Distribution and post-stocking survival of bonytail in Lake Havasu

2010 Annual Report

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Summary

Perseverance of bonytail *Gila elegans* in the Colorado River basin relies entirely on stocking and Lake Havasu is one of few locations where individuals are occasionally contacted. Little information is available concerning the basic ecology of this critically endangered species and a limited number of telemetry studies have been conducted. The only previous study that took place in Lake Havasu indicated a majority of telemetered bonytail dispersed near shore or in coves. Unfortunately, high mortality of tagged fish prevented conclusions from being drawn about dispersal or habitat preferences of bonytail in that system.

We completed the first of a three-year comprehensive study to determine post-stocking dispersal and mortality of bonytail in Lake Havasu using acoustic telemetry. For the initial investigation, small acoustic transmitters (three-month battery life) were surgically implanted in 20 bonytail during April 2010. Individuals were released into Lake Havasu at Bill Williams River National Wildlife Refuge (BWRNWR) along with a batch stocking of 1,880 additional bonytail. Tagged fish were tracked actively by boat and passively with submersible ultrasonic receivers for three months. Fish dispersed between 2.6 km upriver into the Bill Williams River and 27.1 km uplake (toward Lake Havasu City) of the stocking location, but largely remained within a 2-km radius of the release site. Number of fish contacts declined each week, but by the end of the study only one mortality (95% survivorship) was confirmed using SCUBA. Tagged fish moved a mean distance of 0.6 km between contacts. In contrast to previous bonytail telemetry studies, most fish were associated with open waters of the reservoir with little apparent use of near-shore habitats. After the first week, number of fish contacts was greater during crepuscular and nighttime hours compared to daytime. In addition, 42% of fish contacts were in locations with low Secchi disk readings (≤ 0.5 m).

Between July and October 2010, a tag retention study was completed at Dexter National Fish Hatchery & Technology Center to assess our surgical techniques and monitor tagged fish health. Twenty bonytail were implanted with acoustic transmitters (10 fish received three-month tags and 10 received larger six-month tags) and retained in an indoor hatchery raceway along with twenty control fish. No transmitters were shed and all fish remained healthy throughout the three-month study.

High survivorship from our initial telemetry study and results from the transmitter retention study alleviated concerns about post-surgical mortality, and 20 additional bonytail were implanted with six-month acoustic transmitters during December 2010. Those fish were released at BWRNWR along with 2,060 additional bonytail. Active and passive tracking are currently taking place and those results will be provided in our 2011 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 (Fig. 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.

The reservoir's fish community is comprised primarily of introduced nonnative fishes, which support a popular recreational and sport fishery. Three species of Colorado River endemic fishes— a minnow, bonytail *Gila elegans*, and two suckers, flannelmouth sucker *Catostomus latipinnis* and razorback sucker *Xyrauchen texanus*—persist in Lake Havasu; of which, bonytail is considered the most critically endangered (Marsh 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 (Minckley and Thorson 2007; US Bureau of Reclamation 2006) and Lake Havasu is one of few locations where bonytail are occasionally contacted. Past capture events were an indirect result of the Lake Havasu Fishery Improvement Project (1993-2003) which was implemented primarily to enhance recreational sport fishing opportunities in the reservoir and, in part, to augment nearly extirpated populations of razorback sucker and bonytail (Doelker 1994). The resulting socio-economic benefits to the sport fish program have been profound (Anderson 2001), however, based on the prominence of the sport fishery, recruitment for razorback sucker and bonytail remained predictably non-existent (Mueller and Marsh 2002, Marsh and Pacey 2005) and both species continue to rely exclusively on stocking to retain a presence in the wild. More recently, a biological opinion has required the MSCP and USFWS to continue stocking efforts in Reach 3. To date, nearly 200,000 bonytail have been stocked into Lake Havasu, of which, approximately 200 individuals (about 0.1%) have been recaptured as a result of routine monitoring (Lower Colorado River Native Fishes PIT Tag Database, C. Pacey, Marsh & Associates, personal communication).

Monitoring typically occurs in February by personnel from US Fish and Wildlife Service (USFWS), US Geological Survey, US Bureau of Reclamation (Reclamation), Bureau of Land Management (BLM), California Department of Fish and Game (CADFG), Arizona Game and Fish Department (AZGFD), and Nevada Department of Wildlife (NVDOW). Surveys involve trammel netting and occasionally boat shocking the lake portion of the reservoir and the Bill Williams River delta, while the river portion of the reservoir is monitored upstream to Moabi Regional Park near Needles, California. Additional bonytail contacts have been made by anglers who occasionally capture bonytail, often near artificial fishing structures that were placed in the reservoir as part of the Lake Havasu Fishery Improvement Project. Aside from infrequent recaptures, little information is available concerning the basic ecology of bonytail in Lake Havasu. A limited number of telemetry studies elsewhere in the basin suggest bonytail 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). To date, only one bonytail telemetry study has occurred in Lake Havasu (Minckley 2006) and its results indicate a majority of telemetered fish dispersed near shore or in coves. Unfortunately, high mortality of tagged fish prevented conclusions from being drawn about seasonal dispersal or habitat preferences of bonytail in that system. Reasons for mortality are unknown, but previous work in lower Colorado River backwaters (Schooley et al. 2008) and in Lake Havasu (Doelker 1994; Mueller 2003) cited predation of bonytail by nonnative fishes and birds among factors limiting their post-stocking survival. Because stocked fish do not survive there is also no reproduction or recruitment. Thus, under current conditions, conservation and recovery potential are low for this species.

While predation is likely the primary reason for poor bonytail survival in Lake Havasu, key questions regarding their post-stocking survival remain unanswered. Namely, is it possible to increase the number of contacts in Lake Havasu to more clearly understand patterns of dispersal and habitat use? What areas of the reservoir, if any, serve as refugia within the system for the small percentage of bonytail that continue to persist? In order to answer these questions and accurately evaluate the efficacy of the bonytail stocking program in Lake Havasu, it is essential to broaden our understanding of their basic ecology. In response to needs identified by the MSCP, we implemented a multi-year research project that would document in detail the post-stocking distribution and survival of bonytail in Lake Havasu. 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 completed in 1938. The dam creates a 7.98×10^8 m^3 storage capacity reservoir and generates hydroelectric power for MWD and for utilities in Arizona, California, and Nevada. Bill Williams River National Wildlife Refuge (BWRNWR) occupies the southeast terminus of Lake Havasu and is characterized by the Bill Williams River and its delta (Figs. 1 & 2). 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. Cattail *Typha* spp. and sedges Cyperaceae dominate shoreline habitat. Thick beds of nuisance 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 (Mitch Thorson, USFWS, personal communication). Uplake of the refuge (toward Lake Havasu City), water clarity and depth increase and the rocky shoreline becomes sparsely lined with salt cedar *Tamarix* sp. and mesquite *Prosopis* sp. while coves are often densely vegetated with *Typha*. Since 2007, more than 620 brush bundles and artificial fishing structures have been deployed as a part of a larger effort to provide habitat for native fishes and to improve recreational fishing opportunities for 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; Doug Adams, BLM, personal communication).

Outreach

Efforts were undertaken to provide education through literature to local anglers on Lake Havasu. 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 (including 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.

April 2010 Telemetry

SUR Deployment

From 4-15 April 2010, 19 submersible ultrasonic receivers (SURs) were deployed throughout Lake Havasu (10 units), BWRNWR (eight units), and downstream of Parker Dam (one unit; Fig. 3). SURs were programmed to continuously scan select frequencies during 60 s intervals. Detection radius extended 200 m around an SUR and in some cases enabled complete shore-to-shore coverage in places where the river channel was sufficiently narrow.

Surgeries and Stocking

On 13 April 2010, USFWS staff transported 1,900 bonytail from Dexter National Fish Hatchery & Technology Center (DNFHTC), Dexter, New Mexico, to BWRNWR. Forty of the largest individuals were captured in hand nets and transferred to a dual-chamber (1893-L) holding tank filled with water from the hatchery truck. Each tank was supplied with oxygen via a split-valve regulator and air stones. A surgical station was erected under a shade structure near the boat ramp. Two additional aerated tanks (946-L) were filled with lake water and placed in the bed of a pickup truck near the surgical station.

Twenty bonytail (Table 1) were implanted with acoustic transmitters (PT-4; Sonotronics, Inc.), which were chosen based on their small size (27 mm x 9 mm; 4.2 g in air), detection range (750+ m), and battery longevity (three-months). Transmitters were individually coded, and ranged in frequency from 70 to 83 kHz (Table 2). Prior to surgery, each acoustic tag was activated with an external magnet and tested for functionality using a hydrophone and receiver.

Surgical methods generally 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 it lost equilibrium. 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 closed with 3-knot sutures using CP Medical 4/0 Polypro®blue monofilament polypropylene nonabsorbable 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 3). Tagged fish were placed in a recovery tank and monitored until they oriented themselves upright and were swimming independently. All tagged and untagged fish were released together at the BWRNWR boat ramp (Fig. 2).

Tracking Techniques and Database Management

Tracking events took place weekly, beginning near the BWRNWR boat ramp and proceeding upriver in the Bill Williams River to the farthest watercraft accessible location (approximately 2.5 km beyond the US 95 bridge; Fig 2). Tracking resumed downriver of the bridge, covering the entire watercraft-accessible portion of the Bill Williams River delta, then proceeding uplake towards Lake Havasu City, following a grid 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 were triangulated to their exact location where the date, time, surface water temperature, depth, Secchi depth, and distance to shore (DTS) were recorded. DTS was measured using a Bushnell® Yardage Pro Sport 450 Laser Rangefinder. 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. SURs were downloaded during active tracking surveys. Uplake tracking events ended when the first set of SURs with shore-to-shore coverage contained no fish contact data. Periodic surveys of the entire study area covered by SURs took place to maximize the likelihood of contact with all fish.

A Microsoft Excel database was organized for all active and passive fish contacts. SUR contacts for individual fish were considered unique only if the same fish was re-contacted by the same SUR after a two-hour period. Locations of fish recorded by SURs were broken into diel periods, 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/sunrise to one hour after sunset/sunrise; dusk and dawn). The influence of diel period was examined. The influence of this 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. An alpha level of 0.05 was used for this and all statistical tests.

Transmitter Retention Study

On 7 July 2010, an experimental transmitter retention study was initiated at DNFHTC to assess the effects of our surgical technique on bonytail. Twenty bonytail (Table 1) were implanted with acoustic transmitters (Sonotronics, Inc.) following the methods previously outlined. Ten fish received transmitter "blanks" built to the exact dimensional and weight specifications of the PT-4 transmitters used in the telemetry work. The remaining 10 fish received larger IBT-96-6-I transmitters (42 mm x 11 mm; 7.8 g in air; six-month battery life) that were recovered from previous telemetry studies (see Kesner et al. 2008) to assess the possibility of using a larger tag with a longer battery life. Following surgery, fish were released in an indoor fiberglass raceway along with 20 control fish. All fish were fed weekly by hatchery personnel, and raceways inspected for shed transmitters or mortalities. Upon completion of the three-month study, six fish were sacrificed and their abdominal cavities were opened and inspected to assess the effect of the transmitter. A t-test (Cody and Smith 2006) was used to compare growth (TL and M) between the two tag groups and control fish.

December 2010 Telemetry

SUR Deployment

Between 29 November and 3 December 2010, twenty-seven SURs were deployed throughout the project study area: 25 in Lake Havasu between Blankenship Bend and the Bill Williams River, one downriver of Parker Dam, and one in the CAP Canal downstream of the Mark Wilmer Pumping Station. Of the 25 SURs deployed in Lake Havasu, 10 were tethered to weights and sunk to the bottom of the reservoir to avoid fouling by watercraft and potential vandalism. A length of rope attached to each weight remained 3-5 m beneath the surface of the lake due to a buoyant float affixed to its opposite end, which allowed a short duration dive to attach a surface rope to the float and retrieve the SUR for downloading and maintenance. All SURs were programmed to continuously scan select frequencies during 60 s intervals.

Surgeries and Stocking

On 3 December 2010, 40 bonytail were collected from USFWS Achii Hanyo Native Fish Facility (AHNFF), Parker, Arizona. Fish were transported by truck to the boat ramp at the BWRNWR (Fig. 2) where 20 of the largest bonytail (Table 1) were hand-selected. Each was surgically implanted with an acoustic transmitter (IBT 96-6-I; Sonotronics Inc.) and PIT tag following the methods previously outlined. All experimental fish were released into Lake Havasu at the boat ramp along with 2,060 additional bonytail reared at AHNFF. Active and passive tracking began immediately following stocking and will continue through May 2011. Those results will be reported in the 2011 Annual Report.

Results

April 2010 Telemetry

Over the course of the April 2010 study, 2,668 contacts were recorded by active and passive tracking. Of those contacts, 187 (7%) were recorded by active tracking. All bonytail were located post-stocking, however, none of the tagged fish were contacted during all 13 consecutive weeks. Study fish were tracked an average of 57 days (range 14 to 90 days). The mean number of total contacts per fish was 132 (range 13 to 512). Two individuals (Fish 206 and 216) were contacted during each of the first three weeks post-stocking but never again. All other fish were tracked initially, and then experienced various periods of non-detection by both passive and active tracking, only to be contacted again prior to the end of the study (Fig. 4). Total contacts for all fish declined weekly, and by the last week of the study when all tags presumably had expired, no fish were contacted (Fig. 5).

Study fish accumulated a total of 1,755 km after release. Mean movement between contacts was 0.6 km (range 0 to 22.3 km). Fish dispersed between 2.6 km upriver into the Bill Williams River (the limit of our ability to ascend the river with tracking equipment) and 27.1 km uplake of the stocking location. The majority of fish (65%) remained within the boundary of BWRNWR (see Fig. 2). Three individuals that dispersed to the uplake portion of the reservoir, never returned to BWRNWR. Two of those fish (210 and 222) remained active through the end of the study, while one (fish 203) was suspected as a mortality (Appendix A). During the last week of the study, a SCUBA diver investigated fish 203, which was repeatedly detected in the same location. The transmitter was recovered from the bottom of the reservoir and no fish remains were found in its vicinity.

Analysis of SUR data indicated the number of contacts/hour during the day (0.84), night (1.38), and crepuscular (1.42) periods were not significantly different (F = 2.63, df = 2, P = 0.07). When evaluated by sample week, day contacts were highest during the first week, after which, crepuscular periods typically yielded more contacts/hour (Fig. 6). When data from the first week were excluded from the analysis, there was a significant difference between crepuscular and daytime detections (F= 4.64, df = 2, P = 0.01), however night detections were not significantly different from either day or crepuscular detections.

Site-specific habitat characteristics varied among active contact locations (Table 5); mean (±SE) water temperature was 21.0 ± 0.2˚C, water depth was 5.2 ± 0.5 m, DTS was 129 ± 10.2 m, and Secchi depth was 2.3 ± 0.2 m. Forty-two percent of Secchi readings were 0.5 m or less, all of which were taken during the first seven weeks of the study (Fig. 7).

Transmitter Retention Study

Throughout the transmitter retention study at DNFHTC, all 40 bonytail (20 experimental, 20 control) remained active and healthy and no transmitters were shed. Incisions on experimental fish had properly healed, with only minor irritation surrounding sutures three months after surgery, and no irritation after nine months (Fig. 8). Six bonytail were sacrificed at the conclusion of the study (three fish implanted with three-month tags and three fish with six-month tags) to assess transmitter position within the body cavity and condition of the incision. No transmitters were encapsulated with connective tissue (e.g., Tyus 1988) and all incisions had healed. Mean change in total length for all three fish groups (control, three-month tags and six-month tags) was 8.9, 10.2, and 9.1 mm respectively. Mean change in weight was positive for control (12.5 g) and three-month tags (7.0 g) while six-month tags showed a slight drop in weight (-1.5 g). When growth was compared between the two tag groups, there was no significant difference between groups in length ($t = 0.30$, df = 18, P = 0.76) or weight ($t = 0.07$, df = 18, P = 0.94).

Discussion

This study deliberately employed a conservative approach to work toward our goal of determining post-stocking survival, dispersal, and habitat use by bonytail in Lake Havasu. In order to answer the latter points with clarity, we first needed to determine if fish were surviving the initial post-stocking period. During the April 2010 study, bonytail survival was exceedingly high; up to 95% of tagged fish lived. Though only three months in duration, this initial study confirmed bonytail survived longer than previously experienced in Lake Havasu (Minckley 2006), or elsewhere in the lower Colorado River basin (Minckley and Thorson 2007; Karam and Marsh 2010). Our study fish provided limited evidence that stocked bonytail almost exclusively utilized habitat in and near BWRNWR. Additionally, results from the experimental transmitter retention study at DNFHTC established our surgical techniques were sound, and validated use of both three and six-month transmitters for this and upcoming telemetry work.

During the April 2010 study, a single transmitter was recovered using SCUBA, while movements of the other 19 bonytail were tracked (either regularly or sporadically) for the duration of the study period. A relationship between release size and post-stocking survival has been shown for a number of fishes, including razorback sucker (Marsh et al. 2003; Schooley and Marsh 2007). Based on the large size of bonytail used in the Minckley 2006 telemetry study, we would have predicted higher post-stocking survival and can only speculate as to why those fish died. The bonytail released during the April 2010 study were some of the largest bonytail released to date (Table 4). Those fish were intended for stocking during the previous year but were "held over" by DNFHTC personnel until the following year. This extra time for growth may have allowed them to escape the gape size of some predatory fish in Lake Havasu, though predation attempts by a striped bass were witnessed the day of their release.

The sporadic detections, including fish not contacted during the final weeks of the study, were not determined to be mortalities based on the long periods of non-contact. Instead, these periods of non-contact followed by re-establishing contact bring to light the real world application of the monitoring equipment, and demonstrate that even though some fish were not detected by either passive or active sampling gear, they were still likely active in the system. Similar scenarios have been witnessed 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 (Kesner et al. 2010), or years later by remote PIT-scanning equipment (unpublished data). It is plausible that some of the fish not contacted in the study were removed from the system by avian predation, or some other source of mortality, such as angling, but based on those periods of non-contact, they were likely at large in the lake.

In further support of our contention that these fish were surviving, it was reported that recreational anglers caught bonytail on the BWNWR fishing docks seven months after bonytail were last stocked, and nearly three months after the initial telemetry study had ended. Of the four fish captured in October 2010 and reported to the USFWS Parker office, one was retained by USFWS biologists, then scanned, injected with a PIT tag, and released (M. Thorson, USFWS, personal communication).

A relatively large uplake movement pattern by three individuals was detected in this study. Two of three stayed in uplake locations, and did not return to BWRNWR. Large distances 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). However, in a previous study in Lake Havasu the largest cumulative movement was 7.2 km (Minckley 1996).

Bonytail movement was detected during day, night, and crepuscular periods, with more movement detected during crepuscular and nighttime periods. This is similar to the results of the Cibola High Levee Pond and Lake Mohave telemetry studies, which found that most of contacts occurred during evening hours (Marsh 1997; Mueller et al. 2003). Similarly, other native fish in the Colorado River, specifically razorback sucker have also shown an affinity for evening movement (Karam et al. 2008).

Our data suggest bonytail only occasionally utilized near-shore habitat, which differs from the results of a previous telemetry study in Lake Havasu that found 82% of fish contacts occurred near shoreline or in coves (Minckley 2006). However, bonytail in Lake Mohave utilized deep cover, and supported the findings of this study in the lack of shoreline contacts.

Forty-two percent of Secchi disk readings recorded at active contact locations were made in turbid water (≤ 0.5 m visibility). These low-visibility readings took place within the first seven weeks of the study and exclusively took place in and near BWRNWR. During this period, the highest discharge (CMS) for this study of the Bill Williams River were recorded (Fig. 9; USGS 2011). This period also coincided with the greatest number of fish contacts (Fig. 5). This may suggest that low visibility aids in survival of this species, and this relationship will be examined further, as the closely related humpback chub *Gila cypha* has been found to utilize turbidity as cover (Stone 2010).

Continuing Studies

Upon the completion of the April 2010 telemetry study, changes in monitoring protocols were made to improve data collection in future studies. Five more SURs were purchased, and 10 SURs were re-allocated for use in Lake Havasu from other projects. In addition, a towable hydrophone was purchased from Sonotronics, which is being used to monitor fish primarily in BWRNWR, but also in coves and areas with aquatic vegetation. A new strategy for SUR placement was implemented. Tracking for the December 2010 study is currently underway. A detailed description of the methods and results will be included in the 2011 Annual Report.

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Table 1. Study date, release location, number (*N*), and mean (range) total length (TL) and mass (M) for bonytail implanted with acoustic transmitters during 2010.

Study date	Release location	*N*	TL (mm)	M (g)
April 2010	Lake Havasu	20	401 (370-428)	575 (376-755)
July 2010	DNFHTC	20	411 (380-444)	603 (500-774)
December 2010	Lake Havasu	20	393 (380-426)	540 (457-750)

Table 2. Tag number, frequency, code, and interval of acoustic transmitters used during the April 2010 bonytail telemetry study, Lake Havasu, Arizona and California.

Tag Number	Frequency	Code	Interval
202	75	4-8-7-8	1190
203	76	4-8-8-8	1180
204	77	5-6-6-6	1210
205	78	5-6-6-7	1200
206	79	5-8-6-6	1230
207	80	5-8-6-7	1220
208	81	6-8-8-8	1250
209	82	7-8-8-8	1240
210	83	3-5-7	870
212	70	5-7-8	940
213	71	5-8-6	950
214	72	3-3-3-7	960
215	73	4-6-5-6	1170
216	74	3-3-7-4	980
217	75	3-3-7-5	990
218	76	3-4-4-6	1000
219	77	3-4-4-7	1010
220	78	3-4-7-8	1020
221	79	3-4-8-8	1030
222	80	3-5-6-6	1040

Table 3. Categorical chart used to identify appropriate Baytril (Enrofloxacin) dosage based on the mass (M) of each bonytail used during acoustic transmitter surgeries.

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

Table 4. Recent bonytail stocking location, date of release, number of fish stocked (*N*) and mean size at release (TL) in Lake Havasu, Arizona and California. Fish stocked at Lake Havasu Palms Marina in February 2005 were used in the Minckley 2006 bonytail telemetry study.

Stocking Location	Date	*N*	Mean TL (mm)
Pittsburgh Point Cove	April 1996	4	262
Campbell Cove	August 1996	1	291
Lake Havasu	August 1999	222	246
Takeoff Point	Jul ’94-April ‘99	704	239
Bulkhead Cove	Oct ’95-Feb ‘99	43	264
Lake Havasu	June 2001	716	255
Topock Marsh	November 2004	1,182	291
BLM Partner's Point Work Camp	Aug ’02-Nov ‘04	15,322	289
Lake Havasu Palms Marina	February 2005	12	456
BWRNWR	October 2007	2305	300
Office Cove	Oct ’93-May ‘08	7,207	275
BWRNWR (this study)	April 2010	1,900	374
BWRNWR (this study)	December 2010	2,060	335

Table 5. Summary of mean (range) physical characteristics measured at each active contact site for all telemetered fish during the April 2010 bonytail study, Lake Havasu, Arizona and California. DTS is distance to shore.

Fish	Water depth (m)	Secchi Depth (m)	DTS (m)	Water Temp (°C)
202	2.2 (0.1- 6.4)	0.6 (0.3-2.0)	116 (8-349)	—
203	3.9 (0.1-5.4)	3.6 (0.3-5.5)	45 (0.9-216)	19.7 (18.6-20.6)
204	5.2 (0.1-11.2)	1.9 (0.3-7.0)	138 (10-290)	19.7
205	4.5 (1.6-17.6)	1.5 (0.3-6.0)	149 (1.8-418)	20.8 (19.3-22.2)
206	2.1	0.3	271	—
207	1.7 (0.5-2.9)	0.6 (0.3-1.2)	155 (0.9-417)	21.6 (20.0-23.3)
208	2.7	0.3	51 (10-85)	—
209	8.0 (0.9-15.5)	4.1 (0.3-9.5)	85 (7-361)	22.3 (20.4-26.1)
210	5.2 (0.9-9.4)	3.3 (0.3-8.0)	264 (60-367)	22.2 (19.2-25.2)
212	1.5 (0.9-2.1)	0.3 (0.3-0.5)	88 (10-221)	—
213	1.9 (0.3-3.8)	0.9 (0.3-2.0)	114 (0.9-413)	21.2 (19.5-22.7)
214	—	—	98 (3-328)	—
215	5.6 (0.9-12.1)	3.2 (0.3-7.5)	112 (0.9-351)	21.3 (18.2-25.3)
216	2.5 (0.1-5.6)	0.6 (0.3-1.5)	184 (0.9-502)	—
217	2.8 (0.9-5.9)	1.7 (0.5-5.0)	76 (0.9-257)	20.6 (18.6-23.6)
218	20.6 (17.7-23.5)	10.2 (10.0-10.5)	131 (0.9-363)	20.4 (20.1-20.8)
219	6.4 (1.0-12.2)	1.4 (0.5-3.5)	116 (0.9-344)	20.9 (19.7-23.3)
220	16.9 (12.1-19.2)	5.2 (4.5-6.0)	247 (0.9-502)	20.2 (19.0-21.5)
221	8.1 (0.7-10.3)	1.5 (0.5-2.5)	160 (0.9-352)	22.4 (20.4-24.8)
222	0.6	0.5	83 (0.9-258)	—

Figure 1. Map of Lake Havasu, Arizona, California, and Nevada, and general location within the southwestern United States (inset).

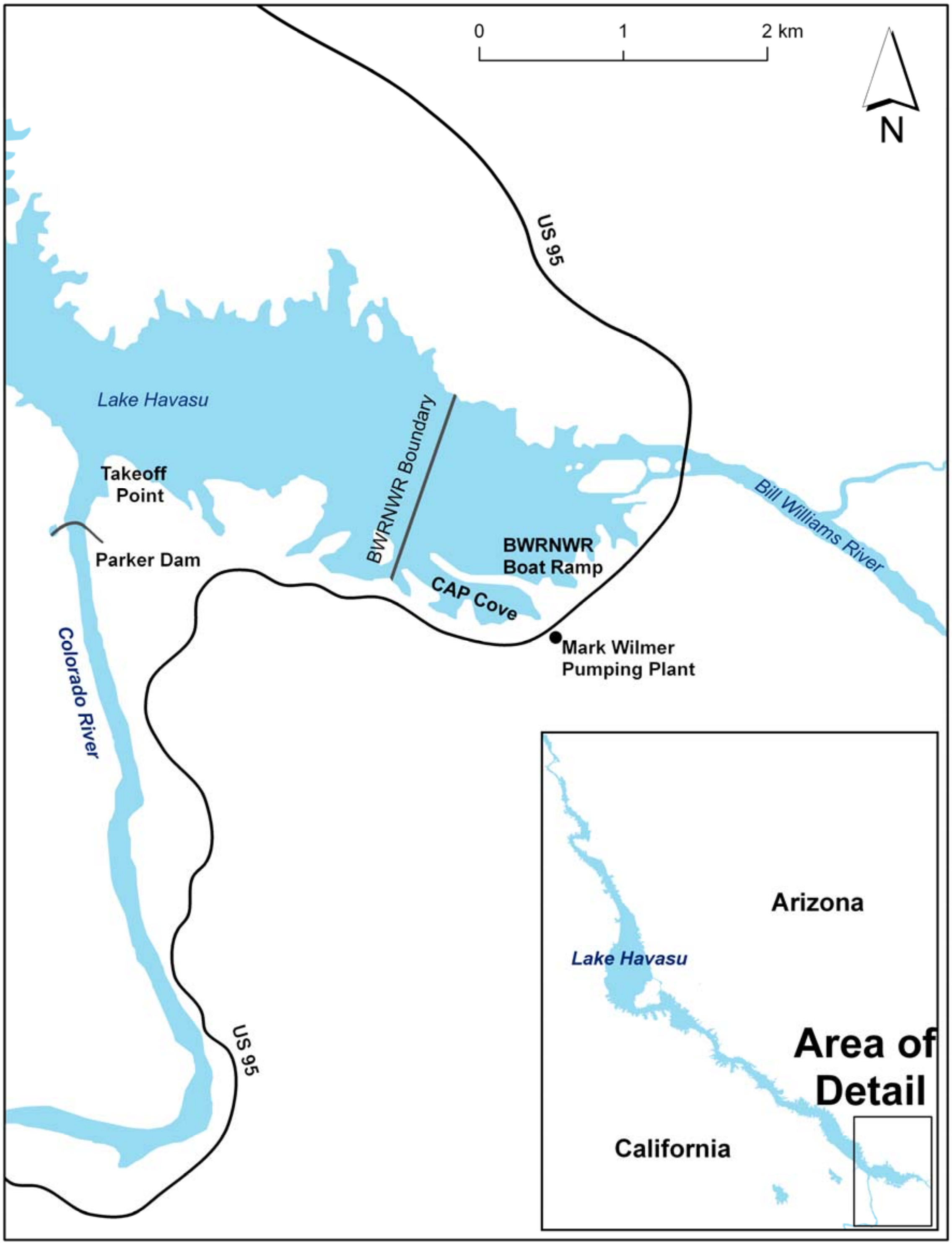

Figure 2. Detailed map of the Bill Williams River delta portion of Lake Havasu, Arizona. The BWRNWR Boat Ramp was the release site for all bonytail telemetry studies reported here.

Figure 3. Location of Submersible Ultrasonic Receivers in Lake Havasu during the April 2010 bonytail telemetry study, Lake Havasu, Arizona and California.

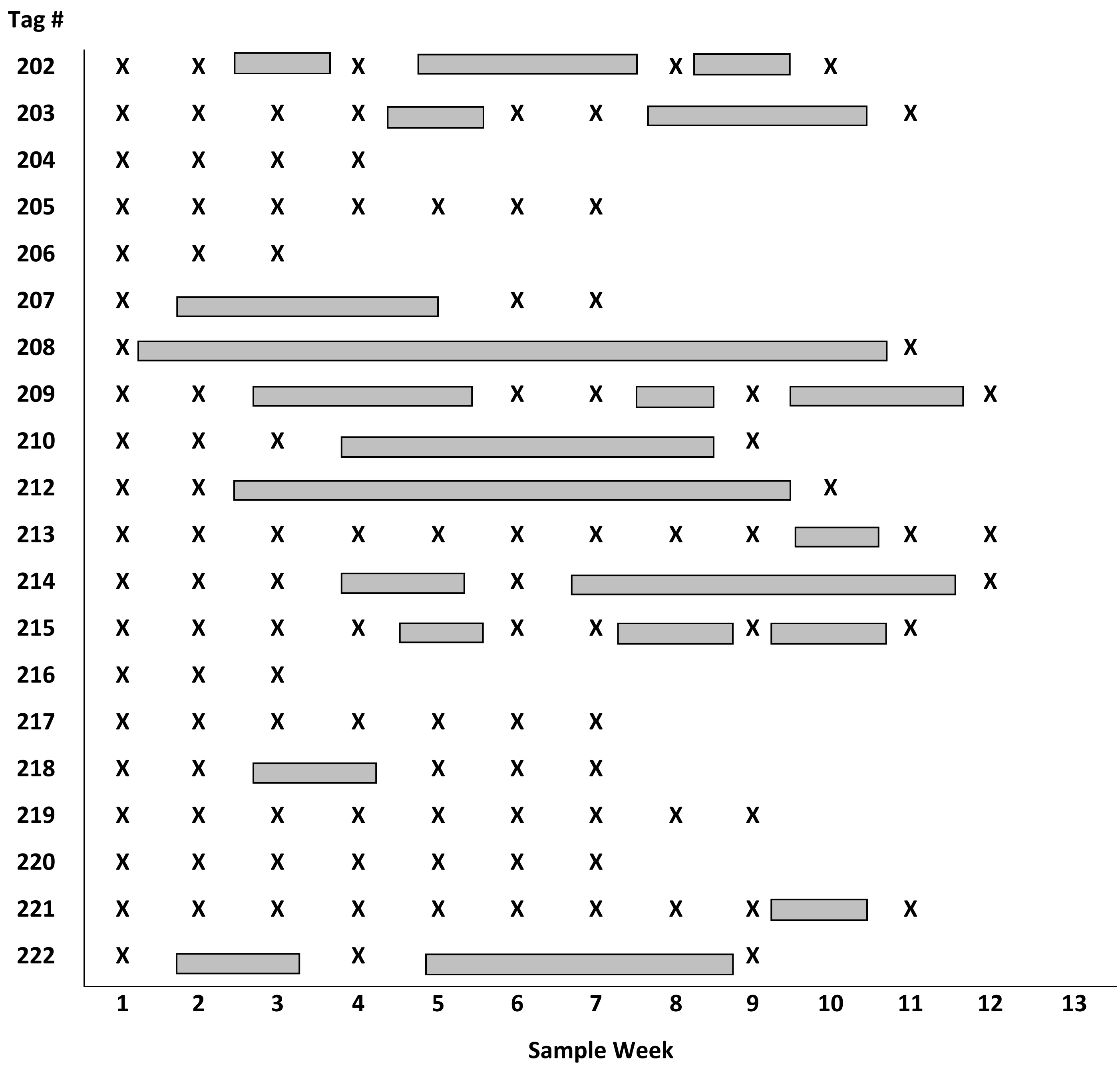

Figure 4. Weekly contacts (X) and non-contacts (gray boxes) for all study fish during the April 2010 bonytail telemetry study, Lake Havasu, Arizona and California.

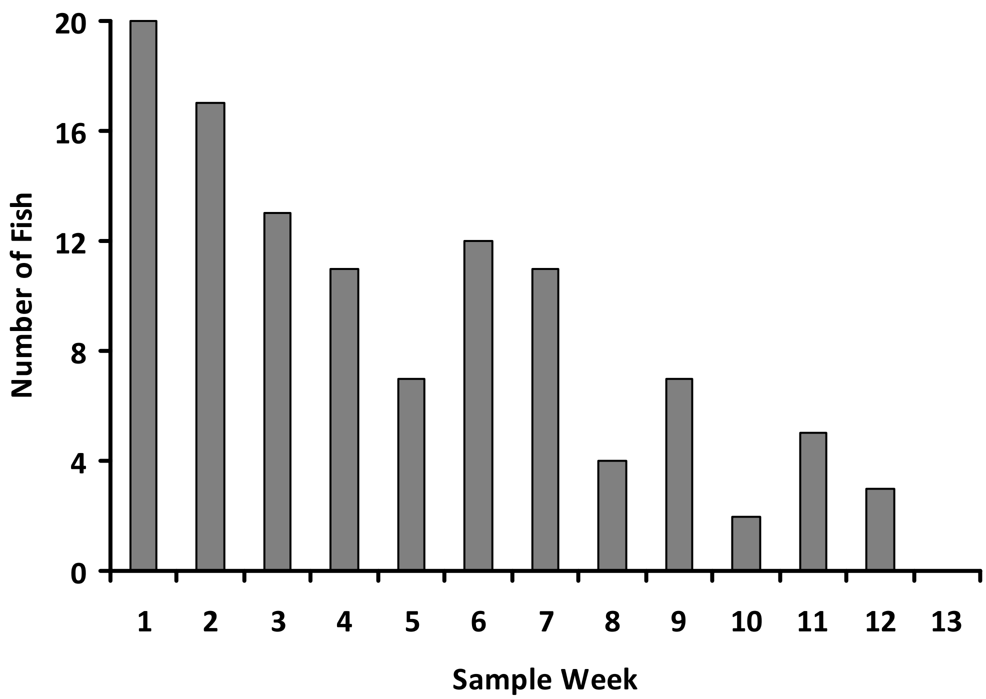

Figure 5. Total number of fish contacted per week during the April 2010 bonytail telemetry study, Lake Havasu, Arizona and California.

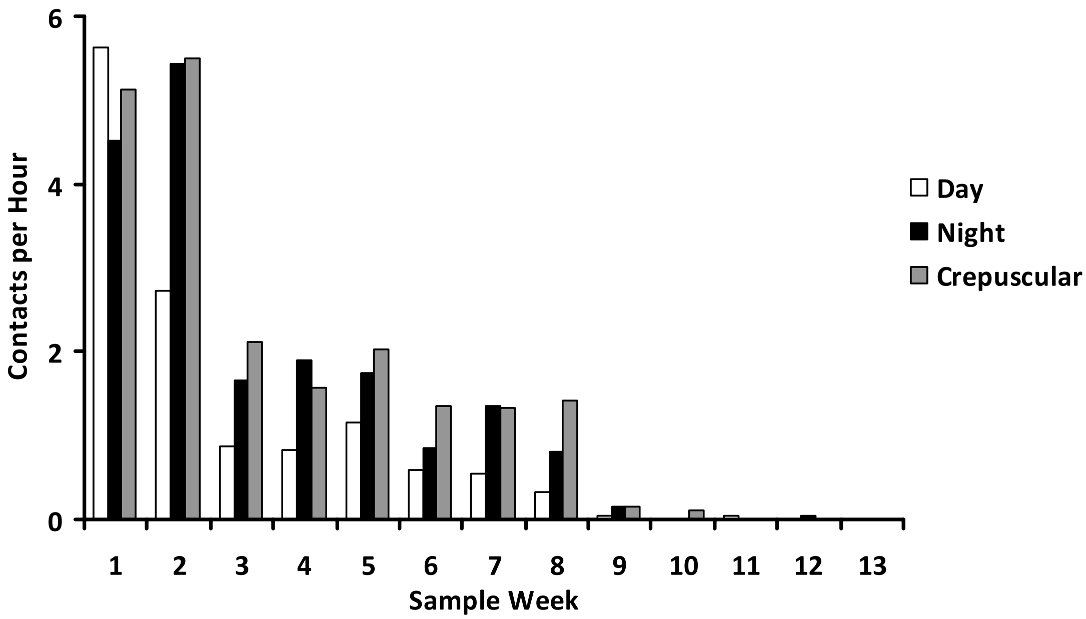

Figure 6. Diel distribution of contacts (active and passive) during the April 2010 bonytail telemetry study, Lake Havasu, Arizona and California.

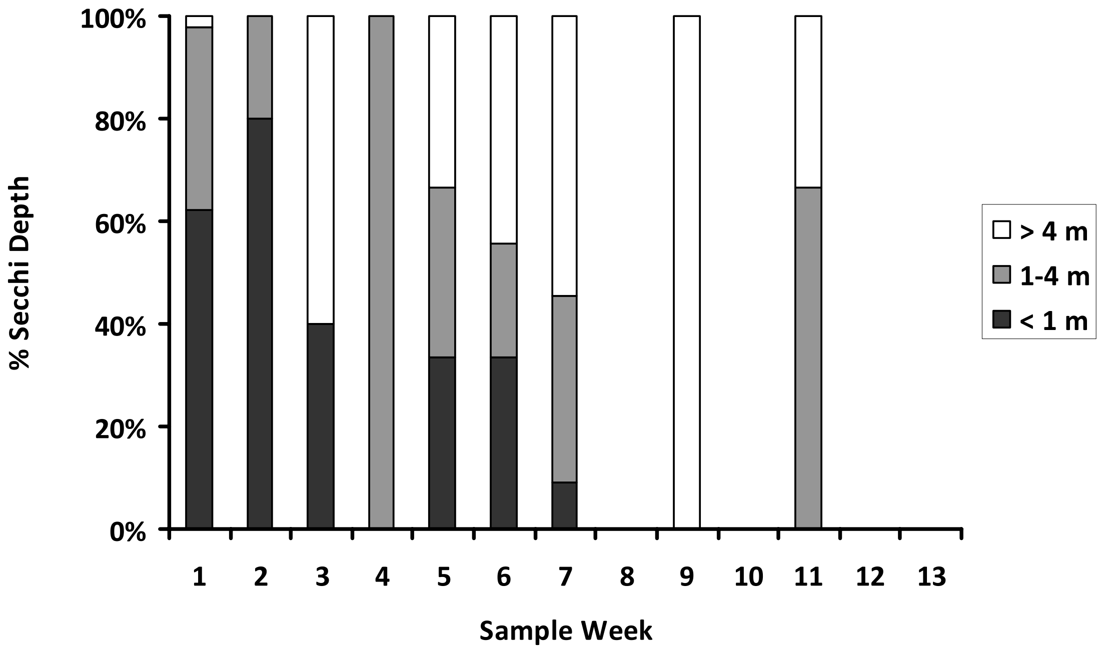

Figure 7. Secchi disk measurements taken at active contact locations during the April 2010 bonytail telemetry study, Lake Havasu, Arizona and California.

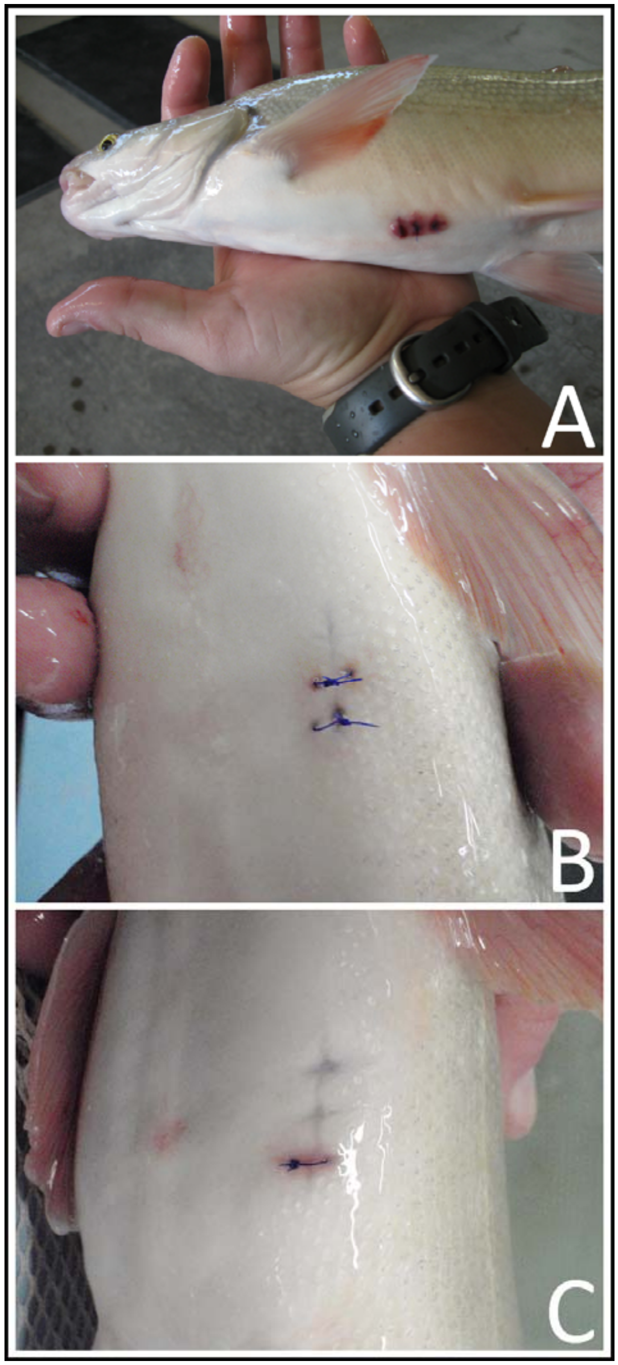

Figure 8. Site of the original incision for a captive study fish three months following surgery (A). At nine months post-surgery, a subsample of study fish was collected by DNFHTC biologists and revealed no irritation and some of the sutures had naturally fallen out (B and C). Photos B and C courtesy of USFWS.

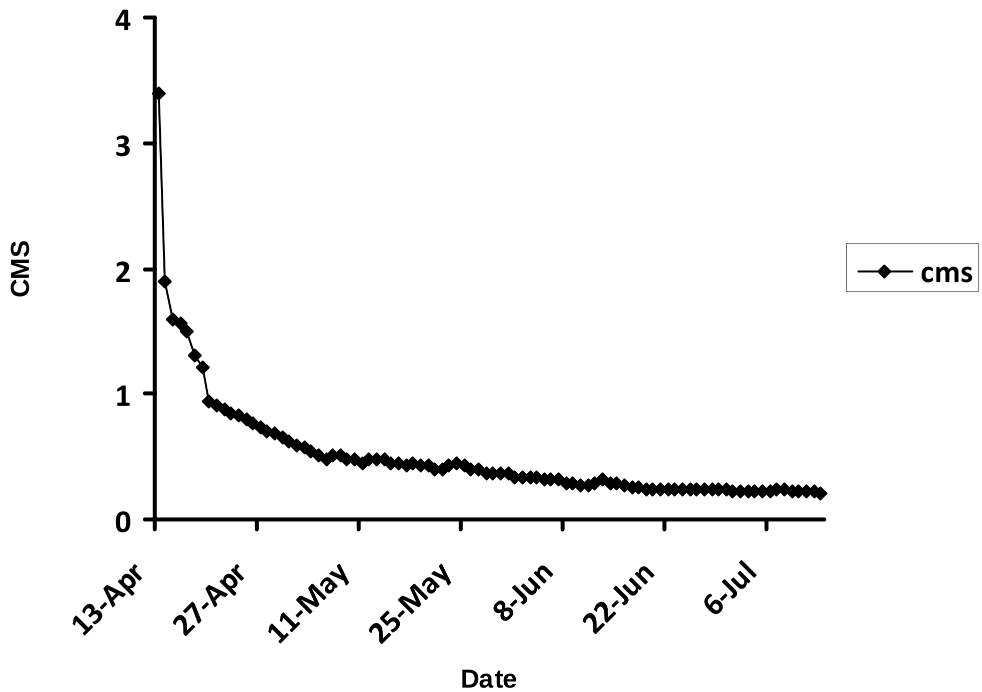

Figure 9. Daily mean discharge of the Bill Williams River during April 2010 bonytail telemetry study, BWNWR, Lake Havasu, Arizona and California (USGS 2011).

Appendix A. Individual Fish Narratives for April 2010 Bonytail Telemetry

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

Fish 202

Fish 202 (TL = 423 mm, M = 707 g) was contacted 0.1 km uplake of the BWRNWR boat ramp 20 minutes after stocking. Within three hours, fish 202 was contacted five times by active tracking and recorded once by an SUR stationed 1.2 km uplake of the stocking location. During the first 72 hours, fish 202 stayed within 3.3 km of the stocking site and was contacted 19 times. This fish was detected repeatedly at the north and south shores in BWRNWR waters, then an uplake movement was recorded by an SUR stationed north of Takeoff Point (Fig. 2). This was the uplake-most detection of fish 202.

This fish ranged from 3.3 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 near Takeoff Point, and the upriver-most location was recorded by an SUR stationed in the cattail channels of the BWRNWR, near the US 95 Bridge.

Mean distance moved between contacts was 0.7 km. Mean distance moved between contacts from passive and active sampling equipment was 0.7 km, and 0.4 km, respectively. Ninety-one percent of the movements for fish 202 were recorded by SURs, with only 9% of contacts occurring by active tracking. This fish was contacted 88 times by both active and passive sampling methods for 9.5 weeks of the three-month study.

Contacts were broken up by diel period; 16.5% of contacts occurred during the day, 68.4% occurred at night, and 15.2% of contacts occurred during crepuscular periods.

Fish 202 was primarily found within the BWRNWR boundaries, with only two detections occurring outside this boundary. The first of these occurred on 14 April when fish 202 was detected at the entrance of Heron Cove, and the second occurred on 15 April near Takeoff Point. From this point forward, fish 202 was detected only within refuge boundaries through the end of the study. Contact with fish 202 was frequent for the first 10 days of the study. After 10 days, contacts became sporadic, with as many as 27 days passing between contacts. The last contact with fish 202 occurred 67 days after its release on 18 June.

Fish 203

Fish 203 (TL= 400 mm, M = 555 g) was contacted 0.2 km upriver of the stocking location 30 minutes post-stocking. Within three hours, it was contacted five times by active tracking and recorded by SURs stationed uplake of the stocking site in BWRNWR waters. During the first 72 hours, fish 203 was contacted 21 times, and progressed in an uplake direction.

This fish was contacted at the furthest point uplake by active tracking, which was 23.5 km from the stocking location near Beaver Island (Fig.3). The furthest upriver contact location was 0.2 km from the stocking location. Mean distance moved between contacts was 0.9 km. Mean distance moved between contacts from passive and active sampling equipment was 0.3 km, and 1.4 km, respectively.

Fifty-seven percent of movements for fish 203 were recorded by SURs, with 43% of contacts occurring by active tracking. SUR contacts were broken up by diel period; 47.6% of contacts occurred during the day, 28.6% occurred at night, and 23.8% of contacts occurred during crepuscular periods. This fish was contacted 35 times by active and passive sampling methods throughout the length of the study, and displayed a large movement uplake, followed by a period of immobility.

The last movement of fish 203 was recorded on a nearby SUR on 24 April. This fish was located by active tracking on 29 April, and it is uncertain when the mortality of the fish occurred relative to the last active movement. During the last week of the study, a SCUBA diver used a UDR to locate and recover the transmitter near its last active tracking location. The transmitter was found in a relatively shallow (5 m) portion of the reservoir with a sand bottom void of aquatic vegetation. No fish remains were present near the site of recovery.

Fish 204

Fish 204 (TL = 425 mm, M = 755 g) was contacted 0.5 km uplake of the BWRNWR boat ramp two hours after stocking. Within three hours, fish 204 was contacted four times by active tracking and recorded once by an SUR stationed 1.9 km uplake of the stocking location. During the first 72 hours, fish 204 was contacted 23 times, and dispersed as far as 3.3 km uplake of the stocking site. Movements consisted of repeated detections at the north and south shores in BWRNWR waters, then an uplake movement where it was detected near Takeoff Point (Fig.2).

This fish ranged from 4.6 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 0.8 km. Mean distance moved between contacts from passive and active sampling equipment was 0.8 km, and 0.4 km, respectively.

Ninety-two percent of the movements for fish 204 were recorded by SURs, with only 8% of contacts occurring by active tracking. This fish was contacted 95 times by active and passive sampling methods for three weeks of the three-month study. SUR contacts were broken up by diel period; 35.2% of contacts occurred during the day, 45.5% occurred at night, and 19.3% of contacts occurred during crepuscular periods.

Fish 204 was primarily found within the BWRNWR boundaries, with only eight detections occurring outside this boundary: two locations east of the BWRNWR buoy line, three detections near Takeoff Point, and three detections at the entrance of Gene Wash Cove (Fig. 3). Contact with tag 204 was frequent upon release into the lake, and occurred daily for the first five days. Later in the study, contacts became sporadic, with as many as six days passing between contacts before contact with 204 ceased. The last contact with fish 204 occurred 20 days after release on 3 May.

Fish 205

Fish 205 (TL = 379 mm, M = 416 g) was contacted 0.4 km uplake of the BWRNWR boat ramp two hours after stocking. Within six hours, fish 205 was contacted five times by active tracking and recorded by SURs stationed 0.8 km uplake of the stocking location. During the first 72 hours, fish 205 was contacted 41 times, and moved as far as 3.3 km uplake of the stocking site. Movements consisted of repeated detections at the north and south shores in BWRNWR waters, an uplake movement to Takeoff Point (Fig. 2), where it was detected by an SUR, then returned to near the original stocking location.

This fish ranged from 3.3 km uplake to 2.4 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by a stationary SUR, but its upriver-most location was recorded by active tracking. Fish 205 was also the only tagged fish to utilize the narrowest section of the Bill Williams River. Mean distance moved between contacts was 0.5 km. Mean distance moved between contacts from passive and active sampling equipment was 0.5 km, and 0.3 km, respectively.

Ninety-six percent of the movements for fish 205 were recorded by SURs, with only 4% of contacts occurring by active tracking. This fish was contacted 341 times by both active and passive sampling methods for six weeks of the three-month study. SUR contacts were broken up by diel period; 36.2% of contacts occurred during the day, 44.6% occurred at night, and 19.2% of contacts occurred during crepuscular periods.

Fish 205 was primarily found within the BWRNWR boundaries, with only three detections occurring outside this boundary; two occurring near Takeoff Point, and one during active tracking event east of the BWRNWR buoy line. Contact with tag 205 frequently for more than a month post-stocking, with only one day passing between contacts before contact with 205 ceased. The last contact with fish 205 occurred 42 days after release on 25 May at the buoy line marking the refuge boundary.

Fish 206

Fish 206 (TL = 406 mm, M = 620 g) was contacted 0.5 km uplake of the BWRNWR boat ramp two hours after stocking. Within 12 hours, fish 206 was contacted twice, once by active tracking, was found 0.5 km uplake of the stocking location, and once by an SUR stationed 0.9 km uplake of the stocking location. During the first 72 hours, fish 206 was contacted 22 times, and moved as far as 0.9 km uplake and 1.1 km upriver of the stocking location. Movements consisted of repeated detections at the north and south shores in BWRNWR waters, and detections uplake and upriver of the stocking location.

This fish ranged from 0.9 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 end of the boundary buoy line, but its upriver-most location was recorded by active tracking in the cattail channels near the Highway 95 Bridge.

Mean distance moved between contacts was 0.4 km. Mean distance moved between contacts from passive and active sampling equipment was 0.4 km, and 0.5 km, respectively. SUR contacts were broken up by diel period; 53.1% of contacts occurred during the day, 28.1% occurred at night, and 18.8% of contacts occurred during crepuscular periods. Ninety-eight percent of the movements for fish 206 were recorded by SURs, with only 2% of contacts occurring by active tracking. This fish was contacted 64 times by both active and passive sampling methods for two weeks of the three-month study.

Fish 206 was found exclusively within the BWRNWR boundaries during the study. Contact with tag 206 was occurred frequently for two weeks post-stocking, with only one day passing between contacts before contact with 206 ceased. The last contact with fish 206 occurred 14 days after release on 27 April at the SUR stationed below the Highway 95 bridge.

Fish 207

Fish 207 (TL = 403 mm, M = 598 g) was contacted 0.5 km north of the BWRNWR boat ramp two hours after stocking. Within six hours, fish 207 was contacted four times by active tracking and recorded by SURs stationed 0.9 km uplake of the stocking location. During the first 72 hours, fish 207 was contacted 44 times, and moved as far as 1.2 km uplake of the stocking site and 1.1 km upriver of the stocking site. Movements consisted of repeated detections at the north and south shores uplake of the stocking site in BWRNWR waters, detections upriver of the stocking site at the Highway 95 Bridge, and then a return to the BWRNWR boat ramp. Fish 207 was detected at these sites repeatedly.

This fish ranged from 1.2 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 0.6 km. Mean distance moved between contacts from passive and active sampling equipment were both 0.6 km.

Eighty-four percent of the movements for fish 207 were recorded by SURs, with only 16% of contacts occurring by active tracking. This fish was contacted 45 times by both active and passive sampling methods for six week of the three-month study. SUR contacts were broken up by diel period; 55.3% of contacts occurred during the day, 28.9% occurred at night, and 15.8% of contacts occurred during crepuscular periods.

Fish 207 was found exclusively inside the BWRNWR boundaries. Contact with tag 207 occurred almost hourly upon release into the lake for the first three days of the study, then contact was lost for three weeks. Fish 207 was then located in a side channel of cattails near the Highway 95 Bridge, and remained there for two weeks, at which point contact was lost for the duration of the study. The last contact with fish 207 occurred 41 days after release on 24 May.

Fish 208

Fish 208 (TL = 407 mm, M = 612 g) was within 50 m of the BWRNWR boat ramp two hours after stocking. After five hours, fish 208 was contacted four times by active tracking and recorded by SURs stationed 0.8 km uplake of the stocking location at the buoy line marking the refuge boundary. During the first 72 hours, fish 208 was contacted 15 times, and strayed as far as 3.3 km uplake of the stocking site near Takeoff Point (Fig. 2). Movements consisted of a westerly movement to its uplake-most location north of Takeoff Point. It was then contacted back in the BWRNWR, then again near Takeoff Point.

This fish ranged from 3.3 km uplake to 0.2 km upriver of the stocking location through the duration of the study. The uplake-most location was recorded by a stationary SUR, and the upriver-most location was recorded by active tracking. Mean distance moved between contacts was 1.0 km. Mean distance moved between contacts from both active and passive tracking was 1.1 km, and 0.5 km, respectively.

Eighty percent of the movements for fish 208 were recorded by SURs, with only 20% of contacts occurring by active tracking. This fish was contacted a total of 15 times by both active and passive sampling methods for 10 weeks of the three-month study, with a long period of non-contact occurring from 15 April to 23 June. SUR contacts were broken up by diel period; 30.8% of contacts occurred during the day, 30.8% occurred at night, and 38.5% of contacts occurred during crepuscular periods.

Sixty percent of the contact with fish 208 was outside the BWRNWR boundaries. Contact with tag 208 was frequent upon release into the lake, and occurred several times per day for the first three days of the study. After three days, contact ceased until it was picked up by a stationary SUR at Takeoff Point 69 days later. This was the last contact with fish 208, 71 days after release on 23 June.

Fish 209

Fish 209 (TL = 390 mm, M = 573 g) was contacted 0.1 km upriver of the BWRNWR boat ramp 2.5 hours after stocking. Within 24 hours, fish 209 was contacted six times, all locations were recorded by active tracking, and this fish was found to have traveled into the CAP Intake cove (Fig. 2). During the first 72 hours, fish 209 was contacted 10 times, and moved as far as 2.2 km uplake and 0.2 km upriver of the stocking location. Movements consisted of an uplake movement, and apparent exploring of coves for the first 72 hours.

This fish ranged from 4.6 km uplake to 0.2 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by a stationary SUR at the entrance of Gene Wash Cove (Fig. 3), but its upriver-most location was recorded by active tracking. Mean distance moved between contacts was 0.9 km. Mean distance moved between contacts from both passive and active tracking was 1.3 km, and 0.5 km, respectively.

Active tracking accounted for 48% of contacts with fish 209, with SURs detecting 52% of this fish's locations. This fish was contacted 27 times by active and passive sampling methods for 11.5 weeks of the three-month study. SUR contacts were broken up by diel period; 14.3% of contacts occurred during the day, 71.4% occurred at night, and 14.3% of contacts occurred during crepuscular periods.

Fish 209 was found throughout the lower 10 km of Lake Havasu, with frequent contacts in and outside the BWRNWR boundaries. Contact with tag 209 was frequent upon release into the lake (multiple detections daily) for two weeks. This was followed by a period of non-contact lasting 24 days. It was then located by active tracking east of Parker Dam for three consecutive weeks. The last contact with fish 209 occurred 81 days after release on 3 July by an SUR stationed at the BWRNWR buoy line.

Fish 210

Fish 210 (TL = 377 mm, M = 376 g) was contacted 0.4 km uplake of the BWRNWR boat ramp three hours after stocking. Within 24 hours, fish 210 was contacted 12 times by active tracking and stationary SURs in the BWRNWR. During the first 72 hours, fish 210 was contacted 39 times, and dispersed as far as 1.2 km uplake and 0.4 km upriver of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters.

This fish ranged from 27.1 km uplake to 0.4 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by active tracking near Partners Point (Fig. 3), and its upriver-most location was recorded by active tracking near the stocking location in the BWRNWR. Mean distance moved between contacts was 0.8 km. Mean distance moved between contacts from passive and active sampling equipment was 0.8 km, and 0.8 km, respectively. SUR contacts were broken up by diel period; 54.2% of contacts occurred during the day, 29.2% occurred at night, and 16.7% of contacts occurred during crepuscular periods.

Active tracking accounted for 8% of contacts with fish 210, with SURs detecting 92% of this fish's locations. This fish was contacted a total of 103 times by both active and passive sampling methods throughout the length of the study, and additionally was detected after the conclusion of the study buy an SUR that was left in the reservoir near Beaver Island (Fig. 3). This detection occurred 95 days after release on 17 July.

Fish 210 was found within the BWRNWR boundaries for two weeks post-stocking, with frequent contacts at the buoy line marking the boundary, as well as at the stocking location. An uplake movement was recorded by a series of SURs during the third week of the study. This fish remained uplake of Beaver Island for the duration of the study after 29 April and was detected uplake of that point by active tracking on two occasions.

Fish 212

Fish 212 (TL = 389 mm, M = 463 g) was contacted 0.7 km uplake of the BWRNWR boat ramp 3.5 hours after stocking. Within 24 hours, fish 212 was contacted 14 times by active tracking and SURs stationed in the BWRNWR. During the first 72 hours, fish 212 was contacted 26 times, moving 0.9 km uplake, and 1.1 km upriver of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters.

This fish ranged from 3.3 km uplake to 2.1 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by an SUR near Takeoff Point (Fig. 2), and its upriver-most location was recorded by active tracking in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.5 km. Mean distance moved between contacts from passive and active sampling equipment was 0.5 km, and 0.4 km, respectively.

Active tracking accounted for 13% of contacts with fish 212, while SURs detected 87% of this fish's locations. This fish was contacted 46 times by active and passive sampling methods for nine weeks of the three-month study. SUR contacts were broken up by diel period; 47.5% of contacts occurred during the day, 40.0% occurred at night, and 12.5% of contacts occurred during crepuscular periods.

Fish 212 was found within the BWRNWR boundaries for two weeks post-stocking, with frequent contacts near the buoy line marking the refuge boundary for the first 24 hours, then moving upriver and residing mostly in the cattail canals near the Highway 95 Bridge. Fish 212 was not contacted then for 56 days, until it was detected on an SUR near Takeoff Point. This was the last contact with Fish 212, and occurred 65 days after release on 17 June.

Fish 213

Fish 213 (TL = 391 mm, M = 506 g) was contacted 0.8 km uplake of the BWRNWR boat ramp 3.5 hours after stocking. Within 24 h, fish 213 was contacted 12 times by active tracking and SURs stationed in the BWRNWR. During the first 72 hours, fish 213 was contacted 39 times, and dispersed as far as 2.2 km uplake and 0.4 km upriver of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters.

This fish ranged from 27.1 km uplake to 1.1 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by a stationary SUR east of Beaver Island (Fig. 3), and its upriver-most location was recorded by an SUR stationed near the Highway 95 Bridge in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.7 km. Mean distance moved between contacts from passive and active sampling equipment was 0.7 km, and 0.6 km, respectively.

Active tracking accounted for 4% of contacts with fish 213, while SURs detected 96% of this fish's locations. This fish was contacted 292 times by both active and passive sampling methods for 11 weeks of the three-month study. SUR contacts were broken up by diel period; 31.8% of contacts occurred during the day, 46.4% occurred at night, and 21.8% of contacts occurred during crepuscular periods.

Fish 213 was found within the BWRNWR boundaries for two weeks post-stocking, with frequent contacts near the buoy line marking the refuge boundary for the first 24 hours, then moving upriver and residing mostly near the original stocking location at the boat ramp. After two weeks, this fish was detected 3.3 km upriver, and 4.5 km uplake of the stocking location. It remained in this location for one week, and then returned to the BWRNWR. It was detected frequently throughout the BWRNWR and CAP Intake cove (Fig. 2), until June when it was detected at sites as far as 27.1 km uplake of the stocking site near Beaver Island on 21 June and 4 July. This was the last contact with Fish 213.

Fish 214

Fish 214 (TL = 410 mm, M = 515 g) was contacted 0.8 km uplake of the BWRNWR boat ramp one hour after stocking. Within 24 hours, fish 214 was contacted five times by active tracking and SURs stationed in the BWRNWR and was located in the CAP Intake Cove (Fig. 2). During the first 72 hours, fish 214 was contacted 15 times, and moved 0.9 km uplake and 1.1 km upriver of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters.

This fish ranged from 3.3 km uplake to 1.1 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by a stationary SUR north of Takeoff Point (Fig. 3), and its upriver-most location was recorded by an SUR stationed near the Highway 95 Bridge in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.7 km. Mean distance moved between contacts from passive and active sampling equipment was 0.7 km, and 0.3 km, respectively.

Active tracking accounted for 5% of contacts with fish 214, while SURs detected 95% of this fish's locations. This fish was contacted 93 times by active and passive sampling methods for 11.5 weeks of the three-month study. SUR contacts were broken up by diel period; 47.7% of contacts occurred during the day, 35.2% occurred at night, and 17.0% of contacts occurred during crepuscular periods.

Fish 214 was found within the BWRNWR boundaries for 10 days post-stocking, with frequent contacts near the buoy line marking the refuge boundary, the original stocking location, and upriver of the stocking location at the Highway 95 Bridge. After 10 days, fish 214 was detected 3.3 km uplake of the stocking site by a stationary SUR located north of Takeoff Point, but then returned to the BWRNWR. It was detected frequently throughout the BWRNWR and CAP Intake cove, with relatively long periods between contacts lasting up to 42 days. The last contact with Fish 214 occurred 81 days after release on 3 July at the Highway 95 Bridge.

Fish 215

Fish 215 (TL = 393 mm, M = 539 g) was contacted 0.2 km uplake of the BWRNWR boat ramp two hours after stocking. Within 24 hours, fish 215 was contacted 13 times by active tracking and passively by SURs stationed in the BWRNWR. During the first 72 hours, fish 215 was contacted 34 times, and dispersed as far as 3.3 km uplake and 0.8 km upriver of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters.

This fish ranged from 18.3 km uplake to 0.8 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by active tracking in Steamboat Cove (Fig. 3), and its upriver-most location was recorded by an active tracking in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.7 km. Mean distance moved between contacts from passive and active sampling equipment was 0.6 km, and 0.9 km, respectively.

Active tracking accounted for 19% of contacts with fish 215, while SURs detected 81% of this fish's locations. This fish was contacted 72 times by active and passive sampling methods for 10 weeks of the three-month study. SUR contacts were broken up by diel period; 39.0% of contacts occurred during the day, 39.0% occurred at night, and 22.0% of contacts occurred during crepuscular periods.

Fish 215 was found primarily within the BWRNWR boundaries for one week post-stocking, with frequent contacts near the buoy line marking the refuge boundary, and the original stocking location. After one week, this fish was detected 3.1 km uplake, and remained near Takeoff Point for the second week post-stocking. At the end of April, an uplake movement was noted by stationary SURs at Gene Wash Cove (Fig. 3; 4.5 km uplake of stocking site) and Red Rock Point (Fig. 3; 12.4 km uplake of the stocking site). Active tracking located fish 215 in Steamboat Cove from 5 May to 23 June, and was not contacted again through the end of the study.

Fish 216

Fish 216 (TL = 413 mm, M = 500 g) was contacted 0.9 km directly north of the BWRNWR boat ramp three hours after stocking. Within 24 hours, fish 216 was contacted 12 times by active tracking and SURs stationed in the BWRNWR. During the first 72 hours, fish 216 was contacted 31 times, and moved as far as 1.5 km uplake and 0.3 km upriver of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters, the CAP Intake Cove (Fig. 2), and one contact uplake of the BWRNWR in Heron Island Cove (Fig. 3).

This fish ranged from 12.3 km uplake to 2.1 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by two SURs stationed on either side of the river at Red Rock Point (Fig. 3), and its upriver-most location was recorded by an SUR stationed in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.7 km. Mean distance moved between contacts from passive and active sampling equipment was 0.7 km, and 0.5 km, respectively.

Active tracking accounted for 7% of contacts with fish 216, while SURs detected 93% of this fish's locations. This fish was contacted 151 times by both active and passive sampling methods for just under three weeks of the three-month study. SUR contacts were broken up by diel period; 41.1% of contacts occurred during the day, 37.6% occurred at night, and 21.3% of contacts occurred during crepuscular periods.

Fish 216 was found primarily within the BWRNWR boundaries for two weeks post-stocking, with frequent contacts at the original stocking location, uplake near the buoy line marking the refuge boundary, and upriver near the Highway 95 Bridge. After two weeks, this fish was detected 3.3 km uplake passing Takeoff Point, then Gene Wash Cove, and finally Red Rock Point, 12.4 km uplake of the original stocking site (Fig. 3). This was the last contact with Fish 216, recorded 19 days after release on 2 May.

Fish 217

Fish 217 (TL = 370 mm, M = 494 g) was contacted 0.8 km uplake of the BWRNWR boat ramp four hours after stocking. Within 24 h, fish 217 was contacted eight times by active tracking and SURs stationed in the BWRNWR. During the first 72 hours, fish 217 was contacted 24 times, and strayed as far as 3.3 km uplake and 1.1 km upriver of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters, uplake as far as Takeoff Point (Fig. 3), and upriver of the stocking location to the Highway 95 Bridge.

This fish ranged from 3.3 km uplake to 2.1 km upriver of the stocking locations through the duration of the study. Its uplake-most location was recorded by an SUR stationed on the opposite shore of Takeoff Point, and its upriver-most location was recorded by an SUR stationed in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.9 km. Mean distance moved between contacts from passive and active sampling equipment was 1.1 km, and 0.6 km, respectively.

Active tracking accounted for 29% of contacts with fish 217, while SURs detected 71% of this fish's locations. This fish was contacted 35 times by active and passive sampling methods for just under six weeks of the three-month study. SUR contacts were broken up by diel period; 28.0% of contacts occurred during the day, 44.0% occurred at night, and 28.0% of contacts occurred during crepuscular periods.

For the first two weeks, fish 217 was found from the stocking location to as far uplake as Takeoff Point. After two weeks, this fish was detected solely by active tracking conducted in cattail channels in the BWRNWR. It remained here until contact with this fish ceased 41 days post-release on 24 May.

Fish 218

Fish 218 (TL = 428 mm, M = 728 g) was contacted 0.8 km uplake of the BWRNWR boat ramp three hours after stocking. Within 24 hours, fish 218 was contacted four times by active tracking and SURs stationed in the BWRNWR. During the first 72 hours, fish 218 was contacted seven times, and dispersed as far as 3.3 km uplake of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters, and as far uplake as Takeoff Point (Fig. 3).

This fish ranged from 12.1 km uplake of the stocking locations through the duration of the study. It was never detected upriver of the stocking site. Its uplake-most location was recorded by an SUR stationed on the opposite shore of Red Rock Point (Fig. 3). Mean distance moved between contacts was 1.3 km. Mean distance moved between contacts from passive and active sampling equipment was 1.3 km, and 1.4 km, respectively.

Active tracking accounted for 38% of contacts with fish 218, while SURs detected 62% of this fish's locations. This fish was contacted 14 times by both active and passive sampling methods for six weeks of the three-month study. SUR contacts were broken up by diel period; 11.1% of contacts occurred during the day, 77.8% occurred at night, and 11.1% of contacts occurred during crepuscular periods.

For the first two weeks, fish 218 was found in the BWRNWR near the stocking location to as far uplake as Takeoff Point. After two weeks, this fish was detected by an SUR stationed at Red Rock Point, and then by active tracking in Satellite Cove (Fig. 3). Where is remained until contact ceased 42 days after release on 25 May.

Fish 219

Fish 219 (TL = 397 mm, M = 695 g) was contacted 0.4 km uplake of the BWRNWR boat ramp 2.5 hours after stocking. Within 24 hours, fish 219 was contacted 18 times by active tracking and SURs stationed in the BWRNWR. During the first 72 hours, fish 219 was contacted 43 times, and moved as far as 1.2 km uplake of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters, and as far uplake as the BWRNWR boundary line.

This fish ranged from 4.5 km uplake of the stocking location, and 2.6 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by an SUR stationed at the entrance of Gene Wash Cove (Fig. 3). Its upriver-most location was recorded by active tracking in the cattail channels of the BWRNWR. Mean distance moved between contacts was 0.7 km. Mean distance moved between contacts from passive and active sampling equipment was 0.7 km, and 0.5 km, respectively.

Active tracking accounted for 2% of contacts with fish 219, while SURs detected 98% of this fish's locations. This fish was contacted 512 times by active and passive sampling methods for eight weeks of the three-month study. SUR contacts were broken up by diel period; 31.1% of contacts occurred during the day, 40.5% occurred at night, and 28.3% of contacts occurred during crepuscular periods.

Fish 219 was found within the BWRNWR for four days post-stocking, both uplake and upriver of the stocking location. After four days, this fish was detected by an SUR stationed at the entrance of Gene Wash Cove, and then near Takeoff Point. After 19 April, Fish 219 was only found within the BWRNWR waters by active and passive tracking. This fish was contacted by SURs often throughout the study, with the longest period of non-contact being four days, until the last contact occurred 58 days post-release on 10 June.

Fish 220

Fish 220 (TL = 400 mm, M = 539 g) was contacted 0.8 km uplake of the BWRNWR boat ramp three hours after stocking. Within 24 hours, fish 220 was contacted 10 times by active tracking and SURs stationed in the BWRNWR. During the first 72 hours, fish 220 was contacted 29 times, and dispersed as far as 3.4 km uplake of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters, and just north of the Takeoff Point SURs (Fig. 3).

This fish ranged from 3.4 km uplake of the stocking location, and was not found upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by an active tracking event just uplake of Takeoff Point. Mean distance moved between contacts was 0.4 km. Mean distance moved between contacts from passive and active sampling equipment was 0.4 km, and 0.7 km, respectively.

Active tracking accounted for 3% of contacts with fish 220, while SURs detected 97% of this fish's locations. This fish was contacted 327 times by both active and passive sampling methods for just under six weeks of the three-month study. SUR contacts were broken up by diel period; 35.1% of contacts occurred during the day, 42.9% occurred at night, and 21.9% of contacts occurred during crepuscular periods.

Within one day, fish 220 left the BWRNWR, and was detected near Takeoff Point. It remained there for one day, then returned to the BWRNWR waters for two weeks, at which point fish 220 took another uplake trip to Takeoff Point. It remained in this vicinity, with multiple detections on both sides of the river channel until 19 May. It was then detected near the BWRNWR boundary by SURs and active tracking. This fish was contacted frequently throughout the study, with the longest period of non-contact being three days, until the last contact occurred 41 days after release on 24 May.

Fish 221

Fish 221 (TL = 421 mm, M = 690 g) was contacted 0.8 km uplake of the BWRNWR boat ramp 3.5 hours after stocking. Within 24 hours, fish 221 was contacted eight times by active tracking and SURs stationed in the BWRNWR. During the first 72 hours, fish 221 was contacted 25 times, and dispersed as far as 3.3 km uplake of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters, and just north of the Takeoff Point SURs (Fig. 3).

This fish ranged from 4.5 km uplake of the stocking location, and 0.7 km upriver of the stocking location through the duration of the study. Its uplake-most location was recorded by an SUR stationed at the entrance of Gene Wash Cove (Fig. 3). Its upriver-most location was detected during an active tracking event near the Highway 95 Bridge. Mean distance moved between contacts was 0.2 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 4% of contacts with fish 221, while SURs detected 96% of this fish's locations. This fish was contacted 248 times by active and passive sampling methods for 10 weeks of the three-month study. SUR contacts were broken up by diel period; 42.7% of contacts occurred during the day, 41.4% occurred at night, and 15.9% of contacts occurred during crepuscular periods.

Within three weeks, fish 221 left the BWRNWR, was detected near Takeoff Point, and the entrance to Gene Wash Cove three times. Each time, it remained in those locations from 1-6 days, and then returned to the BWRNWR. After 6 May, it was detected near the BWRNWR boundary, and remained within the BWRNWR waters for the remainder of the study. This fish was contacted frequently throughout the study with the longest period of non-contact being four days, until the last contact recorded on an SUR occurred on 8 June. This fish was contacted for the final time by active tracking 70 days post release on 22 June, at which point contact was lost.

Fish 222

Fish 222 (TL = 405 mm, M = 625 g) was contacted 0.4 km uplake of the BWRNWR boat ramp three hours after stocking. Within 24 hours, fish 222 was contacted 10 times by active tracking and SURs stationed in the BWRNWR. During the first 72 hours, fish 222 was contacted 36 times, and moved as far as 1.2 km uplake of the stocking location. Movements consisted of active and passive detections throughout the BWRNWR waters, and at the refuge boundary.

This fish ranged from 27.1 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 an SUR stationed across the river channel from Beaver Island. Its upriver-most location was detected during by an SUR stationed just below the Highway 95 Bridge in the BWRNWR. Mean distance moved between contacts was 1.3 km. Mean distance moved between contacts from passive and active sampling equipment was 1.4 km, and 0.3 km, respectively.

Active tracking accounted for 10% of contacts with fish 222, while SURs detected 90% of this fish's locations. This fish was contacted 49 times by both active and passive sampling methods for eight weeks of the three-month study. SUR contacts were broken up by diel period; 46.7% of contacts occurred during the day, 37.8% occurred at night, and 15.6% of contacts occurred during crepuscular periods.

For three days, fish 222 remained in the BWRNWR, and was detected throughout the refuge waters. After three days, a long-distance uplake movement was detected by stationary SURs at Gene Wash Cove, Black Meadow Landing, Red Rock Point, and Beaver Island (Fig. 3) from 16 April to 7 May. This fish was not contacted again until 60 days after release on 12 June when it was detected by an SUR in the BWRNWR. This was the final contact with fish 222.