Lower Colorado River
Multi-Species Conservation Program

Balancing Resource Use and Conservation

Distribution and Post-stocking Survival of Bonytail in Lake Havasu — 2011 Annual Report

April 2012

Lower Colorado River Multi-Species Conservation Program
Steering Committee Members

Federal Participant Group

Bureau of Reclamation
U.S. Fish and Wildlife Service
National Park Service
Bureau of Land Management
Bureau of Indian Affairs
Western Area Power Administration

Arizona Participant Group

Arizona Department of Water Resources
Arizona Electric Power Cooperative, Inc.
Arizona Game and Fish Department
Arizona Power Authority
Central Arizona Water Conservation District
Cibola Valley Irrigation and Drainage District
City of Bullhead City
City of Lake Havasu City
City of Mesa
City of Somerton
City of Yuma
Electrical District No. 3, Pinal County, Arizona
Golden Shores Water Conservation District
Mohave County Water Authority
Mohave Valley Irrigation and Drainage District
Mohave Water Conservation District
North Gila Valley Irrigation and Drainage District
Town of Fredonia
Town of Thatcher
Town of Wickenburg
Salt River Project Agricultural Improvement and Power District
Unit “B” Irrigation and Drainage District
Wellton-Mohawk Irrigation and Drainage District
Yuma County Water Users’ Association
Yuma Irrigation District
Yuma Mesa Irrigation and Drainage District

Other Interested Parties Participant Group

QuadState County Government Coalition
Desert Wildlife Unlimited

California Participant Group

California Department of Fish and Game
City of Needles
Coachella Valley Water District
Colorado River Board of California
Bard Water District
Imperial Irrigation District
Los Angeles Department of Water and Power
Palo Verde Irrigation District
San Diego County Water Authority
Southern California Edison Company
Southern California Public Power Authority
The Metropolitan Water District of Southern California

Nevada Participant Group

Colorado River Commission of Nevada
Nevada Department of Wildlife
Southern Nevada Water Authority
Colorado River Commission Power Users
Basic Water Company

Native American Participant Group

Hualapai Tribe
Colorado River Indian Tribes
Chemehuevi Indian Tribe

Conservation Participant Group

Ducks Unlimited
Lower Colorado River RC&D Area, Inc.
The Nature Conservancy

Lower Colorado River Multi-Species Conservation Program

Distribution and Post-stocking Survival of Bonytail in Lake Havasu — 2011 Annual Report

Prepared by: Abraham P. Karam, Christine M. Adelsberger, and Paul C. Marsh, Marsh & Associates LLC

Lower Colorado River
Multi-Species Conservation Program
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada
http://www.lcrmscp.gov

April 2012

Table of Contents

Summary

Perseverance of bonytail *Gila elegans* in the Colorado River basin relies entirely on stocking programs and Lake Havasu is one of few locations where individuals are occasionally captured. Most information regarding the basic ecology of this critically endangered species is limited to past field observation acquired from the now extirpated wild population and to studies conducted on isolated stocks reared in hatchery or backwater ponds. Results from an earlier telemetry study in Lake Havasu were inconclusive due to possible transmitter loss, premature mortality, and loss of contact with tagged fish, which prevented conclusions from being drawn about the habitat and biology of adult bonytail in that system. As a result, little information exists that could better inform managers of the post-stocking survival and habitat use of hatchery-reared bonytail.

We completed the second of a three-year comprehensive study using acoustic telemetry to describe and characterize inhabitance and dispersal of hatchery-reared bonytail by monitoring their movement and survival after release into Lake Havasu. Results from our initial April 2010 investigation established up to 95% of bonytail implanted with three-month acoustic transmitters and stocked at Bill Williams River National Wildlife Refuge (BWRNWR) were still being actively tracked at the conclusion of that study. Those fish predominantly utilized the low water clarity habitat found in and near BWRNWR. We also performed a transmitter retention study at Dexter National Fish Hatchery & Technology Center (DNFH&TC) that demonstrated bonytail implanted with three and six-month acoustic transmitters remained healthy and active.

Based on results from these first two investigations, 20 bonytail were implanted with six-month acoustic transmitters during December 2010 and released with 2,060 fish at BWRNWR to further document survival and habitat use. Two bonytail captured in BWRNWR during February 2011 netting efforts (see below) also were implanted with previously recovered acoustic tags, then re-released at their site of capture. Bonytail were tracked actively by boat and passively

with a fixed array of submersible ultrasonic receivers through May 2011. Half of bonytail released in December 2010 were active at the end of three months, which was considerably fewer than the number of active fish remaining at the end of the April 2010 study. However, by the end of six months, up to 40% of the bonytail stocked in December 2010 and both fish released in February 2011 still remained active. All immobile tags were recovered using SCUBA within 5 km of the stocking site. No fish remains were located near the sites of recovery. Dispersal and habitat use largely resembled patterns displayed by tagged bonytail stocked during April 2010. Over the course of the study, 20 of 22 tagged bonytail (91%) dispersed between 2.6 km upriver into the Bill Williams River and 4.5 km uplake (toward Lake Havasu City) and two individuals dispersed up to 24 km uplake of the stocking site. Bonytail spent significantly more time in BWRNWR than elsewhere in Lake Havasu, where a majority (97%) of all contacts were made over the course of the study.

During February 2011, Marsh & Associates (M&A) participated in the multi-agency Native Fish Roundup on Lake Havasu. Nine fixed reaches of the reservoir were sampled using trammel nets and electrofishing, of which M&A assisted on three different reaches (trammel netting only). The collective group netting efforts of all participants involved resulted in the capture of 68 bonytail (67 of which were captured within BWRNWR). Two individuals were recaptures from the April and December 2010 telemetry studies.

Inhabitance data from the April and December 2010 telemetry studies and capture data from 2011 Lake Havasu Native Fish Roundup indicated bonytail showed strong preference for habitats found in BWRNWR. To test whether dispersal and survival were related to stocking location or habitat availability, a dual stocking was implemented simultaneously at BWRNWR and Cattail Cove State Park. During November 2011, 15 acoustic-tagged bonytail (ten implanted with six-month battery life transmitters, and five with 45-day battery life depth-sensing transmitters) were released with about 2,000 PIT-tagged bonytail at each location. Remote PIT-scanning antennas deployed throughout BWRNWR for a two-day period after stocking contacted 51 unique PIT-tagged bonytail, 50 of which contained a stocking history in the Lower Colorado River Native Fishes Database. Acoustic tagged fish were tracked weekly and associated habitat parameters (including turbidity) were measured through the end of December 2011. Preliminary active-tracking data indicate depth-tagged bonytail were contacted on average at 80% of the depth of the reservoir water column, though mean fish depth was greater during both crepuscular and nighttime hours than during the day. Fish location relative to the shoreline followed a similar trend; bonytail were contacted further from shore during crepuscular and nighttime hours than during the day. Turbidity readings for depth-tagged fish stocked at Cattail Cove were approximately one-third of those associated with fish stocked in BWRNWR. Continuous inhabitance of bonytail stocked at BWRNWR indicated those fish nearly exclusively utilized habitat found within the refuge. Continuous inhabitance of bonytail stocked at Cattail Cove was higher in Lake Havasu than BWRNWR, however, 20% of those individuals utilized habitats found in BWRNWR longer than those found Lake Havasu. Following the expiration of the acoustic depth tags in January 2012, a bi-monthly sampling routine was implemented to track the remaining fish. Data acquisition is planned through June 2012, and results and analysis will be presented in the 2012 Annual Report.

Introduction

Lake Havasu is a mainstem lower Colorado River reservoir, which extends for 132 km along the Arizona-California and Arizona-Nevada borders (Figure 1). It is designated as Reach 3 of the Lower Colorado River Multi-Species Conservation Program (MSCP) and serves as a diversion basin for providing water to the Metropolitan Water District of Southern California (MWD) via the Colorado River Aqueduct and the Central Arizona Project (CAP) via the CAP Canal. The lake portion of the reservoir is relatively shallow (mean depth ~11 m) and encompasses approximately 45 river kilometers between its downriver terminus at Parker Dam and the northern limits of Lake Havasu City. Upstream from this point, the river portion of the reservoir continues for another 87 km, through Topock Gorge to its boundary at Davis Dam (Figure 1).

Prior to settlement by the Europeans, the mainstem lower Colorado River was occupied by nine native fish species, four of which were endemic (Miller 1961). Decades of non-native fish introductions drastically changed the river's biological community (Moffett 1942; Dill 1944; Minckley 1979; Minckley and Deacon 1991; Mueller and Marsh 2002) and physical alterations transformed its seasonally fluctuating hydrograph into a series of regulated reservoirs and controlled channels that promoted the development of farms and metropolitan areas throughout the southwest (Reisner 1986; Marsh and Mueller 2002). Today, Lake Havasu is comprised primarily of introduced non-native fishes, which support a popular recreational and sport fishery. Three species of Colorado River endemic fishes— bonytail *Gila elegans*, flannelmouth sucker *Catostomus latipinnis*, and razorback sucker *Xyrauchen texanus*—persist in Lake Havasu; of which, bonytail and razorback sucker are federally listed and critically endangered (Marsh 1996, 2004). The last wild bonytail captured downstream of Davis Dam occurred during the early 1970's (Mueller and Marsh 2002) and the species is functionally extirpated from its former range.

The perseverance of bonytail in the Colorado River basin relies entirely on stocking programs (MSCP 2006; Minckley and Thorson 2007) and Lake Havasu is one of few locations where bonytail are occasionally contacted. Approximately 198,000 bonytail have been stocked into the reservoir since augmentations began in 1981, of which, 252 individuals (0.1%) have been recaptured as a result of routine monitoring (C. Pacey, Marsh & Associates, LLC, personal communication). Capture events are an indirect result of the Lake Havasu Fishery Improvement Project (FIP), which was initiated in 1993, in part, to re-establish bonytail and razorback sucker populations in that reservoir (Doelker 1994). The FIP stocking goal (30,000 bonytail greater than 25 cm TL) was reached in 2003 (Minckley and Thorson 2007), though annual monitoring continues under the FIP as the MSCP has transitioned into directing Reach 3 stockings (4,000 bonytail per year greater than 30 cm TL) for the next 50 years (MSCP 2006).

Monitoring typically occurs in February by personnel from US Fish and Wildlife Service (USFWS), US Geological Survey (USGS), US Bureau of Reclamation (Reclamation), Bureau of Land

Management (BLM), California Department of Fish and Game (CADFG), Arizona Game and Fish Department (AZGFD), Nevada Department of Wildlife (NVDOW), and public volunteers (see USFWS 2011). Surveys involve trammel netting the reservoir between the Bill Williams River and Park Moabi near Needles, California and extensive boat electroshocking between Needles and Laughlin, Nevada (Figure 1). Bonytail captures made during past monitoring efforts have been infrequent (19 recaptures between 1994 and 2007; Minckley and Thorson 2007), though bonytail are additionally contacted by recreational anglers who occasionally catch them (M. Thorson, USFWS, personal communication). Previous work in lower Colorado River backwaters (Schooley et al. 2008) and in Lake Havasu (Doelker 1994; Mueller 2003) cited predation of bonytail by birds and non-native fishes among factors limiting their post-stocking survival. Because stocked fish do not survive (Karam and Marsh 2010), there is no reproduction or recruitment (Pacey and Marsh 1998). Thus, under current conditions, conservation and recovery potential are low for this species.

Aside from these infrequent recaptures, little information is available concerning the basic ecology of bonytail in Lake Havasu. Telemetry studies conducted elsewhere in the lower basin examined habitat use of bonytail in relation to diel period and suggested fish utilize cover in deep portions of Lake Mohave (Marsh 1997) and rip-rap shoreline along the banks of Cibola High Levee Pond (Mueller et al. 2003) during daylight, then move into open water at night. One previous bonytail telemetry study has occurred in Lake Havasu (Minckley 2006) and its results indicated a majority of fish contacts were along shorelines or in coves. Unfortunately, possible transmitter loss, premature mortality, and loss of contact with tagged fish prevented conclusions from being drawn about the habitat and biology of adult bonytail in that system.

In response to needs identified by the MSCP, we implemented the second year of a multi-year research project that continues to document in detail the post-stocking distribution, habitat use, and survival of bonytail in Lake Havasu. Results from our initial April 2010 telemetry investigation demonstrated how we successfully increased the number of post-stocking bonytail contacts using acoustic telemetry. By the end of that study, up to 95% of bonytail implanted with three-month acoustic transmitters and stocked at Bill Williams River National Wildlife Refuge (BWRNWR) were still being actively tracked, and fish predominantly utilized the low water clarity habitat found in and near BWRNWR. In a separate transmitter retention study performed at Dexter National Fish Hatchery & Technology Center (DNFH&TC), we demonstrated that bonytail implanted with three and six-month acoustic transmitters remained healthy and active (Karam et al. 2010). Based on this information, our objectives for 2011 were to use longer-term (6-month) acoustic telemetry to further describe patterns of survival and inhabitance by bonytail stocked in BWRNWR and elsewhere in Lake Havasu. Because occupancy is a course descriptor of inhabitance by stocked fish, inferences regarding habitat use can be made based on where fish are contacted over time. BWRNWR exhibits physical and biological characteristics that differ from those found elsewhere in Lake Havasu (see below), thus post-stocking patterns of inhabitance can be described using an array of passive and active acoustic telemetry receivers. The goal of this research is to guide future bonytail stocking endeavors in the reservoir and ultimately aid in the long-term survival of this critically endangered species.

Methods

Study Area

Lake Havasu is impounded by Parker Dam, constructed by Reclamation and closed in 1938. The dam creates a 7.98 x 10^8 m^3 storage capacity reservoir and generates hydroelectric power for MWD, and for utilities in Arizona, California, and Nevada. The Bill Williams River National Wildlife Refuge occupies the southeast terminus of Lake Havasu and is characterized by the Bill Williams River and its delta (Figures 1 and 2). Discharge in the Bill Williams River is primarily controlled by operation of Alamo Dam, which lies approximately 62 km upstream of the delta. At base flows (<2.8 m^3/s), the fraction of water released that passes downstream reaches (near the upstream-most watercraft accessible reach of our study area) is variable. At higher annual discharges, flows decrease by approximately 10% between the dam and delta (Wiele et al. 2009). Turbidity in watercraft accessible portions of the refuge is strongly influenced by discharge from the Bill Williams River, and increases with increased flow from the river (Dill 1944; Wiele et al. 2009). Cattail *Typha* spp. and sedges Cyperaceae dominate nearly all available shoreline habitat in BWRNWR, though riprap lines the narrow peninsula that separates the southern portion of the refuge from the CAP intake canal (Figure 2). Thick beds of aquatic plants *Potamogeton* sp. and *Najas* sp. flourish in spring and summer months, and are seasonally harvested to prevent blockage of the CAP Canal intake at Mark Wilmer Pumping Station (M. Thorson, USFWS, personal communication). Uplake of the refuge (toward Lake Havasu City), water clarity and depth increase (Wiele 2009) and the rocky shoreline becomes sparsely lined with salt cedar *Tamarix* sp., mesquite *Prosopis* sp., and littoral vegetation in coves often is predominated by *Typha* sp. Since 2007, as part of the FIP, more than 1,754 brush bundles and artificial fishing structures have been deployed to attract non-native sport fishes such as largemouth bass *Micropterus salmoides*, smallmouth bass *Micropterus dolomieu*, channel catfish *Ictalurus punctatus*, and flathead catfish *Pylodictis olivaris* (Anderson 2001; D. Adams, BLM, personal communication).

Outreach

Efforts were made to educate local anglers through literature. Prior to stocking events, posters were distributed to boat ramps, state parks, marinas, and bait shops along Lake Havasu. These posters explained the stocking events, gave a brief description of bonytail (with a picture), and explained the goals of the project. Anglers were asked to report any incidental catches of bonytail. Additionally, 3-fold pamphlets were printed and hand distributed to anglers encountered during the study.

December 2010 Telemetry

SUR Deployment

Between 29 November and 3 December 2010, 27 submersible ultrasonic receivers (SURs) were deployed throughout the project study area: 25 in Lake Havasu between Blankenship Bend (Figure 1) and the upstream-most watercraft-accessible portions of the Bill Williams River, one downriver of Parker Dam, and one in the Central Arizona Project (CAP) canal approximately 15 km downstream of the Mark Wilmer Pumping Station (Figure 2). Receivers were programmed to continuously scan select frequencies during 60 s intervals and recorded the transmitter identification number and interval, date, time, tag type, and tag pressure (see November 2011 study below) when fish were within the receiver range (>400 m). Receiver locations were chosen based on: (1) coverage of the immediate stocking area, (2) shore-to-shore linear "gate" coverage of the river and reservoir channel at strategic locations (*N* = 11), and (3) security from theft and vandalism. Of the 25 SURs deployed in Lake Havasu, 10 were tethered to weights and sunk to the bottom of the reservoir near mid-channel to increase radial detection coverage. A length of rope attached to each weight remained ~3 m beneath the surface of the lake due to a buoyant subsurface float affixed to its opposite end, which allowed relatively easy retrieval of the receiver for downloading and maintenance.

Surgeries and Stocking

On 3 December 2010, 40 of the largest available bonytail were collected from USFWS Achii Hanyo Native Fish Facility (AHNFF), Parker, Arizona. Fish were transferred to a dual-chamber (1893-L) holding tank filled with hatchery water and supplied with oxygen via a split-valve regulator and air stones. Bonytail were transported by truck to the boat ramp at the BWRNWR (Fig. 2) where a surgical station had been erected. Two additional aerated tanks (946-L) were filled with lake water and placed in the bed of a separate pickup truck near the surgical station.

Twenty of the largest bonytail (Table 1) were implanted with individually coded acoustic transmitters (Sonotronics, Inc.; IBT-96-6; 42 x 11 mm; 7.8 g; expected battery life = 6 months), which were chosen based on the results from the July 2010 tag retention study (Karam et al. 2010). Prior to surgery, each acoustic tag was activated with an external magnet and tested for functionality using a hydrophone and receiver.

Surgical methods followed those outlined in Marsh (1997) and Karam et al. (2008). Each fish was placed in a solution of tricaine methanesulphonate (MS-222; 125 mg/l) until equilibrium was lost. Individuals were measured (total length [TL], nearest mm), weighed (M, nearest g), then placed in a surgery trough. A short incision (~2 cm) was made anterior to the pelvic fin on the left side of each fish. An acoustic transmitter and Passive Integrated Transponder (PIT) tag sanitized in 70% ethanol were inserted into the abdominal cavity. The incision was sutured with three knots using CP Medical 4/0 Polypro®blue monofilament polypropylene non-absorbable sutures and a NRB-1 tapered cutting needle. MS-222 water was continually passed over each fish's gills to maintain anesthesia for the duration of the surgery. Following surgery, the wound was swabbed with Betadine® and each fish was injected with Baytril® (Enrofloxacin; 23 mg/ml solution) as a preventative measure for post-surgery infection (Martinsen and Horsberg 1995). Individual injections ranged from 0.1-0.3 ml and were based on a categorical chart that identified appropriate dosage based on the M of each fish (Kesner et al. 2010; Table 2). Tagged fish were placed in a recovery tank and monitored until they were upright and swimming independently. All experimental fish were released into Lake Havasu at the BWRNWR boat ramp along with 2,060 additional bonytail. Active and passive tracking began immediately following stocking and continued through May 2011 (Figure 2).

On 11 February, USFWS personnel placed three bonytail captured during the 2011 Lake Havasu Native Fish Roundup (see below) in a net pen at the BWRNWR boat ramp. Two of these fish were implanted with acoustic transmitters (numbers 230 and 274; Table 1) that were previously recovered during the prior month using SCUBA (see Results). Surgical procedures followed those previously described, and all three bonytail were released near their site of capture, approximately 100 m upriver of the US-95 Bridge in BWRNWR.

Tracking Techniques and Database Management

Tracking events took place bi-weekly, beginning near the BWRNWR boat ramp and proceeded upriver in the Bill Williams River to the furthest watercraft accessible location (approximately

2.5 km east of the US 95 bridge; Figure 2). Tracking resumed downriver of the bridge, covering the entire watercraft-accessible portion of the Bill Williams River delta, then proceeded uplake towards Lake Havasu City, following a 1-km grid of locations (*N* = 110) similar to that described in Karam et al. 2008 (see also Mueller et al. 2000) in order to ensure equal coverage of the entire study area. Signals were detected using a handheld directional hydrophone (DH-4; Sonotronics, Inc.) and ultrasonic receiver (USR-08; Sonotronics, Inc.). Individual fish positions were triangulated to their exact location where the date, time, water temperature, reservoir depth, Secchi depth, and distance-to-shore (DTS) were recorded. Distance-to-shore was measured using a Bushnell® Yardage Pro Sport 450 Laser Rangefinder or determined later using individual fish location data plotted into a GIS database (ESRI® ArcMap; v 9.1). When re-contacts were made in the same location, a SCUBA diver was deployed with an underwater diver receiver (UDR; Sonotronics, Inc.) to investigate and, if possible, recover the transmitter. Shore-accessible stationary receivers were downloaded during active tracking surveys and diver-retrievable SURs were downloaded during transmitter-recovery events. Uplake manual tracking events ended at the uplake-most shore-accessible SUR gate where no fish was detected. Periodic surveys of the entire study area covered by SURs took place to ensure no fish had dispersed undetected.

A Microsoft Access® database was created for all active and passive fish contacts. Stationary receiver contacts for individual fish were considered unique only if the same fish was re-contacted by the same individual SUR or SUR gate after a two-hour period. Points of contact made after the original detection at the site of confirmed mortality were excluded from further analysis. Locations of fish recorded by SURs were categorized as daytime (one hour after sunrise to one hour before sunset), nighttime (one hour after sunset to one hour before sunrise), and crepuscular (one hour before sunset or sunrise to one our after sunset or sunrise) contacts. The influence of diel period on the number of contacts per hour was analyzed using a general linear model (Cody and Smith 2006). A Tukey HSD test was conducted post-hoc for pair-wise comparisons of means that were significantly different. A level of $\alpha \leq 0.05$ was considered significant for this and all statistical tests.

Patterns of inhabitance in BWRNWR and Lake Havasu were analyzed using a GIS database. Proportions of all contacts made within specific reservoir reaches "gated" by SURs were determined for the entire study period. Continuous inhabitance (modified from Wingate et al. 2011) was calculated to compare occupancy by bonytail and is defined as entrance (or stocking) into BWRNWR or entrance into Lake Havasu (any area outside the boundary of BWRNWR) followed by passive or active detections that occurred on separate dates within the same zone of detection. Any subsequent detection(s) that occurred in a new contact zone on a single calendar date only were removed from the inhabitance analysis. For example, entrance into the BWRNWR was defined as the first detection by any receiver and exit was defined as the last detection in BWRNWR at least one calendar day later. Continuous inhabitance was calculated as the interval between dates of entrance and exit (Wingate et al. 2011). Multiple periods of continuous inhabitance occurred for individual fish over the 6-month study, and these were summed to estimate the total time spent within BWRNWR and Lake Havasu ("summed inhabitance") for the entire study. A Mann-Whitney test was used to examine differences in continuous inhabitance spent between BWRNWR and Lake Havasu.

2011 Lake Havasu Native Fish Roundup

Marsh & Associates (M&A) participated in the multi-agency Native Fish Roundup on Lake Havasu during February 2011. Nine fixed reaches of the reservoir were sampled using trammel nets and electrofishing, of which M&A assisted on three different reaches (trammel netting only). For our effort in each reach, four to six trammel nets (45.7 m x 1.8 m, 3.8-cm stretch mesh, 30.5 cm bar outer wall) were deployed in overnight sets along the shore of Lake Havasu. Nets were set in the late afternoon, checked and retrieved the following morning, and then re-deployed in a new location later that afternoon for four consecutive nights. All fish were removed and processed (enumerated, measured to total length [mm], weighed [M], sexed, scanned for a wire or 134 kHz PIT tag if native, and tagged if none was present) daily. For detailed description of the entire groups methods, see USFWS 2011.

November 2011 Telemetry

Based on bonytail movements during the December 2010, the largest dispersal distance (sum of furthest uplake and upriver movements) for each fish was averaged for all acoustic tagged bonytail to create a post-release “home-range” for fish stocked at the BWRNWR boat ramp. The uplake boundary of the defined home-range was used as a guide to determine a second stocking location which relative to conditions found in BWRNWR (high turbidity, < 5 m depth, cattail-lined shore, uniform littoral zone), were representative of the aquatic habitat found elsewhere in Lake Havasu (low turbidity, > 5 m depth, rocky shoreline, defined littoral zone).

SUR Deployment

From 18-21 November 2011, 28 SURs were deployed throughout the project study area: 27 in Lake Havasu between Blankenship Bend and the upstream-most motorized watercraft-accessible portions of the Bill Williams River and one downriver of Parker Dam. On 21 December 2011, an additional SUR was deployed at the upstream-most watercraft accessible location in Bill Williams River. Of the 29 SURs deployed in Lake Havasu, 11 were tethered to weights and sunk to the bottom of the reservoir near mid-channel. Some receivers were arranged in a linear gate configuration at strategic locations (*N* = 11) throughout the study area to provide shore-to-shore coverage (Figure 3).

Remote PIT scanning

Remote PIT scanning systems, developed in-house at M&A, were successfully used to monitor razorback sucker populations in Lake Mohave (see Kesner et al. 2011). In order to assess their effectiveness at detecting the presence of PIT-tagged bonytail, those systems were deployed between 29 November and 1 December 2011 along the shoreline of BWRNWR. Two models of PIT scanners were utilized. One type of unit (shore based) is comprised of an antenna and scanner housed in a 2.3 x 0.7 m PVC frame connected by 45.7 m of cable to a waterproof box that protects the logger and battery (55 amp-hours) and is secured to shore. The battery provided power to the scanner to run continuously for 72 hours, eliminating the need for manually removing and charging the batteries. The other units (submersible) are comprised of a 0.8 x 0.8 m PVC frame antenna attached to a scanner, logger and 3.2 amp-hour battery contained in watertight PVC and ABS piping. The units are submersible and scan continuously for up to 24 hours.

From 29 November to 1 December 2011, six submersible units were tethered to the riprap shore near the stocking site at BWRNWR and deployed (~1 m deep). The two shore-based antennas were deployed elsewhere in BWRNWR; one at approximately mid-channel (2.4 m deep) under the US 95 Bridge, the other under the floating dock at the BWRNWR boat ramp (2 m deep). Remote PIT scanning information was recorded on waterproof paper as follows: general location or site name, UTM coordinates, water depth (m), time and date of deployment and retrieval, logger number, logger start and stop times, and the scanning interval. Scanning data were downloaded and imported into a Microsoft Access® database at the conclusion of the trip and all information recorded on datasheets was entered into the database and associated with the scanning data for the given effort.

Surgeries and Stocking

On 28 November 2011, the depth function of a sub-set of acoustic depth transmitters was tested for accuracy in Lake Havasu at Havasu Springs Marina. The following day, USFWS staff from DNFH&TC transported 3,907 bonytail to BWRNWR. All fish had each previously received a 134 kHz PIT tag. Prior to stocking, a surgical station was erected near the BWRNWR boat ramp and each acoustic transmitter was activated with an external magnet and tested for functionality using a hydrophone and receiver. A dual-chamber (1893-L) holding tank positioned in the bed of a pickup truck was filled with water from the hatchery truck. Each tank was supplied with oxygen via a split-valve regulator and air stones. Fifty of the largest bonytail were removed from the hatchery truck using hand nets and transferred into the dual-chamber holding tank (25 fish per side). Two aerated recovery tanks (946-L) were filled with lake water and placed in the bed of a separate pickup truck next to the surgical station.

Bonytail were released by USFWS staff at two separate locations in Lake Havasu: 2,111 fish were stocked at BWRNWR boat ramp and 1,796 fish were stocked at Cattail Cove boat ramp[1]. While the batch stockings were in progress, 30 bonytail[2] were each implanted with an acoustic transmitter; 20 individuals received a six-month battery life acoustic transmitter (Sonotronics, Inc.; IBT-96-6; 42 x 11 mm; 7.8 g) and 10 individuals received a 45 d battery life depth sensing acoustic transmitter (Sonotronics, Inc.; IBDT-97-2; 47 x 10 mm; 6.8g). Surgical procedures followed those previously outlined. Following the first 15 surgeries, 10 bonytail implanted with the IBT-96-6 transmitters, and five implanted with the IBDT-97-2 transmitters were driven by truck to the Cattail Cove boat ramp and released. Fifteen fish were then similarly implanted with acoustic transmitters and released at BWRNWR boat ramp along with all remaining bonytail.

Tracking Techniques and Database Management

Watercraft were staged at each respective stocking location and tracking began immediately after the release of tagged fish. Tracking techniques followed those previously outlined with three exceptions: (1) for the first 45-d post-stocking, active tracking followed a revised grid (750-m intervals) of listening locations (N = 204) to account for the smaller detection range of the depth sensing tags, (2) two watercraft were utilized on most given dates to provide sufficient coverage to both stocking areas, and (3) additional manual tracking took place at both stocking locations after dark. During nighttime tracking, two watercraft were deployed (one to each stocking location) during three of four weeks in December 2011. Surveys started

---

[1] Prior to stocking bonytail at the BWRNWR and Cattail Cove boat ramps, USFWS personnel tempered hatchery fish inside separate holding tanks for approximately two hours. No mortalities were recorded at Cattail Cove, however, immediately following stocking at BWRNWR, more than 200 fish died at the boat ramp.

[2] Ten of the 50 bonytail set aside as potential surgery candidates were determined to be fish used in the July 2010 acoustic transmitter retention study that took place at DNFH&TC. Surgical scars were nearly invisible (Figure 4) and those individuals were returned to the holding tanks and eventually stocked with the telemetry fish.

simultaneously ~2 km uplake of Cattail Cove and at the furthest accessible portion of the Bill Williams River and utilized all listening locations in between the two stocking locations. Individual fish positions were triangulated to their exact location where the date, time, water temperature, reservoir depth, fish depth (if applicable), DTS were recorded or determined later in ArcGIS. Turbidity was measured at the exact location of each bonytail contacted with an acoustic depth tag. A 2.2-L Van Dorn horizontal water sampling bottle tethered to a rope was lowered to the depth where a tagged fish was contacted. A water sample was collected and raised to the water surface. Turbidity was measured using a calibrated LaMotte 2020we/wi turbidimeter. Shore-based SURs were downloaded weekly[3].

Turbidity also was measured weekly at 27 sites along a predetermined grid between the eastern-most watercraft-accessible portion of the Bill Williams River and Lake Havasu City (Figure 4). Turbidity was measured in water samples collected at three locations from each site: 0.3 m from the reservoir bottom, mid-water column (depth/2), and 0.3 m below the surface. Depth was determined using a Lowrance® HDS7 GPS Fish Finder.

All data were entered into a Microsoft Access® database. Pressure readings (pounds per square inch, PSI) associated with SUR detected depth-tagged bonytail were converted to feet below the water surface using the formula (PSI/0.446; D. White, Sonotronics, Inc., personal communication).

Preliminary results from the first month of the November 2011 study are reported below and are subject to change as new data are acquired. Further results and analysis will be reported in the 2012 Annual Report.

[3] Data from dive-retrievable SURs will be collected during Spring 2012.

Results

December 2010 Telemetry

Post-Stocking Survival and Transmitter Recovery

All tagged bonytail (*N* = 22) were contacted during this study for a total of 5,875 contacts up to 162 d after stocking. Passive tracking accounted for 5,776 (98%) contacts, none of which occurred by SURs positioned downstream of Parker Dam, in the CAP canal, or upstream of Thompson Bay (Gate 10; Figure 3) in Lake Havasu. Analysis of SUR data indicated the number of contacts per hour during the day (1.2), night (1.4), and crepuscular (1.4) periods were not significantly different ($F = 0.36$, df = 2, $P = 0.69$). When evaluated by sample week, crepuscular and night periods typically yielded more contacts per hour (Figure 5).

The mean number of total contacts per bonytail was 267 (range 14 - 861) and individuals were tracked an average of 76 days (range 3-172). None of the tagged fish was contacted during all 26 sample-weeks; 63% experienced periods of non-detection by both passive and active tracking, only to be contacted again later (Figure 6). Following the first two weeks of tracking, the proportion of telemetry contacts declined to approximately 50% of all available tagged fish where it remained until the last week of the study, when all tags had presumably expired and no fish were contacted (Figure 7); nominal expiration date was June 3, 2011, 180 days after tag activation on December 3, 2010.

Mortality for the 20 bonytail stocked in December 2010 was relatively high during the first half of the study; only 10 of 20 individuals (50%) were active three months after stocking (Figure 7). By the end of six months, however, up to eight of 20 (40%) fish remained active, as well as the two bonytail additionally tagged and released in February 2011 (Figure 7). Over the course of the study, 12 immobile transmitters were inspected using SCUBA (Table 3) and all were located and recovered within 5 km of the stocking location. Two transmitters were recovered in the Bill Williams River upstream of the US 95 Bridge from a depth of 2.1-2.4 m. Five transmitters were located uplake of the Bill Williams River, but inside the buoy line marking the edge of the refuge, at depths ranging from 3.6-6.4 m. The five remaining transmitters were located in Lake Havasu between the BWRNWR boundary and Gene Wash Cove (Figure 1) and recovered from a depth ranging from 6.7 to 13.1 m. No fish remains were observed near any the recovery sites. Mortalities occurred an average of 44 d (range 2-118) after stocking (Table 3). Two of the transmitters recovered (230 and 274) were re-implanted in fish captured during the 2011 Lake Havasu Native Fish Roundup.

Movement Patterns and Inhabitance

Over the course of the study 20 of 22 tagged bonytail (91%) dispersed between 2.9 km upriver into the Bill Williams River and 4.5 km uplake (toward Lake Havasu City) from the boat ramp at BWRNWR, and two individuals dispersed up to 23.7 km towards Lake Havasu City near the entrance to Copper Canyon (Figures 1 and 8). Fish collectively dispersed 1,319 km, moving an average of 0.2 km (range 0 to 10.3 km) between contacts. The majority of all bonytail contacts (97%) were within the boundaries of BWRNWR, 32% of which were made upstream of the US 95 Bridge in the Bill Williams River. Eight of 22 bonytail (36%) remained exclusively within the boundary of BWRNWR for the entirety of the study.

Bonytail contacted by active tracking were an average of 182 m from shore (range 0-710 m). Mean depth of the water column at each site of contact was 4.2 m (range 0.7 – 13.4 m) and reflected the high proportion of active contacts that occurred within BWRNWR. Water clarity further reflected the location of those contacts; mean depth of Secchi disk measurements was 2.5 m (range 0.5 – 9.5 m). Secchi disk readings taken at sites of active contacts in Lake Havasu (mean depth = 5.8 m) were 2.4 times greater than those taken between the BWRNWR boundary and the Bill Williams River delta (mean depth = 2.4 m) and more than 8.3 times greater than readings taken in the Bill Williams River (mean depth = 0.7 m; Figure 2 and Table 4).

Based on all acoustic-tagged fish (*N* = 22) contacted over the course of the 162-d study, bonytail spent significantly more time in BWRNWR when compared to Lake Havasu (*P* < 0.001). Mean time spent in BWRNWR was 66.1 d compared to 2.5 d spent in Lake Havasu (Table 5). Summed inhabitance in BWRNWR ranged from 0 to 173 d compared with 0 to 29 days in Lake Havasu. When bonytail mortalities (*N* = 12) were excluded, the mean summed inhabitance in BWRNWR increased to 98.1 d and decreased in Lake Havasu to 0.4 d (*N* = 10). The single longest interval of continuous inhabitance in BWRNWR was 173 d (Fish 275; for all fish, mean = 54.1 d), while the longest inhabitance in Lake Havasu was 26 d (Fish 245; for all fish, mean = 2.2 d).

Lake Havasu Native Fish Roundup

A general summary of the results are presented below and focus primarily on bonytail. For a thorough review of results and analysis from all participating members of the Lake Havasu Native Fish Roundup, see USFWS 2011[4]. Over the course of the roundup, 1,587 fishes were captured, representing 14 non-native and three native species. Of those, 67 bonytail were captured within the boundary of BWRNWR, and one bonytail was captured two coves south of Blankenship Bend (Figure 3). Mean TL of captured bonytail was 446 mm (range 345-500 mm). Two individuals caught in BWRNWR had recapture histories in the Lower Colorado River (LCR) Native Fish Database; Fish 275 was released at the BWRNWR boat ramp during the December 2010 telemetry study and Fish 206 was released at BWRNWR during the April 2010 telemetry study. All other bonytail were unmarked and received a 134 kHz PIT-tag.

November 2011 Telemetry

Remote PIT-Scanners

Seven of eight remote PIT antennas scanned for a total of 9,276 minutes. The shore-based unit deployed under the US 95 Bridge was compromised by a leak and did not collect any data.

[4] 2011 marked the first year non-native gizzard shad *Dorosoma cepedianum* was captured during the roundup; it was found only within the BWRNWR.

Over the course of 48-h post-stocking, 51 unique bonytail were contacted by the submersible scanners positioned in the stocking area, 50 of which had marking records in the LCR Native Fishes Database. All of the fish with marking records had been released at BWRNWR on 29 November.

Movement Patterns and Inhabitance

All tagged bonytail (*N* = 30) were contacted during the first 33-d of this study (through December 31, 2011) for a total of 2,362 contacts. Fish tagged with acoustic transmitters and released at BWRNWR dispersed between the upstream-most watercraft accessible portion of the Bill Williams River (2.9 km) and Lake Havasu near Takeoff Point (3.1 km; Figure 2). Fish released in Cattail Cove dispersed between the US 95 Bridge in BWRNWR (9.1 km) and Pilot Rock (Figure 1) near Lake Havasu City (13.4 km)[5].

Preliminary active-tracking data indicate depth-tagged bonytail were contacted on average at 80% of the depth of the reservoir water column, though mean fish depth was greater during both crepuscular (4.6 m) and nighttime hours (5.9 m) than during the day (3.5 m; Table 6). A similar diel pattern was observed for fish location (all acoustic-tagged bonytail) relative to the shoreline; fish were contacted further from shore during the crepuscular (121 m) and nighttime (128 m) hours than during the day (103 m; Table 6). Turbidity readings taken at points of contact for depth-tagged fish reflect conditions at both stocking locations; mean turbidity at Cattail Cove contact locations was 1.6 NTU (range 0.39-9.4) while mean turbidity for contact locations at Bill Williams River boat ramp was 4.1 NTU (range 1.3-8.9). Mean ambient turbidity readings during December 2011 reflect the high turbidity in BWRNWR (7.3 NTU) and decrease drastically in Lake Havasu (0.6 NTU; Figure 9). Further analysis of these data will be available after SUR data are acquired during spring 2012.

[5] Because diver-retrievable SURs were not downloaded in time to be available for this report, post-stocking dispersal distances are subject to change upon collection and analysis of those data.

Based on all acoustic-tagged bonytail released at BWRNWR (*N* = 15) and contacted during the first 33-d of this study, mean time spent in BWRNWR was 26 d compared to 0.3 d spent in Lake Havasu (Table 7). Summed inhabitance in BWRNWR ranged from 6 to 32 d compared with 0 to 2 days in Lake Havasu. The single longest interval of continuous inhabitance in BWRNWR was 29 d (Fish 32; for all fish, mean = 19.5 d), while the longest inhabitance in Lake Havasu was 2 d (Fish 9; for all fish, mean = 0.3 d). All bonytail stocked at BWRNWR remained nearly exclusively in habitats found within the refuge.

Based on all acoustic-tagged bonytail released at Cattail Cove (*N* = 15) and contacted during the first 33-d of this study, mean time spent in BWRNWR was 5.3 d compared to 14.6 d spent in Lake Havasu (Table 7). Summed inhabitance in BWRNWR ranged from 0 to 30 d compared with 0 to 31 days in Lake Havasu. The single longest interval of continuous inhabitance in BWRNWR was 30 d (Fish 33; for all fish, mean = 4.9 d), while the longest inhabitance in Lake Havasu was 31 d (Fish 48; for all fish, mean = 12.6 d). Three of 15 individuals (20%) stocked at Cattail Cove inhabited BWRNWR for more continuous days than habitats found in Lake Havasu.

Discussion

Our stepwise approach to answering basic questions regarding post-stocking survival, dispersal, and habitat use of bonytail in Lake Havasu has been successfully implemented for two consecutive years. The distribution of acoustic tagged fish tracked during 2011 was consistent with concurrent netting efforts that documented a large number of adult bonytail captured in BWRNWR, and not elsewhere in Lake Havasu. Bonytail stocked in BWRNWR dispersed into the upstream-most watercraft accessible reaches of the Bill Williams River, and were frequently contacted within that habitat. Most tagged bonytail dispersed less than 5 km into Lake Havasu, and many never left the boundary of BWRNWR. Continuous inhabitance data indicate a significant preference for habitat in BWRNWR and preliminary data from our most recent stocking support this conclusion. Variation in water clarity levels in BWRNWR may affect post-stocking survival and warrant further investigation.

The June 2010 acoustic transmitter retention study at DNFH&TC (100% fish survival; Karam et al. 2010) provided evidence that post-stocking mortality of acoustic-tagged fish in Lake Havasu was not caused by our surgical techniques. This point was further reinforced prior to the start of our November 2011 telemetry surgeries when ten bonytail collected from a DNFH&TC stocking truck were found to contain acoustic transmitters implanted 511 days prior (Figure 10). No visible abnormalities were observed, surgical scars were completely healed and nearly invisible, and the TL and weight of a subset of those fish was not significantly different from the bonytail that received transmitters for the November 2011 study.

During the April and December 2010 studies, some tagged bonytail went weeks or months without being contacted, and in some cases after initial detection were never re-contacted again (Karam et al. 2010). Similar scenarios have been documented during razorback sucker telemetry studies in Lake Mohave, where fish evaded passive and active detection only to be re-contacted again months later by netting, or years later by remote PIT-scanning equipment (Kesner et al. 2011). Acoustic-tagged fish from both the April and December 2010 telemetry studies were recaptured during the February 2011 netting efforts in BWRNWR. In the case of Fish 206 (released in April 2010), it was contacted for the first three weeks of the study, then not contacted again for the remaining 10 consecutive weeks (Karam et al. 2010). Recapture data from netting or remote PIT scanning events indicate tagged fish that undergo periods of non-contact may still be at large in the reservoir. Conversely, during a razorback sucker radio telemetry study, Marsh and Minckley (1991) found a transmitter previously associated with a tagged fish in a raptor nest above the Gila River. It is plausible some bonytail that sustained lengthy periods of non-contact during our telemetry studies were removed from the system by avian predation (Schooley 2005) or some other source of mortality, such as angling.

The large number of bonytail recaptured (*N* = 68) during February 2011 netting efforts provided evidence of survival when compared with the number of recaptures made during the recent past (19 recaptures between 1994 and 2007; Minckley and Thorson 2007). It is likely that the larger number of recent bonytail recaptures and apparent increase in post-stocking survival were due to their larger size-at-stocking (Table 8), a relationship which has been established for razorback sucker (Marsh et al. 2003; Schooley and Marsh 2007). Adult bonytail, however, remain susceptible to predation by large predatory fish such as striped bass (Karam and Marsh 2010). Because the lower Colorado River is an ecosystem in constant flux due to its ever-changing non-native fish fauna (Mueller and Marsh 2002), the evolutionary life-history dynamics of bonytail are no longer viable in this altered system. The current suite of large-bodied, predatory non-native fishes (largemouth bass, striped bass, channel catfish, and flathead catfish) that occupy all available habitats where bonytail are currently released in Lake Havasu (USFWS 2011) are capable of consuming bonytail larger than the current size being stocked (>300 mm TL)[6].

A small percentage of bonytail from both studies (15% from April 2010 and 9% from December 2010) exhibited relatively large uplake movements. The three bonytail that dispersed to uplake locations in the April 2010 study did not return to BWRNWR (Karam et al. 2010). Conversely, in December 2010, bonytail dispersed to uplake locations within the first month of the study, and then gradually utilized habitat closer to BWRNWR during the remaining months (Figure 8). Large dispersal movements have been recorded in other bonytail telemetry studies as well. In Lake Mohave, four fish were documented to have moved down-lake 56 km from their release location within two weeks of their release (Marsh 1997). Despite these occasional large observed movements, most bonytail in our studies do not seem to be prone to regular movements larger than a few kilometers.

Patterns of inhabitance for bonytail tracked during the April and December 2010 telemetry studies as well as capture data from February 2011 netting demonstrated bonytail stocked in BWRNWR show a clear preference for habitat found within the refuge compared with habitat

---

[6] Bonytail of the current stocking size are vulnerable to predation by the largest piscivorous non-native fish found in Lake Havasu. An assumption adhered to in this study is that any detection with a transmitter is that of a free-swimming bonytail and not of a predatory fish that has ingested a tagged bonytail. Gastric evacuation times (Table 9) were compiled for species that may target bonytail as a prey fish.

elsewhere in the reservoir. Data from February 2011 netting are particularly compelling because bonytail presumably had 10 months to disperse to other portions of Lake Havasu, but were still captured in BWRNWR. Comprehensive netting efforts at other locations throughout Lake Havasu resulted in only one bonytail capture (USFWS 2011). If fish dispersed to these areas, survival was both low and fish were unavailable for recapture, or fish simply did not disperse to other portions of the reservoir. A third telemetry study initiated in November 2011 has already generated data that support our prior observations: fish stocked in BWRNWR will continue to occupy that habitat. Furthermore, fish stocked elsewhere in Lake Havasu, but find their way to BWRNW, appear to remain there. Preliminary data indicate a portion (20%) of bonytail stocked at Cattail Cove have been detected for longer periods in BWRNWR than elsewhere in Lake Havasu.

Because bonytail occupy habitat in BWRNWR, and certain aspects of that habitat, such as water clarity (turbidity), are subject to change due to seasonal forces (weather) or human influence (upstream water releases), their survival may be affected when conditions change. Turbidity in BWRNWR increases, particularly near the delta, as discharge from the Bill Williams River increases (Dill 1944; Wiele et al. 2009). Bonytail utilizing BWRNWR may be more susceptible to predation when turbidity is lower (though still higher than other areas of Lake Havasu) due to low river flows. This may explain the higher number of mortalities during the first three months of the December 2010 study (N = 10) compared to the April 2010 study (N = 1). During the April study, mean Secchi disc readings (1.0 m; see Karam et al. 2010) recorded at active contact locations within BWRNWR were over two time lower than mean Secchi measurements taken at active contact locations within BWRNWR during the December 2010 study (2.1 m). Approximately one month prior to the April 2010 release, peak discharge in the Bill Williams River reached 87 m^3/s (Figure 11) during a one week flood event (mean discharge 52.2 m^3/s; USGS 2012), which is near the upper magnitude of small floods in that system (Schafroth and Beauchamp 2006). Peak discharge was slightly larger than the maximum streamflow (70.1 m^3/s) measured by Wiele et al. (2009), which created a sediment plume in BWRNWR that lasted approximately 14 days. Though Secchi measurement were taken only at sites of active contacts with tagged bonytail during the April 2010 study, no reference could be made until Secchi data were similarly collected during the December 2010 study. Peak flows in the months prior to the December 2010 study were approximately two orders of magnitude smaller than those experienced prior to April 2010 (Figure 11). A direct relationship exists between high turbidity in BWRNWR and increased flows in the Bill Williams River (Wiele et al. 2009). Lower turbidity during December 2010 could explain the lower initial survival since bonytail were potentially more susceptible to predatory fishes immediately after stocking. Humpback chub *Gila cypha*, a closely related species to bonytail, has been shown to utilize turbidity as cover (Valdez et al. 1992) to reduce predation risks (Stone 2010). Similarly, flood induced turbidity in Bill Williams River particularly influences deepwater birds, such as mergansers (*Mergus* spp.) and western grebes (*Aechmophorus occidentalis*) because underwater prey is hidden (Schafroth and Beauchamp 2006). The numbers of western grebes (*Aechmophorus occidentalis*) decrease during high flow events because fish prey, such as bonytail, become more difficult to find. If water clarity is a critical factor in decreasing post-stocking mortality of bonytail at BWRNWR, further studies are warranted to study the effects of increasing flows from Alamo Dam on post-stocking fish survival.

Aquatic plant beds found throughout BWRNWR during spring and summer months may have additionally contributed to high survival observed during the April 2010 study. Aquatic plant beds were observed from the surface in June 2010 and may have started to become established subsurface during April and May, thereby providing potential post-stocking cover to bonytail. Similarly, high initial mortality of December 2010 acoustic-tagged fish could be explained by the lack of aquatic plant beds when bonytail were stocked in BWRNWR. Though mortality was initially high, only two additional mortalities were confirmed during the last three months of that study when aquatic plant beds possibly began to establish in BWRNWR in response to warming water temperatures and increased solar radiation. The CAP currently contracts with work crews to clear parts of the refuge of nuisance aquatic plants to prevent vegetation mats from entering pumps at Mark Wilmer Pumping Station (Figure 2). If bonytail utilize these beds as cover, some caution should be taken to prevent incidental take of bonytail by mechanized removal equipment. Preliminary data collected from depth-tagged bonytail stocked in November 2011 indicate fish are most actively utilizing the lower 80% of the water column, in which case surface removal of those weeds is not an issue. However, if aquatic weed beds are an important source of cover, removal from shallow areas of the refuge (< 3 m) should be considered to avoid any conflict. Further analyses of depth data are ongoing.

Bonytail have consistently shown greater activity during night and crepuscular periods when compared to daytime contacts, as was the case in April 2010. In December 2010, the difference was not significant, but a higher proportion of crepuscular contacts continued (Figure 5). This observation of increased nighttime activity has been documented in other bonytail studies (Marsh 1997; Mueller et al. 2003). Similarly, other native fish in the Colorado River, specifically razorback sucker (Karam et al. 2008) and humpback chub (Valdez et al. 1992) have also shown an affinity for evening movement.

Prior to the November 2011 telemetry study, remote PIT scanners had never been deployed in habitats other than off-channel ponds (Kesner et al. 2011) when attempting to contact PIT-tagged bonytail. Our initial success contacting bonytail (*N* = 51) in BWRNWR immediately after stocking indicates this method is viable tool for monitoring recently stocked bonytail. It also suggests, similar to our preliminary depth tag data from the November 2011 stocking, that bonytail utilize the lower portion of the water column.

Continuing Studies

The telemetry study initiated in November 2011 was designed to investigate both the survival and inhabitance patterns of fish simultaneously stocked into two contrasting habitats: BWRNWR and Cattail Cove. Inhabitance patterns will be used to infer home ranges for stocked fish and depth data will be further analyzed to describe movement pattern of stocked bonytail throughout the water column. Turbidity as cover will be examined. Shore-based remote PIT scanners will be deployed at both stocking locations at least once a month through June 2012.

If bonytail are consistently contacted, scanners will be deployed once a month through the summer. A final round of telemetry will be initiated during late 2012; stocking is again suggested to take place at BWRNWR and at a second location in Lake Havasu.

Acknowledgements

Collections were permitted under the authorization of USFWS and the states of Arizona and California. The Institutional Animal Care and Use Committee, protocol numbers 05-767R and 08-959R, approved the care and use of fish used in this study. This project was made possible with cooperation from M. Ulibarri, W. Knight and other staff from DNFH&TC and AHNFF, M. Thorson and T. Knecht from Arizona Fish and Wildlife Conservation Office-Parker, D. Gilbert and staff from BWRNWR, Parker, AZ, J. Lantow from the Lower Colorado River MSCP office, R. Clarkson, B. Contreras, and A. Montony from Reclamation, B. Kesner and K. Patterson from M&A, and T. Dowling and M. Saltzgiver from Arizona State University. Reclamation Agreement Number R10PC30171 supported this work.

Literature Cited

Anderson, B. E. 2001. The socio-economic impacts of the Lake Havasu Fisheries Improvement Program. Anderson & Associates. Economic and social impact specialists. Durango, Colorado. 56 pages.

Baumann, J. R. and T. J. Kwak. 2011. Trophic relations of introduced flathead catfish in an Atlantic river. Transactions of the American Fisheries Society 140: 1120-1134.

Bond, M. H., C. V. Hanson, R. Baertsch, S. A. Hayes, and B. MacFarlane. 2007. A new low-cost instream antenna system for tracking passive integrated transponder (PIT)-tagged fish in small streams. Transactions of the American Fisheries Society 136: 562-566.

Cody, R. P., and J. K. Smith. 2006. Applied statistics and the SAS programming language, 5th edition. Elsevier Science Publishing Co., Inc. Upper Saddle River, New Jersey.

Dill, W.A. 1944. The fishery of the lower Colorado River. California Fish and Game 30: 109-211.

Doelker, A. 1994. Lake Havasu fisheries improvement program native fish management plan summary of activities May 1993 through December 1994. U.S. Bureau of Land Management, Lake Havasu City, Arizona. 23 pages.

Hurst, T. P, and D. O. Conover. 2001. Diet and consumption rates of overwintering YOY striped bass, *Morone saxatilis*, in the Hudson River. Fishery Bulletin 99: 545-553.

Karam, A. P., B. R. Kesner, and P. C. Marsh. 2008. Acoustic telemetry to assess post-stocking dispersal and mortality of razorback sucker *Xyrauchen texanus*. Journal of Fish Biology 73: 719-727.

Karam, A. P., B. R. Kesner, B.R., and P. C. Marsh. 2009. A comparison post-stocking survival of adult and subadult razorback sucker repatriates in Lake Mohave. Presentation to Colorado River Aquatic Biologist Annual Meeting, Laughlin, Nevada.

Karam A. P. and P. C. Marsh. 2010. Predation of adult razorback sucker and bonytail by striped bass in Lake Mohave, Arizona-Nevada. Western North American Naturalist. 70: 117-120.

Kesner, B. R., A. P. Karam, C. A. Pacey, and P. C. Marsh. 2008. Demographics and poststocking survival of repatriated razorback sucker in Lake Mohave. Final Report, Reclamation Agreement No. 06-FC-300003, Arizona State University, Tempe. 38 pages.

Kesner, B. R., Nelson, J. R., and P.C. Marsh. 2008a. The development of two portable remote pit scanning systems. Presentation to Colorado River Science and Resource Management Symposium, Scottsdale, Arizona.

Kesner, B. R., G. Ley, M. Fell, and P.C. Marsh. 2008b. Imperial ponds native fish research. Final Report, Reclamation Agreement No. 08-FG-30-0001, Arizona State University, Tempe. 27 pages.

Kesner, B. R., A. P. Karam, C. A. Pacey, K. A. Patterson, and P. C. Marsh. 2012. Demographics and poststocking survival of repatriated razorback sucker in Lake Mohave. Final Report, Reclamation Agreement No. 06-FC-300002, Marsh & Associates LLC, Tempe. 72 pages.

Knecht, T. 2010. Tenth Annual Native Fish Roundup on Lake Havasu, Arizona 1-11 February 2010. USFWS-AZFRO-PA-10-003. U.S. Fish and Wildlife Service, Parker, Arizona. 13 pages.

Marsh, P.C. and W.L. Minckley. 1991. Radiotelemetry of razorback suckers in the Gila River, Eastern Arizona. Proceedings of the Desert Fishes Council, Volume 21. Bishop, California.

Marsh, P. C. 1996. Threatened fishes of the world: Xyrauchen texanus (Abbott, 1860) (Catostomidae). Environmental Biology of Fishes 45: 258.

Marsh, P. C. 1997. Sonic telemetry of bonytail in Lake Mohave, Arizona and Nevada. Final Report, U.S. Geological Biological Resources Division Agreement No. 1445-0009-94-1108. Arizona State University, Tempe. 18 pages + figures.

Marsh, P. C. 2004. Threatened fishes of the world: *Gila elegans* Baird and Girard 1953 (Cyprinidae). Environmental Biology of Fishes 70: 144.

Marsh, P. C., C. A. Pacey, and B. R. Kesner. 2003. Decline of the razorback sucker in Lake Mohave, Colorado River, Arizona, and Nevada. Transactions of the American Fisheries Society 132: 1251-1256.

Martinsen, B. and T.E. Horsberg. 1995. Comparative single-dose pharmacokinetics of four quinolones, oxolinic acid, flumequine, sarafloxacin, and enrofloxacin in Atlantic salmon (Salmo salar) held in seawater at 10ºC. Antimicrobial Agents and Chemotherapy 39(5): 1059-1064.

Miller, R.R. 1961. Man and the changing fish fauna of the American Southwest. Papers of the Michigan Academy of Science, Arts, and Letters. 46: 365-404.

Minckley, C.O. 2006. Sonic telemetry of bonytail in Lake Havasu, AZ-CA. USFWS-AZFROPA-06-011. U.S. Fish and Wildlife Service, Parker, Arizona. 18 pages.

Minckley, C. O., and M. S. Thorson. 2007. A review of the distribution and management of bonytail in the lower Colorado River Basin. American Fisheries Society Symposium 53: 129-134.

Minckley, W.L. 1979. Aquatic habitats and fishes of the lower Colorado River, Southwestern United States. Final Report, U.S. Bureau of Reclamation, Boulder City, Nevada. Contract Number 194-06-300-2529. Arizona State University, Tempe, Arizona.

Minckley, W.L., and J.E. Deacon. 1991. Battle against extinction: native fish management in the American West. University of Arizona Press, Tucson, Arizona.

Moffett, J.W. 1942. A fishery survey of the Colorado River below Boulder Dam. California Fish and Game 28: 76-86.

Mueller, G. A., P. C. Marsh, G. Knowles, and T. Wolters. 2000. Distribution, movements, and habitat use of razorback sucker (*Xyrauchen texanus*) in a lower Colorado River reservoir, Arizona-Nevada. Western North American Naturalist 60:180-187.Mueller, G. A. 2003. The role of stocking in the reestablishment and augmentation of native fish in the lower Colorado River mainstem (1998-2002). Open-File Report 03-288. U. S. Geological Survey, Denver, Colorado. 43 pages.

Mueller, G. A. and P. C. Marsh. 2002. Lost, a desert river and its native fishes: a historical perspective of the lower Colorado River. Information and Technology Report USGS/BRD/ITR—2002—0010: U.S. Government Printing Office, Denver, Colorado. 69 pages.

Mueller, G.A., J. Carpenter, P. C. Marsh, and C.O. Minckley. 2003. Cibola High Levee Pond Annual Report 2003. U.S. Geological Survey, Denver, Colorado. 26 pages.

Pacey, C. A. and P. C. Marsh. 1998. Resource use by native and non-native fishes of the lower Colorado River—literature review, summary, and assessment of relative roles of biotic and abiotic factors in management of an imperiled indigenous ichthyofauna. Final Report, Reclamation Agreement No. 7-MT-30-R0012. Arizona State University, Tempe. 70 pages + tables, appendices.

Reisner, M. 1986. Cadillac desert: The American West and its disappearing water. Penguin Books, New York. 582 pages.

Schafroth, P.B. and V.B. Beauchamp. 2006. Defining ecosystem flow requirements for the Bill Williams River, Arizona. U.S. Geological Survey Open-File Report 2006-1314, 135 pages. [http://www.fort.usgs.gov/products/publications/21745/21745.pdf; last accessed April 2012].

Schooley, J. D. and P. C. Marsh. 2007. Stocking of endangered razorback suckers in the lower Colorado River basin over three decades: 1974-2004. North American Journal of Fisheries Management 27: 43-51.

Schooley, J. D., Kesner, B. R., Campbell, J. R., Barkstedt, J. M., and P. C. Marsh. 2008. Survival of razorback sucker in the lower Colorado River. Final Report, Reclamation Agreement No. 06-FC-30-0002. Arizona State University, Tempe. 30 pages + figures, tables.

Shrable, J. B., O. W. Tiemeier, and C. W. Deyoe. 1969. Effects of temperature on rate of digestion by channel catfish. The Progressive Fish-Culturist 31: 131-138.

Stone, D. M. 2010. Overriding effects of species-specific turbidity thresholds on hoopnet catch rates of native fishes in the Little Colorado River, Arizona. Transactions of the American Fisheries Society 139: 1150-117.

Tuomikoski, J. E., P. J. Rudershausen, J. A. Buckel, and J. E. Hightower. 2008. Effects of Age-1 striped bass predation on juvenile fish in Western Albemarle Sound. Transactions of the American Fisheries Society 137: 324–339.

U.S. Bureau of Reclamation. 2006. Lower Colorado River Multi-Species Conservation Program. Final Implementation Report. Boulder City, Nevada.

U.S. Fish and Wildlife Service. 2011. FWS AZFWCO 11th Annual Lake Havasu Round Up. U.S. Fish and Wildlife Service, Parker, Arizona. 35 pages.

U.S. Geological Survey. 2011. USGS Water Data for USA. Available: [http://waterdata.usgs.gov/nwis; last accessed April 2012].

Valdez, R. A., Masslich, W. J., and W.C. Leibfried. 1992. Characterization of the life history and ecology of the humback chub (*Gila cypha*) in the Grand Canyon. Annual Report to Bureau of Reclamation, Contract No. 0-CS-40-09110. BIO/WEST Report No. TR-250-04. 222 pages.

Wetzel, J.E. and C. C. Kohler. 2005. Distinction between gastric digestion and evacuation in black bass fed piscine prey. Transactions of the American Fisheries Society 134: 533-536.

Wiele, S. M., Hart, R. J., Darling, H. L., and A. B. Hautzinger. 2009. Sediment transport in the Bill Williams River and turbidity in Lake Havasu during and following two high releases from Alamo Dam, Arizona, in 2005 and 2006. U.S. Geological Survey Scientific Investigations Report 2009-5195. 22 pages. [http://pubs.usgs.gov/sir/2009/5195/; last accessed April 2012].

Wingate, R. L., Secor, D. H., and R. T. Kraus. 2011. Seasonal patterns of movement and residency by striped bass within a subestuary of the Chesapeake Bay. Transactions of the American Fisheries Society 140: 1441-1450.

Table 1. Stocking date and location, fish (transmitter) number, total length (TL) and mass (M) for bonytail implanted with acoustic transmitters during December 2010, February 2011 (the two fish implanted with previously recovered tags 230 and 274 are indicated by an asterisk next to fish number) and November 2011.

Stocking date	Stocking location	Fish number	TL (mm)	M (g)
Dec 2010	BWRNWR	230	389	534
Feb 2011	BWRNWR	230*	493	820
Dec 2010	BWRNWR	243	402	516
Dec 2010	BWRNWR	245	396	516
Dec 2010	BWRNWR	246	393	606
Dec 2010	BWRNWR	247	385	588
Dec 2010	BWRNWR	248	397	536
Dec 2010	BWRNWR	244	395	545
Dec 2010	BWRNWR	249	383	544
Dec 2010	BWRNWR	257	388	492
Dec 2010	BWRNWR	258	405	555
Dec 2010	BWRNWR	259	392	497
Dec 2010	BWRNWR	260	390	583
Dec 2010	BWRNWR	261	402	551
Dec 2010	BWRNWR	263	391	512
Dec 2010	BWRNWR	264	426	750
Dec 2010	BWRNWR	272	385	459
Dec 2010	BWRNWR	273	380	457
Dec 2010	BWRNWR	274	382	471
Feb 2011	BWRNWR	274*	480	860
Dec 2010	BWRNWR	275	393	566
Dec 2010	BWRNWR	277	402	534
Nov 2011	BWRNWR	2	434	581
Nov 2011	BWRNWR	3	430	680
Nov 2011	BWRNWR	5	446	684
Nov 2011	BWRNWR	7	446	573
Nov 2011	BWRNWR	9	415	533
Nov 2011	BWRNWR	21	425	587
Nov 2011	BWRNWR	22	420	556
Nov 2011	BWRNWR	23	420	600
Nov 2011	BWRNWR	24	455	753
Nov 2011	BWRNWR	32	420	650
Nov 2011	BWRNWR	34	415	649

Table 1. Continued.

Stocking date	Stocking location	Fish number	TL (mm)	M (g)
Nov 2011	BWRNWR	35	445	708
Nov 2011	BWRNWR	49	435	551
Nov 2011	BWRNWR	51	405	588
Nov 2011	BWRNWR	53	460	812
Nov 2011	Cattail Cove	4	408	512
Nov 2011	Cattail Cove	6	400	582
Nov 2011	Cattail Cove	8	446	689
Nov 2011	Cattail Cove	17	400	526
Nov 2011	Cattail Cove	18	421	649
Nov 2011	Cattail Cove	19	422	564
Nov 2011	Cattail Cove	20	405	480
Nov 2011	Cattail Cove	33	392	531
Nov 2011	Cattail Cove	36	422	653
Nov 2011	Cattail Cove	37	423	595
Nov 2011	Cattail Cove	38	442	622
Nov 2011	Cattail Cove	47	432	566
Nov 2011	Cattail Cove	48	416	625
Nov 2011	Cattail Cove	50	419	685
Nov 2011	Cattail Cove	52	401	484

Table 2. Categorical chart used to identify appropriate Baytril (Enrofloxacin) dosage based on the mass (M) of each bonytail used in acoustic telemetry studies, Lake Havasu, Arizona and California.

M (g)	459	689	919	1149	1379	1609
Baytril dose (ml)	0.1	0.2	0.3	0.4	0.5	0.6

Table 3. List of acoustic transmitters (tag numbers) and their corresponding date, depth, and location of recovery for all documented bonytail mortalities that occurred during the December 2010 telemetry study.

Tag number	Recovery date	Recovery depth (m)	Recovery location	
			Easting	Northing
230	1/17/2011	2.4	768613	3798526
243	3/1/2011	2.1	769272	3797988
244	3/1/2011	3.9	766774	3798699
245	3/2/2011	3.7	766498	3798444
246	3/2/2011	13.1	764432	3799653
248	3/2/2011	10.1	765133	3798810
257	6/8/2011	4.3	766355	3798850
258	6/8/2011	12.5	764824	3799830
263	6/8/2011	6.4	765925	3798606
272	3/2/2011	8.8	765585	3798700
273	6/8/2011	4.9	766189	3798965
274	1/17/2011	6.7	762047	3799748

Table 4. Summary of mean (SD) physical characteristics measured at each active contact site for all telemetered fish during the December 2010 bonytail study. Asterisks next to fish numbers 230 and 274 denote previously recovered tags that were re-implanted in different bonytail captured during February 2011. Gray boxes indicate fish that remained exclusively in BWRNWR for the entire study period. [a]Denotes one or more occasions when Secchi data were not collected because the disc was visible at the bottom.

Fish	N	Reservoir Depth (m)	Secchi Depth (m)	DTS (m)	Water Temp (°C)
230	1	1.5	— [a]	149	14.0
230*	6	4.5 (1.7)	2.3 (1.9)	97 (153)	17.8 (2.7)
243	5	4.4 (1.5)	1.3 (1.0)	86 (123)	14.8 (1.3)
244	2	2.5 (0.6)	2.2 (0.3)	124 (120)	12.0 (2.8)
245	1	4.2	—	252	10.0
246	4	7.0 (5.0)	3.6 (2.2)	232 (235)	12.5 (1.2)
247	2	4.8 (1.7)	2.5 (0)	159 (179)	13.5 (0.7)
248	3	7.2 (3.8)	5.5 (3.7)	198 (38)	13.0 (0)
249	3	2.2 (1.6)	1.2 (1.0) [a]	131 (162)	14.3 (0.5)
257	5	4.4 (1.8)	2.8 (0.9)	400 (155)	12.2 (1.3)
258	3	10.8 (4.1)	5.6 (0.5)	202 (155)	13.3 (1.1)
259	1	4.8	2.5	82	14.0
260	3	2.1 (0.3)	1.0 (0)	8.8 (6.8)	15.0 (1.0)
261	13	3.0 (1.2)	1.7 (0.9)	147 (125)	15.0 (3.0)
263	4	7.4 (1.7)	2.8 (1.1)	195 (86)	12.0 (1.4)
264	12	2.6 (1.0)	1.8 (0.5) [a]	105 (39)	14.1 (2.9)
272	5	6.5 (3.0)	2.8 (0.4)	107 (32)	12.2 (1.3)
273	5	6.0 (3.5)	3.1 (1.2)	330 (161)	11.8 (1.3)
274	2	1.5 (0)	1.0 (0) [a]	25 (9)	13.0 (1.4)
274*	1	2.1	0.5	4	14.0
275	9	5.7 (0.3)	2.1 (1.3)	193 (116)	16.8 (3.5)
277	5	4.3 (2.0)	2.2 (1.4)	207 (252)	14.2 (0.8)

Table 5. Summary of telemetry data describing inhabitance (defined in Methods) of acoustic-tagged bonytail monitored in BWRNWR (BW) and Lake Havasu (LH) between December 2010 and May 2011. Asterisks next to fish numbers 230 and 274 denote previously recovered tags that were re-implanted in different bonytail captured during February 2011.

Fish number	Date of stocking	Date of last detection	Summed continuous inhabitance BW (d)	Summed continuous inhabitance LH (d)	Longest continuous inhabitance event BW(d)	Longest continuous inhabitance event in LH (d)
230	3 Dec 2010	19 Jan 2011	48	0	45	0
230*	11 Feb 2011	24 May 2011	103	0	54	0
243	3 Dec 2010	1 Mar 2011	89	0	89	0
244	3 Dec 2010	5 Jan 2011	34	0	31	0
245	3 Dec 2010	1 Feb 2011	32	29	26	26
246	3 Dec 2010	5 Jan 2011	21	3	19	3
247	3 Dec 2010	30 Jan 2011	56	3	47	3
248	3 Dec 2010	23 Dec 2010	18	3	4	2
249	3 Dec 2010	10 May 2011	159	0	159	0
257	3 Dec 2010	18 Jan 2011	47	0	47	0
258	3 Dec 2010	6 Dec 2010	0	2	0	2
259	3 Dec 2010	17 Mar 2011	3	0	3	0
260	3 Dec 2010	24 Mar 2011	15	0	15	0
261	3 Dec 2010	11 May 2011	158	1	90	1
263	3 Dec 2010	5 Jan 2011	29	1	16	1
264	3 Dec 2010	11 May 2011	160	0	160	0
272	3 Dec 2010	1 Feb 2011	61	0	61	0
273	3 Dec 2010	1 Mar 2011	89	0	45	0
274	3 Dec 2010	17 Dec 2010	4	11	4	11
274*	11 Feb 2011	20 May 2011	93	0	50	0
275	3 Dec 2010	24 May 2011	173	0	173	0
277	3 Dec 2010	1 Feb 2011	61	0	54	0

Table 6. Mean (SD) distance to shore for all actively tracked bonytail and depth data (mean fish and reservoir depths) for actively tracked depth-tagged fish only between 29 November and 31 December 2011.

	N	DTS (m)	Fish Depth (m)	Reservoir Depth (m)
Daytime	28	108 (134)	3.5 (2.9)	6.5 (5.7)
Crepuscular	6	149 (184)	4.6 (0.9)	6.2 (2.7)
Nighttime	10	125 (119)	5.9 (4.4)	7.6 (5.3)

Table 7. Summary of telemetry data describing inhabitance of acoustic-tagged bonytail monitored in BWRNWR (BW) and Lake Havasu (LH) between November and December 2011.

Fish number	Stocking Location	Date of stocking	Date of last detection	Summed continuous inhabitance BW(d)	Summed continuous inhabitance LH (d)	Longest continuous inhabitance event BW (d)	Longest continuous inhabitance event in LH (d)
2	BWRNWR	11/29/2011	N/A	22	0	22	0
3	BWRNWR	11/29/2011	N/A	27	0	25	0
5	BWRNWR	11/29/2011	N/A	30	0	6	0
7	BWRNWR	11/29/2011	N/A	22	2	16	1
9	BWRNWR	11/29/2011	N/A	31	2	24	2
21	BWRNWR	11/29/2011	N/A	10	0	5	0
22	BWRNWR	11/29/2011	N/A	32	0	27	0
23	BWRNWR	11/29/2011	N/A	6	0	2	0
24	BWRNWR	11/29/2011	N/A	31	0	26	0
32	BWRNWR	11/29/2011	N/A	29	0	29	0
34	BWRNWR	11/29/2011	N/A	32	0	27	0
35	BWRNWR	11/29/2011	N/A	29	0	29	0
49	BWRNWR	11/29/2011	N/A	29	0	13	0
51	BWRNWR	11/29/2011	N/A	29	0	25	0
53	BWRNWR	11/29/2011	N/A	31	1	16	1
4	Cattail Cove	11/29/2011	N/A	1	24	1	16
6	Cattail Cove	11/29/2011	N/A	9	18	4	11
8	Cattail Cove	11/29/2011	N/A	22	10	22	10
17	Cattail Cove	11/29/2011	N/A	15	8	14	5
18	Cattail Cove	11/29/2011	N/A	2	24	2	16
19	Cattail Cove	11/29/2011	N/A	0	31	0	31
20	Cattail Cove	11/29/2011	N/A	0	30	0	30
33	Cattail Cove	11/29/2011	N/A	30	2	30	2
36	Cattail Cove	11/29/2011	N/A	0	16	0	16
37	Cattail Cove	11/29/2011	N/A	0	2	0	2
38	Cattail Cove	11/29/2011	N/A	0	2	0	2
47	Cattail Cove	11/29/2011	N/A	0	9	0	9
48	Cattail Cove	11/29/2011	N/A	0	31	0	31
50	Cattail Cove	11/29/2011	N/A	0	12	0	8
52	Cattail Cove	11/29/2011	N/A	0	0	0	0

Table 8. History of bonytail stocked (> 10 individuals) into Lake Havasu, Arizona and California. Bonytail stocked at Lake Havasu Palms Marina during February 2005 were used in the Minckley 2006 telemetry study.

Stocking Date	Stocking Location	RKM	N	Mean TL
July-92	Lake Havasu	Unknown	17	167
October-94	Bill Williams River NWR	0.5	25,575	91
October-94	Bill Williams River NWR	0.5	26,500	89
October-94	Lake Havasu	Unknown	48,200	76
October-95	Bill Williams River NWR	0.5	27	270
January-96	Bill Williams River NWR	0.5	13	286
February-96	Bill Williams River NWR	0.5	12	268
March-96	Takeoff Point	0.2	11	286
September-96	Takeoff Point	0.2	11	303
October-96	Bill Williams River NWR	0.5	22	266
November-96	Takeoff Point	0.2	42	302
July-97	Bill Williams River NWR	0.5	10	260
October-97	Takeoff Point	0.2	24	323
October-97	Takeoff Point	0.2	54	269
February-98	Bill Williams River NWR	0.5	19	295
June-98	Bill Williams River NWR	0.5	12	278
October-98	Bill Williams River NWR	0.5	44	265
November-98	Bill Williams River NWR	0.5	274	264
November-98	Bill Williams River NWR	0.5	46	263
November-98	Bill Williams River NWR	0.5	62	269
December-98	Bill Williams River NWR	0.5	39	317
January-99	Bill Williams River NWR	0.5	10	275
January-99	Bill Williams River NWR	0.5	70	255
March-99	Bill Williams River NWR	0.5	10	241
April-99	Takeoff Point	0.2	542	223
August-99	Lake Havasu	Unknown	199	245
August-99	Lake Havasu	Unknown	23	252
June-01	Lake Havasu	Unknown	710	255
July-02	Bill Williams River NWR	0.5	1,161	267
July-02	Bill Williams River NWR	0.5	723	263
August-02	Bill Williams River NWR	0.5	32	266
August-02	BLM Partner's Point Work Camp	25.3	311	268
August-02	Bill Williams River NWR	0.5	1,385	267
August-02	Bill Williams River NWR	0.5	212	261
August-02	Bill Williams River NWR	0.5	685	263
November-02	BLM Partner's Point Work Camp	25.3	1,114	271

Table 8. Continued.

Stocking Date	Stocking Location	RKM	N	Mean TL
November-02	Bill Williams River NWR	0.5	498	284
November-02	Bill Williams River NWR	0.5	500	281
November-02	Bill Williams River NWR	0.5	935	276
November-02	BLM Partner's Point Work Camp	25.3	998	271
November-02	Bill Williams River NWR	0.5	100	269
May-03	BLM Partner's Point Work Camp	25.3	652	262
May-03	BLM Partner's Point Work Camp	25.3	24	266
October-03	BLM Partner's Point Work Camp	25.3	2,544	286
December-03	Bill Williams River NWR	0.5	25	255
December-03	BLM Partner's Point Work Camp	25.3	1,201	282
December-03	BLM Partner's Point Work Camp	25.3	499	290
March-04	BLM Partner's Point Work Camp	25.3	347	288
March-04	BLM Partner's Point Work Camp	25.3	588	275
October-04	BLM Partner's Point Work Camp	25.3	1,655	289
November-04	BLM Partner's Point Work Camp	25.3	5,090	305
November-04	Topock Marsh	67.2	1,182	291
February-05	Lake Havasu Palms Marina	29.6	12	456
November-06	Park Moabi	69.6	2,397	300
January-07	Park Moabi	69.6	1,511	300
March-07	Laughlin Lagoon	118.7	1,264	315
May-07	Bill Williams River NWR	0.5	38	242
October-07	Bill Williams River NWR	0.5	2,305	300
December-08	Bill Williams River NWR, above the bridge	0.5	170	316
December-08	Bill Williams River NWR, above the bridge	0.5	792	319
December-08	Bill Williams River NWR, above the bridge	0.5	1,167	327
December-08	Bill Williams NWR headquarters boat ramp	0.5	2,098	340
October-09	Bill Williams River NWR	0.5	2,000	330
December-09	Bill Williams River NWR	0.5	1,036	331
December-09	Cattail Cove Boat Ramp	7.4	1,037	331
April-10	Bill Williams NWR headquarters boat ramp	0.5	20	401
April-10	Bill Williams River NWR	0.5	600	374
April-10	Bill Williams River NWR	0.5	1,300	374
December-10	Bill Williams NWR headquarters boat ramp	0.5	32	387
December-10	Bill Williams NWR headquarters boat ramp	0.5	2,100	335

Table 9. Gastric evacuation rates for the largest piscivorous non-native fishes present in Lake Havasu. The evacuation rates described are the time (h) it takes for 100% evacuation of the gut at a particular water temperature. Water temperature varied within this study (see Table 4), thus only studies in which water temperatures greater than 10 °C were examined.

Species	Water Temp	Time for Evacuation	Study
Striped bass	11 °C	72 h	Hurst and Conover 2001
Striped bass	27 °C	32 h	Tuomikoski et al. 2008
Flathead catfish	Not specified	2.5 h	Baumann and Kwak 2011
Flathead catfish	Not specified	1.6 h	Baumann and Kwak 2011
Channel catfish	26.6 °C	24 h	Shrable et al. 1969
Largemouth bass	27 °C	15 h	Wetzel and Kohler 2005

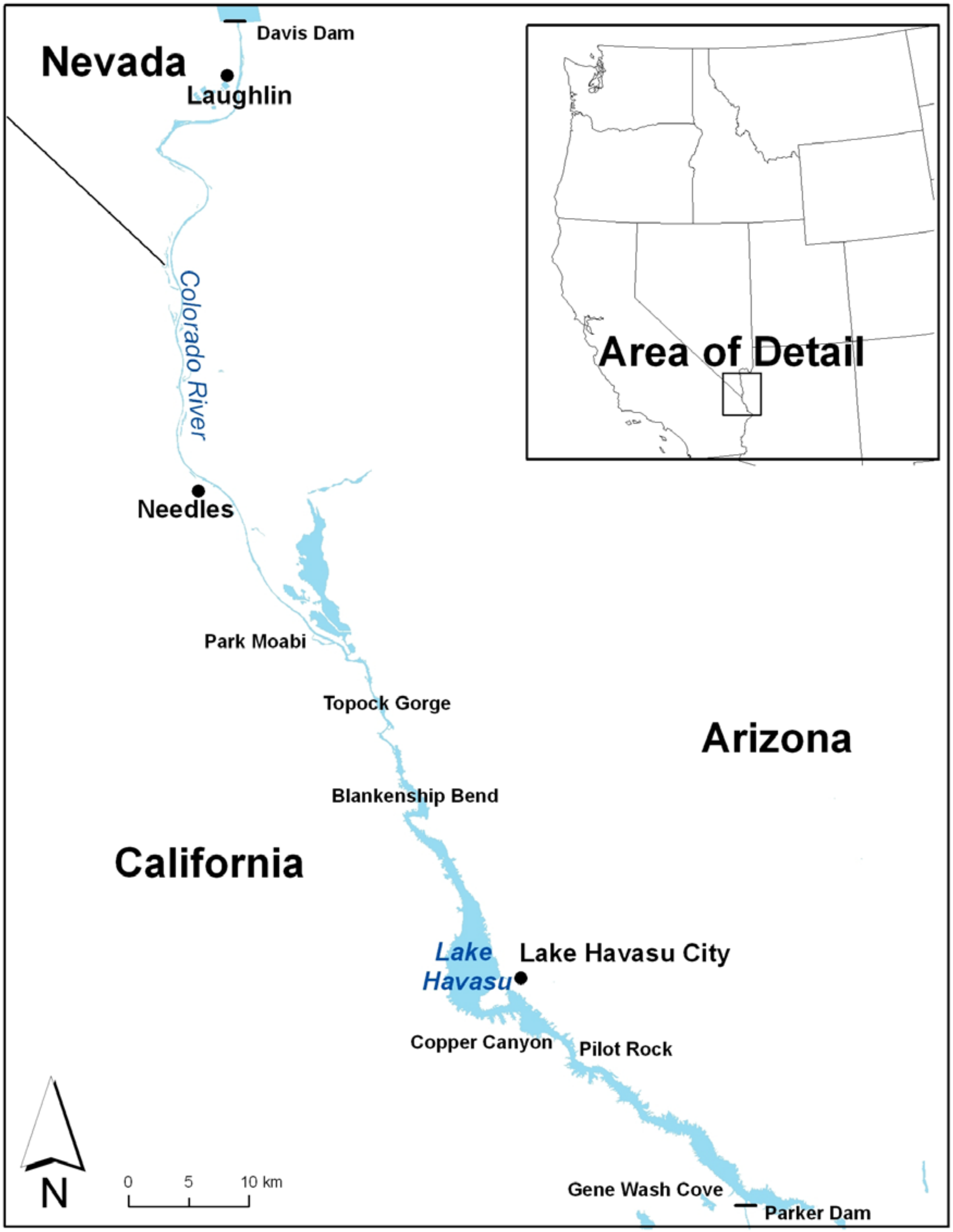

Figure 1. Map of Lake Havasu, Arizona, California, and Nevada.

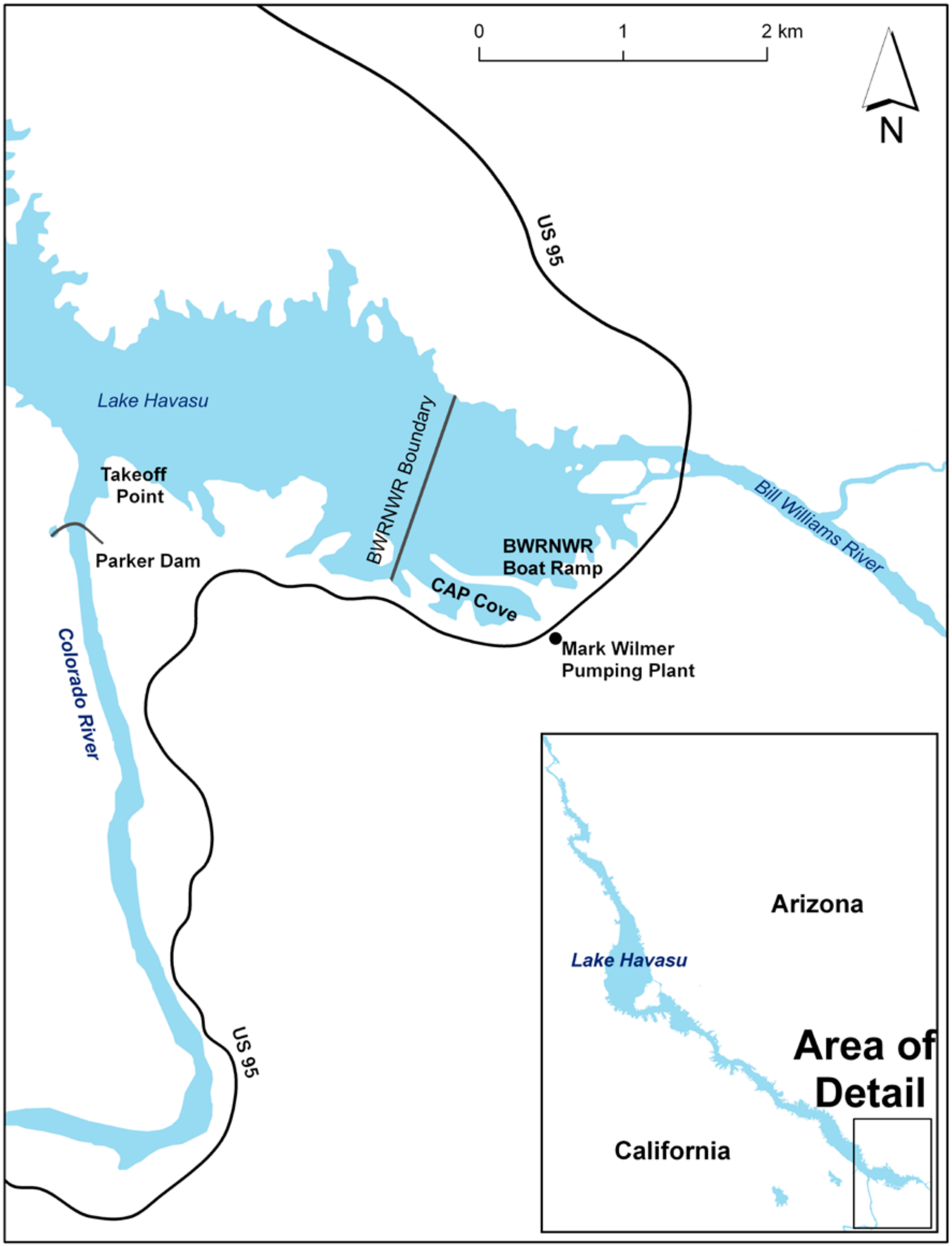

Figure 2. Detailed map of the Bill Williams River delta portion of Lake Havasu, Arizona.

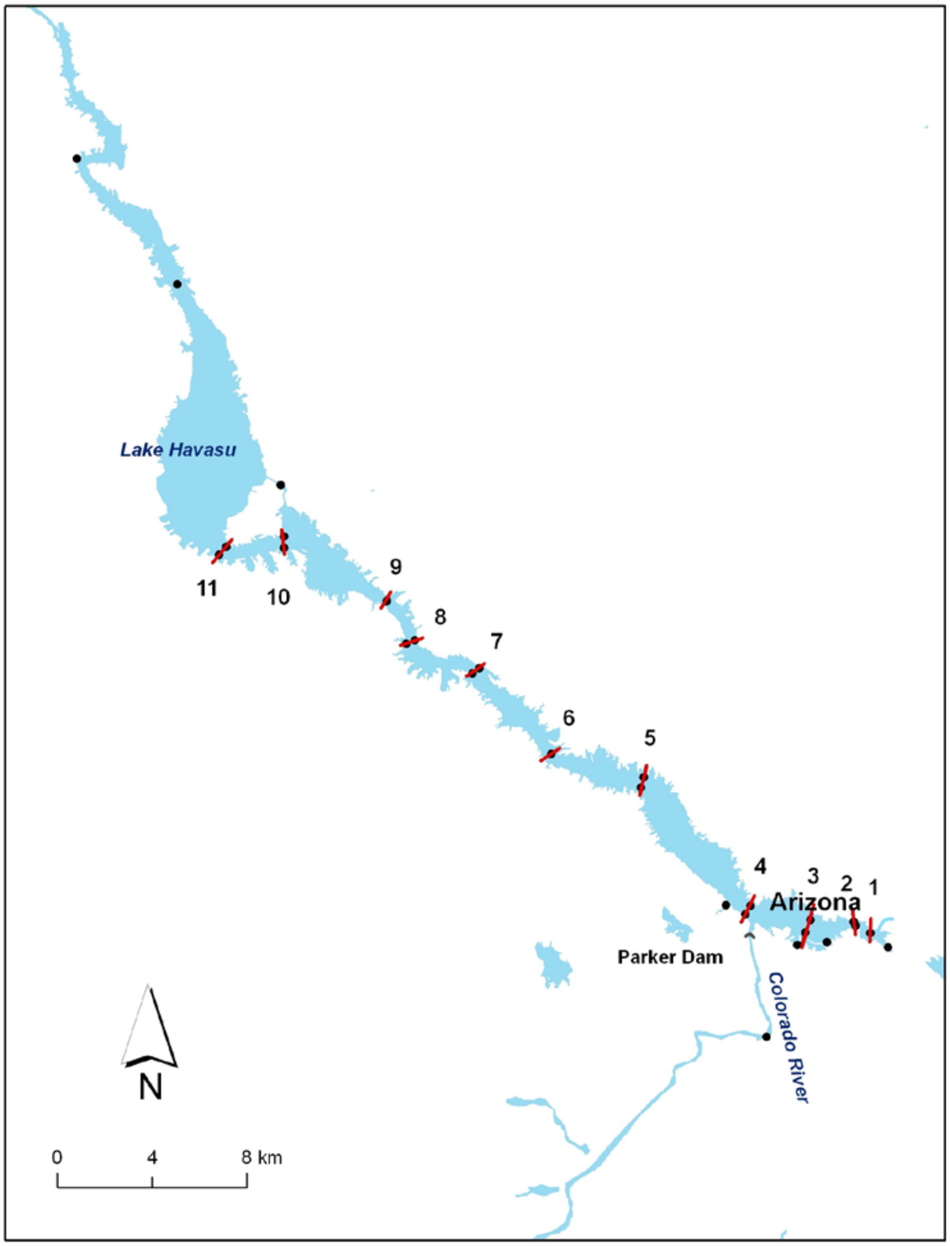

Figure 3. Location of submersible ultrasonic receivers (SURs) in Lake Havasu during the December 2010 bonytail telemetry study, Lake Havasu, Arizona and California. Linear SUR gates (numbered 1-11) provided shore-to-shore coverage and are demarked by red lines. The SUR deployed on the Central Arizona Project canal is not depicted.

Figure 4. Weekly turbidity sampling grid in Lake Havasu during December 2011. Turbidity samples were taken beginning at the upstream-most watercraft accessible portion of the Bill Williams River (1) and proceeded sequentially towards Lake Havasu City (27). At each location, a sample was taken from the surface, mid-column, and bottom.

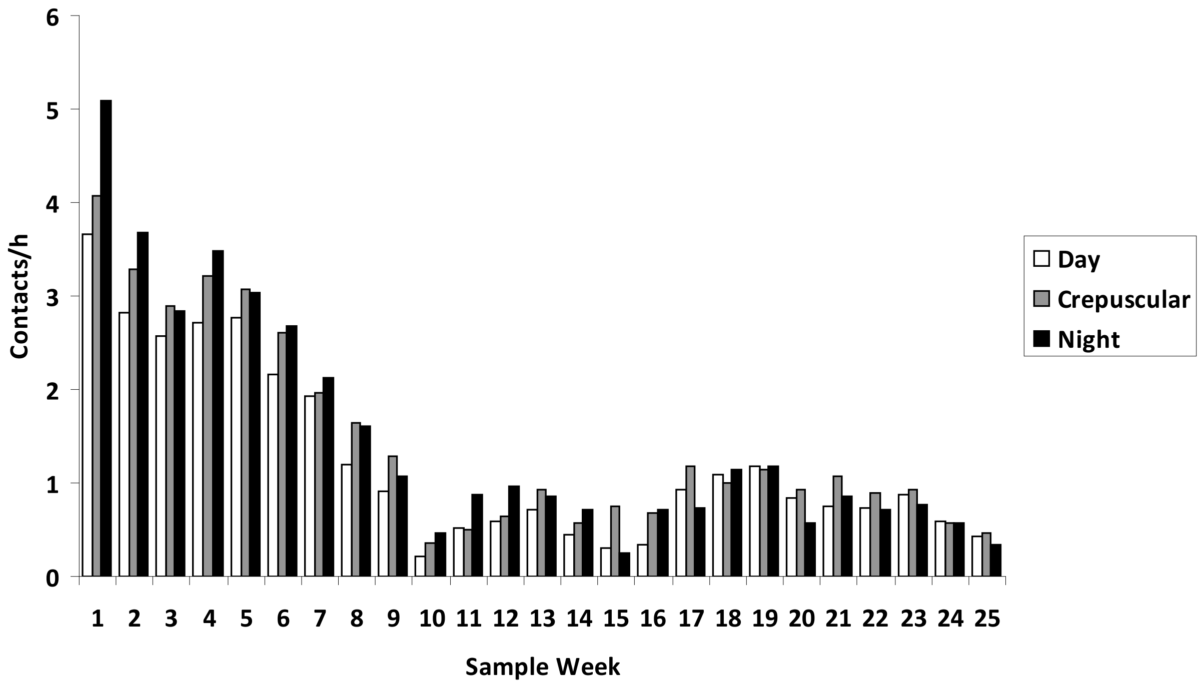

Figure 5. Diel distribution of contacts (active and passive) during the sample weeks in the December 2010 bonytail telemetry study, Lake Havasu, Arizona and California.

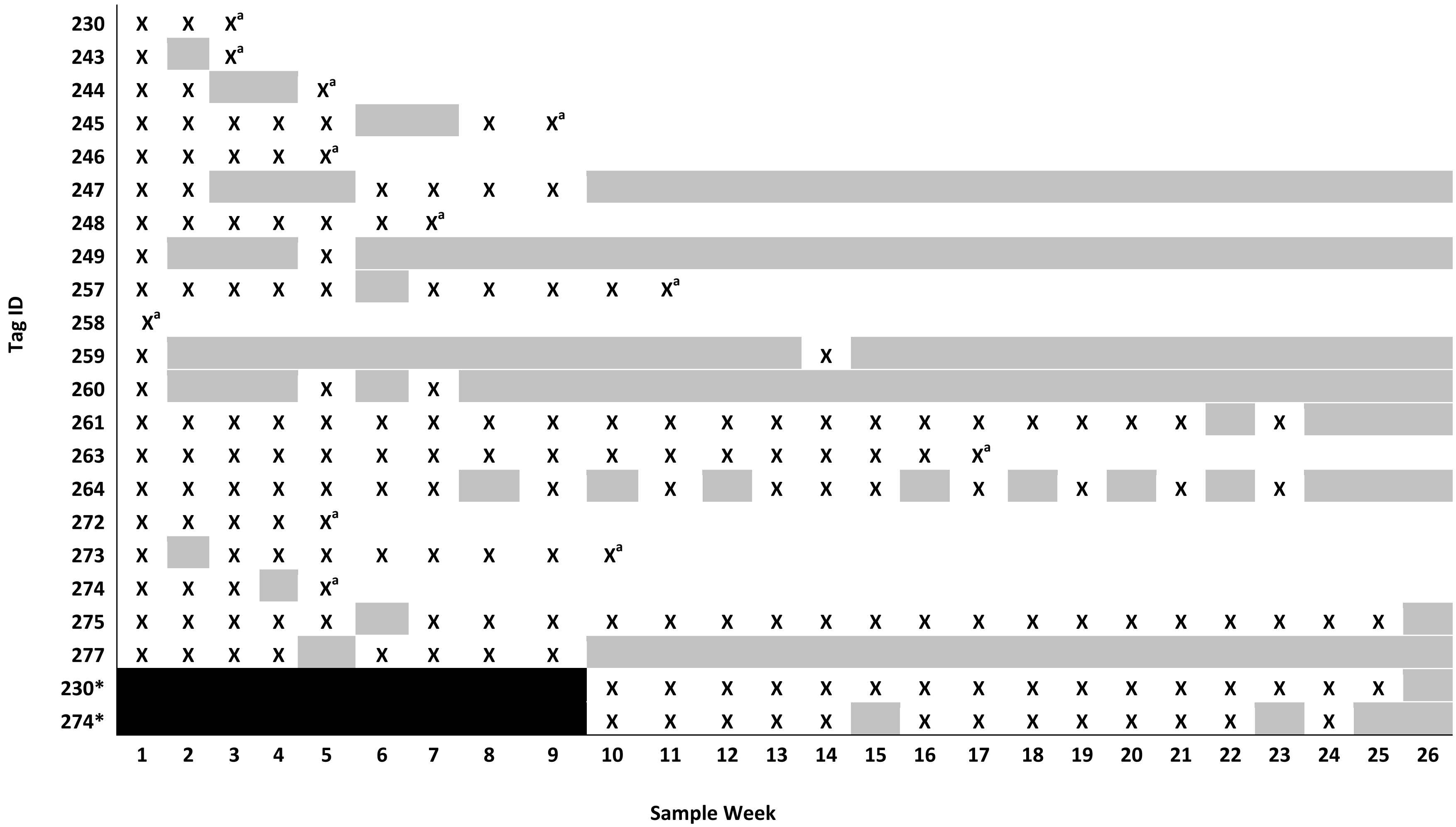

Figure 6. Weekly contacts (X) and non-contacts (gray boxes) for all study fish during the December 2010 bonytail telemetry study, Lake Havasu, Arizona and California. Blacked out boxes represent time prior to tags 230* and 274* being re-implanted in bonytail captured during February 2011 netting. [a] Denotes a confirmed mortality.

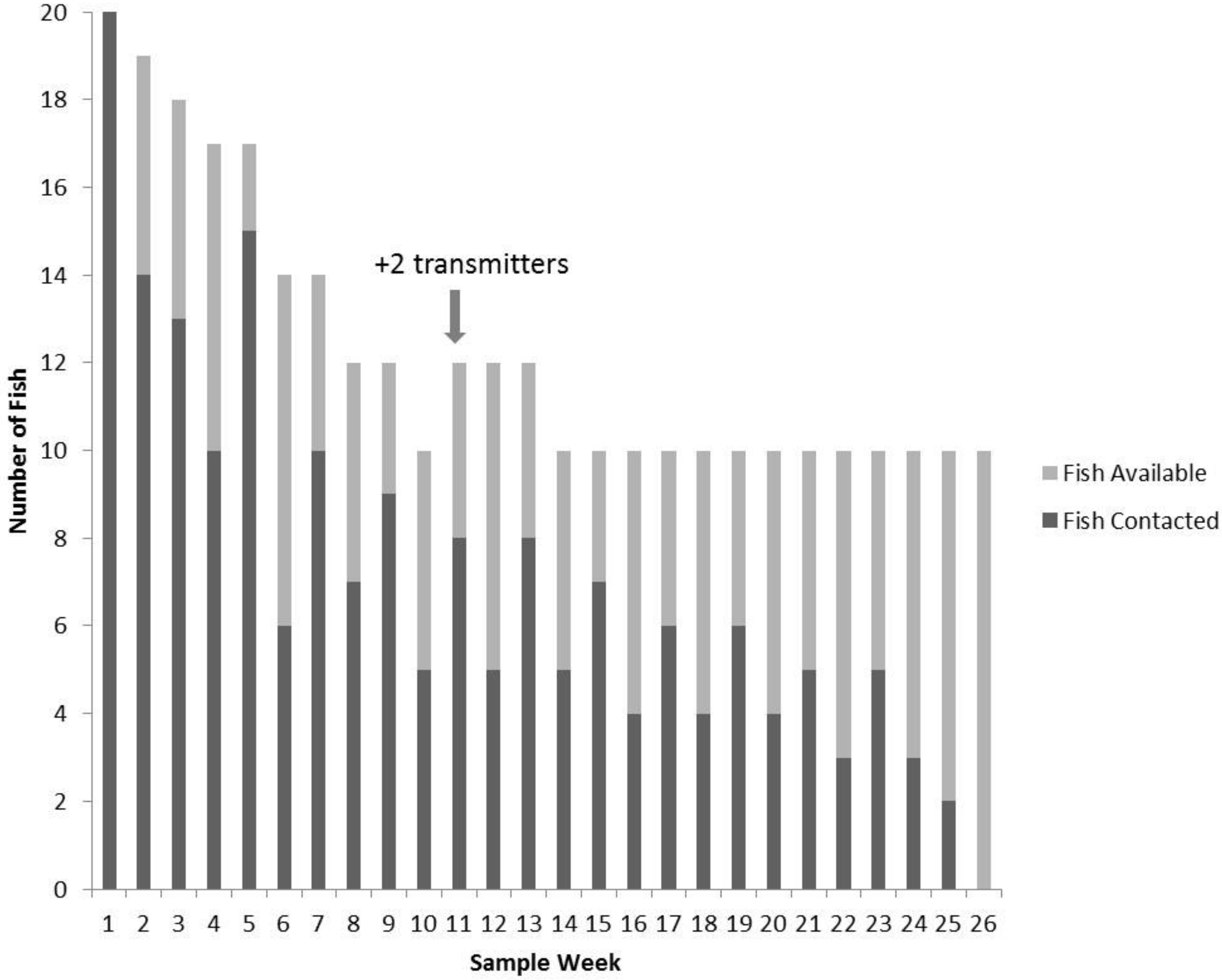

Figure 7. Total number of acoustic tagged bonytail potentially available for contact (light gray box) and those contacted (dark gray box) per week during the December 2010 telemetry study.

Figure 8. Extent of dispersal for two acoustic tagged bonytail during the December 2010 study. Black bars represent the uplake-most detection during the time period specified, and fish progressively utilized lower portions of the lake.

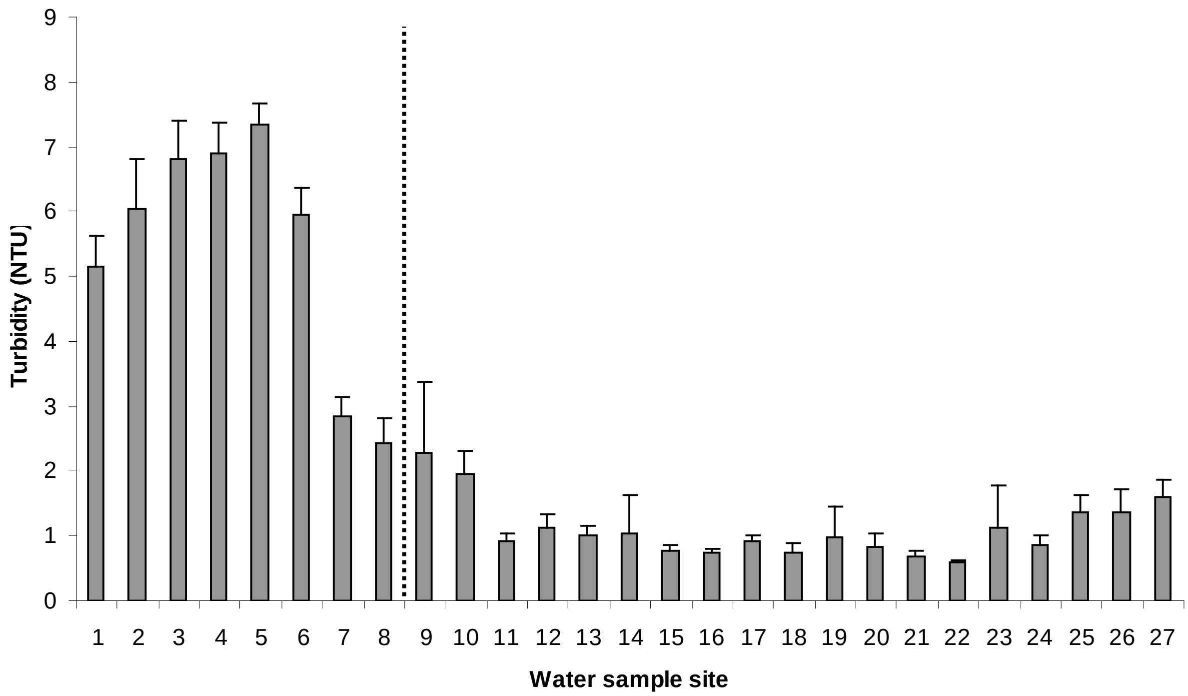

Figure 9. Turbidity (NTU) readings taken during December 2011 beginning in the upstream-most watercraft accessible portions of the Bill Williams River (1) and ending at Lake Havasu City (27). Error bars represent standard error. The dashed vertical line represents the refuge boundary for BWRNWR; see Figure 5.

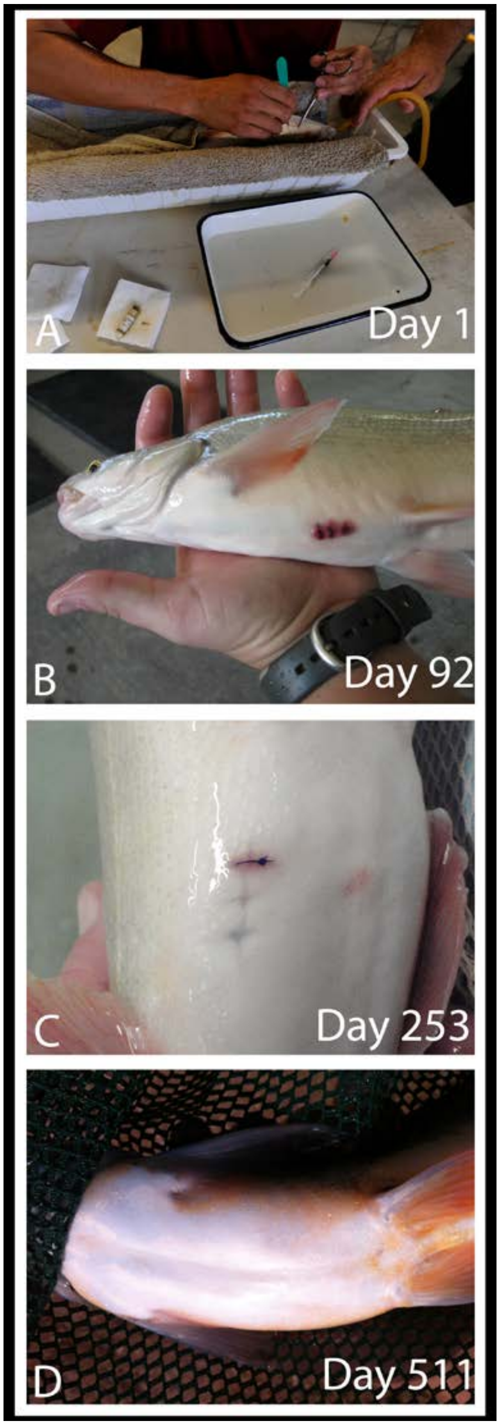

Figure 10. Bonytail implanted with an acoustic transmitter during the July 2010 transmitter retention study and seen at various time intervals post-implantation. Photograph "D" is representative of the ten individuals found while collecting fish prior to surgery for the November 2011 acoustic telemetry study on Lake Havasu.

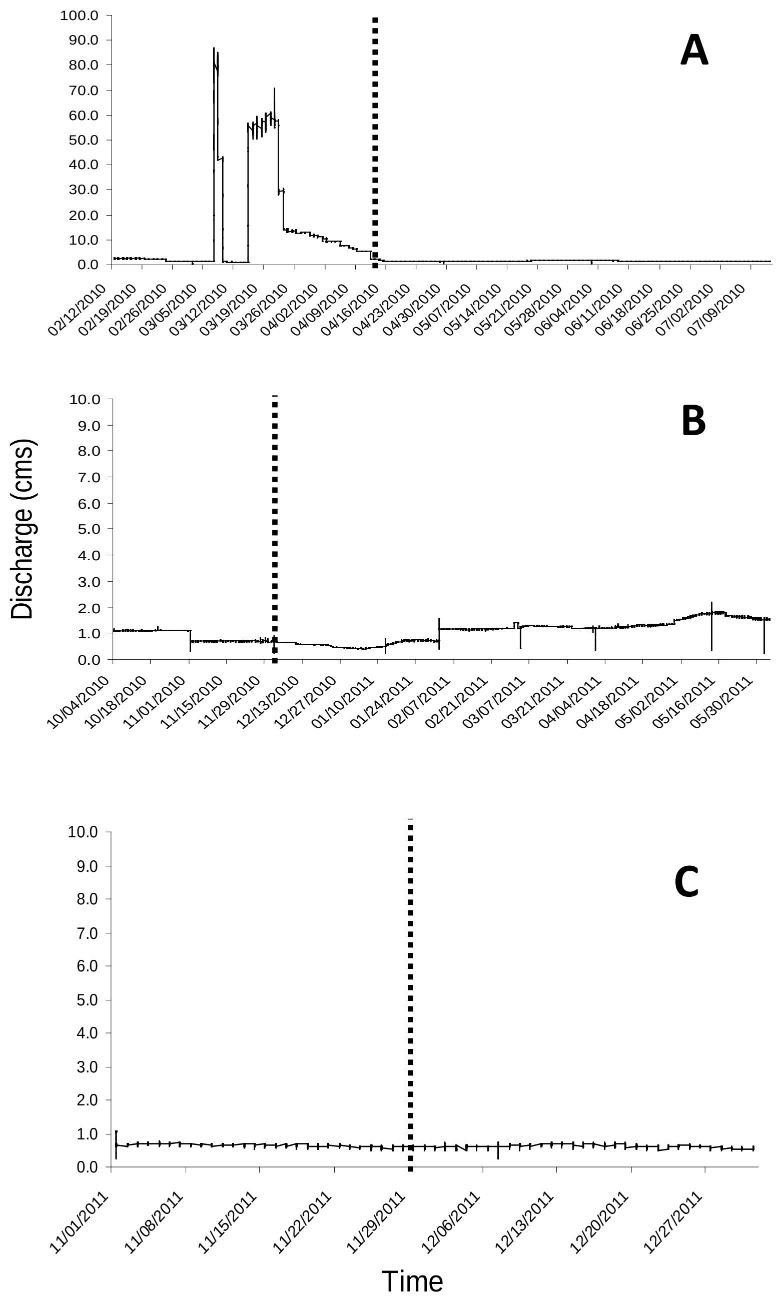

Figure 11. Daily mean discharge of the Bill Williams River (gauge located 1 km downstream of Alamo Dam) 60 days prior the start dates (vertical lines) and up until the end of the April 2010 (A), December 2010 (B), and November 2011 (C) bonytail telemetry studies, Lake Havasu, Arizona and California (USGS 2011). Note the difference in Y-axis scale between graphs.

Appendix A. Individual fish narratives for December 2010 bonytail telemetry

The following narratives provide a detailed account of post-stocking dispersal and tracking efforts for all telemetered fish during the December 2010 bonytail study. A summary of the physical characteristics measured at each active contact site is presented in Table 5.

Fish 230

Fish 230 (TL = 389 mm, M = 534 g) ranged from 1.4 km uplake to 2.1 km upriver of the stocking location through the duration of the study. The uplake-most location was recorded by an SUR stationed in Rose Cove, and the upriver-most location was recorded by an SUR stationed in the cattail channels of the BWRNWR.

Mean distance moved between contacts was 0.03. This fish was contacted 453 times by both active and passive sampling methods for 47 days of the 6-month study. Contacts were broken up by diel period; 37% of contacts occurred during the day, 44% occurred at night, and 17% of contacts occurred during crepuscular periods.

Fish 230 was found almost exclusively within the BWRNWR boundaries, with only one contact occurring just outside the refuge boundary in Heron Cove, north of the CAP intake. It's locations within the BWRNWR ranged from the eastern to western extents of the refuge. Contact with fish 230 was frequent for the all 47 days it was contacted, with multiple detections each day. The last "live" contact with fish 230 occurred 47 days after its release on January 19, 2011. Mortality was confirmed during a SCUBA investigation on January 19, 2011.

Fish 243

Fish 243 (TL= 402 mm, M = 516 g) was contacted at the furthest point uplake by active tracking, which was 0.5 km from the stocking location, and within the BWRNWR boundary (Fig.3). The furthest upriver contact location was 2.7 km from the stocking location, at the furthest boat accessible point. Mean distance moved between any two contacts was 0.32 km. Contacts were broken up by diel period; 50% of contacts occurred during the day, 30% occurred at night, and 20% of contacts occurred during crepuscular periods. This fish was contacted 20 times by active and passive sampling methods.

Fish 243 was found exclusively within the BWRNWR boundaries, with no detections occurring outside this boundary. Movement within the BWRNWR consisted of inhabiting locations from the eastern to the western-most extent of the refuge including the Bill Williams River. Contact with fish 243 was frequent for the first 5 days of the study. After 5 days, only one additional "live" contact was made before it was considered a mortality. The last "live" contact with fish 243 occurred 20 days after its release on March 1, 2011. Mortality was confirmed with SCUBA investigation.

Fish 244

Fish 244 (TL = 395 mm, M = 545 g) ranged from 3.6 km uplake to 1.1 km upriver of the stocking locations through the duration of the study. Both of these locations were recorded by stationary SURs. Mean distance moved between contacts was 0.54 km. Mean distance moved between contacts from passive and active sampling equipment was 0.5 km, and 0.2 km, respectively. SUR contacts were broken up by diel period; 18% of contacts occurred during the day, 69% occurred at night, and 11% of contacts occurred during crepuscular periods.

Fish 244 was primarily found within the BWRNWR boundaries, with only 3 detections occurring outside this boundary: one in Heron Cove and two detections near Gene Wash Cove (Fig. 3). Contact with tag 244 was frequent upon release into the lake, and occurred daily for the first 15 days. After this, only one additional "live" contact was made. Prior to being suspected a mortality, this fish was contacted 85 times using active and passive sampling methods.

Mortality was suspected 33 days into the 6-month study, and was confirmed during a SCUBA investigation. The last "live" contact with fish 244 occurred on January 5, 2011.

Fish 245

Fish 245 (TL = 396 mm, M = 516 g) ranged from 4.6 km uplake to 2.1 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by active tracking in Gene Wash Cove, and its upriver-most location was recorded by active tracking. Fish 245 was also the only tagged fish to utilize the narrowest section of the Bill Williams River. Mean distance moved between contacts was 0.39 km. Mean distance moved between contacts from passive and active sampling equipment was 0.3 km, and 0.2 km, respectively.

Ninety-nine percent of the movements for fish 245 were recorded by SURs, with only 1% of contacts occurring by active tracking. This fish was contacted 137 times by both active and passive sampling methods and was tracked for 60 days of the 6-month study. SUR contacts were broken up by diel period; 21% of contacts occurred during the day, 64% occurred at night, and 13% of contacts occurred during crepuscular periods.

Fish 245 was found primarily within the BWRNWR boundaries, with only 12 detections occurring outside this boundary; 11 occurring outside Gene Wash Cove, and one occurring in Gene Wash Cove. Contact with tag 245 occurred frequently for two months after the stocking event. The last "live" contact with fish 245 occurred on February 1, 2011. Mortality was confirmed during a SCUBA investigation on March 2, 2011.

Fish 246

Fish 246 (TL = 393 mm, M = 606 g) ranged from 3.6 km uplake to 2.1 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by a stationary SUR on the North West side of the reservoir near Gene Wash Cove, and its upriver-most location was recorded by an SUR stationed in the cattail channels of the Bill Williams River.

Mean distance moved between contacts was 0.52 km. Mean distance moved between contacts from passive and active sampling equipment was 0.5 km, and 0.7 km, respectively. SUR contacts were broken up by diel period; 16% of contacts occurred during the day, 64% occurred at night, and 20% of contacts occurred during crepuscular periods. Ninety-nine percent of the movements for fish 246 were recorded by SURs, with only 1% of contacts occurring by active tracking. This fish was contacted 45 times by both active and passive sampling methods, and was tracked for 33 days of the 6-month study.

Fish 246 was found exclusively within 4 km of the stocking location during the study, with movements occurring between Gene Wash Cove, and the eastern-most areas of the BWRNWR. Contact with tag 246 was occurred almost daily for three weeks post-stocking. The last “live” contact with fish 246 occurred 28 days after release on January 5, 2011. Mortality was confirmed during a SCUBA investigation on March 2, 2011.

Fish 247

Fish 247 (TL = 385 mm, M = 588 g) ranged from 21.7 km uplake to 2.1 km upriver of the stocking locations through the duration of the study. Both locations were recorded by stationary SURs. Mean distance moved between contacts was 0.46 km. Ninety-nine percent of the movements for fish 247 were recorded by SURs, with only 1% of contacts occurring by active tracking. This fish was contacted 64 times by both active and passive sampling methods and was tracked for 58 days. SUR contacts were broken up by diel period; 24% of contacts occurred during the day, 62% occurred at night, and 14% of contacts occurred during crepuscular periods.

Fish 247 was primarily found inside the BWRNWR boundaries, with three contacts outside the boundary: at Gene Wash Cove, and at an SUR stationed at Pilot Rock, after which this fish returned to the BWRNWR area. Contact with tag 247 occurred weekly for the first two months of the study, after which contact was lost for the remainder of the study. The last contact with fish 247 occurred on January 30, 2011.

Fish 248

Fish 248 (TL = 397 mm, M = 536 g) ranged from 18.8 km uplake to 1.1 km upriver of the stocking location through the duration of the study. Both locations were recorded by stationary SURs. Mean distance moved between contacts was 0.37 km. Mean distance moved between contacts from both active and passive tracking was 0.3 km, and 2.7 km, respectively.

Ninety-nine percent of the movements for fish 248 were recorded by SURs, with only 1% of contacts occurring by active tracking. This fish was contacted a total of 205 times by both active and passive sampling methods. SUR contacts were broken up by diel period; 31% of contacts occurred during the day, 53% occurred at night, and 16% of contacts occurred during crepuscular periods.

Fish 248 was one of the few individuals who ventured often outside the BWRNWR boundaries. Contact with tag 248 was frequent upon release into the lake, and occurred several times per day for the first five weeks of the study. After six weeks it was suspected a mortality. The last "live" contact occurred on December 23, 2010. Mortality was confirmed during a SCUBA investigation on March 2, 2011.

Fish 249

Fish 249 (TL = 383 mm, M = 544 g) ranged from 1.5 km uplake to 2.7 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by a stationary SUR at the northwest boundary of the BWRNWR, and its upriver-most location was recorded by active tracking at the furthest boat accessible point of the BWRNWR. Mean distance moved between contacts was 0.38 km. Mean distance moved between contacts from both passive and active tracking was 0.2 km, and 0.4 km, respectively.

Active tracking accounted for 1% of contacts with fish 249, with SURs detecting 99% of this fish's locations. This fish was contacted 47 times by active and passive sampling methods and was tracked for 158 days of the 6-month study. SUR contacts were broken up by diel period; 36% of contacts occurred during the day, 47% occurred at night, and 17% of contacts occurred during crepuscular periods.

Fish 249 was found exclusively within the BWRNWR boundaries. Contact with tag 249 occurred daily for six days post-stocking. This was followed by a period of non-contact lasting 26 days. It was then located by active tracking repeatedly in the cattail channels of the BWRNWR. The last "live" contact with fish 249 occurred 32 days after release on March 10, 2011. Mortality is suspected, but could not be confirmed with a SCUBA investigation, as the transmitter was inaccessible in large woody debris.

Fish 257

Fish 257 (TL = 388 mm, M = 492 g) ranged from 18.7 km uplake to 1.1 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by and SUR stationed near Steamboat Cove (Fig. 3), and its upriver-most location was recorded by an SUR stationed at the US-95 Bridge. Mean distance moved between contacts was 0.19 km. Mean distance moved between contacts from passive and active sampling equipment was 0.1 km, and 0.5 km, respectively. SUR contacts were broken up by diel period; 32% of contacts occurred during the day, 53% occurred at night, and 16% of contacts occurred during crepuscular periods.

Active tracking accounted for 1% of contacts with fish 257, with SURs detecting 99% of this fish's locations. This fish was contacted a total of 313 times by both active and passive sampling methods throughout the length of the study.

Fish 257 was found primarily within the BWRNWR boundaries, with only one detection occurring outside this boundary 3.6 km upstream at Gene Wash Cove. This fish was suspected to be a mortality after January 18, 2011 and this suspicion was confirmed during a SCUBA investigation on June 8, 2011.

Fish 258

Fish 258 (TL = 404 mm, M = 555 g) ranged from 3.6 km uplake of the stocking location, and was not detected upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by an SUR near Gene Wash Cove (Fig. 3). Mean distance moved between contacts was 0.62 km. Mean distance moved between contacts from passive and active sampling equipment was 0.4 km, and 1.1 km, respectively.

Active tracking accounted for 1% of contacts with fish 258, while SURs detected 99% of this fish's locations. This fish was contacted 15 times by active and passive sampling methods and was tracked for 3 days of the 6-month study, before it was suspected to be a mortality. SUR contacts were broken up by diel period; 40% of contacts occurred during the day, 46% occurred at night, and 14% of contacts occurred during crepuscular periods.

This fish was tracked within and just outside of the BWRNWR for two days post-stocking, where it was detected during active tracking on December 6, 2010. After this date, Fish 258 was suspected to be a mortality. Mortality was confirmed by recovering the transmitter during a SCUBA investigation on June 8, 2011.

Fish 259

Fish 259 (TL = 392 mm, M = 497 g) ranged from 3.6 km uplake to 1.1 km upriver of the stocking locations through the duration of the study. Both locations were recorded by stationary SURs. Mean distance moved between contacts was 0.43 km. Mean distance moved between contacts from passive and active sampling equipment was 0.4 km, and 0.2 km, respectively.

Active tracking accounted for 1% of contacts with fish 259, while SURs detected 99% of this fish's locations. This fish was contacted 14 times by both active and passive sampling methods for and was tracked for 104 days of the 6-month study. SUR contacts were broken up by diel period; 21% of contacts occurred during the day, 64% occurred at night, and 14% of contacts occurred during crepuscular periods.

Fish 259 was found exclusively within the BWRNWR boundaries three days post-stocking, after which contact was lost for 14 weeks. After this period of non-contact, it was detected on an SUR near Gene Wash Cove, 3.6 km uplake of the stocking location. The last contact with fish 259 was 104 days after release on March 17, 2011.

Fish 260

Fish 260 (TL = 390 mm, M = 583 g) ranged from 1.5 km uplake to 2.9 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by a stationary SUR located on the northwest boundary of the BWRNWR (Fig. 3), and its upriver-most location was recorded by active tracking at the eastern-most boat-accessible part of the BWRNWR. Mean distance moved between contacts was 0.75 km. Mean distance moved between contacts from passive and active sampling equipment was 0.6 km, and 1.0 km, respectively.

Active tracking accounted for 1% of contacts with fish 260, while SURs detected 99% of this fish's locations. This fish was contacted 18 times by active and passive sampling methods and was tracked for 45 days of the 6-month study. SUR contacts were broken up by diel period; 22% of contacts occurred during the day, 67% occurred at night, and 11% of contacts occurred during crepuscular periods.

Fish 260 was found exclusively within the BWRNWR boundary for the duration of the study. Contacts with fish 260 were frequent for the first four days of the study, and ranged from locations at the eastern and western-most points of the BWRNWR. The last contact with Fish 260 occurred 45 days after release on January 17, 2011.

Fish 261

Fish 261 (TL = 402 mm, M = 551 g) ranged from 3.6 km uplake to 2.1 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by a stationary SUR located near Gene Wash Cove (Fig. 3), and its upriver-most location was recorded by a stationary SUR in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.32 km. Mean distance moved between contacts from passive and active sampling equipment was 0.3 km, and 0.4 km, respectively.

Active tracking accounted for 1% of contacts with fish 261, while SURs detected 99% of this fish's locations. This fish was contacted 861 times by active and passive sampling methods and was tracked for 159 days of the 6-month study. SUR contacts were broken up by diel period; 27% of contacts occurred during the day, 54% occurred at night, and 19% of contacts occurred during crepuscular periods.

Fish 261 was found primarily within the BWRNWR boundaries for the length of the study, with frequent contacts near the buoy line marking the refuge boundary, and the original stocking location. Throughout the tracking period, occasional uplake movements to Gene Wash Cove were recorded by stationary SURs (Fig. 3; 3.6 km uplake of stocking site). The last contact with fish 261 occurred 159 days after release on March 11, 2011.

Fish 263

Fish 263 (TL = 391 mm, M = 512 g) was contacted 3.6 km away from the stocking location at its uplake-most point, and was not found upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by a stationary SURs located near Gene Wash Cove (Fig. 3). Mean distance moved between contacts was 0.39 km. Mean distance moved between contacts from passive and active sampling equipment was 0.2 km, and 0.4 km, respectively.

Active tracking accounted for 1% of contacts with fish 263, while SURs detected 99% of this fish's locations. This fish was contacted 223 times by both active and passive sampling methods and was tracked for 33 days of the 6-month study. SUR contacts were broken up by diel period; 30% of contacts occurred during the day, 54% occurred at night, and 16% of contacts occurred during crepuscular periods.

Fish 263 was found inside and near the BWRNWR boundaries for the entirety of its contact history, with frequent contacts at the original stocking location, uplake near the buoy line marking the refuge boundary, and uplake of the boundary near Gene Wash Cove. Mortality was suspected 33 days after release on January 5, 2011. Mortality was confirmed during a SCUBA investigation to recover this transmitter on June 8, 2011.

Fish 264

Fish 264 (TL = 426 mm, M = 750 g) ranged from 1.0 km uplake to 1.1 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by an SUR stationed at the southwest boundary of the BWRNWR, and its upriver-most location was recorded by an SUR stationed at the US-95 Bridge. Mean distance moved between contacts was 0.07 km. Mean distance moved between contacts from passive and active sampling equipment was 0.03 km, and 0.2 km, respectively.

Active tracking accounted for 1% of contacts with fish 264, while SURs detected 99% of this fish's locations. This fish was contacted 298 times by active and passive sampling methods for 159 days of the 6-month study. SUR contacts were broken up by diel period; 27% of contacts occurred during the day, 56% occurred at night, and 17% of contacts occurred during crepuscular periods.

Fish 264 was found exclusively within the boundaries of the BWRNWR for this study, from the refuge boundary to the US-95 Bridge. The last contact with Fish 264, recorded 159 days after release on March 11, 2011.

Fish 272

Fish 272 (TL = 385 mm, M = 459 g) ranged from 1.0 km uplake and 1.1 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by an SUR stationed on the southwest boundary of the BWRNWR (Fig. 3), and its upriver-most location was recorded by an SUR stationed at the US-95 Bridge. Mean distance moved between contacts was 0.09 km. Mean distance moved between contacts from passive and active sampling equipment was 0.1 km, and 0.4 km, respectively.

Active tracking accounted for 1% of contacts with fish 272, while SURs detected 99% of this fish's locations. This fish was contacted 544 times by both active and passive sampling methods for 60 days of the 6-month study. SUR contacts were broken up by diel period; 29% of contacts occurred during the day, 54% occurred at night, and 17% of contacts occurred during crepuscular periods.

Fish 272 was found exclusively within the BWRNWR, from the eastern to western-most boundaries. For six weeks this fish was detected daily by SURs. The last "live" contact with Fish 272 was recorded 60 days after release. Mortality was confirmed during a SCUBA investigation to recover this transmitter on March 2, 2011.

Fish 273

Fish 273 (TL = 380 mm, M = 457 g) ranged from 1.9 km uplake of the stocking location, and 1.1 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by active tracking just outside of the BWRNWR boundary (Fig. 3). Its upriver-most location was recorded by an SUR stationed at the US-95 Bridge. Mean distance moved between contacts was 0.27 km. Mean distance moved between contacts from passive and active sampling equipment was 0.2 km, and 0.4 km, respectively.

Active tracking accounted for 1% of contacts with fish 273, while SURs detected 99% of this fish's locations. This fish was contacted 239 times by active and passive sampling methods for 88 days of the 6-month study. SUR contacts were broken up by diel period; 32% of contacts occurred during the day, 52% occurred at night, and 16% of contacts occurred during crepuscular periods.

Fish 273 was found within and near the BWRNWR for the two months it was contacted, however only two contacts were outside the refuge boundary. This fish ranged from the western boundary to the US-95 Bridge within the refuge. Mortality was suspected after March 1, 2011. Mortality was confirmed during a SCUBA investigation to recover this transmitter on June 8, 2011.

Fish 274

Fish 274 (TL = 382 mm, M = 471 g) ranged from 29.9 km uplake of the stocking location, and 0.5 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by an SUR stationed near Lake Havasu City, and its upriver-most detection was recorded by active tracking just east of the stocking location. Mean distance moved between contacts was 1.25 km. Mean distance moved between contacts from passive and active sampling equipment was 1.2 km, and 0.7 km, respectively.

Active tracking accounted for 1% of contacts with fish 274, while SURs detected 99% of this fish's locations. This fish was contacted 51 times by both active and passive sampling methods for 15 days of the 6-month study. SUR contacts were broken up by diel period; 32% of contacts occurred during the day, 50% occurred at night, and 18% of contacts occurred during crepuscular periods.

Fish 274 was the most traveled fish of the study. This individual left the BWRNWR, and SURs detected its uplake movement, documenting its location at Gene Wash Cove, Black Meadow Landing, Mohave Point, Steamboat Cove, Pilot Rock, Copper Canyon, and the London Bridge Channel. It was contacted during its journey back south, and then was detected inside Gene Wash Cove. This was the last "live" contact with Fish 274, recorded 15 days after release on December 17, 2010. Mortality was confirmed during a SCUBA investigation to recover this transmitter on January 19, 2011.

Fish 275

Fish 275 (TL = 383 mm, M = 566 g) ranged from 1.0 km uplake of the stocking location, and 2.8 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by an SUR stationed at the southwest boundary of the BWRNWR (Fig. 3). Its upriver-most location was detected during an active tracking event at the eastern-most boat-accessible point of the BWRNWR. Mean distance moved between contacts was 0.14 km. Mean distance moved between contacts from passive and active sampling equipment was 0.1 km, and 0.5 km, respectively.

Active tracking accounted for 1% of contacts with fish 275, while SURs detected 99% of this fish's locations. This fish was contacted 719 times by active and passive sampling methods for 95% of the 6-month study. SUR contacts were broken up by diel period; 39% of contacts occurred during the day, 43% occurred at night, and 18% of contacts occurred during crepuscular periods.

Fish 275 was found exclusively within the boundaries of the BWRNWR, with contacts at the eastern and western-most points of the refuge. This was one of the most frequently contacted fish throughout the study. The longest period of non-contact was 13 days. The last contact with Fish 275, recorded 172 days after release on May 24, 2011.

Fish 277

Fish 277 (TL = 402 mm, M = 534 g) ranged from 3.6 km uplake of the stocking location, and 2.1 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by an SUR stationed near Gene Wash Cove on the California side. Its upriver-most location was detected during by an SUR stationed in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.08 km. Mean distance moved between contacts from passive and active sampling equipment was 0.05 km, and 0.3 km, respectively.

Active tracking accounted for 1% of contacts with fish 277, while SURs detected 99% of this fish's locations. This fish was contacted 584 times by both active and passive sampling methods for 33% of the 6-month study. SUR contacts were broken up by diel period; 32% of contacts occurred during the day, 52% occurred at night, and 16% of contacts occurred during crepuscular periods.

Fish 277 was found primarily in the BWRNWR, was detected throughout the refuge waters, and was found as far uplake as Gene Wash Cove. This fish was contacted almost daily until contact was lost. This was the last contact with Fish 277, recorded 60 days after release on February 1, 2011.

*Fish 230**

Fish 230* (TL = 493 mm, M = 820 g). This fish was tracked for 71% of the study post-stocking (February 2011). Fish 230* was contacted a total of 779 times from both active and passive detections. When broken up into diel periods, 44% of contacts occurred during the day, 38% at night, and 19% during crepuscular periods.

This fish ranged from 3.6 km uplake of the stocking location, and 2.1 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by an SUR stationed near Gene Wash Cove on the California side. Its upriver-most location was detected during by an SUR stationed in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.24 km. Mean distance moved between contacts from passive and active sampling equipment was 0.2 km, and 0.4 km, respectively. Active tracking accounted for 1% of contacts with fish 230*, while SURs detected 99% of this fish’s locations.

Fish 230* was found primarily within the BWRNWR, with detections in only two locations outside this boundary. Its movements consisted of detections throughout the boundary, and repeated detections at SURs located throughout the refuge area, and 3.6 km uplake of the stocking location. What is interesting about the movements of this fish, is that it had been living in the BWRNWR for at least two months prior to being tagged and had survived. The last contact with Fish 230*, recorded 102 days after capture on May 24, 2011.

*Fish 274**

Fish 274* (TL = 480 mm, M = 860 g). This fish was tracked for 69% of the study post-stocking (February 2011). Fish 274* was contacted a total of 161 times from both active and passive detections. When broken up into diel periods, 30% of contacts occurred during the day, 50% at night, and 20% during crepuscular periods.

This fish ranged from 3.6 km uplake of the stocking location, and 2.1 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by an SUR stationed near Gene Wash Cove on the California side. Its upriver-most location was detected during by an SUR stationed in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.21 km. Mean distance moved between contacts from passive and active sampling equipment was 0.2 km, and 1.0 km, respectively. Active tracking accounted for 1% of contacts with fish 274*, while SURs detected 99% of this fish's locations.

Fish 274* was found primarily within the BWRNWR, but was found as far uplake as Gene Wash Cove on one occasion. Movements generally consisted of detections from SURs throughout the BWRNWR. This fish was a recapture, and when it was implanted with the transmitter, it had been living and surviving in the BWRNWR for at least two months. The last contact with Fish 274* was recorded 98 days after capture on May 20, 2011.