Cibola High Levee Pond Annual Report 2004

By Gordon A. Mueller and Jeanette Carpenter, U.S. Geological Survey, and Paul C. Marsh, Arizona State University

Open-File Report 2005-1075

U.S. Department of the Interior
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Summary

This represents the fourth and last annual report of a five year study investigating the early life ecology of the bonytail and razorback sucker at Cibola High Levee Pond. The work in 2004 included: telemetry studies, collection of physical water quality measurements, zooplankton samples, netting fish, the collection of scale samples for aging, predator/prey tank tests and a preliminary analysis of the data base.

Juvenile bonytail and razorback suckers were collected this year, demonstrating that natural recruitment occurred for both species. Young from 2004, 2003, and 2002 were all represented in our sample. Unfortunately, we discovered that largemouth bass had also spawned. Approximately 100 young bass were observed during a snorkeling trip in late July. Bass ranged in size from an estimated 5 to 50 cm and were distributed throughout the pond.

Attempts to determine the cover preference of 30-cm bonytail met difficulties. Spawning occurred a month earlier than previous years due to an unseasonably warm spring. The combination of warmer temperatures and the vigors of spawning attributed to higher stress and associated mortality of study fish. We replicated our procedures under hatchery conditions on the chance that transmitter attachment was at fault but we experienced similar post-release mortality, including the control fish. This supports the long held contention that bonytail are extremely fragile during and after spawning.

In the predator-prey tests, young of every species tested ate razorback sucker larvae. The most aggressive predators tested in 2004 (n = 8 species) were young of the year green sunfish, channel catfish, and common carp. Bullfrog tadpoles and red swamp crayfish also ate razorback sucker larvae and eggs, showing predation is not limited to predatory fish. This work illustrates that early life stages are quite vulnerable to small predators that have easy access to shallow nursery habitats.

Remaining work will be finished this coming summer and a final report describing CHLP and the ecology of these fish will be completed by the end of 2005. We offer our assistance to the Fish and Wildlife Service in the pond's renovation and support for the creation of additional refuge ponds. Funding for this work ends September 2005.

Introduction

The Cibola High Levee Pond (CHLP) study is a cooperative project with the goal of describing the early life history and habitat requirements of the bonytail *(Gila elegans)* and razorback sucker *(Xyrauchen texanus).* CHLP represents the only location where both species are successfully producing young. The resulting information will be used to duplicate CHLP on a larger scale to benefit these species elsewhere.

This report is organized into six sections. They include:

- physical water quality parameters,
- preliminary analysis of recapture data,
- cover utilization of bonytail,
- predator tank tests,
- miscellaneous studies, and
- management recommendations.

1. Physical Water Quality Measurements

Physical water quality parameters were measured at 0.5 m depth intervals through the vertical water column during most field trips. Measurements were taken at the pond's deepest location which was approximately 15 m west of the river levee. Parameters were measured using a Hydrolab® and included: temperature, dissolved oxygen, pH and conductance. A Peabody/Ryan paper chart recorder was placed near the southern shoreline to record surface temperatures.

Conductance

Salinity at CHLP fluctuates seasonally in response to river flow. Conductance peaked at 1106 µS/cm in January and gradually declined to 980 µS/cm in June (Figure 1). Pond conductance is directly linked to evaporation and water exchange rates from the river. Its cyclic nature demonstrates the hydraulic connectivity of these two bodies of water. It is speculated that higher spring flows may increase the hydraulic pressure and volume of groundwater entering the pond from the river and exiting toward Pretty Water. Pronounced evaporation by mid-summer (July) combined with decreasing flows in late fall causes salinity to rise. This water exchange maintains lower pond salinity than what would be expected if the site was hydraulically isolated (BR, 2004).

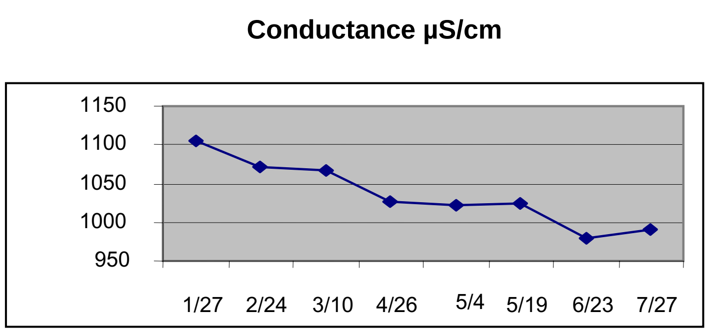

Figure 1. Surface conductance (µS/cm) taken at Cibola High Levee Pond during 2004.

Water Temperature

CHLP experienced an unusually warm March in 2004. Surface water temperatures reached 18˚C nearly 3 weeks earlier compared to the two previous years (Figure 2). Bonytail have spawned in past years when surface temperatures reached 18˚C. They did again this year, nearly a month earlier.

Surface temperatures ranged between 12 and 34˚C, reaching the highest temperatures in July (Figure 3). The coolest temperature during that month was 30.8˚C. Minimum water temperatures by the end of July exceeded 30˚C at all depths. Daily temperatures fluctuated 2-3˚C between day and night cycles, reaching highs in mid-afternoon and lows near dawn. The combination of water influx from the river and the diel temperature cycle may help prevent strong thermal or chemical stratification from developing.

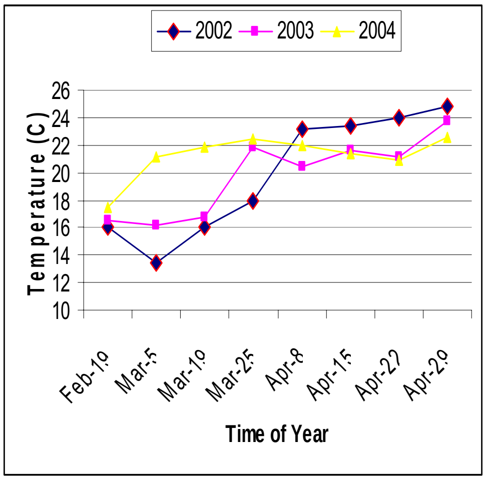

Figure 2. Surface water temperatures taken at Cibola High Levee Pond during 2002, 2003 and 2004 (February through April).

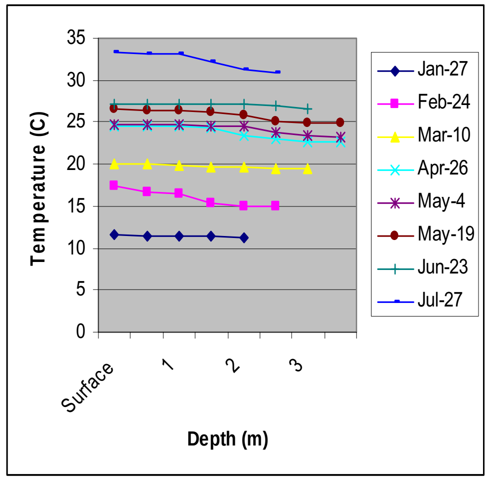

Figure 3. Water column temperatures taken at 0.5 m intervals at Cibola High Levee Pond during 2004 spawning period.

Dissolved Oxygen

Dissolved oxygen levels at CHLP stayed remarkably high during summer months. More than 95% of the pond's volume maintained levels over 6 mg/L (Figure 4). We did not find any evidence of anoxic conditions. The lowest concentration was 3 mg/L; this is more than sufficient to support the native fish.

Oxygenation is influenced by a combination of factors, possibly the most important stemming from the pond's hydraulic connection with the river. Low conductances at greater depths suggest that groundwater upwelling provides circulation that helps prevent stagnation. Another contributing factor may be the diel temperature fluctuation (2-3˚C) that may partially disrupt stratification. This high level of oxygenation undoubtedly contributes to the pond's high level of productivity.

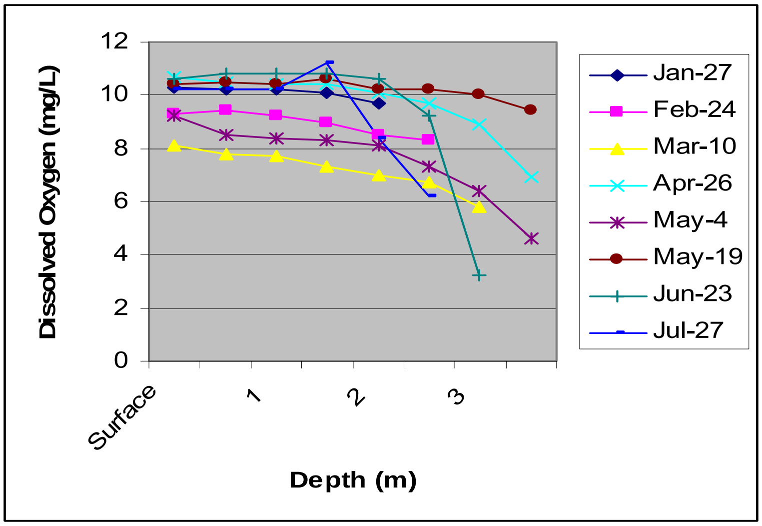

Figure 4. Dissolved oxygen concentrations (mg/L) measured at various depths within the water column at Cibola High Levee Pond during 2004.

2. Prelimary Analysis of Recapture Data

Size Distribution

Bonytail

Small (<200 mm) bonytail were far more abundant than larger fish. Thousands of small fry were observed following spawning. Schools of small juveniles (<50 mm) were commonly concealed amongst shoreline and submerged vegetation and in beaver dens along the bank. Figure 5 shows the size distribution as a percentage of bonytail caught in 2001-2004. However, the data are biased by an artifact of greater numbers of juveniles captured by ½-inch trammel nets used in 2001 and 2002. Small trammel nets were extremely effective in capturing small fish. Unfortunately, a large percentage of these small fish were 'gilled'; as a preventative measure, we switched to large minnow traps and hoop nets in 2003 and 2004. These sampling methods proved to be less stressful but regrettably they were also far less effective, and very few small bonytail were captured.

Razorback Sucker

Size distribution of razorback suckers is just the opposite of bonytail; large fish were more abundant than their young. Sampling revealed larger (300-400 mm) suckers were advancing into the adult population in 2001 and 2002; however, this size class was not present in 2003 and 2004 (Figure 6). Juveniles (<300 mm) that were absent in 2001 and 2002 appear in both 2003 and 2004, indicating that suckers successfully recruited.

Large trammel nets are extremely effective in capturing large suckers, however, their young have proved difficult to collect. The problem is compounded by the fact that they are relatively rare and are both cover- and benthic-oriented. Figure 6 suggests recruitment during 2003 and 2004 was <5%, however, we consider that to be very conservative due to sampling bias. The actual recruitment figure could be closer to 15-20% due to our reluctance to use small trammel nets in 2003 and 2004.

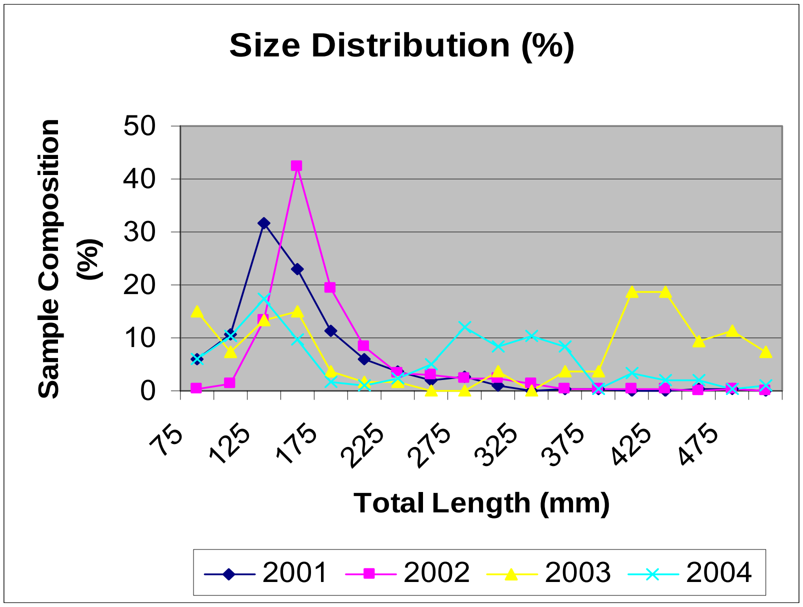

Figure 5. Size distribution of all bonytail captured in Cibola High Levee Pond from 2001 through 2004. Values expressed are a percentage of the total sample.

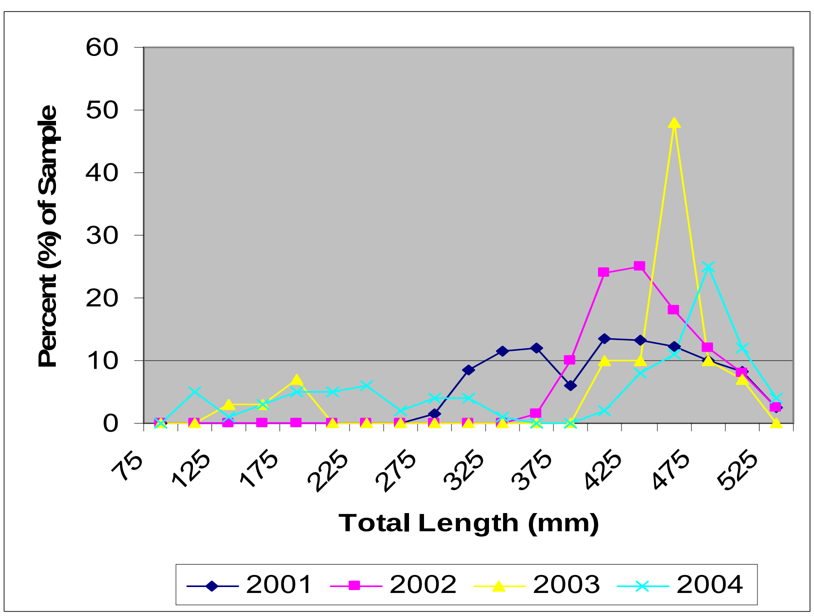

Figure 6. Size distribution of razorback suckers captured in Cibola High Levee Pond from 2001 through 2004 using all types of sample gear. Values expressed are a percentage of the total sample.

Growth Rates

Bonytail

Growth rates were calculated based on data taken from fish pit-tagged and recaptured a minimum of 9 months and a maximum of 24 months following release. The 9-month minimum allowed us to capture an annual growth season while the maximum standard (24 months) reduced the conservative influence that occurs as fish age. We had information for 31 individuals (Figure 7).

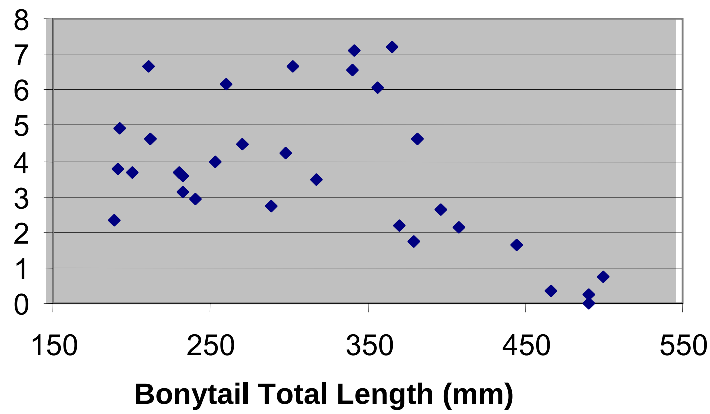

Figure 7. Growth rates of bonytail (*n* = 31) captured from Cibola High Levee Pond for the period of record (1993-2004). Data represent fish recaptured between 9 to 24 months after initial contact.

Data were grouped into 50-mm size categories and the curve was smoothed using a rolling 3 category average (Figure 8). Growth is typically the most rapid during early life, but interestingly for this community it appeared to peak for the 300-mm size group. Smaller-sized bonytail (<200 mm) exhibited a slightly smaller growth rate of 3.5 mm/month, compared to medium-sized (300-400 mm) chub. Growth sharply declined as fish aged and grew in size. Growth for 370 mm bonytail dropped below that measured for smaller fish, and the decline accelerated once fish reach 400 mm.

The retarded growth in the smaller cohort was not expected and would generally not be considered normal for any fish species. In this case, it is quite possible it may represent an artifact of small sample size, measuring error, or possibly marking stress on smaller fish. It is equally possible it reflects differences in growth due to dietary competition among small fish and a change in diet of larger fish.

Bonytail are extremely prolific, producing tens of thousands of young annually. Quite possibly, competition for plankton by chub may be aggravated by their high number and by direct competition from the 1,000 adult razorback sucker that share a similar diet. When larger bonytail shift their diet toward larger invertebrates and small fish, there may be a greater abundance of food which in turn improves growth rates. We plan to examine the diet of smaller (<200 mm) bonytail more closely this year.

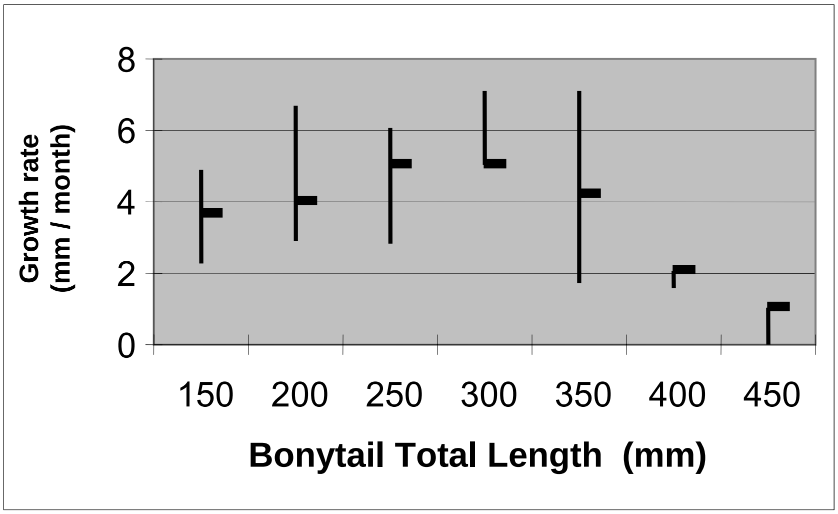

Figure 8. Growth rates of bonytail (*n* = 31) taken from Cibola High Levee Pond based on 50-mm size groups. Vertical bars depict data ranges and horizontal bars represent a 3 size group rolling average used for smoothing.

The largest bonytail were females; several exceeded 500 mm while all males were under 490 mm. There was insufficient data to compare growth rates for both male and females but we suspect that growth for mature females is either accelerated or continued compared to that of mature males. For example, the sex ratio of 350-mm bonytail was 1:1; however, that ratio declined as fish size increased to a point where all fish over 500 mm were females (Figure 9).

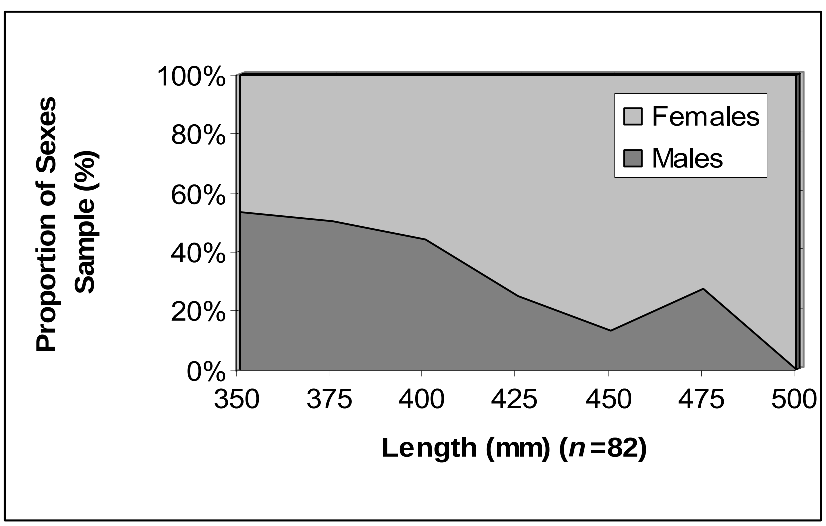

Figure 9. Percentage of bonytail females versus males that were >350 cm taken from Cibola High Levee Pond.

Razorback Sucker

We recaptured substantially more razorback suckers (*n* = 86) than bonytail (*n* = 31). The database contained growth information for 86 suckers that had been recaptured within 9 to 24 months after being marked and released. Growth rates (>6 mm/month) were the largest for smaller fish and declined with size and age (Figure 10). Average growth rate substantially declined for fish >350 mm, dropping to 2.5 mm/month and below. Growth continued for even the largest (<500 mm) suckers, but at the low rate of 0.5 mm/month.

We detected a slight difference in mature male and female growth rates (Figure 11). Growth appeared similar for both sexes until they reached 450 mm. At that point, male growth continued to drop below 1 mm/month while rates for females stabilized at that level. As with bonytail, the extent of the growth difference between sexes becomes more obvious with mature fish. The largest fish are typically females. The size advantage enjoyed by females appears to be from growth that occurs later in life.

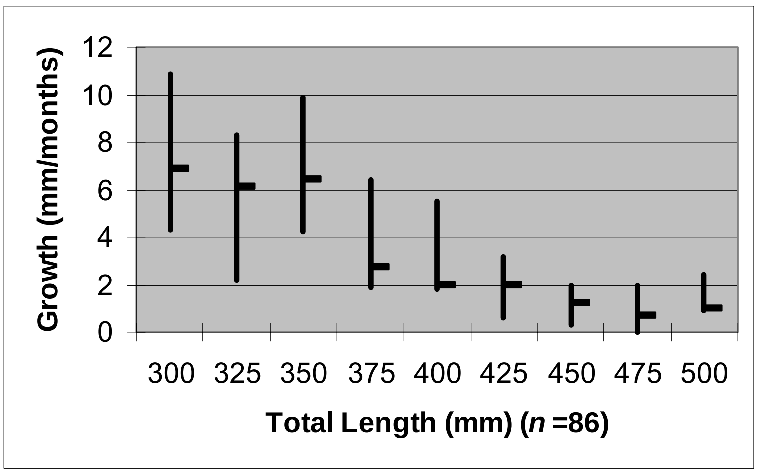

Figure 10. Growth rates of razorback suckers taken from Cibola High Levee Pond based on 25-mm size groups. Vertical bars depict data ranges and horizontal bars represent group average.

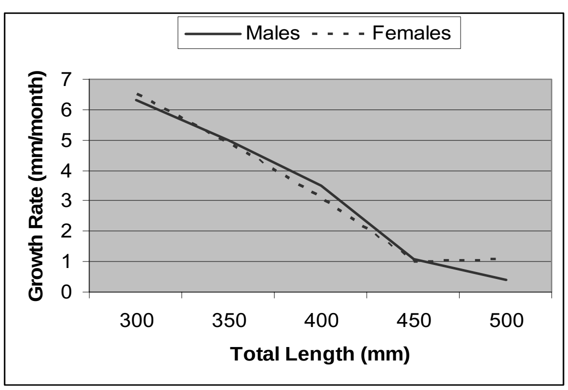

Figure 11. Growth rate for male (*n* = 28) and female (*n* = 27) razorback sucker, based on fish recaptured 9 to 24 months after marking and release.

The proportion of females to males is approximately 1:1 for discernable sexes for fish <450 mm but gradually increases with size (Figure 12). Females comprised 99% of razorback suckers >500 mm. While we would expect the sex ratio of the largest mature fish to remain relatively stable, the overall size of the population should increase as fish age since the population is relatively young. The oldest razorback suckers are <14 years old, which are relatively young adults based on the species' longevity.

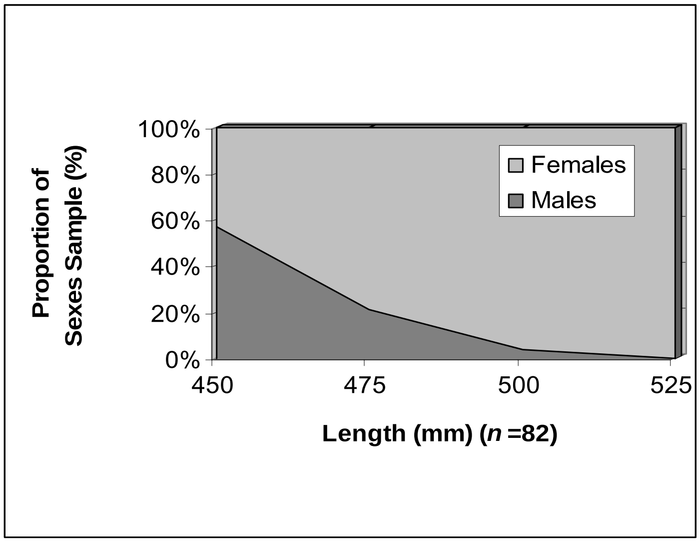

Figure 12. The percentage of females versus males for razorback sucker >450 mm taken from Cibola High Levee Pond.

3. Cover Utilization by Bonytail

Telemetry studies conducted in 2003 indicated that large (>400 mm) bonytail showed a cover preference for large rip-rap along the high levee. We wanted to determine if smaller, intermediate-sized fish shared a similar preference. We used several strategies to test this: (1) telemetry equipment, (2) netting from specific cover types (3), tank tests and (4) snorkeling observations.

Telemetry Study

Another telemetry survey was conducted examining the cover preference of intermediate sized bonytail. The work was accomplished under contract by Arizona State University. The final report covers both the 2003 and 2004 efforts; it is presented in Appendix A in its entirety and the summary is presented below:

Sonic transmitters were affixed to a sample of ten large, adult bonytail (2003) and nine smaller, sub-adult bonytail (2004) in CHLP. Series of point and paired, directional observations showed that adult bonytail used interstices of large rip-rap during the daytime, then came out into open water during hours of darkness, presumably to feed. The spatial pattern of daytime cover use revealed a significant level of site fidelity. Most fish showed some pattern of geographic distribution at night, with most observations in a particular area of the pond, while other fish showed a random distribution. Subadult bonytail apparently occupied open water throughout the day and night and did not seek specific cover. However, all small fish are believed to have expired before the end of the field study in 2004 and their behaviors and habitat use may not have been typical. A combination of sensitivity to capture, handling, and tag attachment are believed responsible for their mortality. Methods that are not harmful to test fish should be identified and implemented to enhance reliability of future data. Selection or design of bonytail management areas including grow-out and refugium sites should consider cover requirements for larger fish, as this may be an important limiting factor.

Netting

In 2003, trammel nets were set adjacent to the high levee, up against the rip-rap just prior to sunset and a couple hours before sun rise. Over 90% of the bonytail captured were either exiting (sunset) or entering the rip-rap (dawn). To reduce the stress associated with trammel nets and handling, we attempted to capture fish using two large hoop nets that were equipped with 20-m wings. Both hoop (1.5 m) nets were double-throated and were constructed of either 1-cm and or 2.5-cm meshed netting. The nets were set perpendicular to the levee, with both wings tied to the rip-rap forming a large 'V'. We believed fish found in the structure located between the wings (>15m) had little recourse but to follow the wings and enter the throat of the trap.

We were wrong. The technique only captured a total of three bonytail from four overnight sets. All three fish had become 'gilled' in the wings; two near the lead line, the other near the float line. Apparently fish were escaping by going over and under the net's wings. Bonytail proved they can easily escape hoop nets when provided sufficient time and in the absence of current. We had similarly poor results with the large minnow traps used in 2002.

Tank Test

Cover preference of small bonytail was evaluated in an aquarium setting. A 114-L (30 gallon) tank was set up at Achii Hanyo and three different cover types were placed in the tank. The right hand side contained a pile of large rock (10 cm), the middle contained gravel, and the right side was a dense arrangement of plastic aquarium vegetation (Figure 13).

Figure 13. An aquarium was set up containing three cover types in an effort to determine the cover preference of 7-cm bonytail.

Fourteen 7-cm bonytail were placed in the tank on 17 April. All 14 bonytail immediately hid in the rock pile where they remained overnight. The following day, 12 fish had moved into the vegetation, while two remained in the rock. When fed, fish would dart out to grab a particle and immediately return to their prospective cover.

By the third day (19 April) fish moved freely throughout the aquarium unless they were disturbed or approached. When bothered they would dart and conceal themselves in cover. Gradually all 14 bonytail were using the vegetative cover instead of the rock.

Snorkeling Observations

We snorkel nearly every trip, but unfortunately visibility was usually <1.5 m. Exceptionally good (> 4 m) water visibility from 26-29 July allowed us our best opportunity to observe fish. Plant growth was extensive, covering 10 to 20% of the pond's surface and possibly 40 to 60% of its volume. A dense column of spiny naiad emanated from the pond's depths (3.5 m) to the surface where it formed a large floating mat. Its diameter was approximately 20 m.

We observed more than 100 razorback suckers and 100 bonytail on the morning of 28 July (9 to 11:30 MST). Fish were concentrated in the deeper portions of the pond, especially around and under the shade of the dense column of naiad. All the fish appeared to be using the lower portion of the water column. Razorback suckers were seen solitary and in a large (>50) school (Figures 14 and 15). Some were lying stationary in the vegetation while other appeared to be actively feeding along the fringes of the plant growth. Fish ranged in size from 30 to 50 cm.

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Observed bonytail ranged from 7 to 35 cm. Fish were generally swimming alone or in small (<6) groups over or along the fringes of the vegetation. Bonytail appeared to be actively feeding from and on new plant growth. They appeared curious, but standoffish (<1.5 m) and if the diver made any sudden move, they would dart into the vegetation.

Figures 14 and 15. Photographs taken July 28, 2004 of razorback suckers in Cibola High Levee Pond. Fish were observed swimming individually and in small schools.

Summary

Cover is obviously an important component of bonytail habitat. Bonytail are extremely timid and when threatened, will rapidly seek the protection of cover. Large adults appear to be generally nocturnal and fish observed during the day are typically found near cover. Cover undoubtedly provides a means of concealment from avian and other predators. Fish-eating birds such as night herons, great blue herons, common egrets, osprey, pelicans, and cormorants are common around the pond. Small bonytail have been observed taken by kingfishers and the frequency of talon scars suggest large bonytail are also targeted by birds.

Cover at CHLP is diverse and the availability of some types is seasonal. For example, large rip-rap, natural bank cavities and beaver dens provided permanent cavities for fish year-round. We found that large bonytail not only preferred rock crevasses, but individuals used specific cavities

that may demonstrate social competition for these resources. Rip-rap or rock was not natural in the lower Colorado River region, but undoubtedly has taken the place of flood debris piles and root wads that were historically abundant before the river banks were deforested. The pond also contains lush stands of cattail and several submergent plant species that both bonytail and young razorback suckers use for concealment.

Submergent vegetation expands and contracts dramatically in response to season. We estimated that plant biomass occupies <10% of the pond's volume during the winter but expands (est. 60%) during peak growing season. Submergent growth is not just limited to shallow areas, but extends to the pond's deepest (>3 m) areas where dense columns of vegetation reach the surface, forming broad floating mats. This vegetation not only provides cover from predators, but also provides thermal shade and important substrates for food organisms. Seasonal shifts in the availability of cover may result in competition for more permanent types of cover during late fall and winter when fish-eating birds are more prevalent.

4. Predator/Prey Tank Tests

There is little information on the predatory role of small-bodied non-natives on fish larvae. Unfortunately, the problem is not just limited to predatory game fish. For instance, predation---not competition---by red shiner *(Cyprinella lutrensis)* and mosquitofish *(Gambusia affinis)* has been implicated in native fish declines in the southwest (Meffe, 1985; Ruppert and others, 1993). Researchers have suspected that tadpoles prey on fish eggs and larvae (Boyd, 1975; Kane and others, 1992; Trammell and others, 2002), however there has been little evidence (Ngueng and others, 2000). Similarly, there is some evidence of crayfish preying upon both fish eggs and larvae (Savino and Miller, 1991; Carpenter, 2000).

Red swamp crayfish *(Procambarus clarkii)* and bullfrogs *(Rana catesbiana)* appear abundant in CHLP, and results of our videography indicate tadpoles and crayfish were present and actively feeding among bonytail and razorback sucker spawners. Our objectives in conducting laboratory experiments on predation were to examine the role of non-native tadpoles and crayfish in CHLP, and to consider the impact of other small-bodied non-natives on razorback larvae as well. We have focused on non-natives that are common in the lower Colorado River.

This was the second year of predator/prey tank tests. In 2003, we tested red shiner, young-of-the-year (YOY) and adult rainbow trout *(Oncorhynchus mykiss),* and YOY bluegill *(Lepomis macrochirus)* and bonytail (as a native "control" species) on razorback larvae <15 mm. We also tested young channel catfish *(Ictalurus punctatus),* largemouth bass *(Micropterus salmoides),* and yellow bullhead *(Ameiurus natalis)* on larvae that were 15-30 mm. In 2004, we tested predation on razorback eggs as well as on larvae <15 mm. Razorback sucker eggs and larvae were supplied by

USFWS while non-natives were captured nearby or purchased from aquaculturists. All tests in 2004 were conducted at the Achii Hanyo Fish Facility. Details of the experimental design can be found in our 2003 Annual Report (Mueller and others, 2003).

At least two control tanks (eggs or larvae with no predator) were used in each predator trial. Trials ended when we removed predators and counted either the number of visible eggs or surviving larvae. Weights, lengths, and gape measurements of predators were recorded at the completion of experiments.

Egg Predation Experiments

We tested the ability of tadpoles and crayfish to prey upon razorback sucker eggs. Our methodology was simple: we placed 20 eggs in 10-gal tanks with no substrate, added either four tadpoles or two crayfish to treatment tanks, and measured predation after a set time period. We used eggs in control tanks to determine if we could accurately count eggs after 72 hours or if they disintegrated beyond recognition; this occurred to one egg in 1 of 6 control tanks used in these egg predation trials. During the experiment we provided tadpoles and crayfish with alternative food sources, including lettuce, bloodworms, and live and frozen brine shrimp. Razorback eggs were obtained from Willow Beach hatchery. We originally planned to run both trials for 72 hours. However, crayfish consumed the eggs rapidly, so in order to obtain instantaneous predation rates we ended these trials after six hours of exposure.

Egg predation experiments were conducted from 15-18 March (Table 1). Both species consumed razorback eggs; predation averaged 74% for crayfish and 45% for tadpoles. In terms of instantaneous predation rates, tadpoles consumed a mean of 0.03 eggs per tadpole per hour (Table 2). Crayfish were more voracious, eating on average 1.1 eggs per crayfish per hour.

Larval Predation Experiments

Experiments on razorback larvae ran from 15-30 March 2004. We tested predation capability of bullfrog tadpoles; young green sunfish, carp, and channel catfish; and adult threadfin shad *(Dorosoma petenense)* and fathead minnow *(Pimephales promelas).* All species that we tested consumed razorback sucker larvae. Mean mortality of larvae ranged from <10% in tanks with tadpoles, threadfin shad, and fathead minnows, and >70% for carp, green sunfish, and channel catfish. There was no consistent relationship between gape size and consumption rate (Table 1). Mortality in the ten larval control tanks was insignificant: one larvae died in a carp trial and one in a tadpole trial.

Compared to the other predator species used in 2004, bullfrog tadpoles were one of the largest predators tested, in terms of both total length and biomass (Table 1). However, the tadpoles had a small gape relative to their size, and they ate relatively few larvae. Their instantaneous predation rates were nearly identical to threadfin shad and fathead minnows (Table 2). Threadfin shad is considered planktivorous; however, Baker and Schmitz (1971) report this species feeding on fish larvae in an Arkansas reservoir. Fathead minnows can be very aggressive towards other small fish (Karp and Tyus, 1990), and Dunsmoor (1995) observed this species preying on catostomid larvae in laboratory experiments. Fathead minnows had the narrowest gape, smallest body size, and lowest predation rate of all species we tested.

Adult green sunfish and channel catfish are known piscivores, and there is clear evidence that they eat razorback larvae (Marsh and Langhorst, 1988; Marsh and Brooks, 1989). However there is little information on the young of these species eating small fish. A recent study determined that 45-55 mm green sunfish---a size very similar to those used in our study---ate up to four YOY (15-20 mm) Gila chub *(Gila intermedia)* within 18 hours (Dudley and Matter, 2000). In our study,

Table 1. Potential predators used in chronological order in razorback larvae trials, 2004. Sample size for predator species is total number used in experiment. All experiments used 4 predators per tank, except crayfish had 2 predators per tank.

Predator species (*n*)	Predator size, mm (range)	Predator biomass, g ($\bar{x}$ ± SE)	Predator gape, mm ($\bar{x}$ ± SE)	Razorback size, mm* ($\bar{x}$ ± SE)	Trial Dates	Origin of predators
			Razorback sucker egg predation			
Bullfrog tadpole (24)	84 - 116	10.0 ± 0.4	4.5 ± 0.1	3.2 ± 0.2	15-18 March	CHLP and Achii Hanyo
Crayfish (12)	26.3 - 40.6 (carapace length)	7.7 ± 1.1	--	3.2 ± 0.1	17-18 March	CHLP
			Razorback sucker larvae predation			
Bullfrog tadpole (28)	78 - 119	10.5 ± 0.4	3.2 ± 0.1	11.5 ± 0.1	19-24 March (2 trials)	CHLP and Achii Hanyo
Threadfin shad (20)	93 - 145	12.2 ± 1.2	7.8 ± 0.4	12.6 ± 0.2	25-26 March	Emerald Cove golf course pond, Parker, AZ
Common carp (24)	58 - 75	2.8 ± 0.1	4.1 ± 0.1	14.2 ± 0.4	26-27 March	Osage hatchery, AK
Green sunfish (20)	45 - 62	2.1 ± 0.1	3.9 ± 0.1	13.2 ± 0.5	27-28 March	Emerald Cove golf course pond, Parker, AZ
Channel catfish (20)	60 - 86	2.7 ± 0.1	4.5 ± 0.1	14.4 ± 0.4	28-29 March	Osage hatchery, AK
Fathead minnow (20)	45 - 65	1.3 ± 0.1	2.6 ± 0.1	14.2 ± 0.2	29-30 March	Osage hatchery, AK

* Razorback size: diameter for eggs and total length for larvae

razorback larvae suffered 100% mortality in tanks with green sunfish. Green sunfish ate 0.21 larvae/predator/hr (Table 2). Karp and Tyus (1990) obtained very similar results in a similar experiment: they observed green sunfish (31-68 mm) consuming 9 of 10 razorback larvae within 1 hr. Although channel catfish are not considered fully piscivorous until they are approximately 390 mm (Tyus and Nikirk, 1990), they consumed razorback larvae at a mean instantaneous predation rate of 0.15 larvae/catfish/hr.

The 58-75 mm common carp were as voracious as the channel catfish. This was surprising, as stomach content analyses indicate the diet of young common carp is primarily plankton, small crustaceans, and small invertebrates (Moen, 1953; Eder and Carlson, 1977). However, Kudryns'ka (1963) noted cannibalism among carp larvae by larger larvae. In the Colorado River, carp >175 mm feed primarily on detritus, phytoplankton, benthic insects, and mollusks (Minckley, 1982). Several

Table 2. Predation rates on razorback sucker by potential predators tested in 2004. Predation is mean number of prey consumed; all tanks began with 20 prey.

Predator	N (# of trt tanks)	Mean predation rate per tank (number of prey consumed out of 20 prey items)		Instantaneous predation rate (number of prey consumed/ predator/hr)		Duration of trial (hr)
		$\bar{x}$ ± SE	95% CL	$\bar{x}$ ± SE	95% CL	
Razorback sucker eggs						
Crayfish	6	14.8 ± 2.8	7.7 – 21.9	1.12 ± 0.22	0.55 – 1.68	6
Bullfrog tadpoles	6	8.7 ± 1.2	5.5 – 11.8	0.03 ± 0.004	0.02 – 0.04	72
Razorback sucker larvae						
Bullfrog tadpoles	7	5.6 ± 1.0	3.1 – 8.1	0.02 ± 0.004	0.01 – 0.03	72
Threadfin shad	5	2.0 ± 1.1	0.0 – 5.2	0.02 ± 0.01	0.00 – 0.05	24
Common carp	6	14.3 ± 3.3	5.9 – 22.8	0.17 ± 0.04	0.07 – 0.27	24
Green sunfish	5	20.0 ± 0.0	20.0 – 20.0	0.21 ± 0.00	0.21 – 0.21	24
Channel catfish	5	14.0 ± 1.8	8.8 – 19.1	0.15 ± 0.02	0.09 – 0.20	24
Fathead minnow	5	1.5 ± 0.9	0.0 – 2.4	0.02 ± 0.01	0.00 – 0.04	24

investigators have reported carp feeding among spawning razorbacks. Some may have assumed they were eating eggs but undoubtedly they also eat larvae.

These trials show that adult game fish are not the only potential predator of native fish in the Colorado River. Crayfish and tadpoles may have a strong impact on egg survival; crayfish may be a considerable issue as they can amass dense populations in the southwest (Carpenter, 2000). Although we found that YOY game fish had the highest predation rates, non-game fish such as common carp should be considered a significant potential predator of fish larvae as well.

Many studies use stomach content analyses to determine consumption rates and presence of different life stages, and some have used the absence of small or larval fish in stomachs to argue that non-native predation is not a concern. However, Kim and Devries (2001) and Lohr and Fausch (1996) conducted laboratory experiments in which they exposed fish predators to larval fish, measured predation, then removed predators immediately after the experiment, preserved them, and attempted to count larvae from predator stomachs. Both studies showed that stomach contents analyses did not accurately measure known predation rates or even consistently identify the presence of fish prey. Their work provides conclusive evidence that when larval fish are consumed, the decomposition or digestion to unidentifiable remains is exceptionally fast. We caution against using the absence of small or larval native fish in stomach analyses to conclude that non-native species are not impacting recruitment of smaller size-classes.

5. Miscellaneous Activities

Aging

Scale samples (150) were collected from both small bonytail and razorback sucker to help determine year class structure and recruitment rates. We have been unable to determine annual growth rates for young-of-year due to the extreme variability of sizes. There is some evidence that limited spawning may also occur in the fall or that growth is much slower than initially thought (Douglas and others, 2000). We have collected YOY bonytail as small as 35 mm and 10 cm razorback sucker. If spawned during their normal reproductive cycle, these fish would have been 10 to 12 months old.

Scales will be mounted, processed and read by Dr. Dennis *Scarnecchia,* at the University of Idaho Coop Unit located in Moscow, Idaho. Results will be presented in the final report.

Telemetry

Dr. Paul Marsh organized a field trip to test new radiosa on small fish. Unfortunately, water conductivity (>1,000 μS) made the transmitters totally ineffective. At a depth of only 1 m, transmission could only be detected at a maximum range of 20 m and when lowered to 2 m, no signal could be heard at all. Future work will have to be accomplished using the acoustic transmitters that we have used in the past.

Underwater Video

The underwater video camera was used on three occasions, twice at CHLP and once at Willow Beach National Fish Hatchery. At CHLP, 12 hours of razorback sucker spawning were recorded in March, and 2 hours of underwater monitoring were recorded in May. Fourteen hours of behavior were recorded in the raceways at Willow Beach National Fish Hatchery.

The primary purpose of these recordings is to provide information on spawning behavior and the presence of other fishes or possible predators. Last year we discovered a unique "eye winking" behavior that we wanted to examine more closely. We are collaborating with a renowned fish-eye physiologist, Dr. Inigo Flamarique (Simon Fraser University, Burnaby, Canada) concerning this behavior. Dr. Flamarique has theorized that some species of fish may be able to see into the non-visible range of the human spectrum. Chester Figiel provided him with preserved eyes from hatchery mortalities for examination. At Dr. Flamaiques suggestion, we recorded spawning using two different filters (<407 nm, >530 nm) to determine if eye reflectivity favored a specific end of the spectrum (UV/IR). The intensity of the reflection appeared similar for both filters so it does not appear the phenomena favors a specific end of the spectrum.

Filming took place during the daylight hours on 11 and 12 March 2004. Due to the unusually warm spring weather, water temperatures in the pond had already reached 19˚C--nearly a month early--and spawners were starting to disperse. Small schools of adults were observed on the surface feeding on zooplankton; this behavior normally does not occur during peak spawning. Actual spawning acts were rare (<1 hr) and schools of suckers were actively feeding on material found among spawning gravels. Nearly all the fish were actively sucking and spitting out benthic material from the loose gravel. The 'eye blinking' behavior was rare, only being observed by 11 fish over the 12-hour recording period. The occurrence of suckers (males) resting on the bottom was also rarely observed this year.

The video equipment was used on 19 May 2004 to record underwater activities at the beaver trail (river levee) during the afternoon (17:45 to 19:45 MST). The camera was set along shore at a depth of 1.5 m. During 110 minutes of filming, we recorded the presence of 9 tadpoles, 42 YOY largemouth bass and 2 bonytail. The largemouth appeared to be 20-25 mm in length and we observed one school of 17 fry. No adults were seen. The bonytail were approximately 12-14 cm in length and seen in late afternoon at the end of the recording (19:40 MST).

We also recorded 14 hours of tape at Willow Beach National Fish Hatchery. The camera was set up in the raceways, for six 2-hour recordings of razorback suckers and one 2-hour recording of bonytail. Again, the purpose was to record behavior and determine if juveniles exhibited the ‘winking’ behavior. The films revealed that the eyes of adults are more deeply recessed into the skull than with juveniles. Eyes of younger fish “bulged slightly,” naturally exposing the outer edge of the sclera. This is most obvious on the dorsal portion of the eyeball by framing the eye with a white crescent moon shaped margin. Schooling activity was rapid and we were unable to detect any behavior similar to what we have seen with spawning adults.

Dietary Analysis

The gut contents of 72 bonytail were collected and analyzed to determine the diet of intermediate to large (>30 cm) sized bonytail. The work was conducted under contract with Arizona State University. A portion of that work was summarized in the 2003 annual report. The work in its entirety is presented in Appendix B.

6. Management Recommendations

It is difficult to overestimate the importance of CHLP in the conservation and potential recovery of the bonytail and razorback sucker. The discovery that these fish can complete their life cycle in isolated ponds provides the first glimmer of hope that these species can be effectively managed. The self-sustaining nature of the community provides an opportunity to examine complex ecological issues on a scale that is realistic, economical, measurable and most importantly manageable. Currently, this opportunity does not exist anywhere else in the basin.

Efforts to establish additional native communities have thus far proved unsuccessful (Brouder and Jann, 2004). While the success of natural recruitment at CHLP is often described as something that we need to duplicate, there has not been any attempt to actually duplicate the physical conditions found at CHLP.

How To Build a Native Fish Refugia

The factors that have contributed to the success of CHLP are undoubtedly many, but there are obvious ones that should be considered in the construction of new habitats. These include:

1. **Absence of Predatory Fish**

   The initial renovation of CHLP appears to have been successful. Stocked fish not only survived but were able to mature and produce young in a relatively predator-free environment. Remarkably, it took 5 years (1993-1998) before bonytail and razorback sucker young were noticed. Recolonization by unwanted fishes is inevitable. Small numbers (<20) of shad, bluegill, largemouth bass, and channel catfish have been removed during the past decade, however, their numbers have remained quite low and only adults were found. We believe the majority--if not all of these fish--were introduced by anglers.

   Overall predation has not been eliminated; it has simply been reduced to a level that allows natural recruitment at a level where the community is able to sustain their number. Native fish eggs, larvae and fry are taken by crayfish, predatory insects, tadpoles, bullfrogs, and birds; even larger (>40 cm) natives fall victim to herons and osprey. It is quite possible non-fish predators could suppress natural recruitment and even the stocking of small fish if adequate cover (e.g., water depth, turbidity, structure) was not available.

Regardless of structural safeguards and monitoring, predation will remain a daunting challenge. It is not a matter of if, but when, predators invade these habitats and that influences if and for how long natural recruitment will occur. Therefore it is critical that mature fish be included in the initial stocking to allow spawning to occur as soon as possible. For instance, bonytail become sexually mature in the first or second year, but it takes razorback females 3 - 4 years to become sexually active. If only juvenile suckers are stocked, it provides non-natives ample time to recolonize and expand their populations to thwart any change of native recruitment. This is not an issue if ponds are only being used to rear or hold relatively large individuals.

2. **Physical Habitat**
    a. **Water Quality**. CHLP is hydraulically connected to the river. It appears ground water upwells at the pond's greatest depth and helps to circulate and maintain good water quality. The water gradient flows from the river through CHLP toward Pretty Water following the historic course of the river. Surface water temperatures did reach 34ºC this summer, however, diel temperature cycles of 3-4ºC combined with river influx helps to suppress thermal and chemical stratification. This circulation maintains sufficient dissolved oxygen in nearly 95% of the ponds volume.
    b. **Cover Complexity**. The pond affords native fish ample cover in the form of seasonal (vegetative) and permanent (rip-rap/beaver cavities) structure and depth (>3 m). Cover provides protection from predators and thermal protection from the sun.
    c. **Water Depth**. Water depth fluctuates seasonally due to river elevation. Summer depths reach 3.4 m compared to just 2+ m during winter months. The concentration of fish at depth during summer months suggests this additional depth may provide a thermal refuge (<31ºC).
    d. **Spawning Habitat**. Substrate conditions provide a wide range of particle sizes and materials, some being successfully used by spawners. Razorback suckers are using gravel/cobble substrate at the river levee's toe (>1.5 m depth) and bonytail are using small (2-5 cm) cobble located (0.1-1.0 m depth) on the river levee.
3. **Relative Size and Location**

The small size and steep banks of the pond make it less attractive to predatory birds, compared to broader, shallower habitats found nearby. The pond is located in a relatively isolated area, which reduces human use and bait bucket introductions. The pond also has a higher bank cover to pond volume ratio.

CHLP has provided bonytail and razorback sucker a habitat where they have sustained a natural population for nearly a decade. Colonization by largemouth bass was unfortunate, but quite frankly inevitable. As pointed out by Minckley and others (2003), these communities are temporary and must be managed accordingly. At CHLP, it appears that natural recruitment occurred in 11 of the past 12 years for bonytail (since 1994) and in at least 5 of the 12 years for razorbacks. Compared to any other conservation or recovery action in the Colorado River basin, this is simply remarkable.

Management Plan for CHLP

The discovery that largemouth bass had successfully spawned in CHLP signifies the eventual failure of native recruitment. Native fish recruitment will simply cease when predator numbers reach a certain threshold that exceeds native fish production. We anticipate that will be soon; within 1 to 3 years, depending on how rapidly the bass population expands. We consider attempts to mechanically suppress predators ill advised at this time. While this would provide important information, we feel the importance of maintaining this community outweighs any benefits derived by research. This type of research should be delayed until additional communities are established. We strongly recommend the pond be renovated in the very near future. It is not entirely certain whether the community can be restored as easily as it was established in 1993.

In conjunction with restoring CHLP, we recommend that a specific management plan be developed which identifies and choreographs specific tasks, secures appropriate clearances, and identifies parties capable or responsible for specific actions. If a plan is developed, we suggest it be structured as a 'working document' to allow flexibility in adapting information that allows management or research to be more effective.

The plan needs to identify the pond's purpose, realizing that management objectives may change in time. We have discussed among ourselves the potential research benefits that could be realized. However, due to the current status of the fish and the uniqueness of this community we feel CHLP should initially be managed solely to maintain the native community. That action would be invaluable in providing management-related information and experience needed to expand these communities elsewhere. This and hopefully other facilities can be built where native fish can live in a semi-natural habitat and be systematically studied to further understand their ecology and determine ways to expand their communities to a more natural state.

a. Management Plan

The plan needs to be designed as a low-maintenance approach, maintaining the level of activity that has occurred the past decade. Activities would include maintaining adequate public signing, periodic monitoring, and annual fall sampling. We recognize that refuge resources are strained and believe these types of facilities can be designed to minimize maintenance costs.

i) The plan should identify primary and secondary goals.
ii) The plan should identify entities responsible for specific management activities, scheduling, environmental compliance, funding and field activities.
iii) The plan should maintain an annual fall sampling effort to monitor fish and determine the presence of unwanted predators.
iv) The plan should identify threshold events that would trigger management responses. For instance, when non-native numbers exceed 5% of the annual sample it would trigger a salvage and renovation program that would be conducted the following spring when adults spawn and are most susceptible to capture. It would identify where fish would be held or released, sources of adults for restocking, and identify and obtain the necessary environmental compliance. Based on the history of CHLP, renovation may only be necessary once every 5-10 years.
v) Fish could be periodically harvested for use elsewhere during annual monitoring. This could include all sizes of fish. Fish could augment river stocking, be used to restock refuge communities, or be used for research.
vi) Aspects of the management plan should follow the basic guidelines and recommendations provided in Minckley and others (2003) and the RIPSWG (Recovery Implementation Plan Scientific Work Group) Management Plan that provides an outline for the use of these facilities.

Activities For 2005

1. Focus points for monitoring the fish community:
    - Monitor the size distribution of the fish community.
    - Monitor the expansion of the largemouth bass population.
    - Continue to mark and recapture fish, including bass.
    - Based on snorkeling observations of relative abundance, determine if bonytail produce a successful spawn and young survive.
2. Complete fish scale analysis.
3. Complete telemetry studies on bonytail.
4. Complete predator/prey studies.
5. Complete dietary analysis.
6. Have zooplankton analyzed.
7. Field-test a Didson Camera to monitor razorback sucker and bonytail spawning.
8. Possibly assist in a salvage effort if one is scheduled for FY-2005.
9. Complete the final products for this study:
    - A brochure
    - Possible video or DVD of the project
    - A final report on the ecology of the bonytail and razorback sucker
    - Various publications and presentations

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Appendix A. Spatial and Temporal Aspects of Bonytail Chub Movement and Habitat Use, Cibola High Levee Pond, Lower Colorado River, Arizona and California, 2003-2004

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Summary

Sonic transmitters were affixed to a sample of ten large, adult bonytail in 2003 and nine smaller, sub-adult bonytail in 2004 released into the Cibola High Levee Pond, a small backwater adjacent to the lower Colorado River. Series of point and paired, directional observations showed that adult bonytail used interstices of large riprap during the daytime, then came out into open water during hours of darkness, presumably to feed. The spatial pattern of daytime cover use revealed a significant level of site fidelity. Most fish showed some pattern of geographic distribution at night, with most observations in a particular area of the pond, while other fish showed a random distribution. Subadult bonytail apparently occupied open water throughout the day and night and did not seek specific cover. However, all small fish are believed to have expired before the end of the field study and their behaviors and habitat use may not have been typical. A combination of sensitivity to capture, handling, and tag attachment are believed responsible for their mortality. Methods that are not harmful to test fish should be identified and implemented to enhance reliability of future data. Selection or design of bonytail management areas including grow-out and refugium sites should consider cover requirements for larger fish, as this may be an important limiting factor.

Introduction

This report presents one of several aspects of ongoing studies of native bonytail *Gila elegans* and razorback sucker *Xyrauchen texanus* in the Cibola High Levee Pond (HLP). The Cibola HLP is a small (ca. 5 acre) remnant of the lower Colorado River channel located between the river (low) and inland (high) levees on the U.S. Fish and Wildlife Service Cibola National Wildlife Refuge in La Paz County, Arizona and Imperial County, California. The pond was reclaimed to eliminate non-native fishes and first stocked with native species in 1993, and since then the site has served roles in both management and research (see LaBarbara and Minckley 1999, Marsh 2000, Mueller et al. 2003).

The purpose of this investigation was to examine temporal and spatial patterns of movement and habitat use by bonytail inhabiting the Cibola HLP. This goal was accomplished using sonic telemetry to acquire location data for bonytail representing relatively larger and relatively smaller fish in separate years.

Methods

Field Collections and Tagging. A sample of 10, relatively large (mean TL 45.3 cm) bonytail was acquired from trammel net collections made on 17 March 2003 and fitted with sonic transmitters (Table 1). A similar collection of nine, smaller (mean TL 28.4 cm) bonytail was made 08 April 2004 and fitted with sonic transmitters (Table 2). Fish were held in a floating live car for a brief time after capture, then measured (total length [TL], nearest mm), weighed (2004 only, nearest 2 gm), examined for sex and general health and condition, scanned for presence of a Passive Integrated Transponder (PIT) tag, tagged if none was present, and fitted with a sonic tag.

Sonic tags were purchased from Sonotronics, Inc., Tucson, Arizona. In 2003, Model IBT-96-2 tags with a nominal 60-day life expectancy were attached with black vinyl electrician's tape to a pair of appropriately sized cable ties, and these in turn were affixed around the test fish caudal peduncle (see Mueller et al. 2003). Cable ties used on these fish were either solid or incorporated a "fusible link" of metal wire that was designed to corrode in time and allow the cable ties and tag to fall off.

Model SMT-01-376 tags with a nominal 14-day life expectancy were used on smaller fish in 2004. Tags were affixed directly to the caudal peduncle using black vinyl electrician's tape. One of 10 tags malfunctioned when it was initially activated so only nine total fish were used. All fish were released near the south end of the Cibola HLP and allowed to disperse without being disturbed.

Tracking. Tracking was done using one or a pair of DH-2 directional hydrophones, an omni-directional hydrophone (DH-2 with shield removed), USR-5W ultrasonic receiver, and either headphones or external speakers. Additional shielding comprised of 6.4-mm neoprene sheeting was affixed to the directional hydrophones to reduced interference from extraneous signals and increase directional specificity. Hydrophones were mounted on 2-m long x 12.7-mm diameter PVC poles, and directional ones were fitted with a horizontally mounted Suunto A-30L magnetic compass that was aligned with directional hydrophone such that compass bearing of an incoming signal could be approximated within about 30 degrees.

Tracking was performed utilizing three different protocols. First, to obtain directional data, listening stations were established at two fixed sites, one at the north end of the high levee, the other on a small spit at the northern end of the river levee (see Fig 1). Nominally, simultaneous readings of fish number (pulse code) and compass bearing were to be taken at 15-minute intervals at each site beginning approximately at sunset and extending until dawn. Additional directional readings were taken from each listening station but these were not temporally synchronized so as to be simultaneous. Second, to acquire "point data," random surveys to locate individual signals were made throughout the pond at various times of day and night, nominally in evening just prior to sunset and in morning just after sunrise. A directional hydrophone was used to determine the presence and general direction of a signal, while the omni-directional hydrophone was used to pinpoint the location of sedentary fish (or tags). Finally, during 2004 only, a fixed listening station was established using an anchor and buoy placed near the geographic center of the pond. That station was manned periodically using both types of hydrophones to ascertain general fish or tag location, and an attempt then was made to establish a precise location using a directed-random survey.

Directional Data Analysis. Compass bearing data were sorted and correlated so that only temporally paired, simultaneous observations were retained, and all values were rounded to the nearest 5 degrees. Data were entered into an Excel spreadsheet that showed all corresponding intersections for the two listening stations, and data then were corrected for geographic declination at Cibola HLP relative to true north by subtraction of 13 degrees.

An ArcView "project" was created to accommodate the paired directional data and, the Cibola NW digital orthographic quarter quadrangle (DOQQ) was downloaded from the Arizona Regional Image Archive (ARIS) and added to the project. Next, a lake poly file to represent the Cibola HLP was created from the Cibola NW DOQQ. Global Positioning System (GPS) coordinates were used to create two point files, one representing the two listening stations and the other representing 26, 5-m wide "zones" that were designated along the high levee (see *Point Data Analysis*, below). An array of 800 m-long radial lines representing each individual bearing observation was created from the stations point file for each listening station, and these were separated into individual shape files based on the listening station from which they were created (i.e., high levee or low [river] levee). The "intersections to points" theme from ESRI then was used to create a single point for each intersection of the radial lines, and these in turn were used to create x-y coordinate fields in an intersection data table. Fish data were added to the ArcView project, and fields showing bearing data for low and high levee stations were inserted. The point intersection shapefile table and the fish data were joined, based upon common station/bearing criteria, and exported as a new table of individual joined data. Finally, a fish shapefile was created from the fish table by converting the fish event theme to a shapefile, and the fish table was summarized based on the low-high levee bearings field. The final result was a graphic that shows which fish were located within each at each two-dimensional space (defined by the intersection of radiating bearings), and the number of occurrences of each fish within each space.

All intersections that fell within the 800 m radius were plotted in ArcView and the remainder was removed from consideration as uninformative. Paired data were sorted by time periods designated as dusk (1945 to 2200), mid-hours (2215 to 0315), and dawn (0330 to 0545), and by fish pulse code number.

Point Data Analysis. During the course of study in 2003 it was discovered that at times some signals originated from within the interstices of the large material used to construct the high levee. It was presumed that individual signals were associated with individual fish. The high levee thus was divided into 26, 5 m wide "zones," consecutively designated with alpha characters A through Z. Signal detections and fish locations were referenced and recorded by zone.

Point data were entered into a two-way spatial distribution table that represented the number of times each fish was observed within each zone of the high levee. The table was used to create a histogram for each fish that depicted the number of times it was contacted within each zone, and a cumulative histogram was constructed that showed the total number of contacts within each zone for all fish combined. A two-way goodness-of-fit test using the Pearson Chi-square statistic (Sokal and Rohlf 1995) was performed for nonrandom association of specific fish with a specific zone(s) to determine if there was any fidelity to a particular zone, or if fish simply were found at random among the 26 zones.

2004 Data Evaluation. Point data were plotted on an area map of Cibola HLP to show known locations and presumed fate of individual fish.

Results and Discussion

Bonytail tagged in 2003 (n=10) ranged in total length from 404 to 514 mm with a mean of 453 (Table 1). Fish from 2004 (n = 9) were smaller; 250 to 301 mm long with mean of 284 mm and weight of 101 to 159 g with a mean of 138 g (Table 2).

Tracking during 2003 was conducted for up to four days each week from release of fish on 19 March to end of the experiment on 07 May. These large bonytail showed a strong tendency during daylight hours to occupy the interstices of the large material that was used to construct the high levee, and visited the open water of the Cibola HLP almost exclusively during darkness. In fact, there was virtually no evidence that any fish utilized open water during daylight. Our initial failure during daylight to detect signals using a directional hydrophone anywhere in the pond a week after fish were tagged and released resulted in a point search using the omni-directional probe. Discovery of fish using the interstices of the high levee was serendipitous and quite a surprise.

Point Data. A total of 32 point surveys of the high levee were performed: 16 in the morning and 16 in the evening. The number of contacts per fish ranged from 26 to 32, signals were encountered at 19 of the 26 designated zones, and total number of contacts (all fish combined) per zone ranged from 1 to 63 (Table 3).

Zone usage was not uniform. Distribution of contacts for the 10 large bonytail demonstrated that site fidelity was high and significant ($X^2 = 697.93$, df = 25, $P < 0.001$). Usage was nil or low in more than half the zones -- no signals were ever contacted within 7 zones (B, C, D, E, K, L and O) and only one or two contacts in each of 8 zones A, F, H, M, N, V, Y and Z (Table 3 and Fig. 2). Five zones had moderate usage (5 to 15 contacts each; zones G, P, Q, R and S) and six zones had high use (19 or more contacts each, up to a maximum of 63; zones I, J, T, U, W, X). The six highest use zones occurred in three nearest-neighbor pairs separated by one or more low use zones.

Generally, once most fish established "residency," those individuals returned each morning to the same zone, often to the same exact location, within the high levee (see Fig. 3). A few fish switched from consistent use of one area to consistent use of another (e.g., Fig. 3, BT666 and BT777).

Nonetheless, we only had information on the 10 marked fish. Other, unmarked individuals may have occupied "empty" zones or been present in the same zones as the marked fish. Habitat differences were not obvious to us, and the high levee appeared relatively uniform from zones A to Z. We thus assume other bonytail, perhaps many, occupied interstices within the high levee.

Perhaps more striking than the consistent high use of certain zones was the apparent fidelity of individual fish for specific zones. Most fish were found with much higher frequency in only one or two zones, with occurrences in other zones being limited to only one or a few observations (Table 3 and Fig. 3). Two or more fish rarely occupied the same zone at the same time, although different fish may have occupied the same zone on different occasions.

Directional Data. There were 2,947 separate recorded bearings; 1,648 and 1,299 observations were made from the high and river levee listening stations, respectively. A total of 508 of 945 simultaneous paired readings fell within the 800 m listening station radius: 161 (16.1 contact per 15-minute period) during dusk (1945-1000), 269 (11.2 contacts per period) during mid-hours (2215-0315), and 78 (7.8 contact per period) during dawn hours (0330-0545). These results are consistent with the pattern of signal detections observed in the field across all contacts – most fish made an appearance shortly after sunset during the dusk period, numbers typically were reduced by one-to-a few during the mid-hours, and signals representing all remaining individuals disappeared as fish returned to the high levee.

Directional data applied almost exclusively to fish activity during periods of darkness because marked individuals spent the daylight hours under cover provided by interstices of the high levee. Number of paired, simultaneous contacts averaged 50.8 per fish and varied among individuals from 0 to 112 (Table 1). Few contact intersections fell within the pond, and interpretation of geographic pattern was based only on the general position of signals (e.g., compass direction) relative to the listening stations (Fig. 4). Some directional error was caused by the acoustical dampening nature of aquatic vegetation and false readings caused by signal reflection of large rip-rap.

Fish numbers BT333, BT357, BT364, BT375 and BT555 tended to be located in the southeastern portion of the pond. This was an area characterized by patches of submerged aquatic vegetation in moderately deep (1-2 m) water, a relatively abrupt, open sandy shoreline, and woody riparian vegetation (Figs. 1 and 4). Fish numbers BT345 and BT666 tended to be located in the northwest portion of the pond. This was an area with little submerged vegetation, relatively shallow (< 1 m), a gently sloping shoreline with dense cattail, and woody riparian vegetation (Figs. 1 and 4). Contacts with fish numbers BT246 and BT444 showed little geographic pattern (Fig. 4) and BT777 was never contacted in open water.

2004 Data. Tracking of smaller fish tagged in 2004 was performed continuously after fish were released on April 8, but results were disappointing and generally uninformative. Although data acquired during the initial days after release suggested that smaller fish were present in open water throughout the day and night and did not enter cover of the high levee during daylight, most fish appeared to become stationary within a few days post release. This was interpreted as indicating either tag loss or fish mortality. Two carcasses and body parts of a third were associated with stationary signals, and two tags were recovered. All fish were presumed expired when field studies were concluded on 05 May, and most or all likely were dead at least a week prior. Subsequent experimental investigations of tagging small bonytail in hatchery raceways resulted in mortality within 14 days for all treatments, including those fitted with caudal tags and control groups. (Mueller et al. 2004).

Small bonytail clearly were more fragile than larger ones and new methods of affixing transmitters that do not harm or kill the fish must be identified if reliable telemetry data are to be acquired. Additionally, sonic tags in our situation provided only a gross approximation of open-water habitat use. Rebounded signals often were diffuse, and the number of valid coordinates was consequently reduced. Preliminary investigations indicated that Lotek radio tags utilizing nano-technology were unsatisfactory for use in the Cibola HLP because signals were weak and detection radius was shorter than 10 m for a tag suspended only 1 m below the surface (Marsh and Mueller, unpublished data).

Conclusion

Telemetry studies at the Cibola High Levee Pond indicate that adult bonytail are active during nighttime and spend the daylight hours dormant and hidden under cover amongst large boulders. This observation is consistent with stomach contents and proportion of empty guts, which indicated the most intense feeding occurred at night (Marsh et al. 2004). Adult bonytail in Lake Mohave, a mainstream Colorado River reservoir, showed a similar spatial distribution in springtime, remaining sedentary in deep water during daytime and moving into shallow, near-shore habitats during darkness (Marsh and Mueller 2000). Association of stream-dwelling chubs with deep pools, undercut banks and shadows in well known, and use physical structure or even turbidity as daytime cover has been reported for several members of the genus *Gila* in Arizona streams and rivers (Minckley 1973, Bio/West 1994). This behavior may serve to avoid sight-feeding predators in addition to supporting other life functions including feeding and reproduction.

Apparent daytime occupation of cover by large bonytail and apparent relegation of smaller fish to open water may have important implications for bonytail management because availability of suitable cover may in part determine habitat carrying capacity. If all available cover is being used and relegation to open water of fish that are denied access to suitable cover results in increased exposure to predators or other mortality factors, then cover becomes a limiting factor at the population level. It might be possible to experimentally investigate the significance of this and other phenomena on bonytail and other native species' population parameters, but suitable field sites to perform such work, replicates of the Cibola HLP, for example, do not currently exist. Regardless, provision of adequate cover should be considered in the selection or design of bonytail management areas such as those used for grow-out, refugium, or long-term population maintenance (e.g. Minckley et al. 2003)

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Table 1. Data for tagged bonytail, Cibola High Levee Pond, Arizona-California, March 18, 2003. TL = total length in mm; status = R (recapture) or N (new PIT tag); code = sonic tag pulse code; Frequency = sonic tag frequency in MHz; method = C (corrosive link sonic tag attachment) or NC (Non-corrosive or fixed sonic tag attachment). Contacts = number of simultaneous compass Bearing readings (see text for explanation). Mean and standard deviation of TL also given.

TL	Sex	PIT Tag No	Status	Code	Frequency	Method	Contacts
493	F	424D1A754B	R	246	77	C	28
412	F	424E681145	N	333	70	NC	112
404	M	424E6C4A1F	N	345	75	NC	44
445	M	424D7C3F5D	N	357	76	C	42
491	F	424E486D0A	N	364	78	NC	49
426	F	424E48665B	N	375	79	NC	112
443	F	424D3F091C	N	444	71	C	110
514	F	424E522816	N	555	72	C	4
419	F	424F193A7D	N	666	73	NC	107
484	M	424E5A2629	N	777	74	C	0
453	Mean						
39	Std Dev						

Table 2. Data for tagged bonytail, Cibola High Levee Pond, Arizona-California, April 8, 2004. TL = total length in mm; weight (gm); status = R (recapture) or N (new PIT tag); code = sonic tag pulse code; frequency = sonic tag frequency in MHz; method = T (black vinyl electrician's tape) Mean and standard deviation of TL and WT also given.

TL	WT	Sex	PIT Tag No	Status	Code	Frequency	Method
250	101	F	424D751C0A	N	345	73	T
292	136	F	424D636176	N	333	70	T
300	162	F	424E6F247E	Y	346	78	T
301	152	M	424D103F70	N	344	77	T
270	131	F	424B057C41	N	444	71	T
296	150	F	424F321732	N	355	79	T
298	159	F	424F036054	N	445	76	T
270	118	M	424E615E39	N	344	74	T
276	130	F	424F093479	Y	555	72	T
284	138	Mean					
18	20	Std Dev					

Table 3. Spatial distribution of point contacts for 10 sonic tagged bonytail, Cibola High Levee Pond, Arizona-California, March-May 2003.

	Zone																										Contacts
Fish ID	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	per fish
BT246																								30	1	1	32
BT333																			4	26	1						31
BT345									1									2			1	1	22				27
BT357	2					1	8	1	2	17				1													32
BT364							2		22	1										1						1	27
BT375													1								17		1	7			26
BT444																		3	1	24				2			30
BT555									26																		26
BT666																13	9	7		1							30
BT777									12	2													17	1			32
Zone totals	2					1	10	1	63	20			1	1		13	9	12	5	52	19	1	40	40	1	2	

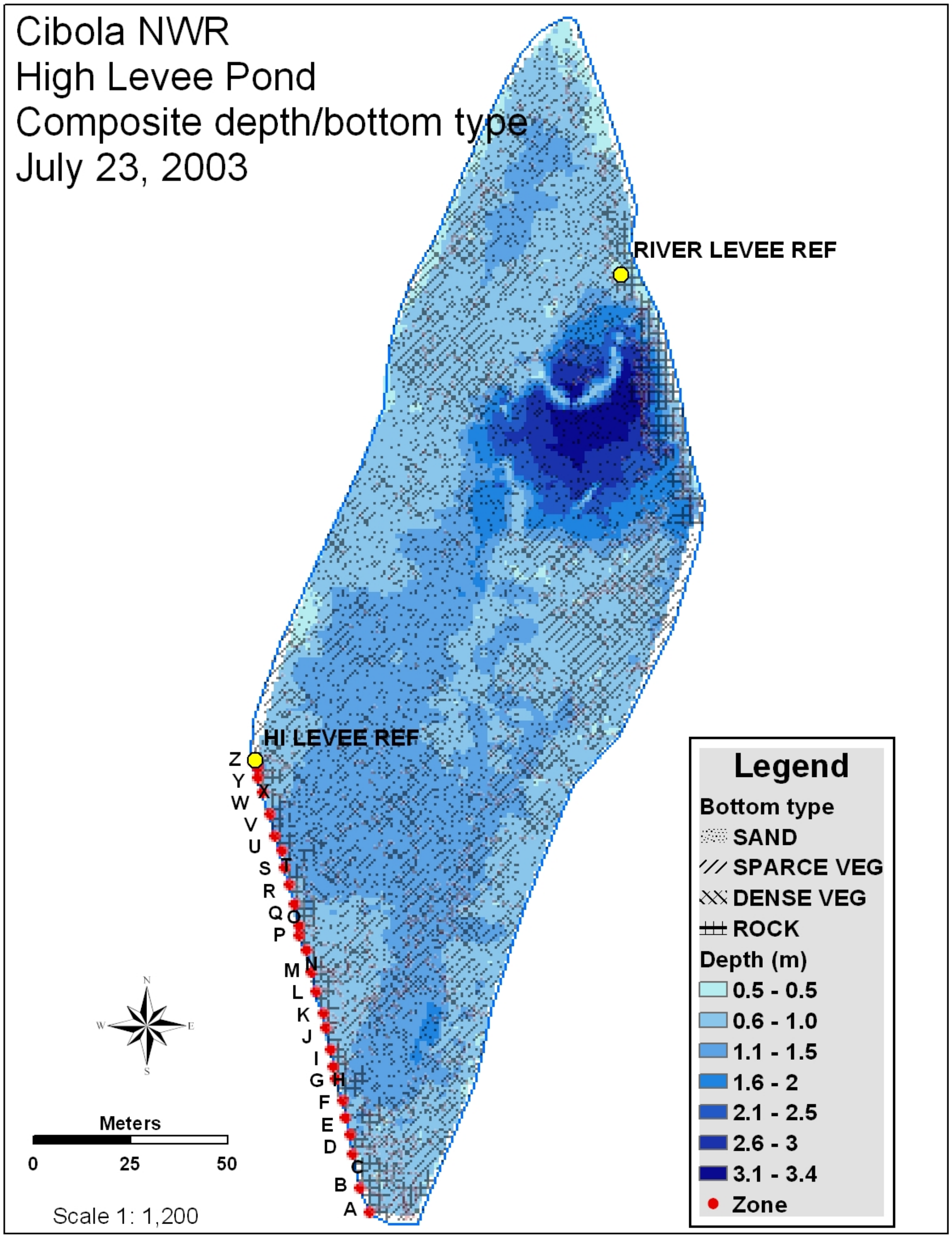

Figure 1. Bathymetric map of the Cibola High Levee Pond, lower Colorado River, Arizona and California, showing locations of two fixed listening (ref) stations, high levee zones A to Z, depths, and bottom types. Map data acquired July 23, 2003.

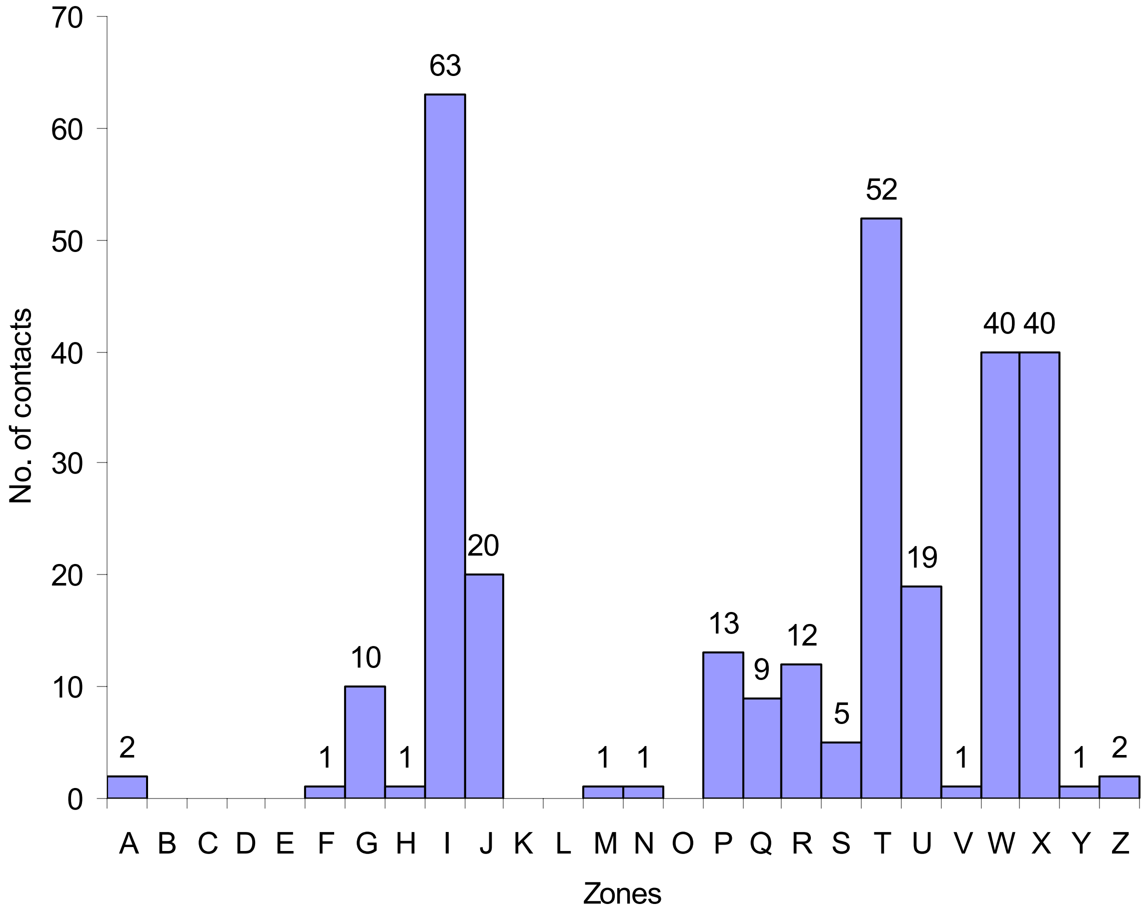

Figure 2. Histogram of spatial use by adult bonytail of interstices (5-m-wide zones A to Z) of the high levee, Cibola High Levee Pond, lower Colorado River, Arizona and California, 2003. See text for detailed explanation and Figure 1 for locations of zones.

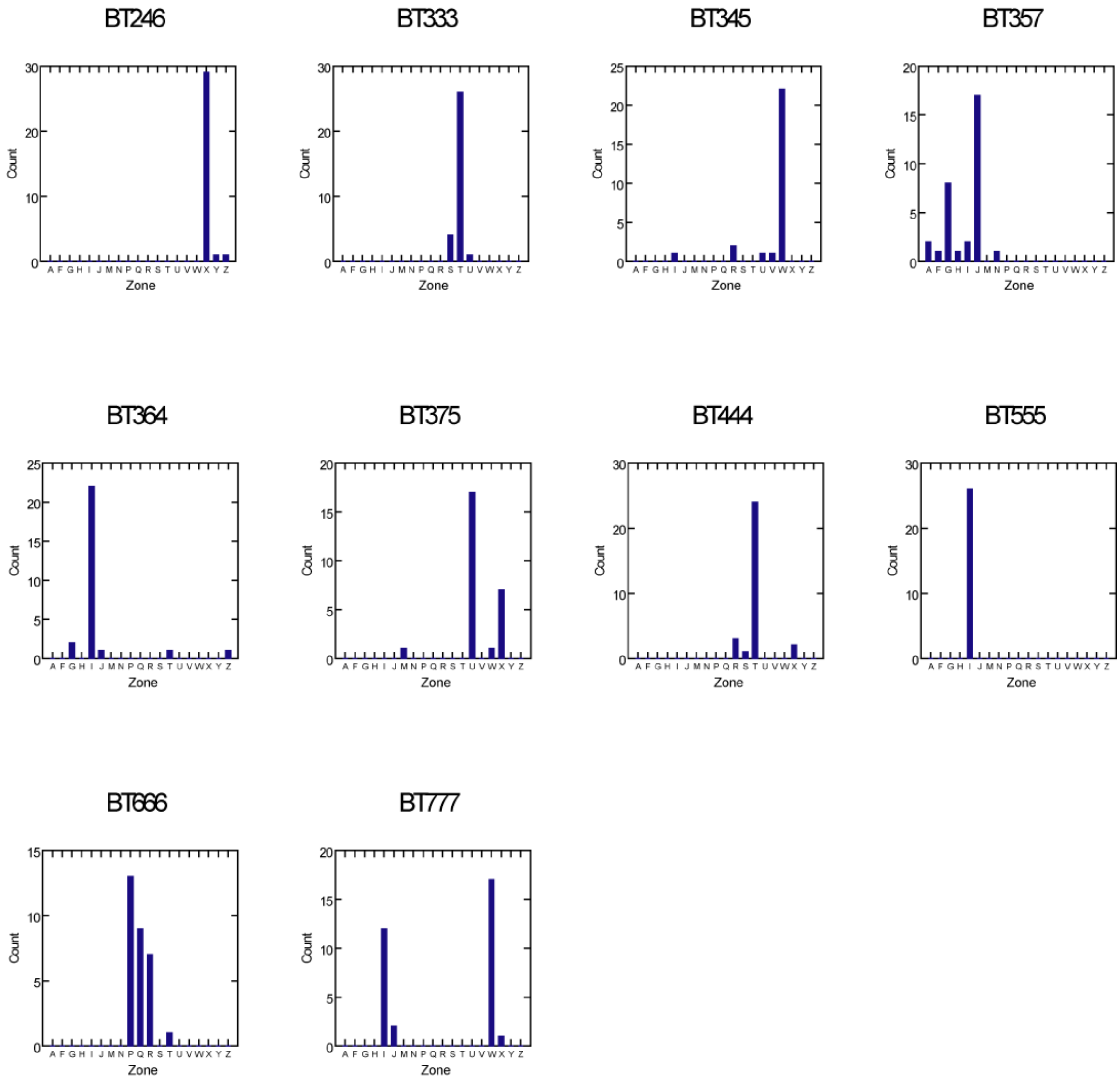

Figure 3. Number of contacts within each 5-m wide zone A to Z for ten adult bonytail in the Cibola High Levee Pond, lower Colorado River, Arizona and California, 2003. See Table 1 for associations of tag pulse codes (BT---) with data for individual fish and Figure 1 for locations of zones.

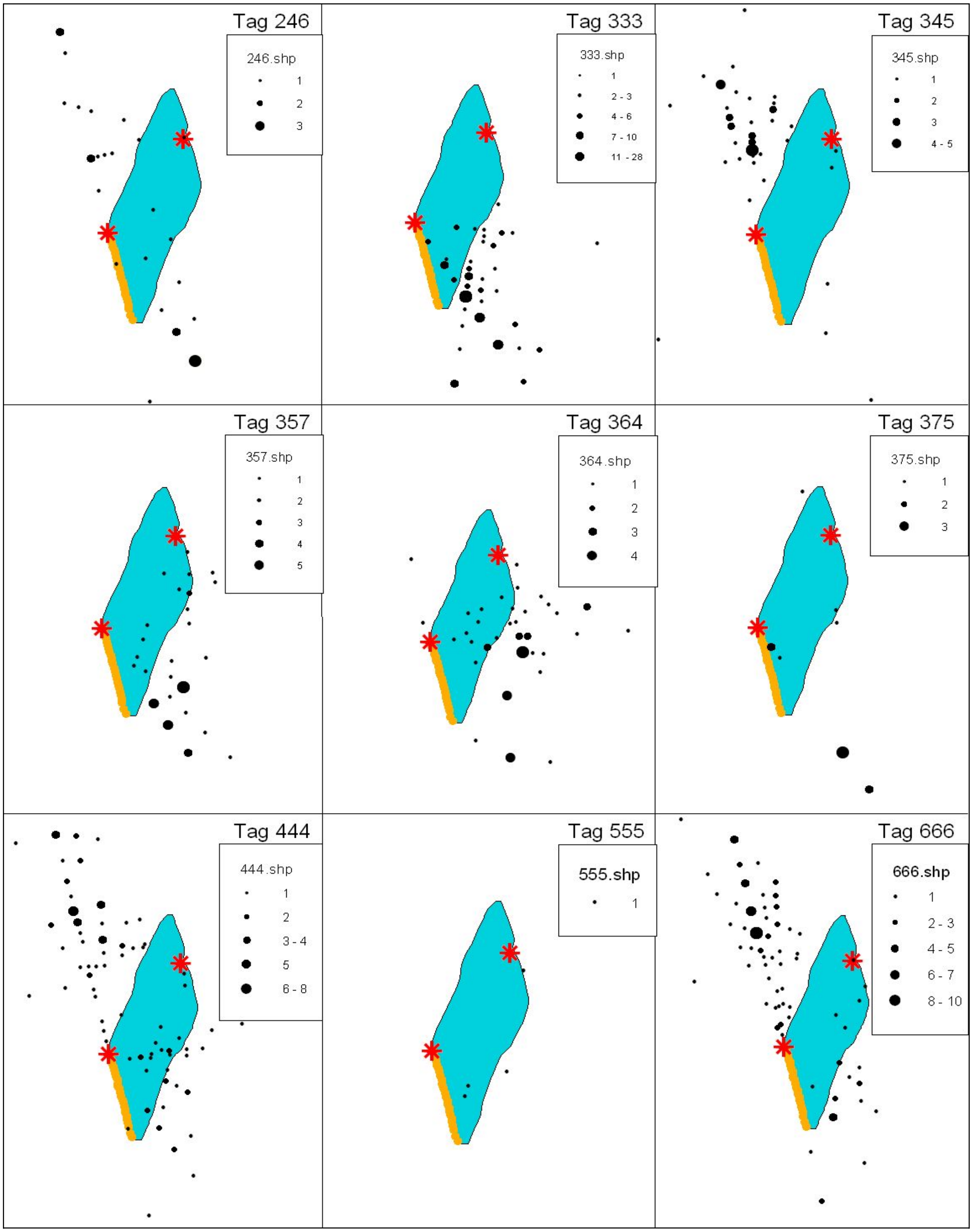

Figure 4. Spatial distribution of nine adult bonytail in Cibola High Levee Pond, lower Colorado River, Arizona and California, 2003, based on directional simultaneous observations. Symbol size corresponds with number of observations. See Table 1 for associations of tag pulse codes (BT---) with data for individual fish. There was no contact with BT777, which is not figured.

Appendix B. Bonytail Chub Foods and Feeding Habits, Cibola High Levee Pond, Lower Colorado River, Arizona and California, 2003-2004

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Introduction

This report presents one aspect of ongoing studies of native bonytail *Gila elegans* and razorback sucker *Xyrauchen texanus* in the Cibola High Levee Pond (HLP). The Cibola HLP is a small (ca. 5 acre) remnant of the lower Colorado River channel located between the river and inland (high) levees on the U.S. Fish and Wildlife Service's Cibola National Wildlife Refuge in La Paz County, Arizona and Imperial County, California. The pond was reclaimed to eliminate non-native fishes and first stocked with native species in 1993, and since then the site has served roles in both management and research (see LaBarbara and Minckley 1999, Marsh 2000, Mueller et al. 2003).

The purposes of this investigation were to (1) document foods utilized by bonytail, (2) examine food utilization as a function of fish size, and (3) investigate temporal aspect of feeding habitats and food utilization by bonytail inhabiting the Cibola HLP. These goals were to be accomplished by acquiring non-lethal stomach samples from evening and nighttime collections of bonytail representing relatively larger and relatively smaller fish across two years.

Methods

Sample Collection. A combined sample of 72 bonytail was acquired from trammel net collections made on 7 May 2003 and 4-5 May 2004. Nets were placed to sample two different feeding times, evening (samples collected from 1800 to 2400 hrs) and night (samples collected from 0100 to 0545 hrs). A distinct size class was sampled each year -- nominal TL for 2003 was >375 mm (n=28) and for 2004 was <375 mm (n=44). Fish were held in a floating live car for a brief time after capture, then measured (total length [TL], nearest mm) and weighted (nearest 2 gm). Stomach and intestinal (GI) contents were removed by flushing GI material through the vent by using a special apparatus inserted into the esophagus (Wasowicz and Valdez 1994) that was an effective method to avoid fish sacrifice. The apparatus consisted of a one-way, rubber squeeze bulb and tygon tubing of varying sizes (6.5, 8.0, 9.5, and 11.0 mm outside diameter), with tubing size matched appropriately to fish gape size. GI tracts were flushed with clear water from the sample site through a sieve, and into a sample container. Fish with empty tracts were noted. Samples were fixed in 10% formalin and later rinsed in fresh water and transferred to 70% ethanol for examination in the laboratory.

Gut Content Examination. Gastrointestinal samples were individually washed through a 500 micron-mesh sieve and solids wet-weighed to the nearest 0.001 g. The contents of each sample was visually examined with the aid of a binocular dissecting scope, and the percent of the total quantity was estimated for each of the following six categories: amorphic organic matter (AOM), inorganic matter, plant, fish, invertebrate, or other. When possible, individual prey items were identified to family-level. Samples were then placed in 70% ethanol for storage.

Results

Bonytail examined from 2003 (n=28) ranged in total length from 376 to 510 mm with a mean of 447, and ranged in weight from 305 to 1136 g with a mean of 565, while fish from 2004 (n=44) were smaller; 271 to 509 mm long with mean of 325 and weight 129 to 710 g with a mean of 222 g (see Fig. 1). Weight-length relationships represented a continuum from smaller to larger fish, and there was more variation among larger individuals (Figs. 1 and 2).

Of 72 fish sampled in both years, 13 GI tracts (18%) were to be empty. The frequency of empty tracts was more than four times higher for evening (33%) than for night (7%) samples (Fig. 3), but the gross composition of GI contents was similar between the two feeding times (Fig. 4).

AOM consisted predominantly of nondescript, brownish material or “grutch.” This might have included stomach lining, mucous, or ingested materials in advanced stages of digestion (beyond identification). Inorganic material consisted of pebbles, rocks, grains of sand, and insect larval cases that were composed of sand grains and pebbles (e.g., trichopterans including hydroptilidae). Plant matter consisted of various aquatic macrophytes including *Najas* sp., *Potamogeton* sp., and *Chara* sp. Fish matter consisted of any fish part or whole including scales, bones, and flesh. Invertebrate matter consisted of a variety of groups including microcrustaceans (copepods, ostracods, and *Daphnia*), crayfish, corbiculidae, tapeworms, dipteran larvae and adults, notonectidae, and odonate nymphs and adults. Asian tapeworm *Bothriocephalus acheilognathi* was positively identified in one specimen and tapeworm proglotids, presumably Asian tapeworm, were found in 8 of 72 (11%) samples representing all available sizes of bonytail. Other matter included both identifiable (bull frog *Rana catesbiana*) and unidentifiable vertebrate remains.

For invertebrate, fish, and plant matter, composition varied by fish size (TL): plant matter decreased while invertebrate matter increased with increased fish size (Figs. 5 and 6). Fish parts were observed in 8% of GI samples (6 of 72), and were restricted to fish longer than 425 mm.

GI sample weights showed little linear relationship to fish body weight or total length (Figs. 7 and 8). Mean stomach sample wet weight was 1.544 g, the nonzero range was 0.061 to 13.970 g, and standard deviation was 2.667. Fish length and weight ranges are provided in Fig. 1.

Discussion

Telemetry studies at Cibola High Levee Pond indicate that adult bonytail are active during nighttime and spend the daylight hours dormant and hidden under cover amongst large boulders. This is consistent with the volume and composition of stomach contents and proportion of empty guts, which indicated the most intense feeding occurred at night.

Asian tapeworm was reported in humpback chub *Gila cypha* from the Little Colorado River in Grand Canyon (Clarkson et al. 1997), but this represents the first record of Asian tapeworm in bonytail from “wild” habitat on the lower Colorado River, and may signal future occurrences of this pest in other species and in other places. It is unknown if the tapeworm was introduced accidentally with hatchery stocks of bonytail or razorback sucker, or with other species that were stocked illegally by unknown persons. Researchers, managers and other should be aware of its potential presence and provide interested parties with incident reports as they occur.

The few available data from other studies indicate that bonytail feed on benthic and drifting aquatic invertebrates and terrestrial insects under natural stream conditions (Kirsch 1889). A composite sample of sub-adult bonytail and roundtail (*Gila robusta*) chubs from Green River, Utah, ate mostly chironomid dipteran larvae and mayfly (ephemeroptera) nymphs when small, shifting to floating items (e.g., terrestrial insects) as they grew (Vanicek and Kramer 1969). Adult bonytail in Green River fed mostly on terrestrial insects, presumably taken from the surface, but there was no evidence of piscivory. In contrast, bonytail in Lake Mohave were found to prey on small (64 mm TL), newly stocked rainbow trout (Wagner 1955). Jonez and Sumner (1954) found plankton, insects, algae, and organic debris in bonytail from Lake Mead, and a few specimens from lakes Mohave and Havasu contained zooplankton (Minckley 1973). Our results contribute substantial new detail to our understanding of bonytail feeding ecology, but add little new qualitative information about their food utilization.

There were several factors that introduce an unknown level of uncertainly into our study. First, on more than one occasion, nets were run in stages such that early catch was held in a live car for a period of time before being re-assimilated with the later catch. This allowed an unequal time for digestion or evacuation of GI contents within sub-samples of fish. Potential effects of this protocol on food consumption results are unknown. Next, there were no control samples that could be used to evaluate the effectiveness of the siphoning method vs. surgical extraction of GI contents. However, studies by others (Bio/West 1994, Wasowicz and Valdez 1994) suggest that siphoning was nearly 100% effective with roundtail chub *Gila robusta* and was assumed similarly effective with humpback chub *Gila cypha.* Bonytail is morphologically similar to these congeners and we are unaware of any reason stomach pumping would be differentially effective among the three species. Finally, an expected linear relationship between fish weight and GI sample size was not observed. Implications of this result are not clear, but it may have been due in part to variation among samples in time elapsed between capture and processing.

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Gordon Mueller, U.S. Geological Survey (USGS) contributed substantially to the design and implementation of this project. Jeanette Carpenter (USGS), Darren Thornbrugh, Robert Colvin and C.O. Minckley (U.S. Fish and Wildlife Service, USFWS), and Michael R. Schwemm (Arizona State University, ASU) provided additional field assistance. Work was performed under ASU Animal Use and Care Protocol No. 05-767R. Appropriate Arizona, California, and USFWS permits authorized collections. U.S. Geological Survey Biological Resources Division provided funding through Cooperative Agreement No. 00CRAG004 Project Award No. 0004CS003 to Arizona State University. Gordon Mueller served as the USGS Project Officer.

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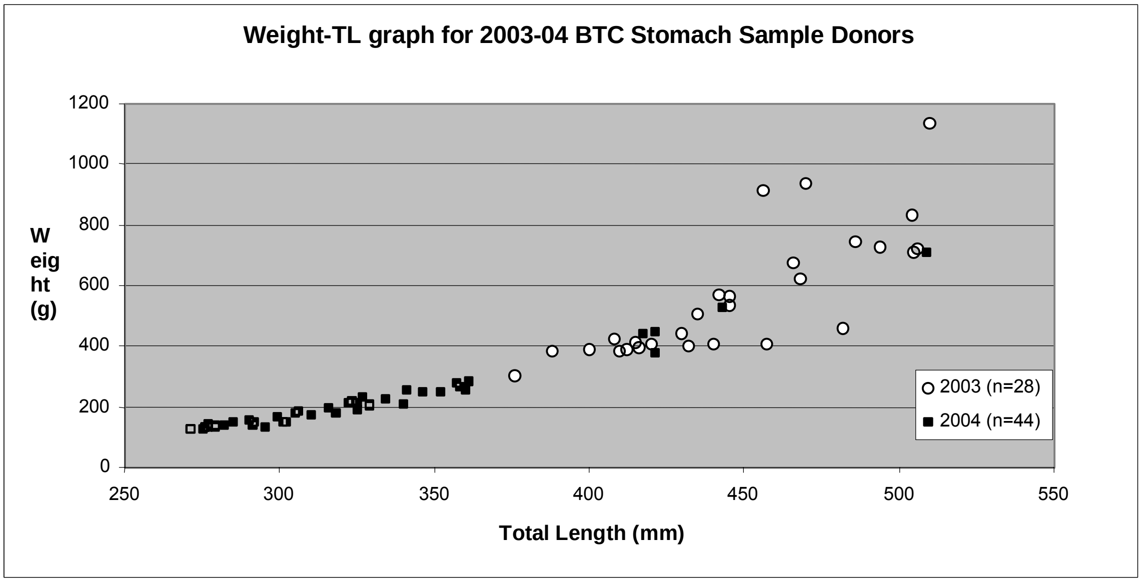

Fig. 1. Weight vs. length raw data plot for bonytail chub sampled for stomach contents, Cibola High Levee Pond, AZ-CA, 2003-2004. Data for fish with empty stomachs are included.

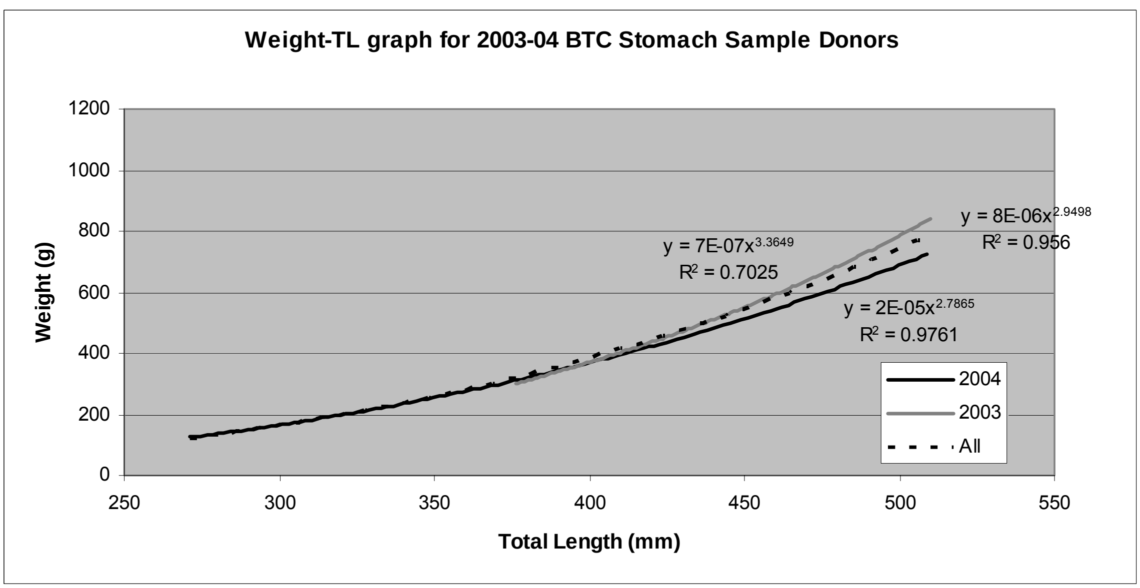

Fig. 2. Weight vs. length relationships for bonytail chub sampled for stomach contents, Cibola High Levee Pond, AZ-CA, 2003-2004. Data for fish with empty stomachs are included.

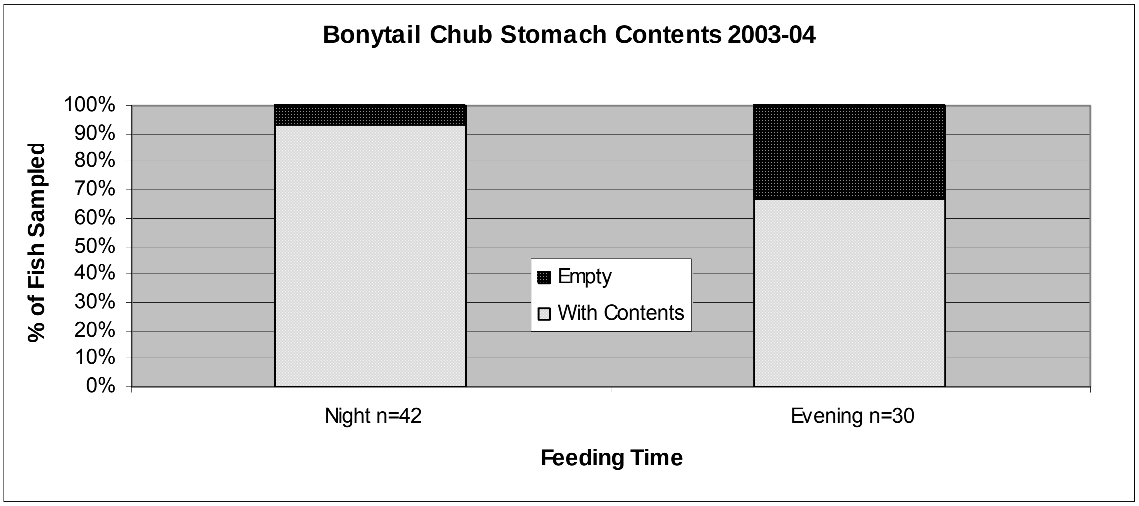

Fig. 3. Bonytail chub stomach contents following daytime and night feeding, Cibola High Levee Pond, AZ-CA, 2003-2004.

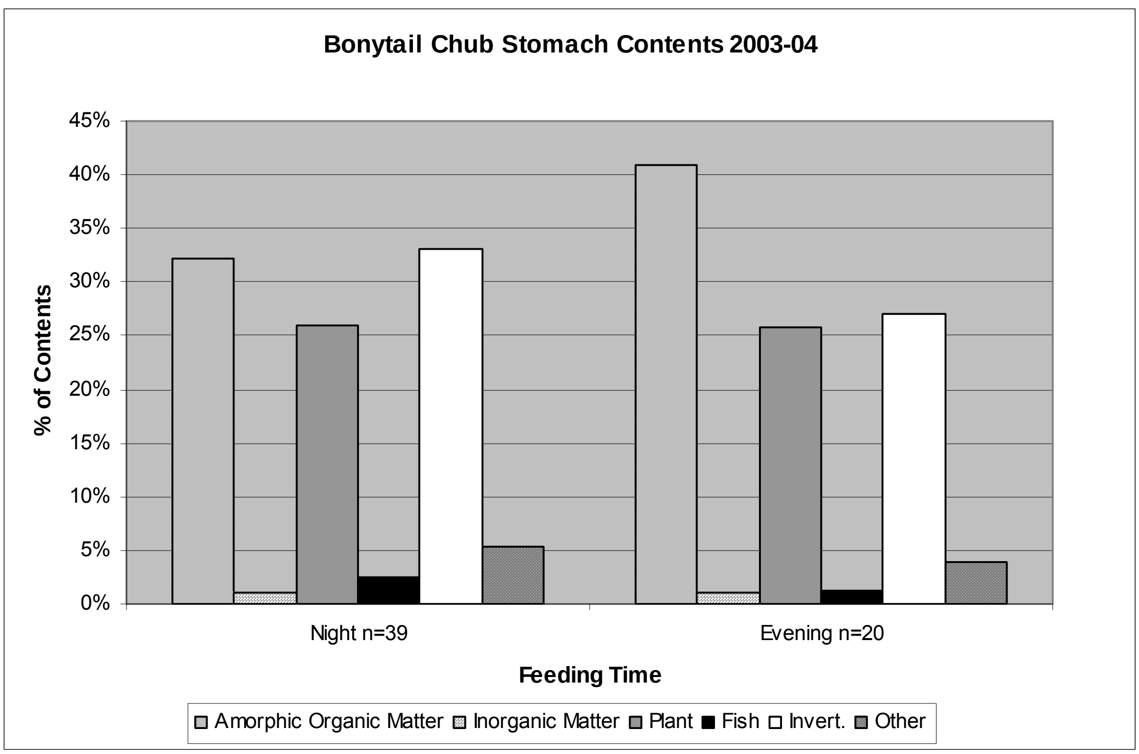

Fig. 4. Bonytail chub stomach contents by feeding time, Cibola High Levee Pond, AZ-CA, 2003-2004. Fish with empty stomachs are excluded.

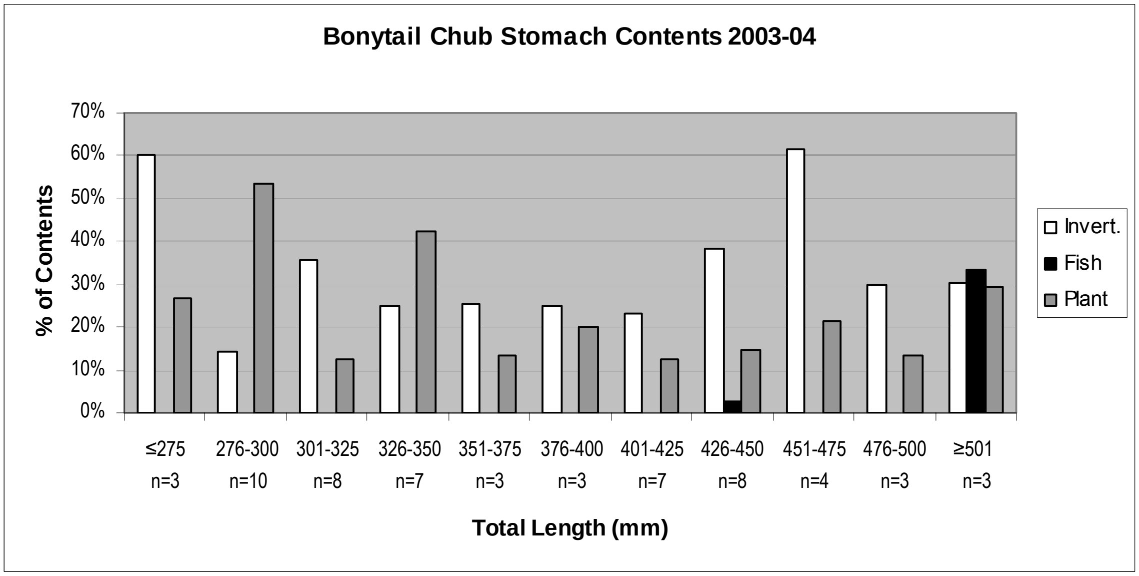

Fig. 5. Bonytail chub stomach contents by 25 mm size class, Cibola High Levee Pond, AZ-CA, 2003-2004. Fish with empty stomachs are excluded.

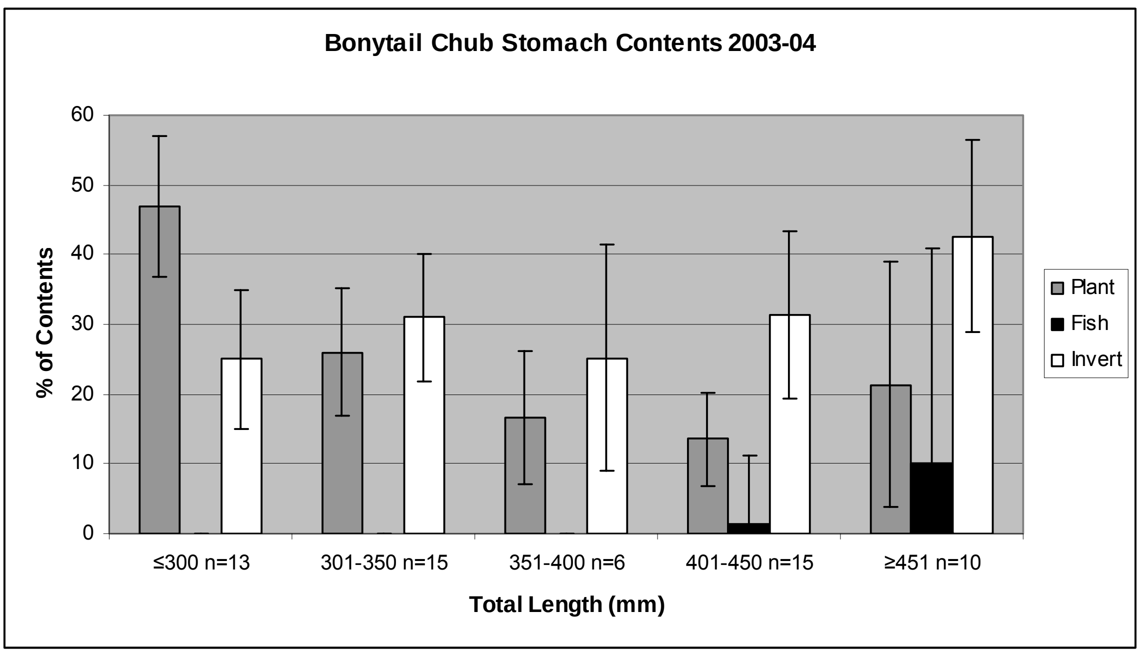

Fig. 6. Bonytail chub stomach contents by 50 mm size class, Cibola High Levee Pond, AZ-CA, 2003-2004. Fish with empty stomachs are excluded.

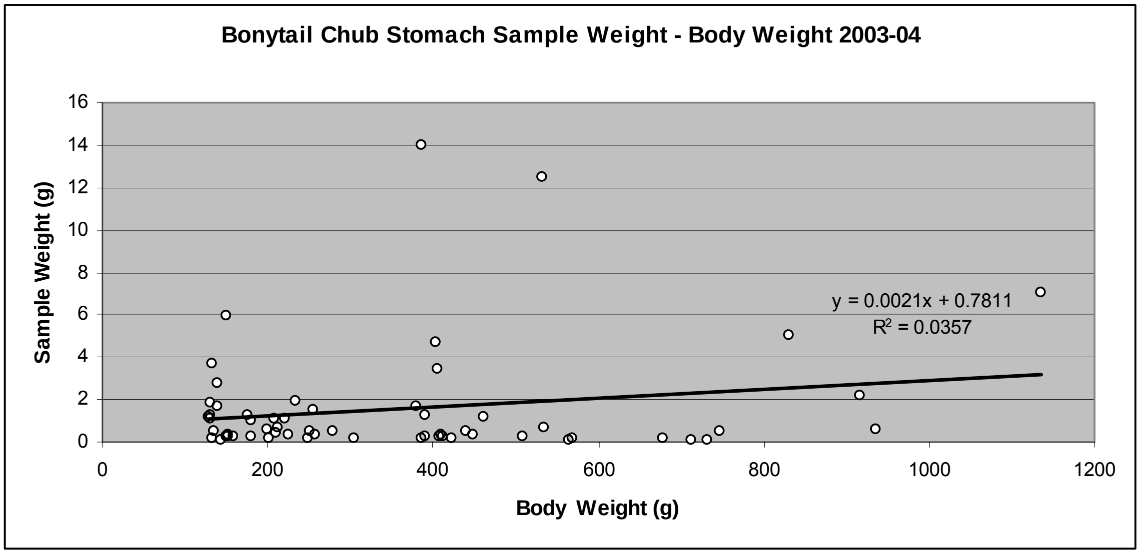

Fig. 7. Bonytail stomach contents weight to fish body weight relationship, Cibola High Levee Pond, AZ-CA, 2003-2004.

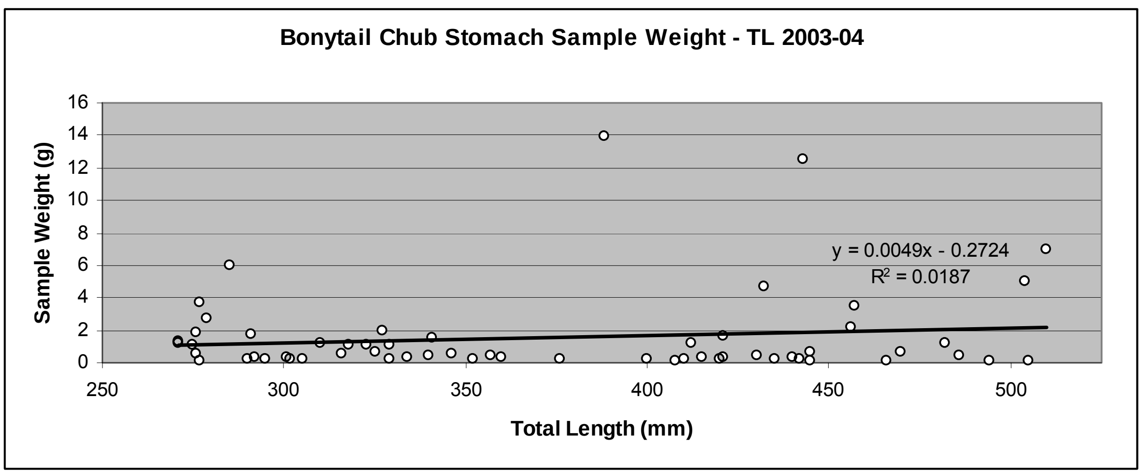

Fig. 8. Bonytail stomach contents weight to fish total length relationship, Cibola High Levee Pond, AZ-CA, 2003-2004.