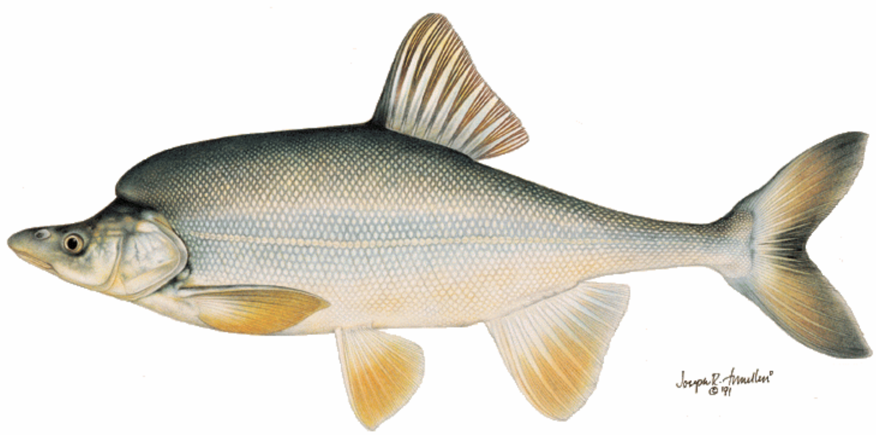
Population Size and Structure of Humpback Chub, *Gila cypha*, in Black Rocks, Colorado River, Colorado, 2003–2004



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Population Size and Structure of Humpback Chub, *Gila cypha*, in Black Rocks, Colorado River, Colorado, 2003–2004

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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EXECUTIVE SUMMARY

The Colorado River in Black Rocks was sampled in 2003 and 2004 to estimate size and structure of the humpback chub population. Sampling began in mid September and continued through October. Four sampling trips (4 days each: conducted in alternating weeks) were conducted in both years. Sampling was primarily done with multi-filament trammel nets (1-in 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 three of four trips each year.

All *Gila* were identified as either humpback chub or roundtail chub, checked for a PIT tag and measured (total length, ± 1 mm). Untagged humpback chub were equipped with a PIT tag before release; roundtail chub were not tagged. 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 chubs were released at the common location and appeared healthy when released.

Catch rates in 2003–2004 were comparable, but slightly higher, than those observed in 2000. A total of 69 individual humpback chubs were collected in 2003 and 74 were collected in 2004. These numbers compare to 68 humpback chubs collected in 2000. Within-year recaptures were low – four humpback chubs were recaptured in 2003, but only one humpback chub was recaptured in 2004. In addition to the within-year recaptures, 11 humpback chubs were recaptured in 2003 and 19 were recaptured in 2004 that had been tagged in previous years. One of the fish recaptured in 2004 was tagged in Westwater Canyon in 2003.

Adult humpback chubs ranged between 20 and 39 cm long. Only one juvenile humpback chub was collected (17 cm). Growth of humpback chubs captured in multiple years averaged 12.0 mm/yr for fish <300 mm long and 3.4 mm/yr for fish > 300 mm long.

The population estimate for 2003 was 478 fish (95% CI; 221–1,176). Because only one humpback chub was recaptured in 2004, the confidence interval for the estimate was so wide that the estimate was unreliable.

INTRODUCTION

The humpback chub (*Gila cypha*) is a 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. 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), the Green River in Desolation and Gray canyons (Chart and Lentsch 1999a), and the Colorado River in Black Rocks (Kaeding et al. 1990), Westwater Canyon (Chart and Lentsch 1999b), and Cataract Canyon (Valdez 1990).

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 provide money for management actions 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). 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 chubs 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 develop the necessary data to produce population estimates have been completed in Yampa, Westwater, Desolation-Gray, and Cataract Canyons. The first series of population estimates for Black Rocks was done in 1998–2000 (McAda 2002). This report presents the second series of population estimates for Black Rocks, 2003–2004.

METHODS

Study Area

Black Rocks is a 1.6 km section of deep-water habitat formed by erosion-resistant igneous rocks in the river channel. This unique area is about 6.4 km upstream from the Colorado-Utah state line and extends from about river kilometer 217-218.4 (RM 135.5 to 136.5; Figure 1). 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 chubs. 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 in mid September through October, after water temperatures began to cool for the year. McAda (2002) recommended that sampling occur in the fall to minimize extra stress on the fish caused by warm water temperatures. To develop reliable population estimates, sampling trips were scheduled to correspond to a mark-recapture sampling design. Sampling was done for four days (one sampling trip) with one week separating sampling trips. Four sampling trips were made in both years of the study. Most sampling was done with multi-filament trammel nets set along shoreline eddies or in other quiet habitats. Four to six trammel nets were set mornings and evenings and checked at 1 to 2 hr intervals. Trammel nets were primarily 1-in inner mesh, but 0.75-in inner mesh nets were also used in an attempt to catch smaller chubs. Nets were left in the same location for 3–4 hr unless no fish were collected or excessive amounts of trash required the net to be moved sooner. As much of the

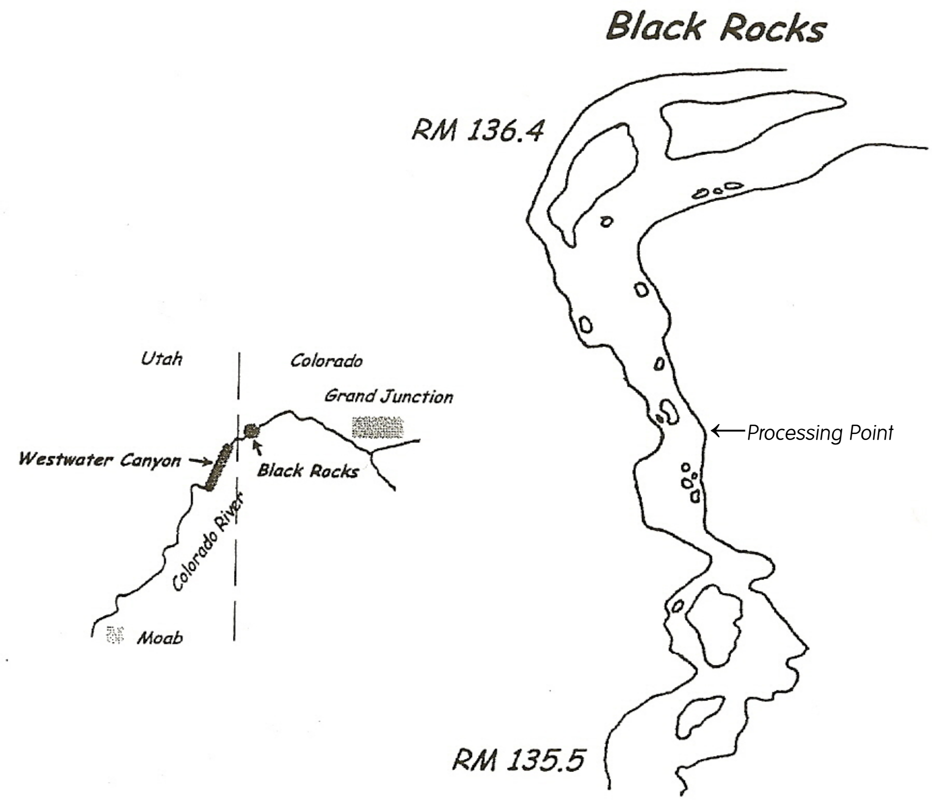

FIGURE 1. — Black Rocks study area and relationship to Westwater Canyon. The upstream end of Westwater Canyon is about 16.8 km (10.5 mi) downstream from Black Rocks. *Gila* were worked up at a central processing point after all trammel nets were run.

Black Rocks area as possible was sampled during each trip to ensure that all humpback chubs had a possibility of being captured; however, a shallow riffle at about KM 218.1 (RM 136.3) limited sampling above that point. Most locations were sampled more than once over the course of a sampling trip.

All *Gila* were removed from the nets, tentatively identified as humpback chub or roundtail chub (*G. robusta*) and immediately placed in a fresh water holding tank. Other species were identified, counted, and released at the collection site. Net locations were identified to the nearest 0.16 km and sampling time was recorded. After all nets were run, all *Gila* were returned to a central location for processing. *Gila* were not released at the sample location to speed removing fish from multiple nets and to prevent immediate recapture.

In addition to trammel nets, the entire Black Rocks reach was sampled with electrofishing twice during most sampling trips (trips 2, 3, and 4 in 2003 and 1, 2, and 3 in 2004). Electrofishing was done once in early morning and once in late evening. Both shorelines were sampled on each occasion. The electrofishing was done to increase the probability of capturing small chubs and to capture fish that might be in areas that were not susceptible to trammel nets. Fish captured with electrofishing were processed at the end of each sample.

During processing, *Gila* were inspected more closely 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) and scanned for a passive integrated transponder (PIT) tag. Untagged humpback chub were equipped with a PIT tag before release; roundtail chub were not tagged. After handling, all *Gila* were placed into an oxygenated holding tank containing a mixture of salt and Stress Coat® for about 1 hr as a skin treatment and to assess general health. Fish were then released at the central processing point.

Data Analysis

Mean catch per effort for trammel netting (CPE, fish per net hour) was calculated for humpback chub and roundtail chub for each sampling trip. Mean CPE was compared among sampling trips using Analysis of Variance; pairwise comparisons were made using a Bonferroni adjustment (P<0.05, SYSTAT, version 11). Mean CPE was not calculated for electrofishing.

Capture-recapture data for all humpback chubs handled were placed into a matrix organized by year and sampling trip. Population estimates were made for adult humpback chubs (≥200 mm TL, USFWS 2002). The matrix identified whether a specific humpback chub was captured or not during each sampling trip. The population estimation program CAPTURE (White et al. 1982) was then used to calculate annual abundance estimates for humpback chub in Black Rocks. CAPTURE 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. Because of the low recapture rate in 2004, a population estimate was also made using a 2-pass Lincoln-Petersen estimator using each year of data as a sampling occasion.

Length-frequency distributions were calculated for each year of sampling. Humpback chubs recaptured within a year were only used once in the analysis. Annual growth was estimated by comparing total length of recaptured fish that had been handled in previous years.

Mean CPE and a length-frequency distribution were also calculated for roundtail chub.

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 between about 2,800 and 3,800 cfs among sampling trips (Table 1). Although river flow varied by as much as 1,000 cfs between trips, fluctuations were gradual and not subject to dramatic, short-term pulses. Fluctuation within passes ranged from 80 to 800 cfs (median, 100 cfs), but never resulted in dramatic changes in river elevation during the sampling period. Mean water temperature was typically 25º C (or greater) in most of July and August, but had 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, 2003-2004. 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)
2003	9/16-19	1	3,660	15.9
	9/30-10/3	2	2,940	17.4
	10/13-16	3	3,358	12.3
	10/28-31	4	3,203	10.1
2004	9/14-17	1	2,810	18.1
	9/27-30	2	3,633	16.1
	10/13-16	3	3,523	13.3
	10/26-29	4	3,795	9.7

[a] Mean of daily means.

Relative Abundance

A total of 69 individual humpback chubs were captured in 2003 (four were recaptured) and 74 in 2004 (one was recaptured; Table A-1). Mean catch rates of humpback chub for trammel nets ranged between about 0.1 to 0.3 fish per net hour in 2003–2004 (Figure 2). Although, mean CPE varied, there were no significant differences among sampling passes ($P<0.05$). Mean CPE was not calculated for electrofishing, but a total of 14 humpback chubs were collected in 2003 and 8 in 2004. Electrofishing captures were not uniform among sampling trips. A total of nine humpback chubs were collected in trip 3 of 2003. Total numbers collected with electrofishing during other sampling trips ranged from none to three.

In comparison, a total of 633 roundtail chubs were captured in 2003 and 349 in 2004 (Table A-1). Mean CPE for roundtail chub usually ranged between 0.6 and 1.2 fish per net hour (Figure 3). However, mean CPE was significantly higher in the last trip of 2003 than in the other sample efforts (3.5; $P<0.05$).

Comparison of humpback chub CPE with 1998–2000 shows that catch rates were approximately equal to that observed in 2000 on most occasions (Figure 4). CPE in one

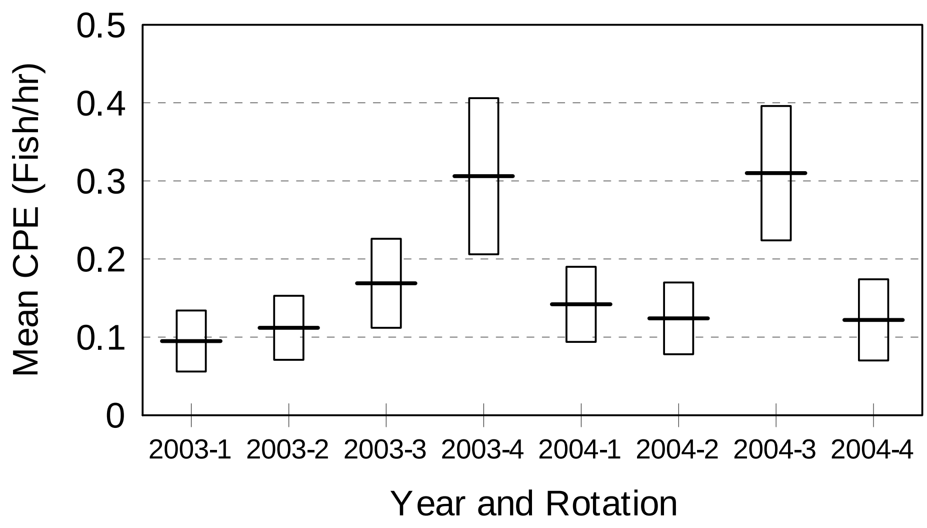

FIGURE 2. – Mean CPE (fish/hr; ± 1 SE) of humpback chub captured using trammel nets in Black Rocks, 2003–2004. Dates of sampling trips (rotations) are provided in Table 1.

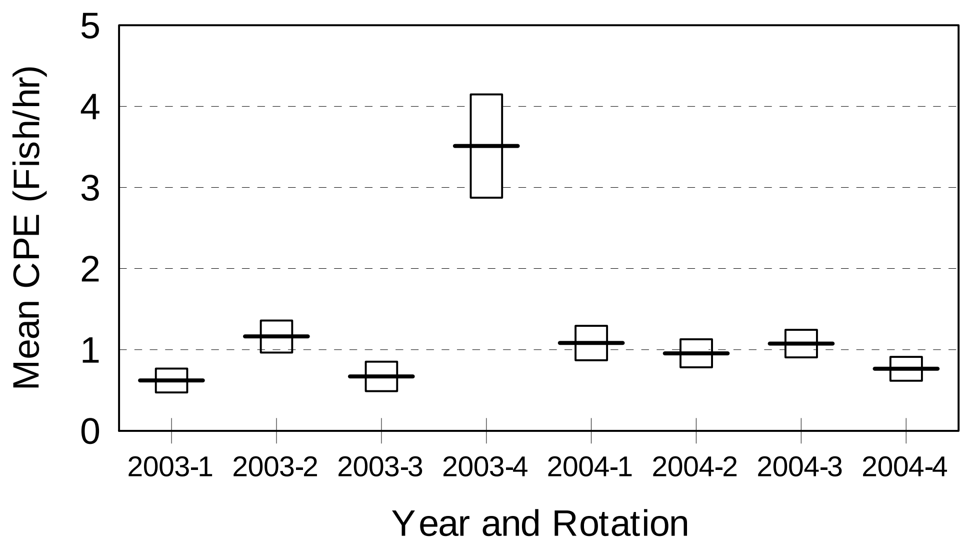

FIGURE 3. Mean CPE (fish/hr; ± 1 SE) of roundtail chub captured using trammel nets in Black Rocks, 2003–2004. Dates of sampling trips (rotations) are provided in Table 1.

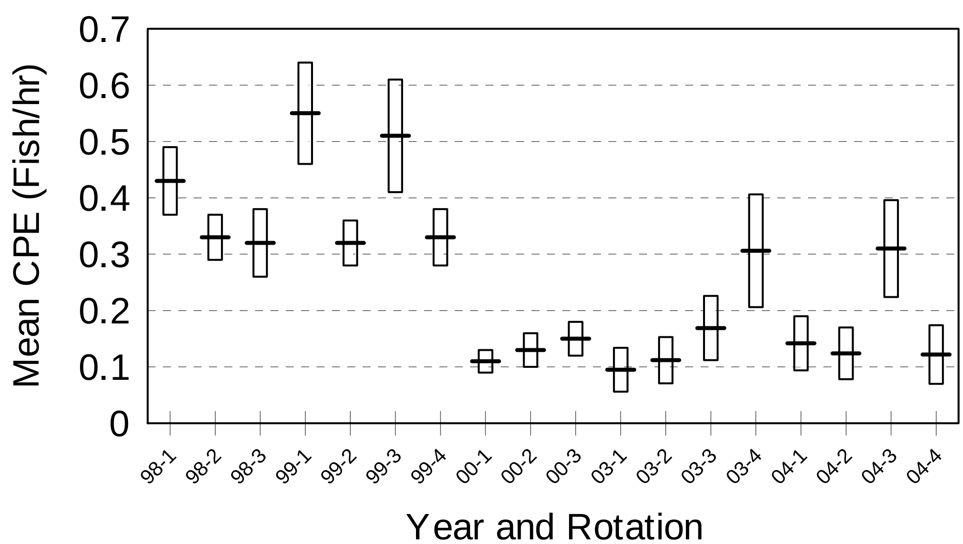

FIGURE 4. – Mean CPE (fish/hr; ± 1 SE) of humpback chub captured using trammel nets, 1998–2000 and 2003–2004.

sampling trip in each year exceeded that in 2000 (not significantly) and was similar to that observed during some sampling trips in 1998–1999.

Fish Condition — After data collection, captured fish were held 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 fish appeared to be in good health during this treatment and swam quickly away after they were released. No evidence of parasites or fungus was noted in captured or recaptured fish.

Movement

One humpback chub was recaptured in Black Rocks in 2004 that had originally been tagged in Westwater Canyon in 2003. Black Rocks and the upstream end of Westwater Canyon are separated by about 16.8 km (10.5 mi). Although not tagged during this study, a humpback chub tagged in Black Rocks in 1999 was recaptured in Westwater Canyon during the most recent series of population estimates there (J. Jackson, personal communication).

Size Structure

Adult humpback chubs captured in Black Rocks ranged from 20 to 39 cm TL (Figure 5). Only one juvenile chub (17 cm) that was identified as a humpback chub was collected during the study. Size structure was similar to that observed in 1998–2000 (McAda 2002, Figure A-1).

Maximum size and adult size structure of roundtail chub was the same as observed for humpback chub (Figure 6). However, more juveniles were collected. About 12% of the roundtail chubs captured in 2003 and 5% in 2004 were less than 200 mm long.

Growth

A total of 25 individual humpback chubs were captured that had been handled in previous years of this or other studies, some more than once. Fish were divided into two length groups for analysis; < 300 mm and ≥ 300 mm TL. Mean annual growth for fish < 300 mm was 12.0 mm/yr (n, 20; SE, 3.7; range 0–58). Mean annual growth for fish ≥ 300 mm was 3.4 mm/yr (n, 7; SE, 0.8; range, 0.4–5.8).

Population Estimate

The relatively few humpback chubs handled and low within-year recapture rates (4 in 2003 and 1 in 2004) resulted in variable population estimates with wide confidence intervals (Table 2). Annual population estimates for 2003 ranged from 365 to 597 individuals for the

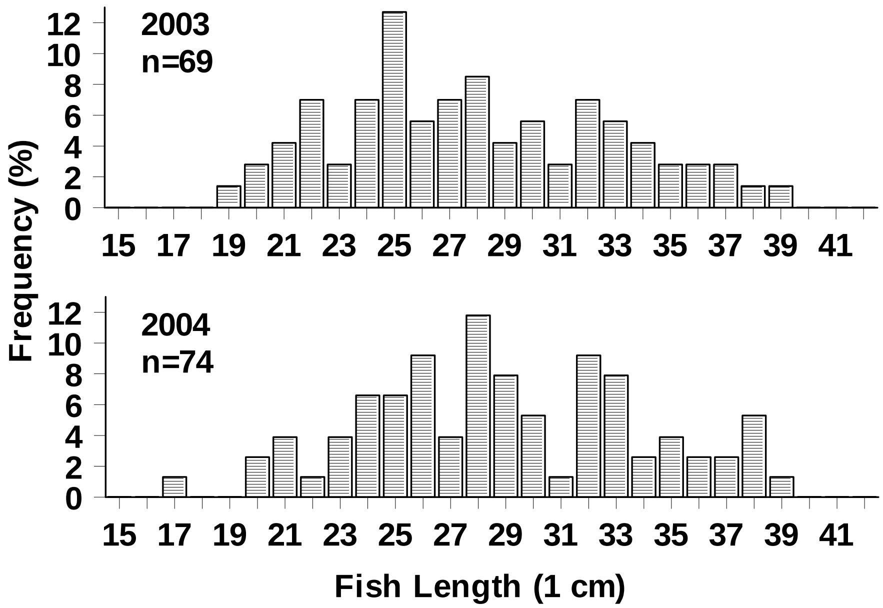

FIGURE 5. Size structure of humpback chub in Black Rocks, 2003–2004.

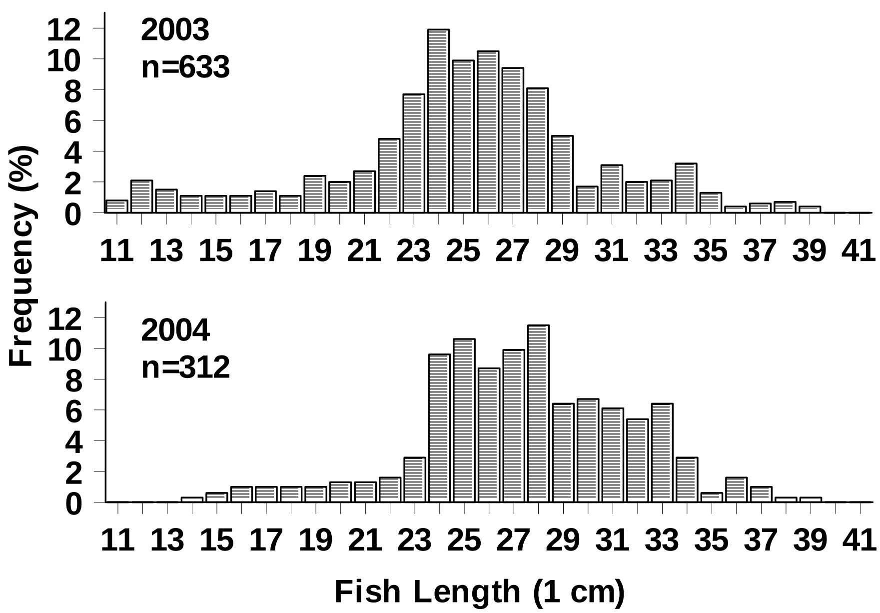

FIGURE 6. Size structure of roundtail chub in Black Rocks, 2003–2004. (Representative sample of all fish collected in 2004.)

TABLE 2. – Population estimates for adult humpback chub in Black Rocks for 2003–2004using models M_o and Chao M_t.

Year	Model	Estimate	95% CI	CV	P-hat
2003	Mo	478	221 – 1,176	0.46	0.04
2004[a]	Chao Mt	932	307 – 3,244	0.98	0.01

[a] Considered unreliable; see text.

different models. Model selection was difficult because of the sparse data. Model Mo was the model used in previous years so the comparable estimate for 2003 would be 478 (± 221 – 1,176). Although estimates for 2004 are reported in Table 2, the 95% confidence intervals are so wide that the estimates are essentially meaningless. As a test, a hypothetical second recapture was added to the 2004 matrix, which reduced the population estimates by about one half (K. Bestgen, personal communication). Coefficient of variation (CV) was 0.4–0.5 for the 2003 estimates and approached 1 for the estimates in 2004 (Table 2), indicating the poor quality of the estimates.

Because of the wide confidence intervals, the population estimate for 2003 was not significantly different from those calculated in previous years (Table 3). The point estimate itself decreased somewhat from 2000, but the difference was not as great as that observed from 1999 to 2000.

The Lincoln-Petersen 2-pass estimate for 2003 was slightly higher than the multi-pass estimate for the same year (Table 4), but similar enough to add credence to both estimates. Confidence intervals were still wide, but CV and capture probability (P-hat) improved slightly.

Although there were few within-year recaptures of fish that could be used in a population estimate, 29 humpback chubs were recaptured that had been handled in a previous year of this study or the earlier population estimate (McAda 2002). In addition, one humpback chub was recaptured that had been captured in Westwater Canyon and two humpback chubs were

TABLE 3. – Population estimates for adult humpback chub in Black Rocks, 1998–2000 and 2003 using Model Mo.

Year	Estimate	95% CI	CV	P-hat
1998	764	512 – 1,206	0.23	0.08
1999	921	723 – 1,208	0.13	0.09
2000	539	223 – 1,497	0.54	0.04
2003	478	221 – 1,176	0.46	0.04

TABLE 4. – Lincoln-Petersen 2-pass estimates for adult humpback chub in Black Rocks for 2003.

Model	Estimate	95% CI	CV	P-hat
Mo	586	346 – 1,098	0.31	0.12
Mt	584	346 – 1,086	0.31	0.11
Chao Mt	541	329 – 977	0.29	0.12

recaptured that had been tagged in Black Rocks the preceding summer during another study (USFWS, unpublished data). The capture history of fish recaptured in different years is presented to illustrate the apparent difficulty of recapturing a fish even though it probably remained within Black Rocks during the sample period (Table 5). Even though only four within-year recaptures were recorded in 2003, nine fish were recaptured in 2004 that were tagged but not recaptured in 2003. In addition, a number of fish were tagged and released in 1999 and not handled again until 2003 or 2004.

TABLE 5. – Capture history of humpback chubs captured in 2003–2004 that were handled in 1998–2000.

PIT Tag	1998			1999				2000			2003				2004			
	1	2	3	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4
2003																		
1F5B0E4830		x											x					
2037247B0A	x					x								x				
416D335A4D			x								x							
51104A131B						x	x							x				
5116171065							x							x				
5123593D29					x	x								x				
5129652C29[a]				x									x					
512A466F30					x	x				x				x				
532660426F									x			x						
5326612322									x			x		x				
2004																		
223F4A554F											x						x	
421440151D	x														x			
425B6C465D												x			x			
426A1D4929													x				x	
426A205D79														x				x
51166D2D4D						x										x		
51276C0D6B					x										x			
5128556409						x											x	
5129523415				x											x			
5129652C29[a]				x									x		x			
512A2C3F71							x										x	
512D584B36											x			x				x
5318106202																x		
5326581836													x				x	
53265F6F40										x							x	
5326676942													x				x	

[a] Fish captured in both 2003 and 2004.

DISCUSSION

Population estimates for 2003 and 2004 were variable and exhibited wide confidence intervals and poor CV values. The population estimate in 2004 was based on only one recapture and exhibited inordinately high confidence intervals that were so wide as to make the estimate unusable. As noted above, the hypothetical inclusion of one additional recapture reduced the point estimate in half for all of the models used. However, because of the unreliability of the 2004 estimate, it is not utilized in any further discussions.

Because of the wide confidence intervals, the population estimate for 2003 was not significantly different from those calculated in previous years. The point estimate itself decreased somewhat from 2000, but the difference was not as great as that observed from 1999 to 2000. The use of the Lincoln-Peterson estimate for 2003 provided some additional support for the small size of the population, but as with all estimates, confidence intervals were wide and did not allow distinction from the larger point estimates. Overall, the point estimates show a declining trend in Black Rocks since 1998. Recent population estimates in Desolation and Gray Canyons (point estimates of about 2,600 to 937; Jackson and Hudson 2005) and Westwater Canyon (point estimates of about 4,700 to 2,200; Hudson and Jackson 2003) have also shown slight declines although the differences among years were not significant. A second round of population estimates for Westwater Canyon has been completed and data analysis and report writing are ongoing.

Mean CPE did not change significantly from 2000 to 2003–2004. Comparable CPE and similar population estimates between 2000 and 2003 suggests that the Black Rocks population has stabilized. However, as noted previously, there are no significant differences among any of the population estimates because of the wide confidence intervals.

Poor recapture rates negatively affected the precision of the population estimates in Black Rocks. Only four fish were recaptured in 2003 (6 %) and only one was recaptured in 2004 (1%). Catchability of individual fish is worse than might be expected in such a confined area. 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 can not be effectively sampled because of deep water and turbulent currents. The recapture of fish that had not been handled during one or more years of sampling post tagging suggests that the fish remain in Black Rocks, but elude capture. Electrofishing was used to capture fish in areas that could not be effectively sampled with trammel nets. However, it only substantially contributed to the number of humpback chubs handled during one of the eight passes executed during the two year study. Electrofishing is only effective in shallow water or when fish are in the upper portion of the water column. This also suggests that the fish are occupying sections of Black Rocks that are difficult to sample. Electrofishing was more effective at capturing roundtail chubs, but that may be related to habitat differences between the two species.

Recapture rates for marked humpback chubs were also poor in the Yampa River. Haines and Modde (2002) only recaptured marked fish in 1 yr of a 3 yr study, and Finney (2006) also recaptured one fish during a 2 yr study. However, humpback chub are much less common in the Yampa River than they are in Black Rocks. Considerably more humpback chub are captured in Westwater Canyon and Desolation-Gray Canyons, but recapture rates are still low. Jackson and Hudson (2005) reported a 2–6 % within-year recapture rate in their 3-yr study in Desolation-Gray Canyon and Hudson and Jackson (2003) reported a 2–3% within-year recaptures during 1998–2000 in Westwater Canyon. These two canyon areas are much larger than Black Rocks, but have similar deep-water habitats that are difficult to sample. Low recapture rates may be all that can be expected with humpback chub studies.

Only one fish that was originally tagged in Westwater Canyon was recaptured in Black Rocks during this study. This compares with capture of a total of 14 fish that had originally been tagged in Westwater Canyon during the 1998–2000 population estimate (McAda 2002). All of those fish had originally been tagged prior to 1998. 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 estimate effort; however intensive sampling during other studies has not captured a single humpback chub in that area (USFWS, unpublished data). The intervening reach is generally shallow with little deep-water habitat that is usually associated with humpback chub.

Size structure of the Black Rocks population did not change appreciably from 1998–2000 to 2003–2004. The largest fish captured in the earlier study was 40 cm long, while the longest captured in the present study was 39 cm long. The size structure was slightly bi-modal during 1998–2000, but was uni-modal during 2003–2004. The median size of fish increased slightly from 2003 to 2004. Mean annual growth rates differed from that observed in 1998–2000. The mean value for both size classes (< 300 mm and ≥ 300 mm) of fish was 7 mm per year (McAda 2002). However, the two size classes differed in this study, 12.0 mm vs 3.4 mm per year. Mean annual growth in Westwater Canyon was similar to that observed here, although size classes were slightly different (< 285 mm, 10.6 mm/yr; ≥ 285 mm, 5.8 mm/yr; Hudson and Jackson 2003). Desolation Canyon humpback chubs grew at about 10.8 mm/yr (Jackson and Hudson 2005).

Recovery Goals require estimating the number of juvenile humpback chubs (150–200 mm TL) preparing to enter into the adult population. Additional sampling with electrofishing and smaller mesh trammel nets were intended to sample this smaller size class. Unfortunately, only one juvenile humpback chub was collected during this study—it was not recaptured. This size class may be particularly difficult to sample effectively. Use of small-mesh fyke nets in previous years also failed to capture small-bodied humpback chubs. However, fyke nets could only be set in areas that did not appear to be good humpback chub habitat. Electrofishing resulted in capturing a higher percentage of juvenile roundtail chubs than humpback chubs, which probably reflects habitat differences between the two species.

Although population estimates were not calculated for roundtail chubs, they are clearly more common in Black Rocks than humpback chub. This increased abundance was probably also reflected in the larger number of juveniles collected. Estimates of roundtail population size were made for Desolation and Gray Canyons (Jackson and Hudson 2005) and it has been suggested that it be incorporated into population-estimate studies for all humpback chub populations (UCRB Biology Committee). This may assist in understanding the population dynamics of these closely related species. However, these estimates are still likely to have wide confidence intervals that will make interpretation of population shifts difficult.

Sampling in Desolation and Gray Canyons was more effective at capturing humpback chub juveniles. Jackson and Hudson (2005) reported that between 5 to 15% of chubs collected were juveniles, but they were unable to do a population estimate for those juvenile fish. Most of these fish were caught with electrofishing. Although turbulent and deep in many places, this canyon reach tends to be shallower than the Black Rocks reach.

Robust size 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 sampling 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 poor recapture rates in those years were the dominating factor in producing high CV values and increased sample effort could not overcome that factor. Efforts need to continue to improve sampling efficiency.

McAda (2002) was concerned that delayed mortality played a role in the apparent decrease in population size during the earlier study. This second study was delayed until later in the fall when water temperatures were cooler and therefore it should have been easier on the fish while they were in the nets and during handling. The time of the nets sets was also reduced in the current study. As an additional precaution, all humpback chubs 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. It is not clear whether this helped the fish recover from handling or not. However, all fish recovered nicely before release and the treatment should have helped them begin the process of replacing any mucous that was lost during handling. Even though short-term mortality was not experienced, it may be that the handling reduced their movement subsequent to release (thus reducing their probability of capture). It is also possible that they may have exhibited some net avoidance behavior after capture. However, the natural poor visibility in the river makes this somewhat unlikely. Any delayed mortality that may have occurred after release could not be measured.

The recapture of a number of fish that had been tagged, but not recaptured in the previous study suggests that poor catchability of individual fish may be more important than the possibility of delayed mortality associated with handling. It may be that the handling reduced their movement subsequent to release (thus reducing their probability of capture).

The displacement of fish from their capture site for data processing may play a role as well. Fish were removed from their captures sites for several reasons—most importantly so that they would not be recaptured in the nets shortly after being released and be subjected to further trauma. The central processing site was removed from the trammel nets and close to mid-channel, deep water habitat where no trammel nets were set. It is possible that the fish remained in the mid-channel habitat longer than expected. It was presumed that 1 wk (or a total of 5 wk for the entire sampling period) would be sufficient time for the fish to return to their original capture site or another suitable location. Kaeding et al. (1990) reported average maximum displacement of radio-tagged humpback chubs to be 1.5 km. This distance is sufficient to move through all of the Black Rocks reach. They also observed a tendency to home to one site. Released fish should have been moving throughout the sample area and had a probability of capture, even though it was apparently low.

Trammel nets remained the most effective technique for capturing humpback chubs. Electrofishing captured a few humpback chubs and supplemented the trammel net data, but not enough to produce a reasonable population estimate. Trammel nets will have to continue to be used as the primary technique. However, they will need to be used cautiously to ensure that fish are treated as gently as possible. This caution would include sampling during the fall when water temperatures are cooling and setting the nets for the shortest time possible.

Electrofishing should continue to be used to supplement the trammel net data. This technique samples different habitats than trammel nets and did capture humpback chubs not handled with the primary technique. In addition, its ability to capture smaller roundtail chubs gives hope that juvenile humpback chubs can be captured in greater numbers in future sampling efforts.

Size estimates for the different humpback chub populations should continue, but the timing should be evaluated. McAda (2002) sampled 3 yr in a row, while this study sampled for 2 yr with an intervening time of 2 yr. No major change was noted between 2000 and 2003, so perhaps the time between sampling could be extended by a year, or more, if deemed appropriate. The number of years sampled for each estimate should also be evaluated. Hudson and Jackson (2003) and Jackson and Hudson (2005) also sampled for 3 yr for their studies. Criteria should be developed that evaluates the benefits of repeated sampling on data quality compared with the potential hazards of stress or injury to the fish population being evaluated.

RECOMMENDATIONS

- Evaluate the time frames that should be adopted by the Recovery Program to measure progress toward recovery of humpback chub.
- Continue sampling at Black Rocks to estimate population size of humpback chub according to a standard time frame.
- 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.
- Continue sampling with electrofishing to supplement trammel net captures to ensure that all humpback chub have a probability of capture.
- Explore sampling Westwater Canyon and Black Rocks on the same time schedule so that population estimates in the two reaches can be more directly comparable.
- Continue exploration of data analysis to improve precision of population estimates.

- Consider tagging roundtail chub to be consistent with other studies.
- Consider timing changes to spread out sampling.

LITERATURE CITED

Chart, T. E., and L. D. Lentsch. 1999a. Reproduction and recruitment of *Gila* spp. and Colorado pikeminnow (*Ptychocheilus lucius*) in the middle Green River 1992–1996. Final Report to the Recovery Program for the Endangered Fishes in the Upper Colorado River Basin, Project Number 39. Utah Division of Wildlife Resources, Moab and Salt Lake City, Utah.

Chart, T. E., and L. D. Lentsch. 1999b. Flow effects on humpback chub (*Gila cypha*) in Westwater Canyon. Final Report to the Recovery Program for the Endangered Fishes in the Upper Colorado River Basin, Project Number 46. Utah Division of Wildlife Resources, Publication 99-36, Moab and Salt Lake City, Utah.

Douglas, M. E., and P. C. Marsh. 1996. Population estimates/population movements of *Gila cypha*, an endangered cyprinid fish in the Grand Canyon region of Arizona. Copeia 1996:15-28.

Douglas, M. E., W. L. Minckley, and H. M. Tyus. 1989. Qualitative characters, identification of Colorado River chubs (Cyprinidae; Genus *Gila*) and the "Art of Seeing Well." Copeia 1989:653-662.

Finney, S. 2006. Adult and juvenile humpback chub monitoring for the Yampa River Population, 2003–2004. Final report to the Upper Colorado River Fish Recovery Program, Project number 133. U. S. Fish and Wildlife Service, Vernal, Utah.

Haines, B., and T. Modde. 2002. Humpback chub monitoring in Yampa Canyon, 1998–2000. Final report to the Upper Colorado River Fish Recovery Program, Project Number 22a4. U. S. Fish and Wildlife Service, Vernal, Utah.

Hudson, J. M., and J. A. Jackson. 2003. Population estimates for humpback chub (*Gila cypha*) and roundtail chub (*Gila robusta*) in Westwater Canyon, Colorado River, Utah, 1998– 2000. Final Report to the Upper Colorado River Fish Recovery Program, Project Number 22c. Publication Number 03-51. Utah Division of Wildlife Resources, Salt Lake City, Utah.

Jackson, J. A., and J. M. Hudson. 2005. Population estimate for humpback chub *(Gila cypha)* in Desolation and Gray Canyons, Green River, Utah 2001– 2003. Final Report to the Upper Colorado River Fish Recovery Program, Project Number 22k. Publication Number 05-25. Utah Division of Wildlife Resources, Salt Lake City, Utah.

Kaeding, L. R., B. D. Burdick, P. A. Schrader, and C. W. McAda. 1990. Temporal and spatial relations between the spawning of humpback chub and roundtail chub in the upper Colorado River. Transactions of the American Fisheries Society 119:135-144.

Karp, C. A., and H. M. Tyus. 1990. Humpback chub (*Gila cypha*) in the Yampa and Green rivers, Dinosaur National Monument, with observations on roundtail chub (*G. robusta*) and other sympatric fishes. Great Basin Naturalist 50:257-264.

McAda, C. W. 2002. Population size and structure of humpback chub in Black Rocks, 1998–2000. Final report to the Upper Colorado River Fish Recovery Program, Project Number 22a3. U. S. Fish and Wildlife Service, Grand Junction, Colorado.

McAda, C. W., J. W. Bates, J. S. Cranney, T. E. Chart, W. R. Elmblad, and T. P. Nesler. 1994. Interagency Standardized Monitoring Program: Summary of Results, 1986–1992. Final report to the Upper Colorado River Fish Recovery Program, Project Number 22. U. S. Fish and Wildlife Service, Denver, Colorado.

Miller, R. R. 1946. *Gila cypha*, a remarkable new species of cyprinid fish from the Colorado River in Grand Canyon, Arizona. Journal of Washington Academy of Science 36:409–415.

Minckley, W. L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix, Arizona.

Pitlick J. and R. Cress. 2000. Longitudinal trends in channel characteristics of the upper Colorado River and implications for food-web dynamics. Final Report to the Recovery Program for the Endangered Fishes of the Upper Colorado River, Project Number 48. Department of Geography, University of Colorado, Boulder.

USFWS (U.S. Fish and Wildlife Service). 1987. Interagency Standardized Monitoring Program Handbook. U. S. Fish and Wildlife Service, Grand Junction, Colorado.

USFWS (U.S. Fish and Wildlife Service). 2000. Code of federal regulations: wildlife and fisheries — endangered and threatened wildlife. 50(17.11):102–143.

USFWS (U.S. Fish and Wildlife Service). 2002. Humpback chub (*Gila cypha*) Recovery goals: an amendment and supplement to the Humpback chub Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

Valdez, R. A. 1990. The endangered fish of Cataract Canyon. Final Report to U. S. Bureau of Reclamation, Salt Lake City, Utah. Contract No. 6-CS-40-03980, Fisheries Biology and Rafting. Report No. 134-3, BIO/WEST, Inc., Logan, Utah.

Valdez, R. A., and G. H. Clemmer. 1982. Life history and prospects for recovery of the humpback chub and bonytail chub. Pages 109–119 *in* W. H. Miller, H. M. Tyus, and C. A. Carlson, editors. Fishes of the upper Colorado River system: present and future. American Fisheries Society, Western Division, Bethesda, Maryland.

Valdez, R., P. Mangan, R. Smith, and B. Nilson. 1982. Upper Colorado River Investigation (Rifle, Colorado to Lake Powell, Utah). Pages 101–279 *in* W. H. Miller et al., editors. Colorado River Fishery Project Final Report; Part Two, Field Studies. U. S. Fish and Wildlife Service and Bureau of Reclamation, Salt Lake City, Utah.

Valdez, R. A., and R. J. Ryel. 1995. Life history and ecology of the humpback chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona. Final Report to Bureau of Reclamation, Salt Lake City, Utah. Contract No. 0-CS-40-09110, Report TR-250-08, BIO/WEST, Inc., Logan, Utah.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, LA-8787-NERP, Los Alamos, New Mexico.

Wydoski, R. S., and J. Hamill. 1991. Evolution of a cooperative recovery program for endangered fishes in the upper Colorado River basin. Pages 123–135 *in* W. L. Minckley and J. E. Deacon, editors. Battle against extinction: native fish management in the American West. University of Arizona Press, Tucson.

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Appendix A

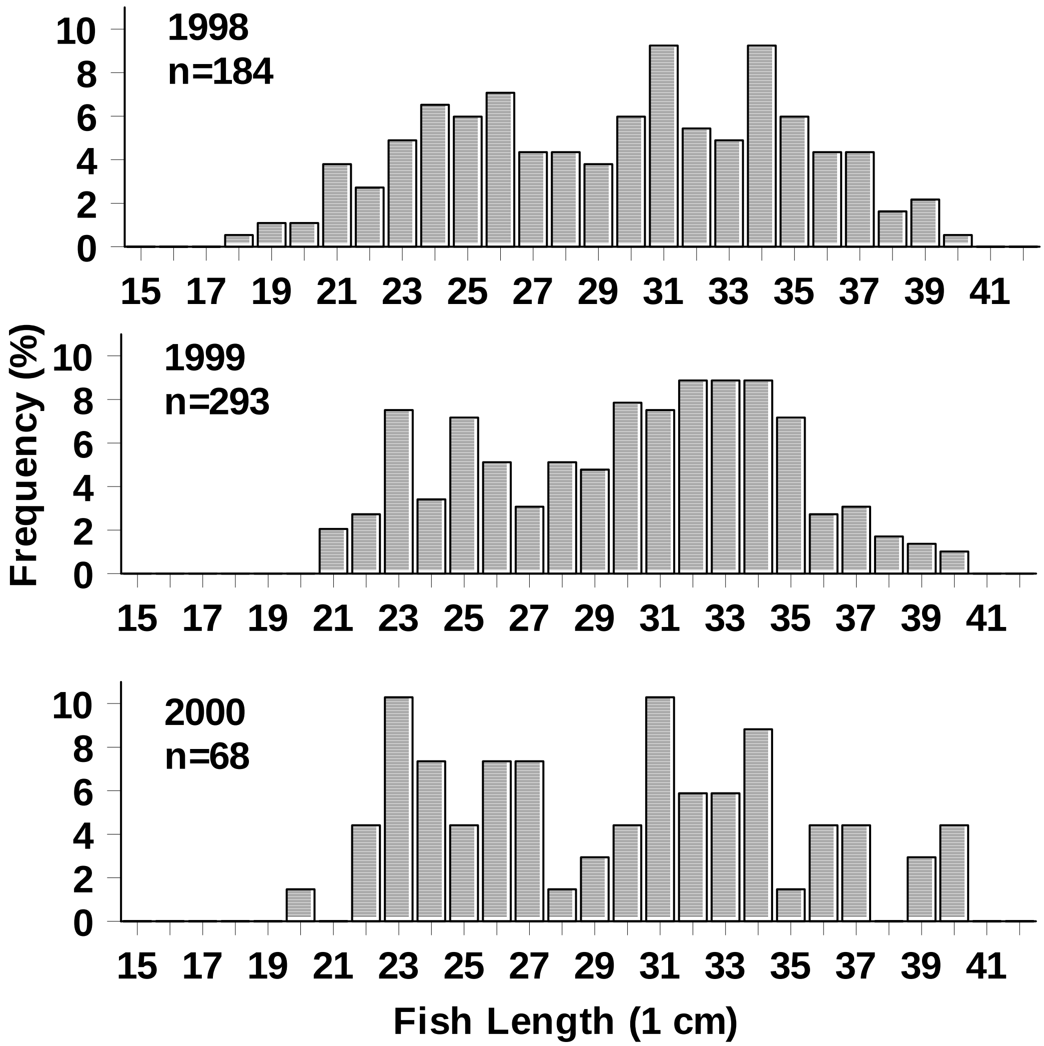

FIGURE A-1. – Population structure of humpback chub in Black Rocks, 1998-2000.

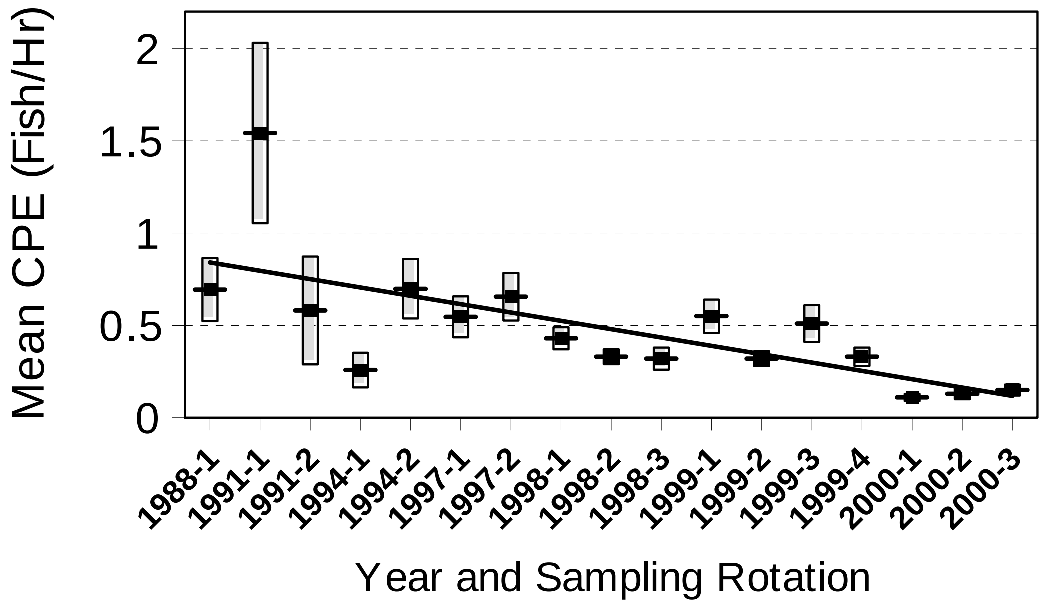

FIGURE A-2. – Mean CPE (trammel nets) of humpback chub in Black Rocks, 1988– 2000.

TABLE A-1. – Total number of *Gila* spp. captured during sampling 2003–2004.

	Trammel Nets		Electrofishing	
Sample Trip	Roundtail	Humpback[a]	Roundtail	Humpback[a]
2003				
1: 9/16 -19	55	11	--	--
2: 9/30-10/3	80	7	62	3
3: 10/13-16	39	17	63	9
4: 10/28-31	268	24	66	2
2004				
1: 9/14-17	75	16	28	3
2: 9/27-30	66	7	52	1
3: 10/13-16	107	34	21	4
4: 10/26-29	72	10	--	--

[a] Includes fish handled more than once.

TABLE A-2. – Summary of population estimates for adult humpback chub in Black Rocks using different models for 2003–2004.

Year	Model	Estimate	95% CI	CV	P-hat	Selection Criteria[a]
2003	Mo	478	221 – 1,176	0.46	0.04	0.80
	Darroch Mt	450	211 – 1,093	0.46	0.04	0.01
	Chao Mt	365	184 – 834	0.42	0.05	0.01
	Chao Mh	597	259 – 1,538	0.50	0.03	0.88
	Chao Mth	475	210 – 1,244	0.50	0.04	0.28
2004	Mo	2,056	457 – 10,355	0.69	0.02	
	Darroch Mt	1,757	403 – 8695	0.96	0.01	
	Chao Mt	932	307 – 3,244	0.98	0.01	

[a] Selection criteria for models Chao Mh and Mo were similar in 2003, but Mh was slightly higher. However, model Mo was chosen to be consistent with the estimates for 1998–2000. Selection criteria were not useful for the 2004 estimates.