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Population Estimates for Humpback Chub (*Gila cypha*) in Desolation and Gray Canyons, Green River, Utah 2006-2007

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Salt Lake City, Utah

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EXECUTIVE SUMMARY

Multiple-pass, mark-recapture sampling was conducted in approximately 19% (12 sites) of the available fall (September–October) habitats with Desolation-Gray Canyon (Desolation-Gray) of the Green River in Utah during 2006 and 2007 to estimate the population size of adult (200 mm TL) humpback chub *Gila cypha.* Twelve sites were sampled in September through October with three sampling passes completed each year. Sampling was primarily conducted with multi-filament trammel nets (1 inch inner mesh), although electrofishing, hoop nets, and minnow traps were used to supplement sampling.

The expected outcome of developing a population trend, which included estimates from 2001–03, could not be met with specified precision (CV ≤ 0.15; p-hat ≥ 0.10), due to violations of model assumptions in previous and current estimates. Changes in sample timing from early summer (June–July) to fall (2003) and high site fidelity displayed by adult humpback chubs required us to abandon population estimates for Desolation-Gray which combined capture-recapture data from all sample sites (total population estimates). Movement studies and our recapture data show humpback chubs maintain fall home ranges of 0.5–0.9 miles; because sample sites are 4 miles apart on average, the assumption of closure is likely only met within each sampling site.

Site specific estimates were calculated for 2006 and 2007 using only the mark-recapture data from each individual site; these site estimates are equivalent to a site density. To estimate the total population size of adult humpback chub in Desolation-Gray Canyon the site densities were extrapolated across the number of available sites within the canyons. The estimated number of sites is 63; this number was developed through personal observation, examination of maps, and 15 years of working on the river.

In 2006, site densities within Desolation-Gray ranged from 10–109 fish per site with an average of 40.92 adult humpback chubs per site. The 2006 extrapolated total estimate for humpback chubs is 2,578 (95% C.I. 1,151–9,736). In 2007 site densities declined by 57%, with a range of 2-53 individuals per site and an average of 17.58 adult humpback

chubs per site. The 2007 extrapolated total estimate for humpback chubs in Desolation-Gray is 1,108 (95% C.I. 1,071–4,914). We are confident that in 2007 the size of the Desolation-Gray population dropped below the level of 2,100 adults required by the recovery goals for maintenance of a core population.

Trends observed in total population estimates for all sites combined (2001–03 and 2006–07) indicate declines from 2003 to 2006 and through 2007. This declining trend is supported by declines in catch per effort rates and the abundance of individuals encountered. The change in sample timing from June-July to September-October began in 2003 and has continued to date. This change in timing may have resulted in differential capture rates due to using a passive collection method (trammel nets). Although we acknowledge that metrics like catch per effort are strongly related to factors such as timing, method of capture, and changes in abiotic conditions, we were able to identify that significant declines in humpback chub catch rates between the periods of 2001–03 and 2006–07 only occurred in sites located in the upper forty miles of Desolation-Gray. These catch rate declines coincide with the establishment of smallmouth bass (*Micropterus dolomieu*) in the upper forty miles of Desolation-Gray in approximately 2003. Nonnative control work found that the downstream extent of the smallmouth bass population remained within the upper forty miles of Desolation-Gray through 2007.

The lack of a length to age relationships for adult humpback chubs and very low capture rates for juveniles in Desolation-Gray constrained our estimates of recruitment to the measure of relative proportion of first-year adults to all adults captured. The relative proportion declined from an average of 12.9% in 2001–03 to 9.2% in 2006 and 5.2% in 2007. The apparent decline in early adult recruits coincides with the timing of smallmouth bass establishment in Desolation-Gray, and may be attributed to predation. Piscivory by smallmouth bass is well known in other systems and pressure on the juvenile component of the humpback chub population could explain some of the declines in the first-year adult population.

Over the last twenty plus years, the primary collection method of trammel netting has proven to be the most efficient and reliable technique for capture of humpback chubs 200 mm and larger and should continue to be the primary method of collection. Collection of juvenile humpback chubs has continued to be difficult in Desolation-Gray Canyon with multiple methods including electrofishing, hoop netting, and minnow traps providing inconsistent and low capture rates.

Adult estimates below the minimum viable adult population size of 2,100 adults, as set forth in the 2002 Recovery Goals document (USFWS 2002) and apparent declines in the proportion of first year adult humpback chubs provide justification to consider development of a captive brood stock for the Desolation-Gray Canyon humpback chub population.

INTRODUCTION

The humpback chub *Gila cypha* is a large-bodied cyprinid endemic to the Colorado River Basin; primarily a canyon-dweller that evolved in seasonally warm and turbid water, adapting to variable hydrologic conditions typical to an unregulated river system. The canyons where humpback chub are found are characterized by swift deep water and rocky substrates (UDWR 1995, Valdez 1990). Humpback chub are believed to presently inhabit approximately 68% of their original range (USFWS 2002). Factors that may have contributed to the decline of this species include: stream alteration, (dams, irrigation, dewatering, and channelization), habitat modification, competition with and predation by introduced, nonnative fish species, parasitism, hybridization with other *Gila* spp., and pollutants (USFWS 2002).

Humpback chub were first reported in Desolation and Gray canyons (Desolation-Gray) on the Green River in 1975 (Holden and Stalnaker 1975). This population has been monitored nearly annually for approximately 25 years. Utah Division of Wildlife Resources has been responsible for this monitoring since 1985. Currently, there are six self-sustaining populations, one within the lower basin in the Grand Canyon on the Colorado River, and five within the upper basin in the Colorado River and Green River sub-basin. The population of humpback chub in Desolation-Gray is considered the third largest in the upper basin, following the Black Rocks and Westwater populations on the Colorado River.

The humpback chub is currently protected under the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 *et. seq*). In 1990, a recovery plan for humpback chub was completed (USFWS 1990), and in 2002, recovery goals that amended and supplemented to the recovery plan were approved (USFWS 2002). Objective and measurable recovery criteria were identified to downlist and delist the humpback chub. To downlist humpback chub, the following criteria must be met for a five-year period: 1) the trend in adult (age-4+; $\geq$ 200 mm TL) point estimates for each of the six populations does not decline significantly; 2) mean estimated recruitment of age-3 (150-199 mm TL)

naturally produced fish equals or exceeds mean annual adult mortality for each of the six populations; 3) two of the genetically and demographically viable, self-sustaining core populations are maintained, such that each point estimate for each core population exceeds 2,100 adults; 4) certain site-specific management tasks to minimize or remove threats have been identified, developed, and implemented. Delisting can occur, if over a three-year period beyond downlisting: (see 1 and 2 above) three genetically and demographically viable, self-sustaining core populations are maintained, such that each point estimate for each core population exceeds 2,100 adults; 4) certain site-specific management tasks to minimize or remove threats have been identified, developed, and attained.

Population estimates were generated by mark-recapture sampling conducted from 2006 to 2007 for the Desolation-Gray humpback chub population. The specific objectives were to: 1) obtain a population estimate of late juvenile/adult humpback chub (≥ 200 mm); and 2) determine mean estimated recruitment of naturally produced subadult humpback chub (150–199 mm). Within these objectives recovery criteria #1 and #2 for downlisting are specifically addressed. Due to its potential designation as a third core population, the Desolation-Gray humpback chub population will likely play a significant role in the delisting of this species, as stated in delisting recovery criteria #3. This two year study represents the second sampling round since finalization of the amended recovery goals and provides a total of five annual point estimates of adult humpback chub in Desolation-Gray over the last seven years.

METHODS

Study Area

Desolation and Gray canyons occur south of the Uinta Basin, UT, beginning at Sand Wash (RM 216) and ending 12 river miles upstream of the town of Green River, UT (RM 120, Figure1). A deep canyon derived from the Wasatch and Green River formations characterizes Desolation Canyon. The stretch of river between Sand Wash and Jack

Creek Canyon (RM 190) is primarily slow flat water with a depositional bed. The canyon becomes more confined and the gradient steeper from this point downstream. Gray Canyon begins immediately below Three Fords Rapid (RM 156) and the gradient decreases to Swasey's Rapid (RM 132).

A total of 12 sites were sampled throughout both canyons located at RM 189, 185, 182, 178.5, 174.4, 166.8, 160.4, 157.4, 154.4, 150.8, 148, and 145.7 (Figure 1). These include the four long-term trend sites that have been sampled since 1985. Several sites sampled between 2001 and 2003 were relocated in 2006 and 2007 to provide tighter coverage of the canyon and redistribute effort from sites which were too close together (less than a ½ mile).

Field Sampling and River Discharge

Three passes were conducted through Desolation-Gray in 2006 on September 24 to October 3, October 10–16, and October 23–28. Flows were 2150–1910 cfs during the first pass, 5160–3380 cfs during the second, and 3430–3210 cfs during the third (all flows determined by USGS gauge #09315000, Green River at Green River gauge). Average main channel temperatures during each pass were, 22.0, 17.0 and 12 ^{o}C, respectively.

In 2007, three passes were conducted on August 24–30, September 20–26, and October 14–20. Flows were 1300–1070 cfs during the first pass, 2510–1320 cfs during the second pass, and 2280–2110 cfs during the third pass. Average main channel temperatures during each pass were 24.2, 19.5 and 12.5 ^{o}C, respectively.

Two sixteen foot catarafts with 9.9 HP motors were used to set and check trammel nets and electrofish. Trammel nets were utilized to target the adult component of the Desolation-Gray humpback chub population and electrofishing was conducted to maximize juvenile captures. Past sampling experience demonstrated that trammel nets target adult sized chub and electrofishing targets a wider size range of chubs, including juveniles. In 2006, electrofishing at each site was conducted before setting trammel nets

in the evening and in the early afternoon after nets were pulled; electrofishing was discontinued in 2007 due to time and equipment constraints. Six to eight trammel nets (12"outer mesh and 1" inner mesh) were set at each sampling location, depending on availability of habitat at each site. Trammel nets were fished at each site from late afternoon until midnight and again the next day during the pre-dawn and morning hours. Each net was checked at two hour intervals. Chub collected in the trammel nets were identified as they were collected and held until all nets were checked. After each net checking round, all chubs were brought back to camp to process, and released.

One night was spent at each of the 12 sites. In 2002 and 2003, hoop nets and minnow traps were set at each site as conditions allowed. Up to four hoop nets and minnow traps were set at each site. Hoop nets and minnow traps were baited with cat food and set parallel to flow. Both the nets and traps were set in the afternoon after arrival at each site and checked in the morning prior to leaving.

Chub species were identified using a suite of qualitative characters (i.e., degree of frontal depression, presence of scales on nuchal hump, angle of the anal fin relative to caudal peduncle, etc; Douglas et al. 1989; 1998). Small juveniles and a few highly hybridized appearing chubs were only identified to genus. All fish identified only to genus were not included in the estimates. Information collected from all chub (individuals identified as humpback chub, roundtail chub, and chub with intermediate characteristics) captures included total length (mm), weight (g), and dorsal and anal fin ray counts. In addition, PIT tag numbers were recorded from recaptures and initial captures of chubs greater than 150 mm received a PIT tag and the number was recorded. Information collected for all fish species caught included total and standard lengths (mm) and weight (g). Information collected for other endangered species captured included total and standard lengths (mm), weight (g), and PIT tag number.

Data Analysis

Population Estimates - Total

Mark-recapture population estimates were calculated for adult humpback chub in Desolation-Gray Canyon using closed population models in program CAPTURE (Otis et al. 1978, White et al. 1982, Rexstad and Burnham 1991). Chubs were marked on each pass each year. Only chubs that had been marked during a previous pass and recaptured within the same year were considered recaptures for the estimate model. This follows the methods applied in 2001–2003 when mixing between sites during the sampling period was assumed (Jackson and Hudson 2005).

The specific estimator used by program CAPTURE for each years estimate was selected based on the programs model selection criterion and professional judgment, as to whether or not, the model fit the behavioral and biological observations in the field. Profile likelihood intervals are provided in lieu of 95% confidence intervals. The profile likelihood interval helps to account for model selection uncertainty and tends to give more accurate confidence intervals for small samples (Gimenez et al. 2005). However, the profile likelihood interval can only be determined for the null estimator (M_o) and the Darroch M_t estimators. The 95% confidence intervals are provided for all other estimators used (Table1; Appendix I).

Population estimates for juvenile humpback chub (150–199 mm) were not attempted due to extremely low numbers of this size class collected throughout all study years. To determine mean recruitment for juveniles into the adult population, we assumed that individuals from 200–220 mm were first year adults; the assumption is based on growth rate data from Westwater Canyon (Hudson and Jackson 2003, Chart and Lentch 1999), Desolation-Gray (Jackson and Hudson 2005), and Cataract Canyon (Valdez 1990). Because this category is based on growth and not actual age data, it must be considered a relative index of first year recruitment and actual recruitment estimates. The relative proportion of the first year adults to total adults is reported.

Population Estimates – Site Specific

Individual Humpback chub inhabit distinct, relatively small, home ranges during the fall (Badame 2008; Jackson and Hudson 2005; Hudson and Jackson 2003; Valdez 1990). These small ranges are typically bound by a rapid and the subsequent pool/eddy complex downstream. Past radio telemetry studies confirm that most fall ranges average 0.9 to 0.5 river miles (Kaeding et al. 1990; Valdez 1990). A solution for estimating population size when humpback chub show high site fidelity was examined in Cataract Canyon (Badame 2008) that suggested site specific estimates be calculated and used to determine a range of densities which could be extrapolated across the entire population in Desolation-Gray. To accomplish this, mark-recapture population estimates were again calculated for adult humpback chub in each unique sampling location within Desolation-Gray using closed population models in program CAPTURE.

In contrast to the "total" estimates, site specific (site) estimates were calculated using only fish captured, marked, and recaptured at each individual sampling location, ideally resulting in twelve site estimates per year. In 2006, mark-recapture estimates were calculated for 11 of 12 sites and in 2007 only 4 of the 12 sites had enough recaptures to produce estimates. For sites where recaptures were too low to produce a population estimate; one was calculated by applying the mean probability of capture (p-hat) from 2006 to the total catch in a given section. This allowed for a more accurate average site estimate or "site density" for comparisons between years.

Each sampling site is representative of a humpback chub's typical fall home range in Desolation-Gray Canyon. I estimate there are 63 sites that have the qualities and area of a typical humpback chub's fall range; the estimate was developed from personal experience of 15 years studying humpback chub on the river and a thorough review of maps. An estimate of the total population of adult humpback chubs in Desolation-Gray Canyon was calculated by multiplying the average of the twelve site estimates for a given year by the 63 available sites. This recalculation of population estimates was only completed for 2006–07 data.

Catch Rates

Trammel net, hoop net and minnow trap catch rates were calculated as the number of fish captured per hour a net was fished. Catch per unit effort (CPUE) was determined for the capture of all *Gila* chub through the period of this study. CPUE was compared between passes within and among years using nonparametric Kruskal-Wallis ANOVA on Ranks along with pairwise multiple comparisons (Dunn's Method) to examine the equality of samples. Total annual CPUE comparisons were tested between years using the same analyses. A two way repeated measures ANOVA was used to examine CPUE before and after the establishment of a smallmouth bass (*Micropterus dolomieu*) population (2004) in sites with and without bass. All statistical tests were performed using SigmaStat 3.5, (SPSS Inc).

Length-Frequency

Length-frequency distributions were calculated for humpback chub during the study period. Distributions for all *Gila* spp. collected in 1985, 1986, and since 1989, are also presented. Length-frequency distributions for humpback chub represent individuals larger than 150 mm TL collected during the study period. Individuals smaller than 150 mm TL are represented in the length-frequency charts for all *Gila* spp. since most can not be identified to species.

Comparisons with ISMP

Data from 2006–07 were added to previous annual monitoring data (1985 and 1986, 1989-2000) to examine long-term trends over the four original monitoring sites in Desolation-Gray (RM 185, 174.4, 160.4, and 145.7). All chub captured were combined for these analyses since in many years chub were not identified to species. Catch rate comparisons among years are standardized by considering the number of fish caught per hour a net was fished.

RESULTS

Total Population Estimates

Probability of capture was significantly higher in 2006 (0.169) and 2007 (0.188) relative to probabilities of 0.045 to 0.083 observed during 2001 to 2003. Probability of capture rates did not appear to vary over sampling periods within each year resulting in selection of the null model (M_o). The lack of variance in p-hat may also be an artifact of very low capture rates and a lack of significant fall movement during both years, resulting in precise but biased estimates.

The adult humpback chub total population estimate (all 12 sites combined) in 2006 was 410 (SE=69.6) with a profile likelihood interval of 305 to 595 and a total probability of capture of 0.14. The precision of the 2006 estimate was good with a C.V. of 17%. In 2007, the adult total estimate was 204 individuals (SE=34.4) with a profile likelihood interval of 153 to 298 and a total probability of capture of 0.19. The precision of the 2007 estimate was good with a C.V. of 17%.

Total population estimates for adult humpback chub showed a significant (p=0.021) decline of over 50% relative to estimates in 2003 to 2006 and also declined significantly (p=0.048) from 2006 to 2007 (Figure 2, Table 1).

The numbers of juvenile humpback chub (150–199 mm) collected by all methods during the study period were: 4 in 2006 and 5 in 2007. As was the case in 2001–2003, we are reporting the estimated number of first year adults (200–220mm) as a proportion of the total adult population estimate. Numbers of first year adults captured in 2006 and 2007 were 16 and 6 respectively and the proportions to the total adult estimates were 9.2% in 2006 and 5.2% in 2007 (Table 2). Relative first year adult proportions have shown a declining trend since the 2001 estimates (Table 2).

In both years of sampling it was found that humpback chub movements were completely localized and that no mixing occurred between any sample sites within a sampling year. The 100% observed site fidelity within a year violates the assumption of mixing between mark-recapture events. The resulting adult point estimates (total population estimates) therefore relate only to the actual sampling areas (12 sample sites) and not the entire Desolation-Gray population.

Site Specific Population Estimates

The site specific adult humpback chub population estimates for 2006 averaged 40.92 humpback chubs per site with a range of 10–109 fish per site (Table 3, Figure 3). The 2006 extrapolated total estimate for humpback chubs in Desolation-Gray is 2,578 (95% C.I. 1,151–9,736). Individual sectional estimates for 2007 showed significant declines at most sites (Table 3, Figure 3) with an average of 17.58 humpback chubs per site and a range of 2–53 fish per site. The 2007 extrapolated total estimate for humpback chubs in Desolation-Gray is 1,108 (95% C.I. 1,071–4,914).

Catch Rates

Catch per unit effort for humpback chub in trammel nets showed a significant decline of over 33% between 2003 and 2006 ($p=0.054$) and declined by another 25% in 2007 (Table 4). Catch rate variation within the 2006 and 2007 sample seasons was present but not significant ($p=0.175$). The catch rates observed in 2007 are the lowest recorded in this canyon since 1996 and the second lowest on record (Figure 4). The variation in CPUE over the period between 2001 and 2007 was examined graphically to observe changes at each sample location over each year sampled (Figure 5). Catch per unit effort varied both between sites and within sites over time, with an apparent trend of sites in the upper forty miles of the canyon seeing larger declines over time.

The establishment of a smallmouth bass population in the upper canyon was strongly associated with declines in humpback chub CPUE. Sites in the lower canyon, which

were downstream of the establishment of a smallmouth bass population, showed no significant difference between mean CPUE before (0.090) and after (0.067) the invasion of smallmouth bass within Desolation-Gray (p=0.464, Figure 6). Sites in the upper canyon, which contained smallmouth bass as of 2004, showed significant differences in mean CPUE before (0.147) and after (0.050) the period of invasion (p=0.012, Figure 6).

Electrofishing was conducted for 16.37 hours over three passes in 2006 and resulted in the capture of 12 humpback chubs. The mean total length for chub captured via electrofishing was 285 mm and the minimum total length was 223 mm. Electrofishing was discontinued in 2007 due to time and equipment constraints.

Length-Frequency

In 2006, the average total length of humpback chub collected by all methods in 2006 was 272 mm (Figure7). Two percent of all humpback chub collected were between 150 and 200 mm, and 0.04 percent was less than 150 mm. In 2007, the mean total length of all humpback chub collected by all methods was 276 mm (Figure7). Two percent of all humpback chub collected were between 150 and 200 mm, and no chubs less than 150 mm were collected.

Mean total length of chubs collected have increased by about 40 mm since the 2001–2003 collections, primarily due to reductions in the proportion of juveniles captured (Figure 7).

DISCUSSION

Population Estimates

The total estimator precision was better in 2006–2007 relative to that of 2001–2003, due to higher probability of capture rates. Tighter estimates allowed for statistical confirmation of declining numbers of adult humpback chubs between 2001 and 2007.

However, comparing spring total estimates (2001–2002) to fall total estimates (2003, 2006–2007) may not be accurate due to potential differences in site fidelity between these periods. Humpback chubs are potentially more active in June–July and may display larger overall movements outside of their fall home ranges; this means a greater extent of mixing may have occurred in 2001–2002 and the estimates would then relate to larger portions of Desolation-Gray.

In contrast, total estimates from 2003 and 2006–2007 occurred during the fall when observed site fidelity was at or near 100%, resulting in no mixing between sample sites, which violates a key assumption of the population estimate model. To remedy this, estimates from 2006 and 2007 were recalculated as sectional estimates, which are used as densities that are then extrapolated to the total population size based on a qualitatively determined number of suitable sites within Desolation-Gray.

Estimates from 2001–2003 were not recalculated or examined in terms of site fidelity rates for this report, therefore relating them to recovery goals is not discussed in this report. I would hypothesize that the June/July estimates of 2001–2002 are under estimates of the actual population size, due to the distance between sample locations relative to the potential home range of humpback chubs during that time of year. On average, sample sites are approximately 5 miles apart with one 20 miles above the next downstream site. The data will have to be examined specifically for movement between sample locations to determine if adequate mixing was occurring. The estimate data for 2003 was also not reexamined, but because it was sampled in the fall it is probable that site fidelity was very high and the total estimate from previous reports was an under estimate on the same scale as the 2006–2007 total estimates; which were approximately $1/6^{th}$ the extrapolated estimates.

The extrapolated estimates from 2006–2007 (2,578; 1,108) show that the Desolation-Gray population fell below the recovery goal minimum core population level of 2,100 adults in 2007. Extrapolated population estimates are highly dependant on the total number of suitable habitats available as fall home ranges. If the actual number of suitable

fall habitats available is 63, then an average density of 34 adult humpback chubs per site would be required for the Desolation-Gray population to be greater than 2,100 adults. A more reliable estimate of the number of fall habitats could be obtained by sampling new locations each year to determine if site fidelity rates are consistent across additional presumed home ranges during fall months.

Catch Rates

Examination of annual CPUE trends since 1985 have shown moderate variation, with the exception of one high outlier in 1989. Overall the trend between 1985 and 1995 was stable, followed by significantly higher rates from 1997 to 2000; between 2001 and 2007 rates declined to levels observed over the first decade of sampling. Past examinations of catch rates have all suggested that temperature, flow, and methods have had a confounding affect on the ability to observe trends (Chart and Lentch 2000; Jackson and Hudson 2005). During the first 15 years of sampling, work typically consisted of one pass at four or five sample locations, occurring in late June through July with flows between 18,400 and 1,380 cfs. Beginning in 2001 sampling consisted of three passes at a larger number of sites and from 2003 sampling was conducted only during September and October when water temperatures and flows were considered more stable (1,070-5,500 cfs). Changes in sample timing and intensity have likely continued to confound our ability to observe catch rate trends relative to periods previous to 2003, however, the rates observed in 2006–2007 still fell within the lower limits of those observed since 1985.

Catch per effort rates for adult humpback chubs within each site over the period of 2001 to 2007 showed a trend of greater declines among sites in the upper 45 miles of Desolation-Gray. Starting in 2001 it was noted (Jackson and Hudson 2005) that smallmouth bass were captured during fall sampling and by 2004 large scale removal efforts for bass were underway in the Green and Yampa Rivers, including Desolation-Gray. From 2004 through 2007 the downstream extent of the smallmouth bass in the Green River was just below RM 160 (Badame et al. 2008). Site specific declines in

humpback chub CPUE were strongly correlated to the arrival and distribution of smallmouth bass. Although smallmouth bass densities within Desolation-Gray have declined by as much as 50% since 2004 (Badame et al. 2008), their distribution has extended to the upper 76 miles of Desolation-Gray by the fall of 2008 (Groves et al. 2008). It is probable that smallmouth bass have applied predatory pressure on the juvenile and small adult humpback chubs within the upper portions of Desolation Canyon.

Juvenile Population

Juvenile population estimates from mark-recapture data were not attempted for the Desolation-Gray humpback chub population since few of these individuals were collected and recaptured. As a proxy for recruitment we examined the relative proportion of individuals from 200–220 mm which are believed to represent first-year adults (Hudson and Jackson 2005, Jackson and Hudson 2003, Chart and Lentch 1999). Without aging data, we are unable to determine with certainty that this size class window truly represents first year adults and therefore must report it as a relative index of recruitment. Declines in the proportion of first year adults in 2006–2007 support the idea that smallmouth bass predation may be suppressing the smaller *Gila*. Length frequency histograms, including chubs captured by all methods, also show an overall decline in the proportion of individuals, less than 200 mm, observed in the past two years of sampling.

Typically trammel nets are effective in capturing only humpback chubs 200 mm or larger. To examine the juvenile portion of the population we have relied on electrofishing and hoop traps. Electrofishing has proven very successful in Westwater Canyon but has met limited to no success in Desolation-Gray and Cataract Canyons. As was the case with electrofishing in the fall for humpback chubs, few to no juvenile chubs were captured during summer sampling for bass in 2005 and 2006 (unpublished data 2006). We assume that if high numbers of juvenile chubs were present in Desolation-Gray, our current sampling methods would capture them.

Canyon Coverage

Assuming that approximately ½ mile is sampled at each of the twelve sites, roughly 7% of Desolation-Gray was sampled during 2006–2007. The 7% figure is misleading, suggesting that 100% of the canyons can be sampled and that the entirety of these two canyons is suitable humpback chub habitat. Large portions of the two canyons include areas of low velocity runs, not typical of habitat in which humpback chub are generally captured. It is more accurate to say we assessed 12 of the 63 available sites (19%), which have similar habitat characteristics occupied by humpback chubs as fall home ranges.

Specific sample sites were determined for this project by including long-term trend sites, other sites sampled during ISMP, and new sites that appeared to be suitable for humpback chub. We made adjustments in sample locations to tighten and maximize coverage given time and logistical constraints. Future sampling in Desolation-Gray should account for overall coverage and consistent methods and timing to maintain a meaningful data set that will track population trends as precisely as possible.

CONCLUSIONS

- The lack of mixing between sample sites caused estimators to underestimate the overall size of the population. The total point estimates calculated for 2006 and 2007 are representative only of the number of fish within the sample areas.

- Site specific estimates for adult humpback chubs declined significantly from 2006 with an average of 40.92 adult humpback chubs per site to 17.58 per site in 2007.

- The extrapolated total adult humpback chub estimate for 2007 (1,108) was below the level set by recovery goals in 2002.

- Capture probabilities of adult humpback chubs were improved by sampling during fall months when chub movements are localized.

- The relative proportion of first-year adult and juvenile humpback chubs encountered has declined since 2001.

- Declines in humpback chub CPUE for sites in the upper 45 miles of Desolation Canyon correlate strongly to the appearance and persistence of a smallmouth bass population.

RECOMMENDATIONS

- Refine the sampling protocol for humpback chub in Desolation-Gray to develop sectional estimates which will be extrapolated into an overall point estimate for the Desolation-Gray Canyon population as required for downlisting according to the 2002 Humpback Chub Recovery Goals.

- Continue sampling two of the four long-term monitoring sites, four of the previously sampled sites, and incorporate sampling of six new un-sampled sites each year. This should help develop more accurate point estimates as well as improve our understanding of variation in spatial distribution.

- Continue electrofishing at all sites to capture juvenile humpback chub and consider use of baited hoop nets to also increase these rates.

- Examine 2001–2003 data to determine the extent of site fidelity during each sampling period. If results warrant, calculate site specific estimates for those years.

- Consider development of a brood stock for the Desolation-Gray population. The exploration of this option is justified by the 2007 extrapolated estimate, declining catch rates, and declines in relative numbers of first year adults.

- Consult a biostatistician to determine if annual sampling and marking of humpback chubs from the period of 1985 to present could be utilized to develop annual adult survival estimates.

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Table 1. Population estimate (N) for adult humpback chub (≥ 200 mm) in Desolation-Gray Canyon 2001–2007. Population estimates generated within program CAPTURE. The profile likelihood interval, coefficient of variation (C.V.), and probability of capture (p-hat) are included with the respective population estimates.

Year	N	Confidence Interval	C.V.	p-hat
2007	1,108[1]	1,071–4,914	0.46	0.188
2006	2,578[1]	1,151–9,736	0.57	0.141
2003	937[2]	636-1,520	0.21	0.083
2002	2,612[2]	1,477-8,509	0.36	0.045
2001	1,254[2]	733-2,697	0.31	0.053

[1]*Estimates based on 12 site-specific estimates, expanded to 63 sites.*
[2]*Estimates based on combined capture-recapture data from all sample sites (Jackson and Hudson 2005).*

Table 2. Relative proportion of first year adult humpback chub (200–220 mm) in Desolation-Gray Canyon 2001–2007 and the resulting population estimate (N) with respective 95% confidence intervals. The first year adult category is based on growth data from multiple populations and does not on actual age data; therefore it must be considered a relative index related to adult recruitment and not an actual estimate of recruitment.

Year	Relative Proportion	N	95% Confidence Interval
2007	5.2%	11	10–12
2006	9.2%	38	36–43
2003	14.3%	134	121–159
2002	11.4%	297	275–343
2001	13.0%	163	149–192

Table 3. Summary of site specific population estimates (N) for Desolation-Gray Canyons 2006 and 2007. All estimates use Model H_o. Summary data includes the 95% confidence interval (C.I.), probability of capture (p-hat), and coefficient of variation (C.V.). For sites with insufficient recaptures for an estimate, (N) was calculated using the average p-hat from 2007 (0.1877) and applying it to the total catch at a site. No summary data is provided for recalculated estimates.

Sampling Site (RM)	Year	N	95% C.I.	p-hat	C.V.
Jack Creek (189)	2007	11	–	–	–
	2006	12	7–51	0.189	70.1%
Cedar Ridge (185)	2007	24	14–72	0.183	50.1%
	2006	10	9–22	0.2994	26.4%
Dripping Springs (182)	2007	2	–	–	–
	2006	37	20–116	0.1435	55.2%
Wild Horse (178.5)	2007	7			
	2006	55	20–257	0.059	85.7%
Log Cabin (174.4)	2007	13	10–31	0.311	32.9%
	2006	28	13–122	0.121	76.8%
Chandler Falls (166.8)	2007	25	–	–	–
	2006	56	33–131	0.116	39.6%
Cow Swim (160.4)	2007	11	–	–	–
	2006	28	18–70	0.205	40.2%
Wire Fence (157.4)	2007	12	–	–	–
	2006	28	22–48	0.242	21.6%
Pat's Squeeze (154.4)	2007	11	–	–	–
	2006	11	–	–	–
Range Creek (150.8)	2007	24	14–72	0.183	50.1%
	2006	41	17–186	0.098	81.9%
Curry Rapid (148)	2007	18	–	–	–
	2006	109	35–518	0.058	88.8%
Coal Creek (145.7)	2007	53	30–137	0.146	45.0%
	2006	76	13–179	0.099	41.0%

Table 4. Summary of hours spent for each gear type, total number humpback chub collected and juveniles identified as Gila, and CPUE for trammel netting during sampling in Desolation-Gray 2001–07.

Year	Trammel Net Hours	Total HBC	Trammel CPUE	Shocking Hours	Total HBC	Hoop & Minnow Trap Hours	Total HBC
2007	2,727	117	0.043	0	0	988	6
2006	2,892	162	0.056	16.4	12	729	9
2003	3,042	232	0.076	11	1	1,946	5
2002	2,008	293	0.146	22.5	38	1,440	7
2001	2,803	337	0.120	8	3	0	0

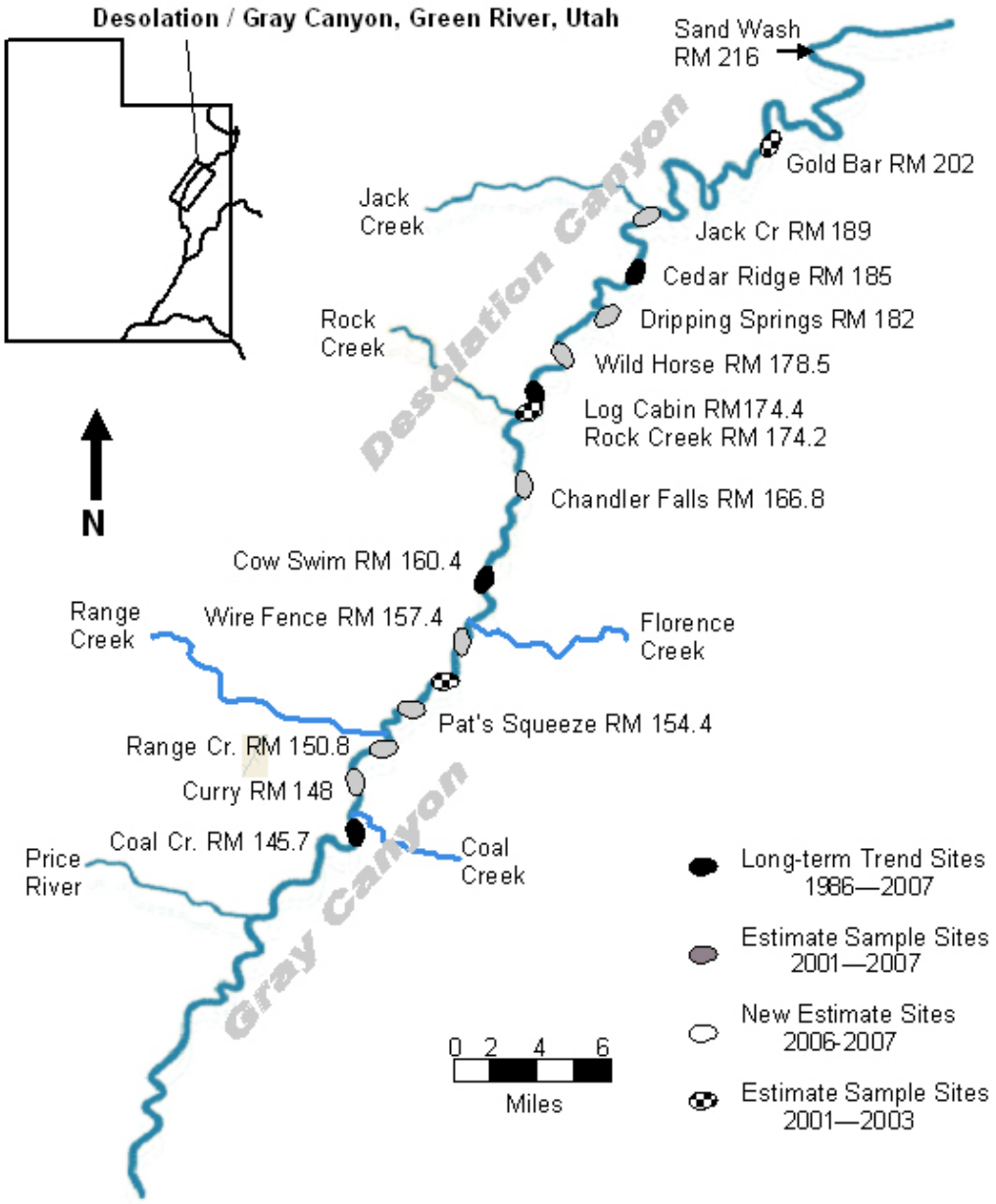

Figure 1. Fifteen current and historical sample sites located within Desolation and Gray Canyons of the Green River.

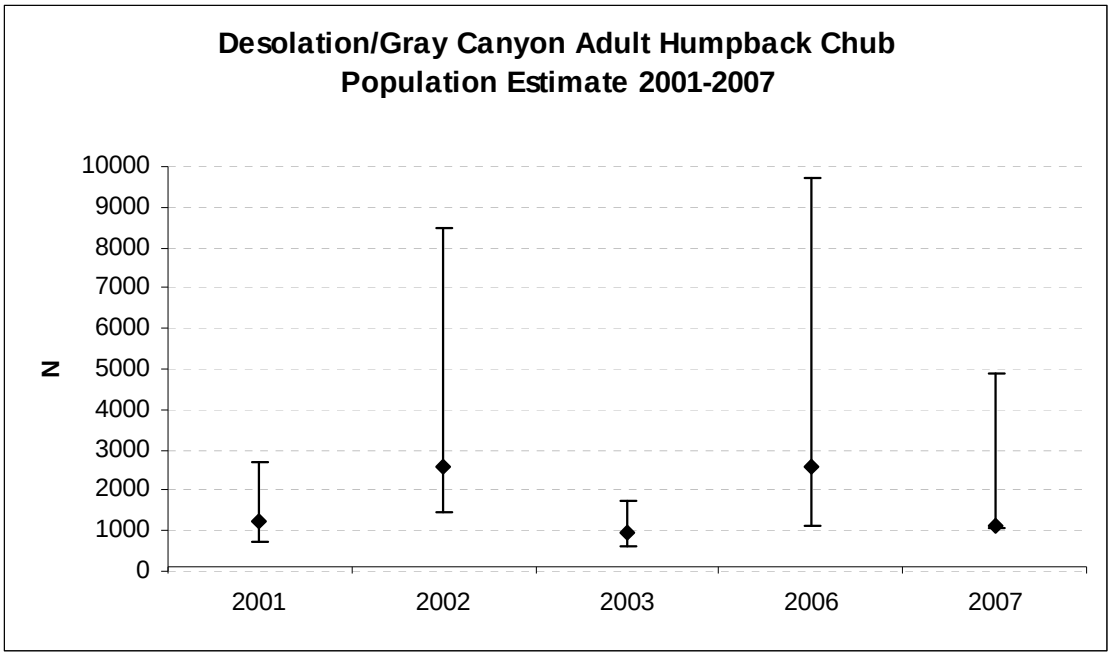

Figure 2. Desolation-Gray adult humpback chub total population estimate (N) for 2001–2007. Each point estimate includes a respective profile of likelihood interval. Estimates for 2006 and 2007 based on 12 site-specific estimates, expanded to 63 sites. Estimates for 2001–2003 based on combined capture-recapture data from all sample sites (Jackson and Hudson 2005). The 2001–2003 estimates presented here have not been recalculated based on potentially high site fidelity and may represent significant underestimates of up to $1/6^{th}$ the estimates that could be derived from site-specific estimates for that time frame.

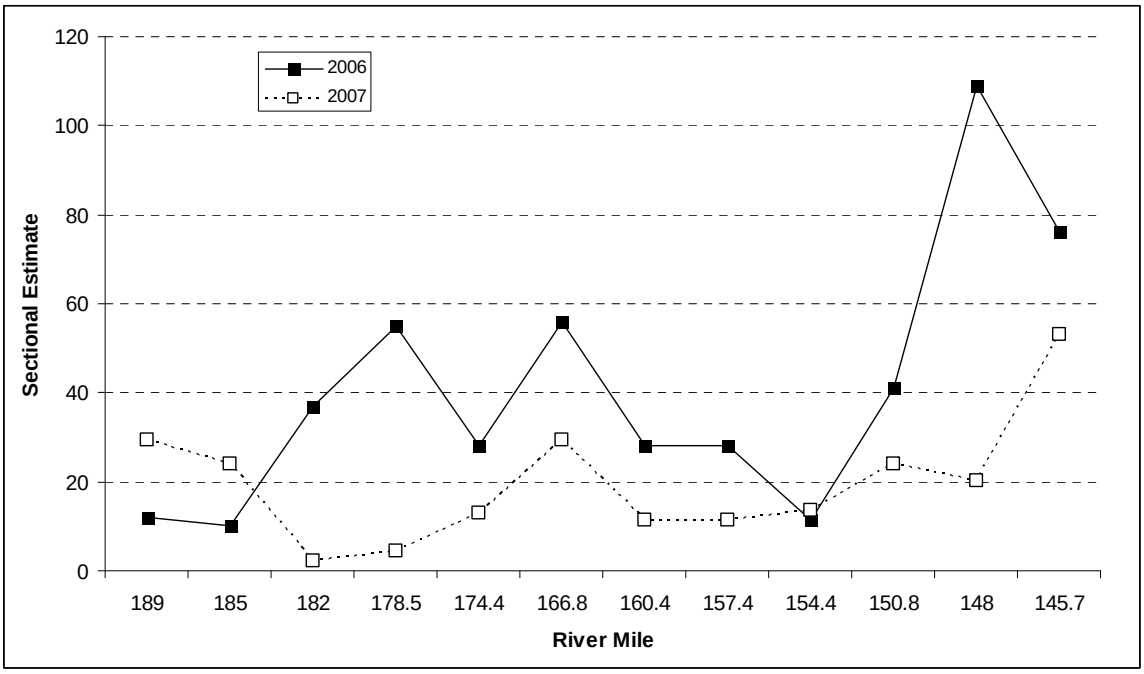

Figure 3. Desolation-Gray adult humpback chub sectional estimates (N) for 12 sampling sites, 2006–2007.

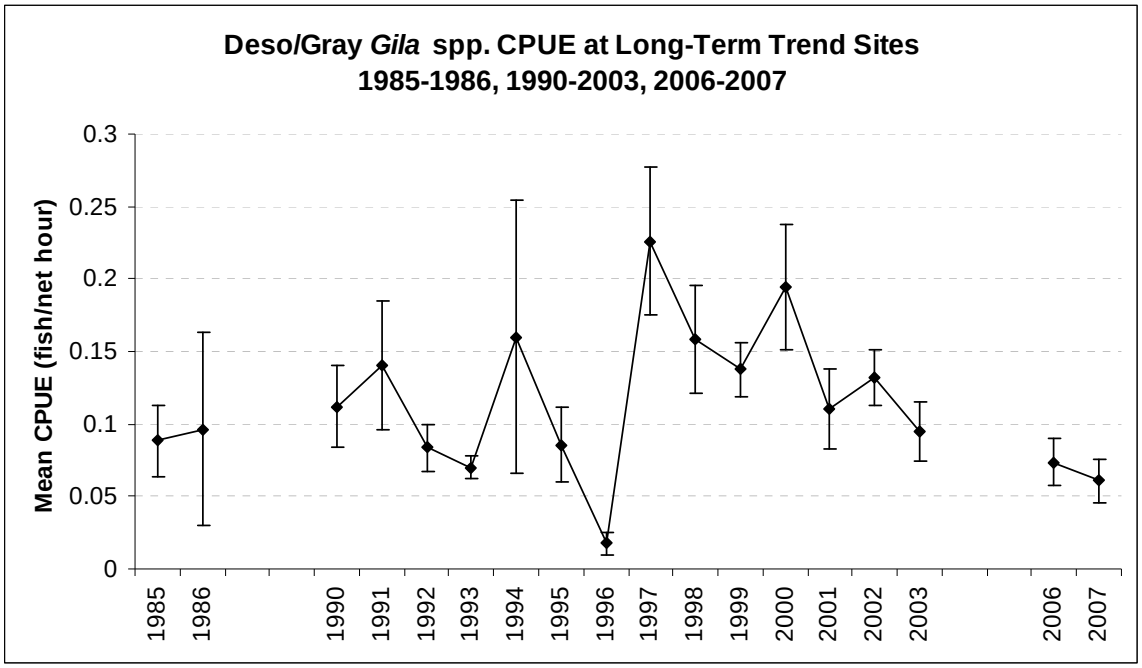

Figure 4. Desolation-Gray long term trend site mean CPUE for all *Gila* by year for 1985–1986, 1990–2003, and 2006–2007. The 1989 data point has been excluded as an outlier (0.59) to maintain scale. Error bars represent one standard error.

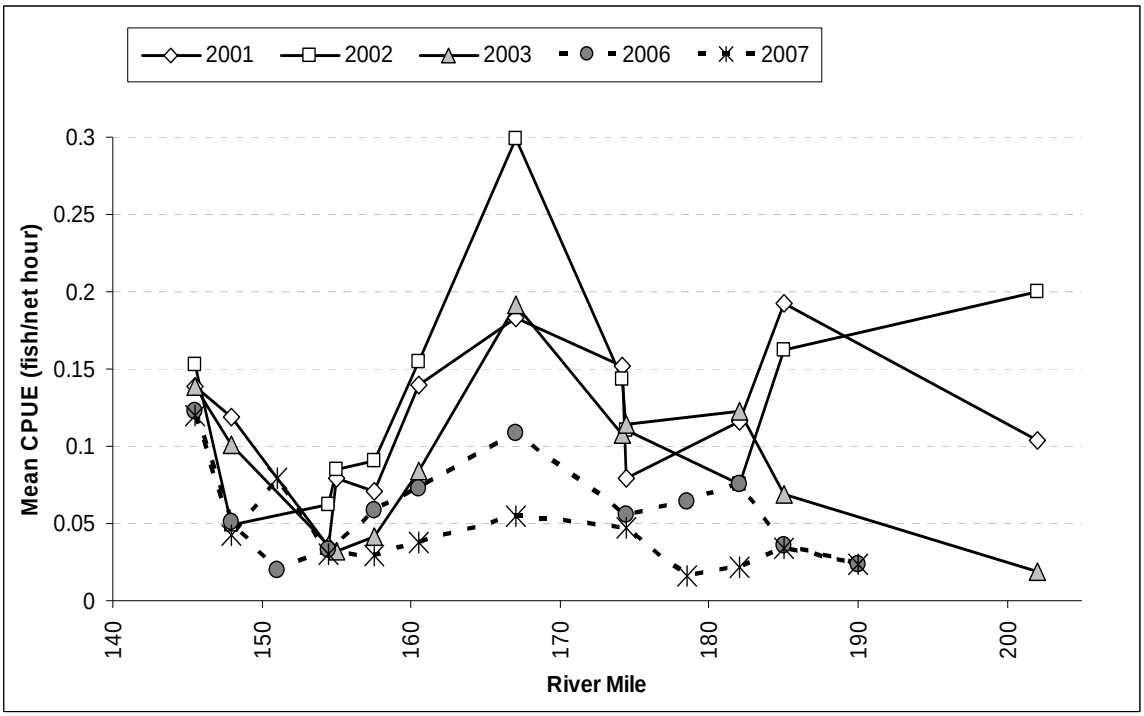

Figure 5. Mean annual CPUE of humpback chub captured at each sample location between 2001 and 2007. Several sample locations changed after 2003, including the site located approximately 20 river miles upstream of all others.

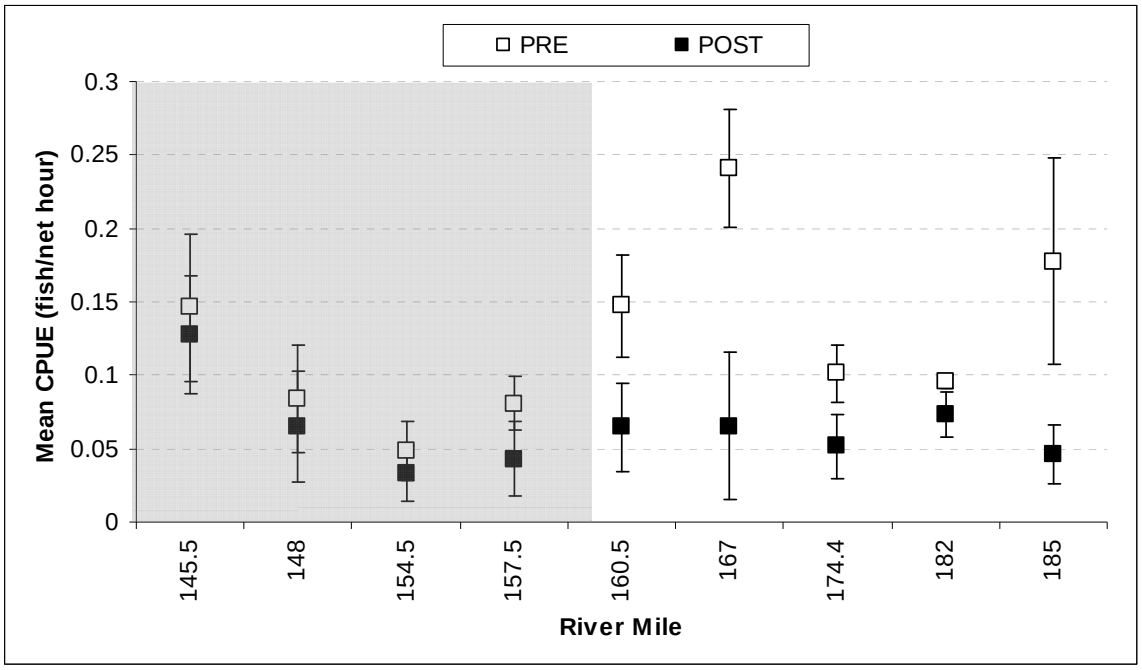

Figure 6. Mean adult *Gila* CPUE at nine sites sampled in five of the seven years between 2001 and 2007. Pre (2001–2003) and post (2006–2007) notate establishment of adult smallmouth bass in 2004. Downstream distribution of smallmouth bass ended at river mile 160, sites in shaded area had no bass discovered as of 2007. Error bars represent one standard error.

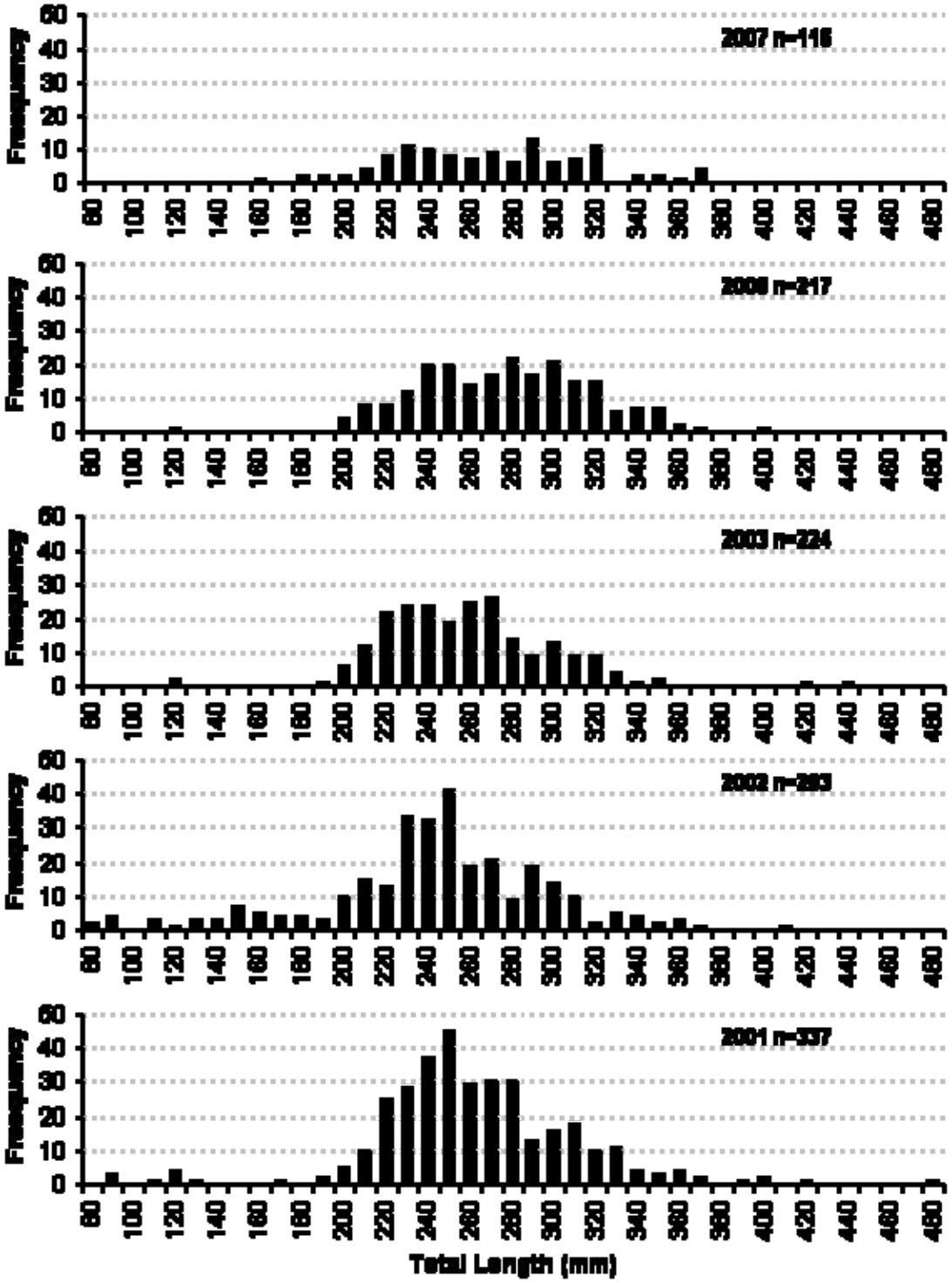

Figure 7. Desolation-Gray adult and juvenile humpback chub length-frequency histograms for 2001–2007. Frequency is illustrated as the number of total individuals within a given size class.

Appendix

Summary of total population estimates models considered and related statistics generated with program CAPTURE for adult humpback chub in Desolation-Gray Canyon, 2001–2003 and 2006–2007. Information for comparison within each year of the study among estimators considered includes the abundance estimate, 95% confidence intervals, coefficient of variation (C.V.), and probability of capture (p-hat). *Values in parentheses are profile likelihood intervals for each point estimate.

Year	Estimator	N	95% Confidence Interval*	C.V.	p-hat
2007	M_o	204	155–294 (153–298)	0.169	0.188
	Darroch M_t	201	154–288 (151–293)	0.165	0.193
	Chao M_t	208	154–314	0.189	0.192
	Chao M_h	280	191–453	0.229	0.137
2006	M_o	410	306–585 (305–595)	0.170	0.141
	Darroch M_t	406	304–577 (302–588)	0.170	0.150
	Chao M_t	391	290–566	0.176	0.150
	Chao M_h	540	376–825	0.206	0.107
2003	M_o	945	656–1,425 (737–1,960)	0.202	0.083
	Darroch M_t	937	634–1,462 (636–1,520)	0.218	0.083
	Chao M_t	1,082	691–1,802	0.253	0.103
2002	M_o	2,198	1,168–4,361 (1,435–9,548)	0.351	0.057
	Darroch M_t	2,612	1,359–5,274 (1,477–8,509)	0.361	0.045
	Chao M_t	2,615	1,305–5,547	0.388	.045
2001	M_o	1,613	887–3,098 (910–3,431)	0.332	0.041
	Darroch M_t	1,254	715–2,346 (733–2,697)	0.315	0.053
	Chao M_t	1,134	658–2,096	0.307	0.06