SMALLMOUTH BASS *(Micropterus dolomieu)* REMOVAL in the MIDDLE GREEN RIVER, UTAH 2004-2006

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF KEY WORDS

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EXECUTIVE SUMMARY

The Upper Colorado River Endangered Fish Recovery Program has determined that control of nonnative fish in the upper Colorado River basin is essential to the recovery of the four endangered fish species: Colorado pikeminnow (*Ptychocheilus lucius)*, razorback sucker *(Xyrauchen texanus)*, humpback chub *(Gila cypha)*, and bonytail *(Gila elegans)*. This determination has been documented specifically for Colorado pikeminnow, razorback sucker, and bonytail in nursery habitats and in the mainstem middle Green River in Section 4.3.2 of each species' Recovery Goals (U.S. Fish and Wildlife Service (USFWS), 2002) document.

Smallmouth bass (*Micropterus dolomieu)* abundance has dramatically increased in the Green River since 2000. This increase resulted in a recommendation from the December 2003 Nonnative Fish Control Workshop (Grand Junction, CO) to attempt control of this species in the Green River. Three years of removal, from 2004-2006 and annual Nonnative Fish Control Workshops have added to the knowledge base of the effort required to successfully remove smallmouth bass from the Green River.

Experimental smallmouth bass removal efforts in the middle Green River began in 2004 and continued to 2006. Removal efforts began in Echo Park (RM 344) and continued to Swasey's Rapid (RM 132). This 212-mile reach of river was split into three different stretches and covered by three different agency groups. Each stretch of river was sampled for smallmouth bass using shoreline electrofishing. Smallmouth bass were captured, weighed, tagged, and released on the first pass of each year. The following three passes were removal passes where all smallmouth bass were again weighed and

measured, inspected for a tag, and then removed. Where possible, population estimates were calculated for each reach.

Information based on catch per unit effort from all three reaches indicates a decrease from 2004 to 2005, but a slight increase in catch per unit effort from 2005 to 2006. With 2004 being the first year of the removal project, smallmouth bass numbers were expected to be high and catch rates, especially compared with later years, did show this to be true. The decrease in catch rates observed in 2005 could be attributed in part to the removal effort, but more than likely some environmental variable caused the smallmouth bass population to drop from 2004 to 2005. In 2006, researchers saw a continued population increase in smallmouth bass numbers, thus initiating concern that more effort may be required to effectively reduce smallmouth bass numbers.

INTRODUCTION

The Green River, a major tributary of the Colorado River in the upper Colorado River Basin, originates in Wyoming, then flows southward into Utah, east into Colorado, and then back into Utah until it meets the mainstem Colorado River near Moab (Figure 1). The Green River was historically a highly variable, turbid river that was home to 14 native species of fish. Over the past 100+ years of human expansion westward, these native fish suffered many setbacks, including introduction of over 40 nonnative species of fish, installation of water diversion structures, and damming of the river near the Utah/Wyoming border (Utah Division of Wildlife Resources (UDWR), 2004). While no one introduction or diversion structure can necessarily be identified as the primary cause, it is likely that the combination of all of these impacts has contributed to the listing of four of these native fishes as endangered under the Endangered Species Act (USFWS, 2002). For a variety of reasons, it has been the Colorado pikeminnow, the humpback chub, bonytail and the razorback sucker that have shown the least ability to cope with the changes that have occurred in the upper basin.

In an effort to recover these fish, the Upper Colorado River Endangered Fish Recovery Program (Program) has identified the most problematic of the nonnative fishes in the river system and has determined that control of these fish is essential to the recovery process (Roehm, 2004). One of these nonnative species, the smallmouth bass, can be highly piscivorous (Pelham et al., 2001), thus making them problematic for the basin's native fish that are ill-adapted to this predator.

Beginning in 2000, the southwestern United States began experiencing drought-like conditions. Researchers believe that low flows and higher temperatures resulting

from the drought likely contributed to the observed increase in smallmouth bass numbers (Bestgen et al., 2007). An increase in this species was observed in the middle Green River drainage (K. Christopherson, UDWR, and M. Fuller, USFWS personal communication) and to a lesser extent in both Desolation and Gray canyons (J. Jackson, Utah Division of Wildlife Resources (UDWR), personal communication). These observed increases resulted in a recommendation from the Program's 2003 Nonnative Fish Control Workshop held in Grand Junction, CO, to attempt control of this species.

The purpose of this project is to minimize the expansion and reduce the abundance of smallmouth bass in the Green River. Objectives necessary to meet this goal are to 1) calculate an annual population estimate of smallmouth bass in the Green River, 2) remove smallmouth bass from the middle Green River from Echo Park (RM 344) to Swasey's Rapid (RM 132) and 3) assess the effectiveness of removal efforts. The information presented in this report details smallmouth bass removal activities in the Green River between RM 344, Echo Park, and RM 132, Swasey's Rapid, from 2004 through 2006.

STUDY AREA

Because the removal area was large (RM 344 – 132), it was split into three sections. For purposes of this document, these sections are referred to as Echo Park, Ouray and Desolation. This encompasses a large portion of critical habitat for the endangered fishes within the Green River (USFWS, 1998).

ECHO PARK

The U.S. Fish and Wildlife Service sampled the furthest upstream 26-mile reach from Echo Park (RM 344) downstream to Split Mountain boat ramp (RM 319). This stretch of river is entirely within Dinosaur National Monument and is thus managed by the National Park Service. The upstream border is just below the Green River and Yampa River confluence at Echo Park, Colorado. From here, the Green River flows southwest through Whirlpool Canyon and into slower open country in Island and Rainbow Parks and then through Split Mountain Canyon.

OURAY

Smallmouth bass removal within UDWR's Northeastern Region was conducted between RM 319 and RM 215, which was selected based on numerous smallmouth bass observations during sampling activities from previous years. The uppermost section of the reach is located within Dinosaur National Monument and has higher gradients and an abundance of cobble/rubble substrate. This section represents a transition zone between the upper canyon reaches and the lower alluvial reach, which extends from the razorback spawning bar at RM 310 to the end of the section at the Sandwash boat ramp, the put-in for Desolation. Both the Duchesne and the White rivers flow into the Green River within this lower section. Beginning just below the razorback bar, most of the adjacent land is

in private ownership, including cattle and sheep ranchers; however, both the Bureau of Land Management (BLM) and the Ute Tribe own or manage large tracts of shoreline in this stretch of river.

DESOLATION

Desolation and Gray Canyons are found south of the Uinta Basin, Utah, beginning at Sand Wash (RM 215) and ending 12 miles above the town of Green River at Swasey's Beach (RM 132). Low gradient runs with few riffles and a primarily sand substrate characterize the upper 25 miles of the reach. Near river mile 190, Jack Creek enters the Green River and the gradient steepens significantly. Moderate to high gradients and numerous rapids and riffles characterize the section below Jack Creek, with substrates comprised mostly of cobble and boulders. The BLM manages much of the land surrounding the Green River in this lower stretch.

METHODS

ECHO PARK

In the Echo Park reach, four complete passes were completed with five person crews and two electrofishing rafts in continual operation along both shorelines. In 2006, a fifth pass was added to target the age 0-1 cohort. During this pass an electric seine was used in shallow areas with small boulder and smaller substrates.

River trips generally started in late July or early August, and continued no later than mid-September. During the first pass of each year, smallmouth bass ≥97mm were tagged with green Floy® tags and released alive. All smallmouth bass were measured (mm) and weighed (g). In successive passes all bass were euthanized and disposed of according to state and federal permit requirements. Nonnative fishes other than smallmouth bass were also removed including green sunfish (*Lepomis cyanellus)*, bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*) and walleye (*Stizostedion vitreum*). Endangered fishes were tagged with PIT (passive integrated transponder) tags, weighed and measured, and released alive.

Population estimates were calculated for each year of the study using both the adjusted Petersen model and a closed population estimate model using Program Mark. Due to assumption violations based on the fact that sampling takes place over an extended time and therefore, smallmouth bass in the reach are growing and recruiting into higher length categories, only recaptures from the first removal pass were used to calculate the population estimate.

OURAY

Within the Ouray section, smallmouth bass were collected during four shoreline electrofishing passes. Two electrofishing boats simultaneously electrofished each side of the river. In 2004, the four passes were conducted beginning approximately two weeks after the spring peak (April 30) through late August. Results of the 2004 removal efforts showed increases in catch rates later in the summer with each subsequent pass. Because of this, in 2005 and 2006, electrofishing began later (July) or when water temperatures reached approximately 20°C. Only shoreline habitat that was likely to contain smallmouth bass was electrofished, i.e., sandbars were not shocked, only areas containing habitat (rocks, woody debris, etc.). All smallmouth bass were marked using red Floy® tags (either flag, streamer or anchor tags, depending on the year) and released on the first pass and then examined for tags and removed on subsequent passes. Based on results of the first two passes, sampling effort during the third and fourth passes was focused in smallmouth bass concentration areas.

All smallmouth bass were measured (mm), weighed (g), and the information recorded. In 2004, smallmouth bass collected in the first pass were tagged with a red Floy® flag tag and returned to the river. In 2005, because the retention of the flag tags was questionable, smallmouth bass collected in the first pass were tagged with Floy® streamer tags, which were recommended by the manufacturer for tagging smallmouth bass. These tags proved to be even less effective than the flag tags, therefore, in 2006, smallmouth bass collected in the first pass were tagged using numbered red Floy® anchor tags, the same type of anchor tag used in the Echo Park reach. In all years, smallmouth bass collected in the three subsequent passes were examined for a tag or a mark left by a tag, and disposed of in accordance with the State of Utah Euthanasia

Policy. Any endangered fish captured was scanned for a PIT tag, tagged if needed, weighed (g), measured for total length (TL, in mm), and released alive.

In 2004, recaptures during the second pass allowed determination of a smallmouth bass population estimate for both juvenile and adults using the Lincoln-Petersen approach. Lincoln-Petersen estimates were not done for the 2005 or 2006 collection efforts due to the lack of recaptured smallmouth bass.

DESOLATION

Four electrofishing passes were completed between Sand Wash (RM 216) and Swaseys Rapid (RM 132) between July and September 2004-2006. During each year, the first pass was used as a marking pass and the remaining three passes as removal passes.

In 2004, the entire Desolation reach was electrofished; after two passes it was apparent that the distribution of smallmouth bass ended near Rock Creek (RM 174). After the second pass in 2004, the majority of electrofishing occurred in the upper 42 miles of the canyon, with additional spot shocking down to Chandler Canyon (RM 167). By the end of the 2005 removal effort, it was clear which specific habitats would or would not contain smallmouth bass based on examining the results of sampling all habitats and river sections within the upper 42 miles. In 2006, efforts within the removal area were focused only on habitats that were likely to hold bass. Long stretches of shallow beach were not shocked; this resulted in overall less sampling time and an improvement in removal efficiency.

Smallmouth bass were marked with green flag tags in 2004. In 2005, bass were marked with small blue Floy® tags. Unfortunately, the anchor bar on these tags were

softer and smaller than those on the flag tags resulting in poor tag retention. In 2006, bass were once again tagged using flag tags.

Mark-recapture population estimates were calculated for 2004, 2005, and 2006 using the Lincoln-Petersen model with Chapman's correction. The population estimates included bass 100 mm and larger in all three years. Estimates were calculated using recaptures from the 2nd pass only and recaptures from all passes, in their respective year of capture. Only estimates using all recaptures are presented and used for calculations of density and removal efficiency. In 2004, the purpose for calculating the population estimate with all recapture passes pooled together was to smooth out the variance seen in recapture rates for all passes and reaches in the Green River removal reaches. In 2005, we had significant tag loss and very low numbers of recaptures, so we used all of the passes. In 2006, our numbers of marked fish were low, so we used all recaptures to have enough for a population estimate.

Nonnative removal and evaluation efforts, which included tagging and marking native, endangered and target nonnative fishes, was also being conducted by other researchers and agencies in other areas of the upper Colorado River Basin. Therefore, sampling crews in all reaches examined all native, endangered and target nonnative fish for tags or marks from all reaches and recorded pertinent information. This information was then reported to principal investigators as appropriate and included in annual reporting.

RESULTS

ECHO PARK

Population estimates were calculated for all years of the study in this reach for smallmouth bass ≥100mm (Table 1 and Figure 2). Densities of smallmouth bass differed spatially and higher densities were associated with particular habitats. Smallmouth bass were rarely collected in the Island Park and Rainbow Park area (RM 327-334), despite intensive sampling. Thereafter, time spent sampling in less populated areas was reduced, and, to maximize effectiveness, effort was directed to areas with higher densities. No tagged fish from outside the Echo Park study area were collected. With the use of the electric seine, 670 bass < 100 mm were collected from areas not accessible to shocking rafts. These fish were not used in population estimation or in the calculation of catch per unit effort (CPUE) presented in the following figures.

The highest exploitation, or percent removed, in a given year was 31%; this was in 2004 (Table 2). Thereafter, 21 and 18% respectively of the 2005 and 2006 estimates were removed. In 2004 we removed 94 bass per mile; in 2005 and 2006 we collected 28 and 29 smallmouth bass per mile (table 2 and Figure 3). As expected, smallmouth bass were more difficult to collect when at lower densities (Figure 4). Fish density estimates ranged (95% confidence interval) from 158-318 bass/RM in 2004, 79-231 bass/RM in 2005 and 77-332 bass/RM in 2006.

Catch rates in 2005 and 2006 were consistently lower than in 2004 (Figure 5). In 2006, the CPUE for all passes combined was 11.17 bass/hour; this is lower than in 2004 but similar to that in 2005 (Figure 6).

In 2004, we removed 2440 smallmouth bass in three removal passes. The mean TL of smallmouth bass collected was 183 mm (Figure 7). In 2005, the catch decreased to 718 smallmouth bass in three removal passes. The mean TL of smallmouth bass collected for all passes was 197 mm. In 2006, the catch was similar to that in 2005, 749 smallmouth bass were removed in three passes. In 2006, we saw the addition of young of year (YOY) smallmouth bass. These YOY showed in our catch beginning in late summer after reaching a size vulnerable to electrofishing.

Movement of bass out of the study area was not detected in downstream sampling, but three recaptured bass from the Ouray stretch (red flag tagged bass from 2004) were collected upstream in the Yampa River (M. Fuller, USFWS, personal observation).

OURAY

2004

An initial population estimate using smallmouth bass 100-199mm for juveniles (Table 3) and ≥200mm for adults (Table 4) was obtained by calculating a Petersen estimate. The estimate was calculated using the first electrofishing pass as the marking pass and the second pass only as the recapture pass. The abundance estimate of smallmouth bass using the first and second passes for juveniles was 7343 with a 95% CI of 1084 – 15,770 (Figure 8). This represents an estimated density of 71 bass/mile. An estimate of 6588 (95% CI 1678 – 11,498) adult smallmouth bass was obtained (Figure 8). This represents 63 bass/mile.

Estimates of capture efficiency per pass for juveniles and adults for the 2004 effort were also estimated based on the number of smallmouth bass removed compared to the population estimates obtained (Table 5). Results show that the capture efficiency

increased with each pass. These results seemed correlated with increasing water temperature.

2005 & 2006

In 2005, no tagged smallmouth bass were recaptured. In 2006, only one tagged smallmouth bass was recaptured, precluding a population estimate using the Petersen estimator and an estimate for capture efficiency per pass.

In 2005, three tagged smallmouth bass from other research locations were encountered in this reach of the middle Green River from Split Mountain boat ramp (RM 319) to Sand Wash (RM 215) (Table 6). They were initially tagged in 2005.

Tag Retention Study – 2005

After one tagging pass and two removal passes, crews had not encountered any of the smallmouth bass that were tagged with streamer tags. Prior to the completion of the final removal pass, a tag retention study was conducted from 24 through 30 August to determine if the streamer tags used were remaining attached to the fish. A known concentration area from Split Mountain boat ramp to Razorback Bar was electrofished to conduct this evaluation. On 24 August, a total of 76 smallmouth bass were tagged with both streamer and flag tags and released in this area. On 30 August, this area was electrofished again and smallmouth bass were removed and examined for tags. During this effort, five smallmouth bass tagged as part of this evaluation were recaptured. Only one of these recaptured smallmouth bass still retained its streamer tag. Three had flag tags with no streamer tag, but a hole in the lip membrane indicating a streamer tag had at one time been inserted. The remaining fish didn't have either a streamer tag or a flag tag, but showed evidence of having been tagged by both.

Length frequency diagrams for all three years (Figure 9) suggest missing or reduced young of year smallmouth bass during the first two years of sampling. In 2006, young of year and juvenile smallmouth bass were more prevalent.

2004-2006

Combining the three years of this study, a total of 794 smallmouth bass were tagged with 47 of these recaptured (none of which were between-year recaptures); 3,423 smallmouth bass were removed from the middle Green River, Ouray (Table 7).

Since no total population estimates were available for 2005 or 2006, a determination of any correlations with catch rates compared to a population estimate between the three years could not be made. The number of smallmouth bass per river mile is also unavailable for 2005 and 2006 due to the lack of population estimates for these years.

Data on catch rates, for all sizes of smallmouth bass captured, was available for the three years for a comparison. When combining the four passes, catch rates decreased after the first year (Table 8). This decrease in catch rate is not correlated with effort, since 2004 had the highest catch rate and the second lowest effort.

Smallmouth bass continued to be distributed throughout the middle Green River, Ouray section over all three years, with certain concentration areas (Figure 10). Catch rates were lowered in some locations between 2004 and 2006: the razorback bar stretch (RM 310-315), around Leota Bottom (RM 255-260), and Ray's Bottom (RM 220-225).

Catch rates for all sizes of smallmouth bass during each pass for the three years were also compared (Figure 11). Trends were evident in the first three passes, with catch rates decreasing over the three years. In 2005, the fourth pass had a much reduced catch

rate compared to the other passes, including 2006 when we would have expected lower catch rates based on the previous three passes. Within years, 2005 was the only year that experienced a decrease in catch rates. This occurred between pass three and pass four. In both 2004 and 2006, catch rates increased over the four passes.

No effort to identify spawning adults or YOY smallmouth bass was made in 2004. This was likely due to the timing of sampling. Sampling in 2004 ended in August, which was much earlier than in 2005 or 2006. Presence of YOY smallmouth bass was documented in 2005 and 2006. In 2005, two dates were noted when YOY smallmouth bass were captured. Three YOY bass were captured on 17 August 2005 near RM 257.8 (Leota) and on 24 August 2005, a congregation of over 50 YOY smallmouth bass was observed near RM 317.8 (Cub Creek) ranging in size from 36 – 67 mm. A study by Oliver et al (1979) indicated that a longer average length of smallmouth bass was correlated with greater overwinter survival. The pre-winter length of smallmouth bass in 2005 could account for the increase in juvenile smallmouth bass that were encountered in 2006. In 2006, no spawning adults were noted, but many YOY bass were captured and removed. The most notable congregations occurred at and around RM 318 (Split Mt.) in late summer, but congregations of YOY bass were seen downriver as well. Length frequency distributions show the presence of multiple year classes including YOY bass throughout the study reach and during all three years (Figure 9). Sampling in 2006 went later into the year (to the end of October), which may be a reason for the increase in smaller bass in 2006 as well.

DESOLATION

2004

The pre-removal abundance estimate for all smallmouth bass in the upper 42 miles of Desolation Canyon in 2004 was 5,087 individuals (Table 9). The density estimate derived for this section of the river was 121.1 fish/mile (Table 9 and Figure 12). During the three removal passes, a total of 937 smallmouth bass were removed, which translates to 18% of the initial population. Exploitation rates increased from 5% during the first two removal passes to 9% during the final pass.

In total 1,117 bass were captured with 141 hours of electrofishing effort expended, resulting in an overall CPUE of 7.83 fish/hr (Table 10 and Figure 13). The total CPUE for bass over 150mm was 7.74 fish/hr, as compared to a CPUE of 0.18 fish/hr for bass under 150mm (Figure 14). The total CPUE for all size classes combined showed an increasing trend during each subsequent pass in 2004 (Figure 15).

2005

During the first pass, 82 smallmouth bass were tagged and released. Over the three subsequent passes, a total of 371 bass were removed. Of the bass removed, 3 were recaptured with blue tags and 6 were recaptured with yellow flag tags from 2004. No bass from other sections were recaptured. The pre-removal abundance estimates for all smallmouth bass in the upper 42 miles of Desolation was 7,677 individuals (Table 9). The density estimate derived for this section of the river was not reliable due to significant tag loss.

In total, 462 bass were captured with 198 hours of electrofishing effort expended, resulting in an overall CPUE of 2.33 fish/hr (Table 10 and Figure 13). The total CPUE for 2005 was 70% lower than observed in 2004. The total CPUE for bass over 150mm was 2.21 fish/hr, as compared to a CPUE of 0.11 fish/hr for bass under 150mm (Figure

14). A comparison of total CPUE for all size classes by pass showed no significant trend during each subsequent pass in 2005 (Figure 15).

A slight increase in the downstream extent of bass distribution was observed in 2005, with 3 bass captured 3-4 miles below Rock Creek (RM 173.8) (Figure 16). The longitudinal distribution of bass captured again varied significantly between Sand Wash and Rock Creek (Figure 16). Qualitatively, the longitudinal variation still appeared to be related to habitat; however in 2005 spring flows topped 30,000 cfs in the canyon, clearing large debris piles and creating significant cut banks in the upper 20 miles of the canyon. Only one section (RM 210-211) in the upper portion of the reach maintained its in-channel cover, and in turn, maintained the highest catch rates in the entire Desolation reach (Figure 16).

Length frequency distributions again showed the presence of multiple year classes; however bass in the 50 to 100 mm size range were not captured this year (Figure 17). For fish over 300 mm, the observed frequency was down 10% between 2004 and 2005.

2006

During the first pass, 42 smallmouth bass were tagged and released. Over the three subsequent passes, a total of 137 bass were removed. Of the bass removed, three were recaptures with orange tags (2006), one had a blue anchor tag (2005) and two had yellow flag tags from 2004. No bass from other sections were recaptured. The 2006 initial abundance estimate for smallmouth bass in the upper 42 miles of Desolation Canyon was 1,483 individuals (Table 9). The density estimate derived for this section of the river was 35.3 fish/mile (Table 9 and Figure 12). Removal of 137 bass translates to

9.1% of the 2006 initial population. Exploitation rates remained stable over the three removal passes at about 3% per pass.

In total, 179 bass were captured with 69 hours of electrofishing effort expended, resulting in an overall CPUE of 2.60 fish/hr (Table 10 and Figure 13). The total CPUE for 2006 was not significantly different than 2005 rates (Table 10 and Figure 13). The total CPUE for bass over 150mm was 2.26 fish/hr, as compared to a CPUE of 0.32 fish/hr for bass under 150mm (Figure 14). A comparison of total CPUE for all size classes by pass showed no significant difference between any passes during 2006 (Figure 15).

The downstream extent of bass distribution was nearly identical to that in 2005 (Figure 16). The longitudinal distribution of bass captures showed no significant variation between Sand Wash and Rock Creek (Figure 16). Qualitatively, the longitudinal variation still appeared to be related to habitat on a small scale; however overall captures throughout the canyon were low, which made it difficult for any large scale patterns to be observed. The one section (RM 210-211) in the upper portion of the reach, which had the highest catch rates during the past two years, was nearly dry in 2006 due to a shift in the channel resulting in no areas of significant concentration (Figure 16).

Length frequency distributions again showed the presence of multiple year classes, including small juvenile bass in the 50-100 mm size class (Figure 17). For fish over 300 mm, the observed frequency returned to levels observed in 2004.

Movement of smallmouth bass between the Ouray reach and Desolation reach was documented by the capture of two red flag tagged smallmouth bass tagged and recaptured in 2004. The two recaptures represented 0.6% of the available tags released in the Ouray reach. These fish were found at river miles 185 and 213.

Length frequency distributions showed the presence of multiple year classes including low numbers of one-year-old smallmouth as far down canyon as river mile 184 (Figure 17). No significant shift in size structure was observed over the removal period.

DISCUSSION

ECHO PARK

This reach experienced a non-significant decline in smallmouth bass numbers and catch rates from 2004 to 2005 and a slight increase from 2005 to 2006. This may be a result of a reduced class of young fish in 2005 and then the subsequent increase in age-0 and age-1 bass in 2006, similar to downstream observations.

OURAY

A comparison among the data from the three years of this study is made difficult due to the lack of a Petersen population estimate for 2005 and 2006. It is unclear whether the removal effort or environmental factors had the larger influence on bass numbers. However, information based on smallmouth bass capture rates correlated with flows and water temperatures can be interpreted.

An attempt was made to correlate smallmouth bass catch rates with spawning flows and rearing conditions based on the flow and water temperature. Data was gathered from the USGS real-time water data website from the gauge near Jensen, Utah (USGS 09261000). We first attempted to correlate catch data with flows during likely smallmouth bass spawning times with the idea that higher flows would result in lower spawning success due to less available spawning habitat and less than ideal spawning conditions. A study in Minnesota showed that no smallmouth bass nest sites were successful in producing fry due to high water flows early in the smallmouth bass spawning season (Mavrakis, 1995). The Pennsylvania Fish and Boat Commission (1997) also noted that flow, along with turbid water conditions, have limited the habitat for spawning smallmouth bass, or have made some habitat unsuitable because of currents that are too fast for smallmouth bass to spawn in. Flow data was analyzed for 2004 –

2006 for water temperatures between 15 – 17 °C, the temperature range during which smallmouth bass spawning occurs (Lorantas and Kristine 2004) (Figure 18).

The flow data for 2004 during smallmouth bass spawning depicts low flows (maximum 11,400 cfs) with one distinctive peak. Flows for 2005 indicate that the peak flow (maximum 19,500 cfs) was reached over a short interval, and then continuous high flows persisted and gradually decreased at the end of the spawning period, which we assumed to be when water temperatures exceeded 17ºC. The high flow in 2006 (18,400 cfs) was reached gradually, and then the flow decreased rapidly.

Data for one month after temperatures reached 15°C during 2004, 2005 and 2006 was also collected from the USGS water data website near Jensen, Utah. This flow and temperature data represents rearing conditions for smallmouth bass after spawning is complete. If spawning took place when water temperatures were between 15 - 17ºC, and smallmouth bass eggs typically hatch 10 days after being laid (Texas Parks and Wildlife, 2007), YOY smallmouth bass should appear one month later (Figure 19, 20 & 21).

Comparing catch data with flow data obtained from the USGS gauge near Jensen, Utah, certain conclusions can be made. The highest numbers of smallmouth bass were caught during the year with the lowest flow conditions over the spawning period. The fewest smallmouth bass were captured during the year with continued high flows during the spawning period. However, 2004 was the first year of the study and therefore, would likely have been the year with the highest numbers of smallmouth bass, regardless of the flow regime for that year. It is still uncertain, however, if the low flows caused an increase in spawning success, or if the continued low flows in 2004 increased the probability of capturing smallmouth bass.

Despite the changing flow conditions among the three years, the area from Split Mountain boat ramp to the Escalante spawning bar (RM 306) continued to have a high concentration of smallmouth bass throughout the three years, although catch rates were greatly reduced over the three years of the study in this area.

Catch rates decreased after the first year, but increased with every pass, excluding pass three and four in 2005. Comparing the catch rates with the temperature and flow data during the rearing period of smallmouth bass, 2004 had the most stable flows and temperatures, while 2005 and 2006 saw variable conditions, perhaps leading to the subsequent decrease in catch rates over the three years. Oliver et al. (1979) found similar results in his study of first winter survival of smallmouth bass. He found that large smallmouth bass survived their first winter better than smaller bass at water temperatures of 2, 4 and 6° C.

Based on other researchers information (Mavrakis,1995 and Pennsylvania Fish and Boat Commission,1997) rearing conditions for smallmouth bass in 2004 in the middle Green River – Ouray seemed ideal, with relatively high temperatures and low flows. Flow and temperature conditions in 2005 indicate high temperatures, although not as high as in 2004, and extended high flows, while conditions in 2006 show an earlier decrease in temperature toward the end of the rearing season as well as an earlier and more sudden decrease in flows compared with the previous two years. Although no definite conclusions can be reached, it does appear that smallmouth bass populations in the Ouray reach are responding to many factors, including flow and temperature.

Unfortunately, we were unable to get population estimates in 2005 and 2006 using the Petersen estimation technique. This was due to a lack of recaptures in both

years. In 2005, it is likely that we did not have adequate tag retention; however, in 2006, we are unable to say whether tag retention was poor or that some other factor was causing the low number of recaptures. The anchor tags seemed to be secure once placed in a fish. The manufacturer does not recommend these tags however, because smallmouth bass tend to rub against rocks and brush, potentially dismantling these types of tags. While it seems unlikely that many of the tagged bass could have lost their tags, it seems more likely that the population of smallmouth bass in this stretch was so large that we only saw one recapture. Other likely possibilities for why we did not get many recaptures include immigration, emigration and avoidance. Smallmouth bass could have come into or out of our study reach, although we didn't see many tags from other reaches (3 total). Avoidance may be the most likely option, though there were 46 recaps in 2004.

Both gear type and sampling technique remained the same throughout the three years of the study. Crew members did change all three years, and this could have affected the capture rate of smallmouth bass. Also, in 2006, the ability to capture smallmouth bass and to be able to target areas of known concentrations became apparent as the field season progressed which could account for the increase in catch rate with every pass.

DESOLATION

Smallmouth bass concentration areas were noticeable within the Desolation reach, with the downstream extent of bass in the Green River ending in Desolation Canyon a few miles below Rock Creek (RM 168). Bass within these concentration areas were associated with cover, either large woody debris or boulder in moderate flows, and there appeared to be only minimal levels of recruitment in the Desolation reach.

Overall, removal of 1,483 bass only represented 28% of the initial population estimate. Yet, population estimates and total catch were down over 70% between 2004 and 2006. If the initial population estimate was relatively accurate, the additional decline points to physical changes in habitat and flows affecting all size classes of this portion of the population. Possible reasons for the large declines are: movement out of this reach or decreased immigration into this reach, decreased recruitment and direct mortality. Indirect effects could be reduction in preferred prey, loss of quality habitat and cover, loss of quality spawning habitat, and spawning disruption due to flow fluctuation or flood duration.

The common factor in all reaches during 2005 was a high spring peak (34,900 in Desolation). Within Desolation Canyon, the high flow caused significant changes in the amount of shoreline woody debris habitat which was previously abundant in the upper 25 mile low velocity section of the canyon which is primarily sand substrates. The spring peak surpassed 20,000 c.f.s. by May 22 and remained above that level until June 12.

The loss of cover and high volume flows could have displaced the small juveniles and caused significant declines in their survival. It is unknown how spawning was affected because we were unsure if the 50-100mm bass observed in the fall were young of year or age 1+ fish. If the fish in this size class were from the previous years spawn and flooding greatly reduced spawning success, it would be expected that the 2006 fall catches for small juveniles would be the lowest observed during the three year removal period; they were actually the highest. A distinction should be made that the largest numbers of small juveniles captured in Desolation were over ten times fewer than were observed in the upstream reaches. So, during the entire three-year removal period, the

lowest reach had low densities of adult and juvenile fish and very low recruitment of small juveniles.

The reduction in density estimates and capture rates observed in Desolation Canyon must have been due to a combination of factors. Although the population estimates suffered from problems such as tag loss and low recapture numbers; the large decline in capture rates was significant (84%) and cannot be completely accounted for with mechanical removal efforts alone. The largest reduction in capture rates occurred between 2004 and 2005. During this period the highest spring flows observed since smallmouth became a concern were observed. It would appear that physical changes in habitat, displacement, and spawning disturbance may have played an important role in reducing the abundance of all size classes of bass.

The likely scenario for the Desolation section is that the combination of mechanical removal and environmental factors greatly reduced bass densities in all size classes from 2004 to 2005 and following this reduction the relatively low recruitment levels there allowed mechanical removal to hold overall densities to low levels. The low recruitment rates were probably caused by a combination of low overall density and a lack of suitable spawning substrate in the upper 20 miles of the canyon. If higher densities of bass find their way into the higher velocity section of Desolation, it may be expected that they would begin recruiting at rates similar to what is observed in the Echo Park reach.

ECHO PARK, OURAY & DESOLATION

Comparing the three reaches, Echo Park had the highest CPUE and total catch over the three years, although CPUE in the upper Ouray reach was similar to the Echo

Park reach in all years likely due to habitat similarities (Table 11, Figure 22 & 23). All three reaches saw the highest CPUE during 2004, with 2005 and 2006 having lower, but very similar catch rates. Based on CPUE data from all three reaches, the Echo Park reach likely had more recruitment, but all three reaches saw the relative decline in catch between 2004 and 2005 (Figure 24). The size structure of smallmouth bass through the three reaches also varied. During the three years, Echo Park and Desolation saw the same dominant size structure (150-250mm), whereas the Ouray reach had varying dominant size structures over the three years ranging from 75 – 225mm. This is most likely due to the timing of the sampling, with sampling continuing later into the year in the Ouray stretch making the smaller size smallmouth bass more susceptible to capture (Figure 25). Combining all reaches while comparing each year's size structure, 2006 saw a shift toward a smaller size class of smallmouth bass (Figure 26).

Smallmouth bass movement between the three reaches was minimal based on the number of recaptured bass found from other reaches. The timing of the tagging and removal effort in the three reaches may have played a role. Smallmouth bass were found to be moving both upstream and downstream. Three tagged fish from the Ouray reach were caught upstream in the Yampa River, above the Echo Park reach. The Ouray reach found 3 tagged fish from the Yampa River and the Desolation reach found 2 tagged fish from the Ouray reach. One similarity between the Ouray reach and the Desolation reach is that both of these lower reaches saw the reduction in the 2005 year class of smallmouth bass, probably due to less recruitment or high flows.

CONCLUSIONS

- Were smallmouth bass population reductions achieved in the Green River?
    - Capture efficiencies based on annual population estimates of adult bass for the Green River varied between 3% and 10% per pass and similar rates were observed for juvenile fish. Over the study period the annual estimates for exploitation varied by reach and year between 9% and 31% with the Echo reach attaining the highest rates each year.
    - Across the Green River, annual CPUE rates for bass, both over and under 150 mm, declined by 50 to 75% between 2004 and 2005. The exploitation rates attained with three passes of removal can not account for the level of reduction in either size category.
    - Extended high flows in the spring of 2005 could have resulted in both poor survival of the 2004 cohort and a significant reduction in spawning success during 2005; combined with mechanical removal this may be a viable explanation for greatly reduced numbers of fish smaller than 150 mm. The flow conditions of 2005 seem much less likely to have affected the survival of fish larger than 150 mm and the overall reduction for this group of fish remains unexplained.
    - Annual comparisons of CPUE longitudinally across the Green River showed yearly declines, but little change in the pattern of distribution, suggesting that migration was not a factor in declines.
- Were concentration areas identified?
    - On a small scale, bass were typically associated with cover such as large woody debris or boulders. Spring flows in 2005 and shifts in channel

braiding in 2006 affected local cover and small scale densities in the two lower alluvial reaches. Local catch patterns in the canyon bound Echo reach remained similar over the study period with no specific concentration areas being apparent.

- In general capture rates increase moving upstream in the Green River, with the Echo reach having significantly higher catch rates than the two lower reaches.

- Were sampling and marking techniques and timing effective?
  - Young of year bass typically were not susceptible to electrofishing capture until they reached 40-50mm, which occurred between August and early October in the Green River. Variations in study duration and timing between years and reaches likely affected our ability to detect within year production of smallmouth consistently.
  - Experimentation with new tag types during 2005 in the Desolation (fine T-bar tags) and Ouray (streamer tags) reaches resulted in significant tag loss and highly unreliable population estimates for that year. As a result of difficulties in consistently estimating population sizes, CPUE rates were therefore the primary metric used to examine trends in all reaches during this study.
  - In most reaches, CPUE rates for adult bass increased over the course of a year, suggesting that continuing removal later into the fall would provide effective catch rates. This is likely a combination of behavioral responses linked to post spawning behavior, changes in food sources over a season

and increases in turbidity during fall monsoon season all resulting in increased use of shoreline habitats increasing their susceptibility to electrofishing.

RECOMMENDATIONS

- Based on the tag retention study, we recommend that t-bar anchor type tags be used to tag smallmouth bass and that streamer type tags be avoided. We also recommend a one-year tag retention study using 400 kHz PIT tags in addition to the t-bar anchor tags as a method to determine if the anchor tags are being retained.
- To improve the total catch and catch rate of smallmouth bass, we recommend that more time be spent in areas where the fish concentrate. Electrofishing in areas and habitats of known concentrations and skipping over sandy stretches would improve the catch rate, the total catch, and our capture efficiency.
- An increased level of effort should also be implemented. Based on the modeling effort of Bruce Haines (USFWS) as well as the discussion of the 2006 nonnative removal workshop, an effort of one tagging and nine to fourteen removal passes should improve the total catch and allow for a greater reduction of smallmouth bass in the Green River.
- Detailed field notes should be taken during the smallmouth bass control effort. New data sheets should be developed to include data on concentration areas of smallmouth bass and any spawning activities. Biologists should also record more environmental information when out sampling. Information on river discharge and water temperature should be gathered to determine if these variables are having an effect on the spawning success of smallmouth bass.
- Sampling efforts should be extended into late fall when catch rates tend to increase and YOY bass are susceptible to present sampling techniques.

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Table 1. 2004-2006 population estimates for smallmouth bass >100mm TL from Echo Park reach (RM 344 – 318). Confidence limits for program Mark are profile likelihood estimates, the confidence limits for the adjusted Petersen estimates are standard symmetrical limits.

Year	Type	Model	N	CI	SE	P-hat	CV
2004	Adj. Petersen		7,462	4,278-10,646	1,592	.062	.21
2004	Mark	M(t)	8,000	5,306-12,294	1,744	.0583	.22
2005	Adj. Petersen		3,203	1,464-4,943	870	.0899	.27
2005	Mark	M(t)	3,437	2,048-6,006	973	.0838	.28
2006	Adj. Petersen		3,543	1,109-5,976	1,217	.056	.34
2006	Mark	M(t)	4,053	1,997-8,625	1,589	.049	.39

Table 2. 2004-2006 smallmouth bass (≥100 mm) annual catch per unit effort (CPUE) from Echo Park reach (RM 344 – 318). Exploitation based on population estimates using Program MARK.

Echo Park – Split Mountain	# Removed	Annual CPUE	Removed /RM	Exploitation
2004	2,440	31	94	.31
2005	718	10	28	.21
2006	749	11	29	.18
Total	3,907			

Table 3. Two-pass abundance estimate for juvenile smallmouth bass (100-199 mm), upper and lower confidence intervals, the number marked on the first pass, the number captured on the second pass, and the number of recaps, in the middle Green River (Ouray; RM 319 - 215): 2004.

Year	Type	N	CI	Marked	Captured	Recaps	SE	CV
2004	L-P	7343	1084 - 15770	88	164	1	8427	57%

Table 4. Two-pass abundance estimate for adult smallmouth bass (≥200 mm), upper and lower confidence intervals, the number marked on the first pass, the number captured on the second pass, and the number of recaps, in the middle Green River (Ouray; RM 319 - 215): 2004.

Year	Type	N	CI	Marked	Captured	Recaps	SE	CV
2004	L-P	6588	1678 - 11498	182	215	5	4910	37%

Table 5. Number of juvenile (100-199mm) and adult (≥200mm) smallmouth bass tagged and removed per pass along with capture efficiency (the percentage of juvenile and adult smallmouth bass removed compared to their population estimates) – 2004 for Ouray; RM 319 - 215.

Pass	1		2		3		4	
	Juv	Adult	Juv	Adult	Juv	Adult	Juv	Adult
# SMB tagged (pass 1) & removed (passes 2-4)	88	182	164	215	387	292	433	306
Capture Efficiency	1.2%	2.8%	2.2%	3.3%	5.3%	4.4%	5.9%	4.6%
Temperature (°C)	16.8		20.7		21.9		20.2	

Table 6. Smallmouth bass movement (all sizes) into Ouray; RM 319 – 215; 2005.

Tag	**Date**	**Initial Tag Location**	**Recapture Location**
Yellow tag	2005	Middle Yampa (RM 46-147)	Split Mountain
White Floy® tag	2005	Upper Yampa (RM 177 – 207)	Horseshoe Bend
Left fin clip	2005	Upper Yampa (RM 147 – 177)	Split Mountain

Table 7. Summary of mark/recapture/removal data of all sizes of smallmouth bass from Ouray; RM 319 – 215; 2004-2006.

	Captured			Number Tagged			Recaptures		
Pass	2004	2005	2006	2004	2005	2006	2004	2005	2006
1	302	316	97	302	316	97	0	0	0
2	457	243	175	0	0	0	5	0	1
3	694	282	288	0	79	0	23	0	0
4	757	97	509	0	0	0	18	0	0
Total Removed	1908	543	972	302	395	97	46	0	1

Table 8. Catch per unit effort for all sizes of smallmouth bass for all passes combined for Ouray; RM 319 – 215; 2004-2006.

	Effort (hours)			Captures			CPUE (Fish/hour)		
All Passes	2004	2005	2006	2004	2005	2006	2004	2005	2006
Total	205.10	153.89	226.55				9.30	4.02	4.28
Total Removed				1908	619	970			

Table 9. Estimate parameters for 2004 – 2006 Desolation reach (RM 215 – 132) for bass over 150mm. M=Total Marked, C=Total Captures, R=Total Recaptures, N=Population Estimate, Density=number of fish per mile. Density, bass per mile, is calculated using 42 river miles, the primary range of bass in Desolation. A density estimate was not provided for 2005 due to the unreliability of the estimate.

Year	M	C	R	N	95% C.I.	Density
2006	42	137	3	1,483	176 – 2,791	35.3
2005	82	369	3	7,677	847 - 14,507	N/A
2004	178	937	32	5,087	3,374 – 6,802	121.1

Table 10. Catch statistics for all smallmouth bass removal electrofishing passes in the Desolation reach of the Green River (RM 215 – 132) 2004-06. Recaptures only include fish marked in the year recaptured.

Pass	Effort (hours)			Captures			CPUE (fish/hour)			Number tagged			Recaptures		
	'04	'05	'06	'04	'05	'06	'04	'05	'06	'04	'05	'06	'04	'05	'06
1	40	41	23	180	91	42	4.44	2.22	1.78	178	82	42	0	0	0
2	36	27	16	270	139	48	7.42	5.08	2.96	0	0	0	14	1	0
3	21	67	15	250	75	46	11.8	1.12	3.13	0	0	0	4	0	1
4	44	63	15	417	157	43	9.35	2.50	3.00	0	0	0	14	2	2
Totals	**141**	**198**	**69**	**1,117**	**462**	**179**	**7.83**	**2.33**	**2.60**	**178**	**82**	**42**	**32**	**3**	**3**

Table 11. Total Catch per Unit Effort (fish / hour electrofishing) for smallmouth bass collected in three contiguous reaches of the Green River, Colorado and Utah; 2004-2006.

Reach / Year	2004	2005	2006
Echo	31	10	11
Ouray	9.3	4.0	4.3
Desolation	7.7	2.2	2.3

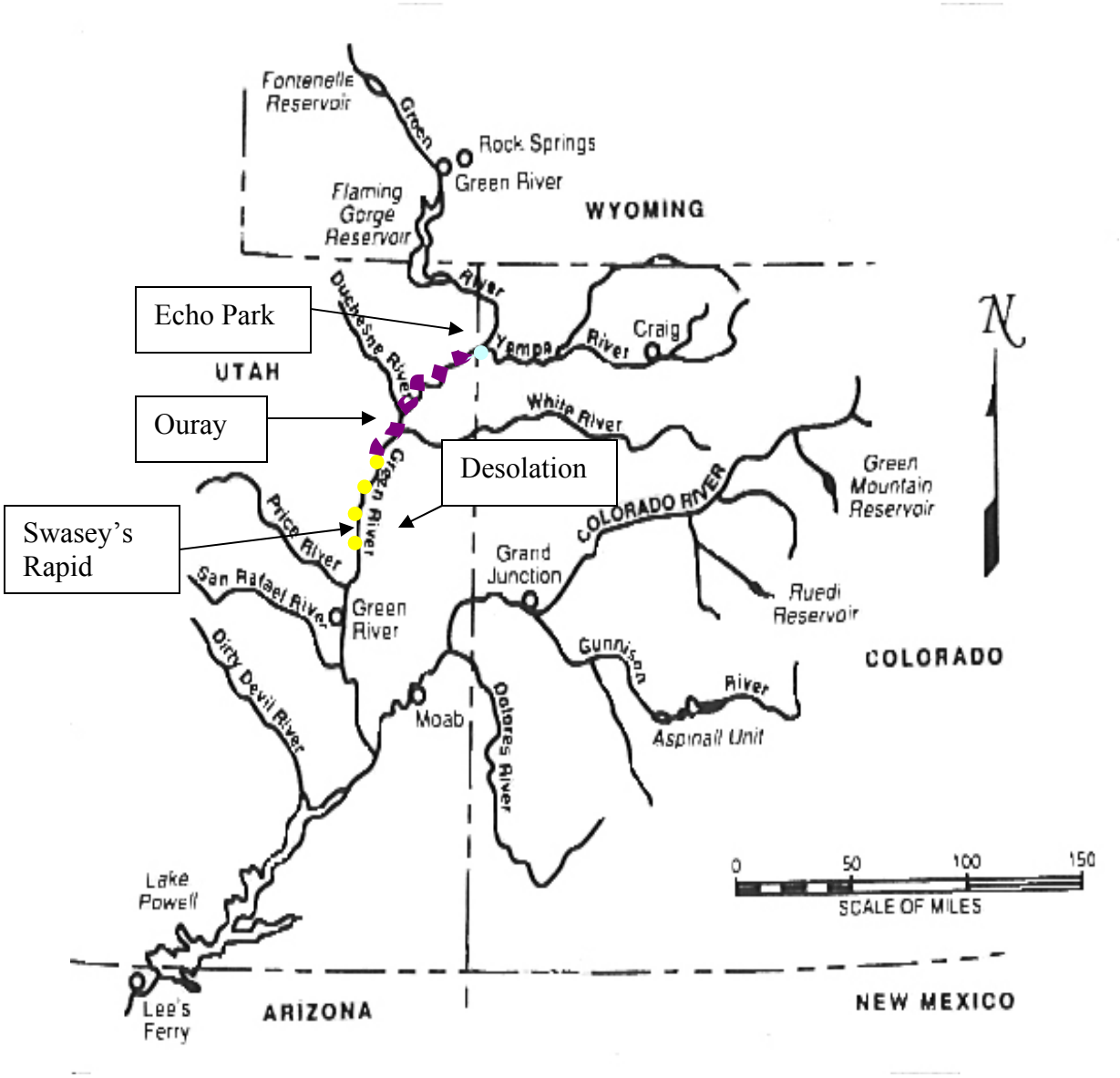

Figure 1. The Upper Colorado River Basin. The smallmouth bass removal area for Echo Park is highlighted in blue, Ouray highlighted in purple and Desolation highlighted in yellow.

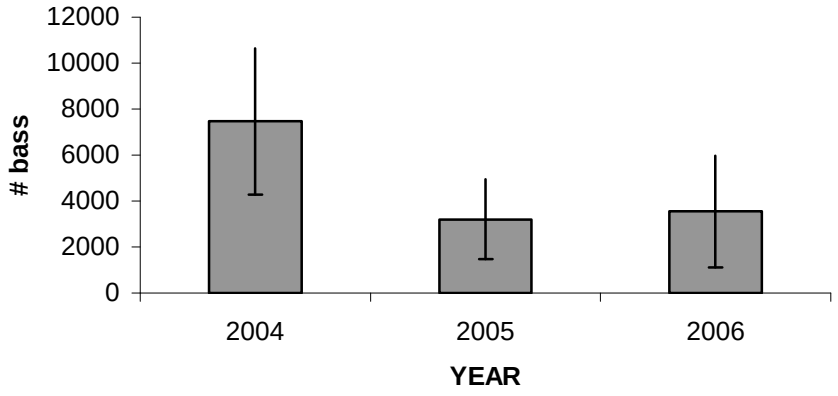

Figure 2. Petersen estimates and 95% confidence intervals for smallmouth bass >100mm TL in Echo Park reach (RM 344 – 319) from 2004-2006.

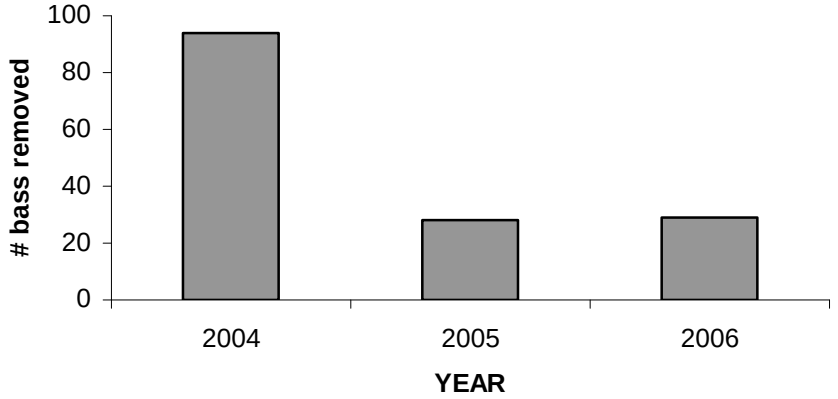

Figure 3. 2004-2006 number of smallmouth bass removed per river mile from Echo Park reach (RM 344 – 319).

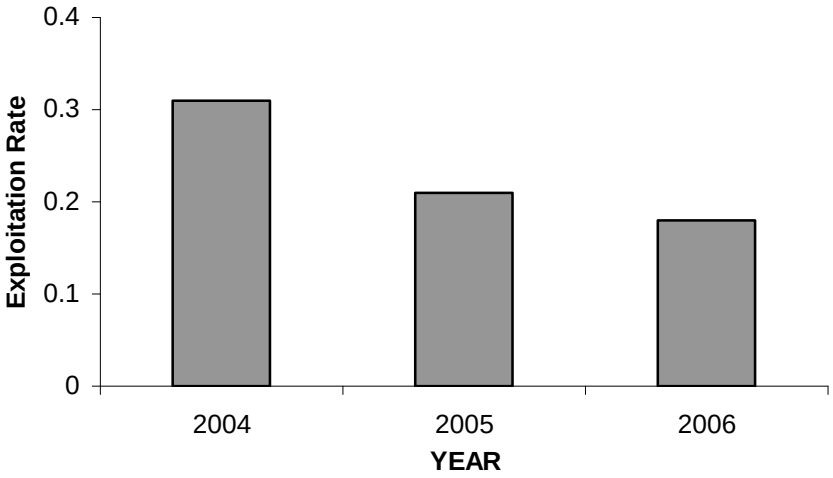

Figure 4. 2004-2006 smallmouth bass electrofishing exploitation from Echo Park reach (RM 344 – 319).

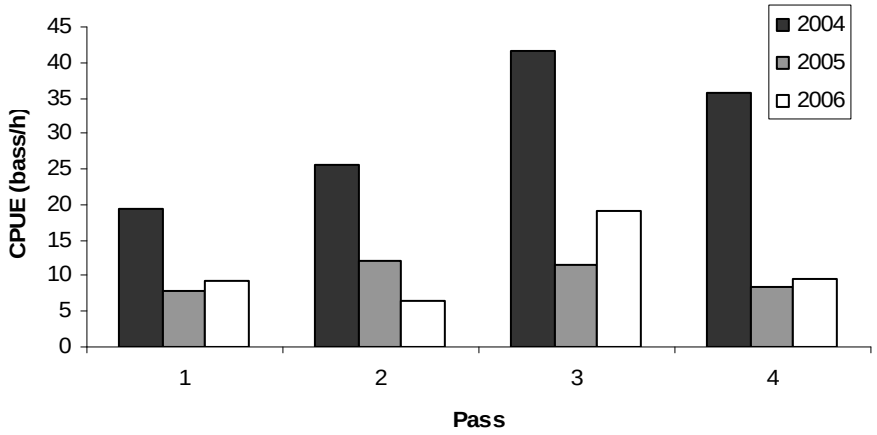

Figure 5. 2004 – 2006 smallmouth bass electrofishing CPUE by pass from Echo Park reach (RM 344 – 318).

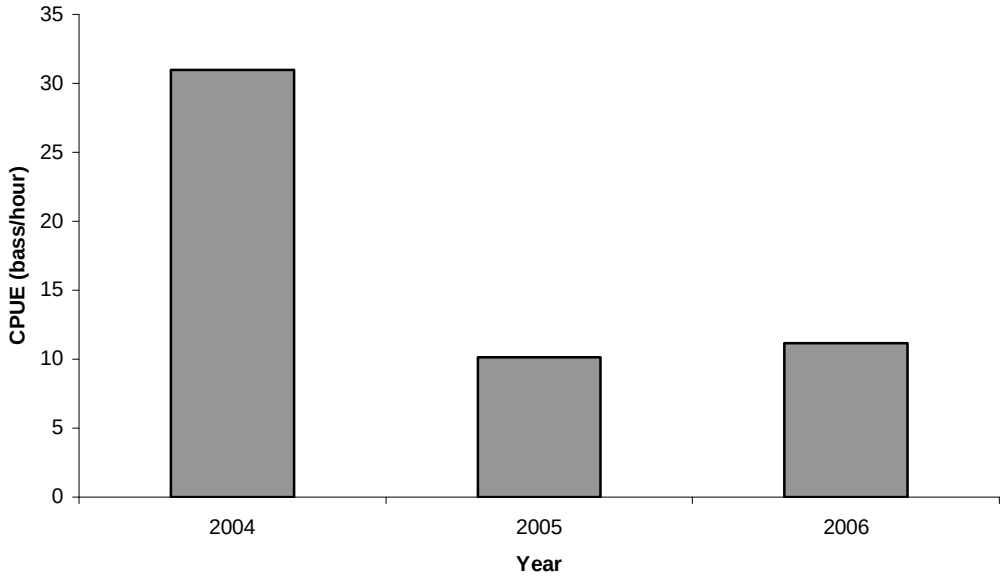

Figure 6. 2004-2006 smallmouth bass electrofishing CPUE for all passes combined from Echo Park reach (RM 344 – 318).

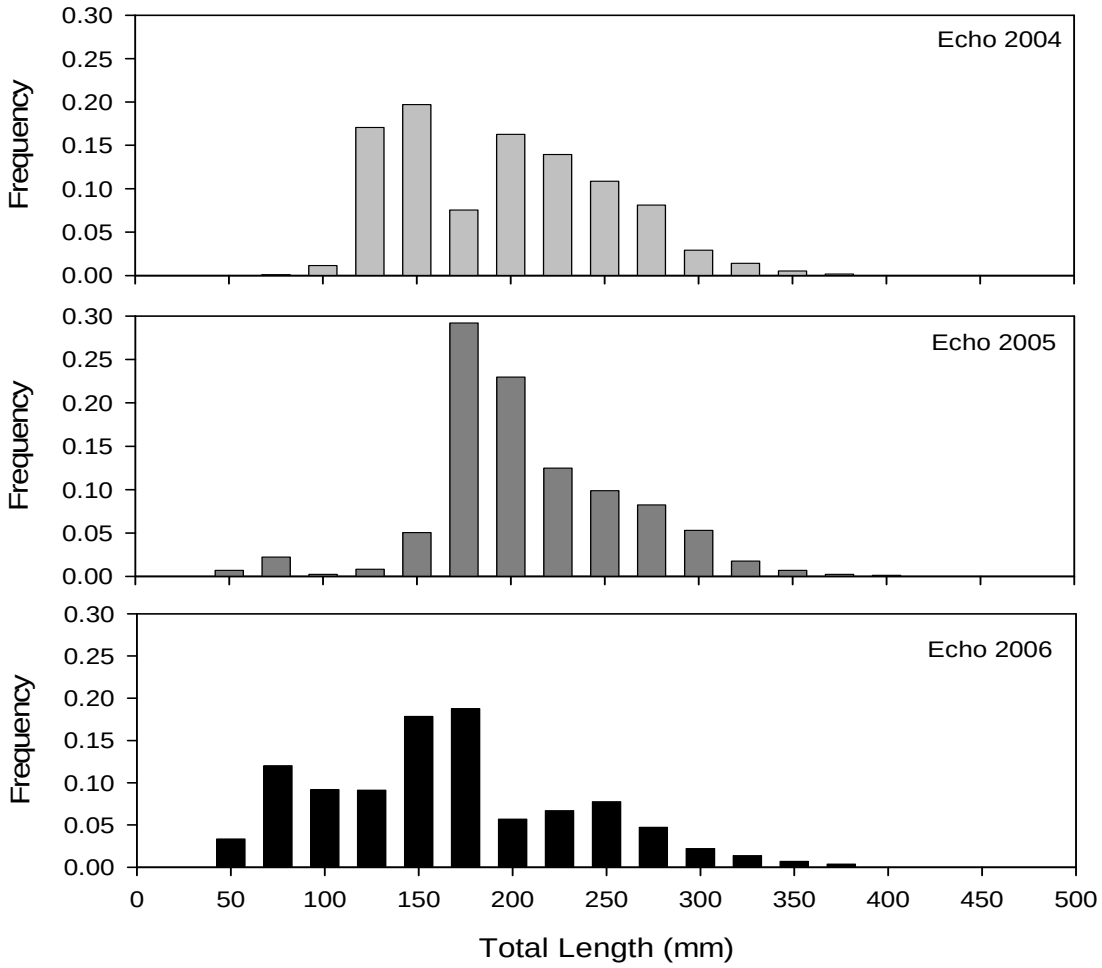

Figure 7. 2004 -2006 smallmouth bass length frequencies (all passes) from Echo Park (RM 344 – 318).

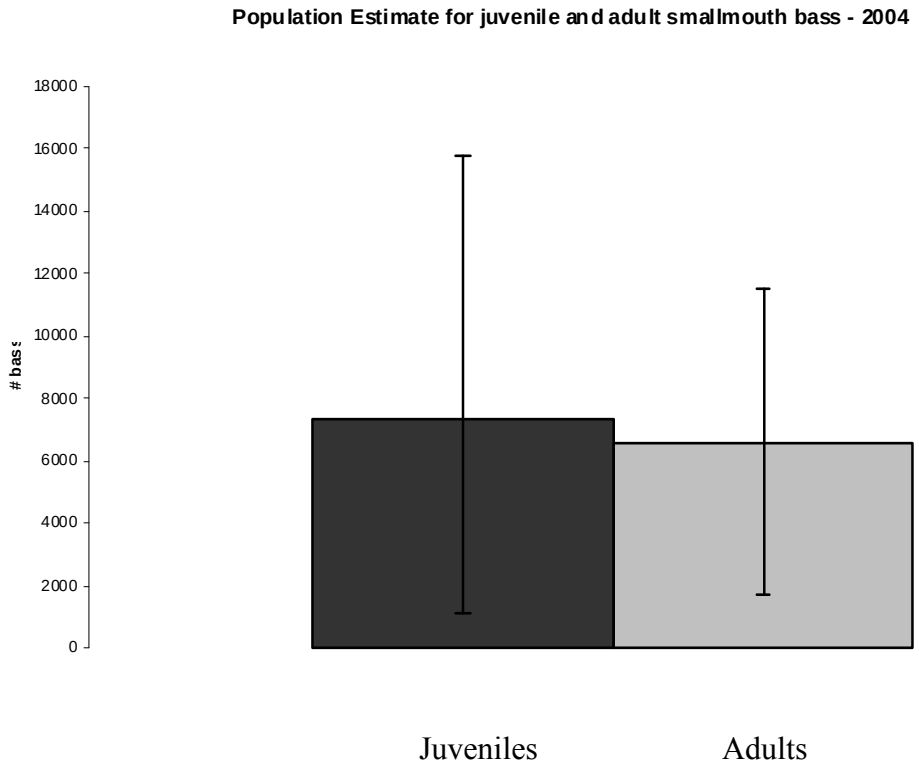

Figure 8. Abundance estimate for juvenile (100-199mm) and adult (≥200mm) smallmouth bass in the middle Green River (Ouray; RM 319 – 215): 2004.

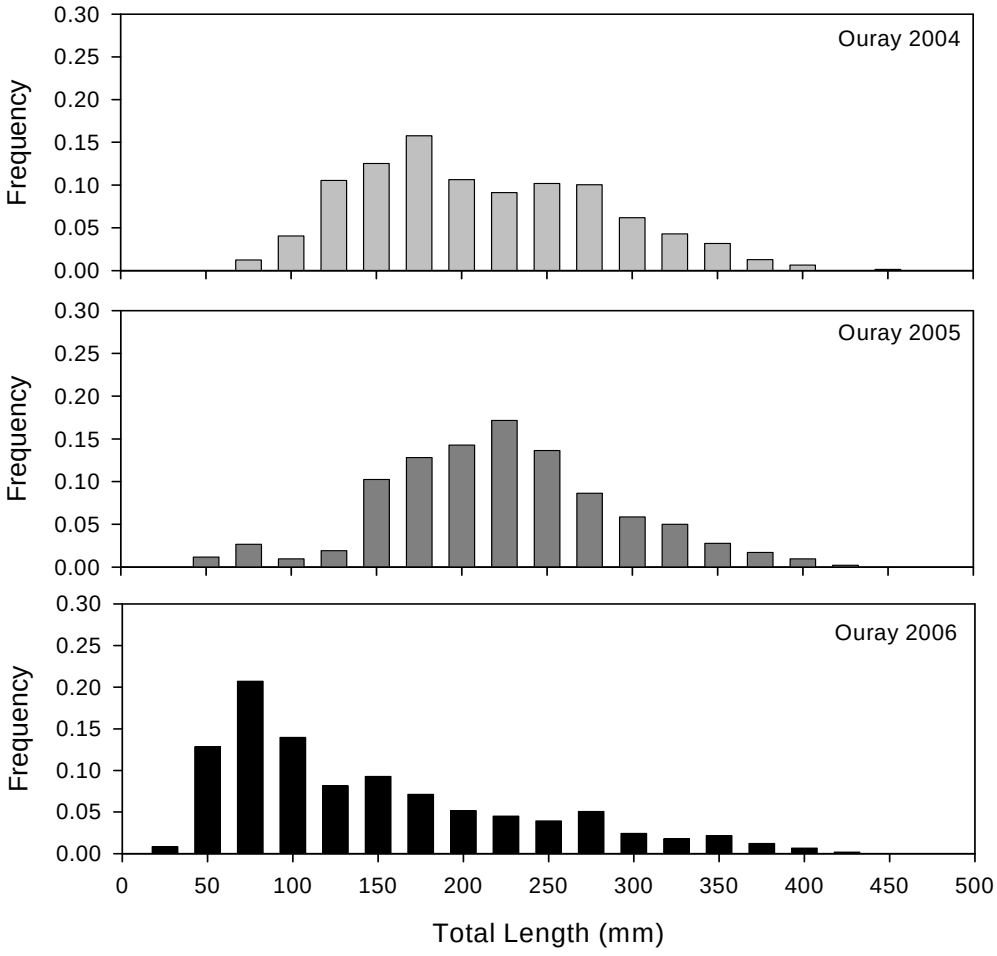

Figure 9. Length frequency of all sizes of smallmouth bass for Ouray; RM 319-215; 2004-2006.

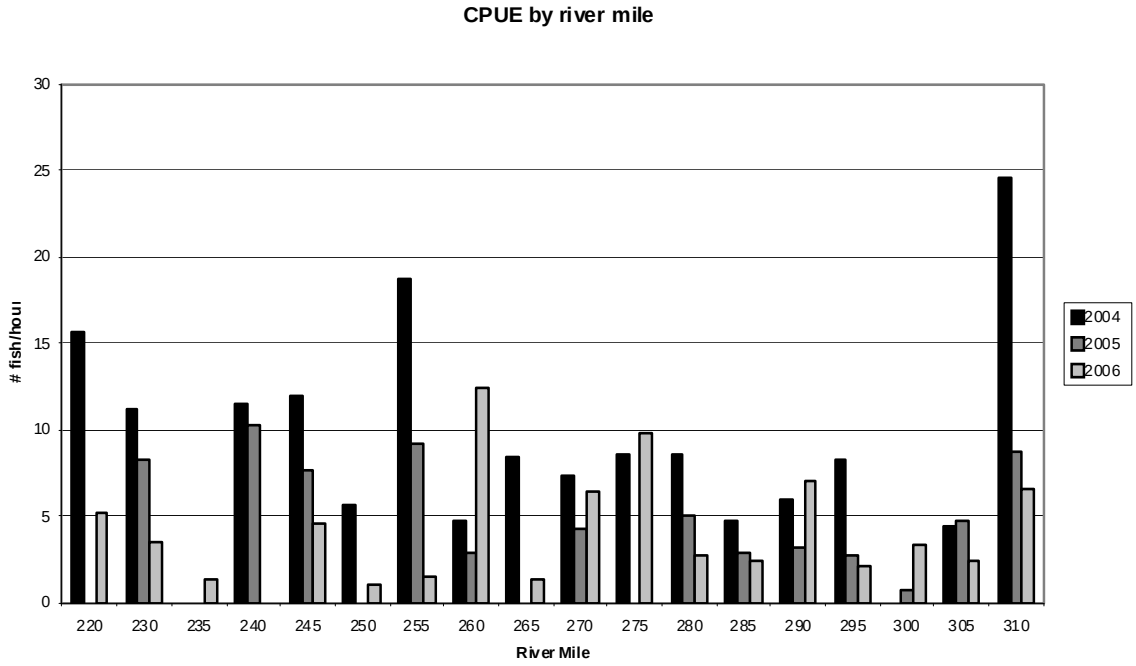

Figure 10. Catch per unit effort by river mile for Ouray for all sizes of smallmouth bass (RM 319 – 215); 2004-2006.

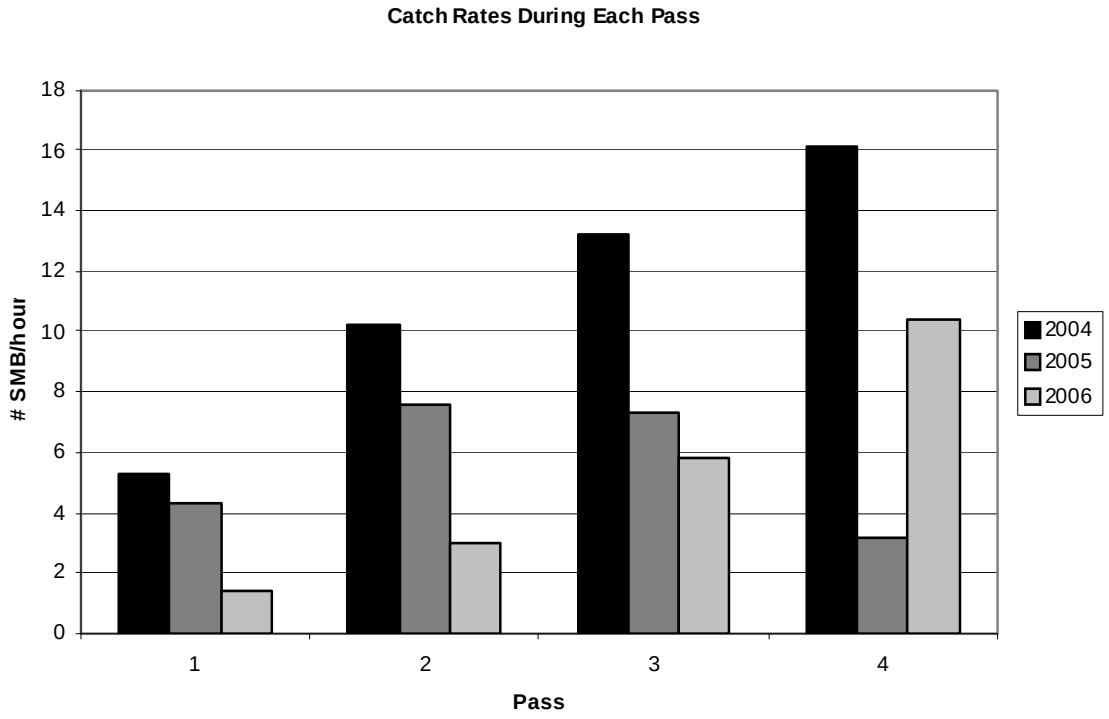

Figure 11. Catch per unit effort for all sizes of smallmouth bass during each pass for Ouray (RM 319 – 215); 2004-2006.

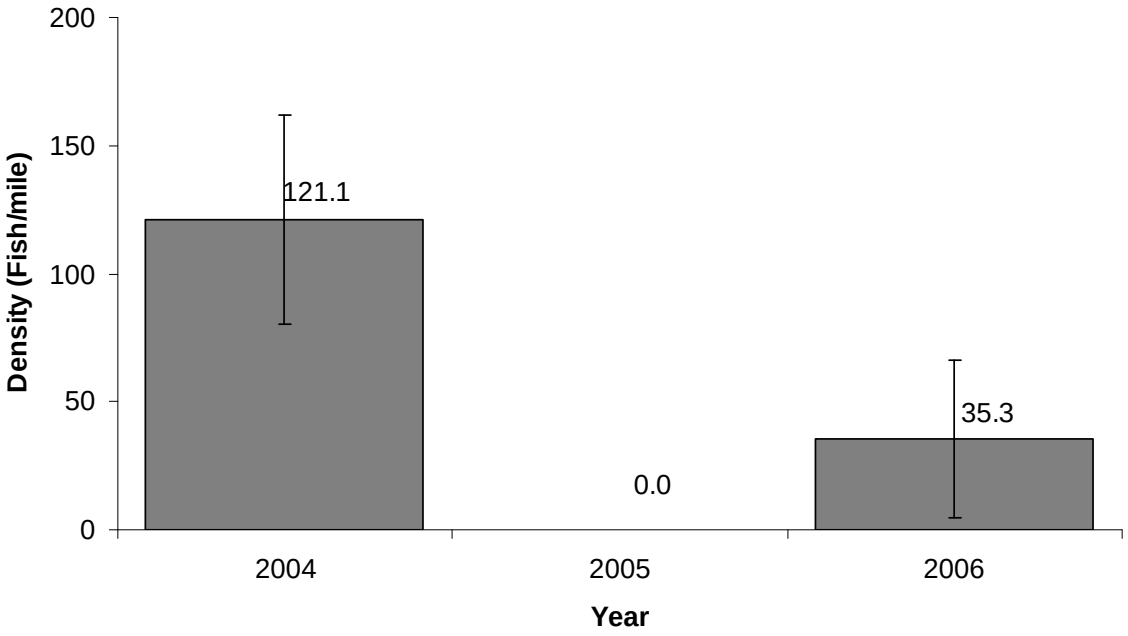

Figure 12. Annual density estimates for smallmouth bass over 150 mm in Desolation (RM 215 – 132) during the period of 2004 through 2006.

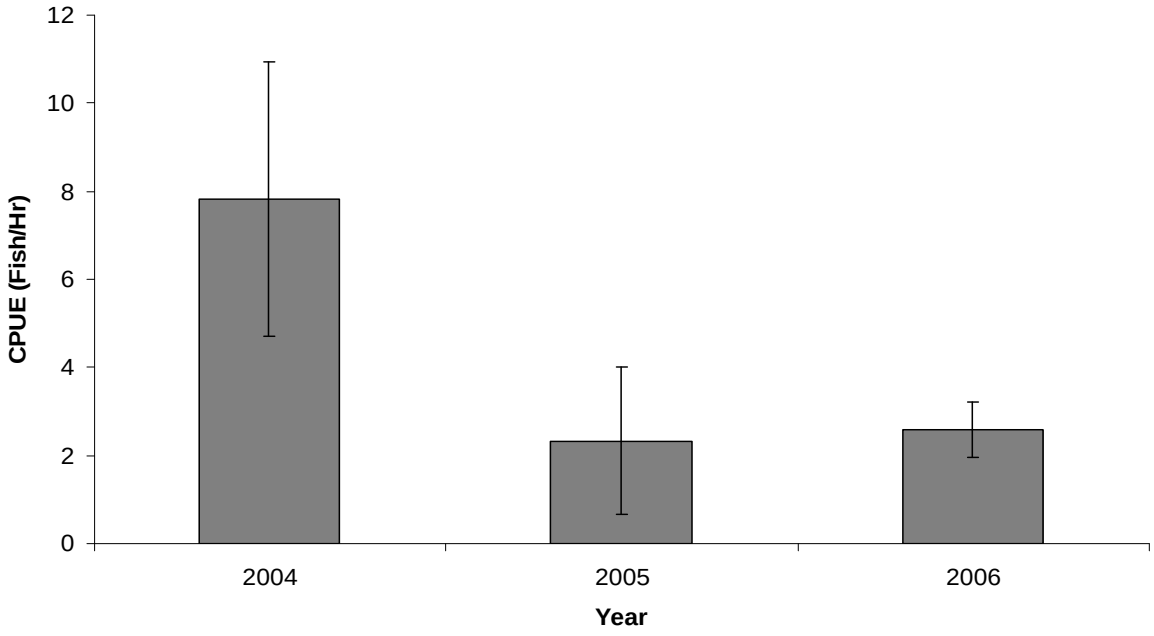

Figure 13. Annual electrofishing catch per unit effort for all sizes of smallmouth bass in the Desolation reach (RM 215 – 132) of the Green River during the period of 2004 through 2006. Error bars represent ± 2 standard errors, based on catch rates for each pass.

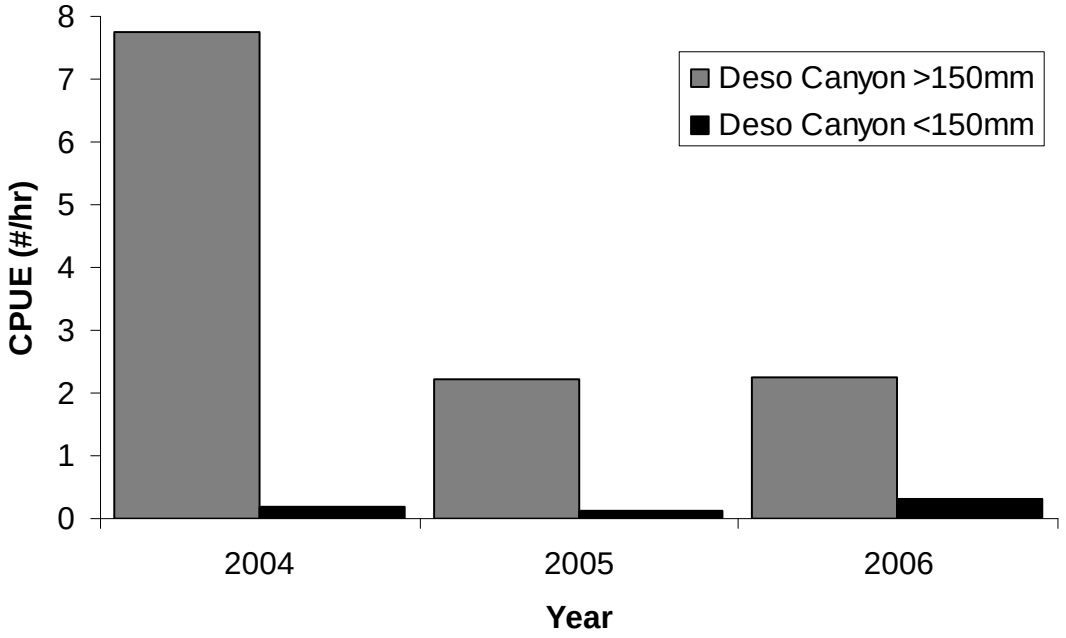

Figure 14. Annual electrofishing catch per unit effort for smallmouth bass over and under 150mm during the period of 2004 through 2006 Desolation reach (RM 215 –132).

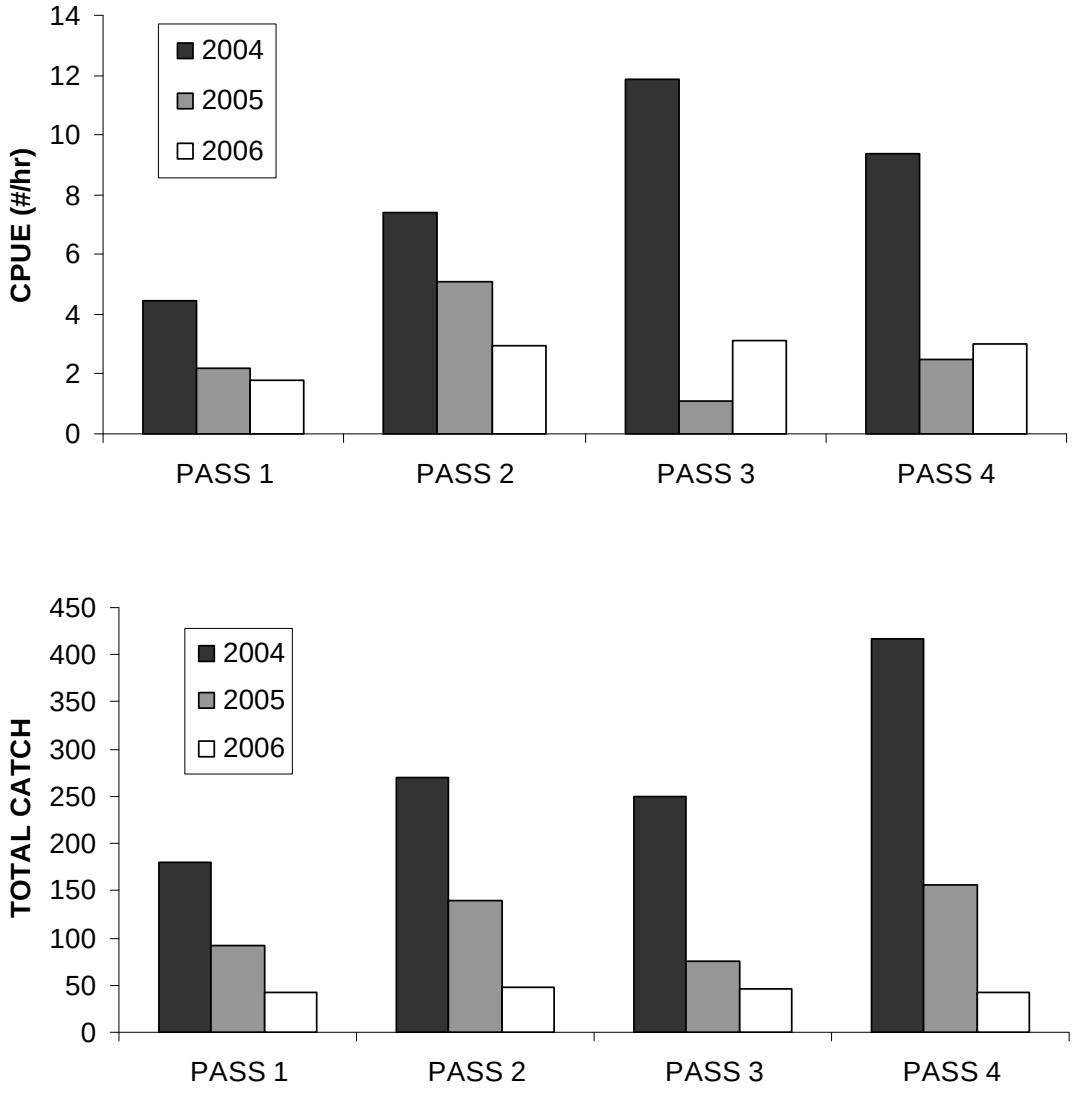

Figure 15. Annual comparison for all sizes of smallmouth bass, catch per unit effort (CPUE) and total catch for each pass completed on the Desolation section of the Green River (RM 215 – 132) during 2004-2006.

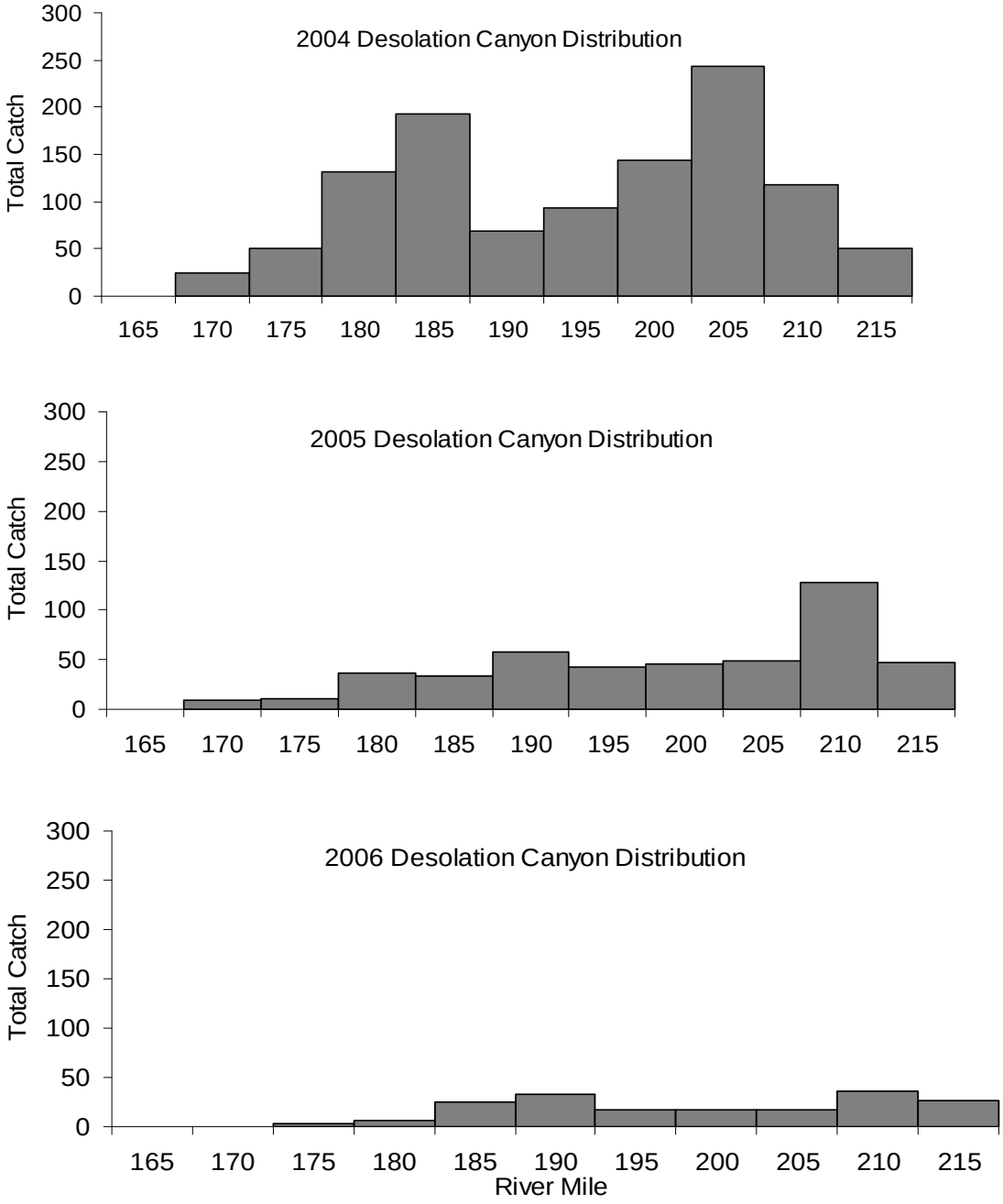

Figure 16. Total catch distribution of smallmouth bass by river mile. All captures occurred between Chandler Canyon (RM 167) and Sand Wash (RM 216).

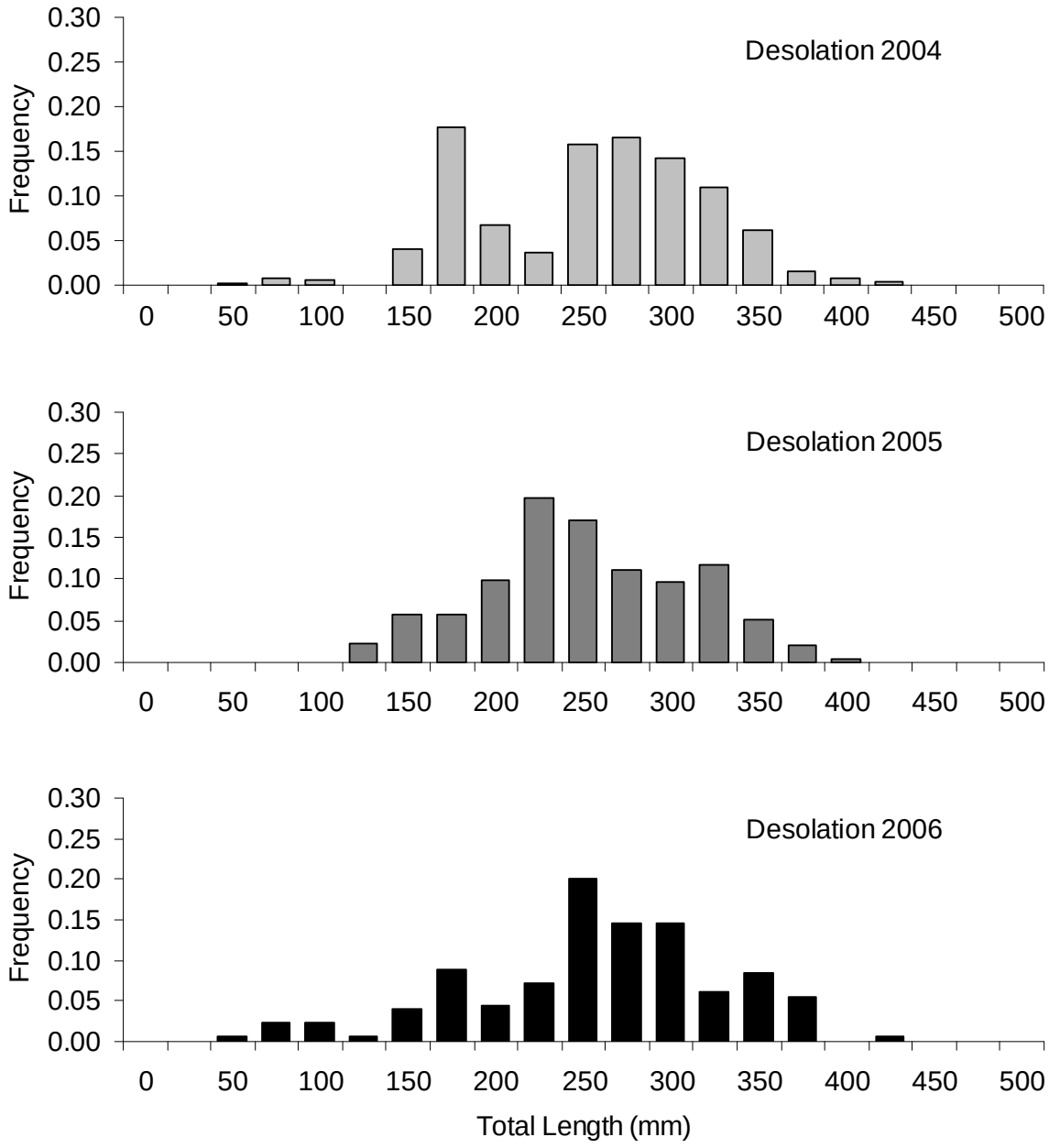

Figure 17. Relative length frequency for all smallmouth bass captured in all passes combined within the Desolation reach (RM 215 – 132) for 2004 through 2006.

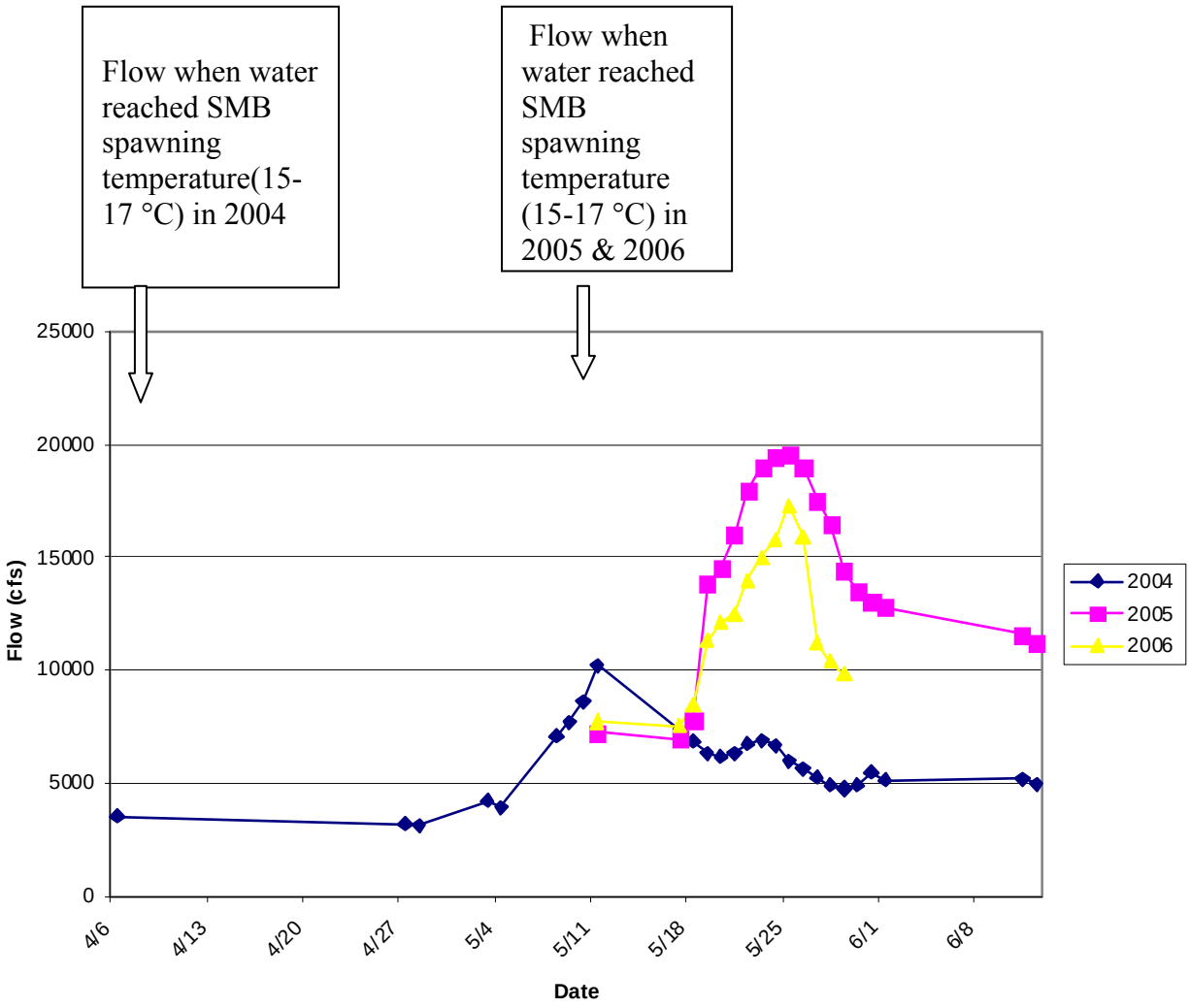

Figure 18. Flow data (cfs) for water temperatures between 15 - 17ºC from the USGS gauge station (USGS 09261000) near Jensen Utah (RM 315).

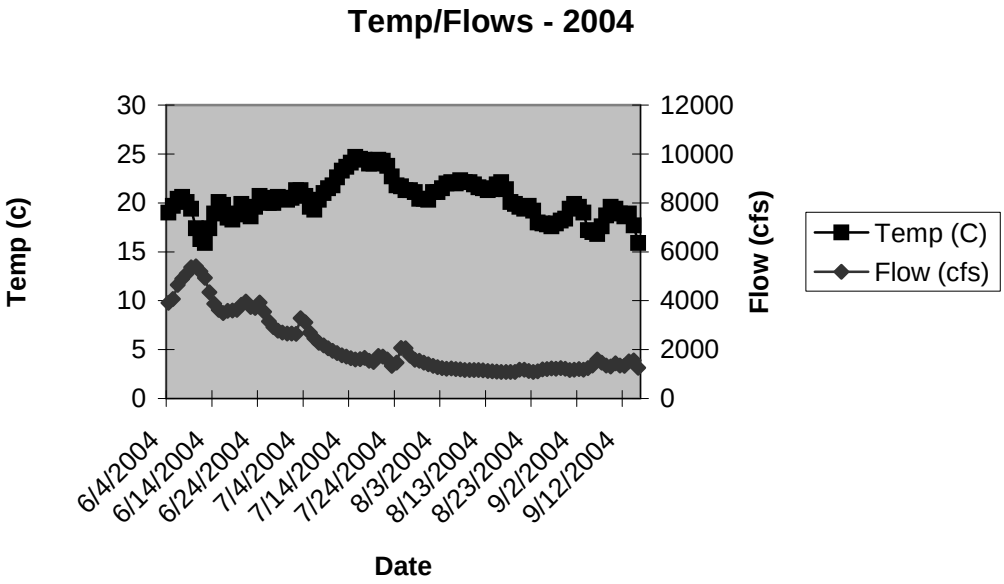

Figure 19. Temperature and flow data from the Jensen gauge (USGS 09261000) representing smallmouth bass rearing conditions – data represents conditions beginning one month after water temperatures reached 15ºC in 2004 for Ouray (RM 319 – 215).

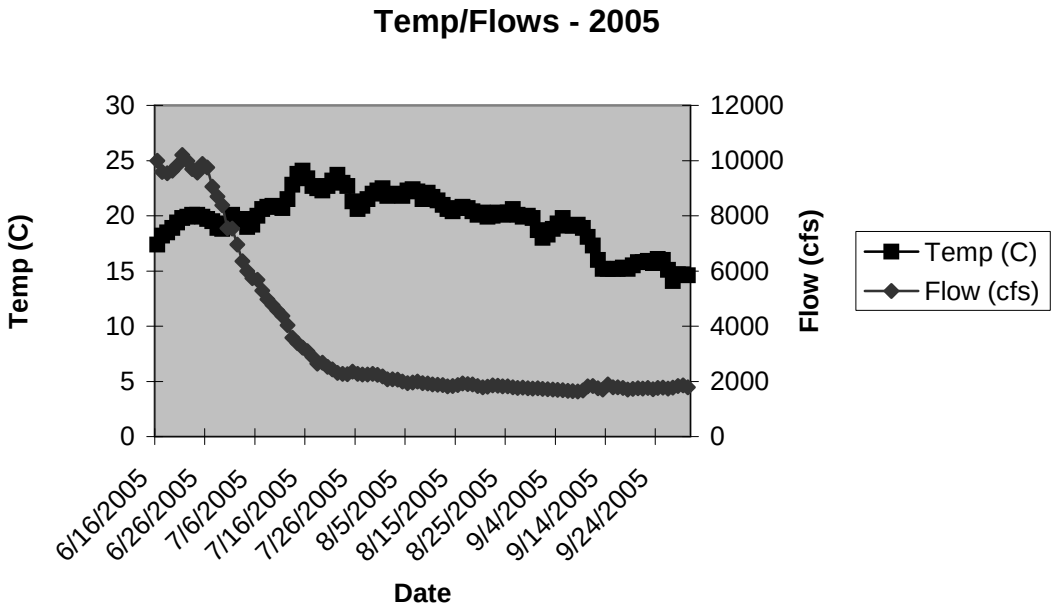

Figure 20. Temperature and flow data from the Jensen gauge (USGS 09261000) representing smallmouth bass rearing conditions – data represents conditions beginning one month after water temperatures reached 15ºC in 2005 for Ouray (RM 319 – 215).

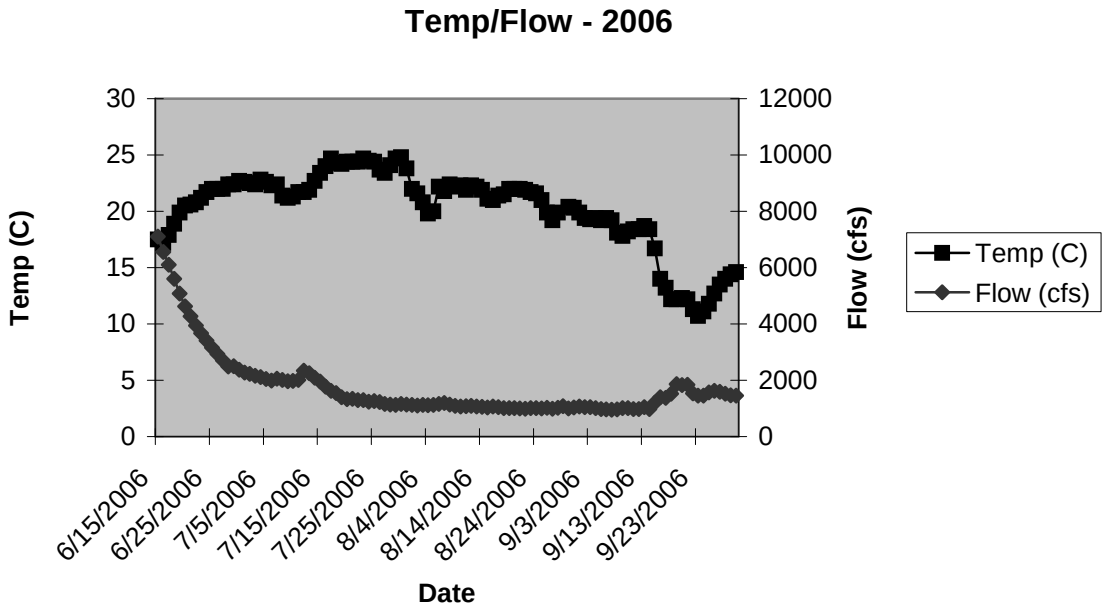

Figure 21. Temperature and flow data from the Jensen gauge (USGS 09261000) representing smallmouth bass rearing conditions – data represents conditions beginning one month after water temperatures reached 15ºC in 2006 for Ouray (RM 319 – 215).

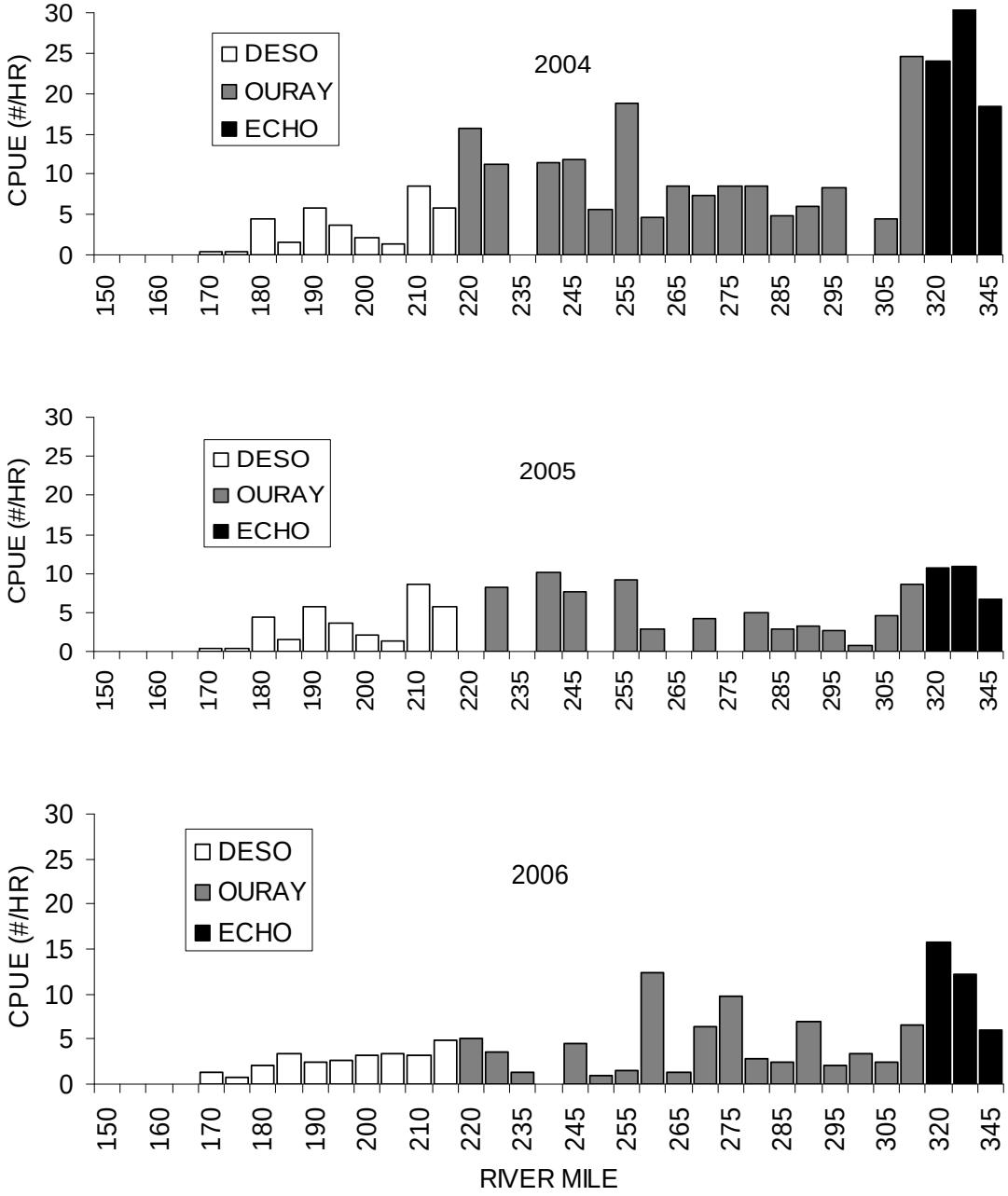

Figure 22. Catch per unit effort for all smallmouth > 100 mm by river mile, 2004-2006 for the Echo Park, Ouray and Desolation reaches. All YOY captures are excluded.

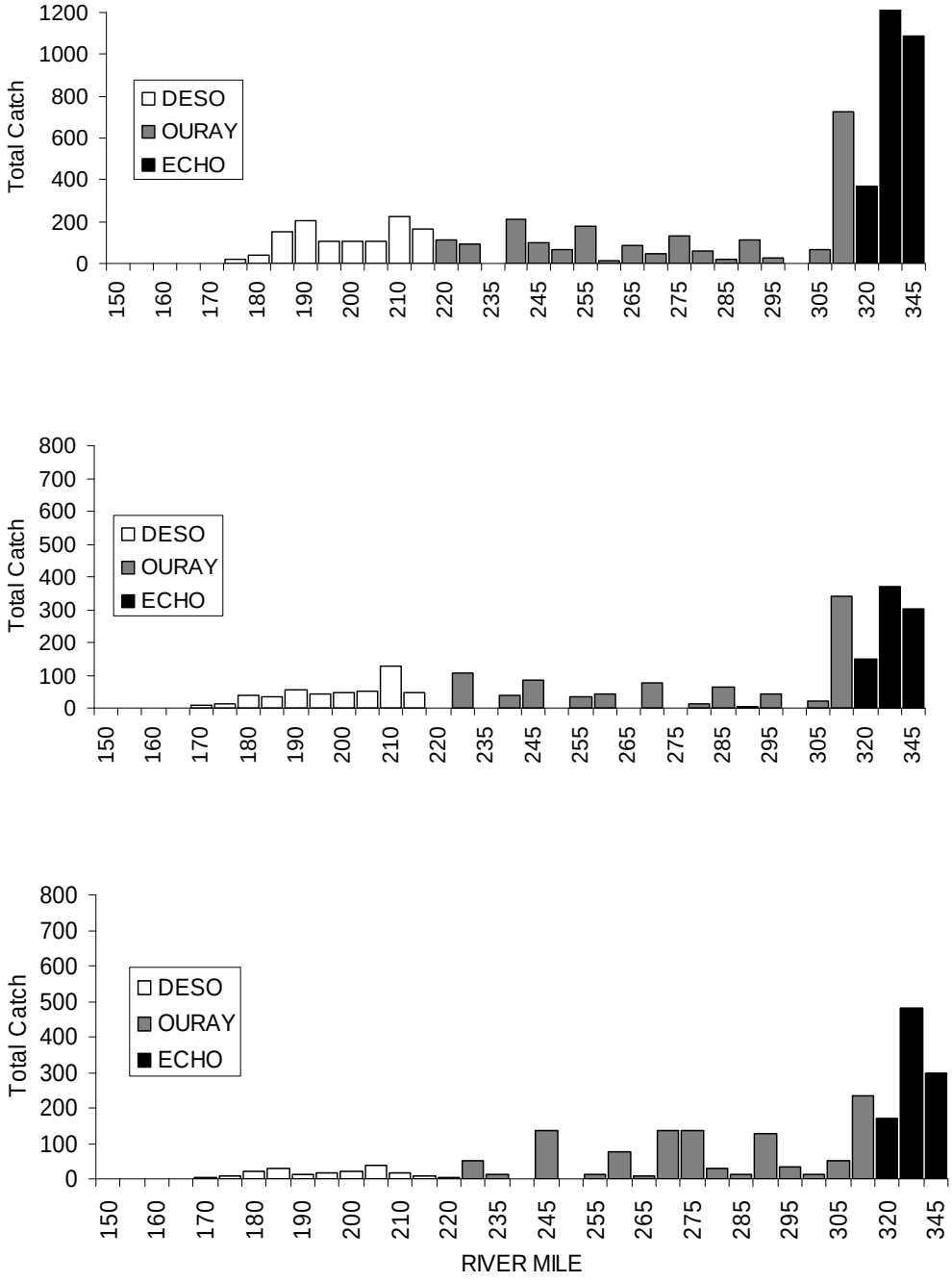

Figure 23. Total catch for all smallmouth > 100 mm by river mile, 2004-2006 for the Echo Park, Ouray and Desolation reaches. All YOY captures are excluded.

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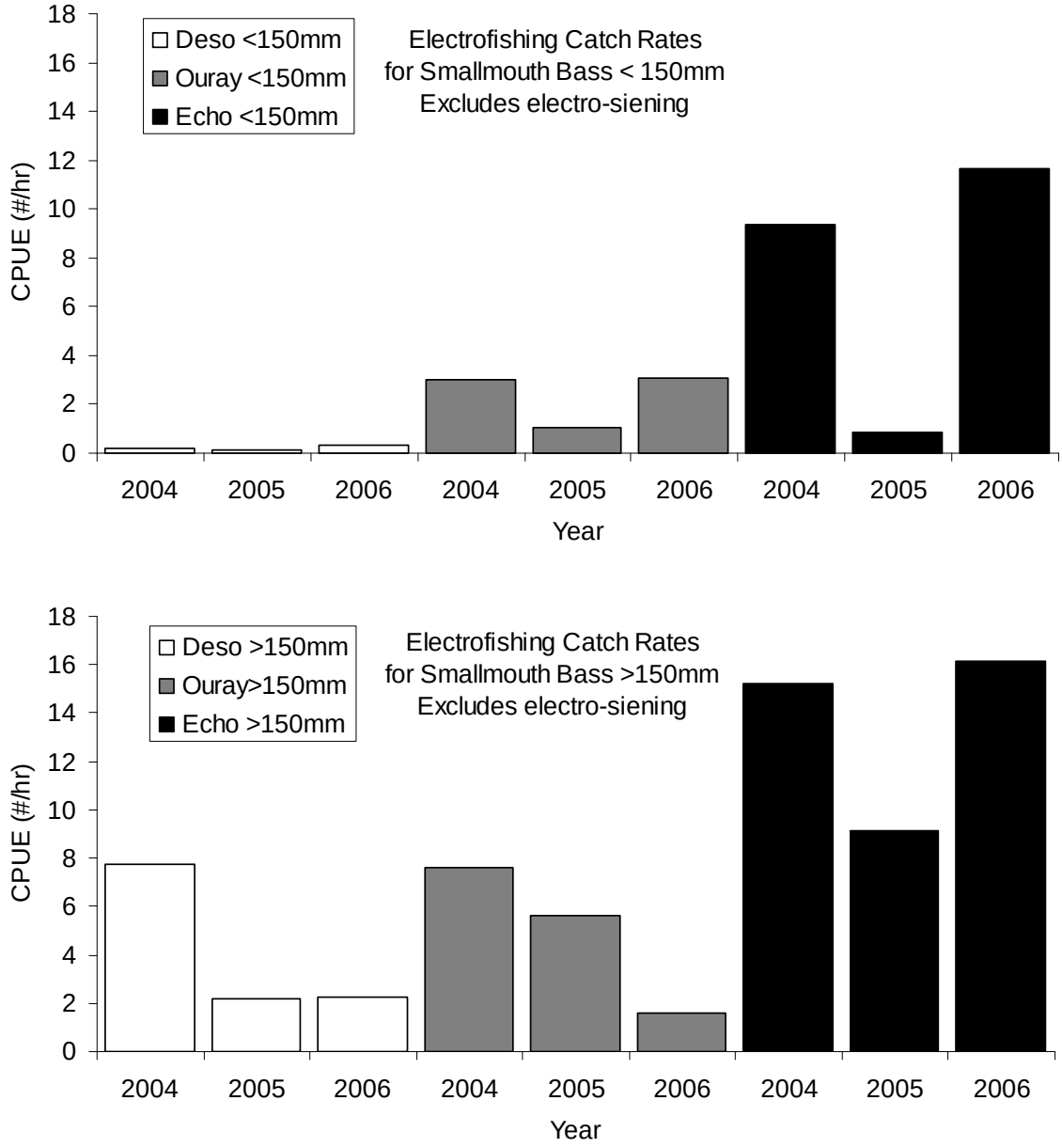

Figure 24. Total catch per unit effort by year and reach for smallmouth bass greater than 150 mm (top) and less than 150 mm (bottom) over the three year study period (2004-06).

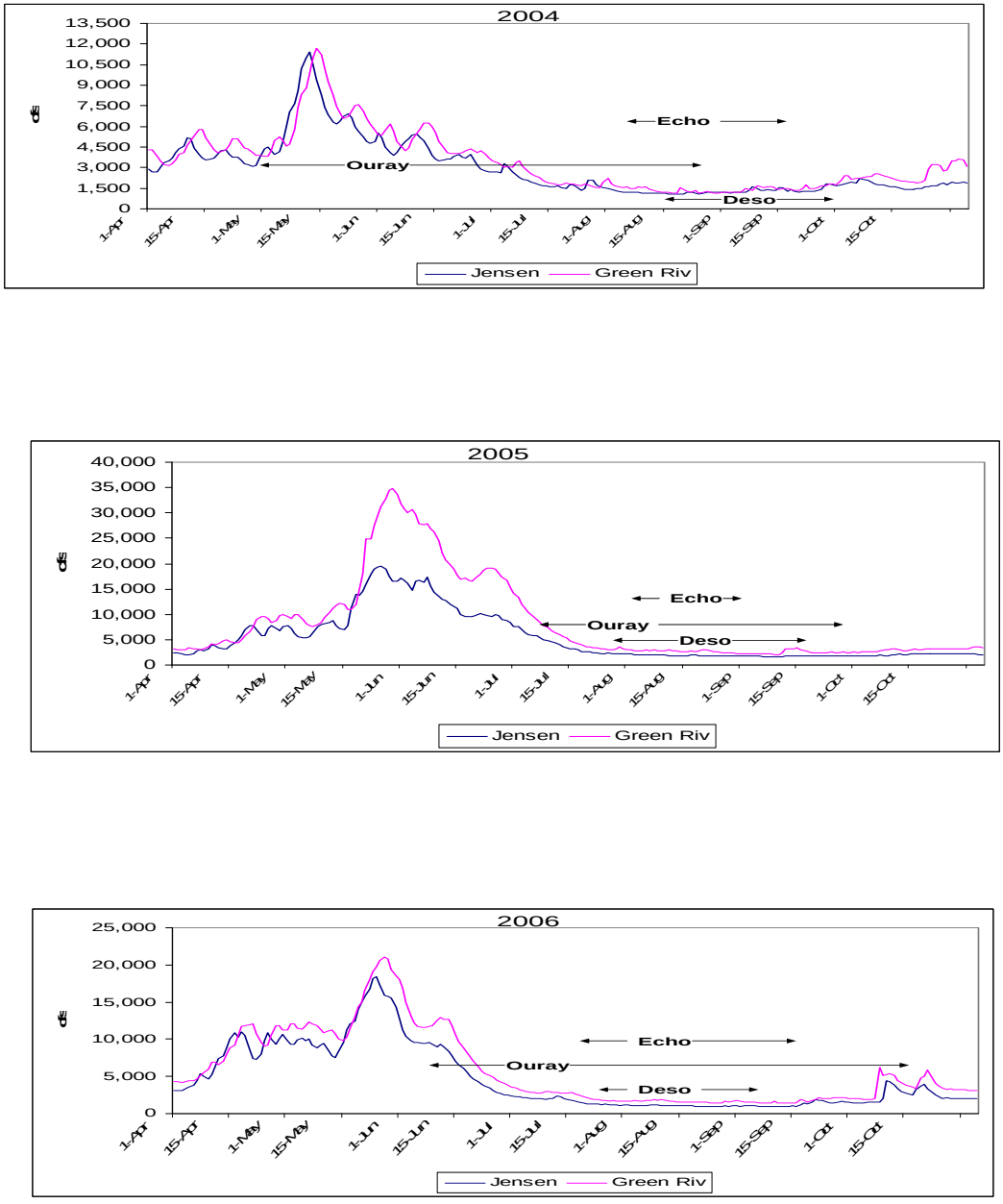

Figure 25. Start/stop sampling dates in three contiguous reaches of the Green River, Colorado and Utah; 2004-2006 as they relate to hydrographs collected by the USGS at their Near Jensen and Green River, Utah gauging stations.

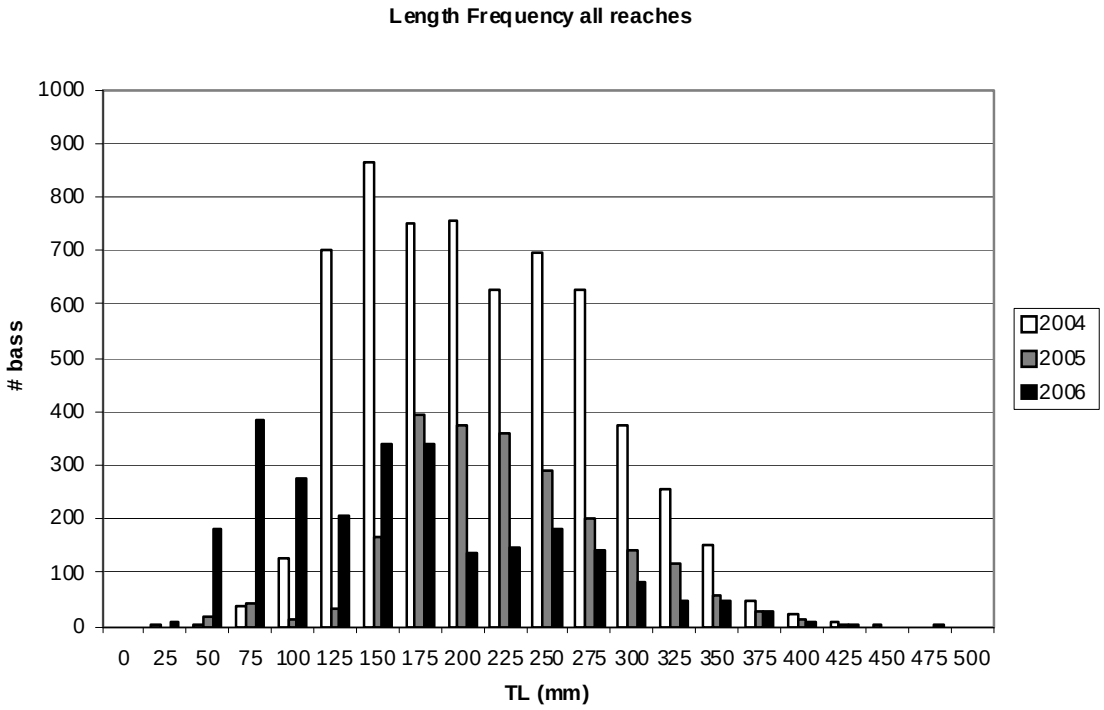

Figure 26. Length frequency of all sizes of smallmouth bass per year, Echo Park, Ouray and Desolation.