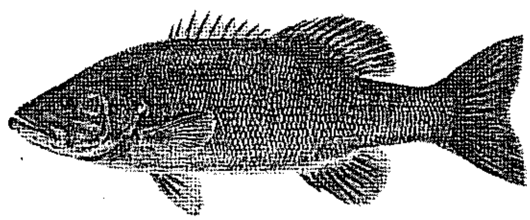
U.S. Fish & Wildlife Service

REMOVAL OF SMALLMOUTH BASS AND FOUR OTHER CENTRARCHID FISHES FROM THE UPPER COLORADO AND LOWER GUNNISON RIVERS: 2004–2006



January 2008

Removal of Smallmouth Bass and Four Other Centrarchid Fishes from the Upper Colorado and Lower Gunnison Rivers: 2004–2006

Recovery Program Project Number 126

FINAL REPORT

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The opinions and interpretation of the data expressed in this report are those of the author and do not necessarily reflect the views of the Fish and Wildlife Service or the Recovery Program.

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Throughout this report, a combination of English and metric measurements are used according to their predominant usage for specific data categories and what are meaningful to many readers. English equivalents are used to identify distances within and along river drainages (river miles). Metric units are most commonly used for biological work associated with endangered and nonnative fishes and they were retained for this report.

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EXECUTIVE SUMMARY

The purpose of this study was to remove as many smallmouth bass of all sizes in main channel riverine habitats in a 105-mile reach of the Upper Colorado River between Rifle and Beavertail Mountain and between Price-Stubb Dam and Westwater boat landing in eastern Utah and a 2.3- mile reach of the Lower Gunnison River. The goal was to reduce the abundance of smallmouth bass as quickly as possible in these river reaches which would ultimately benefit native fishes, and possibly contribute to their recovery. Specific objectives were to:

1. remove all smallmouth bass collected with boat and raft-based electrofishing, and
2. obtain an abundance estimate for smallmouth bass (≥ 100 mm) during 2006 by mark and recapture methods for the Upper Colorado River between Price Stubb Dam and Fruita State Park and 2.3 miles of the Lower Gunnison River between Redlands Diversion Dam and the Colorado/Gunnison River confluence.

The two objectives were achieved during the 3-year study which was initiated in 2004. Additionally, while smallmouth bass were the target fish species of concern, four other centrarchid fishes were also collected and removed from main channel habitats during this study to fulfill objectives associated with other fish research projects in Colorado.

Smallmouth bass abundance was greatest during the summer of 2005 and lowest during 2006. Total number of fish collected with boat and raft-based electrofishing by species during the 2006 smallmouth bass removal from Price Stubb Dam to the Westwater, Utah, Ranger Station and the Lower Gunnison River was, smallmouth bass: 751; largemouth bass: 1,094; black crappie: 70; green sunfish: 1,395; bluegill: 307. Numbers of smallmouth bass collected in 2006 declined by 45% from 2005 and 36% from 2004 in the Grand Valley river reaches and declined 66% from Rifle to Beavertail Mountain from 2005 to 2006. The four highest concentration river sub-reaches for smallmouth bass after three years in descending order in the Upper Colorado and Lower Gunnison rivers were, a) Corn Lake to the Colorado/Gunnison River confluence, b) Colorado/Gunnison River confluence to Fruita State Park, c) Grand Valley Irrigation Company Dam to Corn Lake, and d) Redlands Dam to the Colorado/Gunnison River confluence in the Lower Gunnison River.

Despite both bass species being lethally removed, largemouth bass numbers continued to increase in main channel habitats and were highest in 2006. Largemouth bass numbers in 2006 increased 86% from 2005 and 295% from 2004 in the Grand Valley sub-reaches. From Rifle to Beavertail Mountain, largemouth bass numbers in 2006 increased 455% from 2005 and 225% from 2004.

Green sunfish and black crappie abundance increased in main channel habitats in the Grand Valley sub-reaches of the Upper Colorado and Lower Gunnison rivers from 2004 to 2006. Green sunfish numbers in 2006 increased 33% in the Grand Valley sub-reaches over 2005 but declined 19% between Rifle and Beavertail Mountain; black crappie numbers increased 71% in the Grand Valley reaches. In 2006, bluegill numbers declined in both the Grand Valley sub-reaches (3%) and Rifle to Beavertail Mountain sub-reaches (70%) from 2005.

A decline was detected in abundance of smallmouth bass in 2006 from the previous two years using catch effort indices (fish/hr and fish/mile) in main channel habitats of the Colorado River in western Colorado and eastern Utah and the Lower Gunnison River. Catch/effort mimicked the same pattern as actual numbers of fish collected. In the Grand Valley sub-reaches, mean total catch effort for smallmouth bass declined in 2006 (4.64 fish/hr) from 2005 (7.83 fish/hr) and 2004 (6.91 fish/hr). However, largemouth bass catch rate was the highest in 2006 (6.76 fish/hr) compared to 3.37 fish/hr in 2005 and 1.64 fish/hr in 2004. Green sunfish/black crappie/bluegill aggregate catch rate was the highest during 2006 (10.94 fish/hr) compared to 8.07 fish/hr (2005) and 4.51 fish/hr (2004). Between Rifle and Beavertail Mountain, smallmouth bass catch rate in 2006 (2.10 fish/hr) declined from 2005 (5.78 fish/hr); largemouth bass catch rate increased in 2006 (5.62 fish/hr) from 2005 (0.95 fish/hr) and 2004 (3.29 fish/hr).

A statistically significant increase (α=.05) in mean total length of smallmouth bass was detected in 3 of 5 river segments in 2006 which may be due in part to the lack or absence of fish between 100 and 180 mm in the Grand Valley and between 100 and 200 mm in the Rifle to Beavertail Mountain reach. The hypothesis that the reduced survival and loss of recruitment of the 2005 cohort of smallmouth bass could not be related to mechanical removal or to environmental factors within the range observed in this study. There is still insufficient evidence to support the notion that overwinter survival of a cohort of young-of-the-year smallmouth bass may be size dependent. In other words, have fish attained a size large enough (e. g., 75 mm) by the fall of that year or have they had a long enough growing season to accumulate adequate lipid reserves to survive the winter period and avoid death due to starvation. The little data collected and analyzed to date are, at best, suggestive that some environmental event or physiological factor played a role in the demise of the age-0 smallmouth bass produced in 2005.

A high percentage (85% between Rifle and Beavertail Mountain; 90% between Price-Stubb Dam and Westwater, Utah) of all largemouth bass captured in both major portions of the Upper Colorado and Lower Gunnison rivers were comprised of fish less than 150 mm total length. From Rifle to Beavertail Mountain, of the total 314 largemouth bass collected in this 45-mile reach, only 8% (25 fish) were greater than 254 mm in 2004, 2005, and 2006. Twelve largemouth bass were ≥ 305 mm. Sixty percent of all largemouth bass were < 100 mm and 92% were < 254 mm. Sixty-four percent (16 of 25) of all largemouth bass ≥254 mm total length in 2004, 2005, and 2006 were caught at river mile (RM) 236.6, a large backwater located on the south side of the Upper Colorado.

Between Price-Stubb Dam and Westwater, Utah, and the 2.3 miles of the Lower Gunnison River during 2004, 2005, and 2006, a total of 2,033 largemouth bass were captured. Of this number, only 3% (59 fish) were ≥254 mm. Thirty-six largemouth bass were ≥305 mm. Sixty-two percent of all largemouth bass were < 100 mm and 92% were < 254 mm. Thirty-seven of the 59 (63%) largemouth bass ≥ 254 mm collected during 2004, 2005, and 2006 were caught between Corn Lake (RM 177.4) and Redlands Parkway (RM 166.8) and between Fruita State Park (RM 157.2) and the Loma Boat Landing (RM 152.6). Skipper's Island backwater (RM 154.0) consistently had high densities of largemouth bass ≥254 mm during 2004, 2005, and 2006. In 2006, of the eight largemouth bass ≥ 254 mm total length captured between Fruita State Park and the Loma Boat Landing, seven were caught in the Skipper's Island backwater. In 2005, of the 14 largemouth bass caught between Fruita State Park and the Loma Landing that were ≥ 254 mm, 13 were caught in Skipper's Island backwater.

Unlike largemouth bass collected in main channel riverine habitats of the Grand Valley where a vast majority (~ 90%) of the fish collected were < 150 mm, the length classes for smallmouth bass were more proportionately represented. In 2006, 42.9 % of all smallmouth bass collected in the Grand Valley reaches were ≥255 mm, 15.1 % were ≥306 mm, and 1.4 % were ≥357 mm. Of the total smallmouth bass in 2006 (n=881), 57.1 % were < 255 mm and 29.6 % were < 100 mm. The number of 'trophy-size' (≥255 mm [10-inch]) smallmouth bass collected increased each year since 2004, being greatest in 2006 some of which could be attributed to the increased removal pass in 2006. The number of smallmouth bass ≥306 mm (232; 10.7%), ≥357 mm (41; 1.9%), and ≥406 mm (4; 0.2%) was greatest in 2006.

The Silt to Beavertail Mountain reaches shared a similarity with the downstream Grand Valley reaches: the number of 'trophy-size' smallmouth bass relative to the total number collected were well represented in collections in these upper reaches. The 3-year relative average of smallmouth bass ≥255 mm was 40.1 % (132 of 329 total smallmouth bass) and smallmouth bass ≥306 mm was 19.8 % (65 of 329 fish). About 5 % (n=17) were ≥357 mm.

Also, it was apparent from collections, that in some river segments (15-mile reach [Grand Valley Irrigation Company Diversion Dam to the Colorado/Gunnison River confluence], 18-mile reach [Colorado/Gunnison River confluence to the Loma boat landing], and Rifle to Beavertail Mountain), smallmouth bass reproduced in 2004, 2005, and 2006.

The abundance for smallmouth bass (≥100 mm) in the 18- and 15- mile reaches plus the 2.3 miles of the Lower Gunnison River for 2006 was estimated to be 3,197 ± 2,100 (95% C.I.) individuals or about 91 smallmouth bass per mile using a single mark and first removal pass.

Catches of smallmouth bass appear related to turbid and clear water conditions. Higher catch rates for juvenile and adult smallmouth bass were associated with higher turbidity (usually immediately following summer rainstorms).

Recommendations include, 1) increasing the number of removal passes in 2007 and 2008 at least two-fold (from 4 to 8 passes) with the goal of increasing probability of capture and smallmouth bass exploitation rates; 2) suspending all electrofishing operations during the Colorado pikeminnow spawning period to eliminate the likelihood of harassment, interference, and injury to spawning Colorado pikeminnow; 3) performing mark-recapture population estimates at least once every three years to assess the size of the smallmouth bass population and effectiveness of removal in the Grand Valley reaches of the Upper Colorado and Lower Gunnison rivers; 4) continuing to sample reaches of the Upper Colorado River from the Rifle Bridge to Beavertail Mountain in Debeque Canyon; 5) sampling for young smallmouth bass in the spring prior to runoff to assess overwinter mortality; 6) preventing future escapement of piscivorous fishes (smallmouth bass, walleye, northern pike, and yellow perch) from Rifle Gap Reservoir or their access to the Colorado River; 7) collecting and preserving early-life stages (age-0 and age-1) of smallmouth bass annually during lethal removal passes to determine timing and duration of spawning and early-life stage growth rates; and 8) increasing catches of centrarchid fishes by targeting in-river features that provide habitat for centrarchid fishes and sampling on days when turbidity is high.

INTRODUCTION

Background

Significant anthropogenic changes to the physical riverine habitat have undoubtedly played an important role in the decline and endangered status of Colorado pikeminnow, [1] humpback chub, bonytail, and razorback sucker, but changes in the biological environment may also have been equally significant. Physical changes in the riverine habitat have been accompanied by the introduction, establishment, and proliferation of nonnative fishes, and concomitant declines in native fishes in the Upper Colorado River basin. The role of nonnative fishes is often identified, in association with habitat changes, as a major obstacle to conservation of native fish communities.

At least 67 nonnative fishes have been introduced actively or passively into the Colorado River system during the last 100 years (Minckley 1982; Tyus et al. 1982; Carlson and Muth 1989; Minckley and Deacon 1991; Maddux et al. 1993). By 1980, more than 50 nonnative fishes had been actively introduced into rivers and reservoirs of the Colorado River basin (Minckley 1982; Tyus et al. 1982; Carlson and Muth 1989). Many of the wild populations of the 'big river' native fishes now occupy less of their historic habitat. For example, the endangered Colorado pikeminnow are presently found only in the upper basin in about 25% of historic range basin-wide (Valdez and Muth 2005). The humpback chub occupies about 68% of its historic habitat in the upper basin, the razorback sucker now exists naturally in only a few locations, and bonytail is virtually extinct (Valdez and Muth 2005). Other more abundant, non-endangered native species also occupy less of their historic habitat in the upper Colorado River basin (flannelmouth sucker: 50%; bluehead sucker: 45%; roundtail chub: 55%)(Bezzerides and Bestgen 2002). While native fishes have declined in their historic habitat, introduced fishes have become more widespread and abundant. Former studies have also documented a decline in the abundance of native fish species as nonnative species increased in abundance (Joseph et al. 1977; Behnke 1980; Osmundson and Kaeding 1989; Quarterone 1993).

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[1] Scientific and common names with status (native vs. nonnative) of all fishes mentioned in this report are given in Appendix E; Table E.1. Only common names for these fishes are used in the text.

Many of the nonnative fishes introduced into the Colorado River basin are suspected of adversely affecting the native mainstem fishes in some fashion. Warmwater gamefish are thought to have the greatest adverse effect on endangered native fishes. Centrarchids (e. g., largemouth bass, green sunfish, bluegill, black crappie, and smallmouth bass), ictalurids (e. g., channel catfish and black bullhead), and esocids (northern pike) are frequently listed as contributors to the decline of native fishes. An increasing body of evidence characterizes the negative interactions of nonnative fishes with the endangered big river fishes (Hawkins and Nesler 1991; Minckley et al. 1991; Maddux et al. 1993; Lentsch et al. 1996). Some of this evidence is indirect, including inferences from field data or results from laboratory studies of predation by nonnatives on natives. Laboratory studies have documented agonistic behavior, resource sharing, and vulnerability to predation (Papoulias and Minckley 1990; Karp and Tyus 1990; Ruppert et al. 1993; Johnson et al. 1993). Direct evidence of predation includes native fishes obtained from stomach contents of nonnative fishes and by visual observation of predation. Other means by which nonnative fishes may adversely affect native fishes are by competition for food, which limits the success of razorback sucker (Papoulias and Minckley 1990). The extent of predation pressure by some nonnative fishes on populations of native fishes is not exactly known.

Smallmouth bass have the potential to prey on or compete with different life stages of the four native endangered fishes as well as the unlisted native fishes. During the 1990s the Yampa River experienced a dramatic increase in northern pike and then smallmouth bass in critical habitat. Predation by these species wreaked havoc on the native fish community. Anderson (2004; 2005) documented significant declines of native fish densities in parts of the river between 1998 and 2004 coincident with an increase in smallmouth bass abundance. The rapid increase of the smallmouth bass population in the Yampa River between 2000–2004 was believed, in part, attributed to a response to warmer water temperatures associated with several years of consecutive drought conditions.

Tyus and Saunders (1996) went on to conclude that smallmouth bass along with channel catfish and northern pike were the main threat to juvenile Colorado pikeminnow and razorback sucker. Participants of the smallmouth bass summit held in Grand Junction in November 2005 ranked smallmouth bass as the number one predatory threat in the Upper Colorado River basin to native fishes.

Smallmouth Bass

Upper Colorado River (Colorado)

Prior to 2003, in the Upper Colorado River between Price-Stubb Dam (river mile [RM] 188.3) and the head of Westwater Canyon, (RM 125), abundance and distribution information was scarce for smallmouth bass. Until 2003, smallmouth bass were only reported as incidental, rare captures in the Upper Colorado River from Price Stubb Dam (RM 188.3) to the Colorado/Green River confluence. However, Burdick (2003(a)) documented the capture of 318 smallmouth bass in main channel riverine habitats in a 39-mile reach of the Upper Colorado River from the Gunnison/Colorado River confluence to the Utah/Colorado stateline during a 4-month sampling period between late-June and late-October 2003. Catch rates (fish/hr and fish/mile) steadily increased throughout this 4-month period (1.31 to 4.04 fish/hr; 0.53 to 2.54 fish/mile). The source(s) of these smallmouth bass were unknown.

The rapid increase in the numbers of smallmouth bass in the Upper Colorado River prompted biologists and managers to become concerned that smallmouth bass abundance could increase quickly, and further impact recovery of native endangered fishes (Burdick 2003(a)). Some speculate that the rapid proliferation of smallmouth bass in the Upper Colorado River was the result of a combination of factors. There is speculation that while a small number of smallmouth bass may have been present in the system, an influx of fish from an off-river source created a critical mass of spawners that was followed by optimal spawning conditions (i. e., low-flow years and warmer water temperatures) which were associated with drought years in the late-1990s and early-2000s. The possibility of an influx of smallmouth bass from an accidental release of water from Rifle Gap Reservoir, an off-main channel reservoir, could have provided the critical mass of spawning adults that resulted in the large increase in numbers occurring around 2001–2003. Unauthorized translocation and illicit stocking by non-state or non-federal agencies cannot be ruled out as a contributing factor.

Price-Stubb Dam on the Upper Colorado River upstream from Palisade, Colorado, presently acts as an effective upstream movement barrier for all fishes. Fish passage at Price-Stubb Dam will be completed during the winter of 2008 and will undoubtedly allow further upstream movement past this barrier. A fish passage constructed and completed in August 2004 at the Government Highline Diversion Dam (RM 193.7) 5.4 miles upstream will allow for selective removal of undesirable nonnative fishes. Four smallmouth bass were collected in the fish trap of the Government Highline fish passage during 2005 (Burdick 2005(b)) and one during 2006 (Burdick 2006(a)). Smallmouth bass are located in Rifle Gap Reservoir and adult smallmouth bass have been reported in the Colorado River between Rifle and Price-Stubb Dam (Anderson 1997; this study).

Lower Gunnison River

The Redlands Diversion Dam constructed in 1918 serves as an effective barrier to smallmouth bass and all other fish attempting to move further upstream in the Gunnison River. A fishway with fish trap was constructed and completed at this site in 1996 has provided a means to allow native fish to pass upstream into historic habitat, and allow for selective removal of undesirable nonnative fishes. In the fish trap of the Redlands Dam fish passageway in the Lower Gunnison River, the number of smallmouth bass have recently increased (19 fish in 2002 and 2003)(Burdick 2003(b)) over previous years of monitoring (1996–2001: 1 fish)(Burdick 2001). Nine smallmouth bass were collected in the fish trap at Redlands during 2004 (Burdick 2004(a)) and 21 during 2005 (Burdick 2005(a)). No smallmouth bass were collected in 2006 (Burdick 2006(a)) or 2007. About 1,800 fingerling smallmouth bass were stocked by the Colorado Division of Wildlife (CDOW) in 1973 in the Gunnison River near Delta (Wiltzius 1978) upstream from Redlands Diversion Dam. None of these stocked smallmouth bass have been subsequently captured upstream from the diversion dam (Wiltzius 1978, Valdez et al. 1982; Burdick 1995; Burdick 2003(c); Anderson 2006; Burdick 2006(b)).

Control of Nonnative Fish by Mechanical Removal

Currently, the core of the nonnative fish control strategy in the upper Colorado River basin is mechanical removal. Mechanical removal strives to reduce numbers of problematic fish species, affects long-term viability by suppressing sustainable numbers of fish, and effectively increases native fish populations to promote recovery of endangered fishes. Control of smallmouth bass and other nonnative fish species is a primary emphasis, along with habitat restoration, propagation and stocking, and instream flow management within the Recovery Program for the four endangered fish species. In the strategic plan for the control of nonnative fishes in the Upper Colorado River Basin (Tyus and Saunders 1996), "control" was defined as "reducing the numbers of one of more nonnative species to levels below which they are no longer an impediment to the recovery of endangered fish species." The goal for nonnative fish control or management in the Upper Colorado River Basin is to reduce the adverse impacts of nonnative fishes on the endangered fishes which will hopefully increase the distribution and abundance of the endangered fishes and contribute to their recovery. It is not likely that nonnative fishes that have become established in the Upper Colorado River Basin can be eliminated. However, preventive measures (e. g., reservoir escapement, illicit translocation and release) and active control programs could be implemented to reduce the abundance of nonnative fishes in riverine and adjacent floodplain habitats. Consequently, reducing the abundance of some problematic, nonnative fishes would reduce the potential for predation and competition on both listed and unlisted native fishes.

Management to promote recovery of listed fish species may have to include long-term or periodic suppression of some problematic nonnatives, such as mechanical removal, that minimizes impacts to remaining native fishes. If removal can be sufficient to cause a population collapse, numbers may decline to a density level in which recruitment is not effective and populations remain small until they can expand to a level when they are again abundant. Even if control measures are effective in removing smallmouth bass, an unfortunate event such as an influx of fish from an off-river source as much as ten years apart can negate the gains of multiple years of removal. Mechanical removal is the most common method being used to control nonnative fish in the upper basin. The prevailing gear being used to accomplish this objective is, by far, electrofishing.

Purpose and Objectives

The purpose of this study was to remove as many smallmouth bass of all sizes in main channel riverine habitats in a 105-mile portion of the Upper Colorado River between Rifle and Beavertail Mountain and between Price-Stubb Dam and Westwater boat landing in eastern Utah and a 2.3-mile reach of the Lower Gunnison River. The goal was to reduce the abundance of smallmouth bass as quickly as possible in this reach which would ultimately benefit native listed fishes, and possibly contribute to their recovery. In 2006, objective number 2 was added to obtain an abundance estimate for smallmouth bass in concentration areas of the Upper Colorado River from Price Stubb Dam to Westwater, Utah. The study objectives were to:

1. remove all sizes of smallmouth bass collected by boat and raft-based electrofishing,

and

2. obtain an abundance estimate for smallmouth bass (≥ 100 mm) during 2006 by mark and recapture methods for the Upper Colorado River between Price Stubb Dam and Fruita State Park and 2.3 miles of the Lower Gunnison River between Redlands Diversion Dam and the Colorado/Gunnison River confluence.

Study Area

The study was conducted in both Mesa and Garfield counties in western Colorado and Grand County in eastern Utah. The study area included 105 miles of the Upper Colorado River from Rifle (RM 240.4) downstream to Beavertail boat landing (RM 195.7) and Price-Stubb Dam (RM 187.6) to the Westwater, Utah, BLM ranger station (RM 127.6). On the Gunnison River, 2.3 miles were sampled between Redlands Diversion Dam (RM 3.0) and confluence with the Colorado River (Figure 1). For logistical considerations, the Upper Colorado River portion was divided into four different reaches or segments based on hydro-geomorphic features. These included, 1) a 3-mile section between Price-Stubb and Grand Valley Irrigation dams and the 15-mile section that extended from Palisade to the Gunnison/Colorado River confluence (RMs 185.5–171), 2) the 18-mile reach that extended from the confluence of the Gunnison and Colorado rivers to the Loma boat landing (RMs 171.0–152.6), 3) the 25-mile long reach in Ruby and Horsethief canyons (RMs 152.6–127.6) which extended from the Loma boat landing to Westwater, Utah, and 4) a 45-mile reach between the Rifle Bridge and Beavertail Mountain. The Rifle to Beavertail reach was outside the original defined removal area. However, there were unsubstantiated reports that anglers had encountered smallmouth bass in these upstream reaches, and it was determined that "reconnaissance" investigations were warranted to confirm or refute these claims.

The 15- and 18-mile reaches flow through a wide alluvial section of the lower Grand Valley and the Ruby and Horsethief canyon sub-reach is considered a quasi-alluvial sub-reach. The upper extent (~ 36 miles) of the Rifle to Beavertail reach flows through an alluvial valley; the lower extent (~ 9 miles) flows through a canyon-bound area. The physical characteristics of individual river reaches were previously described for the Upper Colorado River from Rifle to Westwater by Valdez et al. (1982) and Pitlick and Cress (2000), and by Burdick (1995) for the Lower Gunnison River. All of these river reaches are within critical and occupied habitat for Colorado pikeminnow and razorback sucker.

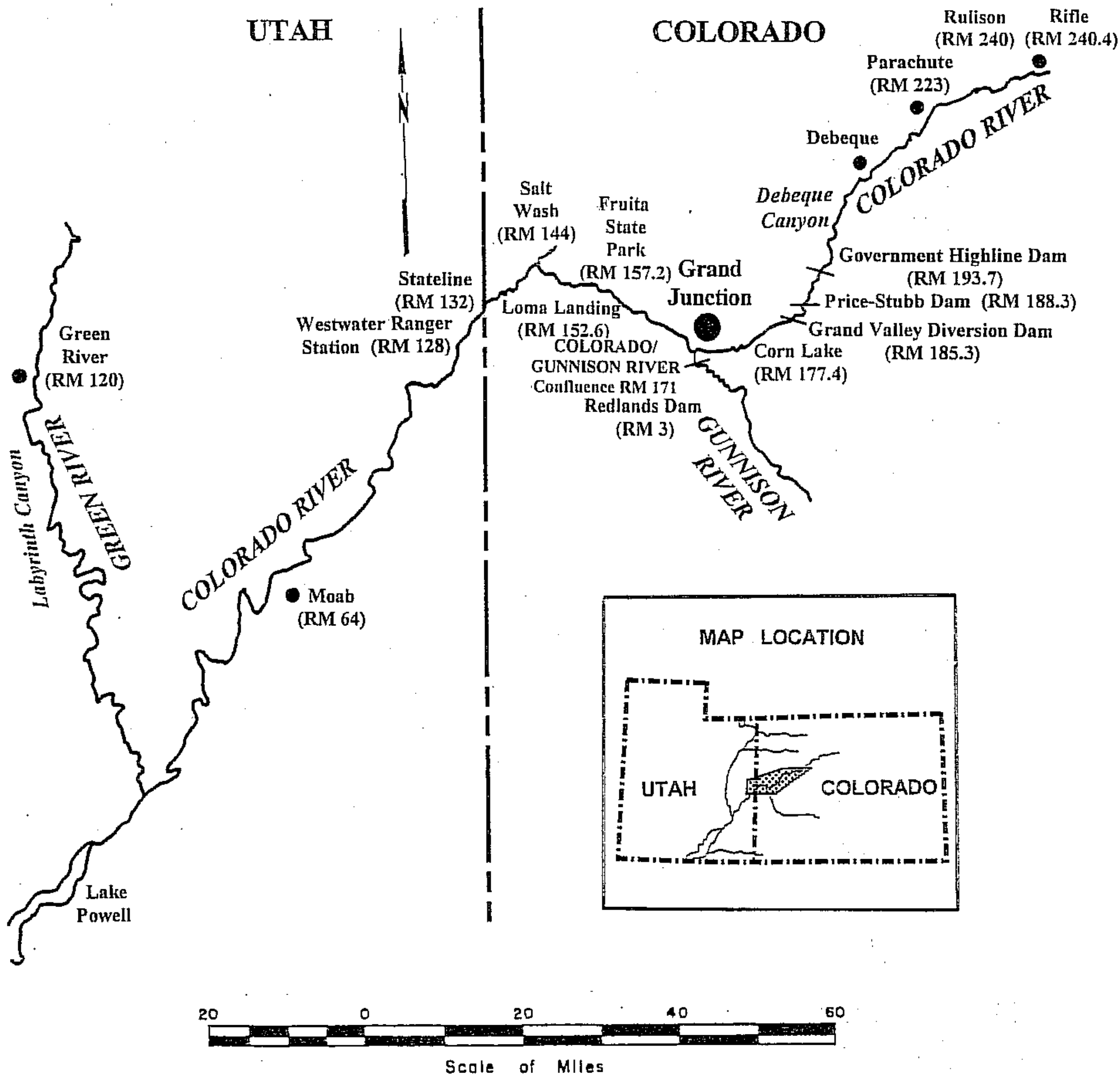

Figure 1. General area for the centrarchid removal study performed during 2004–2006 in the Upper Colorado River of western Colorado and eastern Utah and the Lower Gunnison River in western Colorado with major landmark descriptors. Refer to Table 1.

METHODS

Fish Sampling

The study utilized jon boat and raft-based electrofishing to remove smallmouth bass. Each electrofishing craft was equipped with a Smith-Root (Model GPP 5.0) electrofishing unit. Actual time spent electrofishing (actual circuit time) was also recorded. Main channel habitats sampled included mostly shorelines and backwaters. Two electrofishing craft were used concurrently to collect fish. Although smallmouth bass were the target fish for removal in this project, all other centrarchid fishes encountered were collected. The reason for this was that the CDOW requested that the FWS remove and preserve all centrarchid fishes collected during the removal effort for use in the provenance (isotope signature) study. These fishes included largemouth bass, green sunfish, bluegill, and black crappie. Samples were preserved according to criteria provided by CDOW.

For sampling logistics, each major segment in the Upper Colorado River was further partitioned into sub-reaches. For the Upper Colorado River between Price-Stubb Dam and Westwater, Utah, eight sub-reaches were designated. There was one sub-reach in the Lower Gunnison River (Table 1). Each sub-reach between Price-Stubb Dam and Westwater, Utah, and the Lower Gunnison River during 2004 and 2005 was sampled at least three times with electrofishing. Some sub-reaches where high concentrations of smallmouth bass were collected during the first three passes were sampled a fourth time. Only one electrofishing craft was used during the fourth pass, which was termed a "concentration pass". This pass was dedicated to electrofishing the higher abundance areas determined from the first three passes. All smallmouth bass collected were lethally removed.

During 2006, the protocol was modified to include an additional initial pass to mark and release all smallmouth bass collected in the moderate to high concentration areas of the Upper Colorado River from the Grand Valley Irrigation Company (GVIC) Diversion Dam to the Loma boat landing and the lower 2.3 miles of the Gunnison River. Two electrofishing rafts were used to collect centrarchid fishes during the marking pass. All smallmouth bass collected were marked and released. For the population estimate performed during 2006, smallmouth bass were marked with a Fiskars® hole punch (6.4-mm diameter) in the dorsal part of the caudal fin. All other centrarchid fishes collected were removed. Following the marking pass, four removal passes were made using aluminum boat and raft-based electrofishing to collect centrarchid fishes

Table 1. Designated river segments and sub-reaches for the centrarchid removal project in the Upper Colorado River from Rifle to Beavertail Mountain, Price-Stubb Diversion Dam to Westwater, Utah, and the Lower Gunnison River from the Redlands Diversion Dam to the Colorado/Gunnison River confluence, 2004–2006.

River River Segment Sub-Reach	River Miles	Length of Segment/Sub-Reach
Colorado River		
Rifle to Beavertail Mountain	240.4–195.7	44.7
Rifle Bridge–Rulison	240.4–230.0	10.4
Rulison–Parachute Bridge	230.0–223.0	7.0
Parachute Bridge–Debeque I-70 Bridge	223.0–209.7	13.3
Debeque I-70 Bridge–Beavertail Mountain	209.7–195.7	14.0
Sub-Reach Total	---	44.7
Price-Stubb Diversion Dam–Westwater, Utah	187.7–127.6	60.1
Price-Stubb Dam–GVIC Dam	187.7–185.3	2.4
GVIC Dam–Corn Lake	185.3–177.4	7.9
Corn Lake–Colo/Gunn River Confluence	177.4–171.0	6.4
Colo/Gunn River Confl –Fruita State Park	171.0–157.2	13.8
Fruita State Park–Loma Boat Landing	157.2–152.6	4.6
Loma Boat Landing–Salt Creek Wash	152.6–144.0	8.6
Salt Creek Wash–Utah/Colo State Line	144.0–131.9	12.1
Utah/Colo State Line–Westwater, Utah	131.9–127.6	4.3
Sub-Reach Total	---	60.1
Lower Gunnison River		
Redlands Diversion Dam–Colo/Gunn River Confluence	3.0 – 0.7	2.3
Sub-Reach Total	---	2.3

from 25 July to 19 September 2006. Two electrofishing craft were used in every river segment during passes 1, 2, and 3. One electrofishing craft was used in pass 4. The number of removal passes for areas of low densities of smallmouth bass as determined from 2004 and 2005 capture data was reduced during 2006. These river segments included the canyon-bound reaches of Ruby and Horsethief canyons to Westwater, Utah (RM 152.6–127.6). The reduced effort in these reaches was re-directed to increase the number of removal passes in river segments where smallmouth bass had proliferated over the past two years. Therefore, only one pass was performed from the Loma boat landing to Westwater, Utah, during 2006. Some river segments were not electrofished during pass 4 (e. g., Loma boat landing to the Westwater ranger station and Price-Stubb Dam to GVIC Dam). Captures of smallmouth bass marked during the earlier marking pass were recorded for determining an abundance estimate.

For the Rifle to Beavertail segment the sampling protocol varied from that of downstream reaches. This segment was further partitioned into four sub-reaches for sampling logistics (Table 1). During 2004 two electrofishing craft were used and only one pass was made in the 45-mile segment. During 2005 and 2006, two passes were made. All sub-reaches were sampled during the first pass with two electrofishing craft. During pass 2, only one electrofishing craft was used, but not all sub-reaches were sampled. For pass 2, only the 10.4-mile section from Rifle to Rulison was sampled during 2005 and only a portion (RM 240.4–235.5) of this sub-reach was sampled during 2006. The reason for targeting the Rifle to Rulison sub-reach was that during pass 1 in 2004 and 2005, the highest densities of smallmouth bass were recorded there.

For 2004, 2005, and 2006 the number of individuals was recorded for all centrarchid fishes by species. All smallmouth bass and largemouth bass were measured (total length [TL] ± 2 mm). For all other centrarchids total length was recorded for those specimens that were greater than 100 mm. Capture date and corresponding location (within the nearest river mile) for each centrarchid fish collected were recorded along with actual time electrofished (seconds; converted to hrs fished).

All juvenile and adult endangered fish collected were checked for a PIT tag, weighed, measured, tagged if no tag was detected, and immediately returned to the river. Both 400 khz and 134 khz PIT tags were checked for in endangered fish. The newer 134 khz tag was inserted in endangered fish if they had the older 400 khz tag or were untagged.

Hydrology and Water Temperature Data

Discharge and water temperature records for the Upper Colorado River were retrieved from the U.S. Geological Survey (USGS) stream gauging stations at Cameo (no. 09095500) and stateline (09163500) near the Colorado/Utah border for 2002–2006. Only discharge records from the Palisade USGS gauge (no. 09106150) were retrieved for 2002–2006. Various hydrology and water temperature parameters were used to characterize different flow years (e. g., wet, moderate, and dry) prior to and during the study period. The discharge parameters included highest and lowest daily mean flow, peak instantaneous flow and date it occurred, and 90 % exceedence. Total and cumulative annual degree days (≥14 ° C) were generated for the Cameo and stateline stations for 2002–2006. Additional water temperature parameters included maximum daily water temperature, the number of days the water temperature equalled or exceeded 14 ° C, and the total degree days (≥14 ° C) between June 1 and October 31 of each of the years examined. The years 2004–2006 coincided with biological data collected during the smallmouth bass removal project. Even though smallmouth bass data were not collected during 2002 and 2003 in the same manner as this study, these years were considered drought years and were used to compare discharge and water temperature parameters between 2004–2006.

For this study, a degree day was defined as one degree of temperature (° C) above the developmental zero for a period of one day (Berven et al. 1979). In terms of smallmouth bass growth, developmental zero would be the mean daily water temperature that equalled or exceeded 14 ° C because this was the temperature at which smallmouth bass growth was believed to be initiated (Shuler et al. 1980). For example, a mean daily water temperature of 14.6 ° C on May 1 of a particular year would be calculated as 0.6 (14.6 minus 14.0 = 0.6) degree day. Likewise, a mean daily water temperature of 21.2 ° C on a particular day would calculated as a 7.2 (21.2 minus 14.0 = 7.2) degree day. Negative degree days (e. g., those days when the mean daily water temperatures were less than 14 ° C) were not used and were not subtracted from the days when the mean daily water temperature exceeded 14 ° C. The mean daily water temperature for days when no readings were made or were unavailable were estimated by interpolation.

The total number of degree days for a calendar year was the summation for each of the days when the mean daily water temperature exceeded 14 ° C. The cumulative degree days were the increasing or successive accumulation of additive degree days when the mean daily water temperature exceeded 14 ° C. This statistic was generated primarily for graphic presentation of the onset of the annual thermal regime of the river and the progressive accumulation of degree days in a particular growing season which could be compared among years. For each day that the mean daily water temperature exceeded 14 ° C, this was considered 1 degree day and was irrespective how great the mean daily water temperature exceeded the 14 ° C value. Degree days were a means to characterize and describe the annual thermal water conditions in a particular river reach.

Analyses

While smallmouth bass were the focus of this removal study, data were collected and reported on four other centrarchid fishes that were also removed. Total numbers and catch per unit of effort for smallmouth bass and largemouth bass, and green sunfish, black crappie, and bluegill in the aggregate were determined for each sub-reach per sampling pass for 2004, 2005, and 2006. Catch per unit of effort was computed as total catch per effort and reported as fish/hr. For smallmouth bass only, another catch effort index, fish/mile, was computed. This index was computed from the actual number of fish collected and removed during 2004, 2005, and 2006, for five major riverine segments on the Upper Colorado River and one segment for the Lower Gunnison River for each of the four passes. Changes in the mean individual size (total length ± 2 mm) of smallmouth bass among the 3 years were also compared.

Chapman's (1951) modification of the Petersen-Lincoln estimator was used to determine abundance of smallmouth bass. This estimator was believed to be the most appropriate because it would reduce bias due to the small number of recaptured smallmouth bass.

$$\text{N-hat} = ((n_1 + 1)(n_2 + 1)/(m_2 + 1)) - 1$$

where N-hat = estimated population size

n_1 = the number of smallmouth bass marked in the marking pass

n_2 = the number of smallmouth bass captured in the first removal pass

m_2 = the number of marked smallmouth bass recaptured

The upper and lower 95% confidence limits (C.I.) were computed by:

$$\text{N-hat} \pm 1.96 * \sqrt{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)/(m_2+1)^2(m_2+2)}$$

Probability of capture (p-hat; after White et al. 1982) was also computed:

$p\text{-hat} = (n_2 - u_2)/n_2$

where n_2 = the number of smallmouth bass captured in the first removal pass

u_2 = the number of smallmouth bass captured in the first removal pass that were not marked

Coefficient of variation (CV; Pollock et al. 1990) was also computed:

$CV = SE/N\text{-hat} \times 100$

where SE = standard error

N-hat = estimated population size

For 2004 and 2005, population estimates for smallmouth bass (≥ 100 mm) were not obtained from mark, release, and subsequent recapture of marked fish. However, an attempt was made to linearly extrapolate a population abundance projection for 2004 and 2005 from the 2006 population estimate and catch/effort from all three years. Catch/effort data from all smallmouth bass ≥100 mm collected and removed during all passes and the population estimate computed from marked fish in 2006 of similar size collected and removed within identical river sub-reaches during 2004 and 2005 were used to arrive at these projections. A catch/effort multiplier was computed from the 2006 catch/effort data (e. g., the catch/effort for 2005 and 2006, respectively, was 8.5 and 3.33; therefore the 2005 catch/effort was 2.55 times greater than 2006). The 2006 population estimate and 95% C.I. were multiplied by the multiplier to back-project what the population size of smallmouth bass ≥ 100 mm may have been during 2004 and 2005. For example for 2005: $2.55 \times 3{,}197_{2006} = 8{,}152$; lower C.I. = $2.55 \times 1{,}097_{2006} = 2{,}797$; upper C.I. = $2.55 \times 5{,}297_{2006} = 13{,}507$. The number of smallmouth bass/mile (≥ 100 mm) was then estimated from the population estimate and population projections.

RESULTS AND DISCUSSION

Abundance Indices

Number of Individual Fish by Species

Smallmouth Bass. The number of smallmouth bass collected within each of the four major river segments for each of the three years by pass number is provided in Table 2. This included all smallmouth bass sizes (26–437 mm total length) collected within main channel habitats. Between Price-Stubb Dam and Westwater, Utah, the number of smallmouth bass for 2004, 2005, and 2006, was 1,165, 1,366, and 751 fish, respectively. The actual total number of smallmouth bass removed was highest during 2005 from all reaches combined. The total number of smallmouth bass collected during 2006 declined 45% from 2005 and 36% from 2004.

Between Rifle and Beavertail Mountain, the actual total number of smallmouth bass collected during 2004, 2005, and 2006 was 21, 230, and 79 fish, respectively. The highest total number of smallmouth bass was removed during 2005 for all reaches combined. The actual total number of smallmouth bass removed declined 66% from 2005 to 2006. The total number of smallmouth bass (includes young-of-the-year, juvenile, and adult) collected for each pass for each of the eight sub-reaches in the Upper Colorado River between Price-Stubb Dam and Westwater, Utah, plus the Lower Gunnison River is provided in Appendix; Tables A.1.–A.3. The actual total number of smallmouth bass collected for each of the four sub-reaches between Rifle and Beavertail is provided in Appendix; Tables A.4.–A.6.

The actual total number of smallmouth bass (young-of-the-year, juvenile, and adult; 26 – 414 mm total length) collected and removed/river mile for each of the three years for each of the four passes for five river segments on the Upper Colorado River and one segment on the Lower Gunnison River is provided in Appendix; Table A.7. These fish/mile estimates are not to be confused with the fish/mile estimates projected from population estimates (see Table 6).

Largemouth Bass. The actual total number of largemouth bass collected within each of the four major river segments for each of the three years by pass number is provided in Table 2. This included all largemouth bass sizes (young-of-the-year, juvenile, and adult; 29–544 mm total length) collected within main channel habitats. Between Price-Stubb Dam and Westwater, Utah, the actual total number of largemouth bass removed for 2004, 2005, and 2006 was 277, 589, and 1,094 fish, respectively. The total number of largemouth bass removed was greatest during 2006. Actual total number of largemouth bass that were removed steadily increased throughout the 3-year removal period. The total number of all largemouth bass removed increased 113% from 2004 to 2005 and 86% from 2005 to 2006. Between Rifle and Beavertail Mountain, the total number of largemouth bass collected and removed in 2004, 2005, and 2006 was 65, 38, and 211 fish, respectively. Largemouth bass (all length sizes [38–446 mm total length]) increased

Table 2. Total numbers of centrarchid fishes collected with raft and aluminum boat electrofishing during removal passes 1, 2, 3, and 4 of the smallmouth bass removal project from main channel habitats in the Upper Colorado River and Lower Gunnison River in western Colorado and eastern Utah, July, August, and September 2004, 2005, and 2006. Note: pass 4 was a "concentration pass" which sampled sections of river with high densities of centrarchids determined from passes 1, 2, and 3.

River River Segment (River Miles)	Number of Centrarchids														
	Smth Bass			Lrgth Bass			Green Sunfish			Black Crappie			Bluegill		
Colorado River Rifle to Beavertail Mtn (240.7–195.7)	'06	'05	'04	'06	'05	'04	'06	'05	'04	'06	'05	'04	'06	'05	'04
Pass 1	79	230	21	211	38	65	492	606	36	0	2	0	3	10	0
Colorado River Price-Stubb Dam-Westwater, UT (187.7–127.6) & Lower Gunnison River Redlands Dam-Colo/Gunn River Confluence (3.0–0.7)															
Pass 1 [a]	258	475	219	203	247	28	309	271	119	26	17	2	45	109	20
Pass 2 [a]	159	119	256	326	119	23	320	236	87	18	6	4	90	53	14
Pass 3 [a]	225	313	504	419	168	146	568	366	321	14	8	1	116	103	62
GVIC-Loma + Lower Gunnison River (185.3–152.6 + 3.0–0.7)															
Pass 4 [b]	109	167	186	146	55	80	198	178	116	12	10	0	56	51	15
Year Totals	**751**	**1366**	**1165**	**1094**	**589**	**277**	**1395**	**1051**	**643**	**70**	**41**	**7**	**307**	**316**	**111**

[a] Two electrofishing craft used.

[b] One electrofishing craft used.

225% from 2004 to 2006. The total number of largemouth bass (includes young-of-the-year, juvenile, and adult) collected for each pass for each of the eight sub-reaches in the Upper Colorado River between Price-Stubb Dam and Westwater, Utah, plus the Lower Gunnison River is provided in Appendix; Tables A.1.–A.3. The total number of largemouth bass collected for each of the four sub-reaches between Rifle and Beavertail is provided in Appendix; Tables A.4. –A.5.

Green sunfish, Black Crappie, and Bluegill. The total number of each of these three species for all length sizes collected within each of the four major river segments for each of the three years by pass number is provided in Table 2. Between Price-Stubb Dam and Westwater, Utah, the number of green sunfish increased each year. The total number of green sunfish collected in 2004, 2005, and 2006 was 643, 1,051, and 1,395 fish, respectively. This translated into a 61% increase from 2004 to 2005 and a 33% increase from 2005 to 2006. Between Rifle and Beavertail Mountain, the total number of green sunfish numbers was 36, 606, and 492 in 2004, 2005, and 2006, respectively.

Black crappie comprised the fewest number of fish captured and removed of the five centrarchid fishes encountered during this 3-year removal program. Between Price-Stubb Dam and Westwater, Utah, the total number of black crappie collected increased from 7 fish in 2004 to 41 in 2005 (486% increase) to 70 in 2006 (71% increase). Only two black crappie were collected in the 3 years between Rifle and Beavertail Mountain. Bluegill, traditionally considered a lentic species, were encountered in high numbers in main channel riverine habitats. Between Price-Stubb and Westwater, the total number removed in 2004, 2005, and 2006 was 111, 316, and 307, respectively. Between Rifle and Beavertail Mountain, 10 were removed in 2005 and only 3 in 2006. The aggregate number of green sunfish, black crappie, and bluegill collected and removed in each of the eight sub-reaches between Price-Stubb Dam and Westwater, Utah, plus the Lower Gunnison River is provided in Appendix; Tables A.1.– A.3. The number of each of these three species collected within each of the four sub-reaches from Rifle to Beavertail is provided in Appendix; Tables A.4.–A.6.

Catch/Effort

General. Catch rate or catch/effort is often used as an index of population size if it is consistently proportional to absolute abundance (Ricker 1975). Unfortunately, catch/effort can be highly variable and is not the most reliable metric for population analyses or comparing trends in population abundance densities among years. It is more likely that unexplained variations in capture probability or "catchability" (not catch per unit of effort per se) preclude the use of catch per unit of effort as an abundance estimate. During 2004 and 2005, since the initial study objective was to lethally remove as many smallmouth bass and other centrarchids as quickly as possible, fish were not marked and released and, therefore, a population estimate was not possible. For those years, effort was recorded (Appendix; Tables B.1. and B.2.) and catch/effort was calculated and used to monitor increases and declines in centrarchid populations. To determine if densities of smallmouth bass and largemouth bass were being depleted as a result of the removal effort, we calculated and interpreted catch effort indices (e. g., fish/hr) over time (i. e., by pass) in each river sub-reach (Appendix; Tables B.4.–B.6.). Because population estimates for smallmouth bass were not available for 2004 and 2005, effort was still recorded during 2006 (Appendix; Table B.3.) and catch/effort was computed (Appendix; Table B.6.) for use as a trend to compare annual abundance of smallmouth bass and other centrarchids during 2004, 2005, and 2006.

Electrofishing effort in 2004 (168.665 hours) was similar to 2005 (174.560 hours) between Price-Stubb Dam and the Westwater, Utah, ranger station and the Lower Gunnison River (Appendix; Table B.1.–B.2). In 2006, electrofishing effort in these reaches was 161.906 hours (Appendix; Tables B.3.). Between Rifle and Beavertail Mountain, the effort expended in 2004 was 19.750 hours compared to 39.799 hours during 2005 and 37.512 hours during 2006 (Appendix; Tables A.4.–A.6.).

Smallmouth bass. A decline in abundance of smallmouth bass was detected in 2006 from the previous two years using catch effort indices (fish/hr) in main channel habitats of the Upper Colorado River in western Colorado and eastern Utah and the Lower Gunnison River. From Price-Stubb Dam to the Westwater ranger station, overall mean catch effort (Appendix; Table B.6.) for smallmouth bass during passes 1–4 was: 4.30, 3.87, 5.57, and 5.34 fish/hr, respectively, for 2006. For 2005, overall mean catch effort (Appendix; Table B.5.) during passes 1–4 was: 8.18, 8.53, 6.26, and 9.09 fish/hr, respectively. For 2004, overall mean catch effort (Appendix; Table B.4.) during passes 1–4 was 5.14, 5.58, 8.11 and 10.33 fish/hr, respectively. In the Grand Valley reaches, overall mean catch effort for smallmouth bass declined in 2006 (4.64 fish/hr) from 2005 (7.83 fish/hr) and 2004 (6.91 fish/hr). Smallmouth bass overall mean catch/effort by each of the four passes for each of the three years was graphed. As passes proceeded through each of the three years, catch rates generally increased (Figure 2). During 2004–2006, there appeared to be riverine sub-reaches that consistently had higher abundance of smallmouth bass. For smallmouth bass in 2006, the highest catch rate in main channel habitats was between Corn Lake and the Colorado/Gunnison River confluence (8.94 fish/hr; all passes combined). The second highest river sub-reach was from GVIC Diversion Dam to Corn Lake (6.81 fish/hr) followed third by the sub-reach from the Colorado/Gunnison River confluence to Fruita State Park (3.80 fish/hr). Loma boat landing to Salt Creek had the fourth highest abundance of smallmouth bass (3.04 fish/hr). Smallmouth bass catch rate increased 5.5 fold between Rifle and Beavertail Mountain from 1.06 fish/hr during 2004 to 5.78 fish/hr in 2005. However, during 2006 in this segment, smallmouth bass catch rate precipitously declined to 2.10 fish/hr (Figure 3). For smallmouth bass in 2005, the highest catch rate in main channel habitats was between Corn Lake and the Colorado/Gunnison River confluence (16.36 fish/hr; all passes combined). The second highest river sub-reach was from Price-Stubb Dam to the GVIC Diversion Dam (11.02 fish/hr) followed third by the sub-reach from the Colorado/Gunnison River confluence to Fruita State Park (10.43 fish/hr)(Table 3). GVIC to Corn Lake had the fourth highest abundance of smallmouth bass (8.97 fish/hr). During 2004, the highest abundance of smallmouth bass in main channel habitats was between Corn Lake and the Colorado/Gunnison River confluence (11.88 fish/hr; all passes combined), followed by the sub-reach between the Colorado/Gunnison River confluence to Fruita State Park (9.47 fish/hr; all passes combined) (Table 3). The 2.3-mile segment in the Lower Gunnison River had the third highest abundance of smallmouth bass (9.21 fish/hr; all passes combined).

Smallmouth Bass Concentration Areas. Identifying concentration areas is important because it may allow managers to focus on riverine areas of high densities of smallmouth bass to expedite removal and reduction to control their proliferation/invasiveness and potential negative impacts to native fish conservation and endangered fish recovery. High to low smallmouth bass concentration areas in riverine reaches in the Colorado and Lower Gunnison rivers were determined using 2004, 2005, and 2006 catch/effort values (Table 3). A subjective relative concentration rating was developed and is provided.

The river reach between Corn Lake and the Colorado/Gunnison River confluence has consistently been the highest area of concentration for smallmouth bass during the summers of 2004, 2005, and 2006. The next highest area was between the Colorado/Gunnison River confluence and Fruita State Park. The third highest concentration area was from the GVIC Dam

Table 3. Concentration areas for smallmouth bass in the Upper Colorado and Lower Gunnison rivers during the summer of 2004, 2005, and 2006 using catch effort indices.

	2004		2005		2006	
River River Segment	Catch/Effort[a]	Concentration Rating[b]	Catch/Effort[a]	Concentration Rating[b]	Catch/Effort[a]	Concentration Rating[b]
Upper Colorado River						
Rifle-Beavertail Mtn	1.06	Lowest	5.78	Moderately High	2.10	Moderately Low
Price Stubb Dam-GVIC Dam	4.07	Medium	11.02	Highest	2.89	Moderately Low
GVIC Dam-Corn Lake	7.05	Moderately High	8.97	Moderately High	6.81	Moderately High
Corn Lake-Colo/Gunn River confluence	11.88	Highest	16.36	Highest	8.94	Moderately High
Colo/Gunn River confluence-Fruita State Park	9.47	Highest	10.43	Highest	3.80	Medium
Fruita State Park-Loma Boat Landing	5.35	Moderately High	3.78	Medium	2.15	Moderately Low
Loma Boat Landing-Salt Creek	3.19	Medium	6.21	Moderately High	3.04	Medium
Salt Creek-Utah/Colo Stateline	1.92	Lowest	1.60	Lowest	1.05	Lowest
Utah/Colo Stateline-Westwater, UT, Ranger Station Station	0.47	Lowest	1.02	Lowest	0.94	Lowest
Lower Gunnison River Redlands Dam-Colo/Gunn River confluence	9.21	Highest	7.44	Moderately High	2.68	Moderately Low

[a] All passes combined. Catch effort was defined as the total catch per unit of effort and was reported as fish/hr.

[b] Key

Catch/Effort Value	Relative Concentration Rating
12.00-9.00	Highest
8.99-5.00	Moderately High
4.99-3.00	Medium
2.99-2.00	Moderately Low
< 2.00	Lowest

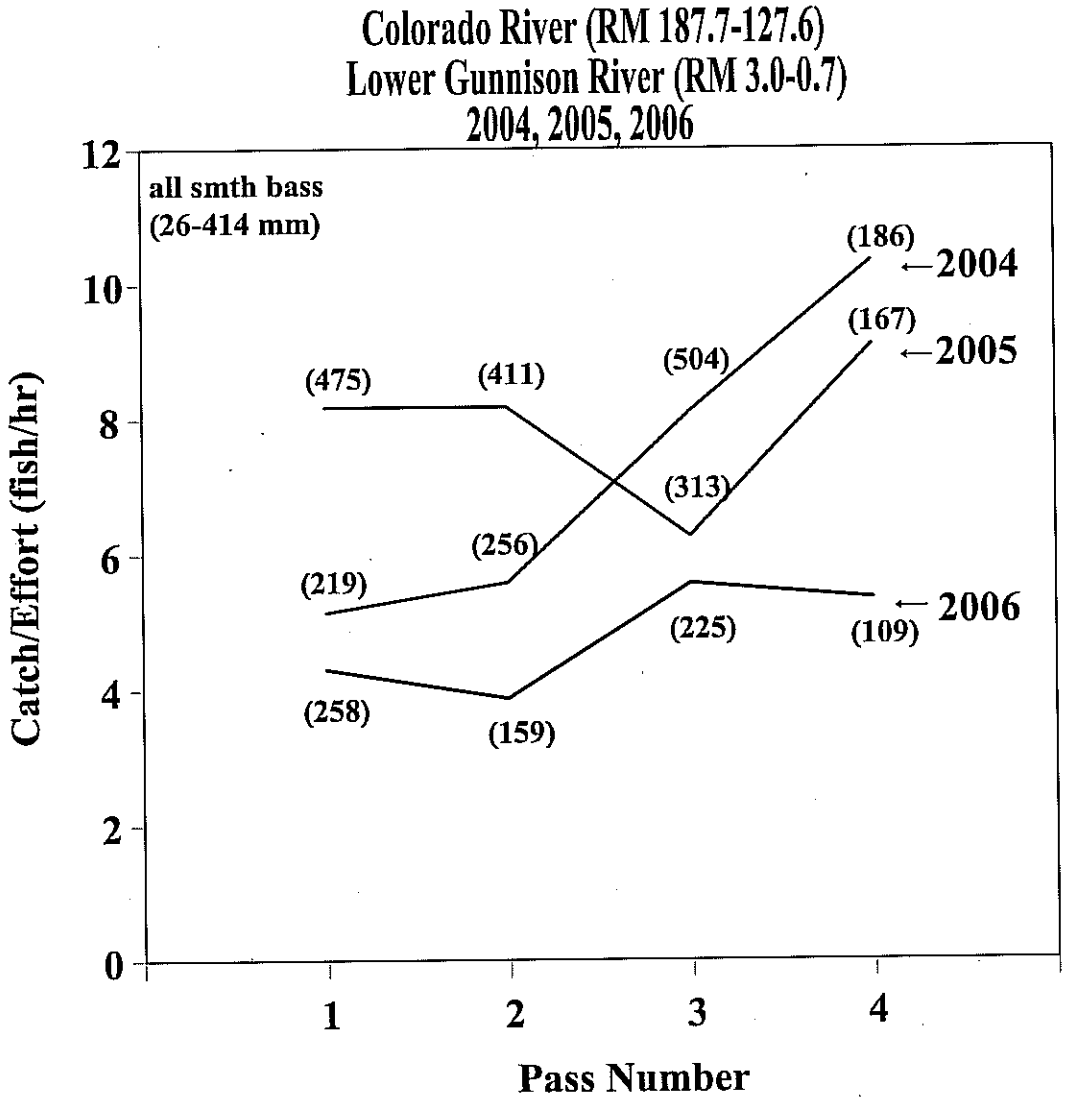

Figure 2. Overall catch effort (fish/hr) by pass for smallmouth bass (26–414 mm) collected from main channel habitats in the Upper Colorado River with electrofishing from RM 187.7–127.6 (Price-Stubb Dam to the Westwater, Utah, BLM ranger station) and in the Lower Gunnison River from RM 3.0–0.7 (Redlands Dam to the Colorado/Gunnison River confluence), 2004, 2005, and 2006. Note: The number of fish collected by pass is in parentheses.

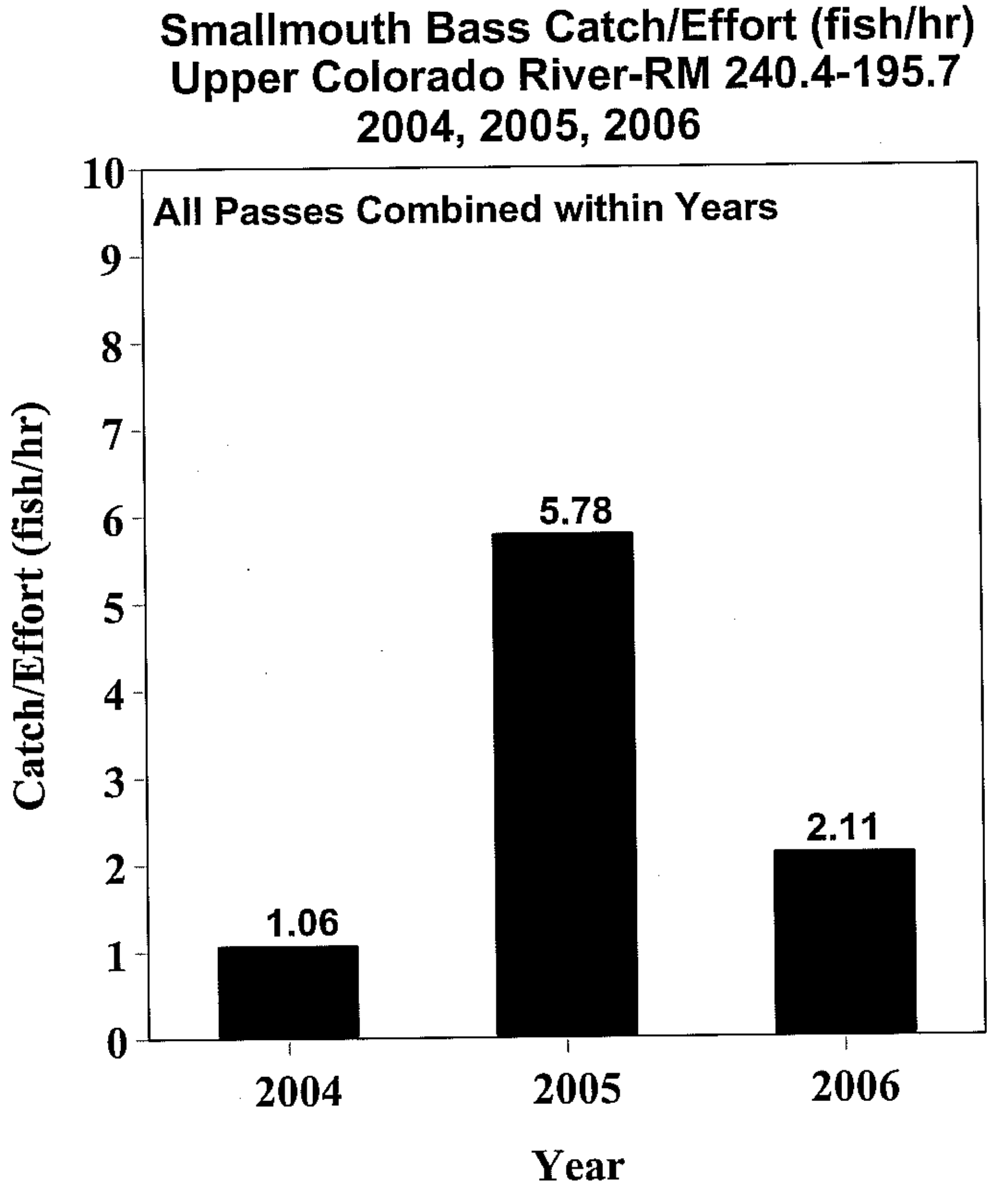

Figure 3. Comparison of catch/effort (fish/hr) for smallmouth bass (41–437 mm) collected with electrofishing from the Upper Colorado River between Rifle and Beavertail Mountain (RM 240.4–195.7) during 2004, 2005, and 2006.

to Corn Lake. The 2.3 miles of the Lower Gunnison River ranks fourth after 3 years which is no surprise because it is adjacent to the two highest concentration areas in the Upper Colorado River. However, during 2006 catch rate decreased in all river sub-reaches from 2005. Only one reach, GVIC to Corn Lake, retained its relative concentration rating of 'Moderately High'. The Colorado/Gunnison River confluence to Fruita State Park sub-reach fell from a 'Highest' to 'Medium' rating. The segment from Rifle to Beavertail Mountain and the Lower Gunnison River fell from 'Moderately High' to 'Moderately Low'. In 2005, the greatest increase in concentration was between Price-Stubb Dam to the GVIC Dam. However, in 2006 this reach fell from a rating of 'Highest' to 'Moderately Low' (Figure 4).

A notable increase in smallmouth bass abundance was recorded between the Rifle Bridge and Beavertail Mountain between 2004 and 2005. In 2004, 21 smallmouth bass were collected in this reach; 20 being collected in the 10.7-mile sub-reach between Rifle and Rulison. During 2005, 230 fish were collected in the 45-mile reach, an 11-fold increase from 2004. During 2005, 187 smallmouth bass were collected between the Rifle Bridge and Rulison. One hundred seventy two smallmouth bass (91%) were collected in a 3.8-mile reach immediately downstream from the Rifle Bridge. And of those 172 smallmouth bass, 90% (154) were captured in a large backwater/side channel habitat (RM 236.6) adjacent to where the Pioneer Irrigation Ditch empties into the Colorado River. Rifle Creek, which drains Rifle Gap Reservoir, empties into the Colorado River at RM 239.6 and the Pioneer Irrigation Ditch, which receives water from Rifle Creek in the town of Rifle, empties into the Colorado River at RM 236.9. Thus, this main channel backwater is in close proximity to the these two tributaries that receive water from Rifle Gap Reservoir which eventually drain into the Colorado River. Rifle Gap Reservoir has a smallmouth bass fishery. However, the number of smallmouth bass captured in main channel habitats in this 45-mile reach declined 66% (79 vs. 230) in 2006 from 2005. Abundance of smallmouth bass (all sizes) in the backwater where a majority of smallmouth bass were collected in 2005 (154 fish) declined precipitously (73%) in 2006 (41 fish).

Largemouth bass. Largemouth bass catch/effort during each of the four passes between Price-Stubb Dam and Westwater, Utah, and the Lower Gunnison River was: 3.38, 7.93, 10.37, and 7.16 fish/hr, respectively, for 2006. In 2005, catch/effort during each of the four passes in these same river reaches combined was: 4.26, 2.47, 3.36, and 2.99 fish/hr, respectively. During 2004, the same metrics were: 0.66, 0.50, 2.35, and 4.44 fish/hr, for each of the four passes (Appendix; Tables B.4–B.6.; Appendix; Figure B.1.). In 2006, the highest catch rate for

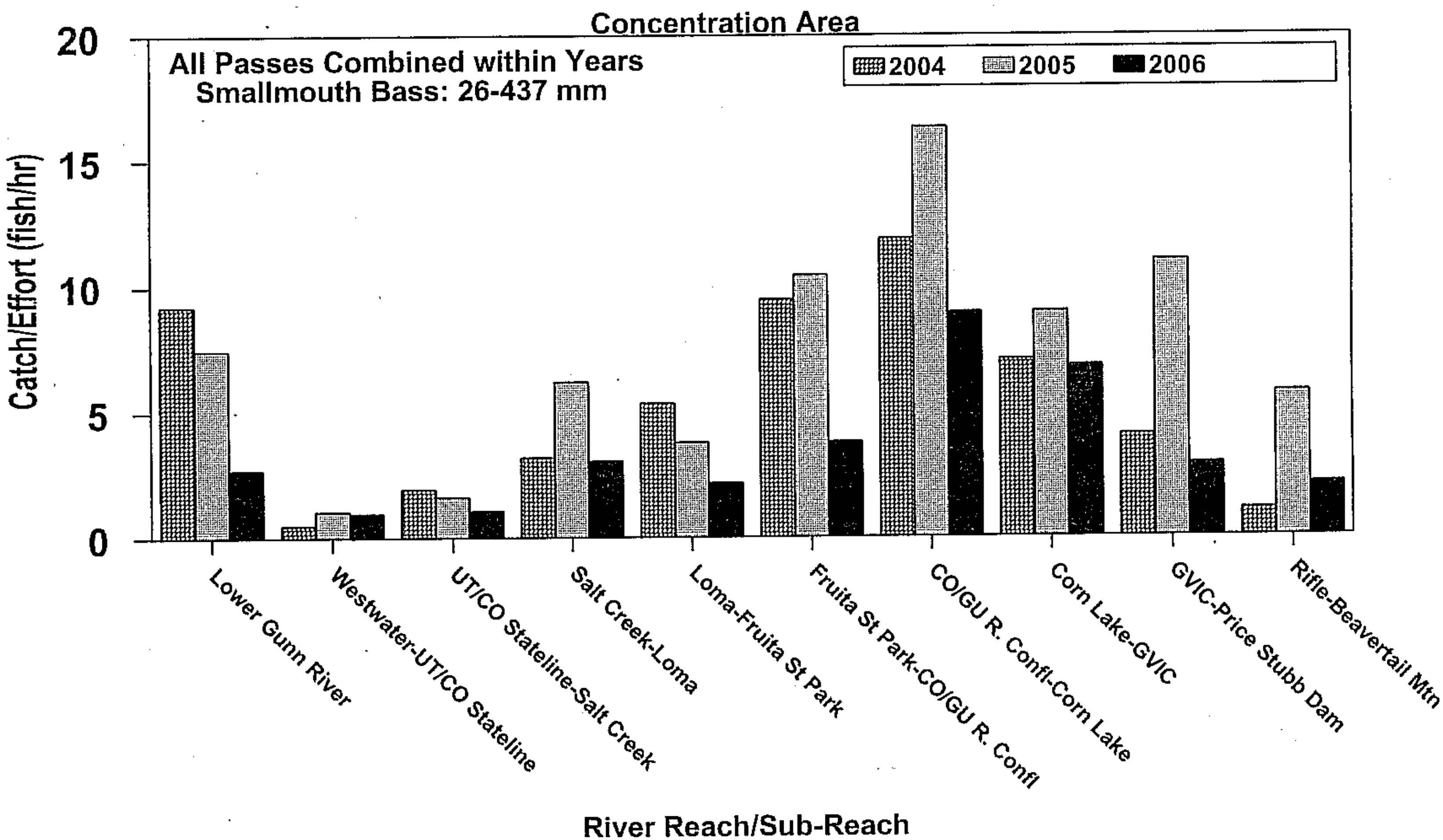

Figure 4. Catch/effort (fish/hr) comparison and concentration areas for all smallmouth bass (26–437 mm) collected in 10 different river reaches/sub-reaches of the Upper Colorado and Lower Gunnison rivers during the summer of 2004, 2005, and 2006. See Table 3 for actual values.

largemouth bass in main channel habitats was between Corn Lake and the Colorado/Gunnison River confluence (11.84 fish/hr; all passes combined) followed by the river reach between GVIC Dam and Corn Lake (9.90 fish/hr), and the segment between Fruita State Park and the Loma boat landing (8.45 fish/hr (Appendix; Table B.6.)). In 2005, the highest catch rate for largemouth bass in main channel habitats was between Fruita State Park and the Loma boat landing (8.19 fish/hr; all passes combined) followed by the river reach between Corn Lake and the Colorado/Gunnison River confluence (6.27 fish/hr), and the segment between the Colorado/Gunnison River confluence to Fruita State Park (4.53 fish/hr)(Appendix; Table B.5.). The highest abundance of largemouth bass was collected between the Colorado/Gunnison River confluence and Fruita State Park during 2004 (2.97 fish/hr)(Appendix; Table B.4.). Between Rifle and Beavertail Mountain largemouth bass catch rate increased in 2006 (5.62 fish/hr) from 2005 (0.95 fish/hr) and 2004 (3.29 fish/hr).

While smallmouth abundance decreased significantly during 2006, the direct opposite was apparent for largemouth bass. Therefore, in main channel habitats of the Colorado River in western Colorado and eastern Utah and the Lower Gunnison River in western Colorado during the summer of 2006, there was a significant increase in largemouth bass abundance (101% in catch/effort) from 2005. The 2006 largemouth bass abundance was also greater (312% in catch/effort) than 2004. Despite both bass species being lethally removed, largemouth bass numbers continued to increase in main channel habitats. The increase in largemouth bass during this 3-year removal period may have been attributed to young fish being produced and reared in off-main channel habitats, e. g., backwaters that were isolated or semi-isolated from the main channel during base flow (due to below-average flow conditions or dammed by beavers). During several consecutive low-water years associated with drought conditions in the early 2000s in the Upper Colorado River, many backwaters did not connect to the main channel in spring as in previous years and became year-round, isolated ponded backwaters. These habitats were more lacustrine-like and may have provided better habitat for centrarchids than more typical backwaters open to the main channel and generally devoid of vegetation. Hydrologic connection to the main channel occurred during spring runoff when they either became flow-through side channels or were either inundated at the mouth. Thus, largemouth bass could have infiltrated into main channel river habitats when higher spring flows returned (e. g., 2005). Irrigation waste water or overflow water from off-channel ponds that are unscreened that return to the river also are another means by which largemouth bass can immigrate to the main channel. These various lacustrine habitats could have and still may be providing a perpetual source of small (< 150 mm) largemouth bass emigrating to the main channel. Osmundson (2003) removed centrarchids twice annually (spring and fall) from backwaters from 1999–2001 in the Upper Colorado River from GVIC Dam to Westwater, Utah BLM ranger station. He concluded that there was no reach-wide depletive effect from one year to the next during this 3-year removal project for largemouth bass. In one backwater, he noted that there was no overall reduction during six samplings and that the total catch in the fall of 2000 increased 5 to 15 times that of the previous three samplings.

Green sunfish, Black Crappie, and Bluegill. For black crappie, bluegill, and green sunfish, the aggregate catch/effort steadily increased from pass 1 through pass 3 (17.27 fish/hr) but dramatically increased to 34.23 fish/hr during pass 4 in 2006 in the sub-reaches between Price-Stubb Dam and Westwater, Utah, and the Lower Gunnison River. During 2005, the same aggregate metric also steadily increased with each successive pass – 6.84, 6.12, 9.55, and 13.00 fish/hr. During 2004, fish/hr catches were 3.31, 2.29, 6.17, and 7.28 for passes 1–4, respectively (Appendix; Tables B.4.– B.6.).

The highest aggregate catch rate for black crappie, green sunfish, and bluegill during 2006 was between Fruita State Park and the Loma boat landing (38.28 fish/hr). Overall mean catch rates (all passes combined between Price-Stubb and Westwater, Utah, plus the Lower Gunnison River) indicate that between the summer of 2004 and summer of 2005 black crappie, bluegill, and green sunfish aggregate catch rate increased from 4.51 to 8.07 fish/hr. Therefore, catch rate for these three centrarchid fishes during 2005 exceeded that of the summer of 2004. In 2006, black crappie, bluegill, and green sunfish aggregate catch rate also increased to a 3-year high of 10.94 fish/hr.

The overall mean catch/effort for each of the four passes for each of the three years was graphed for green sunfish, black crappie, and bluegill collected between Price-Stubb Dam and Westwater, Utah, and the Lower Gunnison River (Appendix; Figures B.2.–B.4.). For green sunfish and bluegill as passes proceeded through each of the 3 years, catch rates generally increased. However, catch rate decreased during pass 4 in 2006 for green sunfish. For black crappie, catch rates were highest during the later passes and highest during pass 4 in 2005 and 2006. In 2004, catch rate declined during passes 3 and 4. Catch/effort for each of these three centrarchid fishes was highest in 2006.

Between Rifle and Beavertail Mountain, green sunfish catch/effort increased from 13.1 fish/hr to 15.2 fish/hr from 2005 to 2006. Numbers of bluegill and black crappie were few and therefore were insignificant in this 45-mile reach during all three years (see 'Numbers of Individual Fish Species' section above for numbers of these species).

Population Estimates/Projections

Smallmouth Bass. A total of 131 smallmouth bass ranging from 66 to 394 mm total length were marked and released alive between the GVIC Diversion Dam and the Loma boat landing and 2.3 miles of the Lower Gunnison River (Table 4). Eight smallmouth bass (202–372 mm) were later recaptured in subsequent passes. Six of these fish were recaptured in pass 1, one each in passes 2 and 3; no fish were recaptured in pass 4. All eight of the marked smallmouth bass were recaptured within the original marking reaches. Two smallmouth bass were recaptured in the 15-mile reach, five in the 18-mile reach, and one in the Lower Gunnison River.

The population estimate generated was for the 15- and 18-mile reaches of the Colorado River and 2.3 miles of the Lower Gunnison River downstream from Redlands Diversion Dam (total=35.3 miles). Four different estimates were calculated: 1a) all smallmouth bass sizes (41–394 mm), using smallmouth bass recaptured from pass 1 only, 1b) all smallmouth bass sizes (41–394 mm), using smallmouth bass recaptured from passes 1, 2, and 3; 2a) only smallmouth bass ≥100 mm, using smallmouth bass recaptured from pass 1 only, and 2b) only smallmouth bass ≥100 mm, using smallmouth bass recaptured from passes 1, 2, and 3 (Table 5). Since smallmouth bass < 100 mm, which mostly represented young-of-the-year fish, were not available to sampling during the marking pass, the abundance estimate which did not include fish < 100 is probably the better population estimate for the smallmouth bass population. Using recaptured smallmouth bass from pass 1 only and smallmouth bass ≥ 100 mm, the population point estimate (95% C.I. in parenthesis) was 3,197 (1,097–5,297). This was the preferred and final population estimate reported on in this study. The probability of capture (p-hat) was computed as 0.033; the CV: 33.5%. This translated to 31.1 to 150.1 fish/mile (mean=91). Using recaptured smallmouth bass from passes 1, 2, and 3 and smallmouth bass ≥100 mm, the population point estimate was elevated to 5,247 (2,152–8,342). The probability of capture (p-hat) was computed as 0.021; the CV: 30.1%. The CV can be used as a measure of estimate precision and Pollock et al. (1990) suggests a good 'rule of thumb' is to achieve a CV of 20% or less. This level of precision was never met in any of the four abundance estimates computed for smallmouth bass during 2006.

Table 4. Number and size of smallmouth bass and other centrarchids captured during the marking pass during July 2006 in main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado. Note: n/s = not sampled.

River (River Miles) River Segment	Marking Pass Number of Fish Smth Bass	Total Length (mm)	Lrgth Bass	Black Crappie/ Green Sunfish/ Bluegill
Colorado River (RM 187.7–127.6)				
Price-Stubb ▸ GVIC Dam	n/s		n/s	n/s
GVIC Dam ▸ Corn Lake	15	151–353	33	14
Corn Lake ▸ Colo/Gunn River Confluence	41	88–394	29	16
Colo/Gunn R. Confl. ▸ Fruita State Park	45	104–298	15	65
Fruita State Park ▸ Loma Boat Landing	25	66–328	9	35
Loma Boat Landing ▸ Salt Creek Wash	n/s		n/s	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	n/s		n/s	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	n/s		n/s	n/s
Lower Gunnison River (RM 3.0–0.7)				
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	5	168–314	0	29
Totals	131		86	159

Table 5. Population point estimates with 95% confidence intervals (C.I.) for smallmouth bass for the 15- and 18-mile reaches (RM 185.3 to 152.6) of the Upper Colorado River and 2.3 miles of the Lower Gunnison River (Redlands Diversion Dam to the Colorado/Gunnison River confluence) for the summer of 2006, and the projected percentage of smallmouth bass removed annually by electrofishing relative to the 95% population interval. Chapman's (1951) modification of the Petersen-Lincoln estimator was used to determine the abundance of smallmouth bass; probability of capture determined from White et al. (1982). Coefficient of variation (CV = SE/N x 100) from Pollock et al. (1990). Note: **bolded** figures is the preferred and final population estimate reported on.

Smallmouth Bass–All Fish (41-394 mm)									
		Pass No. 1 Only					Pass Nos. 1, 2, & 3		
Pop Est	95% C.I.	Total No. of Fish Removed	Total Recaps	% of fish removed annually [a]	Pop Est	95% C.I.	Total No. of Fish Removed	Total Recaps	% of fish removed annually [a]
3,789	± 2,511	200	6	3.8–15.6%	8,300	± 4,927	565	8	4.3–16.8%
probability of capture: 0.03		CV: 33.8%			probability of capture: 0.014			CV: 30.3%	

Smallmouth Bass ≥ 100 mm									
		Pass No. 1 Only					Pass Nos. 1, 2, & 3		
Pop Est	**95% CI**	**Total No. of Fish Removed**	**Total Recaps**	**% of fish removed annually**	Pop Est	95% C.I.	Total No. of Fish Removed	Total Recaps	% of fish removed annually [a]
3,197	**± 2,100**	**181**	**6**	**3.4–16.5%**	5,247	± 3,095	383	8	4.6–17.8%
probability of capture: 0.033		**CV: 33.5%**			probability of capture: 0.021			CV: 30.1%	

[a] Calculated from the actual number of smallmouth bass removed, point estimate, and 95% C.I.

	No. of Smallmouth Bass [a]			
Pass Type & No.	All Fish (41-394 mm)	≥ 100 mm	< 100 mm	Marked Recaps
Marking Pass	131	122	9	- -
Removal Pass No. 1 [b]	200	181	19	6
Removal Pass No. 2 [b]	152	96	56	1
Removal Pass No. 3 [b]	213	106	107	1
Total	565	383	182	8
Removal Pass No. 4 [c]	109	53	56	0

[a] Includes captures and recaptures of smallmouth bass in the Upper Colorado River from river mile 185.3–152.6 (15- and 18-mile reaches) and Lower Gunnison River from river mile 3.0—0.7.

[b] Two electrofishing craft used.

[c] One electrofishing craft used; "concentration removal pass" (not used in population estimate).

A population estimate serves as a baseline for any future abundance estimation comparisons. Periodic population estimates are necessary to assess the size of nonnative fish populations and the effectiveness of removal. One other useful tool from this exercise is that one can calculate the percentage of fish removed annually or exploitation rate (i. e., how efficient are we at mechanical removal) from the total population estimated using the actual number of fish removed, the point estimate, and 95% C.I.s. For example, 181 smallmouth bass ≥100 mm were actually removed during pass 1. We then removed as few as 3.4% (181/5,297: upper limit of the 95% C.I) or as many as 16.5% (181/1,097: lower limit of the 95% C.I.) of the estimated population. The percentage removed using the point estimate would simply be 5.7% (181/3,197) (Table 5). The 2006 population estimate was used to project population abundance for smallmouth bass (≥ 100 mm) in 2004 and 2005 in the same river sub-reaches (Table 6). Overall catch effort for 2006 was 3.33. The 2005 catch/effort was 2.55 times greater than 2006; the 2004 catch/effort was 2.53 times greater than 2006 (Figure 5). The abundance estimate with 95% C.I. projected for 2004 and 2005 was 8,088 ± 5,313 and 8,152 ± 5,355 individuals ≥100 mm, respectively (Figure 6). The number of fish/mile was estimated at 78.6 to 379.6 and 79.2 to 382.6 for 2004 and 2005, respectively (Table 6).

Size Distribution – Length Frequency

Smallmouth Bass

Changes in size (i. e., length) have been used to detect changes in age composition of a fish population over time. Length-frequency distributions provide an important description of population structure (Anderson and Gutreuter 1985). In this instance, we are looking for an index that could reliably be used to detect changes in the overall size [age] structure of smallmouth bass in designated river segments over time. Size structure changes over time then could be used to evaluate whether mechanical removal is reducing the numbers of a particular size [length] group, and therefore, if this technique could be recommended as an effective management tool for removal or to detect failure of year classes.

Length-frequency distribution of all sizes of smallmouth bass collected with electrofishing during 2004, 2005, and 2006 between Price-Stubb Dam and Westwater, Utah, and the Lower Gunnison River was plotted (Figure 7) and for the 45-mile reach between Rifle and Beavertail Mountain (Figure 8). The mean total length and 95% C.I. were calculated for smallmouth bass for all passes combined for five different river segments for 2004, 2005, and

Table 6. Smallmouth bass population projections for 2004 and 2005 extrapolated from the 2006 catch/effort and population estimate. The river segments included the 15- and 18-mile reaches of the Upper Colorado River (GVIC Dam to the Loma boat landing) and the 2.3 miles of the Lower Gunnison River (Redlands Dam to the Colorado/Gunnison River confluence). Note: the number of river miles is 35.3.

Year	No. of Smth Bass ≥ 100 mm Removed [a]	Effort (hrs)	Catch/Effort (fish/hr)	Catch/Effort Multiplier from 2006 [b]	Abundance Estimators (Smth Bass ≥ 100 mm) Population Estimate or Projection w/95% C.I.	Fish/Mile
2006	443	132.968	3.33	---	1,097–3,197– 5,297 [c]	31.1– 90.6–150.1
2005	974	114.655	8.50	2.55X	2,797–8,152–13,507[d]	79.2–230.9–382.6
2004	959	113.973	8.41	2.53X	2,775–8,088–13,401[d]	78.6–229.1–379.6

[a] Four removal passes used to compute catch/effort.

[b] Multiplier used to project population estimate.

[c] One mark and release pass plus one removal pass used to compute population estimate for 2006.

[d] Population projection.

2006 (Figure 9). This analyses was performed to determine if there had been any change (increase or decrease) in the length structure of the smallmouth bass captured over the four passes among 2004, 2005, and 2006. During 2006, overall mean total length increased in four river segments: Westwater, Utah, to the Loma boat landing, Loma boat landing to the Colorado/Gunnison River confluence, Lower Gunnison River, and Beavertail Mountain to Rifle (Figure 9). In three of these four river segments there was a statistically significant increase ($\propto$=.05) in the mean total length of smallmouth bass captured between 2006 and 2005. In only one segment did the overall mean total length decline: Colorado/Gunnison River confluence to Price-Stubb Dam; but the size decline was not statistically significant ($\propto$=.05)(Figure 9). This

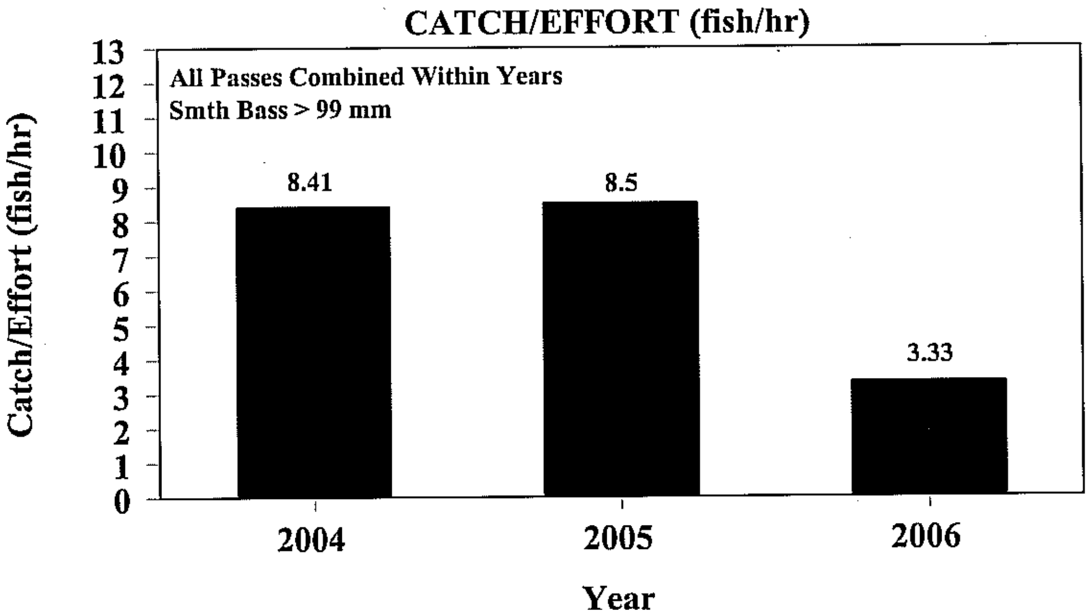

Figure 5. Comparison of overall catch/effort (fish/hr) for smallmouth bass (≥100 mm) with electrofishing from the 15- and 18-mile reaches of Upper Colorado River (RM 185.3.8–152.6) and the Lower Gunnison River (RM 3.0–0.7) during 2004, 2005, and 2006. Note: all passes combined within years. See Table 6.

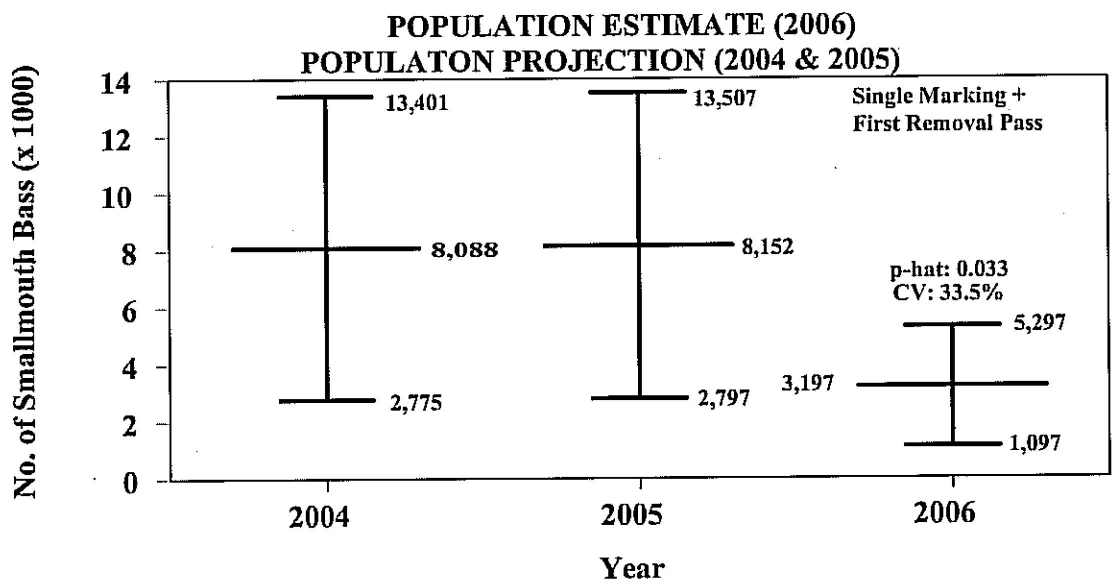

Figure 6. Population point estimate (2006) and projections (2004, 2005) with 95% confidence intervals for smallmouth bass (≥ 100 mm) for the 15- and 18-mile reaches of the Upper Colorado River (RM 185.3–152.6) and the Lower Gunnison River (RM 3.0–0.7). See Table 6.

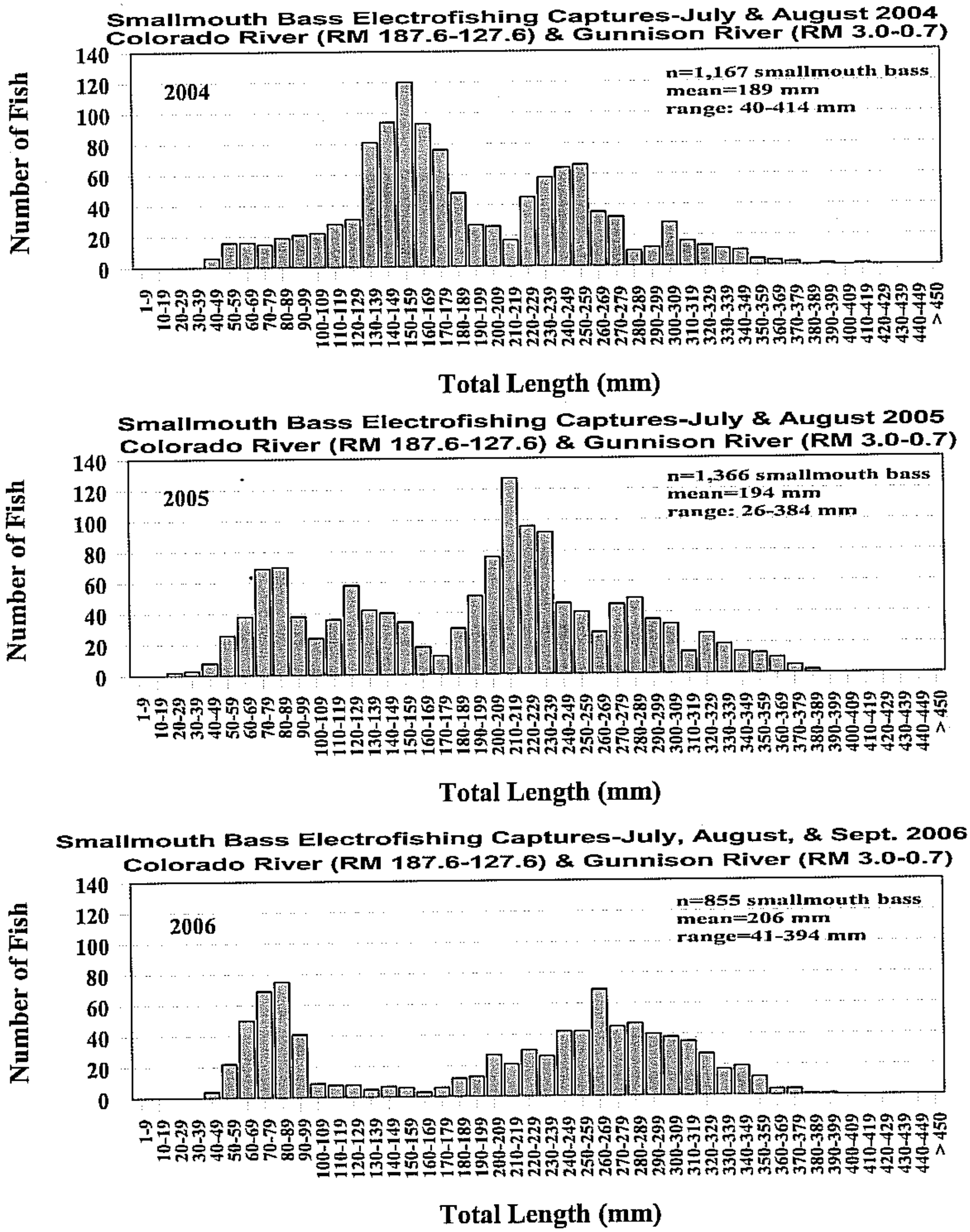

Figure 7. Total length frequency for all smallmouth bass (26–414 mm) collected during the summer of 2004, 2005, and 2006, with electrofishing in the Upper Colorado River (RM 187.8–127.6) and the Lower Gunnison River (RM 3.0–0.7).

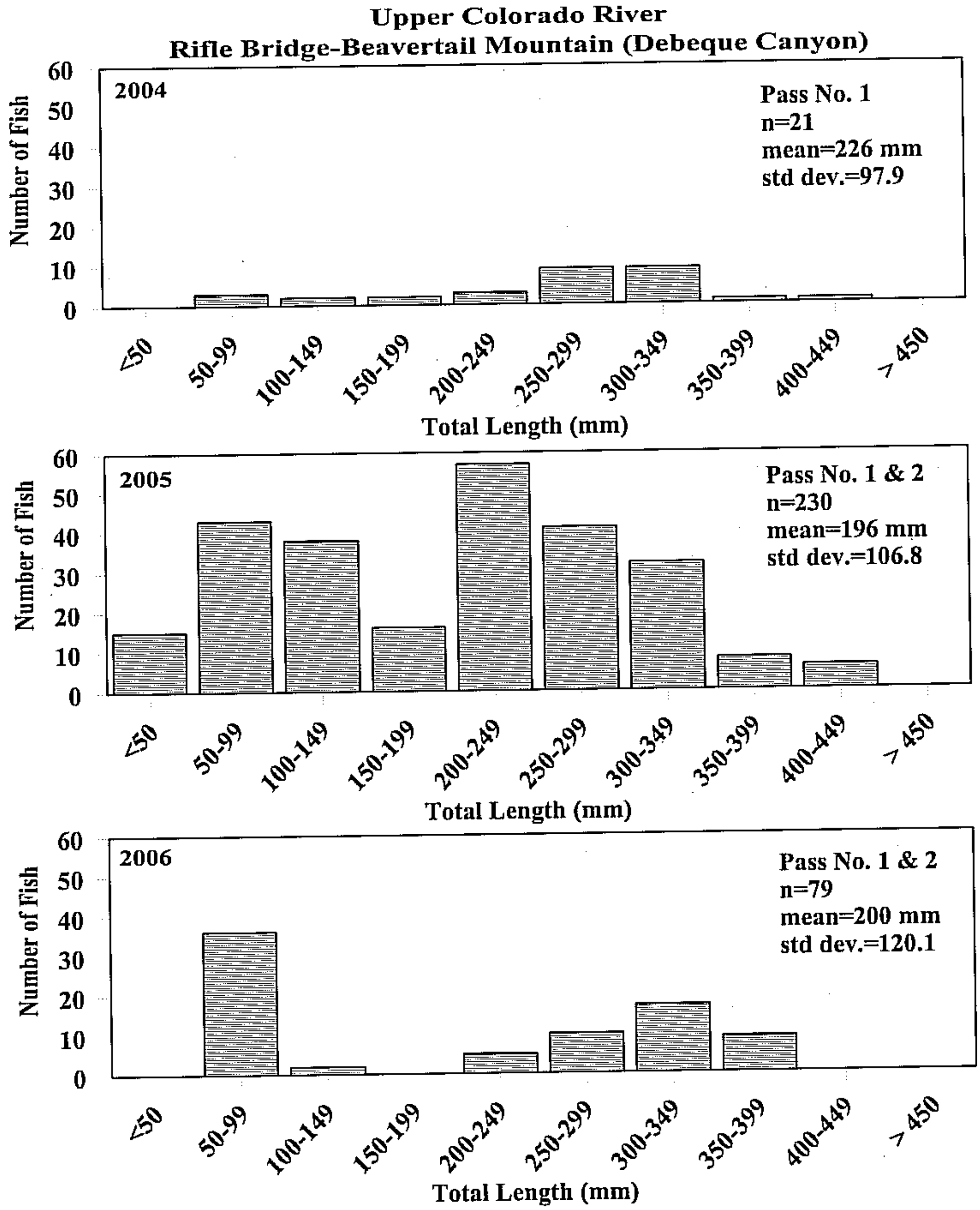

Figure 8. Total length frequency comparison of all smallmouth bass (41–437 mm) collected with electrofishing between Rifle and Beavertail Mountain in Debeque Canyon (RM 240.4–195.7) in the Upper Colorado River, late August 2004, mid-July 2005, and mid-July and mid-September 2006.

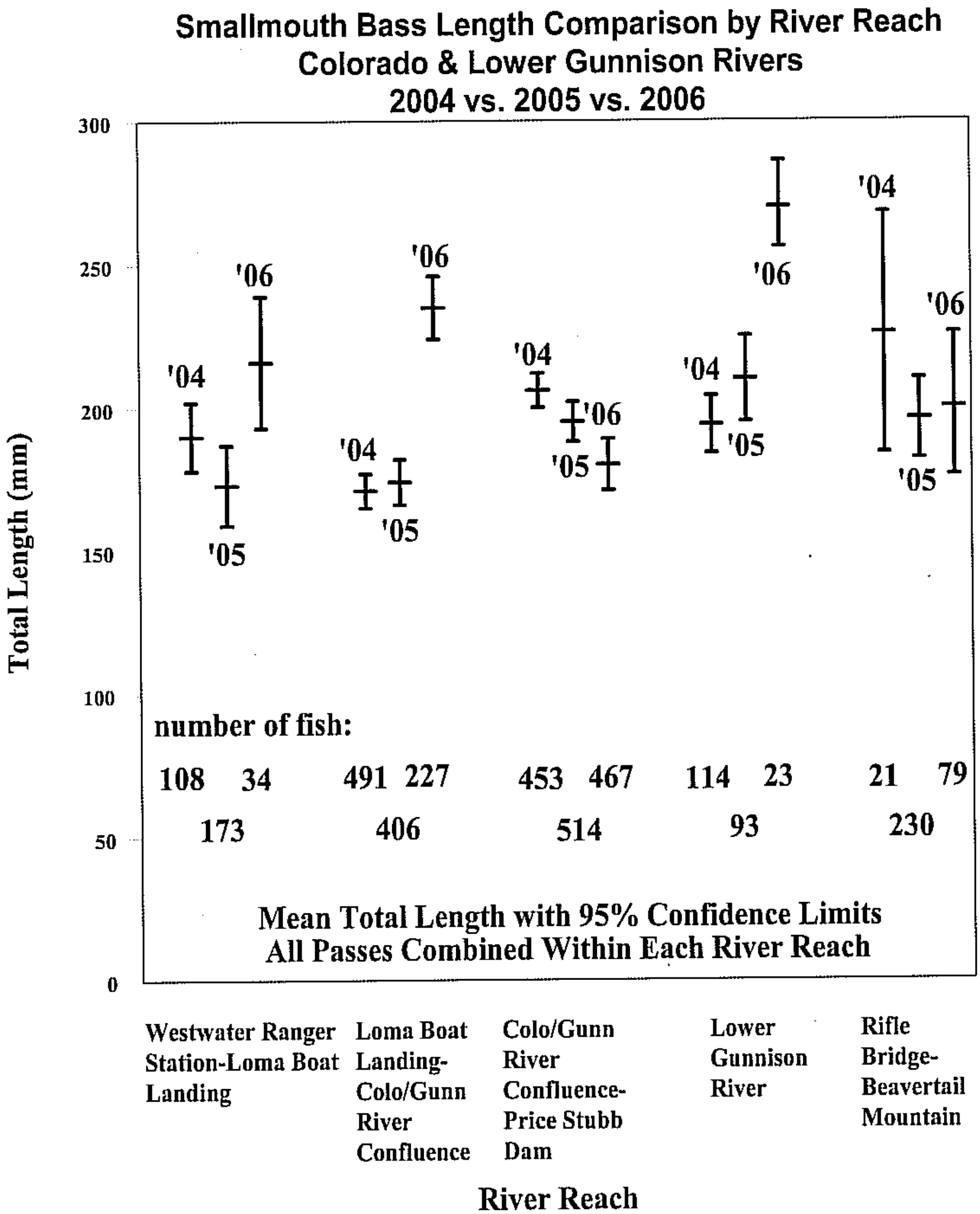

Figure 9. Comparison between the mean total length and 95% confidence interval for smallmouth bass collected with electrofishing from five major river segments on the Colorado and Gunnison rivers during the summer of 2004, 2005, and 2006. The mean is the middle horizontal line; the 95% confidence intervals are represented by the error bars (┬ ┴).

increase in average size is most probably due in part to the lack of or absence of smallmouth bass catches between 100 and 180 mm in the Grand Valley reaches of the Colorado River during 2006. In viewing the 2005 length frequency, it appears that the size group of smallmouth bass between 50 and 100 mm was lost to the population sometime between the winter of 2005/2006 and summer sampling during 2006, or simply were not captured in 2006. There did not appear to be a lack of young-of-the-year smallmouth bass produced in 2005; the numbers appeared to be even greater than those produced during 2004. In any event, size classes of smallmouth bass represented by young-of-the-year and slowing growing age-1 smallmouth bass in 2005 did not recruit to the next size classes as their numbers obviously declined during the summer of 2006. The exact reason for this is unknown. It can be speculated that this size group of smallmouth bass may have been lost prior to high spring runoff and had experienced high overwinter mortality or were lost during the 2006 spring runoff (see later section on 'Annual Abundance of Early-Life Smallmouth Bass Related to Stream Discharge and Water Temperature').

It is also apparent that the number of smallmouth bass within all size groups in 2006 declined from 2004 and 2005. Overall, 3-year catches of smallmouth bass in all sub-reaches were the lowest in 2006. With no certainty can this decline be directly attributed to mechanical removal. However, if the decline was related to an environmental event (e. g., high stream discharges, lower water temperatures), it would be desirable to be able to identify and attempt to mimic that event and utilize that condition to our advantage to continue to reduce smallmouth bass populations. All groups of smallmouth bass (young-of-the-year, juveniles, and adults) were represented in the collections in the summer of 2004, 2005, and 2006. In 2004, smallmouth bass ranged from young (~ 50 mm) to adult (414 mm) fish. During 2005, smallmouth bass ranged from young (26 mm) to adult (437 mm) fish. During 2006, smallmouth bass ranged from young (42 mm) to adult (394 mm) fish.

In addition to the length frequency histograms, the number of smallmouth bass collected for marking and removal passes by seven length categories was tallied for 2004, 2005, and 2006, for the Grand Valley river reaches. The percentage of the smallmouth bass collected was also computed to directly compare numbers collected among the three years because an additional pass (marking) was added in 2006. Unlike largemouth bass collected in main channel riverine habitats of the Grand Valley where a vast majority (~ 90%) of the fish collected were < 150 mm, the length classes for smallmouth bass were more proportionately represented (Appendix; Tables C.1. and C.2.). For example, in 2006, 42.9 % of all smallmouth bass collected in the Grand Valley reaches were ≥255 mm, 15.1 % were ≥306 mm, and 1.4 % were ≥357 mm. Of the total smallmouth bass in 2006 (n=881), 57.1 % were < 255 mm and 29.6 % were < 100 mm. The number of 'trophy-size' (≥255 mm [10-inch]) smallmouth bass collected has increased each year since 2004, being greatest in 2006 some of which could be attributed to the increased removal pass in 2006. The number of smallmouth bass ≥306 mm (232; 10.7%), ≥357 mm (41; 1.9%), and ≥406 mm (4; 0.2%) was greatest in 2006.

For the Silt to Beavertail Mountain reaches, the number of smallmouth bass collected from the removal passes by the same seven length categories was also tallied for 2004, 2005, and 2006 (Appendix; Table C.3.). Because the number of removal passes have been increased steadily from 2004 (n=1) to two removal passes each in 2005 and 2006, comparison of numbers collected among years is more difficult. However, there is one apparent similarity with the downstream Grand Valley reaches: the number of 'trophy-size' smallmouth bass relative to the total number collected were well represented in collections in these upper reaches. For example, a 3-year relative average of smallmouth bass ≥255 mm was 40.1 % (132 of 329 total smallmouth bass) and smallmouth bass ≥306 mm was 19.8 % (65 of 329 fish). About 5 % (n=17) were ≥357 mm.

There is one dissimilarity between these upper reaches and the Grand Valley reaches. In the upper reaches, the number of smallmouth bass < 255 mm collected during 2004–2006 was less than that of the Grand Valley reaches. For example, the three-year relative average of smallmouth bass < 255 mm in the upper reaches was 50.2 % (165 of 329 total smallmouth bass) compared to 68.1 % (2,430 of 3,567 total smallmouth bass) in the Grand Valley reaches.

In the Rifle to Beavertail Mountain reach, apparent was the lack or even absence of smallmouth bass between 100 and 200 mm in 2006, similar to that observed in the Grand Valley reaches of the Colorado River (Figure 8). Also, it was apparent from collections, that in some river segments (15-mile reach [GVIC Diversion Dam to the Colorado/Gunnison River confluence], 18-mile reach [Colorado/Gunnison River confluence to the Loma boat landing], and Rifle to Beavertail Mountain), smallmouth bass reproduced during 2004, 2005, and 2006. It cannot be proven if these fish were produced in the river, or in off-channel habitats (e. g., ponds or irrigation returns that connect to the main river) and later migrated to the river.

Largemouth Bass

While largemouth bass were not the focus of this study, total length was recorded for all largemouth bass collected and removed during this study because there was interest in the location and distribution of 'trophy size' (≥254 mm total length) largemouth bass in main channel river habitats. Furthermore, if enough trophy-size largemouth bass could be located, there was consideration for re locating these sizes of fish alive to other Colorado waters to provide additional sport fishing opportunities. Length-frequency distribution of all sizes of largemouth bass collected with electrofishing during 2004, 2005, and 2006 between Price-Stubb Dam and Westwater, Utah, and the Lower Gunnison River (Figure 10) and for the 45-mile reach between Rifle and Beavertail Mountain were plotted (Figure 11).

A high percentage (85% between Rifle and Beavertail Mountain; 90% between Price-Stubb Dam and Westwater, Utah) of all largemouth bass captured in both major portions of the Upper Colorado and Lower Gunnison rivers were comprised of fish less than 150 mm total length. From Rifle to Beavertail Mountain, of the total 314 largemouth bass collected in this 45-mile reach, only 8% (25 fish) were greater than 254 mm in 2004, 2005, and 2006. Twelve largemouth bass were ≥ 305 mm. Sixty percent of all largemouth bass were < 100 mm and 92% were < 254 mm. Sixty-four percent (16 of 25) of all largemouth bass ≥254 mm total length in 2004, 2005, and 2006 were caught at RM 236.6, a large backwater located on the south side of the Upper Colorado.

Between Price-Stubb Dam and Westwater, Utah, and the 2.3 miles of the Lower Gunnison River during 2004, 2005, and 2006, a total of 2,033 largemouth bass were captured. Of this number, only 3% (59 fish) were ≥254 mm. Thirty-six largemouth bass were ≥305 mm. Sixty-two percent of all largemouth bass were < 100 mm and 92% were < 254 mm. Thirty-seven of the 59 (63%) largemouth bass ≥ 254 mm collected during 2004, 2005, and 2006 were caught between Corn Lake (RM 177.4) and Redlands Parkway (RM 166.8) and between Fruita State Park (RM 157.2) and the Loma Boat Landing (RM 152.6). Skipper's Island backwater (RM 154.0) consistently had high densities of largemouth bass ≥254 mm during 2005 and 2006. In 2006, of the eight largemouth bass ≥ 254 mm total length captured between Fruita State Park and the Loma Boat Landing, seven (mean = 367 mm, 299–420 mm) were caught in the Skipper's Island backwater. In 2005, of the 14 largemouth bass caught between Fruita State Park and the Loma Landing that were ≥ 254 mm, 13 (mean = 343 mm, 259–340 mm) were caught in this

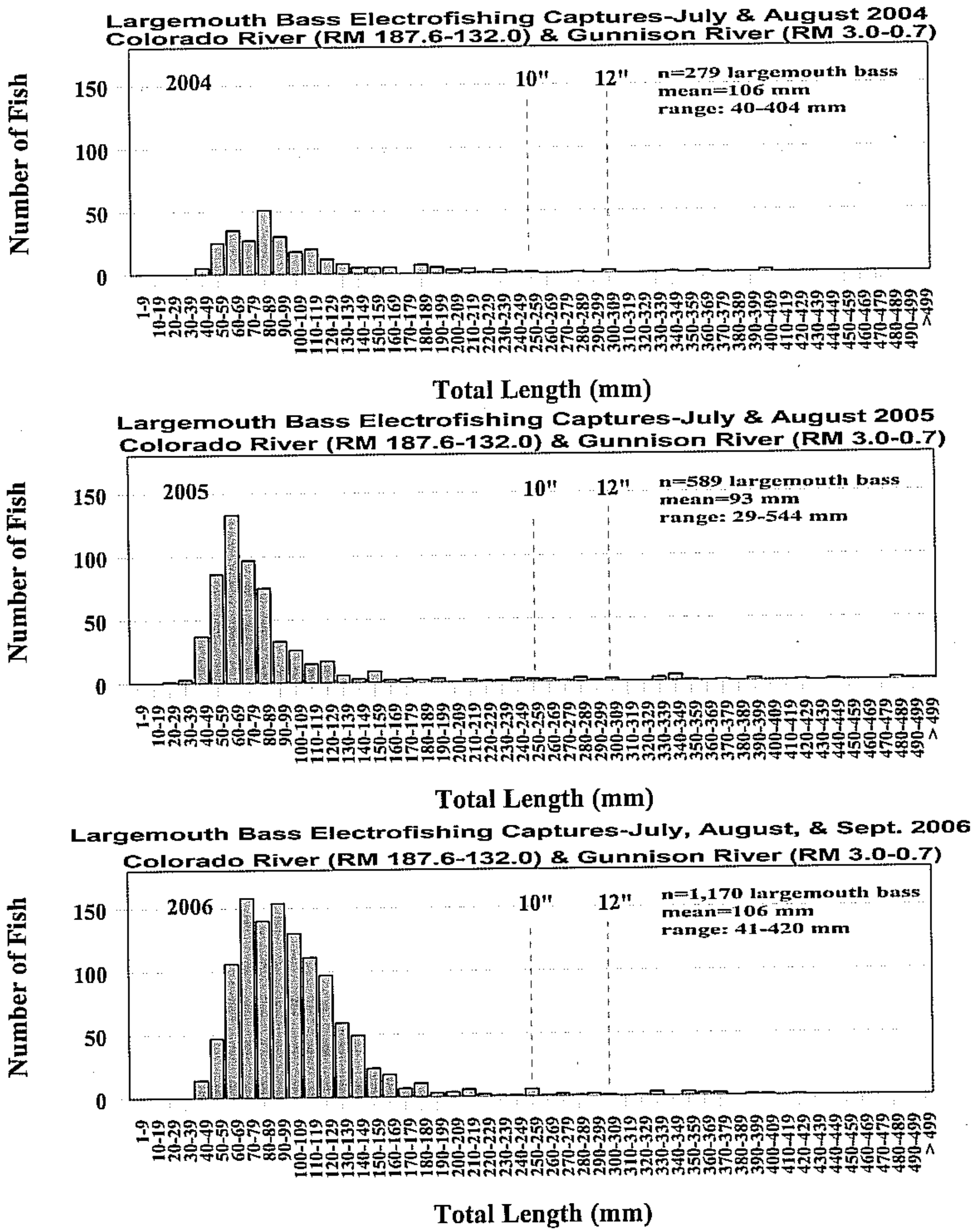

Figure 10. Total length frequency for all largemouth bass (29–544 mm) collected during the summer of 2004, 2005, and 2006, with electrofishing in the Upper Colorado River (RM 187.8–127.6) and the Lower Gunnison River (RM 3.0–0.7).

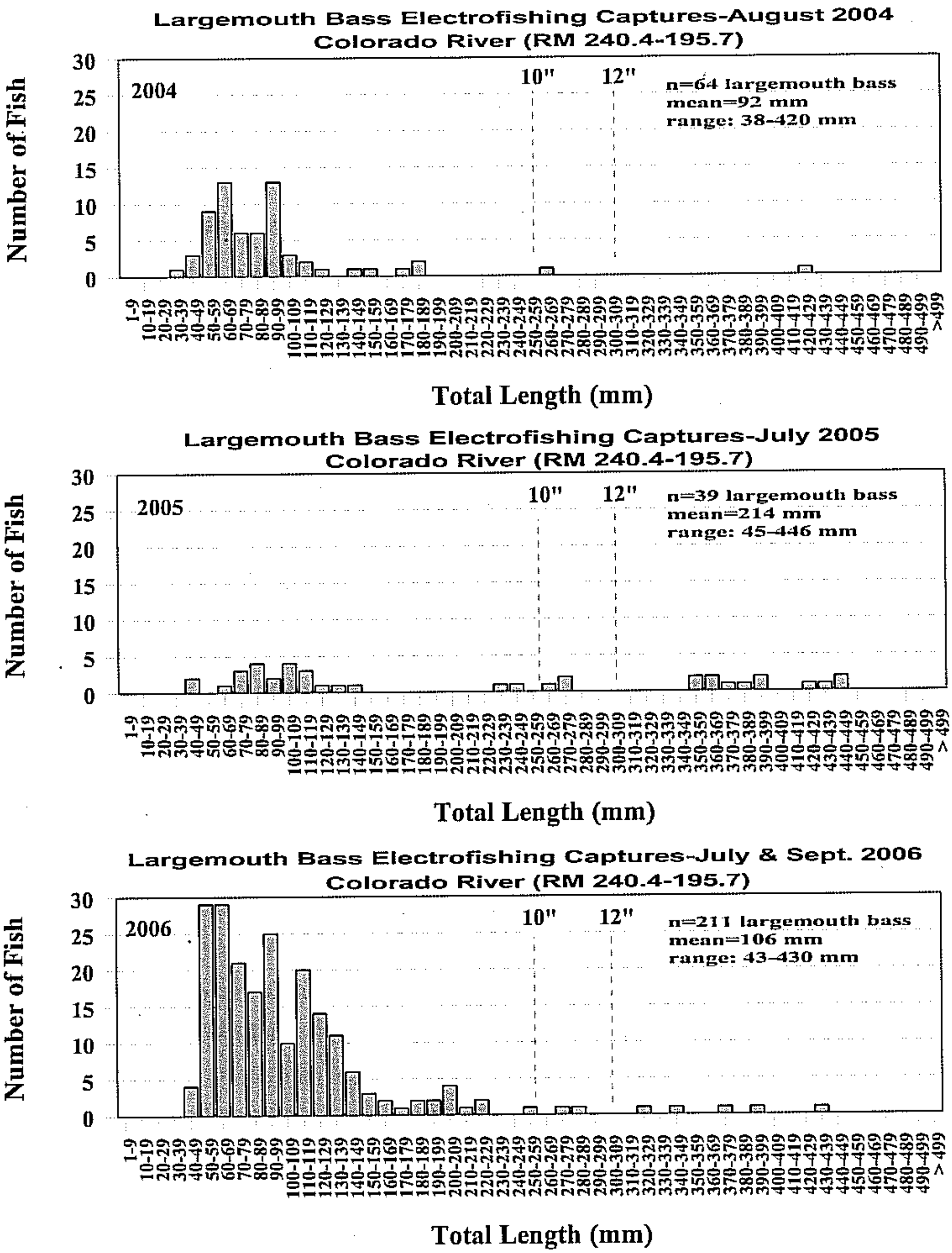

Figure 11. Total length frequency comparison of all largemouth bass (38–430 mm) collected with electrofishing between Rifle and Beavertail Mountain in Debeque Canyon (RM 240.4–195.7) in the Upper Colorado River, late August 2004, mid-July 2005, and mid-July and mid-September 2006.

backwater. In 2004, no largemouth bass ≥254 mm were caught in the Skipper's Island backwater.

Hydrology and Water Temperature

Hydrology

In the Upper Colorado River several years of high flow between 1995 and 1999 were followed by five consecutive years of low flows between 2000 and 2004, 2002 being the lowest (Appendix; Figure D.3.). The annual mean stream discharge in 2005 was the highest since 1999 and mean annual stream discharge in 2006 was slightly less than 2005. The 2005 calendar year was marked by two distinct discharge peaks, the first in mid-May (Cameo: 17,200 cfs on May 24; stateline: 31,000 cfs on May 25) and the second in mid-June (Cameo: 13,200 cfs on June 24; stateline: 17,700 cfs on June 24)(Appendix; Figures D.4. and D.6.). Two peaks also occurred during 2006, but of less magnitude than those of 2005, the first occurring at almost the same period as that in 2005. The second peak in 2006 occurred on June 6 (12,600 cfs) at Cameo which was 18 days earlier than 2005; at stateline the second peak occurred on June 10 (14,900 cfs) which was 14 days earlier than 2005. The duration of both peaks in 2006 was shorter than that observed in 2005. A single peak was observed at both Cameo (21,000 cfs on June 2) and stateline (26,100 cfs on June 3) during 2003 (Appendix; Figures D.4. and D.5.). There was virtually no peak observed in either 2002 or 2004. At the Palisade USGS gauge located at the head end of the 15-mile reach, as expected, the same stream flow pattern mimicked that of the upstream gauge at Cameo and downstream gauge at stateline (Appendix; Figure D.5.).

The seven water years (calendar) between 2000 and 2006 were ranked from highest to lowest using annual mean stream discharge at the Utah–Colorado stateline gauge. This descending order by calendar water year was: 2005, 2006, 2000, 2001, 2003, 2004, and 2002 (Appendix; Figure D.3.). Using the hydrologic categories (wet, average and moderately wet, average and moderately dry, and dry) developed by McAda (2003) at stateline, 2002 was considered a dry or drought year, and the remaining five years fell into the average and moderately dry category (Appendix; Figure D.3.).

Water Temperature

Degree days (≥ 14 °C) at both Cameo (443.7) and stateline (692.0) were lowest in 2005 and greatest during 2002 (749.7 at Cameo; 1,023.4 at stateline)(Appendix; Tables D.1. and D.2.; Figures D.1. and D.2.). The first date that the water temperature equalled or exceeded 14 ° C varied each year. At Cameo, the earliest 14 ° C was reached was April 27 during 2004. During 2005, which was the highest flow year during the study, the first date that water temperature reached 14 ° C occurred the latest of any of the years: June 15 (Appendix; Figure D.1.). At stateline, the earliest water temperature 14 ° C was observed was in 2004 (March 23). Similar to Cameo, in 2005, 14 ° C was first attained the latest of any of the five years analyzed: May 20 (Appendix; D.2.). The total number of days the water temperature equalled or exceeded 14 ° C was highest in 2002 at Cameo (139). At stateline, the highest number of days this occurred was in both 2002 and 2004 (169 days). For 2004 and 2006, at Cameo, an anomalous and unexplainable situation was obvious. At Cameo, the mean annual discharge for the entire year from April 1 to October 1 (considered the growing season for warm water fish) during 2004, was considerably less (~ 40 %) than the same period for 2006. However, both degree days and the number of days water temperature equalled or exceeded 14 ° C were greater during 2006 than 2004. Just the opposite occurred at stateline. At stateline, the number of degree days and days the water temperature equalled or exceeded 14 ° C was what one would expect: 2004 had a greater number of degree days (870.2) and days equalling or exceeding 14 ° C (169) than 2006 (749.4 and 132 days).

The five water years between 2002 and 2006 were ranked warmest to coolest using total degree days (1 April to 1 October) at the Utah–Colorado stateline gauge. This descending order by calendar water year was: 2002, 2003, 2004, 2006, and 2005 (Appendix; Table D. 2.).

Annual Abundance of Early-Life Smallmouth Bass
Related to Stream Discharge and Water Temperature

Smallmouth bass between 100 and 180 mm were noticeably less abundant in the catches during the summer of 2006 than 2004 and 2005 in the Grand Valley sub-reaches of the Colorado River (Figure 7). In the Rifle to Beavertail Mountain segment, apparent was the lack or even absence of smallmouth bass between 100 and 200 mm, similar to that observed in the Grand Valley sub-reaches of the Colorado River. There did not appear to be a lack of young smallmouth bass produced in 2005; the numbers appeared to be even greater than those produced during 2004. In viewing the 2005 length frequency, it appears that the size group of smallmouth bass between 50 and 100 mm produced in 2005 were lost to the population sometime between the winter of 2005/2006 and the summer of 2006. This size class of smallmouth bass may have experienced high overwinter mortality and were lost prior to high spring runoff or were lost during the 2006 spring runoff. In any event, age-0 and possibly some slower growing age-1 smallmouth bass in 2005 did not recruit to the next size classes and their numbers obviously declined prior to the summer of 2006. The exact reason for this decline is unknown. During this study, there was no sampling performed in the spring following the winter months or prior to the spring runoff to assess the abundance of age-1 smallmouth bass. Therefore, it can only be speculated as to the fate of this size class of smallmouth bass.

The rapid increase of the smallmouth bass population in the Yampa River between 2000–2004 was believed, in part, attributed to several consecutive years of drought conditions that brought about habitat changes in the form of altered flows (i. e., reduced spring discharge in duration and magnitude followed by lower than average post-runoff flows) and warmer water temperatures. Warmer water and lower and earlier flow peaks could result in earlier bass spawning, longer growing season, and increased growth rates. Increased size of age-0 smallmouth bass in the summer could lead to increased overwinter survival, which in turn, could result in increased recruitment to the adult population (Bestgen et al. 2007). Thus, successful smallmouth bass recruitment might be related to warmer summer and fall water temperatures.

Anderson (2004) speculated that if these conditions promoted earlier spawning or a longer growing season, then smallmouth bass recruitment could have improved in drought years because age-0 smallmouth bass larger than 75 mm could have had higher overwinter survival rates than smaller young-of-the-year (from Anderson 2004: Pat Martinez, CDOW, personal communication). Anderson (2005) demonstrated that there was strong correlation $r = 0.985$) between water temperature and recruitment to age-1. In the Yampa River, smallmouth bass recruitment to age-1 increased dramatically between 2001 and 2004 which was dominated by lower base flows and warmer water regimes; whereas they were very rare during higher base flows and cooler years (1998 to 2000). A similar pattern occurred in the middle Green River, Utah, at about the same period under similar environmental conditions. Smallmouth bass began increasing in abundance about 2001 or 2002, likely in response to warmer water temperatures (i. e., earlier warming and increased magnitude and duration) associated with drought conditions

(Bestgen et al. 2006(a)). In both river systems, drought conditions provided habitat alterations that were positive for and favored smallmouth bass. Conversely, both Anderson (2004) and Bestgen et al. (2007) hypothesized that higher and cooler flows or releases of cold water from upstream reservoirs could impact survival and recruitment of early-life stages of smallmouth bass by reducing the suitability of the Yampa River for this species and may serve as a riverwide mechanism to reduce their abundance.

However, Anderson (2004) commented that he was uncertain if a return to more normal hydrologic conditions in the Yampa River would restore or increase native fish populations to their historic levels in the presence of smallmouth bass that had become so well established.

The literature supports the notion that cooler, higher flows, flow fluctuations, or turbidity events may limit growth and reproductive success for smallmouth bass (Winemiller and Taylor 1982; Lucas and Orth 1995; Peterson and Kwak 1999) and possibly recruitment. In many natural populations, growth of both young and adult smallmouth bass is influenced by temperature (Langlois 1936; Brown 1960; Coble 1967; MacLeod 1967; Forney 1972). In many northern smallmouth bass populations, cohort size upon recruitment to the adult stock is strongly correlated with average water temperatures during the first growing season (Christie and Regier 1973). Most organisms have a sensitive life stage which make them vulnerable to intrinsic and extrinsic factors that affect survival and recruitment. Identifying an "Achilles Heel" would be critical if managers are to be successful in effectively and economically controlling a problematic nuisance fish species. Two aspects of smallmouth bass early life history have been identified as potential "Achilles Heels" and both can impact the survival of young size classes of smallmouth bass. First, disturbing nesting adults, and secondly, displacing fry. Both stream discharge and water temperature manipulations can disrupt spawning and nesting thus reducing survival. High stream discharge with concomitant lower warmer water temperatures can displace young-of-the-year fish from sheltered habitats and further reduce survival. Higher stream discharges and multiple peaks associated with spring and early-summer runoff usually delay water temperatures from warming resulting in fish spawning and larvae hatching later, a shorter growing season, and, ultimately, reduced growth for smallmouth bass. It is believed, at least in the Upper Colorado River, smallmouth bass larger than 75 mm at the end of the growing season tend to have much better overwinter survival than smaller fish.

An attempt is made here to explain why the cohort of smallmouth bass produced in the summer of 2005 did not recruit to 2006 and determine if this might be associated with discharge, water temperature expressed as degree days, the first date water temperature equalled or exceeded 14 ° C, and length of the growing season during the first year of life for smallmouth bass. If there is an association between higher stream discharge with lower water temperatures that routinely occur during higher discharge years and reduced survivability and recruitment of young size classes of smallmouth bass, this would be an important step in identifying an "Achilles heel" for controlling this species. A series of length frequency histograms in 10-day increments were generated from smallmouth bass collected from the Upper Colorado River from Price-Stubb Dam to Westwater, Utah, and Lower Gunnison River for each of these 3 years (Appendix; Figure C.1.–C.3.). These included smallmouth bass < 115 mm. The basis for this cutoff was that the mean annulus for age-1 smallmouth bass was 111 mm which was determined from ageing otoliths from smallmouth bass collected from the Upper Colorado River during 2004 and 2005 (Pat Martinez, CDOW, personal communication).

The hypothesis presented here is: overwinter survival of a cohort of young-of-the-year smallmouth bass may be dependent upon whether fish grow to a large enough size by the fall of that year. In years of large, prolonged runoff that delays the seasonal warming of the Upper Colorado River, late spawning by smallmouth bass may leave age-0 fish with only 2 to 3 months to grow and accumulate fat (lipid) reserves before the onset of winter. However, length, alone, cannot foretell if fish can accumulate adequate lipid reserves for overwintering. A shorter growing season may allow for growth in length, but may not be enough time for age-0 fish to accumulate adequate lipid reserves. Furthermore, a shorter growing season could lead to a longer winter season in which lipid reserves must be drawn upon longer to ensure survival into the next growing season. The physiological implication is that small and medium-size age-0 smallmouth bass may be unable to accumulate adequate lipid reserves to survive until following spring; death may be due to exhaustion of energy reserves.

Hoar (1983) stated than an organism must maintain a "constant element" of fat in order to survive. Thompson et al. (1991) found that overwinter survival depends on fish size in his laboratory results with age-0 Colorado pikeminnow. Whether an age-0 Colorado pikeminnow survived the winter was a function of fish length and feeding regime (i. e., fed vs. starved). He found that both fed and starved Colorado pikeminnow that were relatively small (mean, 30 or 36 mm TL) had lower survival than larger fish (44 mm) over simulated winter conditions. Further, he reported that lipid content of hatchery-reared age-0 Colorado pikeminnow increased as total length increased. Age-0 Colorado pikeminnow in all size classes and feeding regimes depleted their lipid reserves over time, but only the starved small and medium size fish died. Large age-0 Colorado pikeminnow had higher initial lipid contents and, therefore, had sufficient energy reserves to survive the winter, regardless of feeding regime. To survive through their first winter, fish must either accumulate a certain critical amount of lipid prior to winter or feed during winter to partially offset the drain on lipid reserves typical of this period.

Bestgen et al. (2006(b)) believed that even though relatively small and slow-growing Colorado pikeminnow could survive to autumn, small bodied juveniles may have relatively low overwinter survival. Haines et al. (1998) found that small (mode, 28 mm TL) wild Colorado pikeminnow had only 6 % overwinter survival in the Green River, Utah, during a high-flow winter period, whereas in a different year when Colorado pikeminnow were larger (> 38 mm) overwinter survival was higher (56 to 65 %) despite winter flows being lower. Other researchers have similarly found that mortality of age-0 fish during winter is attributed to exhaustion of stored energy reserves (Oliver et al. 1979; Henderson et al. 1988). Year-class strength in northern populations of smallmouth bass is strongly influenced by winter starvation of young-of-the-year fish (Shuter et al. 1989). In laboratory experiments, at 7 ° C and below, age-0 smallmouth bass ceased to feed (Shuter et al. 1980). In Lake Opeongo, Canada, the smallest young-of-the-year fish began to die and thereafter, the mean size of dying fish increased steadily. Length distributions from field sampling of this Canadian lake implied a relatively higher rate of mortality among the smaller young-of-the year smallmouth bass during their first winter which was consistent with laboratory findings (Shuter et al. 1980). Oliver et al. (1979) reported that large age-0 smallmouth bass survive their first winter better than smaller ones. The probability that an age-0 smallmouth bass will survive the winter starvation period is a function of both its size at the start of the hibernation and the duration of the hibernation period (Shuter et al. 1980).

Age-0 smallmouth bass produced in 2005 had a shorter growing season because the total number of degree days in 2004 (870.2) was greater than 2005 (692.0) at stateline. Possibly, a significant number of these fish produced during 2005 did not attain the size necessary for surviving overwinter during 2005/2006. The suspected reason for the reduced growing season was that 2005 was a higher water year, the highest since 1999, marked by a dual peak during spring runoff in which water temperatures warmed later in the summer than during the previous five lower water years. Information on when smallmouth bass spawn and larvae hatch in the

Upper Colorado River in relation to the type of water year is unknown at this time. Length frequencies can provide some insight for annual comparisons of the magnitude of larval smallmouth bass produced and growth progression of their first year of life. However, length frequencies alone cannot pinpoint annual spawning time and hatching date(s) of larval fish. Consequently, it cannot be determined if smallmouth bass spawned later in 2005 than 2004 or 2006. Additionally, it is acknowledged that length frequency cannot distinguish overlap in age classes, only ageing fish can provide that information. In the case of the length frequency for smallmouth bass collected from the Upper Colorado River, length frequency of early-life fish is probably represented by young-of-the-year and late spawned or slower growing age-1 fish from the previous year.

It was believed that time series of length frequencies partitioned by 10-day periods from July 1 through September 20 for young-of-the-year and slowing growing age-1 smallmouth bass collected in the summer of 2004, 2005, and 2006, would be useful in comparing growth and size of these fish at the end of the growing season. Comparing the length frequency for the 11-day period between August 21–31 during 2005, 67% of smallmouth bass were ≥ 75 mm whereas for the same period in 2006, only 36% of the smallmouth bass were ≥ 75 mm (Appendix; Figures C.2. and C.3.). In 2004, 100% of the smallmouth bass were ≥ 75 mm by this same time period, but this comprised only four fish (Appendix; Figure C.1.). Age-0 smallmouth bass produced in 2004, a low water year, appeared to have good overwinter survival and, therefore, recruited to the next size classes as they were collected in the summer of 2005 (Figure 7). So, according to the length frequency graph, it appears that about two-thirds of smallmouth bass produced during 2005 attained the 75 mm length target, the length CDOW fish researcher Pat Martinez believed was necessary to survive overwinter. This still does not account for the almost complete loss of smallmouth bass that did not recruit to the 100 to 180 size classes in 2006. If the 2005 cohort did overwinter successfully, it is possible some of the remaining cohort were displaced downstream outside the reaches sampled by the 2006 spring runoff discharge or simply did not survive spring runoff, thus the reason for their disappearance in the 2006 summer sampling. Sampling in the spring for young fish immediately prior to runoff might clarify this. Since about 86% of the smallmouth bass collected in 2006 attained a size of 75 mm or greater (Appendix; Figure C.3.) by mid-September, it can be expected that the 2006 cohort should have overwintered. However, the ultimate fate of the 2006 cohort and slower growing age-1 fish and whether they successfully survived and recruited to the next size classes by the summer of 2007 would not be certain until the 2007 field sampling was completed.

Therefore, the hypothesis presented herein regarding loss of recruitment from 2005 to 2006 of early-life smallmouth bass cannot be related to environmental factors within the range observed in this study. The little data collected and analyzed to date are, at best, suggestive at this time that some environmental event or physiological factor played a role in the demise of the 2005 cohort of smallmouth bass. Only three years of biological data have been collected on smallmouth bass from the Upper Colorado River and additional years of data on smallmouth bass spawning dynamics are needed to identify the timing (i.e., hatching dates) and duration of smallmouth bass spawning seasons and annual growth rates of early-life stages. Collection of these data under a variety of flow and water temperature regimes may be useful to predict timing and intensity of spawning. These data also might be used to assist managers in determining if there is an association between year-class strength, survival, and recruitment with certain environmental events over a wide range of different water year scenarios. And, if a consistent association can be shown, could this be used as a management tool to reduce survival of early-life stages of smallmouth bass and minimize recruitment to the adult population? The notion that an environmental event played a role in the demise of the 2005 year class of smallmouth bass in the Upper Colorado River should not be dismissed and warrants further investigation.

Water Turbidity and Smallmouth Bass Catches

Sampling crews on the Upper Colorado River noted in both 2005 and 2006 that catch rates did not decrease when turbidity was high. In other words, higher catch rates for juvenile and adult smallmouth bass were associated with high turbidity (usually immediately following rainstorms). On the Upper Colorado and Lower Gunnison rivers during 2005, water conditions were more turbid in general than 2004; the 2005 Colorado River smallmouth bass catches were higher (about 17%) than that of 2004. These higher catch rates could simply have been a result of higher densities of smallmouth bass during 2005. During August 2006, a 6.4-mile section of the Lower Gunnison (2.3 miles) and Colorado River (4.1 miles) at the upper most portion of the 18-mile reach near Grand Junction were sampled twice within 4 days. Water clarity during the first electrofishing run was clear but was turbid on the second run 4 days later. Smallmouth bass catch rate (8.14 smallmouth bass/hr; 33 fish) was 2.39 times higher on the second run (turbid water) than the first run (clear water: 3.42 smallmouth bass/hr; 9 fish).

There does appear to be a pattern: catch rates for smallmouth bass are higher when water conditions are more turbid. The same pattern for smallmouth bass catches during 2006 was noticed for other river sub-reaches in the Upper Colorado River. At first, this may seem perplexing since one might assume that catch rates may be lower when turbidity is high. Researchers performing smallmouth bass removal in the Green River sub-basin noted that their highest catch rates were associated with high turbid water conditions in both 2005 (e-mail transmittal, Mark H. Fuller, FWS, Vernal, Utah, 8/26/2005), 2006, and 2007 (e-mail transmittal, M. Fuller, 9/19/2007). Fuller attributed the substantial catch of adult smallmouth bass during early-September 2007 to late season storm events that resulted in large flushes of debris and silt into the river between Echo Park and Split Mountain in the Green River, Utah. He further speculated that increased turbidity stressed and increased the catchability of larger smallmouth bass at shoreline habitat. Possibly smallmouth bass are more vulnerable to capture when turbid water conditions exist and less capable of avoiding electroshock and capture because they move to shallower shoreline habitats where most of the electrofishing sampling is performed. Every attempt should be made to sample on days when turbidity is high to increase catches of smallmouth bass.

Other Nonnative Fishes

Despite only a relatively few other nonnative fishes, both game and non-game, being collected during this removal study, the occurrence of some of these fishes deserves mentioning since only a few years ago catches of smallmouth bass were rare and abundance densities were almost non-existent in Grand Valley sub-reaches of the Upper Colorado River. Adult walleye (483–610 mm) were collected in the Rifle to Rulison sub-reach during 2004 (1 fish), 2005 (1), and 2006 (6). Smallmouth bass, walleye, northern pike, and yellow perch occur in Rifle Gap Reservoir which has a spillway that drains into Rifle Creek. Rifle Creek is hydrologically connected to Upper Colorado River south of the town of Rifle. Therefore, the likely source of the walleye found in the river was from Rifle Gap Reservoir. One adult northern pike (589 mm) was collected in 2005 in the 18-mile reach and one young (~ 65 mm) yellow perch was collected in the 15-mile reach in 2006. Twelve adult gizzard shad (338–462 mm) were collected during 2006. Eleven of these fish were collected in the 15- and 18-mile reaches of the Upper Colorado River and one in the plunge pool of the Redlands Diversion Dam in the Lower Gunnison River. This is believed to be the first sightings of gizzard shad in the Grand Valley area of the Upper Colorado River. Gizzard shad occur in Lake Powell which the Colorado River drains into.

CONCLUSIONS

1. Smallmouth bass abundance was the lowest in three years at the end of the 2006 sampling season in main channel riverine habitats. However, it is premature to determine if this downward trend in smallmouth bass abundance will continue.

2. River reaches that had the highest concentration for smallmouth bass after three years in descending order on the Upper Colorado and Lower Gunnison rivers were, a) Corn Lake to the Colorado/Gunnison River confluence, b) Colorado/Gunnison River confluence to Fruita State Park, c) GVIC Dam to Corn Lake, and d) Redlands Dam to the Colorado/Gunnison River confluence in the Lower Gunnison River.

3. Despite smallmouth bass abundance decreasing significantly during 2006, the direct opposite was apparent for largemouth bass. In main channel riverine habitats in the Grand Valley sub-reaches, there was a significant increase for largemouth bass during 2006 from the previous two years: a 101% increase in catch/effort from 2005 and a 312% increase in catch/effort from 2004. Between Rifle and Beavertail Mountain largemouth bass catch rate increased in 2006 (5.62 fish/hr) from 2005 (0.95 fish/hr) and 2004 (3.29 fish/hr). Despite both species being lethally removed, largemouth bass numbers have continued to increase in main channel habitats.

4. Green sunfish and black crappie abundance increased in main channel habitats in the Grand Valley sub-reaches of the Upper Colorado and Lower Gunnison rivers.

5. The smallmouth bass year class produced in the summer of 2005 appeared not to recruit to 2006. The loss of this year class cannot be directly attributed to environmental factors within the range observed in this study. Some of the environmental factors could be colder summer water temperatures that occur during higher discharge water years which result in a later spawning period, later larval hatch, and a shorter growing season. As a result of these environmental factors, the biological and physiological implication could have been that small and medium-size age-0 smallmouth bass were unable to accumulate adequate lipid reserves to survive until the following spring, and death may have been due to exhaustion of energy reserves.

6. Catches of smallmouth bass appear to be related to turbid and clear water conditions. Higher catch rates for juvenile and adult smallmouth bass were associated with high turbid water conditions (usually immediately following summer rainstorms).

RECOMMENDATIONS

The following recommendations are made:

1. Increase the number of removal passes at least two-fold (from 4 to 8 passes) in 2007 and 2008 with electrofishing in river segments that have higher concentrations of smallmouth bass as was performed from 2004–2006. Past 2008, continue to increase the number of removal passes to the point where the desired exploitation rate is achieved. This will increase the number of removal passes to increase the number of smallmouth bass captured and removed with the goal of increasing probability of capture and, therefore, exploitation rates. This should also maximize catches of all centrarchids fishes while at the same time minimizing harassment and negative impacts to native fishes in reaches where centrarchid abundance is low. Concomitantly, decrease electrofishing effort in river reaches of low smallmouth bass densities.

2. Suspend all electrofishing operations when it is determined that Colorado pikeminnow show signs of preparing to spawn, e. g., mid- to late-June. Electrofishing will be suspended during this period to eliminate the likelihood of harassment, interference, and injury to spawning Colorado pikeminnow. Downstream from Price-Stubb Dam, electrofishing should commence following cessation of spawning of Colorado pikeminnow which should be sometime in mid- to late-July.

3. a) Perform mark-recapture population estimates of juvenile and adult (≥ 100 mm) smallmouth bass at least once every three years from GVIC Dam to the Loma boat landing in the Upper Colorado River and from the Redlands Diversion Dam to the Colorado/Gunnison River confluence in the Lower Gunnison River to assess the size of the smallmouth bass population and effectiveness of removal in the Grand Valley reaches of the Upper Colorado and Lower Gunnison rivers.

b) Continue to collect effort data to compute a catch effort indice (total fish/hr) of smallmouth bass and other centrarchids to compare with the earlier years (2004 and 2005) when mark and recapture population estimates were not performed and catch effort was the only metric available to compare annual abundance of smallmouth bass and other centrarchids.

4. Continue sampling in reaches of the Upper Colorado River from the Rifle Bridge to Beavertail Mountain in Debeque Canyon. This is necessary to 1) build upon the existing fishery community database and monitor abundance of nonnative centrarchid fishes and presence of other piscivorous fishes (e. g., northern pike, walleye, and yellow perch) in these reaches which is within critical habitat for Colorado pikeminnow and razorback sucker, and 2) particularly determine if smallmouth bass continue to proliferate in the river reach from Rifle to Rulison. Because there are no known Colorado pikeminnow spawning sites in these reaches, sampling can be performed earlier than those downstream from Price-Stubb Diversion Dam.

5. Sample for young smallmouth bass in the spring prior to runoff to assess overwinter mortality.

6. Investigate possible escapement of smallmouth bass and other game fish (e. g., walleye, northern pike, yellow perch) from Rifle Gap Reservoir via Rifle Creek and associated irrigation laterals into the Upper Colorado River. Prevent future escapement of these piscivorous fishes from this reservoir or their access to the Colorado River. This is consistent with the second part of a management consideration identified in the Colorado River Basin Wildlife Management Plan (CDOW 2003) which states "Evaluate the escapement of these [fish] species from the reservoir [Rifle Gap] to determine the threat to endangered Colorado River fishes." Based on captures of walleye in Rifle Creek downstream of the Rifle Gap plunge pool, CDOW biologists have recently recommended that a screen be constructed in Rifle Creek downstream of the plunge pool of Rifle Gap Reservoir (Lori Martin, CDOW, personal communication).

7. Collect and preserve early-life stages (age-0 and age-1) of smallmouth bass in ethanol to allow for otolith extraction during removal passes. Otolith information may be useful for understanding aspects of smallmouth bass early-life history. Otolith data could be used to

back calculate hatching dates to identify the timing and duration of smallmouth bass spawning. This biological information could be useful to determine if environmental factors, e. g., hydrologic conditions such as higher flows in non-drought periods and accompanying cooler water temperatures might disrupt or delay spawning resulting in slower growth of early-life stages of smallmouth bass reducing survival and recruitment success. Managers might be able to take advantage of such events to periodically reduce smallmouth bass populations in some reaches of the Upper Colorado River.

8. Increase catches of centrarchid fishes by targeting specific in-river features that provide habitat for centrarchid fishes. These include but are not limited to beaver lodges, tree stumps and logs, rock piles, and concrete rip-rap. Sampling these features with electrofishing may increase catches of centrarchid fishes. Also, sample on days when turbidity is high to increase catches of smallmouth bass.

UNCERTAINTIES/UNKNOWNS

1. Growth rate of early-life stages (age-0 and age-1) of smallmouth bass in the Upper Colorado River.

2. Spawning dynamics for smallmouth bass in the Upper Colorado River, i. e., hatching times/dates and duration of spawning over a variety of flow (e. g., wet, moderate, dry) and water temperature regimes.

3. The reason(s) (e. g., an environmental event or physiological factor) why age-0 smallmouth bass produced in 2005 did not survive and recruit to the summer of 2006.

4. The empirical (not theoretical) number of passes required to achieve the desired probability of capture (p-hat) and target exploitation rate or percent of smallmouth bass removed.

5. a) Electrofishing being a cost-effective, long-term mechanical removal method for collecting, removing, and reducing the abundance of nuisance and problematic nonnative fishes.

b) The level of electrofishing effort (e. g., the number of removal passes per year; the annual periodicity or frequency removal passes need to be performed) necessary to affect population self-sustainability which ultimately could provide a measurable, lasting reduction in centrarchid population abundance.

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APPENDIX A

Numbers of Centrarchids by Species
Collected with Electrofishing, 2004–2006,
by Major River Reach and Sub-reach

Table A.1. Numbers of centrarchid fishes collected during pass (P) 1, 2, 3, and 4 of the smallmouth bass removal project from main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado and eastern Utah, July and August 2004. Note: n/s=not sampled; two electrofishing craft were used for passes 1, 2, and 3; one electrofishing craft was used for pass 4.

River (River Miles) River Segment	No. of Centrarchids: Smallmouth Bass P-1	P-2	P-3	P-4	Largemouth Bass P-1	P-2	P-3	P-4	Black Crappie/ Green Sunfish/ Bluegill P-1	P-2	P-3	P-4
Colorado River (RM 187.7–127.6)												
Price-Stubb ▸ GVIC Dam	9	16	5	n/s	0	0	0	n/s	1	18	9	n/s
GVIC Dam ▸ Corn Lake	33	26	69	24	0	0	17	13	57	13	47	23
Corn Lake ▸ Colo/Gunn River Confluence	64	52	100	54	3	3	35	16	16	4	101	31
Colo/Gunn R. Confl. ▸ Fruita State Park	45	82	206	91	15	18	65	35	21	46	152	38
Fruita State Park ▸ Loma Boat Landing	10	19	32	6	5	2	6	12	30	7	52	28
Loma Boat Landing ▸ Salt Creek Wash	23	13	30	n/s	5	0	19	n/s	10	5	15	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	6	19	14	n/s	0	0	3	n/s	0	5	3	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	1	1	1	n/s	0	0	0	n/s	1	0	0	n/s
Lower Gunnison River (RM 3.0–0.7)												
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	28	28	47	11	0	0	1	4	6	7	5	11
2004 Pass Totals	**219**	**256**	**504**	**186**	**28**	**23**	**146**	**80**	**141**	**105**	**384**	**131**
2004 Species Totals				*1,165*				*277*				*761*

Table A.2. Numbers of centrarchid fishes collected during pass (P) 1, 2, 3, and 4 of the smallmouth bass removal project from main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado and eastern Utah, July and August 2005. Note: n/s=not sampled; two electrofishing craft were used for passes 1, 2, and 3; one electrofishing craft was used for pass 4. Note: 2004 species totals are provided for annual comparisons.

River (River Miles) River Segment	Smallmouth Bass P-1	Smallmouth Bass P-2	Smallmouth Bass P-3	Smallmouth Bass P-4	Largemouth Bass P-1	Largemouth Bass P-2	Largemouth Bass P-3	Largemouth Bass P-4	Black Crappie/ Green Sunfish/ Bluegill P-1	Black Crappie/ Green Sunfish/ Bluegill P-2	Black Crappie/ Green Sunfish/ Bluegill P-3	Black Crappie/ Green Sunfish/ Bluegill P-4
Colorado River (RM 187.7–127.6)												
Price-Stubb ▸ GVIC Dam	20	60	11	n/s	10	1	4	n/s	48	10	27	n/s
GVIC Dam ▸ Corn Lake	60	46	64	38	4	12	52	18	39	50	105	74
Corn Lake ▸ Colo/Gunn River Confluence	89	74	70	46	33	35	54	6	57	58	60	33
Colo/Gunn R. Confl. ▸ Fruita State Park	183	158	53	75	132	25	23	24	154	50	38	77
Fruita State Park ▸ Loma Boat Landing	6	2	41	4	56	39	19	1	62	44	201	8
Loma Boat Landing ▸ Salt Creek Wash	79	19	27	n/s	5	2	6	n/s	22	5	18	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	17	9	13	n/s	2	0	5	n/s	9	3	9	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	6	1	2	n/s	5	5	2	n/s	2	2	2	n/s
Lower Gunnison River (RM 3.0–0.7)												
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	15	42	32	4	0	0	3	6	4	73	17	47
2005 Pass Totals	**475**	**411**	**313**	**167**	**247**	**119**	**168**	**55**	**397**	**295**	**477**	**239**
2005 Species Totals				*1,366*				*589*				*1,408*
2004 Species Totals				*1,165*				*277*				*761*

Table A.3. Numbers of centrarchid fishes collected during removal passes (P) 1, 2, 3, and 4 of the smallmouth bass removal project from main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado and eastern Utah, July, August, and September 2006. Note: n/s=not sampled; two electrofishing craft were used for passes 1, 2, and 3; one electrofishing craft was used for pass 4. Note: 2004 and 2005 species totals are provided for annual comparisons.

River (River Miles) River Segment	Smallmouth Bass P-1	Smallmouth Bass P-2	Smallmouth Bass P-3	Smallmouth Bass P-4	Largemouth Bass P-1	Largemouth Bass P-2	Largemouth Bass P-3	Largemouth Bass P-4	Black Crappie/ Green Sunfish/ Bluegill P-1	Black Crappie/ Green Sunfish/ Bluegill P-2	Black Crappie/ Green Sunfish/ Bluegill P-3	Black Crappie/ Green Sunfish/ Bluegill P-4
Colorado River (RM 187.7–127.6)												
Price-Stubb ▸ GVIC Dam	10	8	12	n/s	14	3	9	n/s	8	1	6	n/s
GVIC Dam ▸ Corn Lake	75	48	42	44	59	75	118	52	57	26	38	23
Corn Lake ▸ Colo/Gunn River Confluence	43	49	102	34	44	100	123	35	21	30	63	29
Colo/Gunn R. Confl. ▸ Fruita State Park	78	38	52	17	50	78	102	45	132	154	203	119
Fruita State Park ▸ Loma Boat Landing	12	7	12	11	22	68	63	12	130	200	335	82
Loma Boat Landing ▸ Salt Creek Wash	23	n/s	n/s	n/s	7	n/s	n/s	n/s	20	n/s	n/s	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	8	n/s	n/s	n/s	2	n/s	n/s	n/s	4	n/s	n/s	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	3	n/s	n/s	n/s	3	n/s	n/s	n/s	3	n/s	n/s	n/s
Lower Gunnison River (RM 3.0–0.7)												
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	6	9	5	3	2	2	4	2	5	17	53	13
2006 Pass Totals	**258**	**159**	**225**	**109**	**203**	**326**	**419**	**146**	**380**	**428**	**698**	**266**
2006 Species Totals				*751*				*1,094*				*1,771*
2005 Species Totals				*1,366*				*589*				*1,408*
2004 Species Totals				*1,165*				*277*				*761*

Table A.4. Summary statistics of centrarchids and percids collected during reconnaissance sampling in main channel habitats of the Upper Colorado River from Rifle, Colorado, to Beavertail Mountain in Debeque Canyon, August 23–26, 2004.

Reach: Rifle Bridge–Rulison Bridge
River Mile: 240.7–230.0; River Mile Length: 10.7
Number of Electrofishing Crafts: 2
Effort (hr): 10.26

Smallmouth Bass				Largemouth Bass				Green Sunfish				Walleye			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
20	63	412	235	42	38	184	82	8	<100	112	~100	1	--	--	610

Reach: Rulison Bridge–Parachute Bridge
River Mile: 229.9–223.0; River Mile Length: 6
Number of Electrofishing Crafts: 2
Effort (hr): 2.17

Smallmouth Bass				Largemouth Bass				Green Sunfish				Walleye			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
0	--	--	--	4	66	420	225	3	<100	<100	<100	0	--	--	--

Reach: Parachute Bridge–Debeque I-70 Bridge
River Mile: 223.0–209.7; River Mile Length: 13.3
Number of Electrofishing Crafts: 2
Effort (hr): 4.38

Smallmouth Bass				Largemouth Bass				Green Sunfish				Walleye			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
1	--	--	53	8	43	93	63	19	<100	135	~104	0	--	--	--

Reach: Debeque I-70 Bridge–Beavertail Mountain (Debeque Canyon)
River Mile: 209.7–195.7; River Mile Length: 14.0
Number of Electrofishing Craft: 1
Effort (hr): 2.94

Smallmouth Bass				Largemouth Bass				Green Sunfish				Walleye			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
0	--	--	--	11	85	189	113	6	90	117	99	0	--	--	--

Table A.5. Summary statistics of centrarchids collected during reconnaissance sampling in main channel habitats of the Upper Colorado River from Rifle, Colorado, to Beavertail Mountain in Debeque Canyon, July12–15; 21, 2005.

Reach: Rifle Bridge–Rulison Bridge
River Mile: 240.7–230.0; River Mile Length: 10.7
Number of Electrofishing Crafts: 3
Effort (hr): 12.368

Smallmouth Bass				Largemouth Bass				Green Sunfish				Bluegill				Black Crappie			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
187	41	435	199	13	<100	446	339	353	81	165	117	10	101	174	152	2	106	120	113

Reach: Rulison Bridge–Parachute Bridge
River Mile: 229.9–223.0; River Mile Length: 6
Number of Electrofishing Crafts: 2
Effort (hr): 5.410

Smallmouth Bass				Largemouth Bass				Green Sunfish				Bluegill				Black Crappie			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
0	--	--	--	0	--	--	--	32	<100	130	~115	0	--	--	--	0	--	--	--

Reach: Parachute Bridge–Debeque I-70 Bridge
River Mile: 223.0–209.7; River Mile Length: 13.3
Number of Electrofishing Crafts: 2
Effort (hr): 12.092

Smallmouth Bass				Largemouth Bass				Green Sunfish				Bluegill				Black Crappie			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
31	70	437	204	24	45	373	142	176	<100	175	122	0	--	--	--	0	--	--	--

Reach: Debeque I-70 Bridge–Beavertail Mountain (Debeque Canyon)
River Mile: 209.7–195.7; River Mile Length: 14.0
Number of Electrofishing Crafts: 2
Effort (hr): 9.929

Smallmouth Bass				Largemouth Bass				Green Sunfish				Bluegill				Black Crappie			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
12	78	227	131	1	--	--	--	45	70	151	115	0	--	--	--	0	--	--	--

Table A.6. Summary statistics of centrarchids collected during reconnaissance sampling in main channel habitats of the Upper Colorado River from Rifle, Colorado, to Beavertail Mountain in Debeque Canyon, July 5–7; 10; 12; September 19, 2006.

Reach: Rifle Bridge–Rulison Bridge
River Mile: 240.4–230.0; River Mile Length: 10.4
Number of Electrofishing Crafts: 3
Effort (hr): 12.567

Smallmouth Bass				Largemouth Bass				Green Sunfish				Bluegill				Black Crappie			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
72	58	384	195	115	53	114	430	201	27	158	91	3	112	176	140	0	--	--	--

Reach: Rulison Bridge–Parachute Bridge
River Mile: 229.9–223.0; River Mile Length: 6
Number of Electrofishing Crafts: 2
Effort (hr): 5.563

Smallmouth Bass				Largemouth Bass				Green Sunfish				Bluegill				Black Crappie			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
1	--	--	80	0	--	--	--	17	< 100	147	~ 115	0	--	--	--	0	--	--	--

Reach: Parachute Bridge–Debeque I-70 Bridge
River Mile: 223.0–209.7; River Mile Length: 13.3
Number of Electrofishing Crafts: 2
Effort (hr): 8.100

Smallmouth Bass				Largemouth Bass				Green Sunfish				Bluegill				Black Crappie			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
5	270	357	308	38	45	329	128	97	42	172	94	0	--	--	--	1	--	--	170

Reach: Debeque I-70 Bridge–Beavertail Mountain (Debeque Canyon)
River Mile: 209.7–195.7; River Mile Length: 14.0
Number of Electrofishing Crafts: 2
Effort (hr): 11.282

Smallmouth Bass				Largemouth Bass				Green Sunfish				Bluegill				Black Crappie			
No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean	No. of Fish	Total Length (mm) Min	Max	Mean
1	--	--	82	58	43	161	74	177	41	131	77	1	--	--	< 100	0	--	--	--

Table A.7. Number and catch effort (fish/mile) for smallmouth bass collected from main channel habitats with electrofishing in the Upper Colorado River from RM 187.7–127.6 (Price-Stubb Dam to Westwater Ranger Station, Utah), and the Lower Gunnison River from RM 3.0–0.7 (Redlands Diversion Dam to the Colorado/Gunnison River confluence) during July, August, and September 2006. Note: see Appendix; Tables B.4–B.6. for the total electrofishing effort (hrs) sampled for each river segment; n/s=not sampled. Two electrofishing craft were used for removal passes 1, 2, and 3; one electrofishing craft was used for removal pass 4. Values for 2005 are italicized; values for 2004 and underlined for annual comparisons.

	Smallmouth Bass							
	No. of Fish				Fish/Mile			
	P-1	P-2	P-3	P-4	P-1	P-2	P-3	P-4
Colorado River								
Price-Stubb Dam-	128	105	156	[a] 78	3.8	3.1	4.7	5.5
Colo/Gunn Confl.	*169*	*180*	*145*	[a] *84*	*5.1*	*5.4*	*4.3*	*5.9*
Segment Length: 16.7 miles	106	94	174	[a] 78	3.2	2.8	5.5	5.5
Miles Sampled: 33.4								
Colo/Gunn Confl-	90	45	64	[b] 28	2.5	1.2	1.7	1.5
Loma Boat Landing	*189*	*160*	*94*	[b] *79*	*5.1*	*4.3*	*1.2*	*4.3*
Segment Length: 18.4 miles	55	101	238	[b] 97	1.5	2.8	6.5	5.3
Miles Sampled: 36.8								
Loma Boat Landing-	23	n/s	n/s	n/s	1.4	n/s	n/s	n/s
Salt Creek Wash	*79*	*19*	*27*	*n/s*	*4.7*	*1.1*	*1.6*	*n/s*
Segment Length: 8.4 miles	23	13	30	n/s	1.4	0.8	1.8	n/s
Miles Sampled: 16.8								
Salt Creek Wash-	8	n/s	n/s	n/s	0.3	n/s	n/s	n/s
Utah/Colo Stateline	*17*	*9*	*13*	*n/s*	*0.7*	*0.4*	*0.5*	*n/s*
Segment Length: 12.3 miles	6	19	14	n/s	0.2	0.8	0.6	n/s
Miles Sampled: 24.6								
Utah/Colo Stateline-	3	n/s	n/s	n/s	0.3	n/s	n/s	n/s
Westwater Ranger	*6*	*1*	*2*	*n/s*	*0.7*	*0.1*	*0.2*	*n/s*
Station, Utah	1	1	1	n/s	0.1	0.1	0.1	n/s
Segment Length: 4.3 miles								
Miles Sampled: 8.6								
Lower Gunnison River								
Redlands Div. Dam-	6	9	5	[c] 3	1.3	2.0	1.1	0.7
Colo/Gunn Confl.	*15*	*42*	*32*	[c] *4*	*3.3*	*9.1*	*6.7*	*1.7*
Segment Length: 2.3 miles	28	28	47	[c] 11	6.1	6.1	10.2	4.8
Miles Sampled: 4.6								

[a] Price-Stubb Dam to GVIC Diversion Dam river segment was not sampled during pass 4. Only 14.3 miles were sampled:185.3–171.0.
[b] One electrofishing craft was used; miles sampled=18.4 for Pass 4.
[c] One electrofishing craft was used; miles sampled=2.3 for Pass 4.

APPENDIX B

Catch/effort (fish/hr) for Five Centrarchid Fishes
Collected with Electrofishing, 2004–2006,
by Major River Reach and Sub-reach

Table B.1. Amount of effort (electrofishing hours) expended during four passes of the smallmouth bass removal project sampling main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado and eastern Utah, July and August 2004. Note: n/s=not sampled; two electrofishing craft were used for passes 1, 2, and 3; one electrofishing craft was used for pass 4.

River (River Miles) River Segment	Electrofishing Effort (hr) P-1	P-2	P-3	P-4
Colorado River (RM 187.7–127.6)				
Price-Stubb▸GVIC Dam	2.275	2.438	2.656	n/s
GVIC Dam ▸ Corn Lake	5.432	4.943	8.273	2.920
Corn Lake ▸Colo/Gunn River Confluence	4.701	5.581	8.696	3.750
Colo/Gunn R. Confl. ▸ Fruita State Park	9.248	11.572	16.328	7.633
Fruita State Park ▸ Loma Boat Landing	2.902	3.172	4.496	1.949
Loma Boat Landing ▸ Salt Creek Wash	7.372	5.564	7.733	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	6.029	6.988	7.295	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	1.244	2.434	2.664	n/s
Lower Gunnison River (RM 3.0–0.7)				
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	3.363	3.196	4.070	1.748
2004 Pass Totals	42.566	45.888	62.211	18.00

Table B.2. Amount of effort (electrofishing hours) expended during four passes of the smallmouth bass removal project sampling main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado and eastern Utah, July and August 2005. Note: n/s=not sampled; two electrofishing craft were used for passes 1, 2, and 3; one electrofishing craft was used for pass 4.

River (River Miles) River Segment	Electrofishing Effort (hr) P-1	 P-2	 P-3	 P-4
Colorado River (RM 187.7–127.6)				
Price-Stubb▸GVIC Dam	2.860	2.460	2.794	n/s
GVIC Dam ▸ Corn Lake	6.322	5.434	7.074	4.371
Corn Lake ▸Colo/Gunn River Confluence	7.048	5.842	4.164	3.355
Colo/Gunn R. Confl. ▸ Fruita State Park	16.430	10.727	11.323	6.508
Fruita State Park ▸ Loma Boat Landing	4.154	3.133	4.647	2.103
Loma Boat Landing ▸ Salt Creek Wash	6.823	6.433	5.745	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	8.005	7.654	8.284	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	3.206	2.691	2.950	n/s
Lower Gunnison River (RM 3.0–0.7)				
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	3.194	3.802	2.981	2.043
2005 Pass Totals	58.042	48.176	49.962	18.380
2005 Total			*174.560*	

Table B.3. Amount of effort (electrofishing hours) expended during four removal passes of the smallmouth bass removal project sampling main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado and eastern Utah, July, August, and September 2006. Note: n/s=not sampled; two electrofishing craft were used for passes 1, 2, and 3; one electrofishing craft was used for pass 4.

River (River Miles) River Segment	Electrofishing Effort (hr) P-1	P-2	P-3	P-4
Colorado River (RM 187.7–127.6)				
Price-Stubb▸GVIC Dam	3.739	3.792	2.861	n/s
GVIC Dam ▸ Corn Lake	9.439	8.021	8.540	4.706
Corn Lake ▸Colo/Gunn River Confluence	6.455	7.178	7.574	4.289
Colo/Gunn R. Confl. ▸ Fruita State Park	14.242	13.633	13.088	7.704
Fruita State Park ▸ Loma Boat Landing	5.018	6.360	5.771	2.367
Loma Boat Landing ▸ Salt Creek Wash	7.557	n/s	n/s	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	7.607	n/s	n/s	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	3.202	n/s	n/s	n/s
Lower Gunnison River (RM 3.0–0.7)				
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	2.573	2.108	2.574	1.328
2006 Pass Totals	60.012	41.092	40.408	20.394
2006 Total			*161.906*	
2005 Total			*174.560*	
2004 Total			*168.665*	

Table B.4. Catch effort (fish/hr) for five centrarchid fishes (young-of-the year, juvenile, adult) collected during pass (P) 1, 2, 3, and 4 of the smallmouth bass removal project from main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado and eastern Utah, July and August 2004. Note: n/s=not sampled; two electrofishing craft were used for passes 1, 2, and 3; one electrofishing craft was used for pass 4.

River (River Miles) River Segment	Smallmouth Bass				Largemouth Bass				Black Crappie/ Green Sunfish/ Bluegill			
	P-1	P-2	P-3	P-4	P-1	P-2	P-3	P-4	P-1	P-2	P-3	P-4
Colorado River (RM 187.7–127.6)												
Price-Stubb ▸ GVIC Dam	3.96	6.56	1.88	n/s	0.00	0.00	0.00	n/s	0.44	7.38	3.39	n/s
GVIC Dam ▸ Corn Lake	6.08	5.26	8.34	8.22	0.00	0.00	2.05	4.45	10.49	2.63	5.68	7.88
Corn Lake ▸Colo/Gunn River Confluence	13.61	9.32	11.50	14.40	0.64	0.54	4.02	4.27	3.40	0.72	11.61	8.27
Colo/Gunn R. Confl. ▸ Fruita State Park	4.87	7.09	12.62	11.92	1.62	1.56	3.98	4.59	2.27	3.98	9.31	4.98
Fruita State Park ▸ Loma Boat Landing	3.45	5.99	7.12	3.08	1.72	0.63	1.33	6.16	10.34	2.21	11.57	14.37
Loma Boat Landing ▸ Salt Creek Wash	3.12	2.34	3.88	n/s	0.68	0.00	2.46	n/s	1.36	0.90	1.94	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	1.00	2.72	1.92	n/s	0.00	0.00	0.82	n/s	0.00	0.72	0.82	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	0.80	0.41	0.38	n/s	0.00	0.00	0.00	n/s	0.80	0.00	0.00	n/s
Lower Gunnison River (RM 3.0–0.7)												
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	8.33	8.76	11.55	6.29	0.00	0.00	0.25	6.99	1.78	2.19	1.22	6.29
Mean of 2004 Passes	5.14	5.58	8.11	10.33	0.66	0.50	2.35	4.44	3.31	2.29	6.17	7.28
Mean of 2004 Species				6.91				1.64				4.51

Catch/Effort (fish/hr)

Table B.5. Catch effort (fish/hr) for five centrarchid fishes (young-of-the-year) collected during pass (P) 1, 2, 3, and 4 of the smallmouth bass removal project from main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado and eastern Utah, July and August 2005. Note: n/s=not sampled; two electrofishing craft were used for passes 1, 2, and 3; one electrofishing craft was used for pass 4. Note: 2004 catch/effort by species is provided for annual comparisons.

River (River Miles) River Segment	Catch/Effort (fish/hr) Smallmouth Bass P-1	P-2	P-3	P-4	Largemouth Bass P-1	P-2	P-3	P-4	Black Crappie/ Green Sunfish/ Bluegill P-1	P-2	P-3	P-4
Colorado River (RM 187.7–127.6)												
Price-Stubb ▸ GVIC Dam	6.99	24.39	3.94	n/s	3.50	0.41	1.43	n/s	16.78	4.07	9.66	n/s
GVIC Dam ▸ Corn Lake	9.49	8.47	9.05	8.69	0.63	2.21	7.35	4.12	6.17	9.20	14.84	16.93
Corn Lake ▸Colo/Gunn River Confluence	12.63	12.67	16.81	13.71	4.68	5.99	12.97	1.79	8.09	9.93	14.41	9.84
Colo/Gunn R. Confl. ▸ Fruita State Park	11.20	14.73	4.68	11.52	8.03	2.33	2.03	3.69	9.37	4.46	3.36	11.83
Fruita State Park ▸ Loma Boat Landing	1.44	0.64	8.82	1.90	13.48	12.45	4.09	0.48	14.93	14.04	43.25	3.80
Loma Boat Landing ▸ Salt Creek Wash	11.58	2.95	4.70	n/s	0.73	0.31	1.04	n/s	3.22	0.78	3.13	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	2.12	1.18	1.57	n/s	0.25	0.00	0.60	n/s	1.12	0.39	1.09	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	1.87	0.37	0.68	n/s	1.56	1.86	0.68	n/s	0.62	0.74	0.68	n/s
Lower Gunnison River (RM 3.0–0.7)												
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	4.70	11.05	10.73	1.96	0.00	0.00	1.01	2.94	1.25	19.20	5.70	23.01
Mean of 2005 Passes	8.18	8.53	6.26	9.09	4.26	2.47	3.36	2.99	6.84	6.12	9.55	13.00
Mean of 2005 Species				7.83				3.37				8.07
Mean of 2004 Species				6.91				1.64				4.51

Table B.6. Catch effort (fish/hr) for five centrarchid fishes (young-of-the-year) collected during removal passes (P) 1, 2, 3, and 4 of the smallmouth bass removal project from main channel habitats on the Colorado and Lower Gunnison rivers in western Colorado and eastern Utah, July, August, September 2006. Note: n/s=not sampled; two electrofishing craft were used for passes 1, 2, and 3; one electrofishing craft was used for pass 4. Note: 2004 and 2005 catch/effort by species is provided for annual comparisons.

River (River Miles) River Segment	Catch/Effort (fish/hr) Smallmouth Bass P-1	P-2	P-3	P-4	Largemouth Bass P-1	P-2	P-3	P-4	Black Crappie/ Green Sunfish/ Bluegill P-1	P-2	P-3	P-4
Colorado River (RM 187.7–127.6)												
Price-Stubb ▸ GVIC Dam	2.67	2.11	4.19	n/s	3.74	0.79	3.15	n/s	2.14	0.26	2.10	n/s
GVIC Dam ▸ Corn Lake	7.95	5.98	4.92	9.35	0.53	9.35	13.82	11.05	6.04	3.24	4.45	4.89
Corn Lake ▸Colo/Gunn River Confluence	6.66	6.83	13.47	7.93	4.66	13.93	16.24	8.16	3.25	4.18	8.32	4.29
Colo/Gunn R. Confl. ▸ Fruita State Park	5.48	2.79	3.81	2.21	7.75	5.72	7.79	5.84	9.27	11.30	15.51	15.45
Fruita State Park ▸ Loma Boat Landing	0.20	1.10	2.08	4.65	4.38	10.69	10.92	5.07	25.91	31.44	58.05	34.64
Loma Boat Landing ▸ Salt Creek Wash	3.04	n/s	n/s	n/s	093	n/s	n/s	n/s	2.65	n/s	n/s	n/s
Salt Creek Wash ▸ Utah/Colo Stateline	1.05	n/s	n/s	n/s	0.26	n/s	n/s	n/s	0.53	n/s	n/s	n/s
Utah/Colo Stateline ▸ Westwater, Utah BLM Ranger Station	0.94	n/s	n/s	n/s	0.94	n/s	n/s	n/s	0.94	n/s	n/s	n/s
Lower Gunnison River (RM 3.0–0.7)												
Redlands Div. Dam ▸ Colo/Gunn R. Confluence	2.18	4.27	1.94	2.26	0.73	0.95	1.55	1.51	1.82	8.06	20.59	9.79
Mean of 2006 Passes	4.30	3.87	5.57	5.34	3.38	7.87	10.37	7.16	6.33	10.42	17.27	13.04
Mean of 2006 Species				4.64				6.76				10.94
Mean of 2005 Species				7.83				3.37				8.07
Mean of 2004 Species				6.91				1.64				4.51

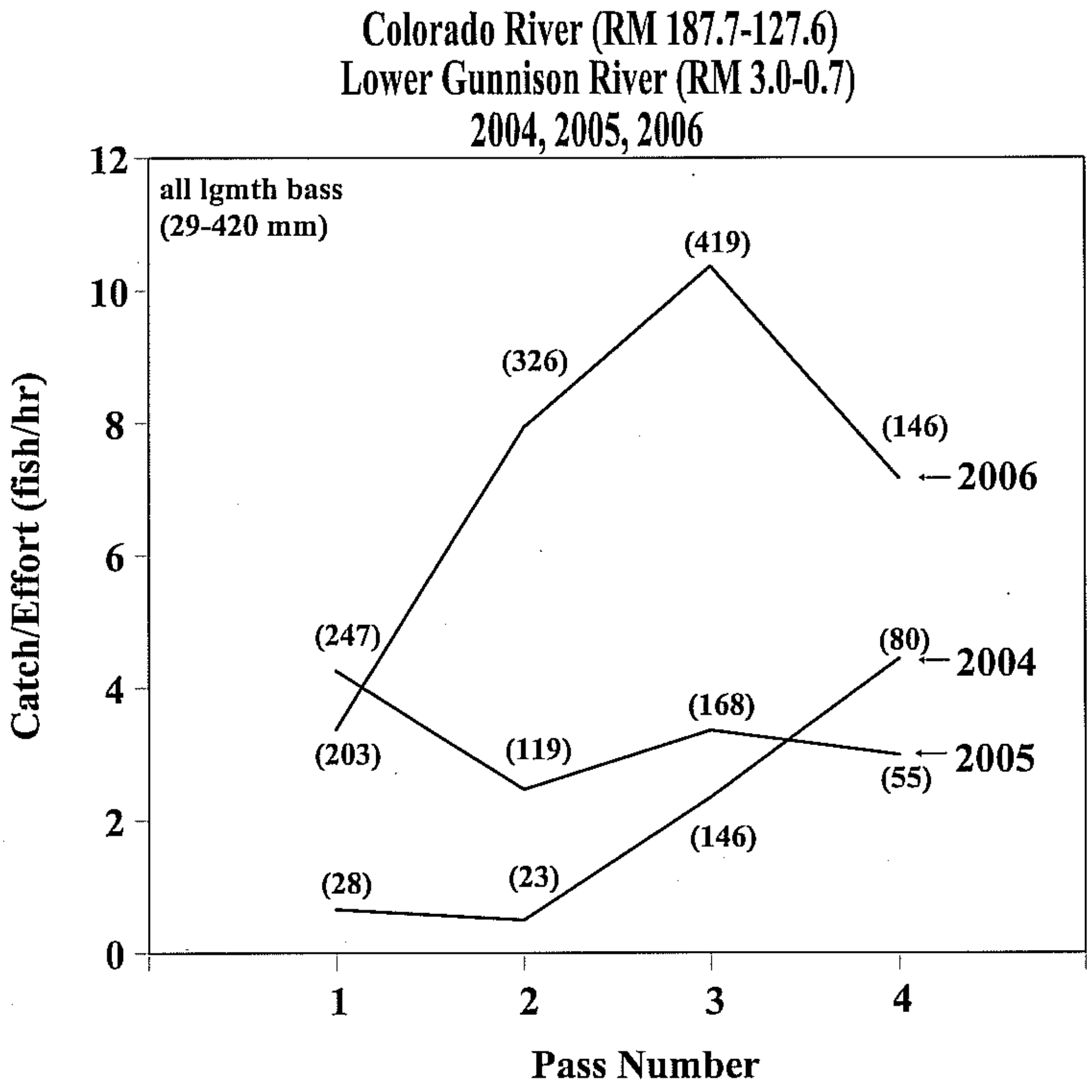


Figure B.1. Overall catch effort (fish/hr) by pass for largemouth bass (29–420 mm) collected from main channel habitats in the Upper Colorado River with electrofishing from RM 187.7–127.6 (Price-Stubb Dam to the Westwater, Utah, BLM ranger station) and in the Lower Gunnison River from RM 3.0–0.7 (Redlands Dam to the Colorado/Gunnison River confluence), 2004, 2005, and 2006. Note: The number of fish collected by pass is in parentheses.

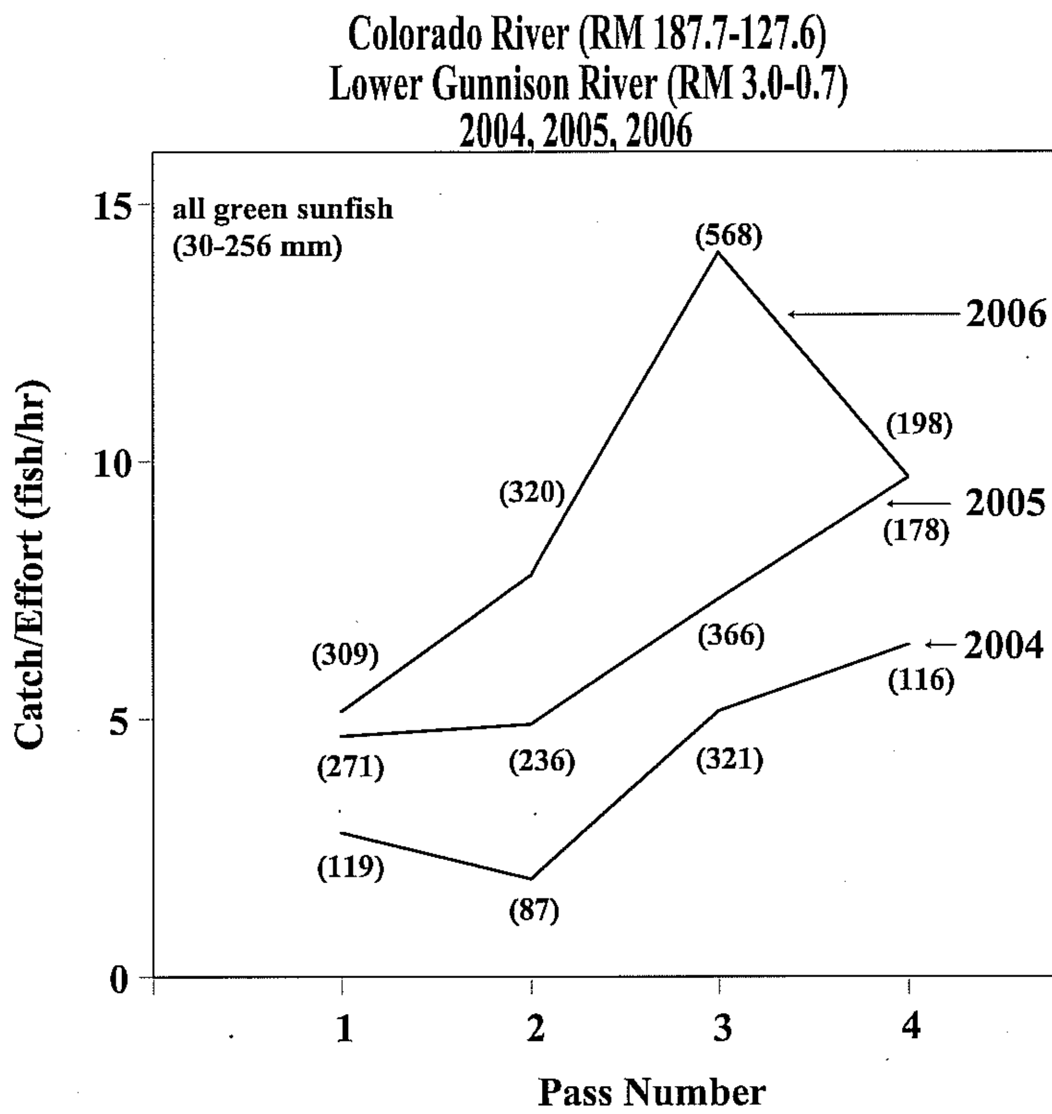


Figure B.2. Overall catch effort (fish/hr) by pass for green sunfish (30–256 mm) collected from main channel habitats in the Upper Colorado River with electrofishing from RM 187.7–127.6 (Price-Stubb Dam to the Westwater, Utah, BLM ranger station) and in the Lower Gunnison River from RM 3.0–0.7 (Redlands Dam to the Colorado/Gunnison River confluence), 2004, 2005, and 2006. Note: The number of fish collected by pass is in parentheses.

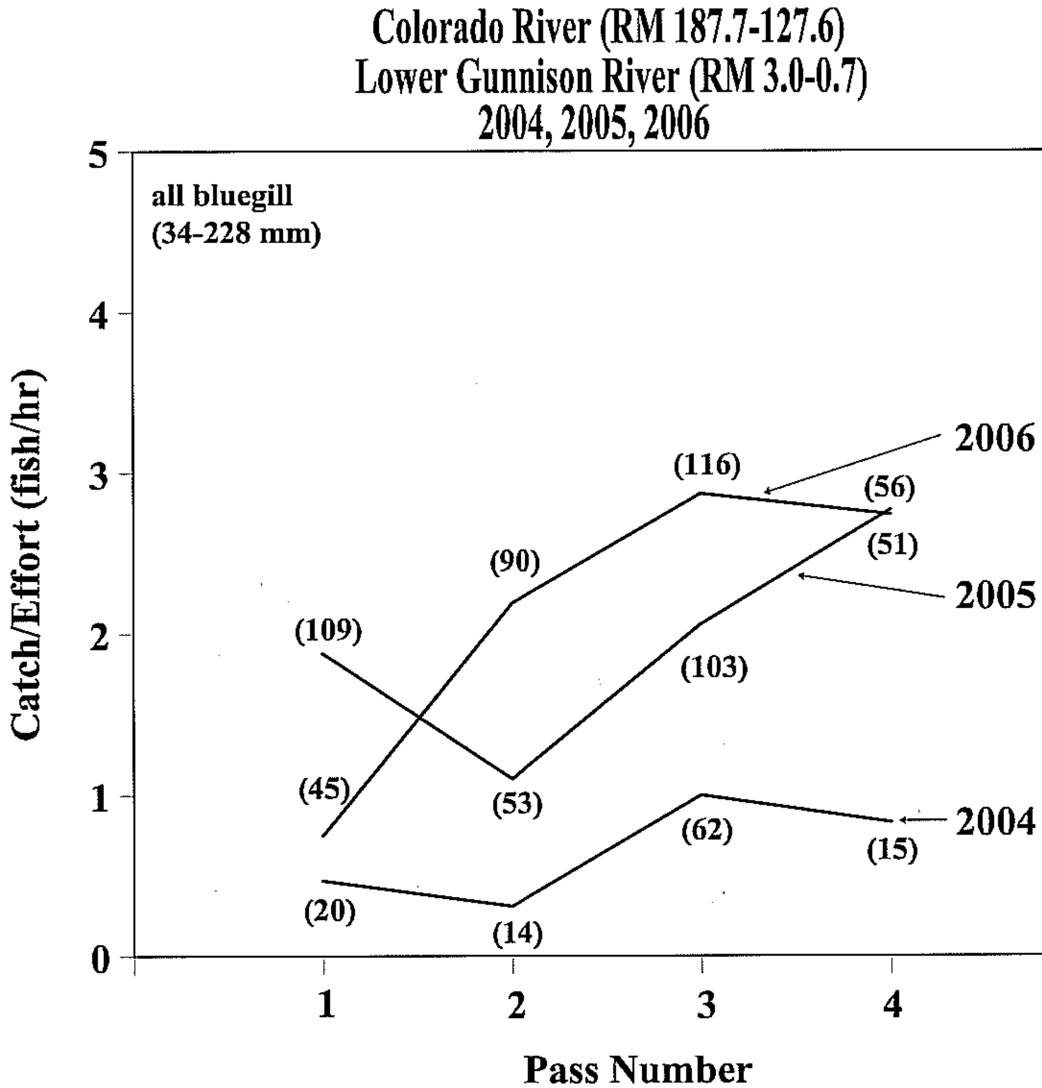


Figure B.3. Overall catch effort (fish/hr) by pass for bluegill (34–228 mm) collected from main channel habitats in the Upper Colorado River with electrofishing from RM 187.7–127.6 (Price-Stubb Dam to the Westwater, Utah, BLM ranger station) and in the Lower Gunnison River from RM 3.0–0.7 (Redlands Dam to the Colorado/Gunnison River confluence), 2004, 2005, and 2006. Note: The number of fish collected by pass is in parentheses.

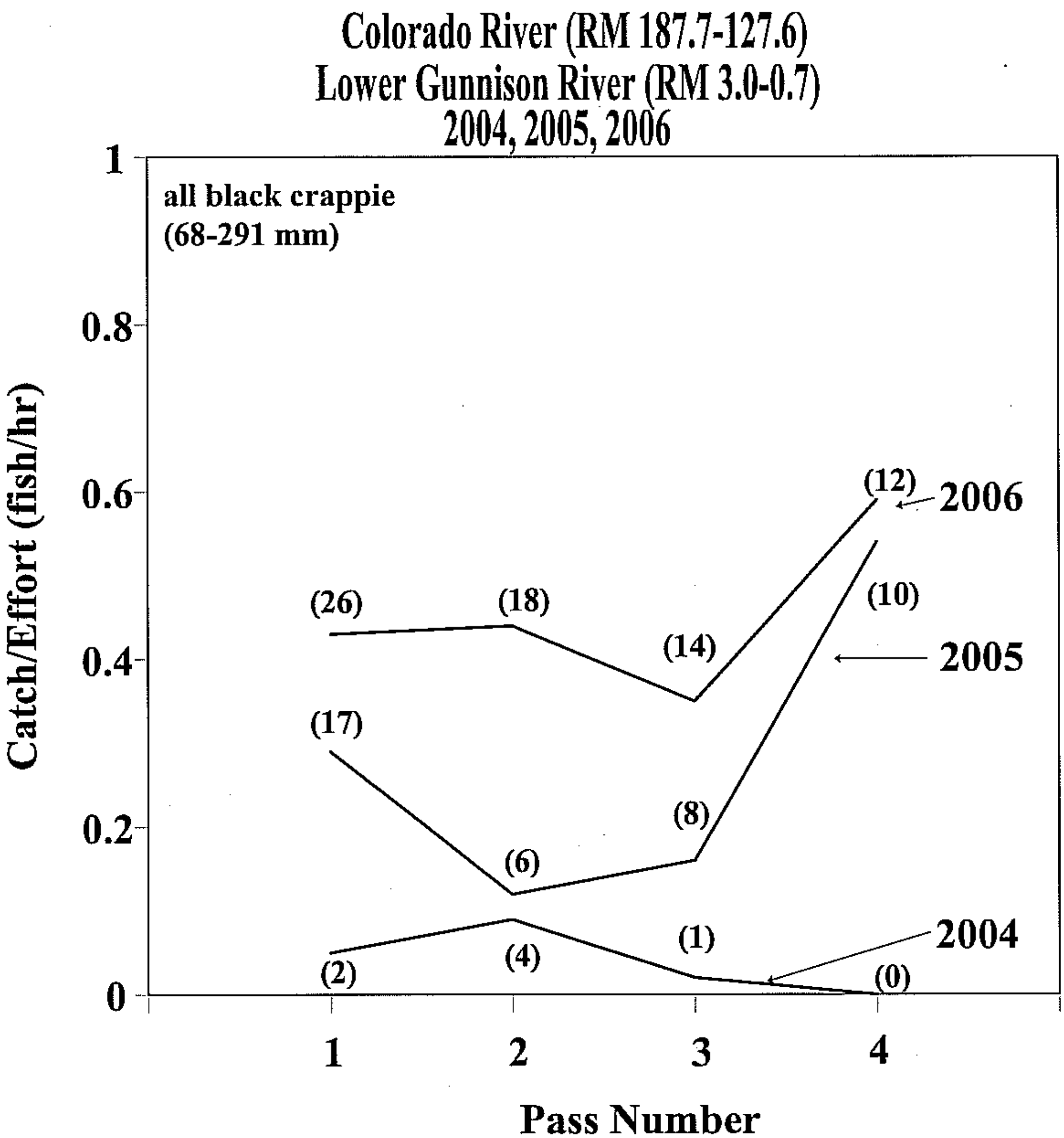


Figure B.4. Overall catch effort (fish/hr) by pass for black crappie (68–291 mm) collected from main channel habitats in the Upper Colorado River with electrofishing from RM 187.7–127.6 (Price-Stubb Dam to the Westwater, Utah, BLM ranger station) and in the Lower Gunnison River from RM 3.0–0.7 (Redlands Dam to the Colorado/Gunnison River confluence), 2004, 2005, and 2006. Note: The number of fish collected by pass is in parentheses.

APPENDIX C

Percentage and Number Comparison of Smallmouth Bass
by Various Length Classes Collected During the Summers of 2004–2006
&
Length Frequency of Age-0 and Age-1 Smallmouth Bass
collected during 2004–2006
in the Upper Colorado and Lower Gunnison rivers

Table C.1. Number of smallmouth bass by seven different length categories collected with electrofishing from marking and removal (REM-) passes from main channel riverine habitats from the Grand Valley river reaches of the Upper Colorado (RM 187.8–127.6) and the Lower Gunnison (RM 3.0–0.7) rivers during the summers of 2004–2006.

Reach: Grand Valley	Smallmouth Bass Length Categories-- mm {inches}						
Year Pass Type/No.	< 100 {< 4}	100-199 {4-8}	200-254 {8-10}	255-305 {10-12}	306-356 {12-14}	357-406 {14-16}	> 406 {> 16}
2006							
Marking	10	26	39	33	21	4	0
REM-1	23	25	61	77	41	6	0
REM-2	49	8	25	29	12	1	0
REM-3	100	9	22	43	17	0	0
REM-4	79	9	18	63	30	1	0
2005							
REM-1	30	152	182	69	35	5	0
REM-2	40	94	165	73	31	8	0
REM-3	99	79	80	38	14	3	0
REM-4	84	20	35	15	8	5	0
2004							
REM-1	0	91	76	34	15	1	1
REM-2	15	119	76	29	17	1	0
REM-3	44	309	74	53	23	2	0
REM-4	33	99	21	23	6	3	0

Table C.2. Percentage and number (in parenthesis) comparison of smallmouth bass by six different length categories collected with electrofishing from marking and removal (REM-) passes from main channel riverine habitats from the Grand Valley river reaches of the Upper Colorado (RM 187.8–127.6) and the Lower Gunnison (RM 3.0–0.7) rivers during the summers of 2004–2006. Number of total passes per year in brackets [ ]. See Table C.1. for number of smallmouth bass collected by pass by length category.

	Smallmouth Bass Length Categories					
Year	< 100 mm {< 4 "}	< 255 mm {< 10 "}	≥ 255 mm {≥ 10 "}	≥ 306 mm {≥ 12 ")	≥ 357 mm {≥ 14 "}	> 406 mm {> 14 "}
2006 [5]	29.6% (261)	57.1% (503)	42.9% (378)	15.1% (133)	1.4% (12)	--- (0)
2005 [4]	18.5% (253)	77.7% (1,060)	83.5% (304)	8% (109)	1.5% (21)	--- (0)
2004 [4]	7% (92)	65.6% (867)	34.4% (455)	5.2% (69)	0.6% (8)	< 0.01% (1)

Table C.3. Number of smallmouth bass by seven different length categories collected with electrofishing from marking and removal (REM-) passes from main channel riverine habitats from the Upper Colorado River (RM 248.0–195.7) during the summers of 2004–2006.

Reach: Silt to Beavertail Mtn	Smallmouth Bass Length Category-- mm {inches}						
Year Pass Type/No.	< 100 {< 4}	100-199 {4-8}	200-254 {8-10}	255-305 {10-12}	306-356 {12-14}	357-406 {14-16}	> 406 {> 16}
2006							
REM-1	2	0	5	10	18	5	0
REM-2	34	2	0	1	1	1	0
2005							
REM-1	10	28	26	34	18	3	3
REM-2	48	26	6	13	10	2	2
2004							
REM-1	3	4	3	9	1	0	1

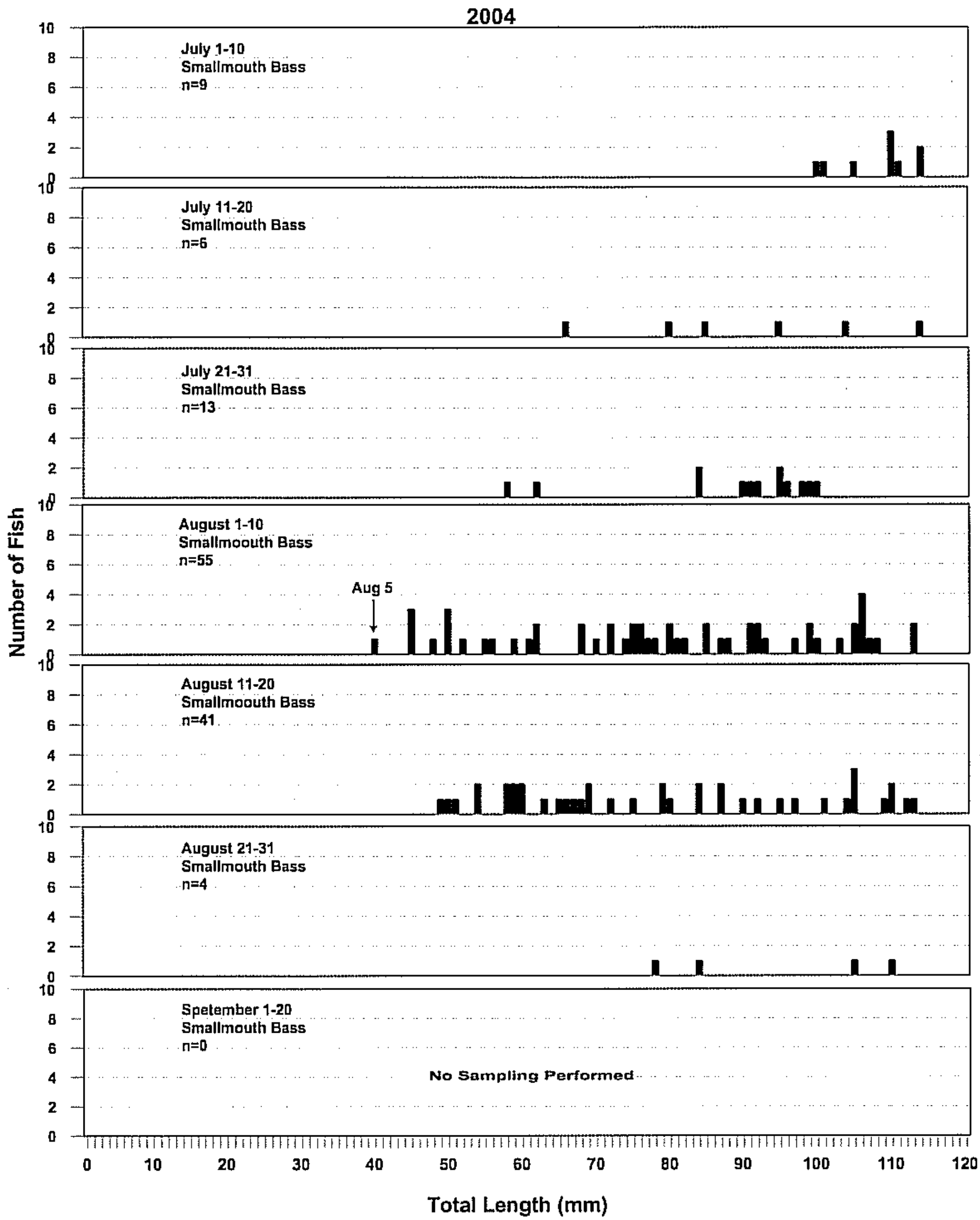


Figure C.1. Time series length frequency for age-0 and age-1 smallmouth bass (< 115 mm total length) collected during the summer of 2004 from the Upper Colorado (RM 187.8–127.6) and Lower Gunnison (RM 3.0–0.7) rivers.

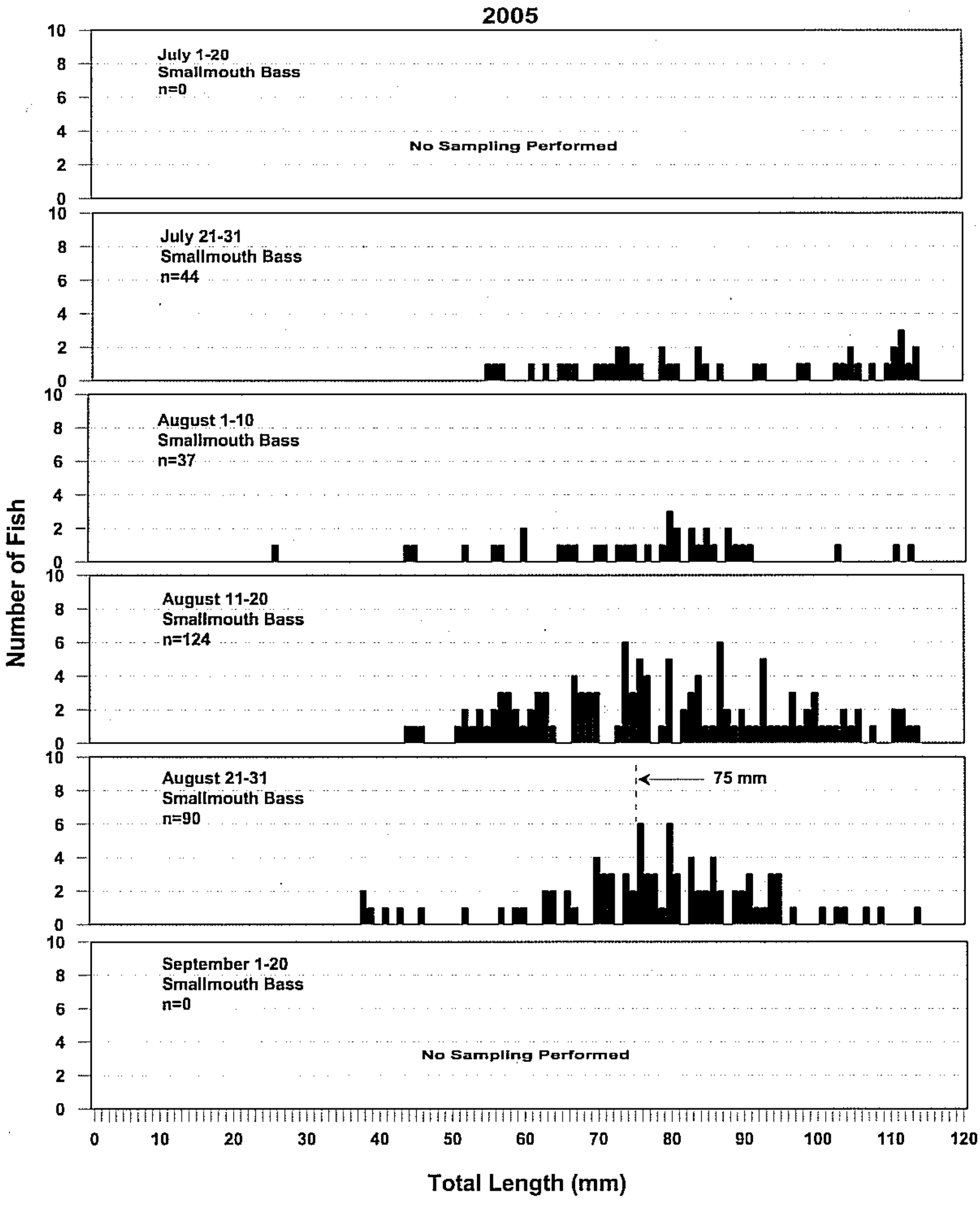


Figure C.2. Time series length frequency for age-0 and age-1 smallmouth bass (< 115 mm total length) collected during the summer of 2005 from the Upper Colorado (RM 187.8–127.6) and Lower Gunnison (RM 3.0–0.7) rivers.

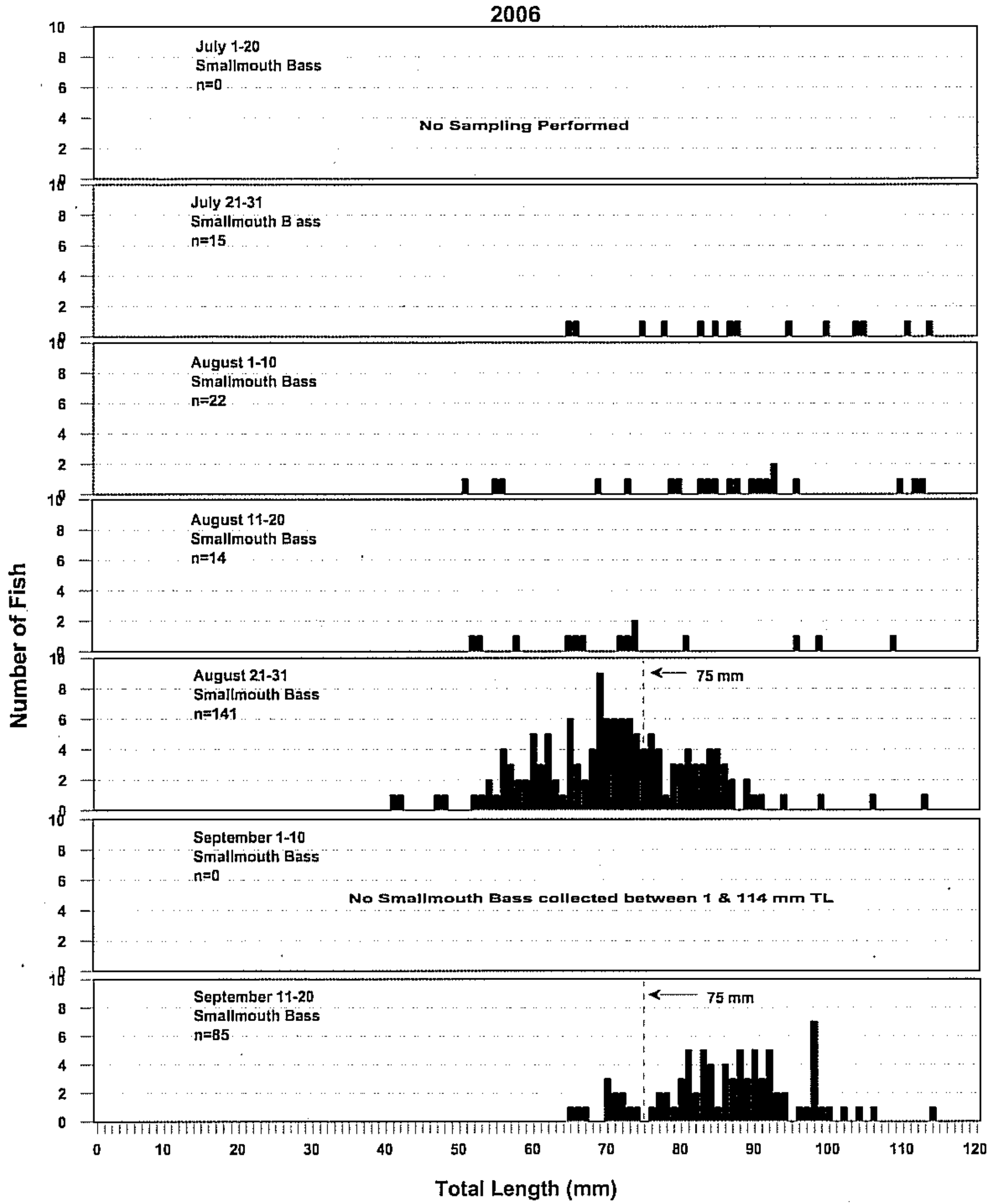


Figure C.3. Time series length frequency for age-0 and age-1 smallmouth bass (< 115 mm total length) collected during the summer of 2006 from the Upper Colorado (RM 187.8–127.6) and Lower Gunnison (RM 3.0–0.7) rivers.

APPENDIX D
Water Temperature and Hydrology Records

Table D.1. Discharge characteristics (instantaneous peak discharge, lowest and highest mean daily flow, and 90% exceedence) and degree days (≥14 ° C) for five calendar years (2002–2006) at the Cameo USGS gauge (RM 199.8) on the Upper Colorado River. N/A=data not available; P=preliminary.

Cameo	2002	2003	2004	2005	2006
Lowest Daily Mean (cfs)	925	871	1,040	1,240	1,360
Highest Daily Mean (cfs)	4,020	20,300	7,010	16,800	16,400
Instantaneous Peak Discharge (cfs) & Date	4,260 6/01	21,000 6/2	7,450 6/8	17,200 5/24	17,700 5/23
90% Exceedence (cfs)	1,160	1,090	1,250	1,390 P	N/A
Total Degree Days ≥14 ° C	749.9	600.9	538.8	443.7	558.8
Total Degree Days ≥14 ° C (6/1–10/31)	718.7	597.5	527.3	443.6	558.8
No. of Days Water Temp Equalled or Exceeded 14 ° C	139	124	129	113	99
Max Mean Daily Water Temp (C)	23.6	24.4	23.4	22.1	24.1

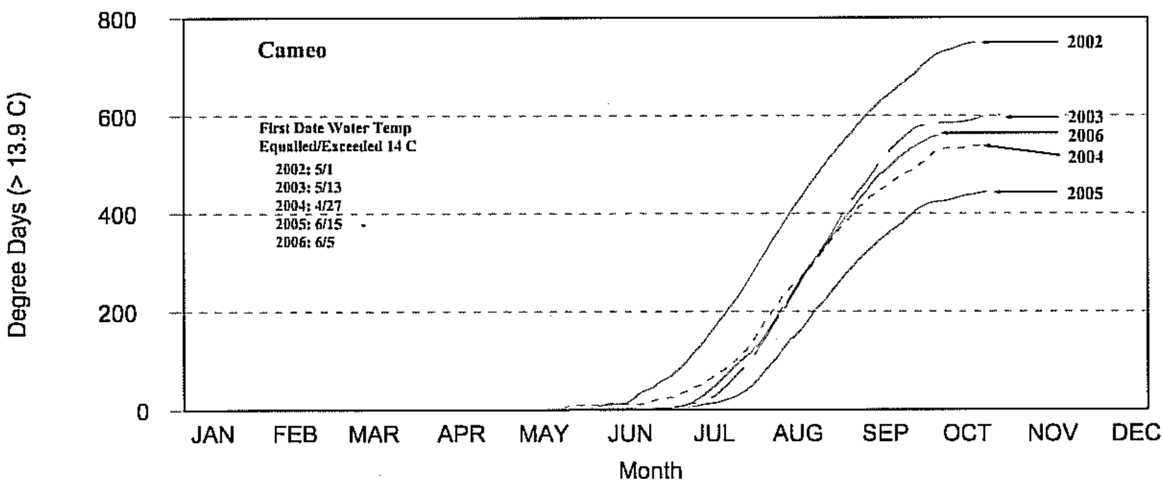


Figure D.1. Cumulative degree days (≥ 14 ° C) on the Upper Colorado River at the Cameo USGS gauge for 2002–2006.

Table D.2. Discharge characteristics (instantaneous peak discharge, lowest and highest mean daily flow, and 90% exceedence) and degree days (≥14 ° C) for five calendar years (2002–2006) at the stateline USGS gauge (RM 133.8) on the Upper Colorado River. N/A=data not available; P=preliminary.

Stateline	2002	2003	2004	2005	2006
Lowest Daily Mean (cfs)	1,280	1,350	1,370	2,500	2,650
Highest Daily Mean (cfs)	4,470	24,500	9,230	30,300	20,900
Instantaneous Peak Discharge (cfs) & Date	5,520 9/12	26,100 6/3	9,450 5/12	31,000 5/25	21,700 5/24
90% Exceedence (cfs)	1,570	1,840	2,110	2,990 P	N/A
Total Degree Days ≥14 ° C	1,023.4	898.7	870.2	692.0	749.4
Total Degree Days ≥14 ° C (6/1–10/31)	923.4	868.8	803.4	690.2	733.9
No. of Days Water Temp Equalled or Exceeded 14 ° C	169	158	169	123	132
Max Mean Daily Water Temp (C)	25.6	26.2	25.8	24.7	25.1

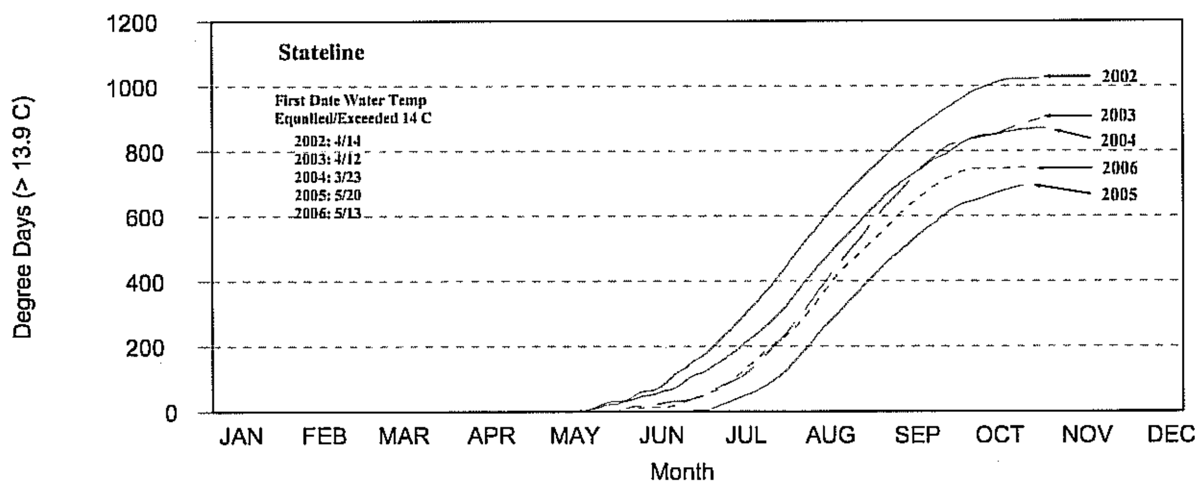
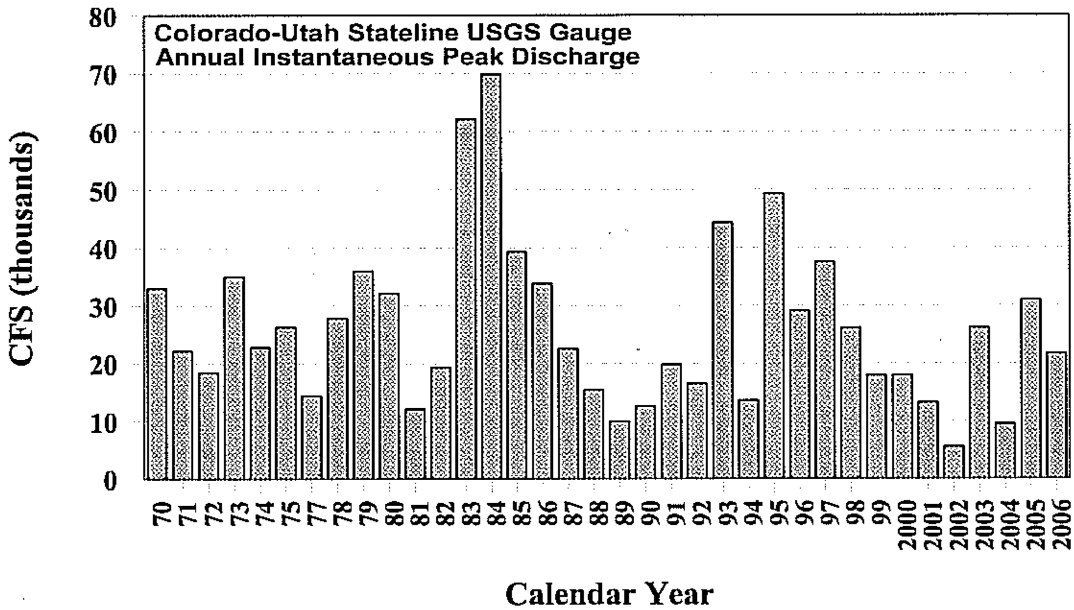


Figure D.2. Cumulative degree days (≥14 ° C) for the Upper Colorado River at the stateline USGS gauge for 2002–2006.



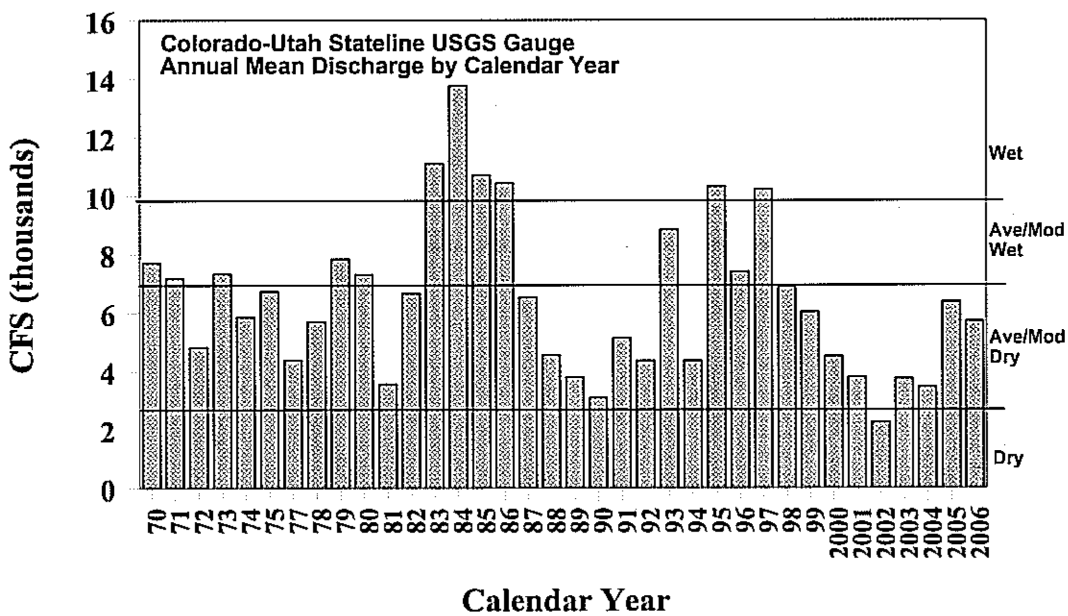


Figure D.3. Annual instantaneous peak discharge (upper) and annual mean discharge (lower) by calendar year for the stateline USGS gauge near the Colorado/Utah border (RM 133.8) for 1970–2006. Designations for "wet" to "dry" water years adopted from McAda (2003).

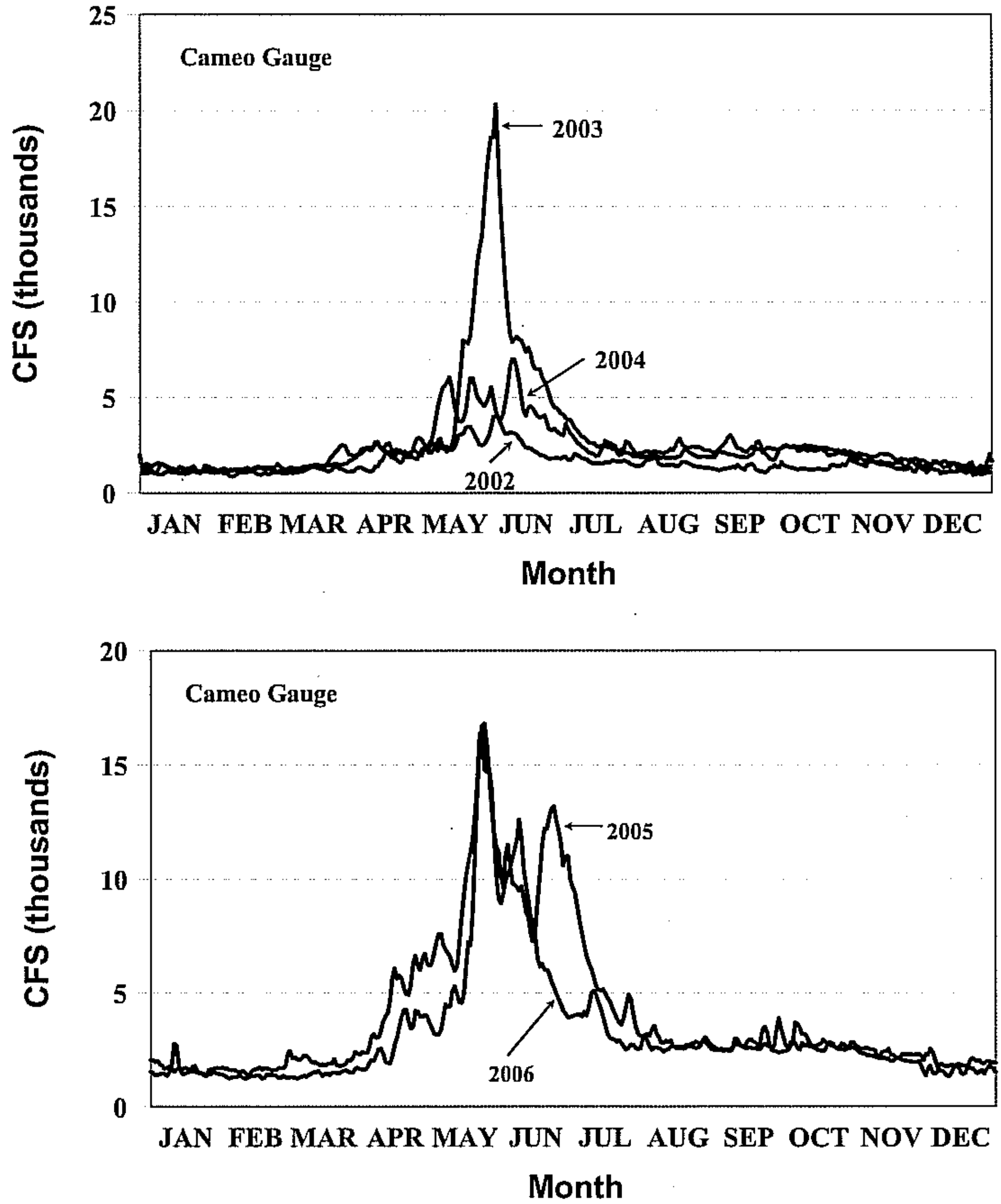


Figure D.4. Mean daily discharge for the Cameo USGS gauge on the Upper Colorado River (RM 199.8) for 2002–2004 (lower water years)(upper) and 2005–2006 (higher water years)(lower).

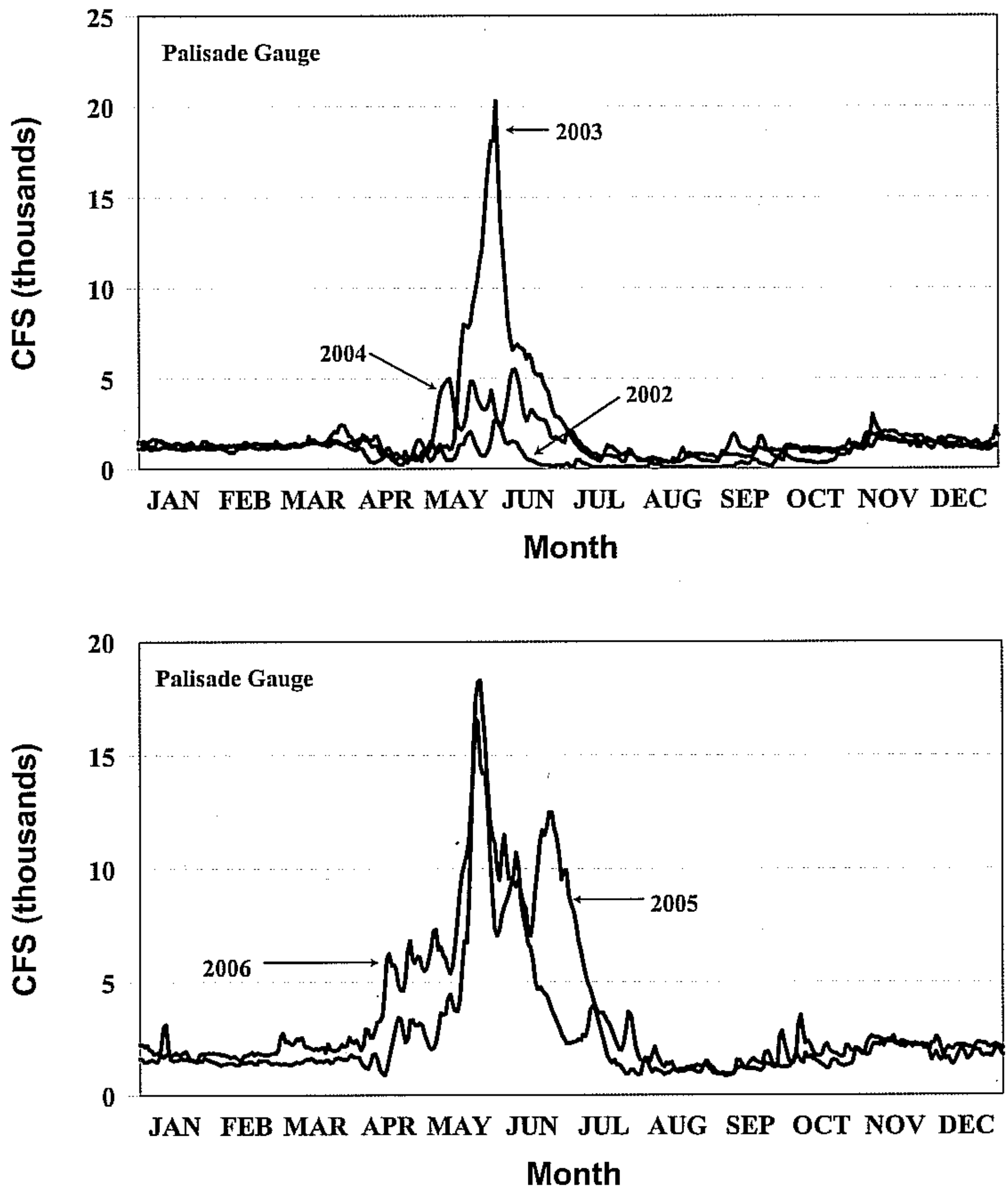


Figure D.5. Mean daily discharge for the Palisade USGS gauge on the Upper Colorado River (RM 184.5) for 2002–2004 (lower water years)(upper) and 2005–2006 (higher water years)(lower).

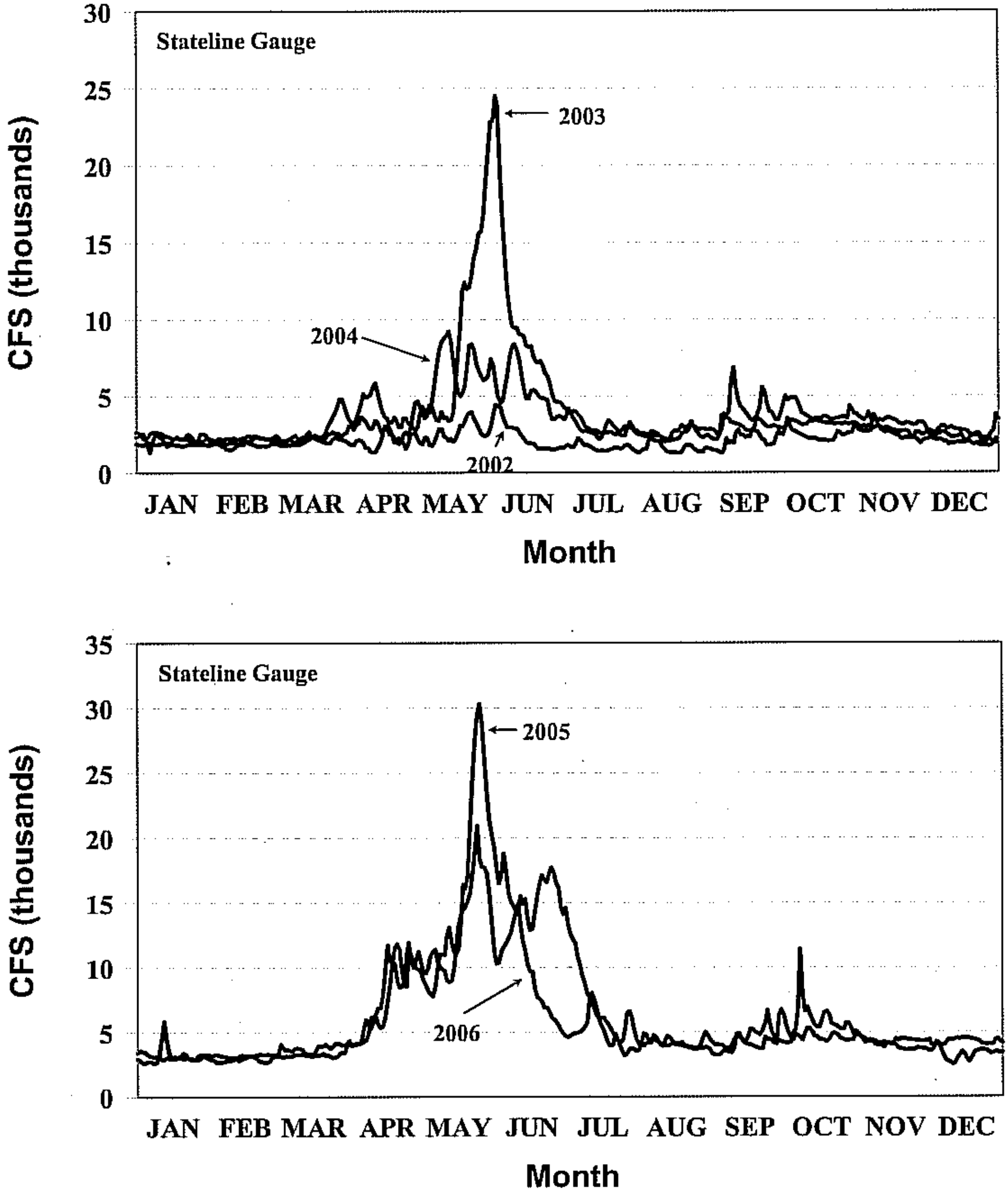


Figure D.6. Mean daily discharge for the stateline USGS gauge on the Upper Colorado River (RM 133.8) for 2002–2004 (lower water years)(upper) and 2005–2006 (higher water years)(lower).

APPENDIX E

Scientific and Common Names of Fishes
Mentioned in the Smallmouth Bass Removal Study
2004–2006

Table E.1. Scientific and common names and status (native vs. nonnative) of fish collected and mentioned in the text of this report during the smallmouth bass removal study in the Upper Colorado and Lower Gunnison rivers, 2004–2006.

Family Scientific Name	Common Name	Status
Clupeidae		
Dorosoma cepedianum	gizzard shad	nonnative
Cyprinidae		
G. robusta	roundtail chub	native
Gila cypha	humpback chub	native
G. elegans	bonytail	native
Ptychocheilus lucius	Colorado squawfish	native
Catostomidae		
Catostomus discobolus	bluehead sucker	native
C. latipinnis	flannelmouth sucker	native
Xyrauchen texanus	razorback sucker	native
Ictaluridae		
Ameiurus melas	black bullhead	nonnative
Ictalurus punctatus	channel catfish	nonnative
Esocidae		
Esox lucius	northern pike	nonnative
Centrarchidae		
Lepomis cyanellus	green sunfish	nonnative
Lepomis macrochirus	bluegill	nonnative
Micropterus dolomieu	smallmouth bass	nonnative
Micropterus salmoides	largemouth bass	nonnative
Pomoxis nigromaculatus	black crappie	nonnative
Percidae		
Perca flavescens	yellow perch	nonnative
Sander vitreus	walleye	nonnative

Cover page images courtesy of New York State Department of Environmental Conservation (smallmouth bass) and Duane Raver, USFWS (largemouth bass, bluegill, green sunfish, and black crappie)

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