Population Size and Structure of Humpback Chub, *Gila cypha* and Roundtail Chub, *G. robusta*, in Black Rocks, Colorado River, Colorado, 2007–2008

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EXECUTIVE SUMMARY

The Colorado River in Black Rocks was sampled in 2007 and 2008 to estimate size and structure of the humpback chub *Gila cypha* and roundtail *Gila robusta* chub populations. Sampling began in mid-September and continued through October. Four sampling passes (4 days each: conducted in alternating weeks) were conducted in both years. Sampling was primarily done with multi-filament trammel nets (3.9 cm inner mesh), although *Gila* captures were supplemented with electrofishing. Trammel nets were set in shoreline eddies in early morning and late afternoon. Nets were run at 1-to 2-hr intervals with 2 hrs set as a maximum interval. All *Gila* were removed from the nets, placed in fresh water and transported to a central processing point. In addition, the entire Black Rocks reach was sampled with electrofishing during two of four passes each year.

All *Gila* were identified as either humpback chub or roundtail chub, checked for a PIT tag and measured (total length [TL]; ± 1 mm) and weighed (± 1 gram). A PIT tag was inserted in all untagged fish. After handling, all *Gila* were placed in an oxygenated tank containing a mixture of salt and Stress Coat® for about 1 hr as a skin treatment and to assess general health. All *Gila* were released at the common location and appeared healthy when released.

Catch rates for humpback chub in 2007–2008 were comparable to those observed in 2003–2004. A total of 61 individual humpback chub were captured in 2007 and 74 were captured in 2008. These numbers compare to 69 and 74 humpback chub captured in 2003 and 2004. Within-year recaptures were modest – five humpback chub were recaptured in 2007, and four were recaptured in 2008. In addition to the within-year recaptures, 14 humpback chub were recaptured in 2007 and 15 were recaptured in 2008 that had been tagged in previous years. Eight of 29 (28%) humpback chub recaptured in 2007–2008 were tagged in Westwater Canyon in prior years.

Catch rates for roundtail chub in 2007 were similar to those in 2003-2004; however, catch rates in 2008 were significantly higher. Captures of roundtail chub totaled 401 in 2007 and 1,001 in 2008. In contrast, 633 and 312 roundtail chub were captured in 2003 and 2004, respectively. Within-year recaptures of roundtail chub were low: eight were recaptured in 2007; 14, in 2008. In addition to within-year recaptures, seven roundtail chub captured in 2007 had been tagged in previous years; in 2008, there were 30 such recaptures. Nineteen of the recaptured roundtail chub were tagged in Westwater Canyon in previous years and three were tagged there in the same year that we captured them in Black Rocks (two in 2007, one in 2008).

Total length of adult humpback chub captured in 2007 and 2008 ranged from 210 to 370 mm. No juvenile humpback chub were captured. Growth of humpback chub captured in multiple years averaged 14.0 mm/yr for fish <300 mm TL and 4.5 mm/yr for fish > 300 mm TL. Mean relative condition of humpback chub improved significantly from 2004 to 2008.

Total length of adult roundtail chub captured ranged from 200 to 390 mm. Fewer juvenile roundtail chub were captured in 2007–2008 than in 2003–2004, and none of those 2007-2008 fish were recaptured. Growth of roundtail chub captured in multiple years averaged 24.5 mm/yr for fish <300 mm TL and 18.1 mm/yr for fish > 300 mm TL. Mean relative condition of roundtail chub improved significantly from 2007 to 2008.

Size of the Black Rocks adult population of humpback chub in 2007 was estimated at 345 individuals (95% CI; 171–795), and in 2008, 287 individuals (95% CI; 179–505). While these estimates are low, they fall within the confidence intervals of earlier abundance estimates (1998-2000 and 2003-2004), so we cannot conclude that the decline observed was real. Development of a captive refuge population may be justified given that the estimates provided here, when combined with those from neighboring Westwater Canyon (1,757 fish [95% CI; 1,097-3,173] in 2007; 1.358 fish [95% CI; 997-1,957] in 2008), total less than the minimum viable adult population size of 2,100 adults, as set forth in the 2002 Recovery Goals document (USFWS, 2002).

Estimates of population abundance generated for roundtail chub were considered unreliable because of documented cases of animals entering the population from outside the study area during the study period (i.e., violation of the models population closure assumption).

INTRODUCTION

The humpback chub (*Gila cypha*) is a long lived (up to 30 years) moderate-sized cyprinid endemic to the Colorado River Basin (Minckley 1973) that is currently listed as endangered under the Endangered Species Act of 1973 (USFWS 2000). The species was not described until 1946 (Miller 1946) and little was known about its distribution until relatively recently. A pronounced hump behind its head gives this fish a striking, unusual appearance used as a hydrodynamic foil that helps it maintain position in whitewater habitat. It has an olive-colored back, silver sides, a white belly, small eyes and a long snout that overhangs its jaw (Miller 1946). Humpback chub are currently found in discrete populations within canyon-bound reaches of large rivers in the Colorado River basin (Valdez and Clemmer 1982). The largest population occurs in the Little Colorado and Colorado rivers in Grand Canyon (Valdez and Ryel 1995; Douglas and Marsh 1996). All other populations occur in the upper Colorado River basin, including the Yampa and Green rivers within Dinosaur National Monument (Karp and Tyus 1990; Finney 2006), the Green River in Desolation and Gray canyons (Chart and Lentsch 1999a; Jackson and Hudson 2005), and the Colorado River in Black Rocks (Kaeding et al. 1990; McAda 2007), Westwater Canyon (Chart and Lentsch 1999b; Jackson 2010), and Cataract Canyon (Valdez 1990; Badame 2008).

Conflicts between water development in the upper basin and endangered fish began soon after the Endangered Species Act (as amended) was passed in 1973 (Wydoski and Hamill 1991). In an attempt to resolve those conflicts, the Upper Colorado River Endangered Fish Recovery Program (Recovery Program) was developed to recover humpback chub (and other listed fishes) and allow the states of the upper basin to continue to develop water to satisfy the needs of a growing population (Wydoski and Hamill 1991). During formation of the Recovery Program, an Interagency Standardized Monitoring Program (ISMP) was developed to monitor trends in the humpback chub populations in Black Rocks and Westwater Canyon (USFWS 1987; McAda et al. 1994). The ISMP sampling was limited to short periods of trammel netting at

2-or 3-yr intervals. This sampling was sufficient to develop catch-per-effort indices indicating that humpback chub still occupied Black Rocks and Westwater Canyon and that young *Gila* continued to recruit to the adult population, but it was not sufficient to develop reliable estimates of population size.

During development of quantifiable Recovery Goals for humpback chub (USFWS 2002) it was determined that regular estimates of size and structure of the major populations were necessary to monitor recovery efforts. Studies designed to obtain the necessary data to produce population estimates have been completed in Yampa-Whirlpool, Westwater, Desolation-Gray, and Cataract Canyons. The first two series of population estimates for Black Rocks humpback chub were done in 1998–2000 (McAda 2002) and 2003–2004 (McAda 2007). The Black Rocks population combined with the Westwater population is the largest core population found in the upper-basin. Amongst many other factors needed for recovery and downlisting, all populations of humpback chub must have self-sustaining populations over a five year period where the trend in adult (Total Length [TL] > 200mm) abundance does not decline significantly and mean estimated recruitment of juveniles (TL 150-199mm) equals or exceeds annual adult mortality. In addition, one of the five upper-basin populations maintains a core population such that each point estimate exceeds 2,100 adults (USFWS 2002). Estimates of roundtail chub population size were made in 2003 and 2004 for Desolation and Gray Canyons (Jackson and Hudson 2005) and Westwater Canyon (Jackson 2010) during humpback chub population studies. The Recovery Program recommended that population estimates for both species should be made concurrently during future work (UCRB Biology Committee).

The first objective of this report is to present the third series of estimates for population size and recruitment for Black Rocks humpback chub and the first for Black Rocks roundtail chub, 2007–2008. And the second objective is to describe the population structure of humpback and roundtail chub captured in Black Rocks, 2007-2008.

METHODS

Study Area

Black Rocks is a 1.4 km section of deep-water habitat formed by erosion-resistant black metamorphic rocks, called gneiss and schist that were intruded by veins of molten rock (igneous materials), in the river channel. This unique area is about 6.4 km upstream from the Colorado-Utah state line and extends from about 217-218.4 river kilometer (RK, as measured from the Colorado River confluence with the Green River RK 0.0; or 135.5 to 136.5 river mile [RM]; Figure 1) within Ruby Horsethief Canyon. Black Rocks and the upstream end of Westwater Canyon are separated by about 16.8 km (10.5 miles). The river channel is narrow and turbulent eddies, pools and runs are located throughout the short reach. Deep areas along the rock faces provide important habitat for humpback chub. Black Rocks is substantially deeper than other parts of the Colorado River, with an average depth of about 5 m and maximum depth of about 18 m (Valdez et al. 1982). Reaches up and downstream of Black Rocks are shallower and rarely exceed 2.5–3 m in depth (Pitlick and Cress 2000).

Field Sampling

Sampling was done during base flows of mid-September through October, after water temperatures began to cool for the year as recommended by McAda (2002, 2007) to minimize handling stress experienced during warm weather. To develop reliable population estimates, sampling passes were scheduled to correspond to a mark-recapture sampling design. Sampling was conducted for four days (one pass), with one week separating passes. Four passes were conducted in both years (2007 and 2008) of the study. Most sampling was done with multi-filament trammel nets set along shoreline eddies or in other quiet habitats. Nets were attached to rock faces with pitons and straps. A sash weight was attached to the lead line and a floating buoy was attached to the float line of the free floating end of the net. Four to six trammel nets were set mornings and evenings during the crepuscular periods and checked at one to two hour intervals.

Trammel nets were primarily 3.9 cm inner mesh, but 2.9 cm inner mesh nets were also used in an attempt to catch smaller *Gila*. Nets were left in the same location for 3–4 hours unless no fish were collected or excessive amounts of trash and debris required the net to be moved sooner. As much of the Black Rocks area as possible was sampled during each pass to ensure that all humpback chub had a possibility of being captured; however, a shallow riffle at about 218.1 RK (136.3 RM) limited sampling above that point. Most locations were sampled more than once during each pass.

All *Gila* were removed from the nets, tentatively identified as humpback chub or roundtail chub (*G. robusta*) and immediately placed in a freshwater holding tank. Other species were identified, counted, and released at the capture site. Net locations were identified to the nearest 0.16 km (0.1 mile) and sampling time was recorded. After all nets were checked, all *Gila* captured were transferred to a central processing location. *Gila* were not released at individual capture sites to expedite removing fish from multiple nets and to prevent immediate recapture.

In addition to trammel nets, the entire Black Rocks reach was sampled with aluminum hulled motorboat-based electrofishing twice during most passes (passes one through four in 2007, passes one and four in 2008). Electrofishing was used once in the early morning and once in the afternoon. Both shorelines were electrofished on each occasion. Electrofishing was utilized to increase the probability of capturing small *Gila* and to capture fish that might be in areas that we could not sample with trammel nets. Fish captured with electrofishing were processed after each sample at the central processing point (Figure 1).

During processing, *Gila* were inspected and categorized as either humpback chub or roundtail chub using criteria outlined by Douglas et al. (1989). Each fish was measured for total length (TL; ±1 mm), weighed with an OHAUS® electronic scale (± 1 gram), and scanned for a passive integrated transponder (PIT) tag. Humpback chub and roundtail chub that lacked a PIT tag were tagged with one. After processing, all *Gila* were placed into an oxygenated holding tank containing a mixture of salt (0.8%

salt/water) and Stress Coat® (five milliliters/ 38 liters of water) for about one hour as a skin treatment and for us to assess their general post-capture health. Fish were then released near the central processing point.

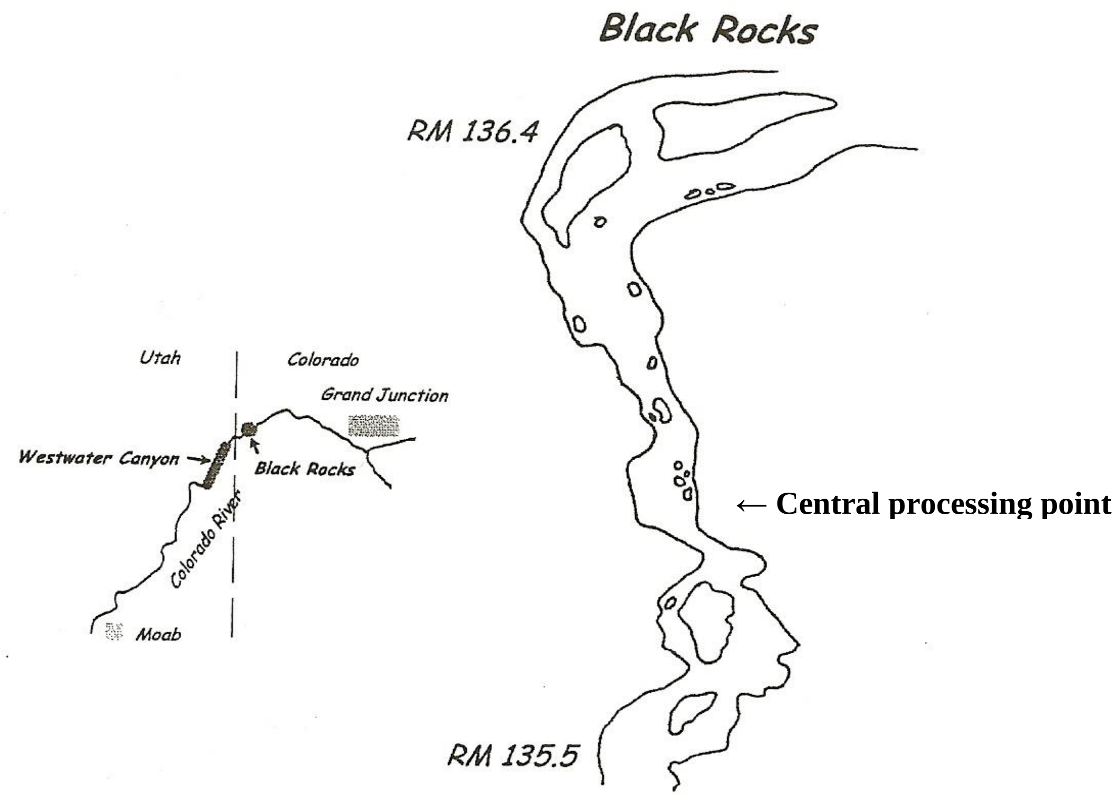

FIGURE 1. Black Rocks study area and relationship to Westwater Canyon. The upstream end of Westwater Canyon is about 16.8 km (10.5 mi) downstream from Black Rocks. *Gila* were worked up at a central processing point after all trammel nets were run.

Data Analysis

Mean catch per effort for trammel netting (CPE, fish per net-hour) was calculated for humpback chub and roundtail chub for each pass and year. Mean CPE was compared among passes and years using Analysis of Variance; pairwise comparisons were made using a Bonferroni adjustment (P<0.05; XLSTAT 2009). Mean CPE was not calculated for electrofishing.

Capture-recapture data for all captured *Gila* were placed into a matrix with a row for each individual fish and columns organized by year and pass. Separate matrices were developed for humpback and roundtail chub, respectively. Estimates of population abundance were made for adult humpback chub (≥200 mm TL; USFWS 2002) and for all captured roundtail chub ≥ 180 mm TL. The matrix indicated whether an individual was captured or not during each pass and the TL at the time of capture (± 1 mm TL). Within pass recaptures were not included in the matrix for parameter estimation. Program MARK (White and Burnham 1999) was used to calculate annual abundance estimates for each species of *Gila* using TL as an individual covariate to model detection probabilities across both years (2007 and 2008). MARK allows a variety of different models to be run and provides a model selection algorithm to suggest the best model for the data set used. The best fit model was Model M_t of CAPTURE:

Real Function Parameters of {S(.) p(year*t + TL) = c(year*t + TL)}

Estimates were generated with the Huggins (1989, 1991) estimator, where the initial capture probability (p) was assumed equal to the recapture probability (c), the parameters in this model are of a constant survival rate [S(.)], and TL was a predictor of capture probability. The capture probabilities are year-specific (the primary sessions occur across years). Within primary sessions, the capture probabilities across secondary occasions are occasion-specific. So each occasion during the entire study had its own capture probability estimated (G.White, Colorado State University, *personal* *communication*). Model M_t of CAPTURE assumes the following about a population: all members of the population are equally at risk of capture, the probability of capture changes from one sampling occasion to the next, the population is closed, PIT tags are not lost during the project, and each animal has a constant and equal probability of capture on each trapping occasion (White and Burnham, 1999). The Coefficient of variation were calculated (CV; standard error divided by the abundance estimate) providing a measurement for the precision of the estimate, or how well the data fits the model. CV values less than 0.20 are generally considered necessary for a robust estimate.

Length-frequency distributions of chub were calculated by year. Humpback chub recaptured within a year were only used once (last capture) in the analysis. Mean annual growth increments were calculated from differences in total length of fish that were captured in more than one year. Mean CPE and a length-frequency distributions were also calculated for roundtail chub.

Consistent with methods used to track body condition of Colorado pikeminnow (*Ptychochelius lucius*) in the upper Colorado River, relative condition was calculated for humpback chub and roundtail chub (Osmundson and White 2009). Relative condition accounts for allometric growth and makes the measurement comparable between species and between different units of measure (Le Cren 1951). The standard average body condition is represented by 100 (x 100). Relative body condition (K_n) is the observed mass (M_o) of a given fish divided by the expected mass for a fish of its length:

$$K_n = (M_o \div M_e) \times 100$$

The expected mass or standard weight (M_e) is calculated using constants derived from mass-length regressions:

$$\log_{10} Me = ((\log_{10} \text{length}) \text{ slope}) + \text{y intercept}$$

The constants for these time-of-year-specific mass-length regressions were derived from humpback chub or roundtail chub captured from the mainstem of the upper Colorado River (Black Rocks and

Westwater) from 1991 through 2008. Wege and Anderson (1978) suggest using samples from the mid-to-late growing season when tissue accumulation is neither high nor low (pre-or-post spawning). Relative condition of each animal was calculated using the constant specific to animals captured from the last week of August through the first week of November. Mean K_n was compared among passes using Analysis of Variance; pairwise comparisons were made using a Bonferroni adjustment (P<0.05; XLSTAT 2009)

RESULTS

SAMPLING DATES, RIVER FLOW AND WATER TEMPERATURE

Sampling began in mid-September and concluded in late October in both years (Table 1). Mean river flow varied among passes, from about 4,400 to 5,700 cfs (Table 1). With the exception of flows dropping 1,000 cfs between the first and second pass in 2007, fluctuations were generally gradual and not subject to dramatic, short-term pulses. Amplitude of fluctuation within passes ranged from 20 to 1,380 cfs (median, 270 cfs), but never resulted in dramatic changes in river elevation during the sampling period. Mean daily water temperature was typically 25º C (or greater) in most of July and August but declined to 17–18º C when sampling began in mid September (Table 1). Cooling progressed rapidly in fall and declined to about 10º C when sampling ended in late October.

TABLE 1. Sampling dates, river flow and water temperature during Black Rocks sampling, 2007–2008. Measurements were made at the USGS river gage at the Utah-Colorado state line (09163500).

Year	Dates	Pass	Mean River Flow[a] (CFS)	Mean Water Temperature[a] (ºC)
2007	9/18–21	1	5,690	17.15
	10/03–06	2	4,700	14.53
	10/15–18	3	4,590	11.78
	10/30–11/02	4	4,495	10.55
2008	9/16–19	1	5,028	17.48
	9/29–10/02	2	4,573	17
	10/14–17	3	4,518	10.13
	10/27–30	4	4,448	9.28

[a] Mean of daily means

GENERAL FISH HEALTH

Most fish appeared to be in good health during and after treatment and swam quickly away after they were released. In 2007, one roundtail chub died after its gills were damaged by a trammel net. In 2008, five roundtail chub appeared stressed and were not tagged; however, they swam away after treatment. All humpback chub appeared healthy on release. No evidence of parasites or fungus was noted in captured or recaptured fish

HUMPBACK CHUB

Relative Abundance—A total of 61 individual humpback chub were captured in 2007 (five were recaptured) and 74 in 2008 (four were recaptured). Mean catch rates of humpback chub captured in trammel nets ranged between about 0.07 to 0.30 fish per net hour in 2007–2008 (Figure 2). Mean CPE in 2007–2008 was similar to that observed during 2000–2004 (Figures 3 and 4). CPE in one pass in each year exceeded that in 2000 (not significantly) and was similar to that observed during some passes in 1998–1999. Although mean CPE varied, there were no significant differences among passes ($P<0.05$). Total numbers collected with electrofishing during other passes ranged from none to one.

Mean CPE was not calculated for electrofishing, but a total of five humpback chub were captured with electrofishing in 2007 and one in 2008. Two humpback chub were electrofished in pass three of 2007: otherwise, no more than one was captured per pass using this method.

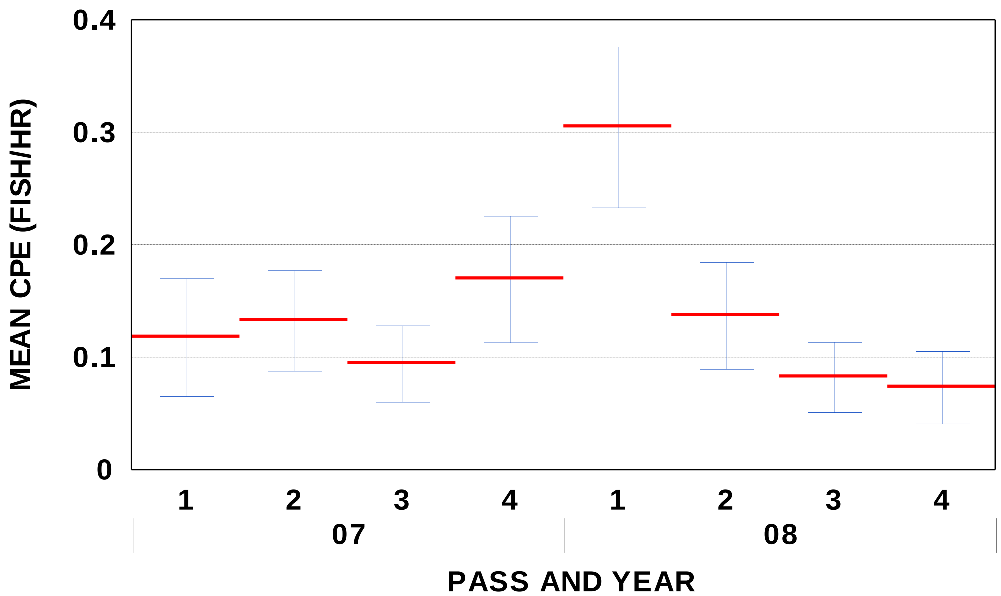

FIGURE 2. Mean CPE (fish/hr; ± 1 SE) for humpback chub captured using trammel nets in Black Rocks, 2007–2008. Dates of sampling trips (passes) are provided in Table 1.

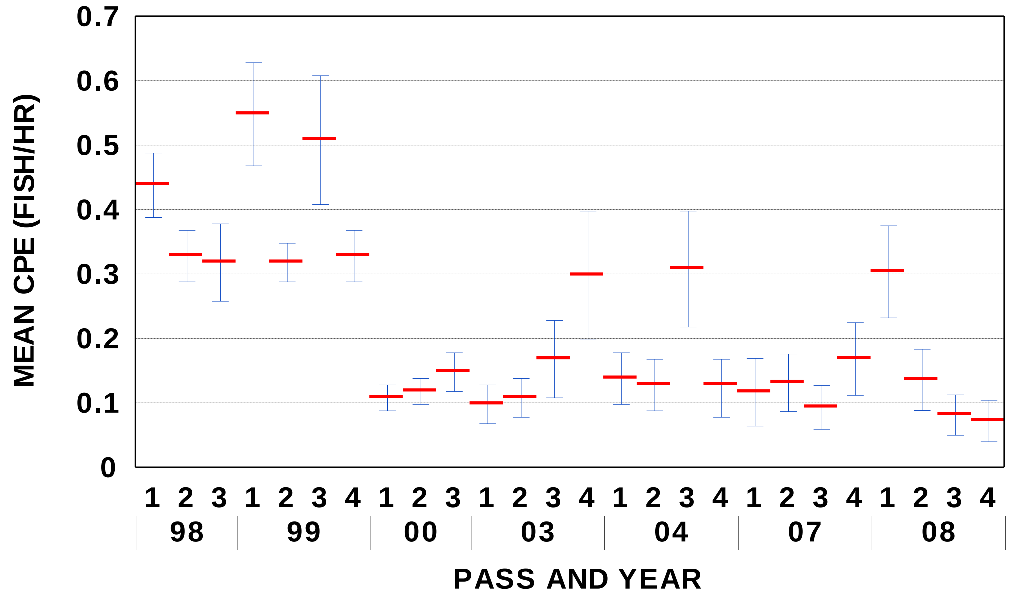

FIGURE 3. – Mean CPE (fish/hr; ± 1 SE) by year and pass for humpback chub captured using trammel nets, 1998–2000, 2003–2004 and 2007–2008.

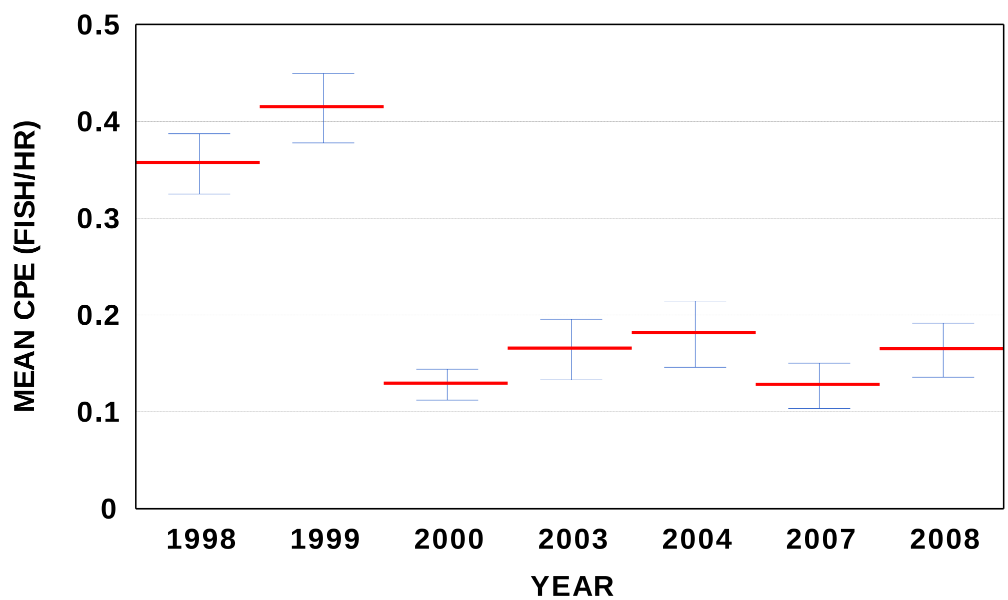

FIGURE 4. – Mean CPE (fish/hr; ± 1 SE) for humpback chub captured using trammel nets, 1998–2000, 2003–2004 and 2007–2008

Movement— Two humpback chub recaptured in Black Rocks in 2007 were originally tagged in Westwater Canyon in 2003 and recaptured there in 2005. Six more humpback chub recaptured in Black Rocks in 2008 were originally tagged in Westwater Canyon; one was tagged in 2004, three in 2005 (one of which was recaptured there in 2007), and two in 2007. One humpback chub tagged in Black Rocks in 2008 was recaptured in Westwater Canyon 19 days later (D. Elverud, Utah Division of Wildlife Resources, *personal communication*). This is the first documented within-year recapture of a humpback chub between the two sites since ISMP sampling shifted to a multi-pass, mark-recapture sampling design.

Size Structure—Adult humpback chub captured in Black Rocks ranged from 207 to 371 mm TL (mean 288 mm; Figure 5). No juvenile *Gila* (< 200 mm) were identified as humpback chub during the study. Size structure was similar to that observed in 1998–2004 (McAda 2007; Figure 6) except that larger chub (380 to 400 mm) were absent from the 2007 and 2008 samples.

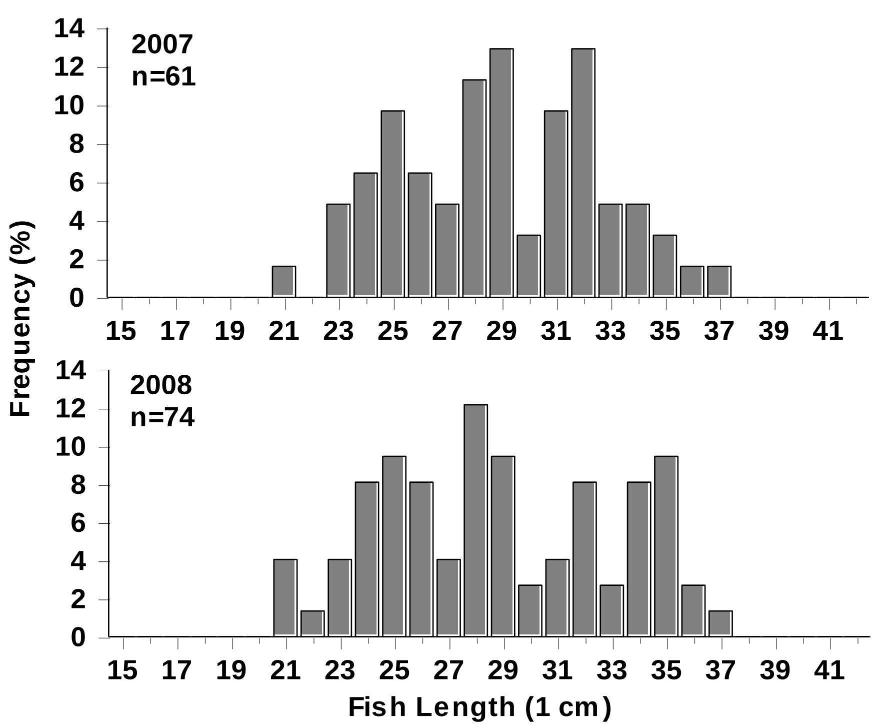

FIGURE 5. Size structure of humpback chub in Black Rocks, 2007-2008.

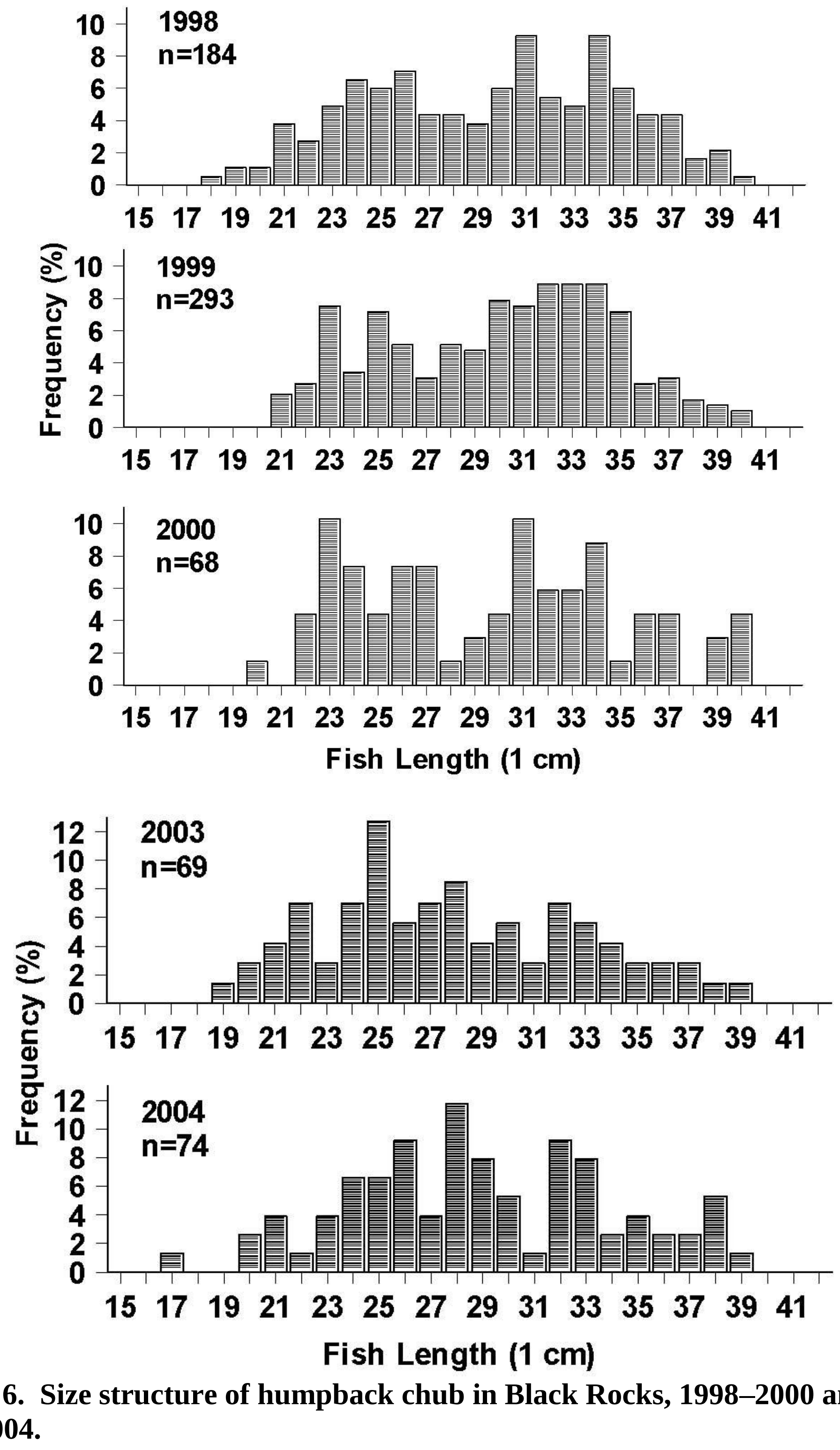

FIGURE 6. Size structure of humpback chub in Black Rocks, 1998–2000 and 2003–2004.

Growth—A total of 29 individual humpback chub were captured during 2007-2008 that had been captured and measured in previous years, in some cases, more than once. These fish were partitioned into two groups based on their length when initially tagged: those < 300 mm TL and those ≥ 300 mm TL. Mean annual growth for fish < 300 mm was 14.0 mm/yr (n = 21; SE = 2.7; range, 0–41). Mean annual growth of fish ≥ 300 mm was 4.5 mm/yr (n = 8; SE = 2.2; range, 0–18).

Condition—The M_e (mass-length regression) equation derived from humpback chub captured in Black Rocks and Westwater Canyon (n = 4,543) is

$$\log_{10} M_e = ((\log_{10} \text{length})\ 2.839) + (-4.732)$$

Mean K_n (relative body condition) increased significantly (P<0.001) between 1991 and 1994, increased again between 1998 and 1999, and again between 1999 and 2000. Mean K_n decreased significantly between 2003 and 2004, but increased again between 2007 and 2008. The lowest level was in 1991; the highest levels in 2000, 2003 and 2008, when means were not significantly different (Figure 7). There appeared to be an overall upward trend in mean K_n from 1991 to 2008. In most years, mean K_n of humpback chub in Westwater Canyon and Black Rocks was similar, with trends tracking one another quite closely (Figure 8). Mean K_n was significantly (P<0.001) higher in Westwater Canyon than Black Rocks in 1999, 2007 and 2008. Mean K_n was significantly (P<0.001) lower in Westwater Canyon than Black Rocks in 2003.

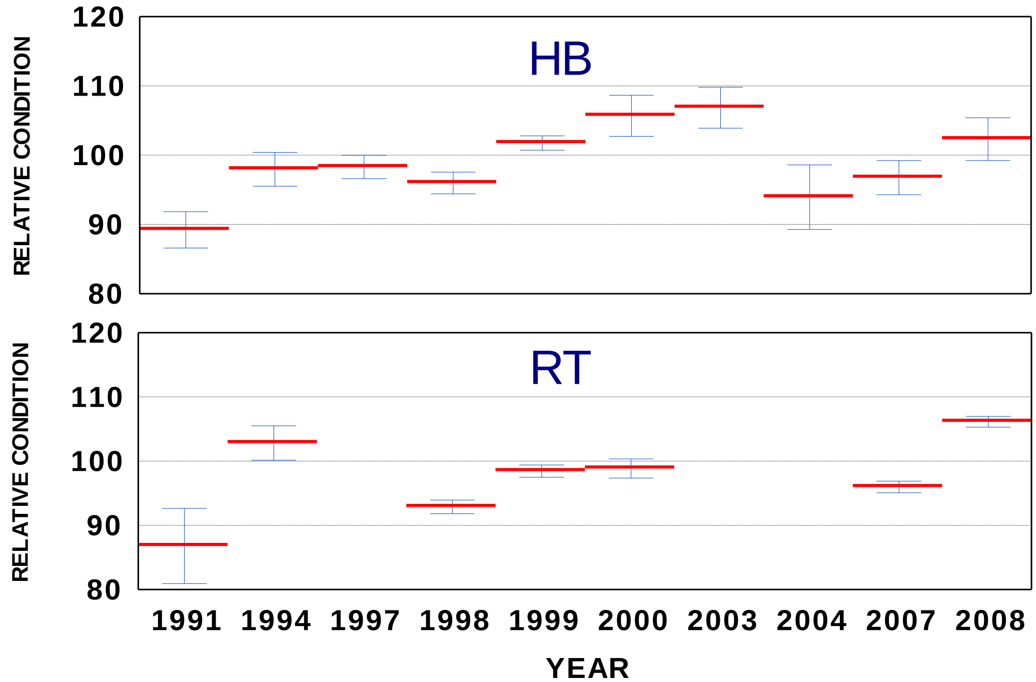

FIGURE 7. Mean relative body condition (K_n) of humpback chub (HB) and roundtail chub (RT) captured in Black Rocks of the Colorado River (RK 217–218.4). Upper and lower bars represent 95% confidence intervals.

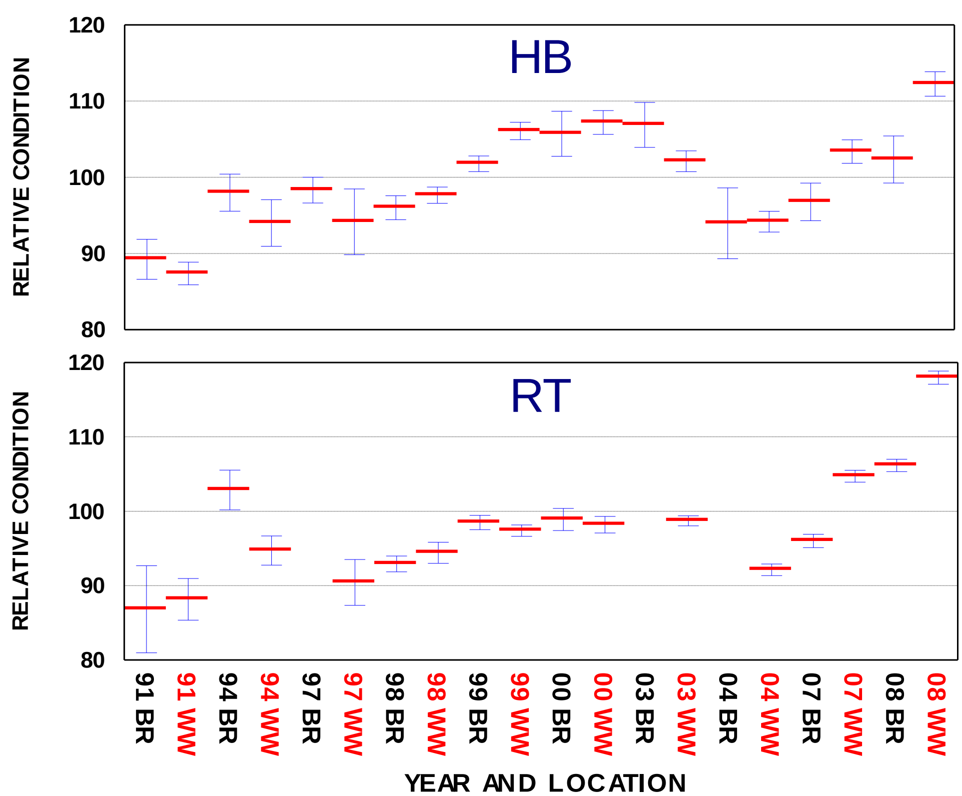

FIGURE 8. Mean relative condition (K_n) of humpback chub and roundtail chub in Black Rocks and Westwater, 1991–2008.

Population Estimate—The top model selected in program MARK for humpback chub was model M_t of CAPTURE (White et al. 1982) with TL used as an individual covariate to model detection probabilities across both years. Total length may affect a fish's probability of capture and the TL specified probabilities were utilized in calculating the 2007–2008 abundance estimates. No model averaging was necessary because model M_t had almost all of the weight (G. White, CSU, personal communication).

Considering the small sample of humpback chub and modest within-year recaptures (five in 2007; four in 2008), the 2007 and 2008 estimates appear reasonable (Table 2). The abundance estimate for 2007 is 345 adults and the confidence interval (171–795 animals) is narrower than those of estimates from 2000–2004. Because earlier estimates had wide confidence intervals, the 2007 estimate is not significantly different from them (Table 3). Abundance in 2008 is estimated at 287 adults with a confidence interval (179–505 animals) slightly narrower than in 2007. The 2008 estimate is significantly lower than the estimates for 1998 and 1999, but is not significantly different than those for 2000, 2003, and 2004 (Table 3). Coefficient of variation less than 0.20 are generally considered necessary for a robust estimate; however, CV values for the humpback chub estimates were 0.42 in 2007 and 0.28 in 2008. The higher CV in 2007 was probably due to a smaller sample size ($n = 61$ in 2007, $n = 74$ in 2008). While these CV values are not ideal (i.e. < 0.20), they are the best values generated since 1999 (Table 3). Because capture probabilities (P-hat) vary with fish length, p-hats were calculated for average-size humpback chub for making among-year capture probability comparisons. This average (mean) total length of 280 mm was calculated from all humpback chub lengths in the Upper Colorado River Recovery Program's database. P-hat for humpback chub in Black Rocks ranged from 0.03 to 0.07 in 2007, and from 0.03 to 0.15 in 2008.

Although there were few within-year recaptures of fish that could be used in a population estimate, 21 humpback chub were recaptured that had been handled in a previous year of this study or in earlier mark-recapture studies (McAda 2002, 2007). In addition, eight humpback chub were recaptured that had been captured in Westwater Canyon (two in 2007, six in 2008). The capture history of fish captured in more than one year illustrates the fact that many fish probably remain within Black Rocks during the annual sampling period. Despite this, it is very difficult to capture and recapture individual fish within a given year (Table 4). Five within-year recaptures were recorded in 2007; however, five more fish were recaptured in 2008 that were tagged but not recaptured in 2007. In addition, six fish were tagged and released in 1999 and not captured again until 2007 or 2008.

TABLE 2. Population estimates for adult humpback and roundtail chub in Black Rocks for 2007–2008 using model M_t of Capture in program MARK.

Estimates of Derived Parameters Population Estimates of {S(.)p(year*t + TL)=c(year*t + TL)}							Capture Probabilities P-hat Based on user-specified 280 mm total length individual covariate							
			95% Confidence Interval											
Sp.	Year	N-hat	SE	Lower	Upper	CV	Pass 1	95% CI	Pass 2	95% CI	Pass 3	95% CI	Pass 4	95% CI
HB	2007	345	146.126	171	795	.423	0.033	.012-.088	0.036	.014-.094	0.045	.017-.112	0.07	.028-.166
HB	2008	287	79.154	179	505	.276	0.145	.078-.252	0.062	.031-.121	0.055	.027-.109	0.025	.01-.061
RT[a]	2007	7230	2569.482	3748	14336	.355	0.005	.002-.011	0.004	.002-.009	0.021	.01-.042	0.04	.02-.079
RT[a]	2008	12938	2322.235	9183	18417	.178	0.011	.008-.016	0.008	.005-.012	0.027	.019-.039	0.05	.036-.07

[a] Considered unreliable, see text

TABLE 3. Population estimates for adult humpback chub in Black Rocks, 1998–2004 using Model M_o and Model Chao M_t (2004).

Year	Model	Estimate	95% CI	CV	P-hat
1998	M_o	764	512 - 1,206	0.23	0.08
1999	M_o	921	723 - 1,208	0.13	0.09
2000	M_o	539	223 - 1,497	0.54	0.04
2003	M_o	478	221 - 1,176	0.46	0.04
2004[a]	Chao M_t	932	307 - 3,244	0.98	0.01

[a]Considered unreliable (McAda 2007)

TABLE 4. Capture history of humpback chub captured in 2007–2008 that were handled in earlier years (B = Black Rocks, W = Westwater).

PIT TAG	1998	1999	2000	2003	2004	2005[1]	2007	2008
2007								
3D9257C69199D		B					B	
3D9257C69ECD9		B					B	
3D9257C6AC975		B		B			B	
3D9257C6B757E		B					B	
3D9257C679FE8				B			B	B
3D9257C6A5A06				B			B	
522A4A073E				B			B	
3D9257C6BAA71				B			B	B
3D9257C6B76B0				B			B	
3D9257C6B6794					B		B	
3D9257C6AC917					B		B	
3D9257C6BD25C					B		B	
3D91BF18C0E9D						W	B	
3D91BF18C281B				W		W	B	
2008								
3D91C2C5729E5		B						B
3D91C2C43E4D4		B						B
3D91C2C5811B2				B	B			B
3D91C2C578E6F				B				B
3D91BF19EC327							B	B
3D9257C6BC58E							B	B
3D9257C69E242							B	B
3D9257C6B6590							B	B
3D9257C6B9029							B	B
3D9257C6ABAB1							W	B
3D9257C6A1B43							W	B
3D91BF18C21AA						W		B
3D91BF1D88B3C					W			B
3D91BF1D86A0E						W	W	B
3D91BF18C2CCF						W		B

[1] Sampling only occurred in Westwater.

ROUNDTAIL CHUB

Relative Abundance—a total of 401 roundtail chub was captured in 2007 and 1,001 in 2008. Mean CPE for roundtail chub ranged from 0.29 to 7.38 fish per net-hour (Figure 9). However, mean CPE was significantly higher in the last two passes of 2008 than in the other sample efforts (4.12, 7.37; $P<0.001$). Mean CPE in 2003–2004 and 2007–2008 is significantly higher to that observed during 1998–2000 (Figure 10).

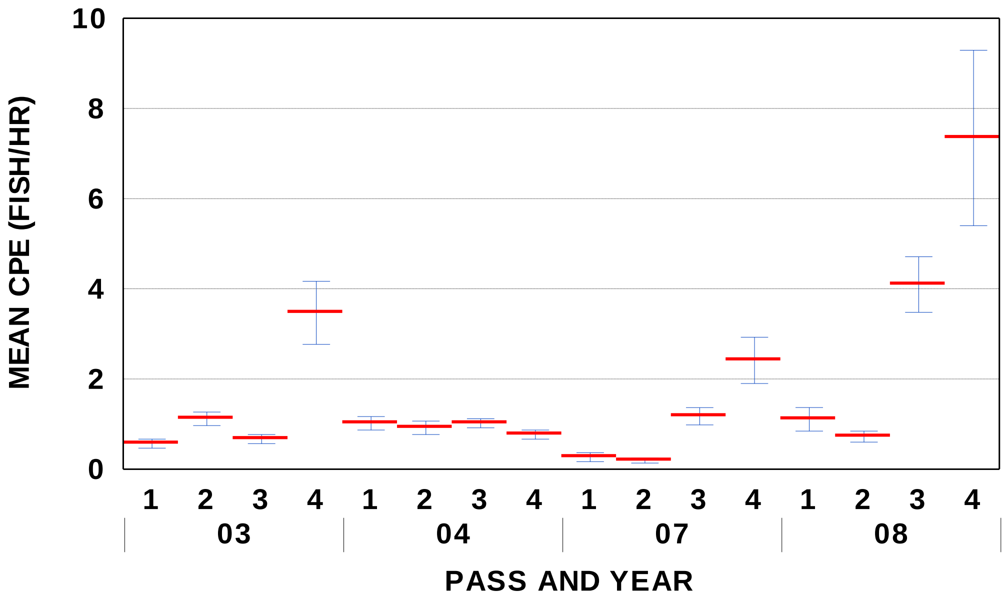

FIGURE 9. Mean CPE (fish/hr; ± 1 SE) by pass and year for roundtail chub captured using trammel nets in Black Rocks, 2003–2004 and 2007–2008. Dates of sampling trips (passes) are provided in Table 1.

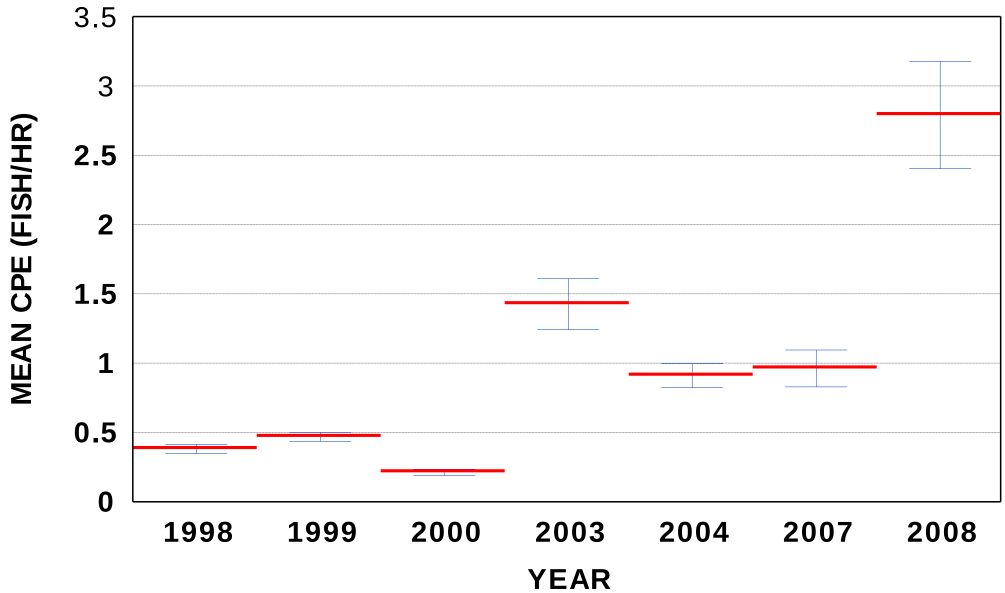

FIGURE 10. Mean CPE (fish/hr; ± 1 SE) for roundtail chub captured using trammel nets in Black Rocks, 1998-2000, 2003–2004 and 2007–2008.

Movement—Seven roundtail chub were recaptured in Black Rocks in 2007 that were originally tagged in Westwater Canyon: one was tagged in 2003: one in 2004: three in 2005: two in 2007. In 2008, twelve roundtail chub were recaptured in Black Rocks that were originally tagged in Westwater Canyon: two were tagged in 2004: two in 2005: eight in 2007. One roundtail chub tagged in Black Rocks in 2007 was recaptured in Westwater Canyon in 2008 (D. Elverud, UDWR, *personal communication*).

Size Structure—Adult size structure of roundtail chub was the same as observed for humpback chub (Figure 11). Roundtail chub size structure was larger in 2007–2008 than in 2003–2004 (McAda 2007, Figure 12). Less than 3% of the roundtail chub captured in 2007 and 0.5% in 2008 were less than 200 mm long (Figure 11).

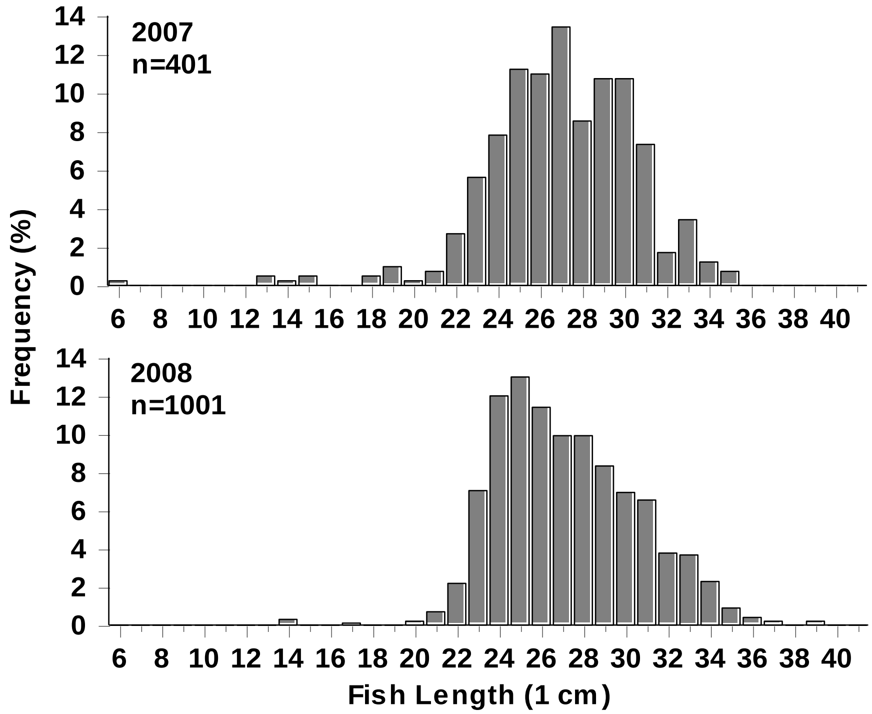

FIGURE 11. Size structure of roundtail chub in Black Rocks, 2007-2008

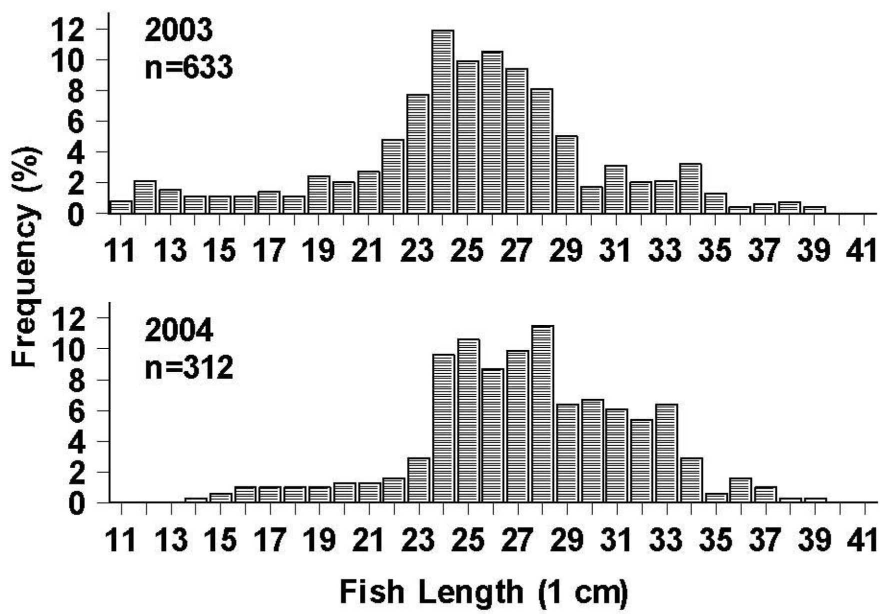

FIGURE 12. Size structure of roundtail chub in Black Rocks, 2003–2004.

Growth—A total of 34 individual roundtail chub was captured in 2007 and 2008 that had been captured and tagged in previous years. Fish were divided into the same two length groups as the humpback chub for analysis. Mean annual growth for fish < 300 mm was 24.5 mm/yr (n = 31; SE = 2.2; range, 6-54). Mean annual growth for fish $\geq$ 300 mm was 18.1 mm/yr (n = 3; SE = 4.1; range, 14–26).

Condition—The M_e equation for roundtail chub from the Westwater-Black Rocks population (n = 8,444) is

$$\log_{10} M_e = ((\log_{10} \text{length})\ 2.928) + (-4.935)$$

The trend in mean K_n for roundtail chub tracked that of humpback chub in the years data were available for both species (Figure 7). Mean K_n increased significantly (P<0.001) between 1991 (the lowest level) and 1994. An upward trend also occurred from 1998 through 2000. Mean relative condition in 2007 was similar to that in 1999 and 2000 and then significantly (P<0.001) increased to the highest level in 2008. In most years, roundtail chub from Westwater Canyon and Black Rocks had similar mean K_n (Figure 8). Mean K_n was significantly (P<0.001) higher in Westwater Canyon than in Black Rocks in 2007 and 2008, and was significantly (P<0.001) lower in 1994.

Population Estimate—Despite relatively large samples, within-year recaptures of roundtail chub were (eight in 2007, and 14 in 2008). The model assumption of population closure was likely violated considering the large pulses of fish detected in passes three and four of 2007 and 2008 (Figure 8) and fish moving within the sample period from Westwater Canyon to Black Rocks (two in 2007, and one in 2008; Table 5). Hence, population estimates offered here (Table 2) have questionable reliability. The abundance estimate for 2007 was 7,230 animals (95% CI:3,748–14,336); the estimate for 2008, 12,938 animals (95% CI:9,183–18,417). However, the wide confidence intervals led to non-significant differences between the two annual estimates. Values of

CV for roundtail chub were 0.36 in 2007 and 0.18 in 2008. The higher CV in 2007 was probably due to a smaller sample size (n = 403) than in 2008 (n = 1,001). P-hat for roundtail chub of average length (280 mm TL) ranged from 0.004 to 0.04 in 2007 and 0.008 to 0.05 in 2008.

The capture history of roundtail chub is included to illustrate that population closure was violated (Table 5). Three fish were captured during the same sample period in both Westwater Canyon and Black Rocks. In addition, more fish were recaptured in 2008 that were tagged in 2007 (18) than were recaptured within the same year of tagging (8 in 2007, and 14 in 2008). In addition, 19 roundtail chub were recaptured in Black Rocks that were originally tagged in Westwater Canyon (7 in 2007, and 12 in 2008).

TABLE 5. Capture history of roundtail chub captured in 2007–2008 that were handled in earlier years (B = Black Rocks, W = Westwater; Roundtail chub were not tagged in Black Rocks during 2003-2004).

PIT TAG	2003	2004	2005	2007	2008
2007					
3D91BF1CCFDEB			W	B	
3D9257C6B9AF0	W			B	
3D9257C6A8001				W & B	
3D91BF18C648C			W	B	
3D91BF1CD628D		W		B	
3D9257C6A0979				W & B	
3D91BF18C2B5D			W	B	
2008					
3D9257C6B814D				B	B
3D9257C6B6B33				B	B
3D9257C6A5816				B	B
3D9257C69E193				B	B
3D9257C6AB2CA				W	B
3D9257C6B9916				B	B
3D9257C6B99F8				B	B
3D9257C6B5F5A				B	B
3D9257C679FC4				B	B
3D9257C6B9037				B	B
3D91BF18C4A79			W		B
3D91BF1A02C60			W		B
3D9257C6A6DAA				W	B
3D9257C6B7AE3				B	B
3D9257C6B8C7D				B	B
3D9257C66CD05				W	B
3D9257C6B9751				B	B
3D91BF1A04080		W			B
3D9257C6798A1				B	B
3D9257C69EC8E				B	B
3D9257C6BA4A4				W	B
3D9257C69F0F5				B	B
3D9257C6A017E				B	B
3D9257C6B69C9					W & B
3D9257C66C54A				W	B
3D9257C6A8A27				W	B
3D9257C66CCF2				W	B
3D9257C69F7AE				B	B
3D91BF1A050A2		W			B
3D9257C6B75CE				B	B

DISCUSSION

Model M_t of CAPTURE assumes the following about a population: all members of the population are equally at risk of capture, the probability of capture changes from one sampling occasion to the next, the population is closed, PIT tags are not lost during the project, and each animal has a constant and equal probability of capture on each trapping occasion (White and Burnham, 1999). Although humpback chub have been shown to move between Black Rocks and Westwater Canyon (e.g. Valdez and Clemmer 1982; McAda 2002; 2007; Jackson 2010, Table 4), the assumption of population closure is largely met because the sampling period is relatively short. One humpback chub did leave Black Rocks in 2008 and was recaptured in Westwater Canyon the same year; however, this is evidently a rare occurrence because it is the first documented case since the onset of the population estimation program (1998–2008). High site fidelity trends have been reported for this species in the fall (Archer et al 1985; McAda 2007; Jackson 2010); however, the small sample area and one-week period between passes should have allowed for adequate mixing and an equal risk of capture. None of the humpback chub handled during this study had evidence of a lost or failed PIT tag (i.e., presence of a PIT tag scar when no tag was detected). Model Mt fit the data best because it allowed capture probability to vary with sampling occasions, thus allowing for abiotic (flow and temperature), behavioral (i.e, feeding behavior associated with insect hatches; personal observation) or other effects associated with some passes but not others.

Compared to estimates derived in 2000, 2003, and 2004 the recent 2007 and 2008 abundance estimates had narrower confidence intervals, the CV improved, and in most passes, the P-hat was higher (Tables 2 and 3). Precision in these estimates is still not meeting those prescribed by the Program Directors Office (2006) of the Upper Colorado River Recovery Program (CV $\leq$ 0.15; P-hat $\geq$ 0.10). However, the 2007-2008 estimates are more precise than any of the estimates obtained since 1999 (Tables 2 and 3). While these estimates are low, they fall within the confidence intervals of earlier abundance estimates, so we cannot conclude that the decline observed was real. Abundance estimates generated in 1998–2000 and 2003–2004 from program CAPTURE (White et al. 1982) were not as robust as our estimates derived from program MARK. The profile likelihood for the earlier estimates was generated from just the captured fish, rather from all fish in the estimated population. Therefore, the earlier estimator (CAPTURE) was unable to use the individual covariates (e.g., TL) that could affect P-hat. For the recent 2007 and 2008 abundance estimates, program MARK was able to use length as an individual covariate to model detection probabilities across both years. This reduced some of the individual heterogeneity that causes estimates to be biased high or low (G. White, CSU, *personal communication*).

The most recent abundance point estimate, calculated from summing the individual adult estimates from Westwater Canyon and Black Rocks, fell below the minimum viable adult population of 2,100 animals (USFWS 2002). The adult abundance estimate for Westwater Canyon humpback chub in 2007 is 1,757 (95% CI: 1,097–3,173) and in 2008 is 1,358 (95% CI: 997–1,957; D. Elverud, UDWR, *personal communication*). These recent estimates, coupled with declining estimates of humpback chub in Desolation-Gray, Yampa and Cataract canyons within the upper Colorado River basin (Jackson and Hudson 2005; Finney 2006; Badame 2008), support the need for continued monitoring and consideration of development of a captive refugium population.

Roundtail chub abundance estimates derived from model M_t of CAPTURE within program MARK are probably unreliable (Tables 2 and 3). The assumption of population closure within Black Rocks was likely violated as informed by within-year recaptures there of individuals tagged in Westwater Canyon (immigration) and by significantly higher catch rates in passes three and four than in passes one and two during 2008 (Figure 9).

For humpback chub, mean CPE did not change significantly from 2000 or 2003–2004 to 2007-2008 (Figure 4). Similar CPE from 2000 to 2008 suggests that the Black Rocks humpback chub population has stabilized. However, as noted previously, population point estimates from 2000 to 2004 may have been high: considering the similar CPE values, the population may have been smaller than previously reported. For consistency, a report should be prepared that provides a synthesis of historical data (1998, 1999, 2000, 2003, 2004, 2007 and 2008) and provides abundance estimates for Black Rocks and Westwater Canyon populations derived from program MARK.

Roundtail chub are especially abundant in Westwater Canyon and Black Rocks during low-water years (Kaeding et al 1990; Chart and Lentsch 1999b). However, 2007 and 2008 were moderate water years within a longer drought period. Average catch ratios (humpback chub and intergrades to roundtail chub: an average ratio calculated from the years 1979-1981, 1983-1985, 1988, and 1991) in Black Rocks have declined dramatically from those reported in the Recovery Goals document (USFWS 2002) from 55:45 to 9:91 in 2007 and 2008. The prolonged drought may be a cause for the change in fish community composition observed at Black Rocks. If this new ratio is reflective of the composition during the spawning season, there might be greater potential for hybridization. However, significant CPE variability among some passes (Figure 9) suggest roundtail chub probably occupied Black Rocks in a transient opportunistic fashion, taking advantage of lower velocities and less turbulent conditions when water levels were low, conditions more suited to their species-specific life histories(Kaeding et al 1990; Chart and Lentsch 1999b).

Catchability of individual fish is less than might be expected for such a short, discrete section of river. Within-year recaptures for humpback chub was 8% in 2007 and 5% in 2008. These rates, coupled with historically low within-year recapture rates reported for Black Rocks (McAda 2002, 2007), Yampa River (Haines and Modde 2002; Finney 2006), Desolation-Gray Canyons within the Green River (Jackson and Hudson 2005), and in Westwater Canyon (Hudson and Jackson 2003; Jackson 2010) suggest that low recapture rates may be all that can be achieved in humpback chub habitat using current sampling techniques. Areas that can be sampled efficiently within Black Rocks are limited. Trammel nets can be set along the rock faces that line the channel, but large amounts of habitat cannot be effectively sampled because of deep water and turbulent currents around exposed boulders. The recapture of fish that had not been handled during one or more years of post-tagging sampling suggests that humpback chub remain in Black Rocks but elude capture. Electrofishing was used in an attempt to capture fish in areas that could not be effectively sampled with trammel nets. However, electrofishing is only effective in shallow water or when fish are in the upper portion of the water column. This sampling method only substantially increased humpback chub catch in one of the eight passes during this recent effort and in one of eight in the 2003–2004 effort (McAda 2007). This also suggests that the fish are occupying sections of Black Rocks that are difficult to sample. Electrofishing was more effective at capturing roundtail chub, but that may be related to habitat differences between the two species.

Eight humpback chub that were originally tagged in Westwater Canyon were recaptured in Black Rocks during this study. In 2003–2004, one such fish was recaptured, and in 1998–2000, 14 such fish were recaptured that were originally tagged in Westwater Canyon (McAda 2002, 2007). All of those fish had originally been tagged prior to 2004. Because of the movement between the two areas, Westwater Canyon and Black Rocks were considered one population when Recovery Goals for humpback chub were developed (USFWS 2002). The reaches are separated by a short river segment, but interchange between the two populations probably occurs infrequently. No movement between Black Rocks and Westwater Canyon was observed for 33 radio-tagged humpback chub during short-term (90 d) studies in the early 1980s (Kaeding et al. 1990). The intervening reach is not sampled as part of either population estimation effort; however, intensive sampling during other studies has captured only seven humpback chub (1 in 1994, 1 in 1995, 4 in 2005, and 1 in 2008) in that reach (USFWS, unpublished data). The intervening reach is generally shallow, containing little deep-water habitat that humpback chub are often associated with.

Size structure of the Black Rocks humpback chub population did not change appreciably from 1998– 2000 and 2003–2004 to 2007–2008 (Figures 5 and 6). The largest fish captured in the earliest study was 400 mm long, while the largest captured in the recent effort was 370 mm long. The size structure was slightly bi-modal during 1998–2000 and 2007–2008, but was uni-modal during 2003–2004. Median size of fish was similar between 2007 and 2008. Mean annual growth rates differed from that observed in 1998–2000. The mean growth increment for both size classes (< 300 mm and ≥ 300 mm) was 7 mm per year during 1998-2000 (McAda 2002). However, the mean annual growth increment differed between the two size classes (not significantly) during 2003-2004 and during this study, 12.0 mm versus 3.4 mm per year (McAda 2007) and 14.0 mm versus 4.5 mm (2007-2008). Mean annual growth in Westwater Canyon was similar to that observed in Black Rocks, although reported size classes were slightly different (< 285 mm, 10.6 mm/yr; ≥ 285 mm, 5.8 mm/yr; Hudson and Jackson 2003). Desolation Canyon humpback chub grew at about 10.8 mm/yr (Jackson and Hudson 2005).

Roundtail chub size structure changed from 2003–2004 to 2007–2008. Juveniles (TL < 200 mm) were nearly absent in the 2007–2008 samples (Figures 11 and 12). Mean TL shifted from 240 mm in 2003–2004 to 270 mm in 2007–2008. Mean annual growth rates for roundtail chub during 2007-2008 were 24.5 mm for animals < 300 mm TL and 18.1 mm for those > 300 mm TL.

Mean K_n (relative condition) might provide insight into what constitutes carrying capacity for the Black Rocks and Westwater populations of roundtail and humpback chub. Although data do not reveal any relationship between mean K_n and abundance or CPE, it may when more samples are available for analysis. Body condition also allows us to track the general health of fish within these populations through time. Condition of both species showed significant improvement during 2007-2008 from the condition of those captured in 2004 (Figure 7).

Recovery Goals for humpback chub specify that abundance of juveniles (150–200 mm TL) preparing to enter into the adult population must also be estimated (USFWS 2002). Electrofishing and use of smaller mesh trammel nets was intended to sample this smaller size class. Unfortunately, no juvenile humpback chub were collected during this study, and only one was captured during the 2003–2004 study (McAda 2007). This size class may be particularly difficult to sample effectively. Use of small-mesh fyke nets in previous years also failed to capture juvenile humpback chub. However, increased use of fyke and/or hoop nets might yield better results (D. Van Haverbeke, U.S. Fish and Wildlife Service, *personal communication*). Electrofishing resulted in capturing a higher percentage of juvenile roundtail chub than humpback chub, which probably reflects habitat differences between the two species. Seining, prior to adult community sampling, when young-of-year *Gila* are occupying slack water, may shed light on their early life histories.

Robust abundance estimates for the different populations of humpback chub in the upper Colorado River basin are necessary to monitor current management efforts designed to lead to recovery of the species (USFWS 2002). Early efforts indicate that population estimates can be made, but confidence intervals around the estimates are large and determination of significant differences between estimates is difficult. Increased sampling (i.e., four versus three passes) improved the reliability of estimates (measured by lower CV and tighter confidence bounds) in the 1998–2000 study. However, four passes in the 2003–2004 study failed to improve the precision of the estimates. The low recapture rates in those years were the principal factor in leading to high CV values, and increased sample effort failed to overcome that limitation. This study (2007–2008) yielded improved precision over those estimates for 2000 and 2003–2004; however, they weren’t as precise as those produced during 1998–1999. Continued efforts to improve sampling efficiency are needed.

McAda (2002) expressed concern that delayed mortality played a role in the apparent decrease in population size during his earlier study. Sampling during 2003–2004 and during this 2007–2008 study was delayed until late fall in the hopes that cooler water temperatures would reduce stress in fish while in nets and during handling. This notion has further support with Theresa Hunt's (2008) master's thesis on the effects of capture by trammel nets on native Arizona fishes. The amounts of time that nets were set were also reduced during the two most recent study periods. All humpback and roundtail chub were held in an oxygenated container containing a combination of salt and Stress Coat® to help the fish begin healing any skin damage that might have occurred during handling (McAda 2007). It is not clear whether this helped the fish recover from handling or not. However, all fish recovered nicely before release and the treatment presumably helped them begin the process of replacing any mucous that was lost during handling. Even though short-term mortality was not observed, handling might have reduced their movement subsequent to release (thus reducing their probability of capture). Reduced recaptures might also have resulted from net avoidance behavior after initial capture. However, if humpback chub rely on sight to detect nets, low river water clarity may preclude the development of net avoidance behavior. Any delayed mortality that may have occurred after release could not be measured.

Trammel nets remained the most effective technique for capturing humpback chub. A few humpback chub were captured with electrofishing, supplementing the trammel net data, but not enough to produce a reasonable population estimate without trammel net captures. Trammel nets will continue to be used as the primary technique. Albeit, shorter durations of time for net sets and fall sampling should continue as means to minimize potential stress in fish.

Electrofishing should continue to be used to supplement the trammel net sampling. This technique samples different habitats and has proved successful in capturing humpback chub not caught using the primary technique. In addition, the capture of small roundtail chub during this study and Jackson's (2010) report of increased juvenile humpback chub captures in Westwater Canyon, suggests that electrofishing may be essential in future efforts to capture greater numbers of juvenile humpback chub.

Use of mark-based abundance estimates for monitoring humpback chub populations should continue; however, any future decreases in abundance estimates may necessitate cost benefit analysis if the decreases can be attributed to our sampling. Further experimentation with supplemental sampling techniques is warranted, considering that current methods result in low recapture rates and possible harm to fish.

CONCLUSIONS

1. Black Rocks humpback chub abundance estimates for 2007-2008 [n=345 (171-795) in 2007: n=287 (179-505) in 2008] are more precise than any of the estimates obtained since 1999, While these estimates are low, they fall within the confidence intervals of earlier abundance estimates, so we cannot conclude that the decline observed was real.
2. The most recent abundance point estimate, calculated from summing the individual adult estimates from Westwater Canyon and Black Rocks (1645 in 2008), fell below the minimum viable adult population of 2,100 animals (USFWS 2002). This warrants consideration for developing a captive refuge population.
3. Average catch ratios (humpback chub and intergrades to roundtail chub: an average ratio calculated from the years 1979-1981, 1983-1985, 1988, and 1991) in Black Rocks have declined dramatically from those reported in the Recovery Goals document (USFWS 2002) from 55:45 to 9:91 in 2007 and 2008. If this new ratio is reflective of the composition during the spawning season, there might be greater potential for hybridization.
4. Catchability of individual fish is less than might be expected for such a short, discrete section of river. Within-year recaptures for humpback chub was 8% in 2007 and 5% in 2008. These rates, coupled with historically low within-year recapture rates reported for Black Rocks (McAda 2002, 2007), Yampa River (Haines and Modde 2002; Finney 2006), Desolation-Gray

Canyons within the Green River (Jackson and Hudson 2005), and in Westwater Canyon (Hudson and Jackson 2003; Jackson 2010) suggest that low recapture rates may be all that can be achieved in humpback chub habitat using current sampling techniques.

5. Relative condition of both roundtail and humpback chub showed significant improvement during 2007-2008 from the condition of those captured in 2004. Future monitoring of relative condition may shed insight on carrying capacity within this reach.
6. Low historical and current capture rates of juvenile humpback chub (150 mm to 200mm) suggests that they may be particularly difficult to sample effectively. Continued experimentation with different fisheries techniques is necessary to achieve abundance estimation of fish entering the adult population.

RECOMMENDATIONS

- Continue sampling Westwater Canyon and Black Rocks on the same time schedule so that population estimates in the two reaches can be more directly comparable.
- Consider seining back waters and slack water habitat, within Black Rocks and downstream to Westwater Wash in early August, to monitor the presence or absence of young-of-year *Gila* during a rest year between estimates.
- Evaluate the availability of young-of-year and juvenile *Gila* and adult humpback chub for the development of a captive refugia population.
- Continue sampling with trammel nets, but use techniques to minimize stress during capture or handling, including:
    - Sample during mid-September to late October when water temperatures range between 10 and 18°C.
    - Minimize fishing time of nets to reduce capture stress.

- Continue use of salt to assist with stress reduction.
- Use more fyke/hoop nets (potentially baited) than were used in previous attempts.

- Continue sampling with electrofishing to supplement trammel net captures to ensure that all humpback chub have a probability of capture.
- Continue to research additional capture methods for juveniles.
- Work with a statistician to improve our understanding of survival, trap shyness, abundance, and transition probabilities across and between years in Westwater Canyon and Black Rocks utilizing all data collected since the onset of population estimates for these populations (1998-2008).
- Continue tagging and monitoring sympatric roundtail chub; however, consider tracking just CPE or explore open-abundance estimators.

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