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Population Estimate for Humpback Chub (*Gila cypha*) in Desolation and Gray Canyons, Green River, Utah 2001-2003

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EXECUTIVE SUMMARY

Humpback chub population estimates were determined for Desolation and Gray canyons (Deso/Gray), on the Green River, by conducting multiple pass capture-recapture sampling. Three sampling passes were conducted in 2001 and 2003, and two passes were conducted in 2002 due to low water. In 2003, sampling was moved to the fall to avoid capturing Colorado pikeminnow that use Desolation Canyon for spawning. Twelve sites were sampled throughout the two canyons. Included within these sites, were four long-term sites sampled annually by Utah Division of Wildlife Resources since 1989. Analysis of point estimates generated by capture-recapture data demonstrated that the adult humpback chub population was composed of 1,254 individuals in 2001, 2,612 individuals in 2002, and 937 individuals in 2003. Many factors were at play during the three-year period that may have contributed in the variation in point estimates among years. Non-biological factors complicating the validity of the estimates include moving sampling from summer to fall and low water conditions at the time of sampling. Factors that may have directly affected the humpback chub population biologically include, the Rattle Complex fire and subsequent fish kill in late summer 2002, and the apparent increase in smallmouth bass occupying Deso/Gray. The authenticity of the point estimates will be more clearly analyzed when population estimates are conducted consistently during the fall months of 2006-2008.

Population estimates for the juvenile portion of the population could not be determined since very few individuals were collected each year. Numbers of humpback chub juveniles collected by all methods during the study period were: 5 in 2001, 24 in 2002 and 4 in 2003. To determine mean recruitment for juveniles into the adult population, we assumed that individuals from 200-220 mm would be first year adults. Point estimates for this size class were derived by taking the proportion of these fish relative to the total numbers used in the adult population estimate. Therefore, estimates of first year adults were 163 (95% CI=149-192) for 2001, 297 (95% CI=275-343) for 2002, and 134 (95% CI=123-159) for 2003. In order to increase the catch of juvenile humpback chub we recommend the continuation of electrofishing to the extent possible, utilization of hoop nets and minnow traps, and incorporation of smaller mesh trammel nets.

Catch rate data incorporated to analyze changes over time at four long-term sites illustrated that catch rates for humpback chub have not changed substantially since 1989. Furthermore, examination of pre-study and study period data suggest that catch rates can be extremely variable and possibly dependent on environmental factors during sampling.

This study represents the first sampling period since finalization of the amended recovery goals for humpback chub in 2002 and is valuable in the initial evaluation of population size of humpback chub in Deso/Gray. Furthermore, it serves to illuminate any necessary adjustments to the sampling design before population estimate sampling for humpback chub in Deso/Gray resumes in 2006.

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INTRODUCTION

The humpback chub (*Gila cypha*) is a large-bodied cyprinid endemic to the Colorado River Basin. It is 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 (Valdez 1990). Humpback chub are believed to presently inhabit approximately 68% of their original range. 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 pesticides and pollutants.

Humpback chub were first reported in Desolation and Gray canyons (Deso/Gray) on the Green River in 1975 as a result of investigations conducted from 1967-1971 (Holden and Stalnaker 1975). This population has been monitored nearly annually for approximately 25 years. The Utah Division of Wildlife Resources has been responsible for this monitoring since 1985. Currently, there are six self-sustaining populations that exist, 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 Deso/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, an amendment and supplement to the recovery plan was approved (USFWS 2002). Objective and measurable recovery criteria were identified in the amendment and supplement for the downlisting and delisting of humpback chub. Recovery criteria were developed for the upper and lower Colorado River basins that outlined the goals that must be met for downlisting and delisting to be considered. 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; 3) 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 generated by mark-recapture sampling and analysis were conducted from 2001 to 2003 for the Deso/Gray humpback chub population. The specific objectives were to: 1) obtain a population estimate of late juvenile/adult humpback chub in Deso/Gray; and 2) determine if a relationship exists between Interagency Standardized Monitoring Program (ISMP) catch rates and population size. Within these objectives, recovery criteria #1 for downlisting, is specifically addressed. The other recovery criteria are not addressed within our objectives and this study was not designed to address other recovery criteria. Due to it's potential designation as a third core population, the Deso/Gray humpback chub population will likely play a significant role in the delisting of this species, as stated in delisting recovery criteria #3. Therefore, this study, which represents the first sampling period since finalization of the amended recovery goals, is valuable in the initial evaluation of population size of humpback chub in Deso/Gray. Furthermore, it illuminates any necessary adjustments to the sampling design before population estimate sampling resumes in 2006.

METHODS

Study Area

Desolation and Gray canyons occur south of the Uinta Basin, UT, beginning at Sand Wash (RM 216) and ending at 12 river miles upstream of the town of Green River, UT (RM 120; Fig.1). A deep canyon derived from the Wasatch and Green River formations characterizes Desolation Canyon. The stretch of river between Sand Wash and Cedar Ridge Canyon (RM 186) is primarily slow flat water. The canyon becomes more confined and the gradient more steep from this point downstream. Gray Canyon begins immediately below Three Fords Rapid (RM 156) and the gradient decreases to Swazey's Rapid (RM 132).

A total of 12 sites was sampled throughout the canyons including the four long-term trend sites at RM 185, 174.4, 160.4, and 145.7 that have been sampled annually since 1989. The other sites were located at RM 202, 182, 174.2, 166.8, 158.7, 155, 153.5, and 147.5. Four "wild card" sites (alternative sites from previous ISMP monitoring) were included within the 12 sites.

Field Sampling and River Discharge

Three passes were conducted through Deso/Gray in 2001 on June 16-22, July 1-5, and July 15-20. Flows were 5699-3560 cfs during the first pass, 2620-2220 cfs during the second, and 1750-1620 cfs during the third (all flows determined by USGS gage #09315000, Green River at Green River gage). Sampling, in general, was conducted during the descending limb of the hydrograph. Sampling had been scheduled during this time to take advantage of higher flows. In 2001, flows dropped rapidly between the second and third passes. Main channel water temperatures were 19-21^{o}C during the first and third passes, and 25-28^{o}C on the second pass.

Attempts were made to take advantage of higher flows by moving the project forward two weeks in 2002. Two sampling passes were conducted during June 1-8 and June 15-22. A third sampling pass was scheduled for June 29-July 6 but was not conducted.

Flows dropped more rapidly than in 2001 and the third pass was canceled to avoid damage that had been done to boats during the third pass in 2001. Flows were 5600-4700 cfs during the first pass and 3170-1810 cfs during the second pass. The third pass would have occurred during flows of 1250-1040 cfs. It was determined from the previous year that flows of less than 1800 cfs were damaging to sport boats and motors. Average main channel temperatures for June were 23^{o}C.

Sampling was conducted in the fall of 2003. Three sampling passes were conducted through Deso/Gray on August 31-September 8, September 28-October 4, October 22-29. Sampling was scheduled for this time when ambient and water temperatures were lower to reduce stress on humpback chub collected and to avoid capturing Colorado pikeminnow that use Desolation Canyon for spawning in the summer. Flows were 1050–1250 cfs during the first pass, 1300–1520 cfs during the second pass, and 1430–1470 cfs during the third pass. Average main channel temperatures during each pass were, 23.0, 19.0 and 11.5^{o}C, respectively. No sport boats were used in the canyon in 2003 because of low flows. A 14' raft with a 9.9 motor and a 16' cataraft with a 30 HP motor were used to set and check trammel nets. An oar driven 14' raft was used to conduct electrofishing. Available sample area at many sites had been reduced because of low flows.

Trammel nets were utilized to target the adult component of the Deso/Gray humpback chub population. Past research indicated that trammel nets provided the greatest numbers of adult sized chub and electrofishing was a better technique to collect juveniles. Electrofishing was conducted in attempt to maximize our captures. During 2001, electrofishing was conducted on one pass at the upper river sites (RM 202-166.8). In 2002, one pass of electrofishing was conducted throughout the study area (between sites in the middle of the day where feasible) with more intensive sampling at each of the twelve sites. Electrofishing in 2003 was conducted at the upper sites on the first pass and at the lower sites on the second pass. No between-site electrofishing was conducted in 2003 due to low catch rates from the previous year and low water conditions. Electrofishing at each site was conducted before setting and after pulling trammel nets in the evening. Six to eight trammel nets (12"outer mesh and 1/2" or 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 one and a half to two hour intervals and during the first two years, all chub were removed and placed in a holding pen to avoid recapturing the same fish twice within a sample site. In 2003, a holding pen was not used and recaptures of the same fish at the same site occurred frequently. Chub collected in the trammel nets were identified only as chub when first removed from the net for later identification and processing.

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 if any existed. Both the nets and traps were set in the afternoon after arrival at each site and checked in the morning prior to leaving.

Chub were identified to species using a suite of diagnostic 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 and 1998). Some chub collected in 2001 were identified only to genus, but then recaptured in subsequent years or passes and identified to species. Chub identified only to genus in 2001, but later identified as humpback, were included in the 2001 population estimate. All other fish identified as chub were not included in the estimates. Information collected from all chub captures included total length (mm), weight (g), sex (mature chubs), and dorsal and anal fin ray counts. In addition, PIT tag numbers were recorded from recaptured chub. Initial chub captures of fish 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 Estimate

Individual humpback chub collected by trammel nets made up the majority of fish used in generating population estimates. Individuals collected during electrofishing were used to increase the number of marked individuals. Individuals that were recaptured during electrofishing were not used in the estimate due to the variability in the amount of electrofishing effort per pass. Population estimates were determined for adult humpback chub (>200 mm) in Deso/Gray using closed population models within Program CAPTURE (Otis et al. 1978, White et al. 1982, Rexstad and Burnham 1991). Program CAPTURE was used for model-selection to aid in determining the most appropriate estimator, but population estimates were routinely calculated using several estimators: M_0 (null estimator), Jacknife M_h, Darroch M_t, Chao M_{th}, Chao M_t, and Chao M_h. Models were ultimately determined by considering selection results generated in Program CAPTURE and by considering other data available (i.e. capture probabilities, catch rate variability, and number of passes conducted). The Darroch M_t model was used for each year. A separate adult population estimate was calculated for each year. Program CAPTURE was used to determine confidence intervals around the estimate, the coefficient of variation, and the probability of capture.

Confidence intervals were determined for all estimators. Profile likelihood intervals are provided in lieu of 95% confidence intervals for the M_t model. The profile likelihood interval helps to account for model selection uncertainty by providing wider confidence intervals (Appendix I). In addition, these intervals tend to give more correct confidence intervals for small samples (Ross Moore, Mathematics Dept., Macquarie University, Sydney Australia *personal communication*). All confidence intervals are provided for comparison among all estimators used to calculate population estimates in Deso/Gray (Appendix I).

Population estimates for juvenile humpback chub (150-199 mm) were not attempted using mark-recapture data due to extremely low numbers of this size class being collected throughout all study years. To determine mean recruitment for juveniles into the adult population, we assumed that individuals from 200-220 mm would be first year adults. This assumption was determined by taking growth rate data from Westwater Canyon (Hudson and Jackson 2003, Chart and Lentch 1999), Deso/Gray (this study), and Cataract Canyon (Valdez 1990). Estimates for this size class were derived by taking the proportion of these fish relative to total numbers used for the adult estimate. From that proportion, confidence intervals were generated by the following formulas:

p= (# 200-220 mm)/total caught 200+ mm)
q=1-p
SE= sqrt(p*q/n), where n is the total caught
95% CI: p+/- (st err) * 1.96

Catch Rates

Trammel net, hoop net and minnow trap catch rates were determined by the number of fish caught per hour a net was fished. Electrofishing catch rates specifically are not included in this report due to the limited amount of data and inconsistency in effort among trips and years. Numbers of humpback chub collected and the amount of effort is included in the catch rate section. Electrofishing data was specifically used for initial captures in the population estimate, length frequency analysis and determining movement of humpback chub in Deso/Gray.

Catch per unit effort (CPUE) was determined for trammel net effort toward the capture of humpback 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 or a t-test to analyze CPUE between two passes, as in 2002. Total annual CPUE comparisons were tested between years using the same analyses. All statistical tests were performed using SigmaStat 3.0, (SPSS Inc).

Length-Frequency

Length-frequency distributions were determined for humpback chub during the study period. Distributions for all *Gila* spp. collected in 1985, 1986, and since 1989, were also determined. 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 were not identified to species. Individuals less than 100 mm TL are not represented in the length-frequency charts since very few of this size were collected. However, their numbers are reported in the text.

Comparisons with ISMP

Data from 2001-2003 was added to previous annual monitoring data (1985 and 1986, 1989-2000) to examine long-term trends over the four original monitoring sites in

Deso/Gray (RM 185, 174.4, 160.4, and 145.7). All chub captured (individuals identified as humpback chub, roundtail chub, and chub with intermediate characteristics) 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. Net lengths varied somewhat during the earlier years sampling was conducted. The number of nets set per site did vary somewhat between pre-study and study years, yet only usually by two nets. Time that nets were set was also variable between pre-study and study years. Most of this variation occurred prior to 1991.

RESULTS

Population Estimates

Population estimates for adult humpback chub ($\geq$ 200 mm) declined slightly over the three-year study period (Fig.2). The adult humpback chub population estimate in 2001 was 1,254 (SE=396; Table 1). The profile likelihood interval around this estimate was 733-2,697. The precision of the estimate was poor with a CV of 31%. In 2002, the population estimate increased slightly to 2,612 (SE=944) with a profile likelihood of 1,477-8,509. The precision of this estimate was poor with a CV of 36%. Finally, in 2003, the adult population estimate for humpback chub was 937 (SE=205) with profile likelihood intervals of 636-1,520. The precision of the estimate in 2003 was the best of the three years at 21%. Probability of capture or p-hat was variable throughout the study years from 0.053 in 2001, to 0.045 in 2002, and finally to 0.083 in 2003.

Population estimates for juvenile humpback chub (150-199 mm) were not attempted by mark-recapture data due to extremely low numbers of this size class being collected throughout all study years. Numbers of humpback chub juveniles collected by all methods during the study period were: 5 in 2001, 24 in 2002 and 4 in 2003. Instead, we assumed that individuals from 200-220 mm would be first year adults, and we could then estimate mean recruitment for juveniles into the adult population. Numbers of individuals 200-220 mm from 2001 to 2003 were 26, 28, and 32, respectively. Therefore, estimates of first year adults were 163 (95% CI=149-192) for 2001, 297 (95% CI=275-343) for 2002, and 134 (95% CI=121-159) for 2003 (Table 2).

Catch Rates

2001- Catch rates of humpback chub in trammel nets varied among sampling passes through Deso/Gray (Fig. 4). A total of 214 humpback chub were captured in 2,803 hours of trammel netting, 4 of these were juveniles (Table 3). Mean catch rates of humpback chub in trammel nets decreased significantly between all passes ($p<0.001$; Fig.4).

Electrofishing, in 2001, was conducted during the second pass at the upper six sites only. Fifteen chub were collected. Four were adults, two were juveniles greater than 150 mm, and nine were juveniles less than 150 mm. Only three of these fish were identified as humpback chub. No additional electrofishing was conducted since humpback chub captures by this method were low. Fifty-nine percent of all *Gila* spp. collected by all methods in 2001 were humpback chub.

2002- A total of 239 humpback chub were collected in 2,008 trammel net hours, eleven of these were juveniles greater than 150 mm and five were less than 150 mm. Four additional chub collected, less than 150 mm, were not identified to species. Mean catch rates of humpback chub in trammel nets increased between passes but the change was not significant (p=0.316; Fig.4).

Electrofishing effort in 2002 was twice that in 2001. Thirty-eight humpback chub were collected during electrofishing, twelve of those fish were juveniles greater than 150 mm. Eight of the thirty-eight were less than 150 mm. Four additional chub collected during electrofishing were not identified to species (82-126 mm). Electrofishing captured thirteen percent of all humpback chub collected by all methods. Captures of humpback chub between sites were low (2% of total humpback chub caught by all methods). Hoop nets and minnow traps set at each of the sampling sites collected seven humpback chub three of these were adults. Two additional chub collected were too small to identify to species (71 and 72 mm). Ninety percent of all *Gila* spp. collected by all methods in 2002 were humpback chub.

2003- A total of 236 humpback chub were collected in 3,042 trammel net hours, three were juveniles greater than 150 mm (Table 3). No humpback chub less than 150 mm were collected in trammel nets. Mean catch rates of humpback chub increased significantly across sampling passes, specifically between the first two passes and the third pass (p=0.004; Fig.4). Fifteen percent of humpback chub collected were recaptured at least once within the same pass at the same site.

Eleven hours were spent electrofishing resulting in the capture of one adult humpback chub. Hoop nets and minnow traps were set at each of the sampling sites during the first two passes, and collected five humpback chub. One of the five humpback chub was a juvenile greater than 150 mm. One additional chub collected was too small to identify to species (114 mm). Ninety-seven percent of all *Gila* spp. collected by all methods in 2003 were humpback chub.

Length-Frequency

2001- Average total length of humpback chub collected by all methods in 2001 was 261 mm (Fig.5). Five percent of all chub collected were between 150 and 200 mm, and three percent were less than 150 mm (Fig. 8). Average total length of humpback chub caught in trammel nets was 260 mm (range 186-473 mm).

2002- Average total length of all chub collected by all methods was 239 mm (Fig.5). Fifteen percent of the total chub catch were juveniles. Of this 15%, 7.8% were greater than 150 mm, and 7.2% were less than 150 mm. Average total length of humpback chub caught in trammel nets was 250 mm (range 131-409). Average total length of humpback chub collected during electrofishing was 205 mm (range 117-359 mm). Humpback chub captured in hoop nets and minnow traps averaged a total length of 190 mm.

2003- Average total length of all humpback chub collected by all methods was 256 mm (Fig.5). Four were juveniles greater than 150 mm. Average total length of humpback chub caught in trammel nets was 256 mm (range 188–434 mm). Humpback chub captured in hoop nets averaged a total length of 231 mm (n=5, range 196–266 mm). One chub collected in a minnow trap was 114 mm, but was not identified to species because of its size.

Comparisons with ISMP

Comparisons of humpback chub catch rates to population estimates for 2001 to 2003, illustrated a positive but insignificant relationship ($r = 0.868$, $p = 0.32$). Catch rates of chub from the four long-term trend sites in Deso/Gray have varied significantly from 1985 to 2003 (Fig. 6). The highest and lowest CPUE between 1985 and 2003 were in 1989 and 1996, respectively. A regression line drawn through the data points does not significantly depart from zero ($r^2=0.020$, $p=0.58$). When the 1989 data point is treated as an outlier and removed, the regression line remains stable and slightly increasing, however, not significantly ($r^2=0.078$, $p=0.29$; Fig.7).

Length frequency analysis of all *Gila* spp. collected from 1989 to 2000 during ISMP indicates shifts in size structure, and in some years an apparent absence of recruits (Fig. 8). The same type of cycle is likely continuing and occurred from 2001 to 2003. However, comparisons between the 2001-2003 and the pre-study data are rough considering differences in study design and timing (i.e., omission of seining and sampling in the fall).

Growth

Twenty-five humpback chub recaptured between 2001 and 2003 demonstrated an average growth rate of 10.8 millimeters per year (SD=9.3, range 0-31). These growth rates for humpback chub are similar to those found in other upper basin humpback chub populations (Hudson and Jackson 2003, McAda 2002, Chart and Lentch 2000, Valdez 1990).

Movement

Recaptured humpback chub in Deso/Gray displayed more movement between years than between passes from 2001 to 2003. In 2001, recaptured humpback chub did not move between sites. In 2002, two humpback chub were recaptured within the same trip, five days apart. One of these fish moved 10 miles upstream while the other moved 13 miles downstream. Six chub were recaptured during the second trip that had been tagged during the first trip. Of these six fish, one moved downstream 8 miles while the remaining 5 stayed within a mile of their original capture location. In 2003, one humpback chub was recaptured on the third pass that had been captured on the first pass. It had moved 14 miles downstream. No other movement of chub was observed. Between years of this study, 2 fish captured in 2002 had moved approximately 7 miles upstream since sampling in 2001. One fish captured in 2002 moved 17 miles upstream since 2001 sampling. From 2001 to 2003, two fish moved upstream 7 and 20 miles, while 5 fish moved 7 to 26 miles downstream of their original capture locations.

Fifteen humpback chub were recaptured during 2001-2003 that been captured at least once, one to 7 years prior to the study period. Of these 15 fish, 11 did not move more than one mile between capture events. Two of the 15 fish moved 7 and 14 miles upstream, while two others moved 3 and 27 miles downstream.

DISCUSSION

Population Estimates and Catch Rates

Model Selection

Due to the variability in capture probabilities in 2001 and 2003, we chose to use the Darroch M_t model for the population estimate. Since only two passes were conducted in 2002, the Darroch M_t model was again used. Program CAPTURE chose the M_b model in 2001, M_{bh} model in 2002, and M_h model in 2003. Since the model selection tool in CAPTURE does not perform well with sparse data such as ours, it appears that the best models for our data are the M_o and M_t models. Additionally, heterogeneity (M_h) and behavior (M_b) components are difficult to model when data are sparse. In 2003, the M_o model ranked second highest after the $M_{h,}$ yet again we chose the Darroch M_t. In 2003, the difference in the actual point estimate between the M_o model and the Darroch M_t model was negligible (945 vs. 937), and the profile likelihood intervals around these two numbers were comparable (737-1,960 vs. 636-1,520).

Population Estimates

The preliminary abundance estimate for the Deso/Gray humpback chub population was approximately 1500 adults (USFWS 2002). The 2001-2003 population estimates when averaged are relatively close to the original estimate. Differences in season and flow between the first two and the final year of this project confound the interpretation of the estimates generated, and caution should be taken in doing so. The lower population estimate in 2003 may simply reflect the variable efficiency in capturing humpback chub between the two seasons. Sampling when flows are relatively low may produce point estimates that are precise yet underestimated if fish are not mixing adequately. During 2003, CV and p-hat were the best of the three years. This is likely related to the relatively high percentage of captures and recaptures on the third pass.

Rates of recapture were highest on the third pass compared to the second pass in 2003, and the majority of third pass recaptures were fish originally marked on the second pass.

Proportions of marked to unmarked fish on the third pass were double what they were on the second pass. From these observations it appeared that the majority of fish from the first pass were not available for subsequent recapture, while many more fish from the second pass were available. In other words, fish from the first pass may have moved out of the sample area or experienced delayed mortality, while fish from the second pass stayed within the sample area and were available for recapture. Furthermore, many more fish overall were collected on the third pass suggesting either an increase in activity and availability for capture, immigration from intervening reaches, or both.

Initial examination of the data suggested that fish might not have been mixing adequately between passes, possibly because of low water conditions. In order to test this possibility, the Lincoln-Peterson estimator was used to calculate population size for the first and third passes in which the fish would have had more time to mix. The estimate generated by this model was 997 with SE=116, and the 95 % CI was 273-1,720. The small difference between this and the three-pass estimate (937) suggests that fish did mix adequately between all three passes. Yet the relatively large proportion of fish recaptured on the third pass that were marked on the second pass suggests little mixing between these two sampling events.

Catch Rates

Similarly, catch rates in 2003 were highest on the third pass, and may have been related to weather and water temperature at the time of sampling. Catch of humpback chub in trammel nets increased noticeably in the lower section on October 27 during the first net set following a storm event (Appendix II). Catch rates twenty-five miles upstream in the upper section were relatively high by October 24. Comparably high catch rates, presumably related to weather, were observed on November 3, 2003 in Westwater Canyon.

Water temperature during the third pass in 2003 may have contributed to higher catch rates as well. During the first two passes temperatures were recorded at 23^{o}C and 19^{o}C, by the third pass they had dropped to 11.5^{o}C. Changing environmental factors that affect flow, turbidity, and temperature influence the fish as well, and ultimately catch rates and population estimates. Estimating abundance by using the M_t model should aid in accounting for these factors.

Other Factors

The Rattle Complex fire burned more than 94,600 acres in the East Willow and Willow Creek drainage in the Book Cliffs in July 2002. This drainage flows into the Green River just downstream of the Duchesne River, and upstream of Deso/Gray. After heavy rain at the beginning of September, river rafters reported dead fish along the shoreline in Deso/Gray. Employees from our office responded by traveling to Nefertiti Rapid (RM 140) to examine dead fish. People reporting the fish kill indicated they had observed humpback chub, but biologists observed none. A similar fish kill was reported in August 1992 during low flows and after rainstorms occurred which were speculated to have washed debris into the river (UDWR, 1995). The author reported a decrease in catch rates between a July and September sampling trip, but noted that the decrease could not firmly be attributed to a fish kill since other decreases between the two sampling seasons were observed in 1985 and 1986, and their sample size in 1992 was small. Furthermore, it was stated that the potential for fish kills is likely present during low flow years, and that runoff after thunderstorms exacerbates stressful situations already present. In 2003, the year following the Rattle Complex fire, large-scale changes were not observed in the population of humpback chub.

Over the three year-study period, smallmouth bass catch increased in Deso/Gray. U.S. Fish and Wildlife Service-Vernal reported observing many more smallmouth bass in spring 2003 in Deso/Gray, during their data collection for Colorado pikeminnow population estimates, than in previous years. In 2003, forty-six smallmouth bass were collected during humpback chub population estimates, relative to 9 in 2001 and 13 in 2002. Predation from smallmouth bass on the adult population was not directly observed. Due to the size of individual smallmouth bass collected, it is likely that only young-of-year and juvenile humpback chub would be susceptible to predation. Effects of predation by smallmouth bass on the smaller year classes of humpback chub were not detectable by this study.

Canyon Coverage

Assuming that approximately ½ mile is sampled at each of the twelve sites, roughly 7% of Deso/Gray was sampled during 2001-2003. The 7% figure may be misleading suggesting that 100% of Deso/Gray can be sampled and that the entirety of the two canyons are desirable to humpback chub. Large portions of the two canyons include areas of low gradient slow runs, not typical of habitat in which humpback chub are generally captured. Furthermore, there are many portions of the river that are logistically inaccessible for a sampling crew. However, fish from the primary sampling sites may be moving out of these areas to the intervening reaches where they are not available for recapture. 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.

Before future population estimate sampling is conducted, the sampled sites should be re-examined, and possibly modified to include other sites that also contain suitable habitat. For example, humpback chub were collected at the Big Bend site (RM 153.5) yet their numbers tended to be low. Surprise Canyon (RM 176) was sampled prior to, but not during this project. It was not included originally since other sites were relatively close (within two river miles). Replacing the Big Bend site with the Surprise Canyon site may be warranted (Figure 1). However, the Surprise Canyon site may be difficult to sample during low flows.

A more precise estimate might be attained by including sites that are known to have higher numbers of humpback chub versus trying to spread the sites evenly among the canyons. Increased sampling in concentration sites may provide for a tighter estimate with good precision and increased probabilities of capture and recapture. In order to attain a more representative population estimate, it may be necessary to expand coverage of the canyon by increasing the number of sampling sites. This should increase the number of marked fish and increase recapture rates by decreasing the distance between sites. Adding more sites however is not guaranteed to provide the desired results and other possibilities should be explored. Investigations into the actual habitat use of humpback chub in Desolation/Gray Canyon may be warranted. Sampling sites in this canyon were chosen based on characteristics similar to those in other canyons such as Black Rocks, Westwater and Cataract. Desolation/Gray Canyon is comparatively different from these other canyons and habitat use by humpback chub may be different as well.

Juvenile Population Estimates

Juvenile population estimates from mark-recapture data were not attempted for the Deso/Gray humpback chub population since few of these individuals were collected and recaptured. To determine mean recruitment for juveniles into the adult population, we assumed that individuals from 200-220 mm are first year adults. The trends observed for first year adults are similar to those for the entire adult population. Gear types that more readily collect juvenile fish should be employed consistently (i.e., trammel nets with ½"and ¾" inner mesh, hoop nets, and electrofishing) in order to generate population estimates of fish less than 200 mm.

Catch Rate Comparison with ISMP

Long-term trend data show variable catch rates since 1985. Chart and Lentch (2000) speculated that the low flow period of 1988-1992 was a likely cause of the low catch rate observed from 1993 to 1996. Catch rate in 1997 was the second highest of those from 1985 to 2003. Examinations of length frequency in 1995 show high numbers of fish 100-200 mm, which may have successfully recruited to the adult population by 1997 to account for the high numbers. Based on the speculation that recruitment and subsequently high catch rates followed high flow years, catch rate from 2000 to 2003 should have been higher. Catch rate in 2000 was relatively high but dropped in the 2001-2003 period. If recruitment of juvenile fish occurred in 1996, 1998, and 1999, during moderate-high flow, a higher catch rate would be expected from 2000 to 2003. Therefore, lower catch rates from 2001 to 2003 are not well explained by the previous data. The 2001-2003 catch rates do fall within the range of the pre-study catch rates. Multiple samples within a given year (i.e. 2001-2003) provide a more accurate picture of the existing population. Chart and Lentch (2000) recognized the limitation of single pass sampling in determining recruitment and catch efficiency, and believed that sampling flow confounded their results. Furthermore, variability in sampling effort (i.e. number of nets set at a site, length of nets used, amount of time nets were fished) complicates comparisons between pre-study and study data to some extent. Data used prior to this study is often representative of one sampling pass (1985, 1986, 1992 show data collected from more than one pass in the same season). All other years are one pass conducted in summer months of June or July, while our data consists of two to three passes within two months.

During the 2001-2003 period of this study, catch rate varied significantly between sampling passes conducted one week apart, in some cases. This data illustrates the importance of sampling season and conducting several passes, especially when considering trends over time. In the years of the highest and lowest catch rate, 1989 and 1996 respectively, only one sampling pass was made during the summer. During this study (2001-2003), sampling was conducted during June and July in 2001 and 2002. In 2003, sampling was conducted during September and October. All pre-study sampling, (i.e. 1985-2000) was conducted in the months of June and July except for the 1992 sampling period conducted in July and September, and the 1993 sampling period conducted in late August. As illustrated in the long-term trend chart, the only year with a lower catch rate than 1992 and 1993, was 1996, in which high flows (12,300 cfs) were likely causative.

Chart and Lentch (2000) reported the highest catch rate during the lowest flows in 1989 (trip mean flow of 1380 cfs). The highest mean flow occurred during sampling in 1985 at 18,400 cfs. Catch rate at that time was similar to those in the 2001-2003 period. They surmised that the best sampling flow was between 7,000-8,000 cfs. During this study, the majority of sampling flows were well below the formerly perceived optimal value. Flows from 2001 to 2003 were the lowest in 100 years of record. Mean monthly flows from 1894-2003 were 7,831 cfs for July, 3,640 cfs for August, 2,814 cfs for September, and 3,018 cfs for October. At the time of sampling from 2001-2003, flows were roughly half of the annual monthly means. Low flows in Deso/Gray reduce the frequency of habitat typically preferred by humpback chub (i.e., deep eddies), and the majority of habitats become shallower and pools are created in place of many eddies.

Population Estimate and ISMP Comparison

Catch rates of humpback chub appeared to be related to population estimates generated within the study period. The relationship within the study period is probably more closely related since at least two passes were conducted. Objective 2 of this project is to determine the relationship between ISMP data and population estimates. However, linking population estimates to pre-study ISMP data may be problematic since only one sampling pass was required for ISMP. Catch rate data among trips was shown to be highly variable between 2001 and 2003. Therefore, one sample in time may not provide an accurate picture of the population within a given year.

Length-Frequency

Length frequency histograms of humpback chub in Deso/Gray illustrate a unimodal distribution during 2001. In 2002, juveniles are present. In 2003, the histogram shifts back to a unimodal distribution. Sampling during the 2001-2003 period was conducted to target adult fish. In 2002 and 2003, electrofishing and hoop net effort increased; yet the primary collection method was by trammel net with a 1” inner mesh. This size of trammel net tends to catch fish greater than 200 mm. It is likely, due to gear types and effort expended, that smaller humpback chub are not fully represented in each year.

By-Catch of Colorado pikeminnow

Even though sampling was moved to the fall in 2003, Colorado pikeminnow were still caught in trammel nets. Colorado pikeminnow captured during the fall tended to be smaller than those caught in the summer and in most cases were successfully resuscitated after moving fish back and forth in fresh water for up to 30 minutes. Since many of these Colorado pikeminnow were small, some experienced significant opercle damage after they were gilled in the inner mesh of the trammel net. Some humpback chub experienced similar stress and opercle damage, but most were successfully resuscitated. Successful resuscitation of fish may have been achieved due to lower ambient and water temperatures during this time of year.

Identification of *Gila* spp.

Identifications of chub in Deso/Gray were conducted using a collection of diagnostic characters. In the past, researchers have expressed difficulty in identifying chub from this canyon (Holden and Stalnaker 1970, Chart and Lentch 2000). McElroy and Douglas (1995) stated that humpback chub collected in Deso/Gray were more robusta-like, and that sympatric humpback chub and roundtail chub in Deso/Gray were more similar to each other than allopatric conspecifics.

Some identifications of recaptured chub varied within the study period. In most cases individual identifications were first identified as chub and upon recapture were identified as humpback chub. Any fish that were identified at some point in their capture history, over the study period, as humpback chub were considered humpback chub and included in the population estimate. In 2001, chub were identified using a combination of qualitative diagnostic characters including the degree of frontal depression, presence of scales on nuchal hump, angle of the anal fin relative to caudle peduncle, as described in Douglas et al., 1989 and 1998. In December 2001, one of the recommendations that evolved from the Population Estimate Workshop held in Fort Collins, CO, was to include key meristic and/or morphometric measurements described in Douglas et al. 1998, to aid in the identification of chub to species. In 2002, during the Deso/Gray population estimates, morphometric measurements were taken to distinguish between humpback chub and roundtail chub. It was subsequently discovered that a discriminate function had not yet been developed for distinguishing between these two species. The discriminate function that is available distinguishes among humpback chub, roundtail chub, and bonytail. In order to employ this discriminate function, other measurements were required. Unfortunately those measurements had not been collected. From this information, to further insure correct identifications of chub in Deso/Gray, either a discriminate function should be developed to distinguish between humpback chub and roundtail chub, or all measurements should be taken to distinguish between the humpback chub, roundtail chub and bonytail. The latter may be the most appropriate course of action, given that bonytail are being stocked upstream of Deso/Gray and are likely to be found in this canyon in the future.

Douglas et al. (2001), recommended geometric morphometrics over qualitative evaluation and stated that the application of geometric morphometrics provides classificatory cues at a broader and more visual level than does a qualitative evaluation described in Douglas et al. (1989). They recommended the use of this technique to quantify and visualize morphological differences among populations and species. Furthermore, they concluded that even though morphological analyses can designate individuals to species or groups, these techniques cannot unambiguously ascertain the degree of introgression exhibited by individuals or populations or even if hybridization has occurred. Only genetic analyses will unambiguously answer questions about morphological intermediacy of populations and species.

CONCLUSIONS

- Population estimates generated during the study period illustrate a limited amount of precision even though a significant amount of effort was expended. Due to the large area of Deso/Gray canyon, our effectiveness in sampling the population may be limited because of our inability to sample adequately enough in between the primary sites.

- Population estimates generated from 2001-2003 should be considered preliminary since estimates were not conducted during the same season for each year. The next period of population estimates conducted in the fall will help to determine the validity of the 2001-2003 estimates.

- Factors other than sampling season may have contributed to the difference in the estimate for humpback chub in Deso/Gray during 2003 including the Rattle Complex Fire and subsequent fish kill in 2002. The increase in numbers of smallmouth bass was a concurrent observation, however it is not likely that an effect from these fish would have been detectable during the study period.

- Juvenile humpback chub population estimates were not generated do to the low numbers of this size class collected. Attempts at capturing smaller fish were made in 2002 and 2003 with the addition of hoop netting and the expansion of electrofishing.

- Catch rates during the study period compared with previous catch rates were roughly similar. Analysis of long-term trends illustrated extremely variable CPUE with a slightly decreasing trend line, however it did not significantly depart from zero. When the extremely high data point from 1989 was removed, the trend line remained fairly level with a slightly increasing slope, but still did not significantly depart from zero.

- Colorado pikeminnow continued to be captured in trammel nets after sampling was moved to the fall in 2003. Colorado pikeminnow captured in the fall tended to be smaller than those captured in the summer and appeared to recover more quickly.

RECOMMENDATIONS

- Population estimate sampling should continue to be conducted in the fall in Deso/Gray. Lower temperatures in the fall seem to decrease stress to Colorado pikeminnow and humpback chub. However, if fish are not mixing adequately, especially during low water, estimates may be more precise yet biased low.

- Electrofishing and sampling with hoop nets and minnow traps should continue during future population estimates to capture juvenile humpback chub. A combination of ½" and 1" inner mesh trammel nets should be used to increase juvenile catch as well. However, sampling methods should remain relatively consistent in order to keep the 2001-2003 somewhat comparable to the 2006-2008 data. The amount of effort expended in 2006-2008 should be as consistent as possible between passes within a year.

- Electrofishing should be conducted during the evening crepuscular when fish are most active to increase numbers of captures and recaptures.

- Since environmental conditions such as temperature, turbidity, and storm events appear to affect catch rates, conducting at least three passes is recommended. Extreme high or low CPUE may be more accurately interpreted with several data points.

- Current sampling locations for humpback chub collected in Deso/Gray should be re-examined. Substituting the Surprise Canyon site for the Big Bend is recommended. Other substitutions may be warranted as well. Adding more sites may result in capturing individuals that may be moving into unsampled reaches, and may ultimately increase recapture rates and improve estimates.

- Due to the ambiguity of chub characteristics in Deso/Gray it is recommended that the entire suite of morphometric measurements provided in Douglas et al. (1998) be taken, perhaps on a percentage of fish to verify ratios. In order to prevent handling stress induced by intense morphological measurements, we alternately recommend digitally photographing questionable *Gila spp*. on a grid background for later evaluation.

- A fin clip taken from all *Gila* spp. collected will provide for further verification of species identifications and the degree of intermediacy present within species.

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Table 1. Population estimate (N) for adult humpback chub ($\geq$ 200 mm) in Deso/Gray Canyon 2001-2003. Population estimates generated within program CAPTURE. The profile likelihood interval, coefficient of variation (CV), and probability of capture (p-hat) are included with the respective population estimates.

Year	N	Confidence Interval	CV	p-hat
2001	1,254	733-2,697	0.31	0.053
2002	2,612	1,477-8,509	0.36	0.045
2003	937	636-1,520	0.21	0.083

Table 2. Population estimate (N) of first year adult humpback chub (200-220 mm) in Deso/Gray Canyon 2001-2003, with respective 95% confidence interval.

Year	N	95% Confidence Interval
2001	163	149-192
2002	297	275-343
2003	134	123-159

Table 3. Summary of hours spent for each gear type, total number humpback chub collected, and percent of recaptured individuals during humpback chub population sampling in Deso/Gray Canyon 2001-2003.

Year	Trammel Net Hours	Total HBC	Electrofishing Hours	Total HBC	Hoop Net and Minnow Trap Hours	Total HBC	Percent Recaptures
2001	2,803	214	8	3	0	0	3
2002	2,008	239	22.5	38	1,440	7	2
2003	3,042	236	11	1	1,946	5	6

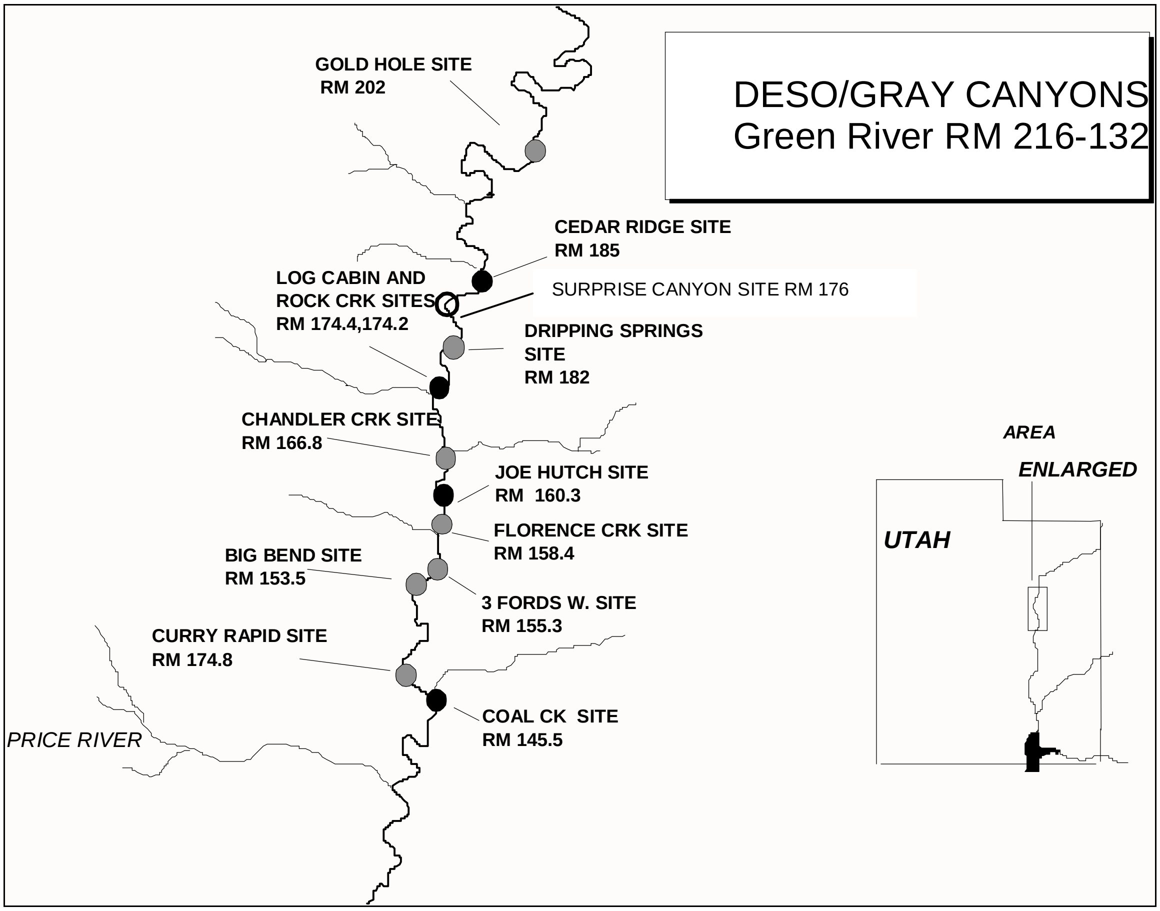

Figure 1. Twelve sample sites located within Desolation/Gray Canyon. Black circles represent long-term monitoring sites. Open circle represents proposed site at Surprise Canyon.

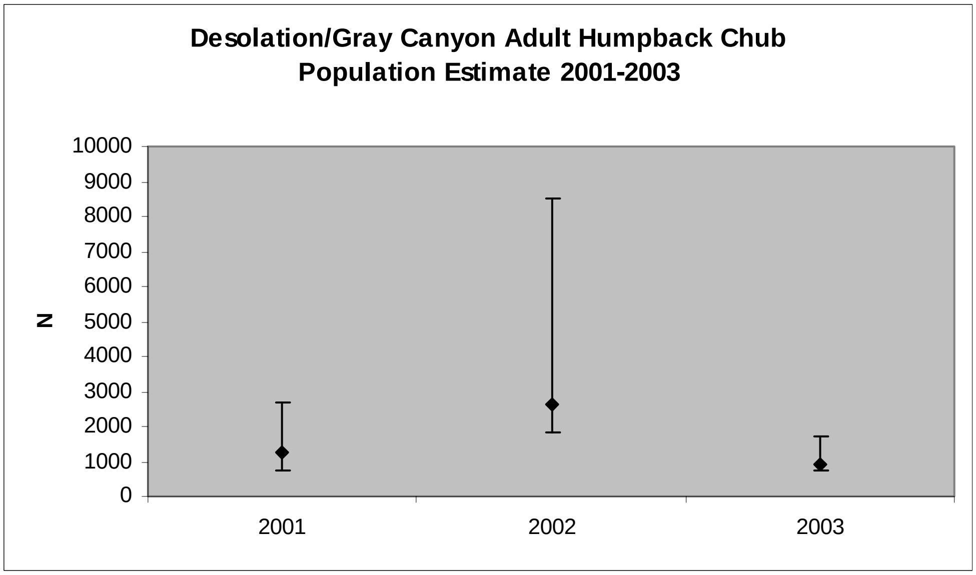

Figure 2. Desolation/Gray Canyon adult humpback chub population estimate (N) for 2001-2003. Each point estimate includes respective profile likelihood intervals.

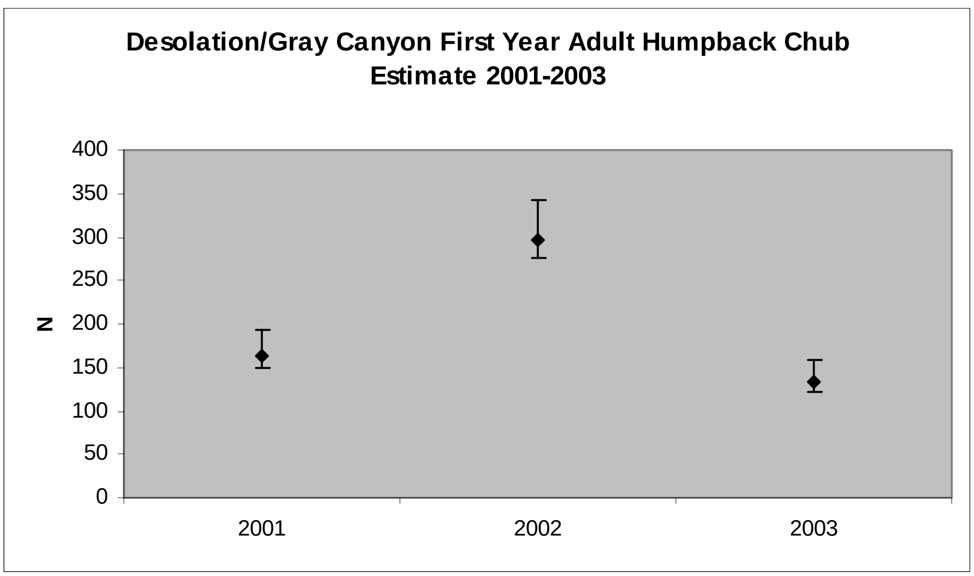

Figure 3. Desolation/Gray Canyon first year adult humpback chub estimate (N) for 2001-2003. Each point estimate includes respective 95% confidence intervals.

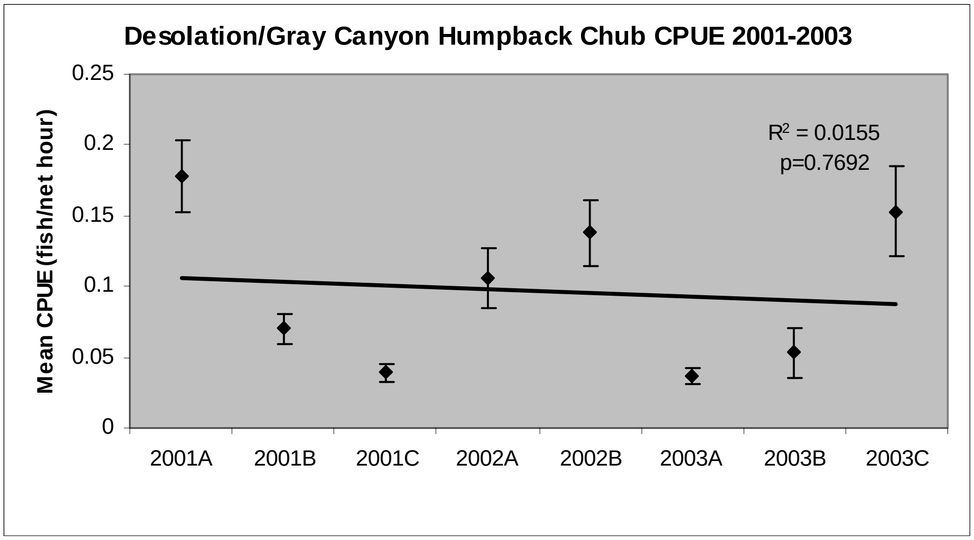

Figure 4. Desolation/Gray Canyon humpback chub trammel net catch rate (CPUE) by pass for 2001-2003. Catch rate for each pass includes respective standard error. Line represents the trend among all passes in all years. P-value indicates statistical significance of the trend line.

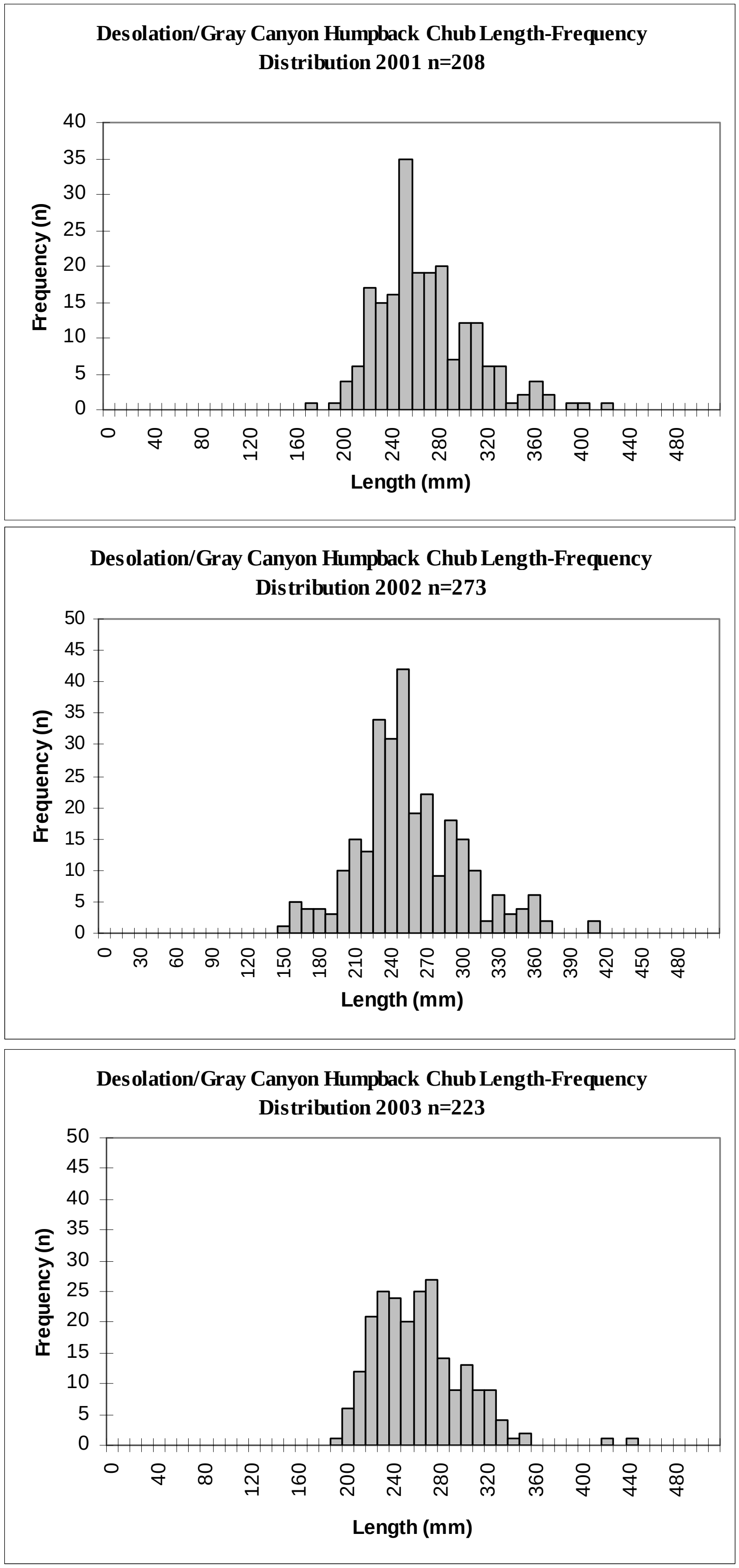

Figure 5. Desolation/Gray Canyon humpback chub length-frequency histograms for 2001-2003. Individuals greater than 150 mm TL only are included. Frequency is illustrated as the number of total individuals within a given size class.

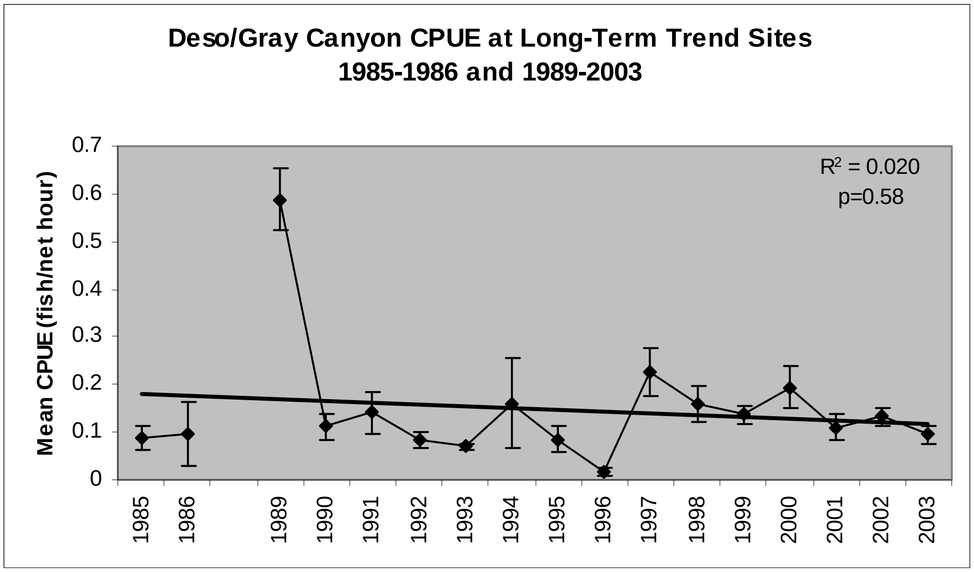

Figure 6. Mean CPUE of *Gila* spp. at the four long-term trend sites in Desolation/Gray Canyon from 1985 to 1986 and 1989 to 2003. Error bars represent standard error. Line represents the trend among all years. P-value indicates statistical significance of the trend line.

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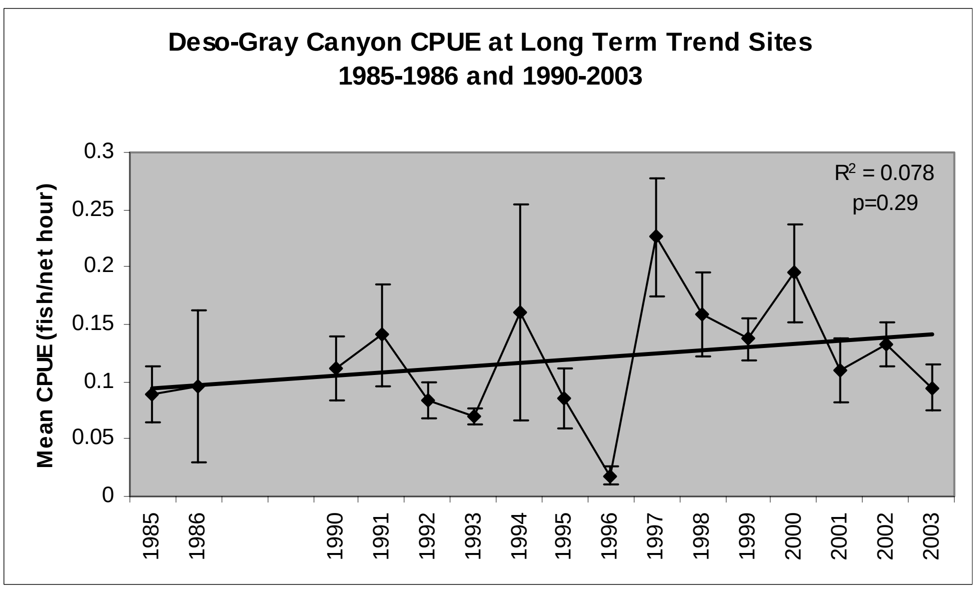

Figure 7. Mean CPUE of *Gila* spp. at the four long-term trend sites in Desolation/Gray Canyon from 1985 to1986 and 1990 to 2003. Data point from 1989 has been treated as an outlier and deleted. Error bars represent standard error. Line represents the trend among all years. P-value indicates statistical significance of the trend line.

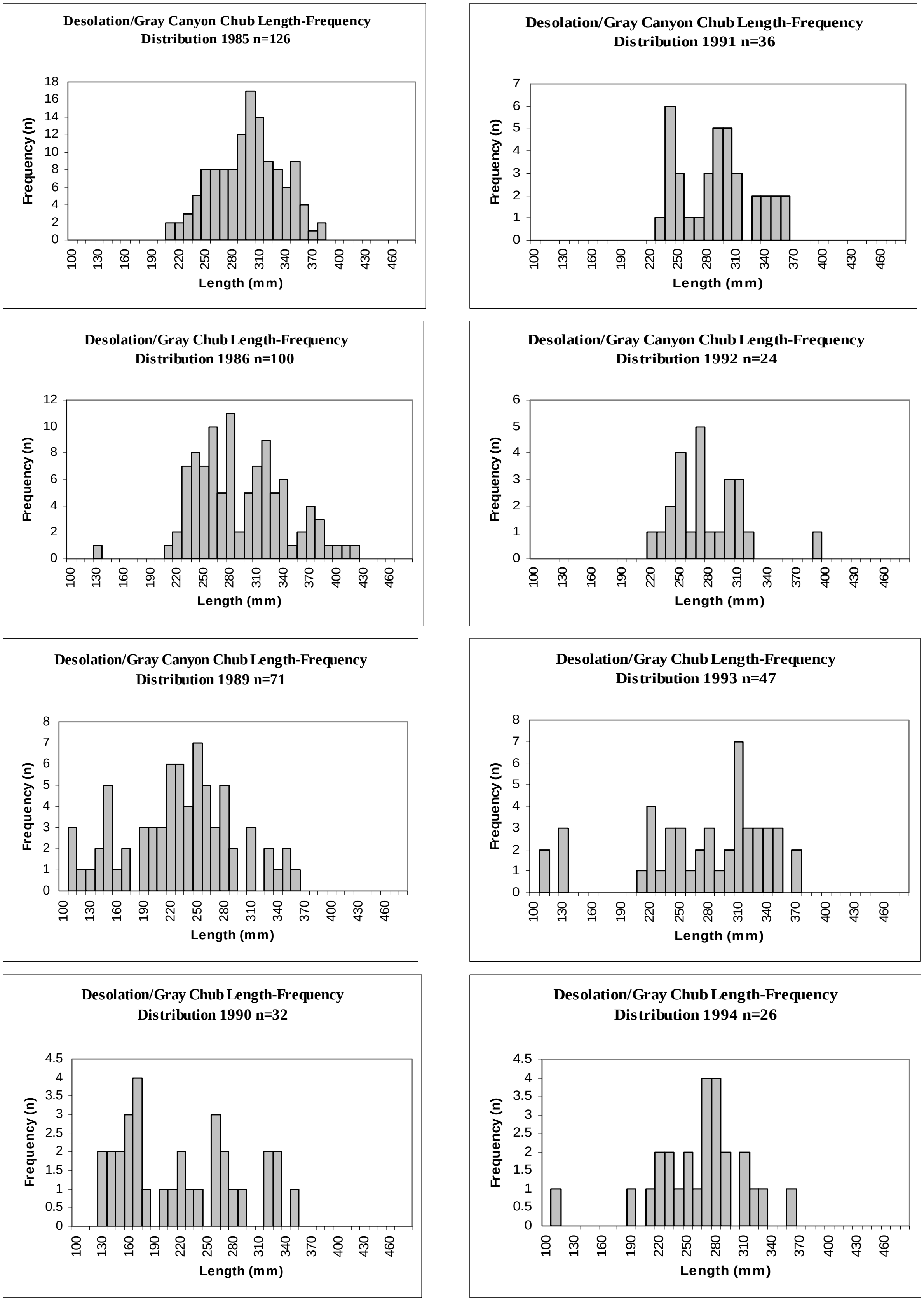

Figure 8. Desolation/Gray Canyon *Gila* spp. long-term length-frequency histograms for 1985, 1986, and 1989-2003. Frequency is illustrated as percentage of total individuals (n) within a given size class.

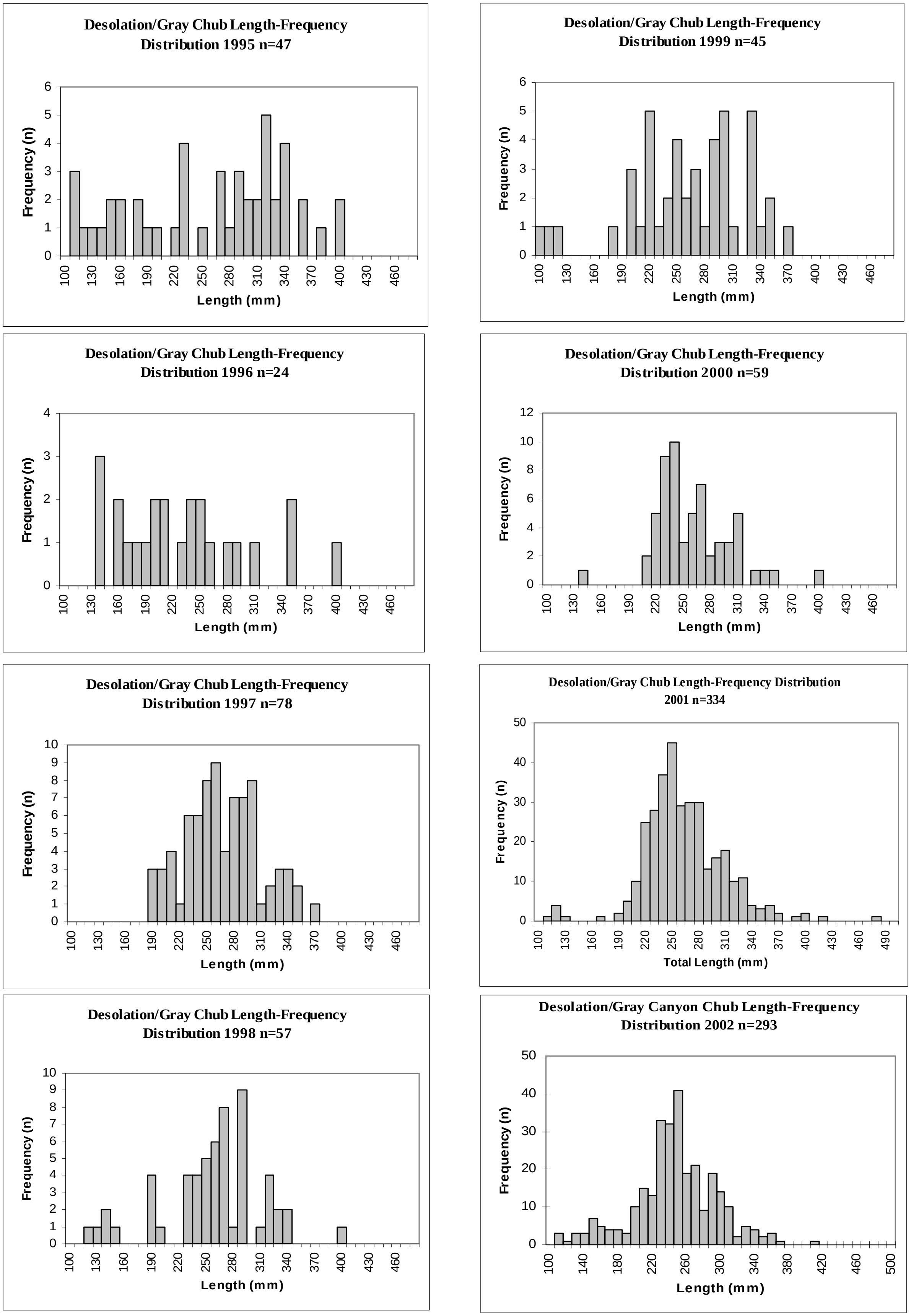

Figure 8. (*continued*) Desolation/Gray Canyon *Gila* spp.long-term length-frequency histograms for 1985, 1986, and1989-2003. Frequency is illustrated as percentage of total individuals (n) within a given size class.

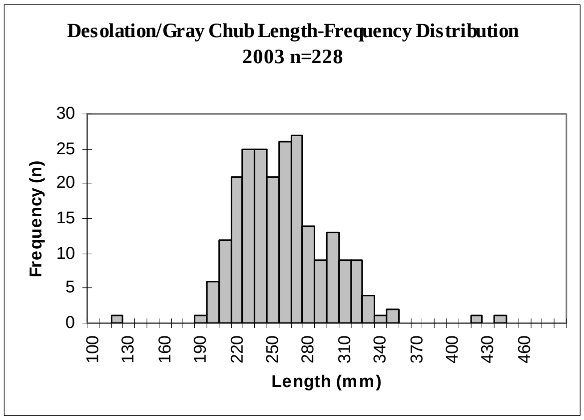

Figure 8. (*continued*) Desolation/Gray Canyon *Gila* spp. long-term length-frequency histograms for 1985, 1986, and 1989-2003. Frequency is illustrated as percentage of total individuals (n) within a given size class.

Appendix I. Summary of population estimates generated within Program CAPTURE for adult humpback chub in Deso/Gray Canyon, 2001–2003. Information for comparison within each year of the study among estimators considered includes the abundance estimate, 95% confidence intervals, coefficient of variation (CV), probability of capture (p-hat). *Values in parentheses are profile likelihood intervals for each point estimate.

Year	*Estimator*	*N*	*95% Confidence Interval**	*CV*	*p-hat*
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
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
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

Appendix II. CPUE of HBC at 12 sites by net set in Deso/Gray canyon during the third pass in 2003. Top table represents the six upstream sites and the bottom table represents the downstream sites. Both sections were sampled simultaneously as reflected by date.

	RM 202	RM 185	RM 182	RM 174.4	RM 174.2	RM 166.8
Date	10/22	10/23	10/24	10/25	10/26	10/27
Set time						
1400	-	-	-	-	-	0.09
1600	0.15	0.07	0.79	0.23	0.36	0.29
1800	0	0.14	0.67	0.14	0.23	0.39
2000	0	0.25	0.16	0.29	0.14	-
600	0	0	0.13	0.46	0.23	-
800	0	0.08	0.19	0.23	0.14	0.47
1000	-	-	-	-	-	-

	RM 160.3	RM 158.4	RM 155.3	RM 153.3	RM 147.8	RM 145.5
Date	10/23	10/24	10/25	10/26	10/27	10/28
Set time						
1500	-	0	0.12	0	0.31	0.82
1700	0.27	0.19	0.07	0.12	0.12	0.26
1900	0.13	0.12	0	0.07	0.12	0.27
2100	0.08	0	0.06	0	0	0
600	0.07	0.20	0	0.07	0.21	0.38
800	0	0	0.13	0.06	0.12	0.09
1000	0	0	0	0	0.13	-