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DIEL COVER USE AND LOCAL SITE FIDELITY OF A LARGE SOUTHWESTERN CYPRINID, BONYTAIL *GILA ELEGANS*, IN A LOWER COLORADO RIVER BACKWATER

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ABSTRACT.—Sonic transmitters were affixed to 10 large (40.4–51.4 cm TL) adult bonytail *Gila elegans* in 2003 from Cibola High Levee Pond, a small, isolated backwater adjacent to the lower Colorado River in Arizona and California. Point and paired directional observations showed that all marked adult bonytail occupied interstices of large riprap during daytime and used open water areas during darkness, presumably to feed. There were 2 spatial patterns of nighttime distribution by adult fish: 70% of fish exhibited mesohabitat site fidelity to a particular area of the pond, while others appeared to move about at random. Selection or design of bonytail management areas including grow-out and refuge sites should consider cover requirements for larger fish, as this may be a limiting factor if lack of cover subjects some individuals to higher predation risk.

RESUMEN.—Transmisores sonicos se fijaron a 10 charolito elegante (*Gila elegans*) adultos grandes (40.4–51.4 cm LT) en el 2003 localizados en el estanque dique superior de Cibola (Cibola High Levee Pond), un pequeño remanso adyacente a la parte baja del río Colorado en Arizona y California. Observaciones direccionales de punto y de pareja demostraron que los charolitos adultos que fueron marcados utilizan intersticios en escolleras grandes durante el día, y luego salen a áreas de aguas abiertas cuando oscurece, al parecer para alimentarse. Los pecess adultos exibiheron dos patrones espaciales de distribución nocturna: 70% de los peces mostraron fidelidad de mesohábitat a una determinada zona de la laguna, mientras que otros parecerían moverse al azar. La selección o el diseño de áreas de manejo de charolito elegante, incluyendo áreas de crecimiento y sitios de refugio, debe considerar los requerimientos de encubrimiento de los peces más grandes, ya que esto puede ser un importante factor limitante si la falta de encubrimiento somete a algunos individuos a un riesgo de depredación más alto.

Cibola High Levee Pond (HLP) is an isolated remnant of the lower Colorado River channel located between the river (low) and inland (high) levees on U.S. Fish and Wildlife Service Cibola National Wildlife Refuge in La Paz County, Arizona, and Imperial County, California. The pond and river lack surface connection but are hydrologically connected through the porous river levee. The site was reclaimed as a refuge without nonnative fishes and was first stocked with native bonytail *Gila elegans* and razorback sucker *Xyrauchen texanus* in 1993.[a] Since then the pond has served roles in both management and research (see LaBarbara and Minckley 1999, Marsh 2000, Mueller et al. 2005). In winter 2002, the site was occupied by an estimated 6189 (95% CI 4814–8663) bonytail <20 cm TL (total length) and 1653 (95% CI 1145–2972) bonytail ≥20 cm TL (Mueller unpublished data).

Sites like Cibola HLP play a central role in the management strategy for endangered Colorado River fishes (Minckley et al. 2003, USFWS 2005) because they provide habitats where native species can complete their life cycles and maintain populations without human intervention to ensure habitat quality and absence of nonnative fishes (Mueller 2006). These conditions are generally not possible elsewhere because of the presence of nonnative fishes (Minckley and Deacon 1991, Clarkson et al. 2005).

Bonytail is a critically imperiled endemic cyprinid of the Colorado River basin, where it once was widely distributed and locally abundant in main channels of larger rivers (Marsh

[a]Individuals of other, nonnative fish species (channel catfish *Ictalurus punctatus,* threadfin shad *Dorosoma petenense,* bluegill *Lepomis macrochirus,* largemouth bass *Micropterus salmoides,* and mosquitofish *Gambusia affinis* have been sporadically encountered since 1993 and removed; none was known to be present during the time of our work.

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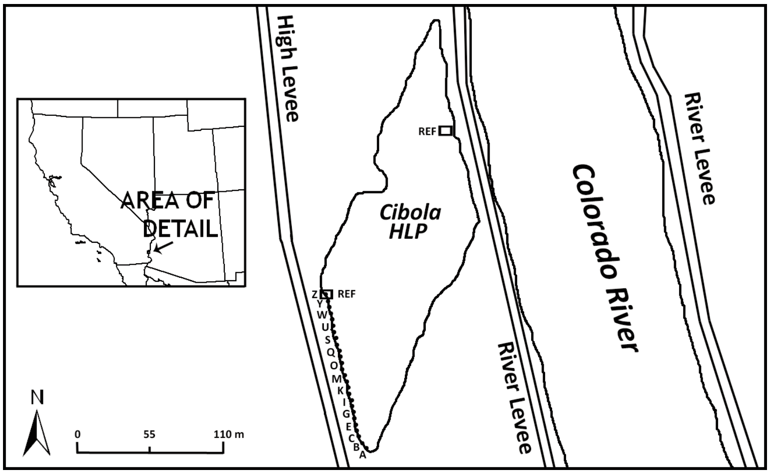


Fig. 1. Sketch map of Cibola High Levee Pond, lower Colorado River, Arizona and California. The map shows locations of the high levee and the river levee, 2 fixed listening stations (REF), high levee riprap zones A to Z, and general location map (inset).

2004). The species was little studied before its range contracted and numbers dwindled in response to habitat changes associated with construction and operation of large dams and the introduction and establishment of nonnative fishes (Minckley and Marsh 2009). It was listed as endangered in 1980 (USFWS 1980), and subsequently a recovery plan was developed, revised, and amended (USFWS 1984, 1990, 2002). Wild populations of bonytail are functionally extirpated, recruitment is nil, and the species now is sustained only by hatchery-based stocking. However, implementation of novel conservation strategies (Minckley et al. 2003, USFWS 2005) may provide opportunities for the species to persist in nature without need for artificial propagation.

The goal of this investigation was to better understand how off-channel refuge areas fulfill life history requirements of bonytail by examining temporal and spatial patterns of movement and habitat use. This information could then be applied to the design and construction or modification of grow-out and refuge sites to support bonytail conservation and recovery. The goal was accomplished using sonic telemetry to acquire location data from a sample of adult fish.

METHODS

Cibola HLP is about 2 ha in surface area and shaped like a parallelogram (Fig. 1). Maximum depth is about 3.4 m, and substrate is sand, rock, and detritus. The high levee (SW shore) is large riprap (ca. 1 m) and the river levee (NE shore) is mixed gravel and smaller riprap (<0.25 m). Both levee slopes are near 1:1. The high-levee riprap is honeycombed with large (up to 0.5-m) openings on the surface that connect to interstitial spaces of unknown shape and volume. There were 2–5 such openings at the water surface in each 5-m zone and other openings below the surface. The pond exchanges water with the Colorado River main stem through the porous river levee, and water physicochemistry mimics the adjacent river; seasonal ranges were 19.5–22.2 °C water temperature, 3.2–10.8 mg · L^{-1} dissolved oxygen, 935–1440 μS · cm^{-1} specific conductance, and 7.3–9.3 pH (Marr and Velasco 2005). Turbidity in similar lower Colorado River backwaters rarely exceeds 10 NTU (Prieto 1998), and the bottom always was visible during our visits. Water depth adjacent to the high levee varies with stage of the Colorado River, from about 0.6 to 1.5 m. Submergent vegetation is widespread and seasonally dense. Cattail (*Typha*) lines the northwestern and east central shorelines, and mesquite (*Prosopis*), willow (*Salix*), and desert shrubs are along the southeastern shore.

A sample of large adult bonytail (n = 10; mean total length [TL] 45.3 cm, range 40.4–51.4 cm; mean weight 586 g, range 400–808 g) was collected in nighttime trammel net sets in Cibola HLP on 17 March 2003. Size at maturity is about 28–36 cm, and maximum TL is ~64 cm (Minckley and Marsh 2009). Fish were held in a floating live car briefly after capture, measured (TL, nearest 0.1 cm), weighed (nearest 2 g), examined for sex (sex determination based on external morphology is unreliable for this species, but expression of gametes is definitive) and general health and condition, scanned for presence of a passive integrated transponder (PIT) tag, tagged if none was present, and fitted with a uniquely identifiable external sonic tag by using a collar attachment around the caudal peduncle (Marukawa and Kamiya 1930, Rounsefell and Kask 1945). Sonic tags were selected because preliminary investigations indicated that sonic tags were suitable, whereas radio-tags utilizing nanotechnology were unsatisfactory because signals were weak and detection radius was shorter than about 10 m for a tag suspended only 1 m below the surface (PCM unpublished data). Because of the short-term nature of our study, collars included a "weak link" designed to fail approximately 90 days after immersion and allow the tag to separate from the fish. Model IBT-96-2 tags (28 × 9.5 mm, 2.5 g in water, 60-day life) were used (Sonotronics, Inc., Tucson, AZ), and tag weights were well within the nominal 2% tag-to-fish weight proportion (Winter 1996). Fish were released near the south end of Cibola HLP and allowed to disperse undisturbed. Immediate post-release monitoring indicated that all tags were transmitting and all fish were actively swimming.

Tracking

Individuals were tracked with one or a pair of Sonotronics DH-2 directional hydrophones, an omnidirectional hydrophone (unshielded DH-2), a USR-5W ultrasonic receiver, and headphones or external speakers. Directional hydrophone bells were shrouded with 6.4 mm thick neoprene to minimize extraneous signal noise and were also fitted with a horizontally mounted compass aligned such that the bearing of an incoming signal could be approximated within ±15°.

Adult bonytail were tracked during 4 days each week from release on 19 March 2003 to 7 May 2003. On each occasion, tracking continued until all available signals were detected. Tracking ended when batteries in all tags had expired and all signals had ended. Tracking utilized 2 different protocols. First, to obtain directional data, listening stations were established at 2 fixed sites on opposing shores of the pond (Fig. 1). Simultaneous readings of tag pulse code and compass bearing were taken at 15-min intervals continuously between sunset and dawn. Second, to acquire "point data," the pond was surveyed twice daily to locate individual signals at various times of day and night, typically prior to sunset and after sunrise. On each occasion, we rowed along the entire shoreline and crisscrossed the pond between opposite corners. A directional hydrophone was used to locate and determine general direction of a signal, while the omnidirectional hydrophone pinpointed location of sedentary fish; the latter method allowed location of the individual fish to within <0.5 m, as determined from preliminary "blind" searches for randomly placed tags.

Data Analysis

It was discovered early in the study that, at times, some signals originated from within the interstices of the large riprap material used to construct the high levee that defines the southwestern margin of the pond (Fig. 1). To quantify the use of these rock spaces by individual fish, the high levee was divided into 26 adjacent 5 m wide "zones," consecutively designated with alpha characters A through Z (Fig. 1). Signal detections and exact fish locations within the riprap were determined twice daily during crepuscular periods, once at dusk and once at dawn, on 2 or 3 days during each of 6 weeks (total of 16 days) and were referenced and recorded by zone. Point data were entered into a 2-way spatial distribution table that represented the number of times each fish was observed within each zone of the high levee; a histogram for each fish was created that depicted the number of contacts within each zone; and a cumulative histogram was constructed showing the total number of contacts within each zone for all fish combined. A 2-way goodness-of-fit test using the Pearson chi-square statistic (Sokal and Rohlf 1995) was performed to detect nonrandom association of specific fish with a specific zone(s).

RESULTS AND DISCUSSION

After initial positive detection of all tags in open water on the day of release, 17 March

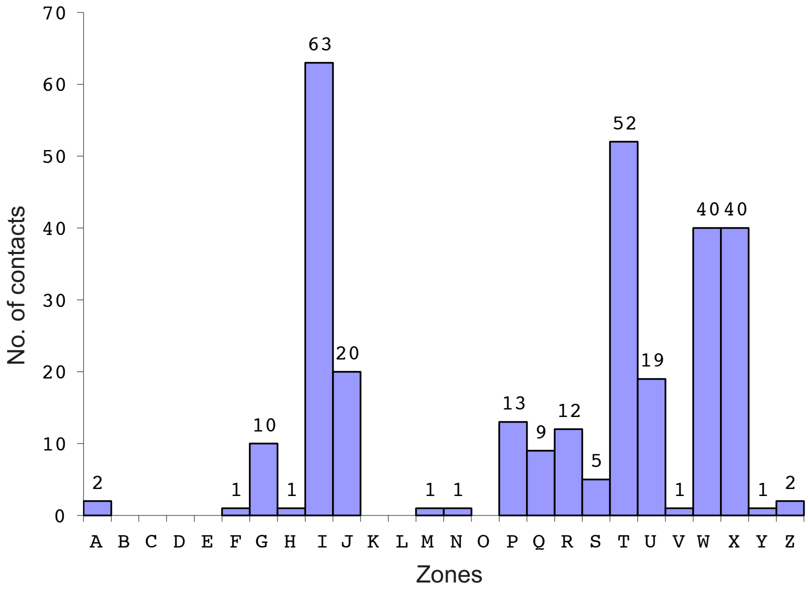


Fig. 2. Histogram of spatial use during daytime by adult bonytail of interstices (5 m wide zones A to Z) of the high levee, Cibola High Levee Pond, lower Colorado River, Arizona and California, 26 March to 7 May 2003. See text for detailed explanation and Figure 1 for locations of zones.

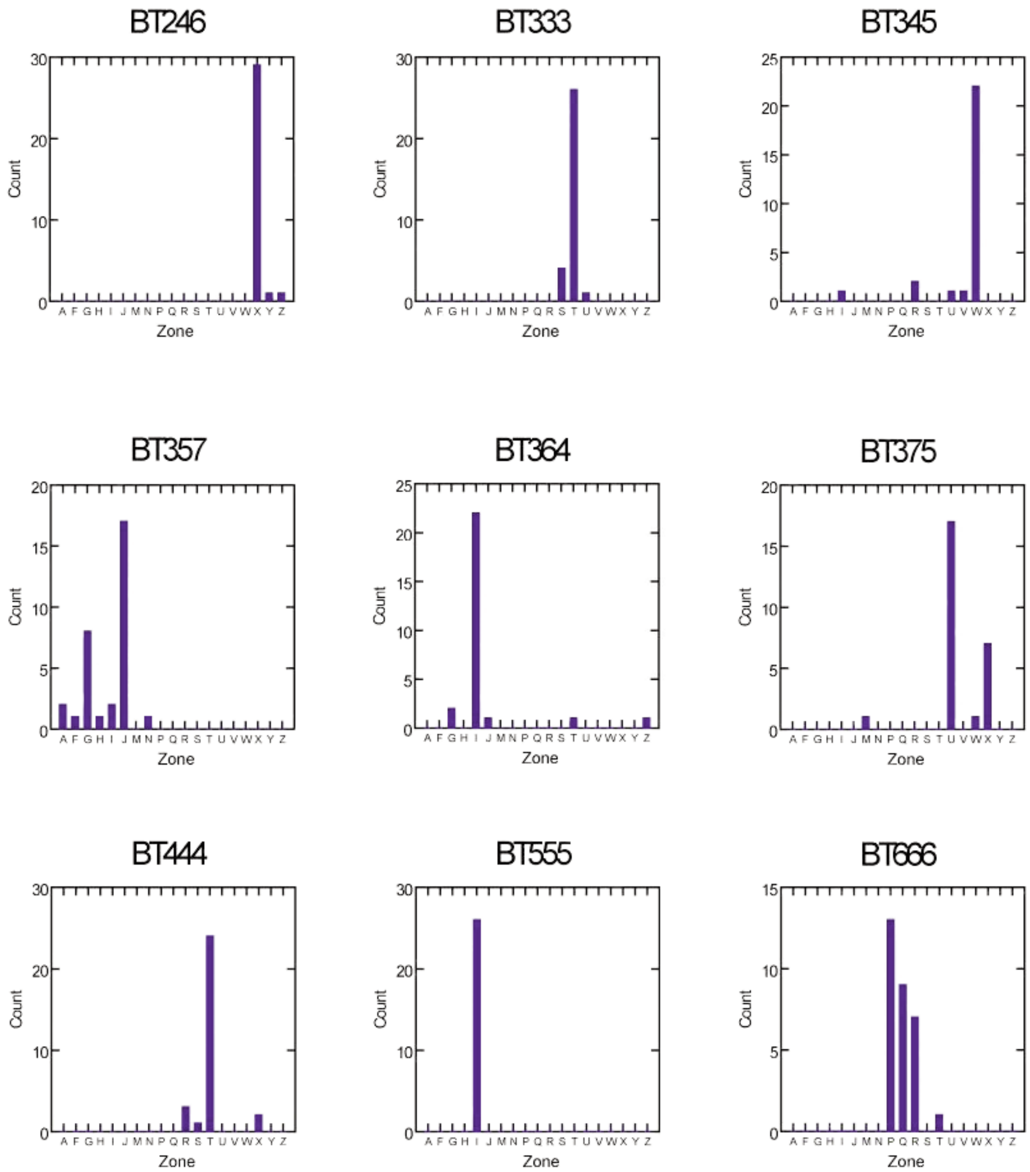
2003, we were perplexed by failure to detect any signals during daylight hours for the first week postrelease. Signal strength should have been sufficient to detect tags anywhere within the pond. This failure was because, unbeknownst to us, tagged adult bonytail were out of listening range deep within crevices of the high levee riprap. Lack of contact prompted us to switch to a point search using the omnidirectional probe. To our surprise, fish were serendipitously detected in the interstices of the riprap that comprised the high levee. This discovery was possible because the unshielded omnidirectional probe had limited range, and actual fish location could be determined by monitoring increase in strength as the probe was moved within and among the rock crevices. On several instances, fish were actually disturbed by proximity of the probe because abrupt local signal loss and detection of the tagged fish in open water indicated they had vacated the high levee. These large, adult bonytail occupied interstices of the high levee only during daylight hours and moved into open water of Cibola HLP exclusively during darkness between dusk and dawn. There was no evidence that any tagged fish utilized open water during daylight.

Point Data

Thirty-two point surveys of the high levee riprap were performed: 16 in the morning and 16 in the evening. Number of contacts (individual signal detections) per adult fish ranged from 26 to 32, signals were encountered at 19 of 26 designated zones, and total number of contacts (all fish combined) per zone ranged from 1 to 63. There was little signal overlap.

Zone usage by adult fish was not uniform. No signals were ever detected within 7 zones (B, C, D, E, K, L, and O), and there were only 1 or 2 total contacts totaled in each of 8 other zones (A, F, H, M, N, V, Y, and Z; Fig. 2). Five zones had moderate use (5–15 contacts each; zones G, P, Q, R, and S), and 6 zones had high use (19–63 contacts; zones I, J, T, U, W, and X). The 6 highest-use zones occurred in 3 nearest-neighbor pairs separated by one or more low-use zones.

Local site fidelity (i.e., within a particular zone) was high and significant ($\chi^2 = 697.93$, df $= 25$, $P < 0.001$) for adult bonytail. Once a fish established "residency," it generally returned each morning to the same zone, often to the same exact location, within the high levee (Fig. 3). This level of accuracy was possible because individual crevices or openings



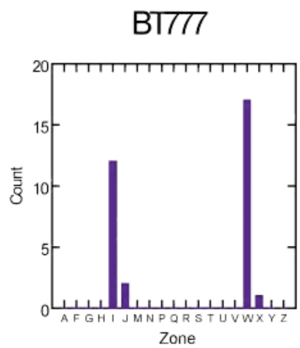


Fig. 3. Total number of daytime contacts for each of 10 adult bonytail within each of twenty-six 5 m wide zones A to Z of the high levee at Cibola High Levee Pond, lower Colorado River, Arizona and California. The 26 riprap zones were searched twice daily, once at dusk and once at dawn, 2 or 3 days each week (16 total days, 32 total searches) between 26 March and 7 May 2003. See Figure 1 for locations of zones.

within zones were recognizable to us, and the probe allowed signal localization to 0.5 m or less. A few fish switched from consistent use of one area for a time to consistent use of another area (e.g., Fig. 3, BT666 and BT777), but there were no instances in which an individual fish was found in one zone at dawn and another zone at dusk within a single day. Two or more tagged fish only twice occupied the same zone at the same time, although different fish may have occupied the same zone on different occasions. Unmarked individuals may have occupied "empty" zones or crevices or the same ones as the 10 marked fish. Microhabitat 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 of them, occupied interstices within the high levee.

The importance of cover for fishes is widely recognized (e.g., Allouche 2002) and members of the genus *Gila* are known for their daytime use of structure and shade (Minckley 1973). Valdez et al. (2001) suggested that humpback chub *G. cypha* in the Colorado River within Grand Canyon utilized cover from turbidity, and reported a paucity of daytime contacts with telemetered fish (see also Bio/West, Inc. 1994). The latter result may have reflected use of boulder interstices similar to that observed in the Cibola HLP.

Directional Data

There were 2947 separate recorded bearings for adult bonytail in Cibola HPL; 1648 and 1299 observations were made from the high levee and river levee listening stations, respectively. Totals were 161 (16.1 contacts per 15-min period) during dusk (19:45–10:00), 269 (11.2 contacts per period) during midnight hours (22:15–03:15), and 78 (7.8 contacts per period) during dawn hours (03:30–05:45). These results were internally consistent with the pattern of signal detections observed in the field across all contacts—8 or 9 fish usually made an appearance shortly after sunset during the dusk period (one fish was never contacted in open water at night, but its signal was detected at multiple locations within the high levee during daytime). Numbers typically were reduced by 1–3 or 4 fish during the midnight hours, and signals representing all remaining individuals disappeared as fish returned to the high levee not later than sunrise.

Directional data applied exclusively to adult fish activity during periods of darkness, because marked individuals spent daylight hours under cover provided by interstices of the high levee. Interpretation of geographic pattern was based on only the general position of signals (i.e., compass direction) relative to the listening stations (Fig. 1). Some directional error and false readings resulted from combined effects of signal reflection from bank crenulations and large riprap plus the acoustical dampening nature of aquatic vegetation. Despite these inaccuracies, consistent general trends were documented for most fish.

Five adult fish tended to be located in the southeastern portion of the pond. This area was characterized by patches of submerged aquatic vegetation in moderately deep water (1–2 m); a relatively abrupt, open sandy shoreline; and woody, overhanging riparian vegetation (Mueller 2006). Two fish tended to be located in the northwestern portion of the pond, which was an area with little submerged vegetation, relatively shallow water (<1 m), a gently sloping shoreline with dense cattail, and overhanging woody riparian vegetation (Mueller 2006). These distributions may have reflected use of each area for feeding, cover (in situ vegetation or shade from the riparian canopy), or other function. Contacts with 2 fish showed little geographic pattern, and one fish moved among zones within the high levee but was never contacted in open water.

Conservation Implications

Telemetry studies at Cibola HLP indicate that some adult bonytail are active in open water only during nighttime and spend daylight hours dormant and hidden under cover amongst large riprap boulders. This observation is consistent with stomach contents and proportion of empty guts, which indicated that the most intense feeding occurred at night (Marsh et al. in press). Adult bonytail in Lake Mohave, a mainstem lower 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 is well known, and use of physical structure or even turbidity as daytime cover has been reported for several members of the genus *Gila* (Minckley 1973, Bio/West, Inc. 1994, Minckley and Marsh 2009). This behavior may allow fish to avoid sight-feeding predators, as well as support life functions such as feeding and reproduction. All Colorado River *Gila,* including bonytail, are broadcast spawners (Minckley and Marsh 2009), so use of crevices for reproduction is unlikely.

Daytime occupation of cover by large bonytail and apparent relegation of smaller fish to open water (Mueller 2006) may have important implications for bonytail management because availability of suitable cover may in part determine habitat carrying capacity. If all available cover is occupied, then fish that are denied access to suitable cover may be subject to increased exposure to predators or other mortality factors (Eklöv and Persson 1995, Stuart-Smith et al. 2008). Cover thus becomes a limiting factor at the population level. Cibola HLP in winter 2002 was occupied by an estimated 1653 bonytail ≥20 cm long (Mueller unpublished data). At the time of our studies, space would likely have been inadequate for all these fish within the interstices of the riprap that comprised the high levee. An unknown number of individuals would have been in open water or associated with other cover such as submergent or emergent aquatic vegetation, or shade from overhanging riparian trees and shrubs. It might be possible to experimentally investigate the significance of this phenomenon to 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 (but see USBR 2005 for a template of such replicates).

Bonytail recovery plans include the re-establishment of self-sustaining populations in natural waters among the criteria for recovery (USFWS 1984, 1990, 2002, 2005). However, achieving such goals seems unlikely, at least in the lower Colorado River basin, where nonnative predatory fishes are ubiquitous and more than 3 decades of bonytail stocking has failed to establish a single population (USFWS unpublished data). Instead, recovery in the lower Colorado River is likely only in off-channel places like Cibola HLP and other habitats where nonnative fishes are not "problematic." Provision of adequate cover should be considered in the selection or design of bonytail management areas used for grow-out, refuge, or long-term population maintenance (Minckley et al. 2003, USFWS 2005).

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