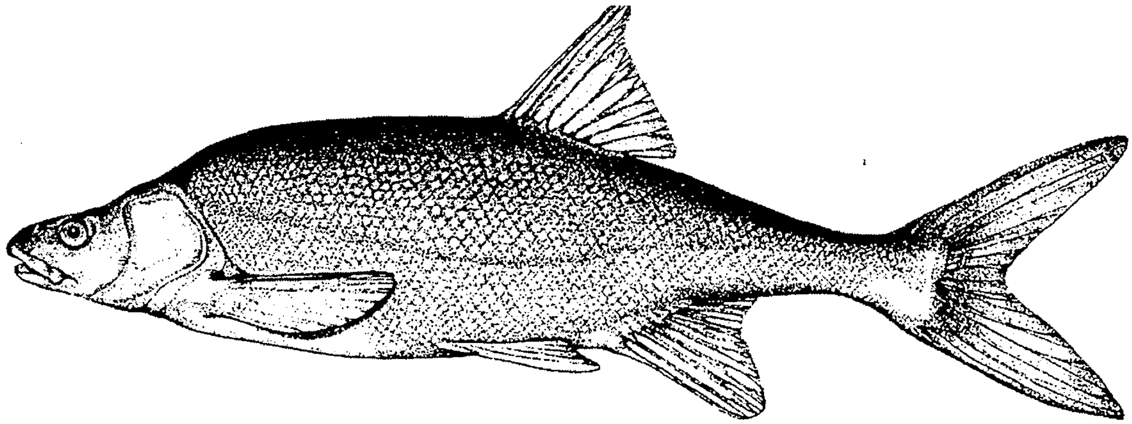

*Technical Guidance Bulletin No. 3 - July 2000*

# LIFE HISTORY AND ECOLOGY OF THE ROUNDTAIL CHUB *GILA ROBUSTA*, FROM TWO STREAMS IN THE VERDE RIVER BASIN

**Federal Aid in Sportfish Restoration**
**Project F-14-R**

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## INTRODUCTION

The life history and ecology of the roundtail chub *Gila robusta*, in the upper Verde River, Arizona, were studied from March 1998 through March 2000. Although not Federally listed as threatened or endangered, the roundtail chub, also a sportfish in Arizona, is nearly extirpated from sections of the Verde and Salt river drainages. Despite declining numbers, little is known about the status of many Arizona populations, and factors that limit their survival are poorly documented. The purpose of this investigation was to describe ecological requirements and population dynamics of roundtail chub. The objectives were to describe species composition, distribution and abundance, quantify habitat selection by different life stages, estimate population size, quantify movement and age and growth, and describe the reproductive capacity of roundtail chub. Other important biotic interactions for roundtail chub in the upper Verde River are presented, as well. In addition, we sampled West Clear Creek, Arizona, near the Bullpen Campground from June 1998 through December 1999 to quantify abundance and age structure as well as, habitat selection by different life stages of roundtail chub. Life history information gathered from both streams was then used to identify management and/or conservation options for this unique, Arizona sportfish.

## VERDE RIVER

The Verde River is 1 of the largest perennial rivers in the Gila River Basin, Arizona. The Verde River originates at an elevation of 1,325 m at Sullivan Lake and flows southeasterly, ~ 300 km, until it joins the Salt River at an elevation of 402 m. The upper 72 km of Verde River is 1 of the few remaining unregulated reaches of river in the desert Southwest (Fig. 1). This section of river

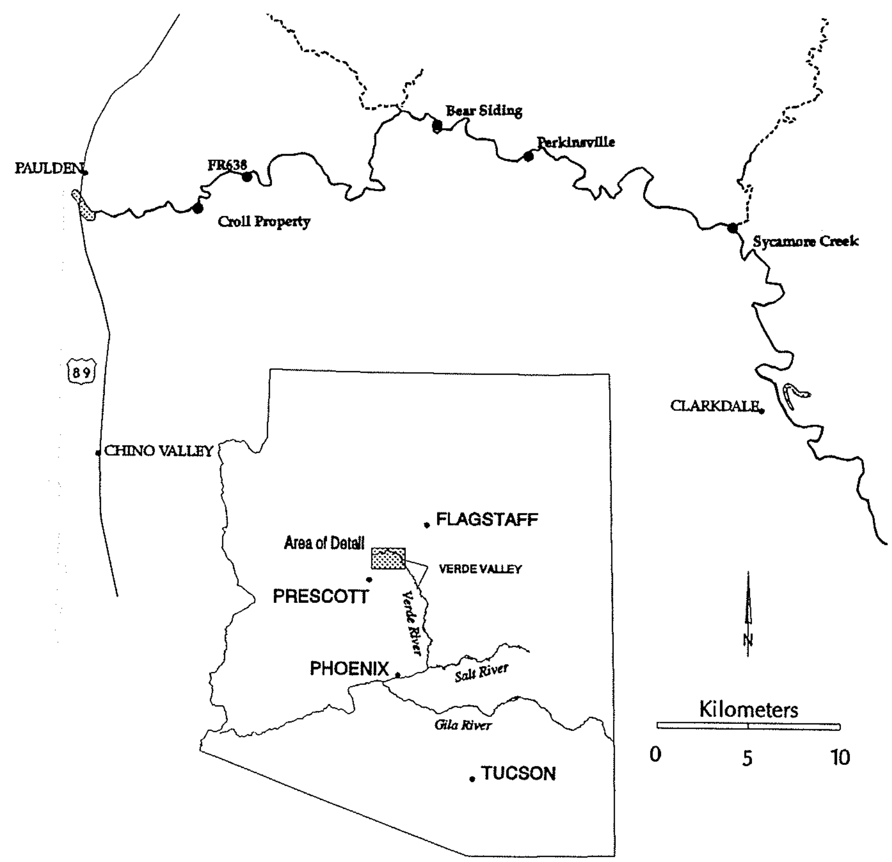


*Figure 1.* Map of sample sites on the upper Verde River, Arizona, March 1998 - March 2000.

drains an area approximately 8,148 $km^2$, has a base flow of 0.57 $m^3/s$ at USGS gaging station # 09503700 near Paulden, Arizona, has periodic, seasonal spates and large floods (> 400 $m^3/s$) that occur on the order of every 5 to 10 years (Stefferud and Rinne 1995). Stream habitat types consist of cobble/boulder-strewn, high-gradient riffles; low-gradient riffles with pebble/gravel substrates; and runs and glides with primarily gravel and/or sand substrates (Rinne and Stefferud 1996). Base flow at USGS gaging station is 0.57 $m^3/s$. Discharge data for the upper Verde River from 1997 through 1999 are presented in Fig. 2.

**WEST CLEAR CREEK**

West Clear Creek is a tributary of the Verde River whose headwaters begin at an elevation of 1,811 m on the Mogollon Plateau (Fig. 3). West Clear Creek flows approximately 60 km west, southwest through a deeply incised gorge with deep pools, drains an area approximately 262 $km^2$, and has a base flow of approximately 0.45 $m^3/s$. The majority of West Clear Creek is high gradient with predominantly cobble/boulder-strewn reaches contained between sheer cliff walls and enters the Verde River just upstream of Beasley Flat at an elevation of 914 m. Similar to the upper Verde River, West Clear Creek experiences periodic, seasonal spates and large floods every 5 to 10 years, however, because West Clear Creek originates on the Mogollon Rim, spring floods occur more frequently due to snow melt/runoff. Discharge data for West Clear Creek near Bullpen Campground were compiled from USGS gaging station # 09505800 and are presented in Fig. 4.

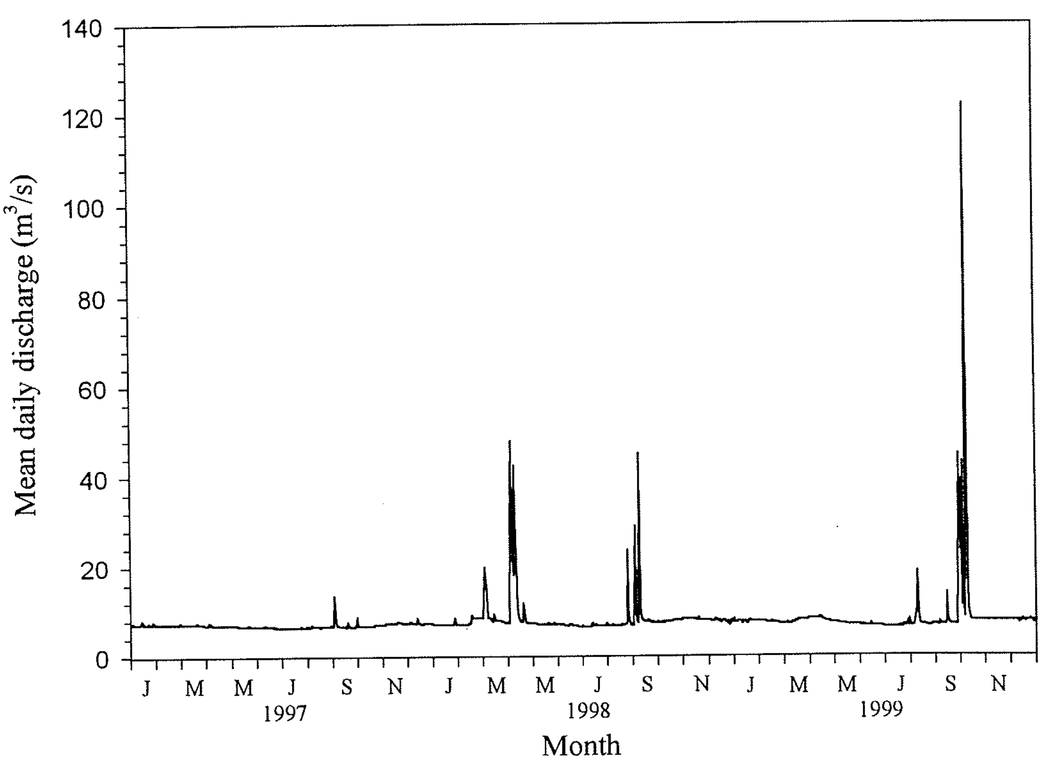


*Figure 2.* Mean daily discharge ($m^3/s$) at USGS gaging station #09503700 on the upper Verde River, January 1997 - December 1999.

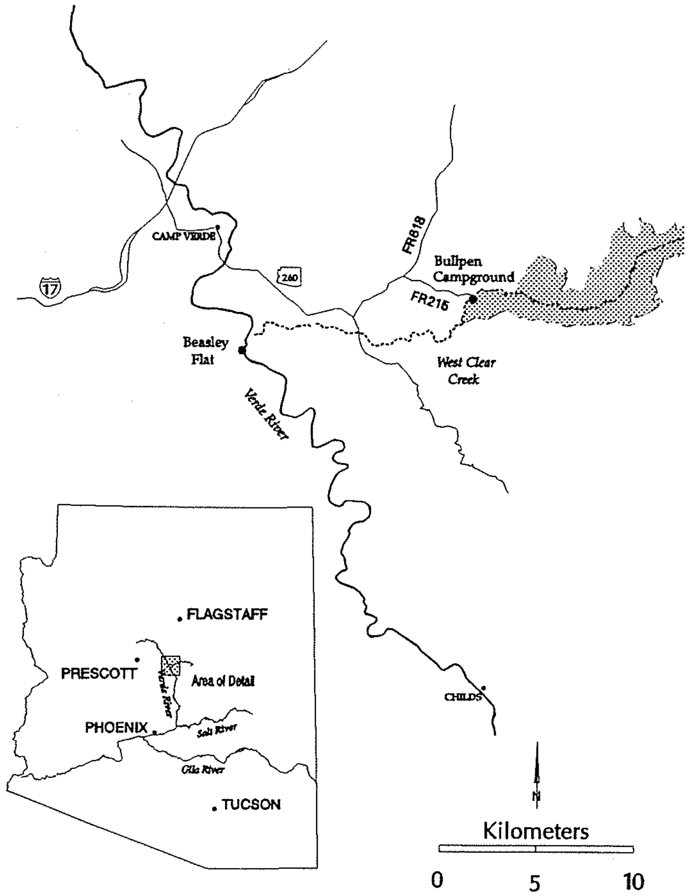


*Figure 3.* Map of sample site (Bullpen Campground) on West Clear Creek, Arizona, June 1998 - December 1999.

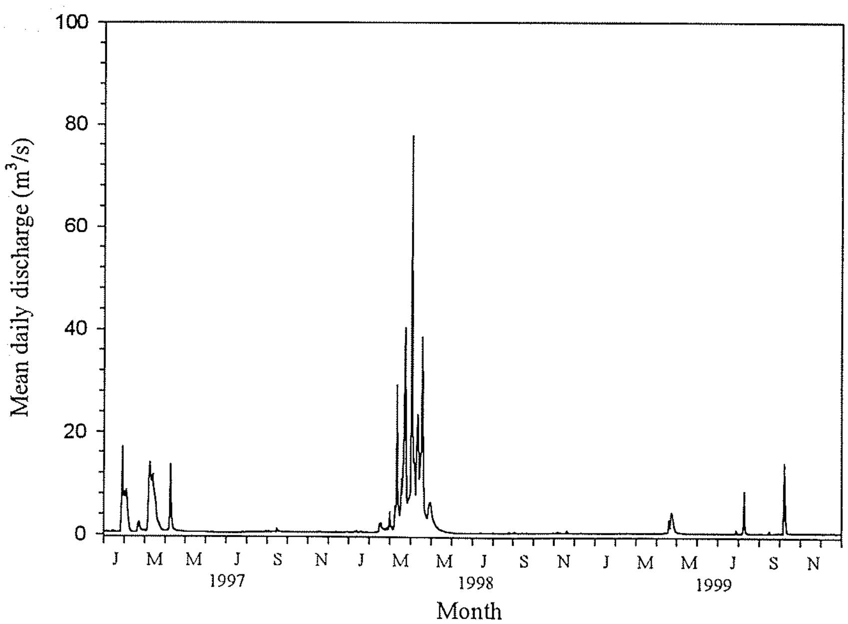


*Figure 4.* Mean daily discharge ($m^3/s$) at USGS gaging station #09505800 near Bullpen Campground, West Clear Creek, January 1997 - December 1999.

## SPECIES COMPOSITION, DISTRIBUTION, AND ABUNDANCE

### *Verde River*

Roundtail chub were collected at 5 sites in the upper Verde River from March 1998 through March 2000, and when combined with all other native species collected (Sonora sucker *Catostomus insignis*, desert sucker *Catostomus clarki*, and longfin dace *Agosia chrysogaster*), native fish comprised the majority of the catch at 4 of the 5 sites (Fig. 5). The highest percent of the catch comprised of roundtail chub was 21% at the Croll Property site, whereas the lowest percentage was 5% at Bear Siding (Fig. 5). A clear trend in percent composition of roundtail chub and native fishes as a whole was apparent with a decrease in both as nonnative species increased. Roundtail chub catch-per-unit-effort (CPUE) was significantly higher, but not different from each other, at the 2 uppermost sites (Croll Property and FR-638) than the 3 remaining downstream sites (Fig. 5). In addition, there was no distinct yearly or seasonal trend in CPUE of roundtail chub (Table 1). In 1998, CPUE was highest in the fall and spring whereas in 1999, CPUE was highest in the summer.

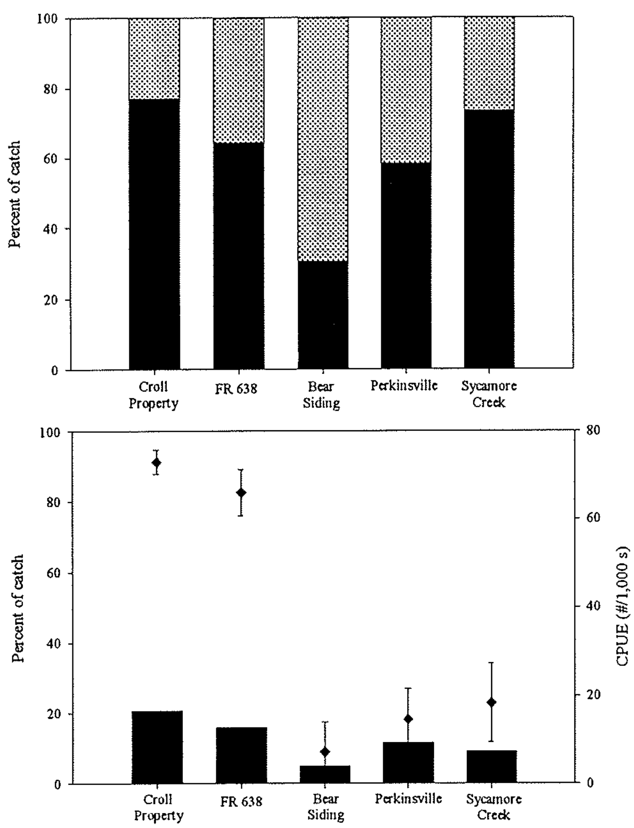


*Figure 5.* Percent composition of native (black) and nonnative (gray) fish [top] and percent composition (bars) and CPUE (diamonds) of roundtail chub [bottom] in the upper Verde River, Arizona, March 1998 - March 2000.

Table 1. Yearly and seasonal CPUE (#/1,000 s) of roundtail chub collected in the upper Verde River, March 1998 - March 2000

| Year | Spring | Summer | Fall | Winter |
|---|---|---|---|---|
| 1998 | 31.2 | 24.4 | 42.4 | 10.8 |
| 1999 | 10.6 | 25.7 | 13.3 | 8.8 |
| 2000 | 15.3 | - | - | - |

Roundtail chub collected in the upper Verde River ranged from 65 to 428 mm total length (TL) with an average of 276 $\pm$ 3.7. Distinct cohorts of roundtail chub were difficult to discern from length-frequency distributions, with the majority of fish collected being greater than 200 mm TL (Figs. 6 & 7). However, in the fall of 1998, age-

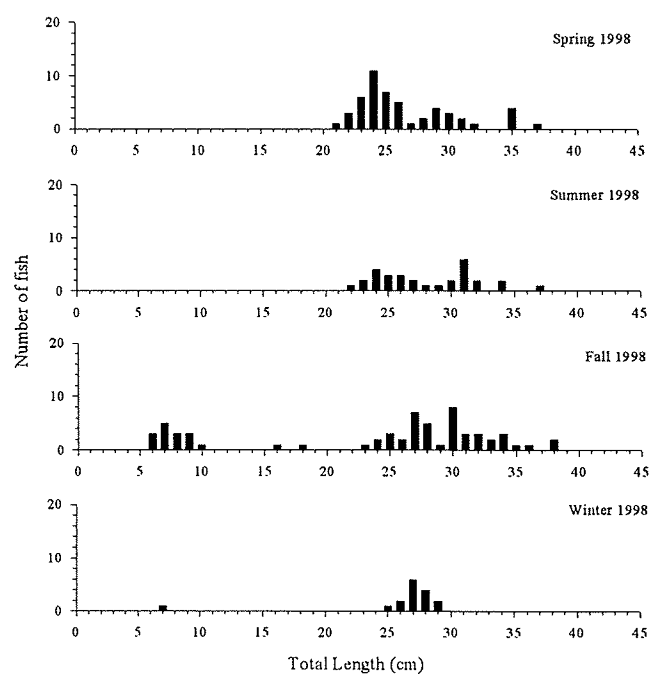


*Figure 6.* Length-frequency histograms of roundtail chub collected in the upper Verde River, Arizona, 1998.

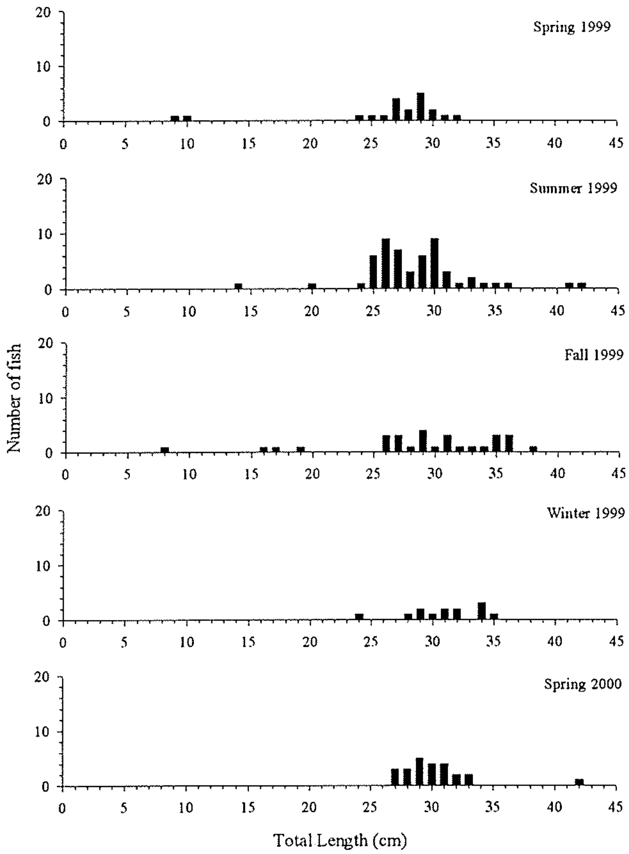


*Figure 7.* Length-frequency histograms of roundtail chub collected in the upper Verde River, Arizona, Spring 1999 - Spring 2000.

0 roundtail chub (modal length = 7 cm TL) were present and appear to have been collected in the spring of 1999 (now age-1), indicating over-winter survival. In the fall of 1999, 1 fish (8 cm TL group) was collected, possibly an age-0 fish spawned in the spring of the same year. In the summer of 1999 and fall of both 1998 and 1999, juvenile roundtail chub (14 - 19 cm TL) were collected, indicating recruitment, albeit low, into the adult population.

The presence of age-0 roundtail chub in the fall of 1998 may be attributed to a springtime flood that occurred in the same year. Brouder (*in press*) observed a significant increase in roundtail chub recruitment to age-1 in years following a flooding event in the late-winter/early spring of the previous year.

### *West Clear Creek*

The majority (84.4%) of fish collected at the Bullpen Campground site on West Clear Creek from 1998 through 1999 was native species. In 1998 and 1999, roundtail chub comprised 28.6% and 49.7%, respectively. Total catch and CPUE of roundtail chub tended to be greater in the summer and fall than in winter (Table 2), however, roundtail chub CPUE over the 2-year period was highest in the spring of 1999 and lowest in the winter of the same year.

Table 2. Yearly and seasonal CPUE (#/1,000 s) of roundtail chub collected in West Clear Creek, June 1998 - December 1999.

| Year | Spring | Summer | Fall | Winter |
|---|---|---|---|---|
| 1998 | - | 16.3 | 17.5 | 7.6 |
| 1999 | 44.9 | 22.3 | 12.1 | 2.2 |

Mean total length of roundtail chub collected in West Clear Creek in both 1998 and 1999 was 125 $\pm$ 2.8 and 118 $\pm$ 3.2 mm, respectively, and was much smaller than roundtail chub collected in the upper Verde River or lower Verde and Salt rivers below Bartlett and Stewart Mountain dams (355 mm TL; Bryan et al. 2000). The lack of roundtail chub greater than 272 mm TL and thus, smaller mean length of roundtail chub, may be indicative of the available habitat in the section of stream we sampled. Generally, fish get smaller with distance upstream (Schlosser 1982), however, Hughes and Reynolds (1994) suggest that differences in fish size upstream to downstream are related to size-dependent habitat selection and competition.

Three cohorts of roundtail chub were discernable during 1998 through 1999 (Fig. 8). An age-0 cohort was present in September 1998 (modal length = 7 cm TL) and was easily tracked through September 1999 (modal length = 15 cm TL); this cohort grew approximately 8 cm in 1 year. Putative age-1 (modal length = 10 cm TL) and age-2 fish were captured in June 1998, both of which disappeared from the catch by December 1998. In March 1999, the now age-2 fish (modal length = 14 cm TL) were again present in the catch as they were in June 1999 (modal length = 16 cm TL), but this age class was

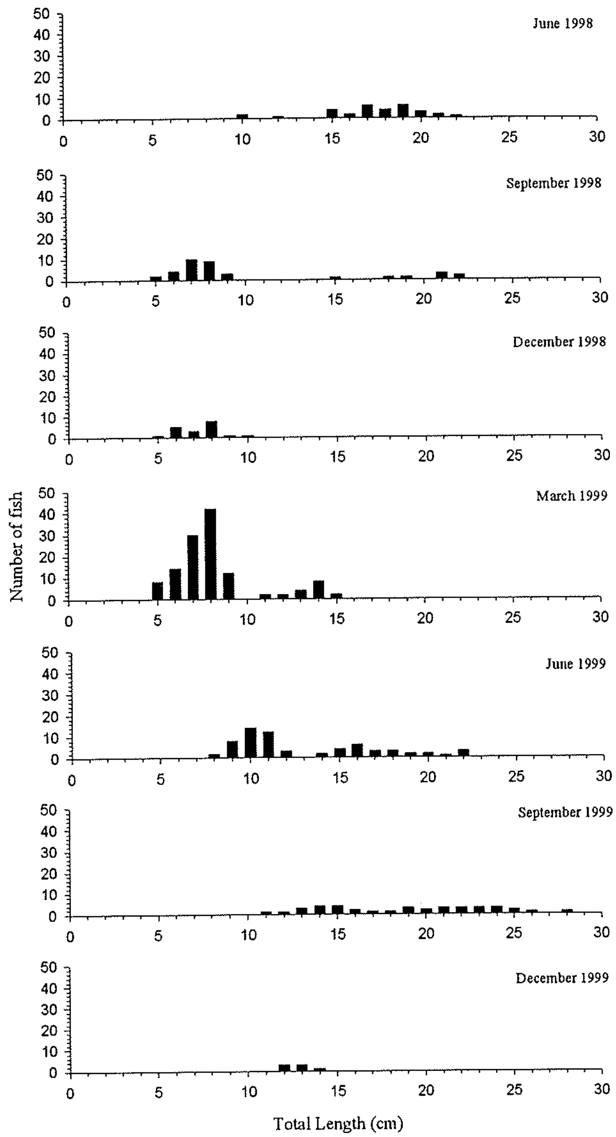


*Figure 8.* Length-frequency histograms of roundtail chub collected in West Clear Creek, Arizona, June 1998 - December 1999.

indistinguishable from older fish by September 1999. Only age-1 roundtail chub were caught in December 1999 and no age-0 roundtail chub were caught at anytime in 1999.

Collection of age-0 roundtail in the fall and winter of 1998 indicates successful spawning by roundtail chub in the spring of that year. In March of 1999, age-1 fish were collected indicating over-winter survival of the 1998 cohort. Absence of age-0 roundtail chub in 1999 may be attributed to the lack of a late-winter/early-spring flood. A spring flood occurred between March and late-April, 1998 (Fig.4), and large numbers of age-0 roundtail chub were collected in the fall and winter of that year. In spring 1999, large numbers of age-1 roundtail chub continued to be caught. In spring 1999, no flood occurred and age-0 roundtail chub were absent from our catches in 1999.

Overall, species composition of fish collected at 3 of 5 sites in the upper Verde River and at Bullpen Campground on West Clear Creek, was dominated by native fishes in both years. These results are somewhat "atypical" compared to many Arizona streams where non-native fishes dominate the catch (Ohmart 1982; Clark et al. 1998; Rinne et al. 1998).

## HABITAT SELECTION

### *Verde River*

Habitat selection by 3 life-stages [young-of-year (YOY), juvenile, and adult] of roundtail chub were quantified at 5 sites (Croll Property, FR-638, Bear Siding, Perkinsville, and Sycamore Creek) in the upper Verde River. Croll Property, FR-638, Bear Siding, Perkinsville, and Sycamore Creek had an average surface area of 127.5 $m^2$, 1,036.2 $m^2$, 4,578.2 $m^2$, 4,968.0 $m^2$, and 6,862.8 $m^2$, respectively.

Over the 2-year period and across sites, glides were the dominant macro-habitat available, however, adult roundtail chub primarily used and selected for pool habitat. Adult roundtail chub negatively selected (avoided) both riffle and glide habitat types. Data were too sparse to determine macro-habitat selection by juvenile and YOY roundtail chub. However, both YOY (96%) and juvenile (82%) roundtail chub were collected along vegetated shorelines within glides.

All sites combined, 9 pool types were identified in the upper Verde River: backwater pool - boulder formed, backwater pool - rootwad formed, channel confluence pool, corner pool, instream pool - boulder formed, pocket water, lateral scour pool, lateral scour pool - bedrock formed, and lateral scour pool - rootwad formed. In both 1998 and 1999, backwater pools - boulder formed comprised the majority (20.5%) of the available pool habitat followed by pocket water

(18.2%), lateral scour pool - bedrock formed (15.9%), and corner pools (9.1%). In both years, adult roundtail chub positively selected for backwater pools - boulder formed, pocket waters, and corner pools, and negatively selected (avoided) lateral scour pools. Pocket waters consist of a slack-water area (eddy) behind or downstream of an instream obstruction, typically a boulder.

The majority of the microhabitat available consisted of depths 21 - 50 cm (54.1%) and < 20 cm (35.3%). However, adult roundtail chub used depths in the 21 - 50 cm (38.6%) and 51 - 100 cm categories (35.7%) most frequently. In addition, adult roundtail chub avoided depths < 20 cm.

Current velocities at all sites combined were predominantly low velocity and adult roundtail chub selected for velocities ≤ 20 cm/s and used velocities > 20 cm/s in proportion to their availability. Sand was the predominant substrate type in the upper Verde River, however, adult roundtail chub did not select for any substrate type. Lastly, shoreline vegetation (28.6%), overhanging vegetation (6.3%), and instream boulders (5.8%) were the dominant cover types in the upper Verde River over the 2-year period. Adult roundtail chub avoided cover types typically associated with shallow water (i.e., shoreline and overhanging vegetation) and positively selected for instream boulders. All other cover types were used in equal proportion to their availability.

### *West Clear Creek*

Habitat selection by YOY, juvenile, and adult roundtail chub was quantified at Bullpen Campground, West Clear Creek, identical to the 5 sites in the upper Verde River. The reach sampled on West Clear Creek had a surface area of approximately 4,105 $m^2$. Glides were the dominant macro-habitat type available, however, all 3 size-classes of roundtail chub primarily used and selected for pool habitat. Juvenile and YOY roundtail chub used glides less than expected, and juveniles also used riffles less than expected. Adult use of riffles and glides was similar to available proportions.

Four pool types were identified at Bullpen Campground: pocket water (50.7%), plunge pool (32.7%), lateral scour pool - bedrock formed and lateral scour pool - boulder formed (13.3% and 3.3%, respectively). Of the 4 pool types, adults used each in proportion to their availability. Juvenile and YOY roundtail chub negatively selected (avoided) lateral scour pool habitat but positively selected for pocket water.

The majority of the West Clear Creek site had depths that fell within the shallowest 2 depth categories (39% ≤ 20 cm and 3% 21 - 50 cm) and these were depths most frequently used by all 3 size-classes of roundtail chub. Adult roundtail chub used all depths in equal proportion to their availability, whereas juveniles used depths ≤ 100 cm in equal proportion to their availability but avoided depths > 100 cm. Young-of-year roundtail chub avoided depths of 51 - 100 cm and were never collected in water > 100 cm.

Current velocities at transect points were predominantly low velocity and the 3 size classes of roundtail chub used velocities in equal proportion to their availability.

Cobble was the predominant substrate type in this study site. Adult roundtail chub did not select for any substrate, but juveniles avoided boulders and bedrock. Young-of-year roundtail chub avoided areas with bedrock and cobble.

Instream boulders were the dominant cover type in this reach of river. Adult roundtail chub avoided cover types typically associated with shallow water (i.e., emergent and shoreline vegetation) and used the remaining available cover types in equal proportion to their availability. Juvenile roundtail chub selected for instream boulders and avoided areas with emergent vegetation, instream trees, undercut banks or areas with no cover available. Similar to juveniles, YOY roundtail chub avoided emergent vegetation, instream trees, undercut banks, and areas with no cover. The majority (79%) of YOY roundtail chub was collected from interstices between and under boulders or the slack-water area behind them. All life-stages of roundtail chub were collected during the day in and around some type of cover; primarily instream boulders associated with pocket water areas.

Differences in habitat selection by roundtail chub in the upper Verde River and West Clear Creek may be attributed to differences in nonnative predator densities. Densities of nonnative, potentially predatory fish in West Clear Creek were lower (3.2 predatory fish/1,000

$m^2$) than densities in the upper Verde River (8.6 predatory fish/$m^2$). Therefore, greater density of predators may influence YOY and juvenile roundtail chub habitat use in the upper Verde River, an effect observed in other fish assemblages (Fraser and Sise 1980; Gilliam and Fraser 1987; Greenberg 1994), or the difference in habitat use may be reflective of a difference in the overall availability of habitat between streams.

Overall, macro-habitat use by adult roundtail chub in both the upper Verde River and West Clear Creek was similar to that reported in other streams (Bestgen and Propst 1989; Barrett and Maughn 1995). In both the upper Verde River and West Clear Creek, the different life-stages of roundtail chub either selected for or avoided certain depths, velocities, and substrates. However, the micro-habitat variables selected for or avoided were typically those variables that comprise a given macro-habitat type, which was also selected for or avoided (e.g., pools = deep, low velocity, fine substrates). Minimal information exists in the peer-reviewed literature regarding macro-habitat selection and micro-habitat use/selection by different life-stages of roundtail chub. Therefore, these results provide insight into how roundtail chub use habitat with regards to what is available.

## POPULATION ESTIMATES

Population estimates of roundtail chub > 200 mm TL were generated for 2 sites (Croll Property and FR-638) on the upper Verde River under the assumption that populations at each site were closed. We believe this assumption was valid given the brief sampling period at each site (Otis et al. 1987) and the fact that only fish > 200 mm were encountered. Closure was further supported by the lack of significant movement by roundtail chub (see **MOVEMENT**).

Several different population estimates were generated using an updated version (March 2000) of the computer program MARK (White and Burnham 1999). In the first analysis, population estimates for each year and site were generated separately. In a second analysis, a population estimate for each site with years combined was generated and finally, an overall population estimate for both sites and years combined was constructed. Population estimates for each site were comparable because of a lack of significant difference in fishing effort and length of river reach sampled (1 km at both sites).

The model that best fit the roundtail chub mark-recapture data was $\{\Phi_t, p.\}$, where ($\Phi$) is the survival rate between capture periods and ($p$) is the capture probability or the probability of an individual being caught. Therefore, the model $\{\Phi_t, p.\}$ considered survival rates between capture periods to be time varying ($\Phi_t$) and the recapture probability of a given fish to be constant ($p.$).

Estimates of the population size of roundtail chub at Croll Property varied greatly depending on the analysis (Table 3). In 1998, the population was estimated at approximately 740 individuals, with large 95% upper and lower confidence

Table 3. Yearly and overall population estimates ($N_i$) of roundtail chub at Croll Property and FR-638 based on model ($\Phi_t$, $p.$, time varying survival and constant recapture probability) from program MARK. Also shown are theoretical SEs (in parenthesis) and 95% confidence intervals (profile likelihood).

| Site | Year $_i$ | $N_i$ / 1 km (SE) | 95% Confidence Interval |
|---|---|---|---|
| Croll Property | 1998 | 740 (53) | 216 - 5,178 |
| Croll Property | 1999 | 217 (62) | 150 - 424 |
| Croll Property | 1998 & 1999 | 240 (47) | 162 - 347 |
| FR-638 | 1998 | 68 (42) | 18 - 274 |
| FR-638 | 1999 | 72 (28) | 32 - 219 |
| FR-638 | 1998 & 1999 | 121 (83) | 29 - 310 |
| Overall | 1998 & 1999 | 361 (82) | 223 - 714 |

intervals. In 1999, the population estimate was much smaller (217) but with narrower confidence intervals, and for the 2-years combined, the estimate was 240 individuals (95% CI = 162 - 347). Estimates of the roundtail chub population at FR-638 were much smaller than those at Croll Property (Table 2) and were 68 individuals (95% CI = 18 - 274) in 1998, 72 individuals (95% CI = 32 - 219) in 1999, and 121 (95% CI = 29 - 310) individuals for both years combined. The overall population estimate for roundtail chub, with sites and years combined, was 361 individuals (95% CI = 223 - 714). The estimated population of roundtail chub > 200 mm TL at Croll Property was almost twice that of FR-638. Interestingly, CPUE of roundtail chub was not significantly different between the 2 sites, nor was available habitat. However, both percent composition and CPUE of nonnative, predatory fishes were higher at the FR-638 than Croll Property (see **SPECIES COMPOSITION, DISTRIBUTION, AND ABUNDANCE**), indicating that nonnative fishes may be negatively impacting (predation/competition) roundtail chub populations more so at FR-638 than at Croll Property.

## MOVEMENT

Movement of roundtail chub > 200 mm TL at 2 1-km sites (Croll Property and FR-638) in the upper Verde River was evaluated from March 1998 through March 2000 using PIT-tag, mark-recapture data. Because surveys were not continuous in time, displacement of individual PIT-tagged fish between surveys was used as an index of movement. "Net displacement" was defined as longitudinal upstream or downstream distance from release site to last recapture, whereas "gross displacement" was defined as cumulative distance between successive recapture sites. "Mean displacement" was calculated as the average distance between recapture locations.

A total of 240 and 121 fish were PIT-tagged at Croll Property and FR-638, respectively. Of the 240 fish marked at Croll Property, 43 were recaptured and movement evaluated, and of the 121 fish marked at FR-638, movement of 27 recaptured fish was determined. Overall, 21 of 70 recaptured fish were recaptured more than once.

There was no significant difference between mean displacement of roundtail chub between the 2 sites and therefore, data were pooled. Mean net displacement for all 70 fish was 263.9 m (range 0.0 - 5.7 km) based on 72 total movements. Eight fish had net displacements greater than 1 km and after being removed from the analysis, mean net displacement of roundtail chub was 96.8 m. Net displacements were equally divided between upstream and downstream movements, with nearly half (43%) of the net displacements being less than 50 m (Fig.9). There was no significant seasonal effect on mean displacement of roundtail chub nor was there a significant correlation between total length of fish and mean displacement, indicating a potential lack of movement based on reproductive activity. Gross and mean displacement of roundtail chub in the upper Verde River were similar, (Fig. 9) with the majority (55.7%) of fish moving distances < 100 m. Very few studies have quantified movement of roundtail chub in small, desert streams. Mean displacement by roundtail chub in the upper Verde River was similar to that reported for roundtail chub in Aravaipa Creek, Arizona (Siebert 1980), both of which observed the majority of movement being less than 100 m. Minimal movement by roundtail chub may be associated with a strong selection for pool habitats also observed in this study (see **HABITAT SELECTION**). The majority (83%) of roundtail chub captured and recaptured throughout the study sites was collected from pool habitats, which comprised the smallest percentage of overall macro-habitat available. Pools are intermittently dispersed throughout both study sites, offering only a "handful" of refugia from the intense direct sunlight that can cause thermal stress in the more abundant shallow, clear water, open areas. In fact, fishes of the genus *Gila* sp. appear to actively avoid sunlight (Deacon and Minckley 1974), and therefore, direct sunlight may stimulate or force roundtail chub to move to or remain in deep pools that provide shade. Finally, an apparent "site fidelity" was observed for 18 roundtail chub that showed no movement at all, being recaptured where initially tagged, with a mean residence time of 325 $\pm$ 32 days.

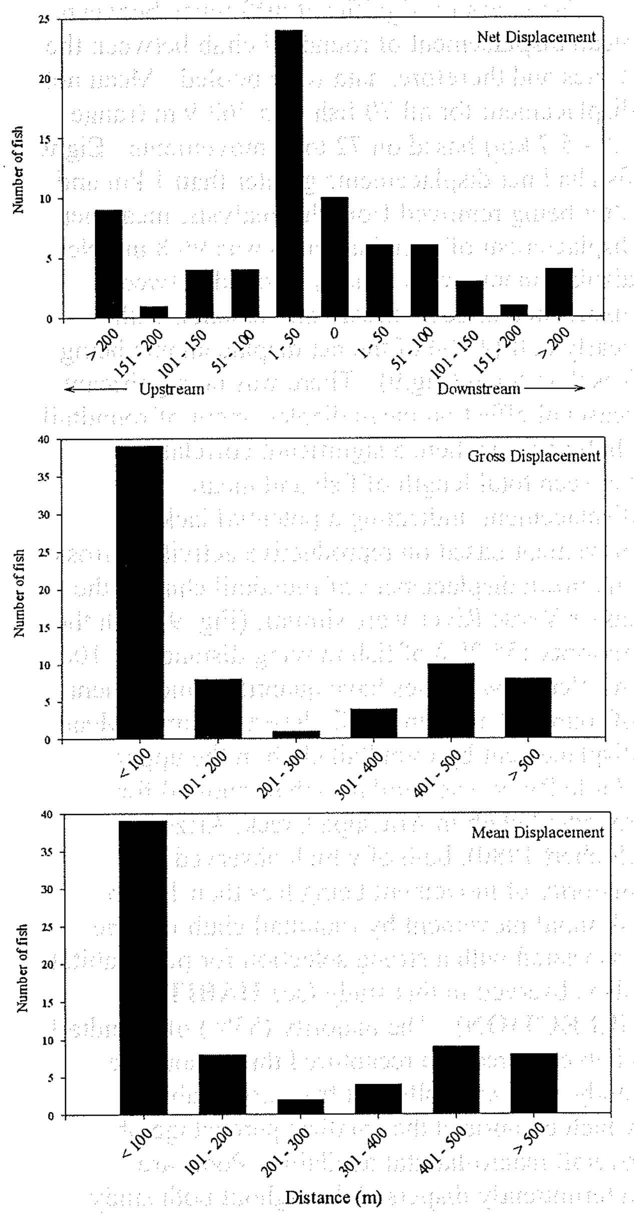


*Figure 9.* Net (top), gross (middle), and mean (bottom) displacement of 70 PIT-tagged roundtail chub > 200 mm TL in the upper Verde River, Arizona, March 1998 - March 2000.

## AGE AND GROWTH

A total of 280 roundtail chub, ranging in total length from 50 - 415 mm, were collected and sacrificed seasonally from the spring of 1998 through winter 1999 to examine the feasibility of using otoliths to age roundtail chub. In addition, roundtail chub were hatched and reared at Arizona Game and Fish Department's (AGFD) Bubbling Ponds Fish Hatchery, and therefore, were of known age, and used to validate annuli formation and measure the agreement between the known-age of fish and age assigned by 3 independent otolith readers.

Annuli were present on otoliths of wild-caught roundtail chub and were validated by distinct annulus formation and known number (age) of hatchery reared roundtail chub. Results of marginal increment analysis of otoliths indicate that annuli are laid down once per year, in approximately May (Fig. 10), most likely with the onset of spawning. Likewise, ages assigned by 3 independent readers to otoliths from known-aged fish were in exact agreement 100% of the time; further indicating that otoliths are a valid technique to age roundtail chub.

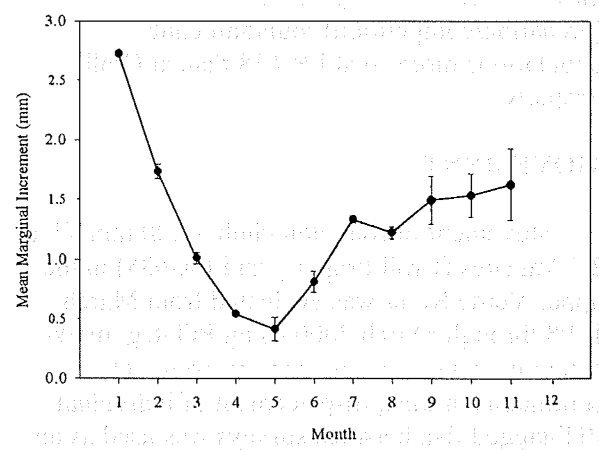


*Figure 10.* Marginal increment analysis for roundtail chub from the upper Verde River, Arizona. Ages 1-7 were used in the analysis.

Roundtail chub collected from the upper Verde River ranged from age-0 to age-7 based on annulus counts. Two distinct cohorts of roundtail chub were present in both 1998 and 1999. The majority (44%) of fish in 1998 were age-5 (1993 year-class) followed by age-3 (36%; 1995 year-class). Similarly, roundtail chub from the 1993 and 1995 year-classes (age-6 and age-4, respectively) comprised the 2 highest percentages of the fish in 1999 at 42% and 28%, respectively. These results further support the hypothesis that flooding enhances recruitment of roundtail chub (Brouder *in press*). In both 1993 and 1995, late-winter/early-spring floods had occurred and recruitment of roundtail chub to age-1 the following spring was significantly higher. Even though the majority of fish collected were from the 1993 and 1995 year-classes, there were fish from other year-classes collected, as well. The occurrence of other cohorts, albeit low, indicates that reproduction does occur in non-flood years, but to what extent remains uncertain.

The total length to otolith radius relationship was best described using log-transformed data and the following equation:

$$\log_e(\mathbf{TLc}) = 1.084 * \log_e(\mathbf{ORc}) + 2.410,$$

where **TLc** equals the total length of fish at capture and **ORc** equals the otolith radius at capture. Back-calculated length at age (using methods in Campana 1990) of roundtail chub age-1 through age-7 were 101, 182, 248, 301, 344, 379, 407 mm TL, respectively (Fig. 11). Back-calculated length at age-1 for successive age groups did not show a consistent pattern of differences or Lee's phenomenon. Back-calculated lengths at age of roundtail chub using PIT-tag mark/recapture data indicate that total length of roundtail chub at age-1 through age-7 was 101, 176, 234, 277, 309, 333, 351, respectively (Fig. 11). Slightly longer fish at older ages using otoliths may be attributed to the small number of large fish collected (n = 26 for fish > age-4). Conversely, both von Bertalanffy equations estimated length at age for fish less than age-4 quite closely. Therefore, PIT-tag mark/recapture data may be a more accurate representation of length at age of roundtail chub across all ages and thus, provide what appears to be a more accurate representation of age and growth of roundtail chub from the upper Verde River. These findings are somewhat encouraging in that future age and growth studies may be able to employ a non-lethal, mark-recapture experiment instead of extracting otoliths. Mark-recapture experiments should allow for an accurate representation of growth in wild-caught fish to be obtained, assuming accurate length at age data for age-1 fish are available.

Mean annual growth rates from PIT-tag recapture data were 33.7, 21.4, 17.8, and 10.3 mm for fish in 50-mm length groups of 200 - 250 mm TL, 251 - 300 mm TL, 301 - 350 mm TL, and > 350 mm TL, respectively.

Lengths at previous age of roundtail chub in this study are much larger than those assigned to roundtail chub from 2 streams in the Gila River Basin, New Mexico (Bestgen 1985), Fossil Creek, Arizona (Neve 1976), and the Green River, Utah (Vanicek and Kramer 1969). The large discrepancy may be attributed to the use of scales by previous researchers compared to otoliths in this study. Both Bestgen (1985) and Neve (1976) concluded that because of the difficulty in discerning distinct annuli and therefore ages, the use of scales may not be an accurate method for aging roundtail chub and therefore, should be viewed as tentative. Large discrepancies in length at age data between populations inhabiting different systems can be indicative of variation in life history strategy in different habitats (Smith 1981). Typically, fish in large habitats select for fast growth and older maximum age while fish in small habitats reproduce at an early age, causing subsequent declines in growth rate and maximum age. If this were the case, one would expect lengths at age of roundtail chub from the Green

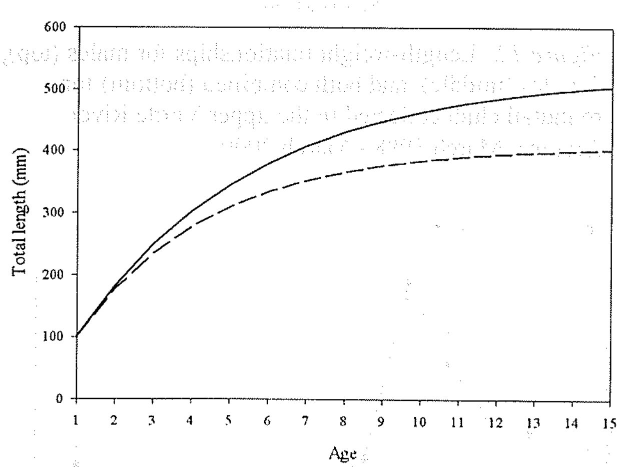


*Figure 11.* Von Bertalanffy growth curves for roundtail chub collected in the upper Verde River, Arizona, using otoliths (solid line) and PIT-tag mark/recapture data (dashed line).

River, Utah (large system) to be greater than lengths of roundtail chub from the upper Verde River (small system). Again, however, this discrepancy may be attributed to ages obtained from the use of scales from roundtail chub collected from the Green River, Utah.

## REPRODUCTIVE CAPACITY

Self-sustaining populations of roundtail chub appear to exist in sections of the upper 72km of Verde River, indicating that, to at least some extent, spawning and recruitment are successful. Data pertaining to sex of roundtail chub were available from 207 fish and resulted in a 151:56 (~3:1) ratio of males to females. Length-weight relationships for males, females, and both sexes combined were described, and exponents of 3.161, 3.151, and 3.022 indicate that growth was isometric as an exponent of 3.0 indicates a constant relationship between length and weight (Fig. 12). In addition, there was no difference between growth pattern of male and female roundtail chub.

Male roundtail chub averaged 277 ± 3 mm TL and the smallest male expressing milt was 156 mm TL and, based on otolith analysis, was age-2. Female roundtail chub averaged 329 ± 8 mm TL with the smallest female with mature, extrudable eggs being 189 mm TL or age-2, possibly age-3.

Gonadosomatic index (GSI) was calculated as:

**ovary wt (g)/total body weight (g) * 100**

and plotted against month of capture to determine time of spawning by roundtail chub. Mean GSI was highest in April followed by a sharp decrease in May, indicating that spawning had occurred during this period (Fig. 13). This hypothesis was further supported by the collection of larval roundtail chub on April 24, 1998. Lowest mean GSI was in September followed by an increase in November/December.

Total fecundity (# eggs/fish) ranged from 7,267 to 26,903 eggs. Fish ranged in length from 270 to 427 mm TL and from age-4 to age-7. The average reproducing female from the upper Verde River was age-5, 328 mm TL, and produced 13,948 eggs.

Forty-two separate observations of roundtail chub spawning were made between 1115 and

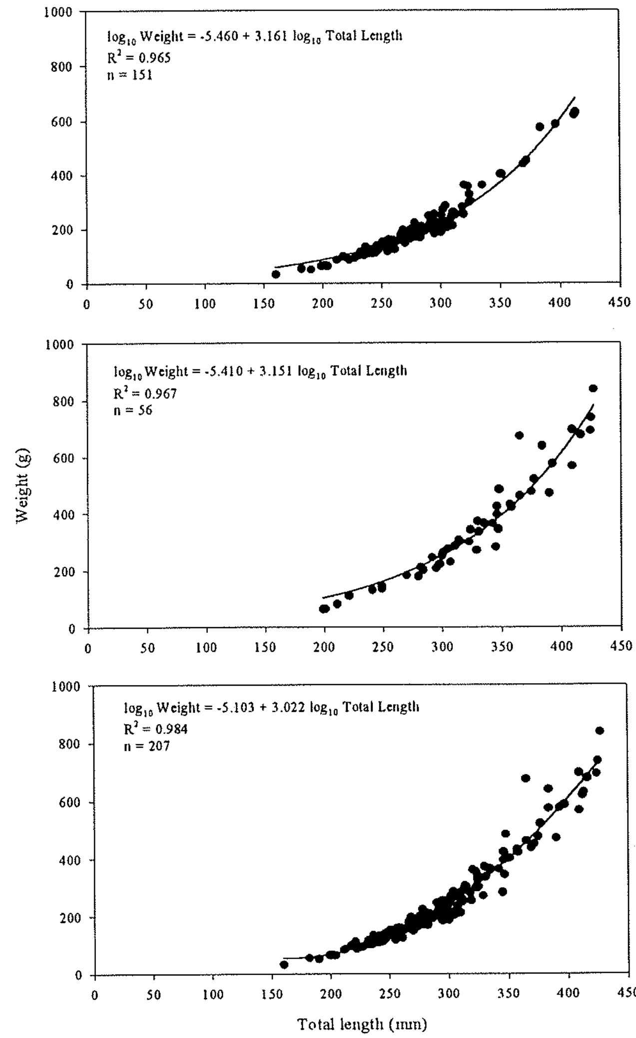


*Figure 12.* Length-weight relationships for males (top), females (middle), and both combined (bottom) for roundtail chub collected in the upper Verde River, Arizona, March 1998 - March 2000.

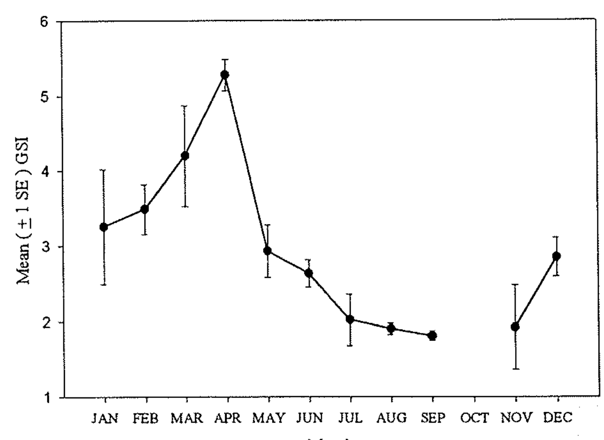


*Figure 13.* Mean (± 1 SE) gonadosomatic index (GSI) of roundtail chub collected in the upper Verde River, 1997.

1445 h on May 16 and 17, 1998, in the Verde River immediately upstream (~20 m) of the confluence with Sycamore Creek. Several groups consisting of a single large female and 2 to 3 smaller males were observed mating. The mating act itself consisted of 2 to 3 males positioned next to and posterior-laterally to the female with their vents in close proximity to each other. The female would rapidly "quiver" her caudal region while the males followed suit, pressing their bodies against the female. The mating would last approximately 4 - 10 seconds. Eggs recovered from spawning sites were adhesive and ranged from 1.8 - 3.8 mm in diameter with a mean of 2.7 mm (n = 39).

Roundtail chub were observed spawning and depositing eggs over clean gravel at the base of a riffle in close proximity to the transition from riffle to glide. Average depth of the water column was 31.6 cm and average current velocity was 43.8 cm/s. Average water temperature on both days was 18.3 C.

Coincidentally, Sonora suckers were observed spawning at the same location approximately 3 - 4 weeks prior to roundtail chub. Sonora suckers were observed actively "cleaning" the substrate (quantified as predominately fine silt) at this location, a behavior not observed by roundtail chub. In addition, both spawning by Sonora sucker and roundtail chub followed a small spate (Sonora sucker, ~ 1 week post-spate; roundtail chub, ~ 3 weeks post-spate); again, an hypothesized spawning cue for several southwestern native fishes.

## BIOLOGICAL INTERACTIONS

### *Predation*

Diets of 6 nonnative predatory fishes were quantified in relation to abundance of roundtail chub, as well as other native fishes. Overall, roundtail chub, and native fishes as a whole, comprised small numeric and gravimetric percentages of the diet of all predatory fishes. Crayfish and aquatic invertebrates comprised the highest percent by number and weight for all predatory species. The majority of native fishes preyed upon ranged in length from 34 - 90 mm, indicating that nonnative fish predation may limit recruitment more than adult survival.

Abundance of YOY and juvenile roundtail chub and other native fishes varied seasonally, but increased abundance did not necessarily translate to increased predation. The observed low levels of predation on roundtail chub may be attributed to the availability of a more abundant, alternative food source, habitat partitioning between predatory and prey, and/or a lack in abundance of YOY/juvenile roundtail chub; the latter of which appears to be most likely (see **SPECIES COMPOSITION, DISTRIBUTION, AND ABUNDANCE**).

In fact, with a lack in abundance of YOY/juvenile roundtail chub, any predation by nonnative fishes could be detrimental to the roundtail chub population. On several occasions, numerous smallmouth bass contained significant numbers ($\leq$ 55) of prey fish and overall, 67 smallmouth bass contained 87 prey fish. Hypothetically, if this is a continuing occurrence, and roundtail chub recruitment continues to be low, then continuous removal of even a portion of the population can have a severe negative impact.

The population of smallmouth bass > 100 mm TL at the Croll Property site was estimated at 183 (95% CI = 153 - 228) in the fall of 1998. Our data indicate that on average about 1% of the smallmouth bass ate an average of 2 roundtail chub. If this estimated average meal of 2 roundtail chub occurs once a week, a smallmouth bass population of 183 would annually consume 19,302 roundtail chub at Croll Property alone. Five other nonnative fish species were collected in the upper Verde River: green sunfish *Lepomis cyanellus*, channel catfish *Ictalurus punctatus*, flathead catfish *Pylodictis olivaris*, yellow bullhead *Ameiurus natalis*, and red shiner *Cyprinella lutrensis*; all of which are piscivorous and occur at all of the sites we sampled.

### *Parasites and Health*

All roundtail chub collected were examined for the parasitic copepod, *Lernaea* sp. and total number was counted. Twenty-two percent of roundtail chub collected were infected with the parasitic copepod. Mean number of *Lernaea* by season, year, and season*year was not significantly different. Highest infection occurred in the fall of 1999 (76%), with mean number of *Lernaea*/fish ranging from 1 to 4, with highest infection intensity being 19 *Lernaea*/fish. The lowest infection intensity (6%) occurred in the spring of 1999.

In 1997, roundtail chub were collected and sacrificed to determine "health" of the fish using a modified Health Assessment Index (mHAI: Robinson et al. 1998). The mean mHAI of roundtail chub in 1997 was 9.4, indicating that fish were in "good" condition. In fact, roundtail chub mHAI in 1997 was much lower than that reported in 1996 (36.9) by Robinson et al. (1998), who also concluded that roundtail chub were in "good" condition; "health" of fish improves with a decrease in mHAI value.

Lastly, the Asian fish tapeworm *Bothriocephalus acheilognathi*, was found in roundtail chub being raised at AGFD's Bubbling Ponds Hatchery for validating use of otoliths to age roundtail chub (see **AGE AND GROWTH**). Significant correlations between total length and weight of fish and number of tapeworms were observed. In addition, fish infected with the Asian fish tapeworm were significantly smaller than those uninfected. Infection by the Asian fish tapeworm may slow growth, increase susceptibility to infestation, and increase predation on roundtail chub and possibly other native cyprinid fishes.

## ANGLER SURVEY

A roving creel survey was conducted in May and June 2000, to gather information from anglers regarding the roundtail chub as a sportfish in Arizona. Questions pertaining to angler knowledge of the species being a sportfish, the current regulations on the species, the amount of effort expended toward catching this species, and what, if anything, AGFD could do to make roundtail chub a more "appealing" species to fish for, were asked of each individual surveyed.

A total of 105 anglers were interviewed, of which, 74% had heard of the roundtail chub. Of the 74% that have heard of the roundtail chub, 32% were aware that it is a sportfish in Arizona. However, 80% of the anglers that heard of roundtail chub were not aware of the current fishing regulations for this species. The majority of anglers interviewed (83%) had never caught a roundtail chub and only 3% have fished specifically for roundtail chub. Anglers that have caught roundtail chub claim that they are "fun to catch", "like the way they fight", and are "similar to trout but not as good".

Anglers that were unaware of the roundtail chub were asked if they would fish for them after having been "introduced" to the species. Fifty-four percent of the anglers responded that they would not fish for roundtail chub and 43% were interested in fishing for roundtail chub, but did not know how to fish for roundtail chub, where to fish for roundtail chub, and/or what bait to use to catch roundtail chub.

## MANAGEMENT OPTIONS

The roundtail chub, like many native fishes in the desert Southwest, has been declining since the late 1800s (Miller 1961). Competition and predation by introduced fishes (Bestgen and Propst 1989; Marsh and Douglas 1997) and inadvertent introductions of parasites (Brouder and Hoffnagle 1997) have been suspected in declines of native fishes. In addition, alterations to the hydrograph (e.g., dams, diversions and water pumping) have negatively affected many native fishes (Minckley and Deacon 1968; Gido et al. 1997).

The results of this investigation suggest that, similar to many other native Southwestern fishes, alterations to the habitat, non-native predatory fishes, and regulation of stream discharge have the greatest potential of limiting roundtail chub survival. When planning management and/or conservation efforts for roundtail chub, managers are encouraged to consider the following options:

1) Priority should be given to protecting and/or restoring stream habitats so that distinct macro-habitats (i.e., runs/glides, riffles, and pools) exist that allow for both inter- and intra-specific resource partitioning;

2) Priority should also be given to areas with a natural hydrograph, more specifically, sections of streams where late-winter/early-spring floods ($\geq \sim 40$ - $50\ m^3/s$) occur and, areas where an intact riparian corridor exists. Both of these variables prove beneficial for the reproduction, recruitment, and survival of roundtail chub;

3) The introduction or spread of undesirable exotic fishes should be avoided;

4) Suppress non-native fish and possibly crayfish densities at a minimum, seasonally;

5) Currently, existing fishing regulations [1/day; >13 inches (~330 mm) and angling effort allow roundtail chub to reach sexual maturity and spawn several times before becoming susceptible to exploitation, therefore, not likely having a severe negative impact on roundtail chub populations;

6) Increase public awareness of the sportfish status that roundtail chub has in Arizona, and increase public knowledge on how to and where to fish for the species;

7) Continue collection of and monitoring PIT-tagged roundtail chub so that the current population model can be used to determine status and trend of the roundtail chub population in the upper Verde River.

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Brouder, M. J. in prep. Habitat selection and overlap of a native/non-native fish community in an unregulated desert stream.

Brouder, M. J. in prep. Population estimate and movement of roundtail chub, *Gila robusta*, an imperiled native fish in a small desert stream.

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