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Division of Wildlife Resources – Native Aquatics

POPULATION ESTIMATES FOR HUMPBACK CHUB (*GILA CYPHA*) AND ROUNDTAIL CHUB (*GILA ROBUSTA*) IN WESTWATER CANYON, COLORADO RIVER, UTAH, 1998–2000

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Utah Division of Wildlife Resources
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Population Estimates for Humpback Chub (*Gila cypha*) and Roundtail Chub (*Gila robusta*) in Westwater Canyon, Colorado River, Utah, 1998–2000

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humpback chub, *Gila cypha*, roundtail chub, *Gila robusta*, Westwater Canyon, Colorado River, population estimate, growth, movement

EXECUTIVE SUMMARY

Humpback chub (*Gila cypha*) are listed under the Endangered Species Act of 1973, as amended. In accordance with recovery goals finalized in 2002, a population estimate was completed for adult humpback chub in Westwater Canyon on the Colorado River. This population estimate was conducted from 1998 to 2000 with the objectives of obtaining population estimates for humpback chub and roundtail chub in Westwater Canyon. Sampling occurred during September and October throughout the three years of the study. Three passes were conducted annually with approximately one week between passes. The primary method of capture was via trammel netting with supplemental electrofishing on one pass per year. Population estimates were generated from recapture data using the null estimator (M_o) within Program CAPTURE. Separate estimates were generated for each year of the study. Results indicated a decline in the adult humpback chub population between 1998-1999 with a retention in abundance between 1999-2000: 4,744 in 1998; 2,215 in 1999; and 2,201 in 2000. This overall declining trend was not statistically significant, but may be of concern. The adult roundtail chub population in Westwater Canyon during this time period was relatively stable: 5,005 in 1998; 4,234 in 1999; and 4,971 in 2000. Length-frequency analysis for both species indicated shifts in the size class structure through the three years. Growth of humpback chub was slower than roundtail chub based on recapture data from this and previous studies. Analysis of recaptures indicated more net movement from humpback chub than from roundtail chub. However, both species exhibited movement between Black Rocks and Westwater Canyon. This movement was frequent enough to consider Black Rocks and Westwater Canyon a single population for humpback chub and roundtail chub. Analysis of catch per unit effort (CPUE) data from this study and historic interagency standardized monitoring indicated a continued declining trend in mean CPUE for humpback chub that was significant. Mean CPUE for roundtail chub also indicated a continued declining trend, but it was not statistically significant. The results of this study will provide valuable information for conducting future population estimates of chub in the upper Colorado River basin in addition to providing three point estimates that will be used to determine if humpback chub have met the recovery goals.

INTRODUCTION

The humpback chub (*Gila cypha*) was first described in 1945 (Miller 1946). Due to declines in distribution and abundance throughout its range, the humpback chub is currently protected under the Endangered Species Act of 1973, as amended (ESA, 16 U.S.C. 1531 *et. seq*.). Previously, it was protected under the Endangered Species Conservation Act of 1969 (16 U.S.C. 668aa). The most recent recovery plan was finalized in 1990 (USFWS 1990), with an amendment and supplement to that plan approved in 2002 (USFWS 2002). The amendment and supplement to the 1990 recovery plan identifies objective, measurable recovery criteria to downlist and delist humpback chub in both the upper basin recovery unit and the lower basin recovery unit. Within the upper basin recovery unit, one of the criteria to downlist humpback chub is the maintenance of one of the five upper basin populations (Black Rocks, Westwater Canyon, Cataract Canyon, Yampa Canyon, Desolation/Gray Canyon) as a core population with a minimum viable population of 2,100 adults (≥ 200 mm) for five consecutive years. To delist humpback chub, the upper basin recovery unit will have to maintain this minimum viable population for an additional three years in two of the five upper basin humpback chub populations. The adult humpback chub population will be determined via point estimates in 2–3 of every five years to measure progress toward achieving and maintaining the minimum viable population. Within each core population, there must not be a significant decline of the trend in adult point estimates to downlist and delist humpback chub.

The Westwater Canyon adult humpback chub population estimate, along with the Black Rocks humpback chub population estimate, is one of the first upper basin population estimates to be conducted in accordance with these recovery goals. This study was conducted from 1998 to 2000 with the objective of obtaining a population estimate of adult humpback chub in Westwater Canyon. A secondary objective was to obtain a population estimate for roundtail chub (*Gila robusta*) in Westwater Canyon. Previous efforts (e.g., Chart and Lentsch 1999) to estimate the adult humpback chub population in this canyon had been relatively unsuccessful due to a sampling approach that was not designed to obtain a population estimate. Recommendations from that report included the need to initiate a specific study to generate population estimates in Westwater Canyon with a more aggressive sampling program and a more rigid study design.

The result was the current study design. This study was initiated with the understanding that modifications would be made to the approach as more information was gained toward obtaining the most accurate and precise population estimate for adult humpback chub in Westwater Canyon. The results of this study will provide valuable information for conducting future population estimates of chub in the upper Colorado River basin in addition to providing three point estimates that will aid in reclassification of humpback chub under ESA (i.e., downlist, delist).

The objectives of this study are:

- To obtain a population estimate of adult humpback chub (≥ 200 mm) in Westwater Canyon.
- To obtain a population estimate of adult roundtail chub (≥ 200 mm) in Westwater Canyon.

These objectives are specific to Task 4 of the Upper Colorado River Endangered Fish Recovery Program Project 22c – Interagency Standardized Monitoring Program – Utah. This task was added to a much larger ongoing project encompassing the entire Colorado River basin in Utah that included many additional objectives. These additional objectives are not addressed in this report.

METHODS

Study Area

Westwater Canyon is located on the Colorado River downstream of the CO-UT border. The length of the canyon extends approximately twelve miles (RM 124.5–112.5). It is characterized by the black Proterozoic gneiss and granite complex that comprise the inner gorge. The habitat in the upper section of the canyon consists of runs, eddies, and pools interspersed between riffles and rapids. The steepest part of Westwater Canyon is the middle section (RM 119.5–116.5). This portion of the canyon was not sampled due to the turbulent flows and Class III rapids. However, U.S. Fish and Wildlife Service sampled the middle section of Westwater Canyon during 1979-1981 and humpback chub were present (Valdez et al. 1982). The lower section of Westwater Canyon is a confined canyon reach with a reduced gradient that primarily comprises a homogeneous run where chubs are scarce (Chart and Lentsch 1999).

Humpback chub sampling occurred at three sites in the upper portion of Westwater Canyon previously established for the Interagency Standardized Monitoring Program (ISMP): Miners Cabin (RM 124.1–123.8), Cougar Bar (RM 121.5–121.0), and Hades Bar (RM 120.0–119.8). Depth measurements collected in 1994 for each of these sites resulted in maximum depths of 21.8 m at Miners Cabin, 19.5 m at Cougar Bar, and 10.6 m at Hades Bar (Chart and Lentsch 1999). Each of these deep canyon habitats is bounded by a riffle area.

Sampling

Humpback chub sampling in Westwater Canyon occurred during September and October throughout the three years of the study. Three sampling passes were conducted each year. Eight days lapsed between the end of one pass and the beginning of the subsequent pass. During each pass, Miners Cabin was sampled for two nights, Cougar Bar was sampled for two nights and Hades Bar was sampled for one night. Gear included the use of trammel nets (23 m x 2 m; 2.5 cm and 1.25 cm mesh) and a pulsed DC Coffelt® electrofishing unit mounted on an inflatable sport boat.

Trammel nets were set in mid-afternoon and checked every two hours until midnight, at which time they were pulled. Nets were reset before dawn and allowed to fish until late morning while being checked every two hours. Trammel nets were set to target juvenile and adult chubs. Trammel nets were primarily set in deep eddies off boulders or rock faces. Nets were occasionally set in relatively shallow riffle/run areas off in-channel boulders. All *Gila* spp. caught were removed from the net and placed in a holding pen until they were processed at the end of each 18-hour sampling period.

Electrofishing was conducted at each site during a single pass each year to continue the protocol established with ISMP (USFWS 1987). Shoreline habitats were electrofished within each site. Electrofishing efforts occurred prior to nets being set in late afternoon and subsequent to nets being pulled at night during each 18-hour sampling period. Electrofishing was conducted to monitor the fish community of Westwater Canyon and to target smaller *Gila* spp. in addition to the late juvenile/adult component of the population. Electrofishing data was specifically used for initial captures in the population estimate, length-frequency analysis and determining movement of *Gila* in Westwater Canyon.

Gila were identified to species using a suite of diagnostic characters (i.e., degree of frontal depression, presence of scales on nuchal hump, "angle of the dangle", etc.) in conjunction with the "art of seeing well" (Douglas et al. 1998). Information collected from all *Gila* spp. captures included total length (mm), weight (g), sex (mature chubs; 1998 and 2000), and dorsal and anal fin ray counts. In addition, PIT tag numbers were recorded from recaptured chubs. 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 length (mm), weight (g), and PIT tag number.

Data Analysis

Population Estimate

Population estimates were determined for adult humpback chub and roundtail chub (>200 mm) in Westwater Canyon 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 help determine the most appropriate estimator but population estimates were routinely calculated using several estimators (Appendices I–II): M_o (null estimator), Jackknife M_h, Darroch M_t, Chao M_{th}, Chao M_t, and Chao M_h. A separate adult population estimate was calculated for each species in each year. Program CAPTURE was used to determine confidence intervals around the estimate, the coeffiecient of variation, and the probability of capture. Linear regression analyses were conducted on the resulting population estimates for the respective species to examine short-term trends in the populations throughout the period of this study.

Confidence intervals were determined for all estimators. Profile likelihood intervals are provided in lieu of 95% confidence intervals for M_o (null estimator) and the Darroch M_t. The profile likelihood interval helps to account for model selection uncertainty by providing wider confidence intervals (Appendix I; David R. Anderson and Gary C. White, Colorado State University, Ft. Collins, Colorado *personal communication*). In addition, these intervals tend to give more correct confidence intervals for small samples (Ross Moore, Mathematics Department, Macquarie University, Sydney, Australia *personal communication*). All confidence intervals are provided for comparison among all estimators used to calculate population estimates in Westwater Canyon (Appendices I–II).

CPUE

Catch per unit effort (CPUE) was determined for trammel net effort toward the capture of humpback chub and roundtail chub through the period of this study. CPUE was compared between passes within and among years using the Kruskal-Wallis nonparametric ANOVA with Dunn's multiple comparisons test to examine the equality of samples and the two-sample Kolmogorov-Smirnov to compare the distribution of catch rates. In addition, total annual CPUE comparisons were tested between years using the same analyses. Data collected from electrofishing effort was not analyzed separately due to a limited amount of information to analyze.

Length-Frequency

Length-frequency distributions were determined for humpback chub and roundtail chub through the period of the study.

Growth

Mean annual growth rates were determined from one year of growth on recaptured humpback chub and roundtail chub from 1992–2000 and compared with respect to the length-frequency distributions determined each year of the study. Mean annual growth rates were also estimated and compared among annual recaptured individuals from 1999 and 2000, and all recaptured individuals from 1992-2000.

Movement

Movement of individuals was also described within Westwater Canyon and between Westwater Canyon and Black Rocks (Chuck McAda, USFWS, Grand Junction, Colorado *personal communication*).

Comparison with ISMP

Interagency standardized monitoring program (ISMP) protocol was followed within one pass during each year of this study to allow comparison with historic humpback chub and roundtail chub CPUE information. CPUE was compared between years (1988–2000) using the Kruskal-Wallis nonparametric ANOVA with Dunn's multiple comparisons test to examine the equality of samples and the two-sample Kolmogorov-Smirnov to compare the distribution of catch rates.

RESULTS

Humpback Chub

Population Estimates

The model selection function of Program CAPTURE resulted in variability among years in determination of the most appropriate estimator for the humpback chub capture-recapture data (Appendix I). The null estimator (M_o) ranked highest in 1998 and 2000 (1.00 and 0.74, respectively). There was no appropriate estimator for the data from 1999. In that year, the highest ranking of the estimator routinely used to calculate population estimates in this study was 0.36 (Chao M_{th}). Considering the results of the model selection function, the lack of any real justification to consider another estimator (i.e., changes in the probability of capturing an individual due to behavior, flow, etc.), and the outcome of consultation with Dr. Ron Ryel (Utah State University, Logan, Utah), the null estimator (M_o) was used to determine the population estimates of adult humpback chub in Westwater Canyon, 1998–2000.

The adult humpback chub population estimate was 4,744 individuals in 1998 (Table 1). The profile likelihood interval around this estimate was 3,760 – 14,665 (CV = 0.23; p-hat = 0.035). In 1999, the adult humpback chub population estimate decreased to 2,215 individuals (Table 1). The profile likelihood interval around this estimate was 1,608 – 7,508 (CV = 0.28) with a slightly higher probability of capture (p-hat = 0.041). The adult humpback chub population estimate in 2000 remained approximately the same at 2,201 individuals (Table 1). The probability of capture also remained the same (p-hat = 0.041). However, the profile likelihood interval was tighter (1,335 – 4,124; CV = 0.28).

The relationship among these three estimates indicates a short-term decreasing trend in the Westwater Canyon adult humpback chub population (Figure 1). However, the slope of this short-term trend does not significantly depart from zero and each point estimate exceeded the minimum viable population identified in the recovery goals (USFWS 2002).

CPUE

Total trammel net captures for humpback chub were 501 in 1998, 278 in 1999, and 277 in 2000 (Table 2). Total captures in 1998 included 486 adults, 12 of which were recaptured. An additional three subadult humpback chub were captured in trammel nets. In 1999, 267 adults were included in the total captures. Eight of these individuals were recaptured. Subadult captures in the trammel nets were once again three individuals. The total captures for 2000 included 261 adult humpback chub. Eleven of these were recaptured. Subadult captures included in total trammel net captures for 2000 were slightly increased at five individuals.

Mean catch per unit effort (CPUE) decreased across all passes from 1998 to 2000 (Figure 2). The slope of this decreasing trend significantly departs from zero ($p < 0.05$). The Kruskal-Wallis test indicated there were no significant differences between passes within years, but there were significant differences ($p < 0.05$) between passes among years. The Kolmogorov-Smirnov test indicated there were no significant differences in the distribution of catch rates between passes within 1998 and 1999. However, there were significant differences ($p < 0.05$) between passes within 2000 and among years. Comparisons of mean CPUE and the distribution of catch rates between years (all passes combined) indicated significant differences ($p < 0.05$) between all years.

Length-Frequency

The length-frequency histograms for Westwater Canyon humpback chub indicated similar bimodal distributions for 1998 and 1999, with a majority of fish in the 240–280 mm and 310–350 mm size classes (Figure 3). In 2000, this distribution became trimodal, with the size classes being 230–260 mm, 280–310 mm, and 340–360 mm. The largest humpback chub caught in each year was 380 mm in 1998, 390 mm in 1999, and 410 mm in 2000 (Figure 3).

Growth

Mean annual growth rates of Westwater Canyon humpback chub (1992-2000) were compared with respect to the bimodal and trimodal distributions of size classes determined from the length-frequency histograms. Mean annual growth rates were 10.58 ± 1.92 mm for humpback chub less than 285 mm and 5.84 ± 1.87 mm for humpback chub greater than 285 mm. Humpback chub mean annual growth was 10.15 ± 2.94 mm for individuals less than 260 mm, 7.70 ± 1.90 mm for individuals between 260 mm and 320 mm, and 6.14 ± 3.11 mm for individuals greater than 320. Analysis of the larger data sets from recaptures in 1999 and 2000 indicate a high degree of variability in growth rates within size classes between years relative to growth rates from all recaptured individuals between 1992-2000 (Figure 4).

Movement

Movement of humpback chub determined from long-term recaptures (individuals tagged in previous years) varied from 1998 to 2000. However, through the entire study, 80% of recaptures exhibited no net movement. There were 37 long-term recaptures of humpback chub in 1998. These individuals had been tagged in the period 1–6 years prior to 1998. Of the 37 recaptures, 17 (45.9%) were recaptured in the same location, 17 had moved from Cougar Bar (RM 121.5) to Miners Cabin (RM 124.1), and three had moved from Hades Bar (RM 120) to Miners Cabin. Only three of these humpback chub had been captured in 1997. One additional humpback chub was tagged in Black Rocks (RM 136) in August 1998 and recaptured at Miners Cabin in October of the same year. In 1999, there were 44 long-term recaptures of humpback chub that had been initially captured in the previous 1–8 years. Of those, 39 (88.6%) were recaptured in the same location, two had moved from Hades Bar to Cougar Bar, one had moved from Cougar Bar to Hades Bar, one had moved from Miners Cabin to Cougar bar, and one was recaptured in October at Miners Cabin that had moved from Black Rocks, where it had been tagged in September 1998. In addition, twenty-six of these 44 long-term recaptures were captured in 1998. The final year (2000) resulted in the recapture of 65 humpback chub that had been previously captured in the preceding 1–8 years. Of these 65 long-term humpback chub recaptures, 60 (93.8%) were recaptured in the same location, three had moved from Hades Bar to Cougar bar, one had moved from Cougar Bar to Hades Bar, and one had moved from Black Rocks since its original capture in 1999. The 65 long-term recaptures in 2000 resulted in 30 individuals that were captured in 1999 and 23 individuals that were captured in 1998.

Comparison with ISMP

The historic (1988–2000) ISMP catch per unit effort for humpback chub in Westwater Canyon indicates a decreasing trend (Figure 5). The slope of this decreasing trend significantly departs from zero ($p < 0.05$). Mean catch per unit effort between 1988 and 2000 as per ISMP sampling protocol was significantly different among years ($p < 0.05$; Kruskal-Wallis). Furthermore, the distribution of catch rates around the mean was significantly different among years ($p < 0.05$; Kolmogorov-Smirnov).

Length-frequency analysis of humpback chub (≥ 150 mm) data collected via ISMP protocol from 1988–2000 indicates frequent shifts in size structure (Figure 6). Humpback chub in Westwater Canyon appear to move through several types of multi-modal size distributions from year to year.

Roundtail Chub

Population Estimates

The model selection function of Program CAPTURE resulted in variability among years in determination of the most appropriate estimator for the roundtail chub capture-recapture data (Appendix II). The jackknife estimator (M_h) ranked highest in 1998 and 2000 (0.85 and 0.88, respectively). However, this estimator was inappropriate for the data in 1999 (0.00). The Darroch estimator (M_t) ranked highest in 1999 (1.00). However, this estimator was not appropriate for the data in 1998 or 2000 (0.05 and 0.00, respectively). Considering these results and to allow a better comparison with the population estimate of humpback chub in Westwater Canyon, the null estimator (M_o) was used to determine the population estimates of adult roundtail chub in Westwater Canyon, 1998–2000.

The adult roundtail chub population estimate was 5,005 individuals in 1998 (Table 3). The profile likelihood interval around this estimate was 3,586 – 19,781 (CV = 0.30; p-hat = 0.026). In 1999, the adult roundtail chub population estimate decreased to 4,234 individuals (Table 3). The profile likelihood interval around this estimate was 3,349 – 12,917 (CV = 0.23) with a slightly higher probability of capture (p-hat = 0.037). The adult roundtail chub population estimate in 2000 increased to approximately the 1998 abundance at 4,971 individuals (Table 3). The probability of capture also decreased at the same time (p-hat = 0.031), while the profile likelihood interval was slightly tighter (3,824 – 16,641; CV = 0.25). The relationship among these three estimates indicates short-term stability in the Westwater Canyon adult roundtail chub population (Figure 7).

CPUE

Total trammel net captures for roundtail were 397 in 1998, 481 in 1999, and 521 in 2000 (Table 2). Total captures in 1998 included 389 adults, seven of which were recaptured. One additional subadult roundtail chub was captured in the trammel nets. In 1999, 457 adults were included in the total captures. Twelve of these individuals were recaptured. Subadult captures in the trammel nets increased to twelve individuals. The total captures for 2000 included 458 adult roundtail chub. Ten of these were recaptured. Subadult captures included in total trammel net captures for 2000 were a project high of 53 individuals.

Mean catch per unit effort (CPUE) slightly decreased across all passes from 1998 to 2000 (Figure 8). The slope of this decreasing trend does not significantly depart from zero. Contrary to this decreasing trend, CPUE appeared to increase among passes within years. The Kruskal-Wallis test supported this observation indicating significant differences ($p < 0.05$) between passes within and among years, except for 2000. The Kolmogorov-Smirnov test indicated there were significant differences ($p < 0.05$) in the distribution of catch rates between passes within and among all years. Comparisons of mean CPUE and the distribution of catch rates between years (all passes combined) indicated significant differences ($p < 0.05$) between all years except for mean CPUE between 1999 and 2000.

Length-Frequency

The length-frequency histograms for Westwater Canyon roundtail chub indicated no clear separation of size classes for 1998 and 1999 (Figure 9). In 2000, there was a bimodal distribution with the size classes being 170–190 mm and 240–350 mm. The largest roundtail chub caught in each year was 390 mm in 1998, 380 mm in 1999, and 390 mm in 2000 (Figure 9).

Growth

Mean annual growth rates of Westwater Canyon roundtail chub were compared with respect to the bimodal distribution of size classes determined from the 2000 length-frequency histogram. To allow comparison between roundtail chub and humpback chub, mean annual growth rates were also examined with respect to the bimodal distribution of humpback chub exhibited in the 1998 and 1999 length-frequency analyses (Figure 3). Mean annual growth rates were 45.67 ± 8.51 mm for roundtail chub less than 210 mm and 16.10 ± 1.70 mm for roundtail chub greater than 210 mm. Roundtail chub less than 285 mm had a mean annual growth rate of 22.56 ± 2.26 mm and roundtail chub greater than 285 mm had a mean annual growth rates of 7.30 ± 1.60 mm. Analysis of the larger data sets from recaptures in 1999 and 2000 indicate a pattern of growth that may shift slightly between years (Figure 10).

Movement

Movement of roundtail chub as determined from long-term recaptures (individuals tagged in previous years) varied from 1998 to 2000. However, through the entire study, 89% exhibited no net movement. There were 29 long-term recaptures of roundtail chub in 1998. These individuals had been tagged in the period 1–6 years prior to 1998. Of the 29 recaptures, 24 (82.8%) were recaptured in the same location, three had moved from Hades Bar to Cougar Bar, and two had moved from Miners Cabin to Cougar Bar. Only three of these roundtail chub had been captured in 1997. In 1999, there were 34 long-term recaptures of roundtail chub that had been initially captured in the previous 1–7 years. Of those, 33 (97.0%) were recaptured in the same location and one individual had moved from Hades Bar to Cougar Bar. In addition, twenty-two of these 34 long-term recaptures were captured in 1998. Two additional fish were tagged in Black Rocks in September 1999 and subsequently recaptured at Miners Cabin in October 1999. The final year (2000) resulted in the recapture of 46 roundtail chub that had been previously captured in the preceding 1–8 years. Of these 46 long-term roundtail chub recaptures, 41 (87.2%) were recaptured in the same location, two had moved from Hades Bar to Cougar bar, one had moved from Cougar Bar to Miners Cabin, and one had moved from Black Rocks to Miners Cabin (originally tagged in 1999). The 46 long-term recaptures in 2000 resulted in 27 individuals that were captured in 1999 and 13 individuals that were captured in 1998.

Comparison with ISMP

The historic (1988–2000) ISMP catch per unit effort for roundtail chub in Westwater Canyon indicates a slight decreasing trend (Figure 11). The slope of this trend does not significantly depart from zero. Mean catch per unit effort between 1988 and 2000 as per ISMP sampling protocol was significantly different between 1990 and 2000 and between 1993 and 2000 ($p < 0.05$; Kruskal-

Wallis). The distribution of catch rates around the mean was significantly different among years ($p < 0.05$; Kolmogorov-Smirnov).

Length-frequency analysis of roundtail chub (≥ 150 mm) data collected via ISMP protocol from 1988–2000 indicates frequent shifts in size structure (Figure 12). Roundtail chub in Westwater Canyon appear to predominantly move between single mode and bimodal size distributions.

DISCUSSION

Population Estimates

Population estimates of humpback chub in Westwater Canyon demonstrated a downward trend from 1998 to 2000. This trend is consistent with the point estimates (1998–2000) of humpback chub in Black Rocks (McAda 2003). Previous population estimates (Chart and Lentsch 1999; Nesler 2000), while not as robust, indicate that the humpback chub population in Westwater Canyon is highly variable. Chart and Lentsch (1999) determined the population to be 5,621 individuals in 1994, 10,148 individuals in 1995, and 5,186 individuals in 1996. Nesler determined the Westwater Canyon humpback chub population to be anywhere from 5,719 in 1993 (90% survival) to 1,164 in 1997 (59% survival). Point estimates in Westwater Canyon for 1999 and 2000 may be indicative of a leveling off prior to a rebound in the humpback chub population, or the declining trend could continue. The Westwater Canyon roundtail chub population appeared to be relatively stable from 1998 to 2000. Chart and Lentsch (1999) indicated that the roundtail chub population was declining in the period from 1993 to 1996 (6,809 in 1993, 5,733 in 1994, and 2,551 in 1996). These combined datasets further support the observed variability of chub populations in Westwater Canyon. Identical effort was applied toward the capture of humpback chub and roundtail chub throughout the three years of the study, and, therefore, increases the likelihood that the humpback chub decline is real and not an artifact of sampling bias.

This study was not designed to sample for subadult humpback chub in Westwater Canyon for the purpose of generating subadult abundance estimates. Future efforts should include a component of sampling designed to capture subadult humpback chub. This would provide information toward the recovery goal component of determining mean estimated recruitment of humpback chub and also provide additional insight toward population dynamics of the Westwater Canyon population as revealed by the adult population point estimates.

Humpback chub and roundtail chub population size patterns observed in this study and by Chart and Lentsch (1999) may indicate that these two species coexist in Westwater Canyon through an equilibrium of population dynamics. While these two studies are not strictly comparable due to different approaches to sampling and analysis of the data, some general observations can be made. From 1993 to 1996, the Westwater Canyon roundtail chub population appeared to be declining. At the same time, the humpback chub population was variable, but relatively higher. Conversely, from 1998 to 2000, adult humpback chub appeared to decline and stabilize while the roundtail chub population was stable and relatively higher. Population estimates of Westwater Canyon humpback chub scheduled for 2003–2005 will contribute to the existing data and further clarify the short-term population trends and population dynamics between humpback chub and roundtail chub in Westwater Canyon.

Confidence intervals around humpback chub point estimates became tighter from 1998 to 2000, but there was no considerable improvement in the coefficient of variation or the probability of capture. Tighter confidence intervals in 1999 than in 1998 were an artifact of a smaller population estimate. However, increased trammel net effort in 2000 relative to previous years (1,329 hours in 1998, 1,306 hours in 1999, and 1,951 hours in 2000) resulted in tighter confidence intervals while maintaining a similar point estimate to 1999. Increased effort using alternative sampling methods (e.g., hoop nets and electrofishing) may improve the coefficient of variation and probability of capture for humpback chub and roundtail chub. McAda (2003) demonstrated an improvement in these measures by incorporating a fourth pass to the sampling design.

Due to the uncertainty surrounding the model selection function of CAPTURE, it may be necessary to conduct further analyses with this dataset or a combined Black Rocks/Westwater dataset in an attempt to resolve which model is most appropriate. This is especially important given the wide range of estimates generated with the models used (Appendix I and II). Investigation into the utility of Program MARK (White 2002) may result in a more appropriate method of generating future population estimates.

Length-Frequency

Length frequency analyses for humpback chub and roundtail chub from historic ISMP data and the current study indicate frequent shifts in size distribution. The consistent amount of effort applied toward the current project indicates that the shifts in size distribution in 1998-2000 are probably not due to gear selectivity. However, failure to efficiently capture subadults may contribute to shifts in size distribution within smaller size classes. Shifts in size distribution of adult humpback chub are most probably attributable to annual variations in recruitment and variable growth rates.

Growth

Growth rates of humpback chub are slower than those of roundtail chub in Westwater Canyon. Growth rates within different size classes of Westwater Canyon humpback chub are variable while those of Black Rocks were not (McAda 2003). Patterns of growth observed in 1998–2000 are similar to those reported by Chart and Lentsch (1999). Chart and Lentsch (1999) reported that humpback chub less than 250 mm grew at approximately twice the rate of those larger than 250 mm. Likewise, humpback chub recaptured in this study less than 285 mm grew at approximately twice the rate of those larger than 285 mm. Roundtail chub also exhibited a similar pattern in growth rates as those reported by Chart and Lentsch (1999). Mean annual growth rate of roundtail chub less than 210 mm in this study and less than 225 mm in the Chart and Lentsch (1999) study was approximately 46 mm. Mean annual growth rate for roundtail chub larger than 210 mm in this study was approximately 16 mm, while Chart and Lentsch (1999) reported 15.6 mm for roundtail chub between 226–250 mm and 12.6 mm for individuals larger than 250 mm. Growth rate and size class differences reported between the two Westwater Canyon studies can be attributed to different conditions (i.e., temperature, water year, food base) that influence these factors.

Movement

Humpback chub have previously been documented to move less than roundtail chub and other Colorado River fishes (Valdez and Clemmer 1982, Archer et al. 1985, Kaeding et al. 1990, Valdez and Ryel 1995, Chart and Lentsch 2000). Archer et al. (1985) found in Black Rocks that roundtail chub moved more than humpback chub. Valdez and Ryel (1995) later supported that finding by stating that humpback chub moved substantially less than other Colorado River fishes. Valdez and Clemmer (1982) recaptured seven humpback chub in Desolation/Gray canyons that had originally been captured in the same locations. Chart and Lentsch (2000) further supported this finding by reporting the recapture of nine chub at the original capture locations in Desolation/Gray canyons.

In Westwater Canyon, little movement of humpback chub and roundtail chub has been documented in the past, but the limited data indicates humpback chub move more than roundtail chub (Chart and Lentsch 1999). A substantially larger dataset of recaptured humpback chub and roundtail chub from this study indicates similar levels of movement: 20% of humpback chub were recaptured in a different location; 11% of roundtail chub were recaptured in a different location. However, from 1998 to 2000, there was a substantially higher rate of movement by humpback chub among all three sites. All roundtail chub movements from 1998 to 2000 were between Cougar Bar and one of the other two sites, while, in addition, Chart and Lentsch (1999) observed limited movement from Miners Cabin to Hades Bar.

As long-term recaptures increased in 1999 and 2000 with a smaller period of time between capture occasions for an individual, there was less evidence of movement in recaptured individuals. In 1998, the number of recaptured individuals from 1997 was relatively low. Long-term recaptures were more representative of humpback chub that had been captured from 1992 to 1996, and these individuals exhibited more movement among sites within Westwater Canyon. Thus, short-term site fidelity is supported by the data. However, once humpback chub move to a new location, short-term site fidelity may be re-established for that area. A radiotelemetry component added to future population estimates may provide insight to within and among site movements of humpback chub in Westwater Canyon.

Movement of humpback chub and roundtail chub between Black Rocks and Westwater Canyon has been previously documented (Chart and Lentsch 1999; McAda 2003). The capture of three humpback chub and three roundtail chub from 1998 to 2000 in Westwater Canyon that were originally tagged in Black Rocks supports the theory of continued exchange between these two areas. Furthermore, McAda (2003) documented 14 humpback chub that had originally been tagged in Westwater Canyon prior to 1998 that were recaptured in Black Rocks from 1998 to 2000. This migration of approximately 10.5 miles between Black Rocks and Westwater Canyon violates the assumption of closure associated with the models being used for population estimates. The frequency of movement between the two canyon areas is similar to that between areas within Westwater Canyon and exceeds the one migrant per generation required to prevent genetic differentiation (Mills and Allendorf 1996). It may be more appropriate to consider Black Rocks/Westwater Canyon humpback chub a single population and analyze it as such.

Comparison with ISMP

The decreasing trend of historic CPUE was statistically significant across all years for Westwater Canyon humpback chub. In addition, the difference in mean CPUE was statistically significant between all years except for 1999 and 2000. The adult population point estimates indicated a decreasing trend for 1998-2000. However, the point estimates for 1999 and 2000 were similar. McAda (2002) statee that the marked decline in mean CPUE suggests the Black Rocks humpback chub population has declined since 1986. This statement was further supported by a decrease in CPUE in 2000 and a reflected decrease in the adult population point estimate. Thus, based upon an extremely limited dataset, it appears that CPUE may be indicative of trends in the adult humpback chub population. Additional information from future sampling efforts in Westwater and Black Rocks canyons will aid in further refining the relationship between CPUE and adult population point estimates.

CONCLUSIONS

- The adult population point estimates of humpback chub in Westwater Canyon indicated a downward trend from 1998 to 2000, though not statistically significant.
- The adult population point estimates of roundtail chub in Westwater Canyon indicated a stable trend between 1998 and 2000.
- Increased trammel net effort (CPUE) resulted in tighter confidence intervals but no real improvement in probability of capture (p-hat) or coefficient of variation (CV).
- Growth rates of humpback chub are lower than those for roundtail chub in Westwater Canyon.
- Humpback chub and roundtail chub move between Black Rocks and Westwater Canyon consistently enough to consider that these two areas contain a single population for each species.

RECOMMENDATIONS

- Increase trammel net effort (CPUE) in Westwater Canyon.
- Use hoop nets and electrofishing to improve probability of capture (p-hat) and coefficient of variation (CV).
- Use smaller mesh trammel nets, hoop nets, minnow traps and electrofishing to target subadult humpback chub in Westwater Canyon.
- Incorporate a fourth pass and additional sampling locations (i.e., upper Cougar, Big Hole) to improve (p-hat) and coefficient of variation (CV).
- Consider Black Rocks and Westwater Canyon a single population and determine a single point estimate for each year to be consistent with the assumptions for closed population estimates.
- Investigate use of most appropriate statistical programs and associated models to generate future adult humpback chub population estimates.
- Include a radiotelemetry component in future adult humpback chub population estimates to provide additional resolution of movement and site fidelity within and among sampling areas of Westwater Canyon.

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Table 1. Population estimate (N) for humpback chub adults (>200 mm) in Westwater Canyon 1998–2000. Population estimate generated using the null estimator (M_o) 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*	*Profile Likelihood Interval*	*CV*	*p-hat*
1998	4,744	3,760–14,665	0.23	0.035
1999	2,215	1,608–7,508	0.28	0.041
2000	2,201	1,335–4,124	0.28	0.041

Table 2. Total humpback chub captures in Westwater Canyon 1998–2000. Includes number of adult captures, adult recaptures, and subadults caught.

Year	*Total Captures*	*Adult Captures*	*Adult Recaptures*	*Subadult Captures*
1998	501	486	12	3
1999	278	267	8	3
2000	277	261	11	5

Table 3. Population estimate (N) for roundtail chub adults (>200 mm) in Westwater Canyon 1998–2000. Population estimate generated using the null estimator (M_o) 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***	***Profile Likelihood Interval***	***CV***	***p-hat***
1998	5,005	3,586–19,781	0.30	0.026
1999	4,234	3,349–12,917	0.23	0.037
2000	4,971	3,824–16,641	0.25	0.031

Table 4. Total roundtail chub captures in Westwater Canyon 1998–2000. Includes number of adult captures, adult recaptures, and subadults caught.

Year	***Total Captures***	***Adult Captures***	***Adult Recaptures***	***Subadult Captures***
1998	397	389	7	1
1999	481	457	12	12
2000	521	458	10	53

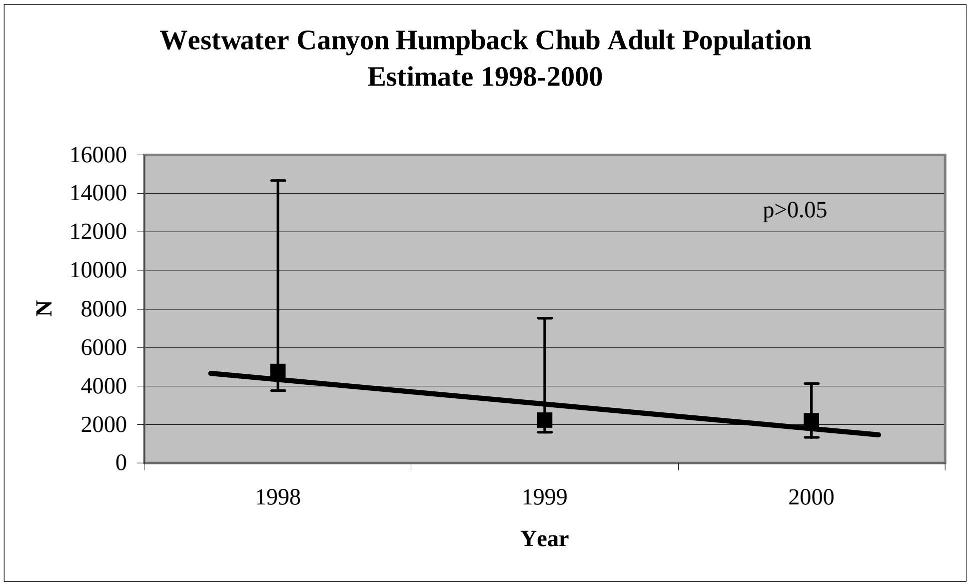

Figure 1. Westwater Canyon adult humpback chub population estimates (N) for 1998–2000. Each point estimate includes respective profile likelihood confidence intervals. Line represents short-term trend among the three point estimates. The p-value indicates statistical significance of the trend line.

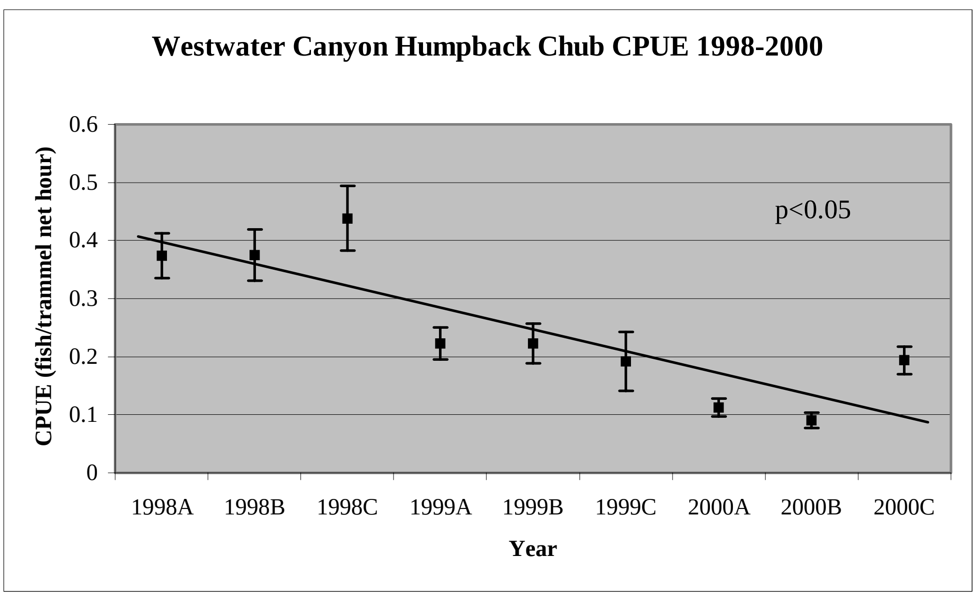

Figure 2. Westwater Canyon humpback chub trammel net catch per unit effort by pass for 1998–2000. CPUE for each pass includes respective standard error. Line represents trend among all passes in all years. The p-value indicates statistical significance of the trend line.

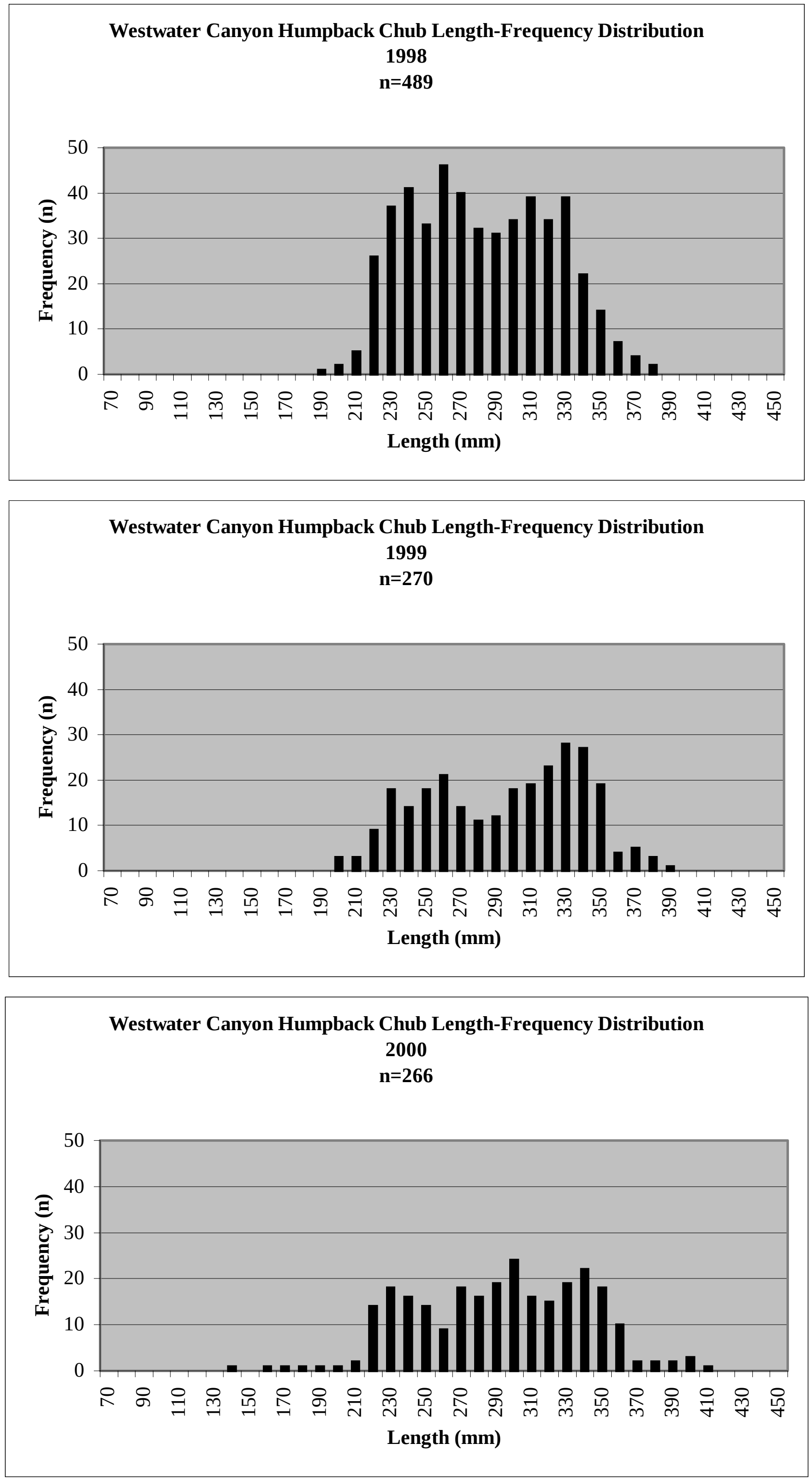

Figure 3. Westwater Canyon humpback chub length-frequency histograms for 1998–2000. Frequency is illustrated as number of total individuals within a given size class.

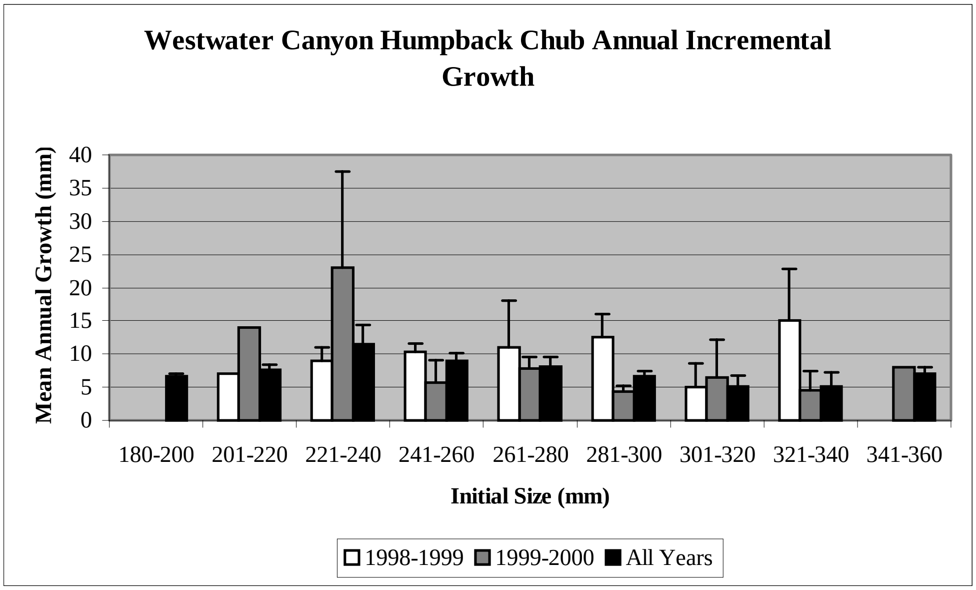

Figure 4. Westwater Canyon humpback chub annual incremental growth for individuals between 1998–1999 and 1999–2000, and among all years (1992–2000). All years data includes estimates of average annual growth for individuals that were recaptured after more than one year at large. Standard error is not included for respective size classes and years that annual incremental growth was determined from one individual.

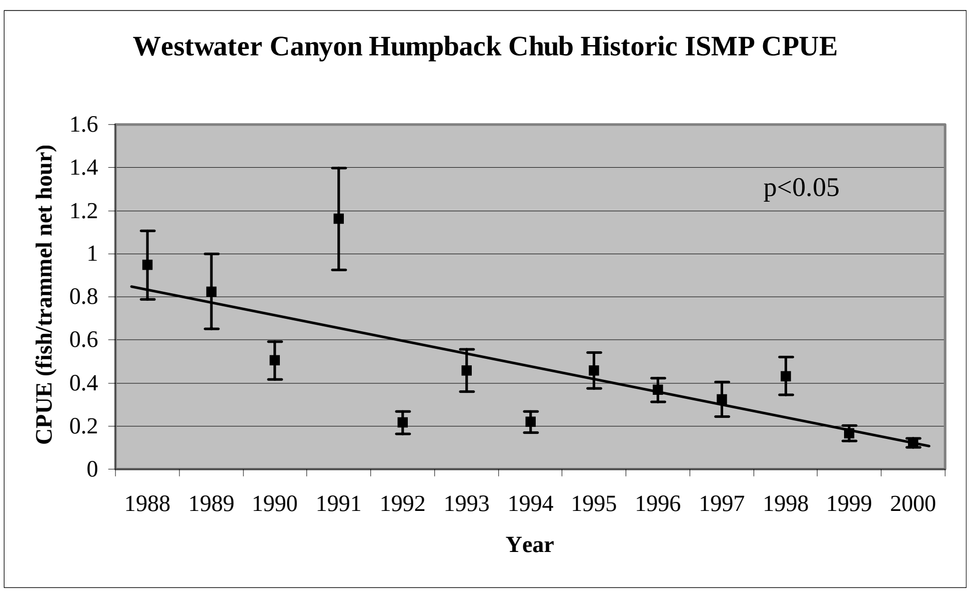

Figure 5. Westwater Canyon humpback chub catch per unit effort for samples collected using ISMP protocol from 1988 to 2000. CPUE for each year includes respective standard error. Line represents trend among all passes in all years. The p-value indicates statistical significance of the trend line.

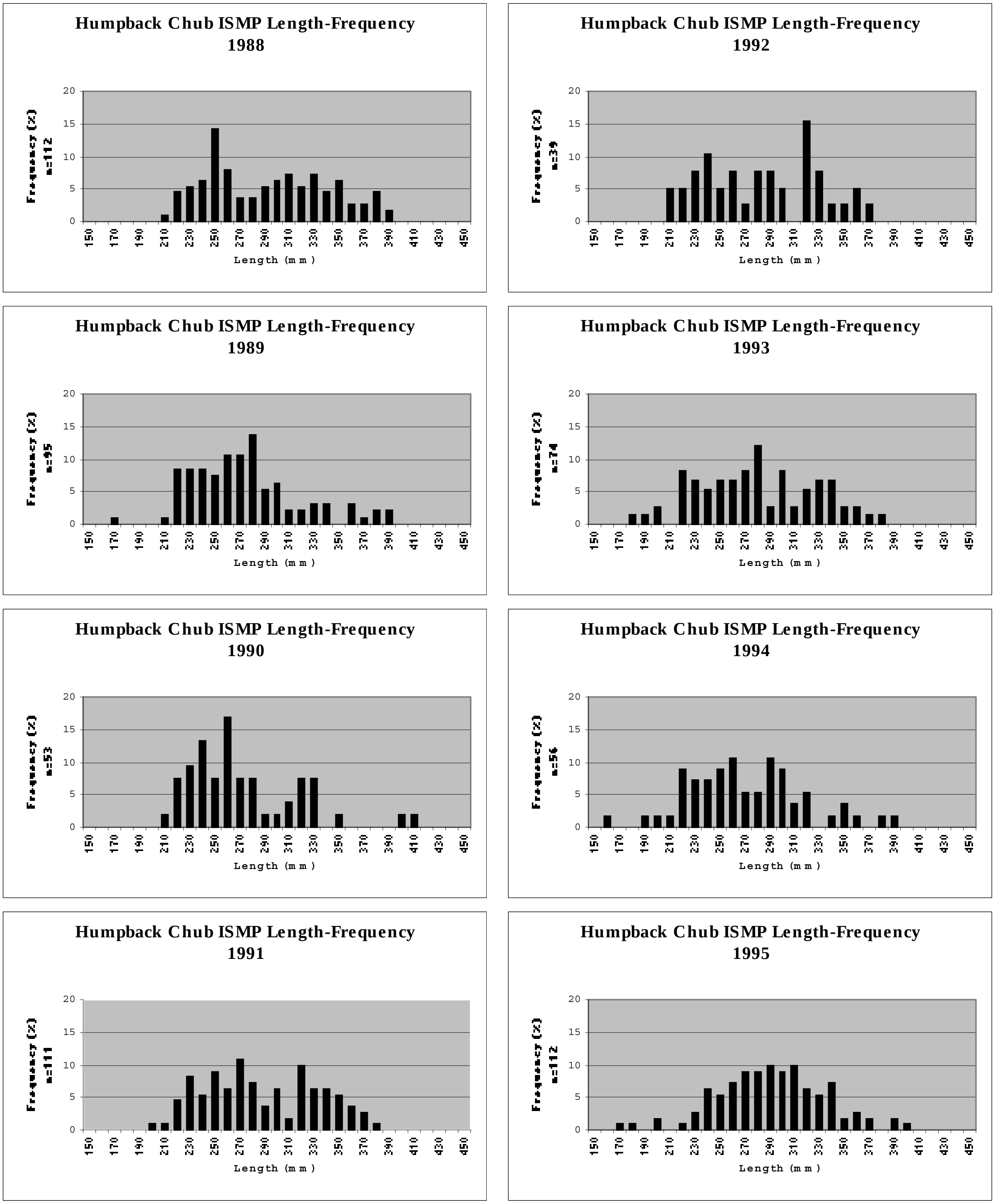

Figure 6. Westwater Canyon humpback chub ISMP length-frequency histograms for 1988–2000. Frequency is illustrated as percentage of total individuals (n) within a given size class.

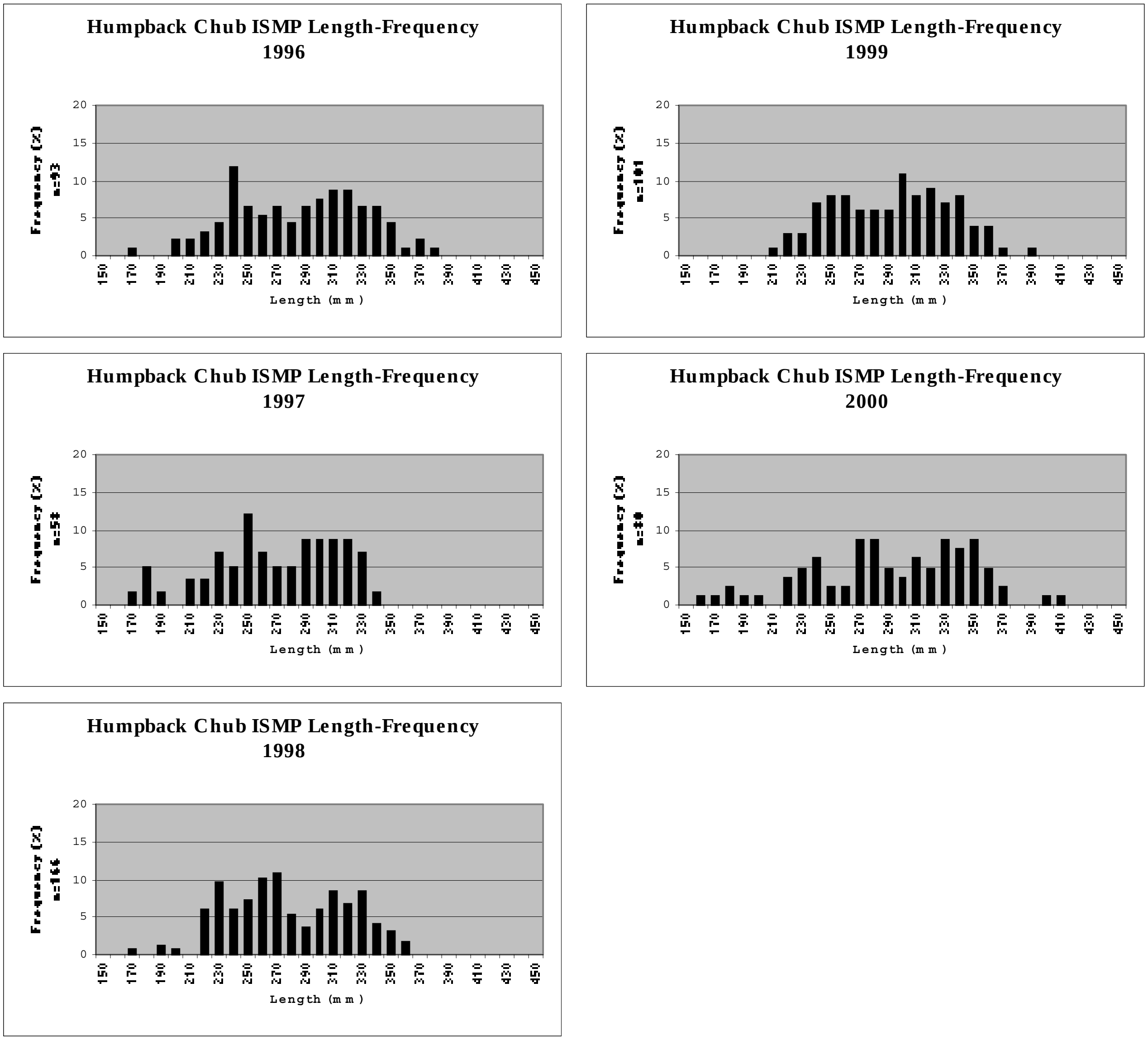

Figure 6 (*continued*). Westwater Canyon humpback chub ISMP length-frequency histograms for 1988–2000. Frequency is illustrated as percentage of total individuals (n) within a given size class.

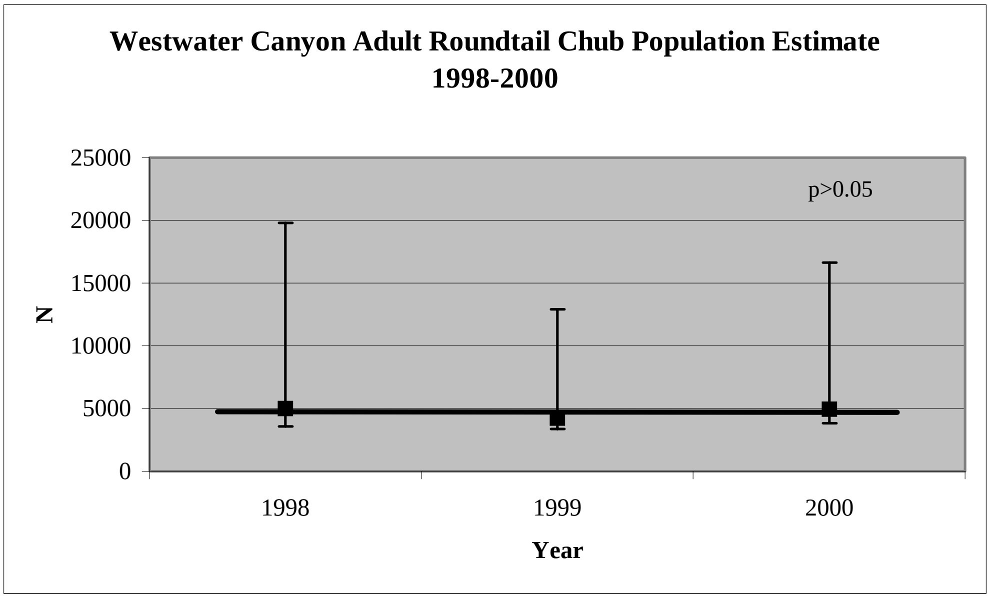

Figure 7. Westwater Canyon adult roundtail chub population estimates (N) for 1998–2000. Each point estimate includes respective profile likelihood confidence intervals. Line represents short-term trend among the three point estimates. The p-value indicates statistical significance of the trend line.

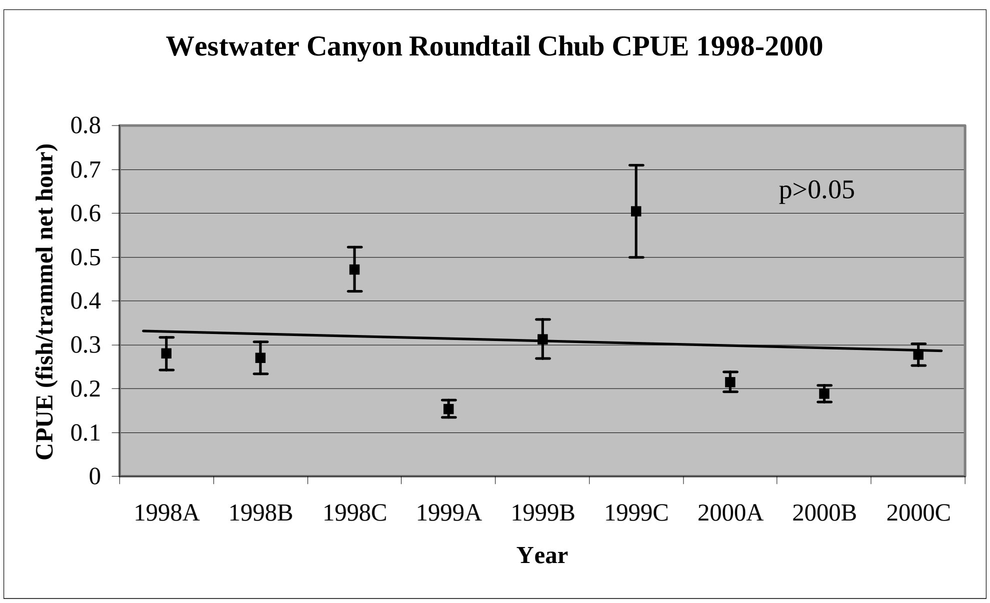

Figure 8. Westwater Canyon roundtail chub trammel net catch per unit effort by pass for 1998–2000. CPUE for each pass includes respective standard error. Line represents trend among all passes in all years. The p-value indicates statistical significance of the trend line.

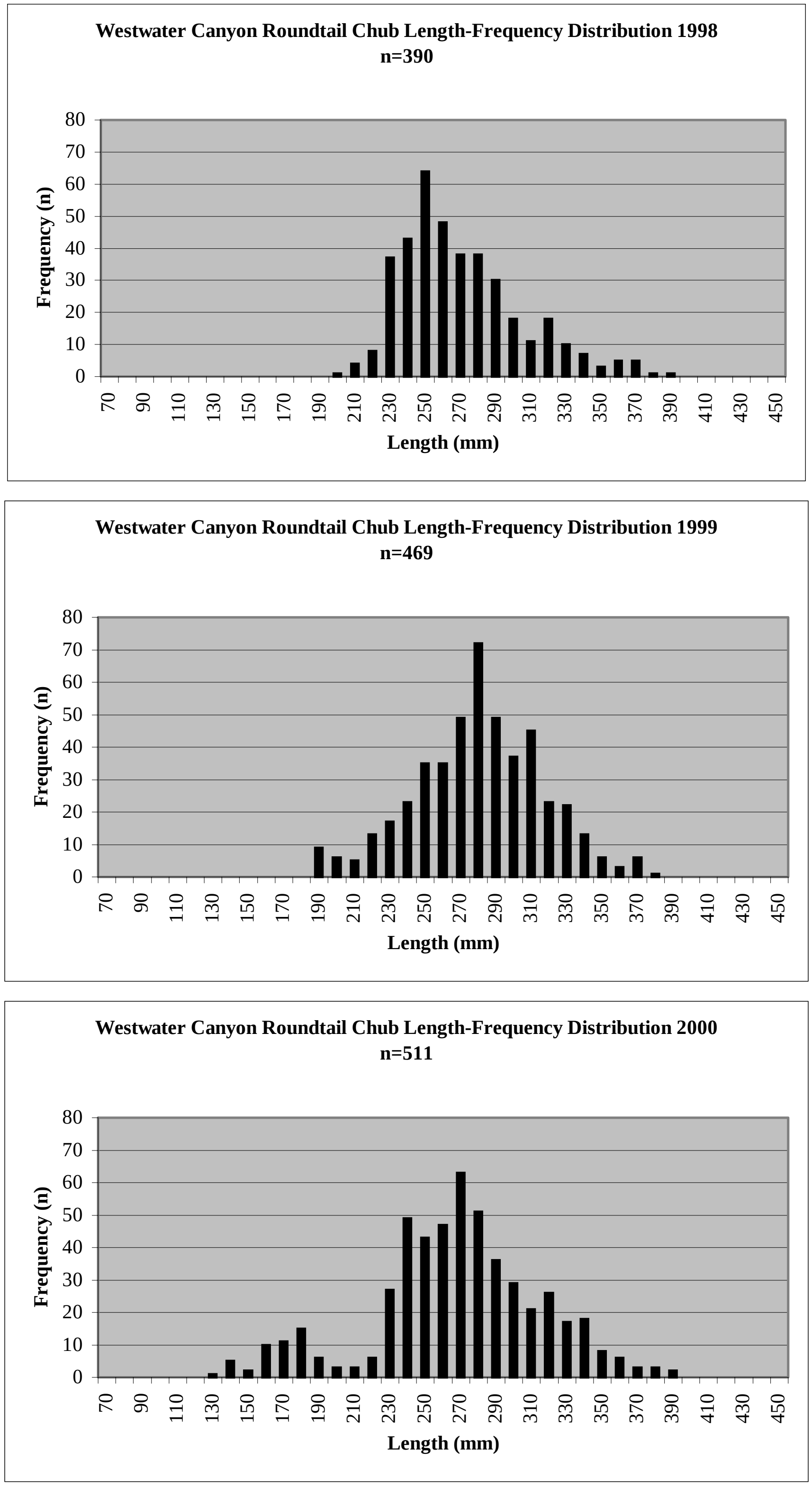

Figure 9. Westwater Canyon roundtail chub length-frequency histograms for 1998–2000. Frequency is illustrated as number of total individuals within a given size class.

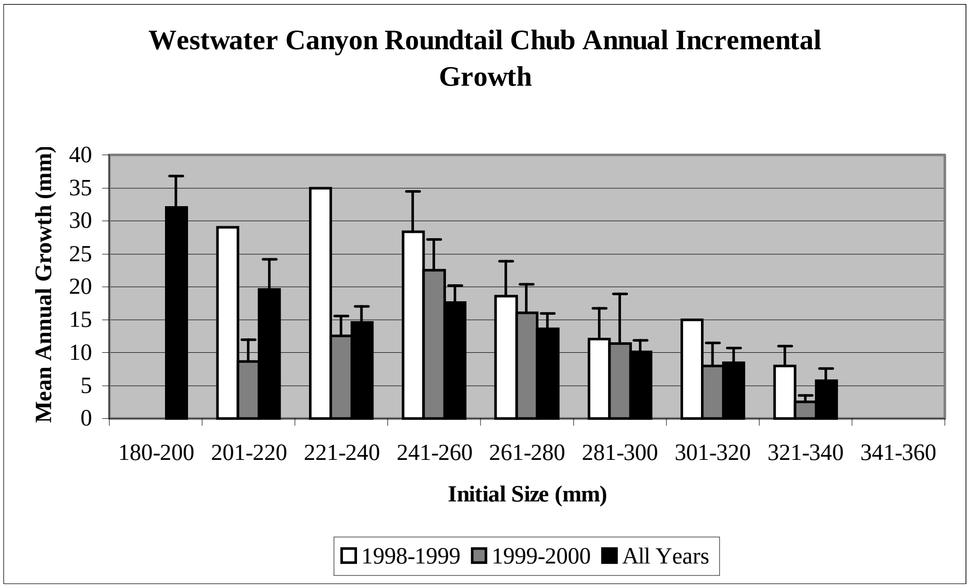

Figure 10. Westwater Canyon roundtail chub annual incremental growth for individuals between 1998–1999 and 1999–2000, and among all years (1992–2000). All years data includes estimates of average annual growth for individuals that were recaptured after more than one year at large. Standard error is not included for respective size classes and years that annual incremental growth was determined from one individual.

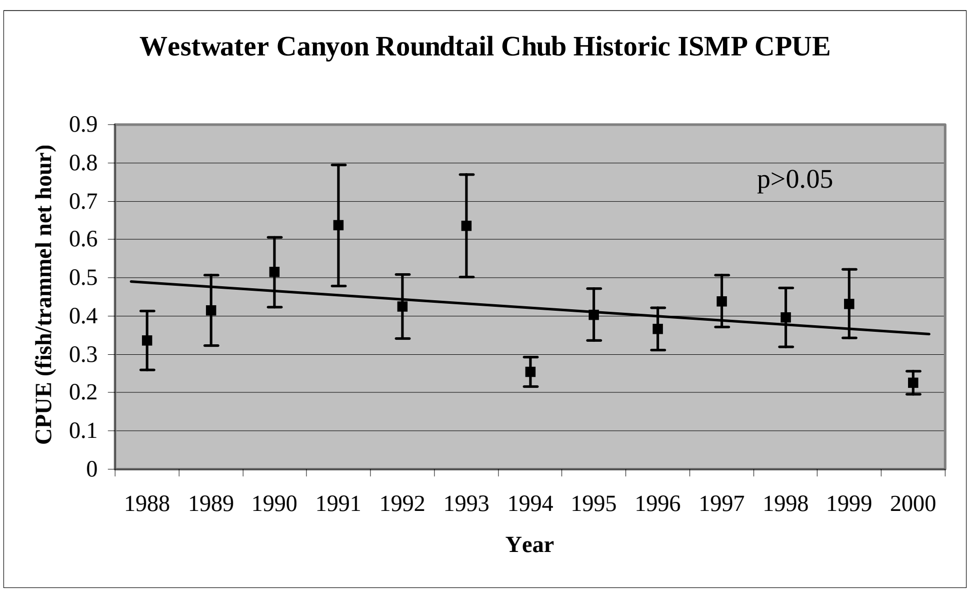

Figure 11. Westwater Canyon roundtail chub catch per unit effort for samples collected using ISMP protocol from 1988 to 2000. CPUE for each year includes respective standard error. Line represents trend among all passes in all years. The p-value indicates statistical significance of the trend line.

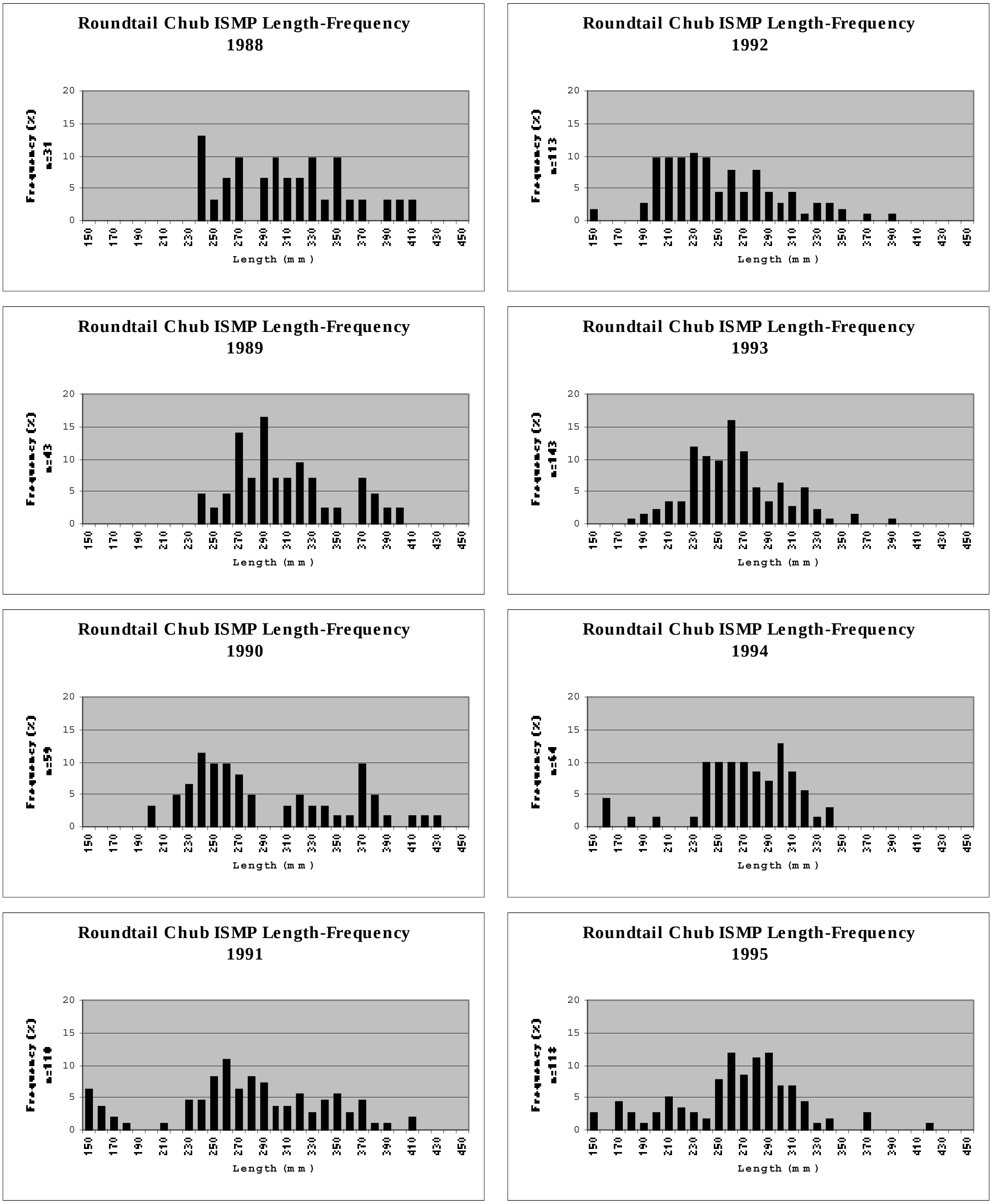

Figure 12. Westwater Canyon roundtail chub ISMP length-frequency histograms for 1988–2000. Frequency is illustrated as percentage of total individuals (n) within a given size class.

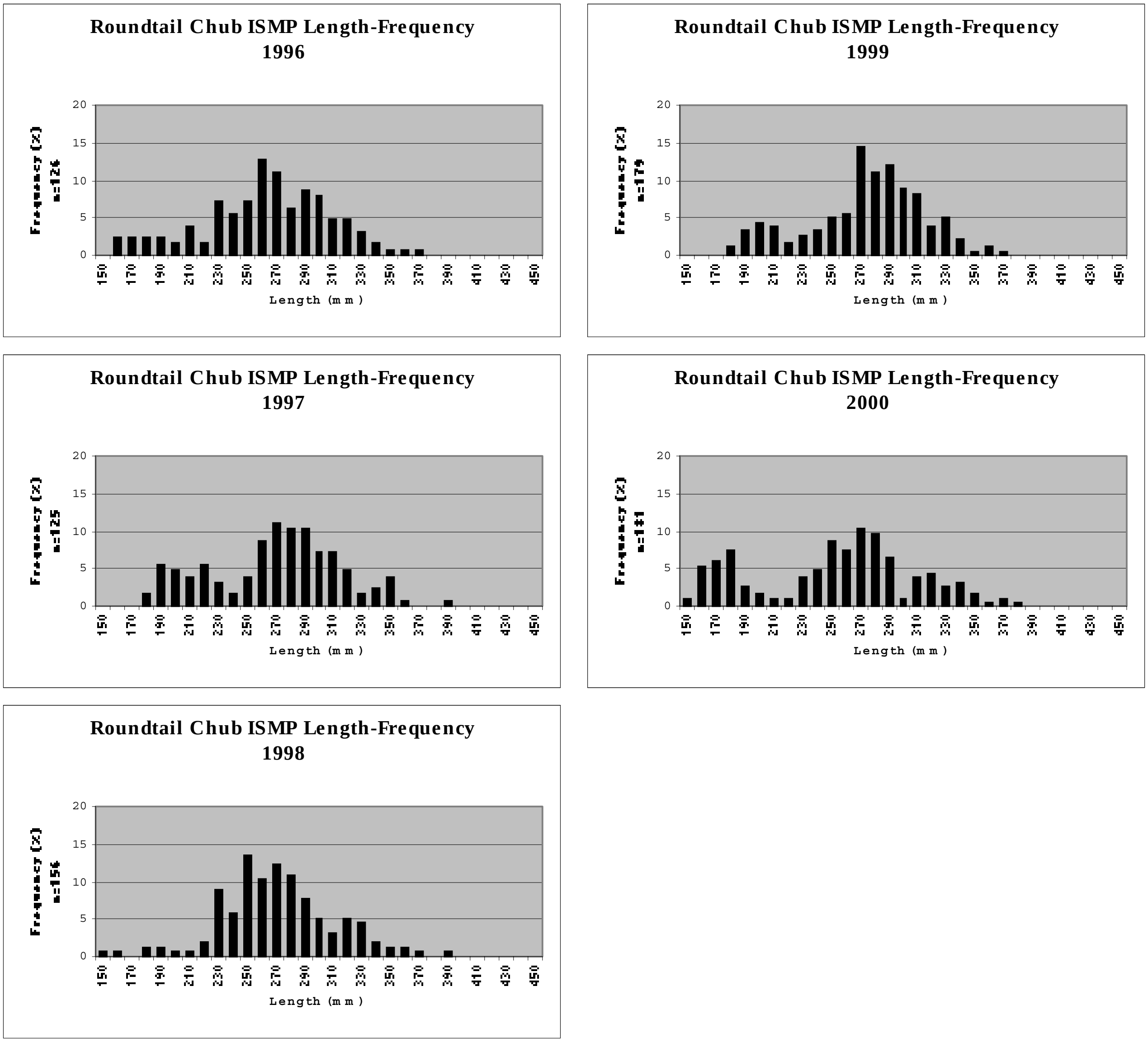

Figure 12 (*continued*). Westwater Canyon roundtail chub ISMP length-frequency histograms for 1988–2000. Frequency is illustrated as percentage of total individuals (n) within a given size class.

Appendix I. Summary of population estimates generated within Program CAPTURE for adult humpback chub in Westwater Canyon, 1998–2000. Information for comparison within each year of the study among the six estimators used includes the population estimate (N), 95% confidence intervals, coefficient of variation (CV), probability of capture (p-hat), and the model selection criteria.

Year	***Estimator***	***N***	***Confidence Interval****	***CV***	***p-hat***	***Model Selection Criteria***
1998	M_o	4,744	3,085–7,462 (3,760–14,665)	0.23	0.035	1.00
	Jackknife M_h	958	902–1,022	0.03	0.173	0.84
	Darroch M_t	3,190	2,427–4,251 (2,860–24,710)	0.14	0.050	0.00
	Chao M_{th}	6,723	3,972–11,647	0.28	0.023	0.46
	Chao M_t	6,243	3,770–10,579	0.27	0.030	-
	Chao M_h	9,848	5,722–17,224	0.29	0.017	-
1999	M_o	2,215	1,322–3,863 (1,608–7,508)	0.28	0.041	0.24
	Jackknife M_h	525	484–573	0.04	0.175	0.15
	Darroch M_t	2,670	1,551–4,766 (1,673–6,613)	0.30	0.033	0.00
	Chao M_{th}	3,059	1,637–5,961	0.34	0.030	0.36
	Chao M_t	2,699	1,502–5,057	0.32	0.033	-
	Chao M_h	4,460	2,326–8,803	0.35	0.021	-
2000	M_o	2,201	1,308–3,855 (1,335–4,124)	0.28	0.041	0.74
	Jackknife M_h	509	469–556	0.04	0.178	0.74
	Darroch M_t	1,713	1,116–2,728 (1,218–3,978)	0.23	0.053	0.60
	Chao M_{th}	2,216	1,276–4,028	0.30	0.040	0.62
	Chao M_t	1,862	1,134–3,199	0.27	0.047	-
	Chao M_h	3,102	1,781–5,571	0.30	0.029	-

**95% confidence intervals are provided for all estimators. Profile likelihood intervals are provided in parentheses for M_o and the Darroch M_t.*

Appendix II. Summary of population estimates generated within Program CAPTURE for adult roundtail chub in Westwater Canyon, 1998–2000. Information for comparison within each year of the study among the six estimators used includes the population estimate (N), 95% confidence intervals, coefficient of variation (CV), probability of capture (p-hat), and the model selection criteria.

Year	***Estimator***	***N***	***Confidence Interval****	***CV***	***p-hat***	***Model Selection Criteria***
1998	M_o	5,005	2,869–8,980 (3,586–19,781)	0.30	0.026	0.76
	Jackknife M_h	770	720–827	0.04	0.171	0.85
	Darroch M_t	2,553	1,824–3,651 (2,180–27,386)	0.18	0.053	0.05
	Chao M_{th}	9,179	4,532–19,041	0.38	0.013	0.29
	Chao M_t	5,121	2,738–9,922	0.34	0.023	-
	Chao M_h	10,812	5,360–22,246	0.38	0.012	-
1999	M_o	4,234	2,754–6,665 (3,349–12,917)	0.23	0.037	0.13
	Jackknife M_h	900	846–962	0.03	0.174	0.00
	Darroch M_t	2,999	2,231–4100 (2,622–16,739)	0.16	0.050	1.00
	Chao M_{th}	6,206	3,599–10,978	0.29	0.027	0.66
	Chao M_t	5,129	3,115–8,673	0.27	0.030	-
	Chao M_h	8,708	5,064–15,235	0.29	0.018	-
2000	M_o	4,971	3,107–8,144 (3,824–16,641)	0.25	0.031	0.78
	Jackknife M_h	904	850–966	0.03	0.173	0.88
	Darroch M_t	5,038	3,266–7,929 (3,718–14,667)	0.23	0.033	0.00
	Chao M_{th}	7,458	4,123–13,830	0.31	0.020	0.27
	Chao M_t	6,116	3,544–10,831	0.29	0.027	-
	Chao M_h	10,493	5,800–19,309	0.32	0.015	-

**95% confidence intervals are provided for all estimators. Profile likelihood intervals are provided in parentheses for M_o and the Darroch M_t.*

Appendix III. Colorado River Water Data 1998-2000

Environmental conditions of the Colorado River in Westwater Canyon for 1998-2000 are presented in the following tables and figures. Mean daily discharge (cfs), mean daily temperature (^oC) and suspended sediment (mg/l) were recorded at USGS gage #09163500 (Colorado River near Colorado-Utah State Line; above Westwater Canyon). In the absence of that data daily instantaneous temperature (^oC) values and suspended sediment (mg/l) data are reported as recorded at USGS gage #09180500 (Colorado River near Cisco; below Westwater Canyon). Additional environmental parameters for the period of record as recorded at both gages are reported in Herbert et al. (1999, 2000, 2001, 2002).

Appendix III Table 1. Mean daily discharge (cfs) of Colorado River near Colorado-Utah state line (USGS gage #09163500) for Fall 1998. Westwater Canyon humpback chub sampling dates are in bold.

Date	***Discharge***	***Date***	***Discharge***
9/1/1998	3660	**10/1/1998**	**4120**
9/2/1998	3820	**10/2/1998**	**4210**
9/3/1998	4020	10/3/1998	4540
9/4/1998	3990	10/4/1998	4680
9/5/1998	3800	10/5/1998	5060
9/6/1998	3720	10/6/1998	5180
9/7/1998	**3760**	10/7/1998	5090
9/8/1998	**3670**	10/8/1998	4920
9/9/1998	**3600**	10/9/1998	4760
9/10/1998	**3550**	10/10/1998	4780
9/11/1998	**3670**	10/11/1998	4740
9/12/1998	**4310**	10/12/1998	4670
9/13/1998	5500	10/13/1998	4640
9/14/1998	5200	10/14/1998	4590
9/15/1998	5090	10/15/1998	4560
9/16/1998	4930	10/16/1998	4470
9/17/1998	4880	10/17/1998	4620
9/18/1998	4800	10/18/1998	4660
9/19/1998	4710	**10/19/1998**	**4750**
9/20/1998	4550	**10/20/1998**	**4730**
9/21/1998	4430	**10/21/1998**	**4700**
9/22/1998	4360	**10/22/1998**	**4770**
9/23/1998	4400	**10/23/1998**	**4860**
9/24/1998	4450	**10/24/1998**	**4970**
9/25/1998	4260	10/25/1998	4840
9/26/1998	4190	10/26/1998	5350
9/27/1998	4080	10/27/1998	5500
9/28/1998	**4020**	10/28/1998	5920
9/29/1998	**3990**	10/29/1998	5740
9/30/1998	**4040**	10/30/1998	5360
--	--	10/31/1998	5400

Appendix III Table 2. Daily instantaneous temperature (^oC) values (September) of Colorado River near Cisco (USGS gage #09180500) and mean daily temperature (^oC) of Colorado River near Colorado-Utah State line (USGS gage #09163500) for Fall 1998. Westwater Canyon humpback chub sampling dates are in bold.

Date	***Temperature***	***Date***	***Temperature***
9/1/1998	23.0	**10/1/1998**	**17.3**
9/2/1998	23.0	**10/2/1998**	**15.8**
9/3/1998	23.0	10/3/1998	15.6
9/4/1998	23.0	10/4/1998	13.8
9/5/1998	22.0	10/5/1998	12.6
9/6/1998	22.0	10/6/1998	11.6
9/7/1998	**22.0**	10/7/1998	11.8
9/8/1998	**22.0**	10/8/1998	12.2
9/9/1998	**22.0**	10/9/1998	12.8
9/10/1998	**22.0**	10/10/1998	13.0
9/11/1998	**22.0**	10/11/1998	12.9
9/12/1998	**22.0**	10/12/1998	12.8
9/13/1998	21.0	10/13/1998	12.6
9/14/1998	21.0	10/14/1998	12.7
9/15/1998	21.0	10/15/1998	12.9
9/16/1998	21.0	10/16/1998	12.5
9/17/1998	20.0	10/17/1998	11.8
9/18/1998	20.0	10/18/1998	11.2
9/19/1998	20.0	**10/19/1998**	**10.8**
9/20/1998	18.0	**10/20/1998**	**10.9**
9/21/1998	18.0	**10/21/1998**	**11.0**
9/22/1998	18.0	**10/22/1998**	**11.3**
9/23/1998	18.0	**10/23/1998**	**12.0**
9/24/1998	18.0	**10/24/1998**	**12.0**
9/25/1998	18.0	10/25/1998	11.6
9/26/1998	18.0	10/26/1998	11.4
9/27/1998	18.0	10/27/1998	11.4
9/28/1998	18.0	10/28/1998	11.0
9/29/1998	18.0	10/29/1998	10.2
9/30/1998	18.0	10/30/1998	9.8
--	--	10/31/1998	9.8

Appendix III Table 3. Suspended sediment (mg/l) of Colorado River near Cisco (USGS gage #09180500; September) and Colorado River near Colorado-Utah state line (USGS gage #09163500; October) for Fall 1998.

Date	***Time***	***Suspended Sediment***	***Date***	***Time***	***Suspended Sediment***
9/23/1998	1135	164	10/8/1998	1115	104
9/23/1998	1136	159	10/8/1998	1200	82

Appendix III Table 4. Mean daily discharge (cfs) of Colorado River near Colorado-Utah state line (USGS gage #09163500) for Fall 1999. Westwater Canyon humpback chub sampling dates are in bold.

Date	***Discharge***	***Date***	***Discharge***
9/1/1999	5270	10/1/1999	6140
9/2/1999	5730	10/2/1999	6630
9/3/1999	6200	**10/3/1999**	**7260**
9/4/1999	6830	**10/4/1999**	**7870**
9/5/1999	6780	**10/5/1999**	**8010**
9/6/1999	6640	**10/6/1999**	**7300**
9/7/1999	6140	**10/7/1999**	**6600**
9/8/1999	5800	**10/8/1999**	**6420**
9/9/1999	5610	10/9/1999	6280
9/10/1999	5470	10/10/1999	5780
9/11/1999	5390	10/11/1999	5270
9/12/1999	5380	10/12/1999	4930
9/13/1999	5600	10/13/1999	4800
9/14/1999	5400	10/14/1999	4810
9/15/1999	5270	10/15/1999	4660
9/16/1999	5450	10/16/1999	4690
9/17/1999	5730	**10/17/1999**	**4820**
9/18/1999	5820	**10/18/1999**	**5050**
9/19/1999	**5970**	**10/19/1999**	**5110**
9/20/1999	**6580**	**10/20/1999**	**5150**
9/21/1999	**6900**	**10/21/1999**	**5130**
9/22/1999	**6740**	**10/22/1999**	**5040**
9/23/1999	**6440**	10/23/1999	5130
9/24/1999	**6340**	10/24/1999	5120
9/25/1999	6380	10/25/1999	5120
9/26/1999	6540	10/26/1999	5110
9/27/1999	6390	10/27/1999	5100
9/28/1999	6190	10/28/1999	5200
9/29/1999	6110	10/29/1999	5190
9/30/1999	6140	10/30/1999	5150
--	--	10/31/1999	5280

Appendix III Table 5. Mean daily temperature (^oC) of Colorado River near Colorado-Utah State line (USGS gage #09163500) for Fall 1999. Westwater Canyon humpback chub sampling dates are in bold.

Date	***Temperature***	***Date***	***Temperature***
9/1/1999	20.0	10/1/1999	13.3
9/2/1999	19.0	10/2/1999	13.5
9/3/1999	18.9	**10/3/1999**	**13.8**
9/4/1999	18.1	**10/4/1999**	**13.8**
9/5/1999	17.8	**10/5/1999**	**13.6**
9/6/1999	18.1	**10/6/1999**	**13.8**
9/7/1999	18.4	**10/7/1999**	**13.8**
9/8/1999	18.7	**10/8/1999**	**13.6**
9/9/1999	18.4	10/9/1999	13.7
9/10/1999	18.6	10/10/1999	14.1
9/11/1999	19.3	10/11/1999	14.3
9/12/1999	19.1	10/12/1999	14.2
9/13/1999	18.6	10/13/1999	14.2
9/14/1999	17.8	10/14/1999	13.8
9/15/1999	17.5	10/15/1999	13.3
9/16/1999	17.3	10/16/1999	12.5
9/17/1999	17.9	**10/17/1999**	**10.5**
9/18/1999	18.0	**10/18/1999**	**9.7**
9/19/1999	**17.5**	**10/19/1999**	**10.0**
9/20/1999	**16.4**	**10/20/1999**	**9.8**
9/21/1999	**16.2**	**10/21/1999**	**9.9**
9/22/1999	**15.7**	**10/22/1999**	**10.1**
9/23/1999	**16.0**	10/23/1999	10.3
9/24/1999	**16.6**	10/24/1999	10.1
9/25/1999	17.0	10/25/1999	9.9
9/26/1999	17.0	10/26/1999	9.8
9/27/1999	15.9	10/27/1999	9.8
9/28/1999	14.0	10/28/1999	9.4
9/29/1999	12.7	10/29/1999	9.5
9/30/1999	12.3	10/30/1999	9.0
--	--	10/31/1999	8.9

Appendix III Table 6. Suspended sediment (mg/l) of Colorado River near Cisco (USGS gage #09180500; September) and Colorado River near Colorado-Utah state line (USGS gage #09163500; October) for Fall 1999.

Date	***Time***	***Suspended Sediment***	***Date***	***Time***	***Suspended Sediment***
9/20/1999	1200	1350	10/8/1999	1130	105
9/20/1999	1240	1190	10/8/1999	1200	51

Appendix III Table 7. Mean daily discharge (cfs) of Colorado River near Colorado-Utah state line (USGS gage #09163500) for Fall 2000. Westwater Canyon humpback chub sampling dates are in bold.

Date	***Discharge***	***Date***	***Discharge***
9/1/2000	4480	10/1/2000	3280
9/2/2000	4210	10/2/2000	3200
9/3/2000	3890	10/3/2000	3090
9/4/2000	3750	10/4/2000	2910
9/5/2000	3740	10/5/2000	2900
9/6/2000	3740	10/6/2000	3140
9/7/2000	3790	10/7/2000	3240
9/8/2000	3870	**10/8/2000**	**3200**
9/9/2000	4020	**10/9/2000**	**3160**
9/10/2000	**3980**	**10/10/2000**	**3150**
9/11/2000	**3930**	**10/11/2000**	**3170**
9/12/2000	**3720**	**10/12/2000**	**3340**
9/13/2000	**3490**	**10/13/2000**	**3390**
9/14/2000	**3290**	10/14/2000	3410
9/15/2000	**3160**	10/15/2000	3420
9/16/2000	3090	10/16/2000	3520
9/17/2000	3030	10/17/2000	3470
9/18/2000	3110	10/18/2000	3480
9/19/2000	3330	10/19/2000	3370
9/20/2000	3300	10/20/2000	3310
9/21/2000	3300	10/21/2000	3230
9/22/2000	3520	10/22/2000	3280
9/23/2000	3710	10/23/2000	3330
9/24/2000	**4160**	10/24/2000	3620
9/25/2000	**3870**	10/25/2000	3770
9/26/2000	**3830**	10/26/2000	3810
9/27/2000	**3760**	10/27/2000	3760
9/28/2000	**3560**	10/28/2000	3710
9/29/2000	**3250**	10/29/2000	3730
9/30/2000	3320	10/30/2000	3770
--	--	10/31/2000	4040

Appendix III Table 8. Mean daily temperature (°C) of Colorado River near Colorado-Utah State line (USGS gage #09163500) for Fall 2000. Westwater Canyon humpback chub sampling dates are in bold.

Date	***Temperature***	***Date***	***Temperature***
9/1/2000	20.0	10/1/2000	16.9
9/2/2000	18.6	10/2/2000	16.9
9/3/2000	18.8	10/3/2000	17.0
9/4/2000	19.3	10/4/2000	16.9
9/5/2000	19.5	10/5/2000	16.5
9/6/2000	18.2	10/6/2000	15.5
9/7/2000	18.3	10/7/2000	14.8
9/8/2000	19.1	**10/8/2000**	**14.4**
9/9/2000	18.3	**10/9/2000**	**14.4**
9/10/2000	**18.5**	**10/10/2000**	**14.2**
9/11/2000	**18.3**	**10/11/2000**	**13.4**
9/12/2000	**18.7**	**10/12/2000**	**12.9**
9/13/2000	**19.0**	**10/13/2000**	**12.4**
9/14/2000	**19.2**	10/14/2000	12.2
9/15/2000	**19.4**	10/15/2000	11.8
9/16/2000	19.6	10/16/2000	11.6
9/17/2000	19.2	10/17/2000	11.6
9/18/2000	19.2	10/18/2000	11.5
9/19/2000	19.2	10/19/2000	11.5
9/20/2000	18.8	10/20/2000	11.6
9/21/2000	17.8	10/21/2000	11.5
9/22/2000	17.1	10/22/2000	11.7
9/23/2000	16.3	10/23/2000	11.8
9/24/2000	**14.2**	10/24/2000	11.5
9/25/2000	**13.4**	10/25/2000	11.3
9/26/2000	**13.4**	10/26/2000	10.9
9/27/2000	**14.4**	10/27/2000	10.9
9/28/2000	**15.5**	10/28/2000	11.1
9/29/2000	**16.4**	10/29/2000	10.8
9/30/2000	16.6	10/30/2000	11.0
--	--	10/31/2000	10.2

Appendix III Table 9. Suspended sediment (mg/l) of Colorado River near Cisco (USGS gage #09180500; September) and Colorado River near Colorado-Utah state line (USGS gage #09163500; October) for Fall 2000.

Date	***Time***	***Suspended Sediment***	***Date***	***Time***	***Suspended Sediment***
9/14/2000	1230	94	10/30/2000	1020	63
9/14/2000	1330	99	10/30/2000	1100	69