatment reach and a 5-mile concentration reach, and estimate the fraction of the population removed from each reach.

The objectives for smallmouth bass included the following: 1) to obtain an estimate of the number of smallmouth bass in the 12-mile control and 12-mile treatment reaches in Little Yampa Canyon and the 5-mile reach in Lily Park using a mark recapture abundance estimator, 2) to remove a large portion of the estimated population of smallmouth bass from the 12-mile treatment reach in Little Yampa Canyon and the 5-mile concentration area in Lily Park, 3) and to calculate the proportion of smallmouth bass removed from each study area based on initial population size, and comparison of capture rates between control and treatment reaches, 4) and to evaluate the movement of tagged smallmouth bass from the control reach to ensure that immigration or emigration does not confound comparisons between control and treatment sites.

2005

The CDOW became the lead agency for removal of northern pike from critical habitat of the middle Yampa River, and evaluation of such removal efforts. CSU complimented the efforts of CDOW by assisting in marking, removal, and translocation of northern pike from Little Yampa Canyon and Lily Park river reaches. Conversely, CSU continued as the lead agency for removal of smallmouth bass from critical habitat of the middle Yampa River, and evaluation of such efforts. CDOW supplemented the efforts of CSU by recording applicable data related to smallmouth bass from specific river reaches.

CDOW Goals and Objectives for Northern Pike:

The two goals of the CDOW for northern pike were to: 1) reduce the number of northern pike occupying 54 river miles (RM) of critical habitat within the Yampa River downstream of Craig (RM 139 – RM 59), and 2) transport live northern pike collected from the study reach for release in Loudy Simpson ponds (Craig) and Rio Blanco Lake (White River Basin, near Meeker, Colorado), to increase angler opportunities to harvest northern pike.

The objectives for northern pike included the following: 1) removal and translocation of as many northern pike as possible within the study area via three or more removal passes, 2) estimation of the number of northern pike occupying the study area by generating a population estimate for northern pike utilizing a mark-recapture methodology, and 3) calculation of the proportion of the estimated northern pike population that was removed.

CSU Goal and Objectives for Northern Pike:

The 2005 goal and objectives of CSU for northern pike were the same goal and objectives as in 2004.

CSU Goal and Objectives for Smallmouth Bass:

The 2005 goal of CSU for smallmouth bass was the same goal in 2004.

All 2004 objectives were included in the 2005 objectives, with an additional objective included. This objective was to remove large numbers of age-0 and age-1 smallmouth bass from the 12-mile treatment reach in Little Yampa Canyon.

2006 and 2007

The CDOW continued as the lead agency for removal of northern pike from the middle Yampa River, and evaluation of such efforts. CSU continued complimenting the efforts of CDOW by assisting in marking, removal, and translocation of northern pike from Little Yampa Canyon and Lily Park river reaches. CSU also continued as the lead agency for removal of smallmouth bass from the middle Yampa River, and evaluation of such efforts. Conversely, CDOW complimented the efforts of CSU by recording applicable data related to smallmouth bass from specific river reaches. In 2006, CDOW also began removal of smallmouth bass in one, 10.2 mile section of river (South Beach

reach). The CDOW continued removal of smallmouth bass in the South Beach reach.

CDOW Goals and Objectives for Northern Pike:
The 2006 and 2007 goals and objectives of the CDOW for northern pike were the same goals and objectives as in 2005.

CDOW Goals and Objectives for Smallmouth Bass:
The two goals of the CDOW for smallmouth bass in 2006 and 2007 were to: 1) reduce the number of smallmouth bass occupying 10.2 river miles of critical habitat (South Beach reach) within the middle Yampa River downstream of Craig, Colorado (RM 134.2-RM 124.0), thereby benefiting native fishes of the Yampa River Basin, as well as native fish communities downstream within the Green River Basin; and to 2) transport live smallmouth bass (> 10" in total length) collected from the study reach for release in the Craig Justice Center pond, thereby increasing angler opportunities to harvest smallmouth bass.

The objectives for smallmouth bass included the following: 1) to remove and translocate as many smallmouth bass as possible within the South Beach reach via three or more (maximum of seven) removal passes, 2) to estimate the number of smallmouth bass occupying the South Beach reach by generating a population estimate for smallmouth bass utilizing a mark-recapture methodology (1 marking pass, minimum of three removal passes), and 3) to calculate the proportion of the estimated smallmouth bass population that was removed.

CSU Goals and Objectives for Northern Pike:
The 2006 and 2007 goal and objectives of CSU for northern pike were the same goal and objectives as in 2004 and 2005.

CSU Goal and Objectives for Smallmouth Bass:
The 2006 and 2007 goal of CSU was to remove as many smallmouth bass as possible from a 24-mile treatment reach and a 5-mile concentration reach, and estimate the proportion of the population removed from each reach.

The objectives for smallmouth bass in 2006 and 2007 included the following: 1) to obtain an estimate of the number of smallmouth bass in the 24-mile treatment reach in Little Yampa Canyon and the 5-mile reach in Lily Park using a mark recapture abundance estimator, 2) to remove a large portion of the estimated population of smallmouth bass from the 24-mile treatment reach in Little Yampa Canyon and the 5-mile concentration area in Lily Park, 3) to remove large numbers of age-0 and age-1 smallmouth bass from the 12-mile treatment reach in Little Yampa Canyon, 4) to calculate the proportion of smallmouth bass removed from each study area based on initial population size, and comparison of capture rates between control and treatment reaches, and 5) to understand movement of recaptured smallmouth bass tagged in previous years or during the first (tagging) pass each year.

Appendix B: Field Methods/Approach, Results/Discussion, and Literature Cited for the Colorado Division of Wildlife's 2006 Early Fyke Net and Pheromone Experimental Study

Methods/Approach-Early Fyke Net and Pheromone Experimental Study

In 2006, an experimental study was planned to utilize hoop and fyke net sets, as well as use of pheromones to attract northern pike. Fyke nets and white suckers were utilized in this experiment. The white sucker was selected as the "bait" species of choice due to the availability of the fish, and the species' known emission of pheromones (Chivers and Smith 1995; Mathis et al. 1995; Chivers et al. 1996; Chivers et al. 1999). The use of sexually mature northern pike that were ripe would have been preferred as "bait." However, not enough of these individuals were collected for use in each of the five fyke nets utilized.

Fyke nets were set for a 24 hour time period in three backwaters, Spring Creek (RM 81.6), Sand Creek (RM 72.9), and Overholt Draw (RM 76.1) from April 18 through April 21, 2006. A control (pheromone absent) and treatment (pheromone present) approach using white suckers was followed. A 1" aperture gill net was set at the mouth of each backwater, followed by electrofishing with "scare-and-snare," and "block-and-shock" techniques. The gill net was removed once electrofishing within the backwater was completed, and the fyke net(s) had been set successfully. Two, non-baited fyke nets (one large and one small) were each set in Spring and Sand Creeks, while one large fyke net was set in Overholt Draw on each of three consecutive days. The sample process was replicated 24 hours following the initial sample. On day two, fyke nets were reset with two, live white suckers in one chum bag attached to the internal throat within each fyke net. The lateral line of all white suckers was scraped to generate pheromone emission. On day three, fyke nets were reset with the same white suckers used in day two. However, the white suckers were euthanized prior to placement in the chum bags. The fyke nets were removed on day four when the project was completed.

All fish captured in gill nets, via electrofishing, and in fyke nets were identified to species, measured in total length to the nearest millimeter (mm), weighed to the nearest gram (g), and analyzed with Pass 1 data. Northern pike collected were examined for the presence of FLOY tags and fin clips. Colorado pikeminnow and roundtail chub captured were scanned to determine the presence of passive integrated responder (PIT) tags. Individuals without PIT tags were implanted with a new, 134.2 kilohertz (kH) tag following the appropriate protocol. Tags for Colorado pikeminnow were provided by the USFWS. All Colorado pikeminnow and roundtail chub captured were released back to the river immediately. All northern pike captured (a minimum of 200 mm in total length) were marked in the dorsal fin region with individually numbered CDOW 2004, yellow, t-bar FLOY tags, and released near the area of capture. Five smaller (< 400 mm in total length) northern pike were removed, euthanized, and provided to the CDOW Aquatic Research Section.

A high water discharge, backwater fyke net study was conducted May 23 through May 25, 2006. The objective of this study was to exploit northern pike in backwater areas during runoff. One fyke net was set in each of the three backwaters investigated during the CDOW's Early Fyke Net study. These backwaters included Spring Creek (RM 81.6), Sand Creek (RM 72.9), and Overholt Draw (RM 76.1). A 1" aperture gill net was set at the mouth of each backwater, followed by electrofishing with "scare-and-snare," and "block-and-shock" techniques. The gill net was removed once electrofishing within the backwater was completed, and the fyke net(s) had been set successfully. Nets were set for 19 hours across the first study period. The sample process was replicated in each backwater following the initial sample, and nets were set across 24 hours for the second study period. All fish were handled as described below, and analyzed with data from Pass 3.

Results and Discussion-Early Fyke Net and Pheromone Experimental Study

Forty two (42) northern pike capture events occurred during the experimental fyke net and pheromone study. Twenty three (23) northern pike were captured by electrofishing, utilizing "block-and-shock" and "scare-and-snare" tactics. Nineteen (19) northern pike were collected in fyke nets. Three (3) Colorado pikeminnow were collected in fyke nets, while one (1) roundtail chub was collected by electrofishing. Northern pike did not appear to prefer or select one backwater over another throughout the experimental fyke net study. Data from the experimental fyke net and pheromone study are included within various tables and graphs included in a 2006 DRAFT CDOW report, not released to date (Figures 1-6, 12-15; Tables 1, 3-8, 15-16).

Electrofishing total catch per unit effort during the experimental study was 7.95 northern pike/hour. Fyke net total catch per unit effort across the study was 0.060 northern pike/hour. Electrofishing and fyke net total effort combined decreased from day to day (Figure 2). This decrease was a significant reduction in catch per unit effort (R^2=0.99, p=0.003). Passive fyke net sets were efficient, as nets were set for extended periods (overnight) while other activities could be completed.

Eighteen (18) northern pike were captured once during the four day effort, while two northern pike were captured three times, and nine northern pike were collected on two occasions. All northern pike recaptures were collected in the same backwater as the first capture location, except one fish.

"Baiting" of fyke nets with white suckers did not appear to increase catch of northern pike. However, use of ripe male or female northern pike may prove more successful in attracting other northern pike adults, provided enough of these individuals can be collected when needed.

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