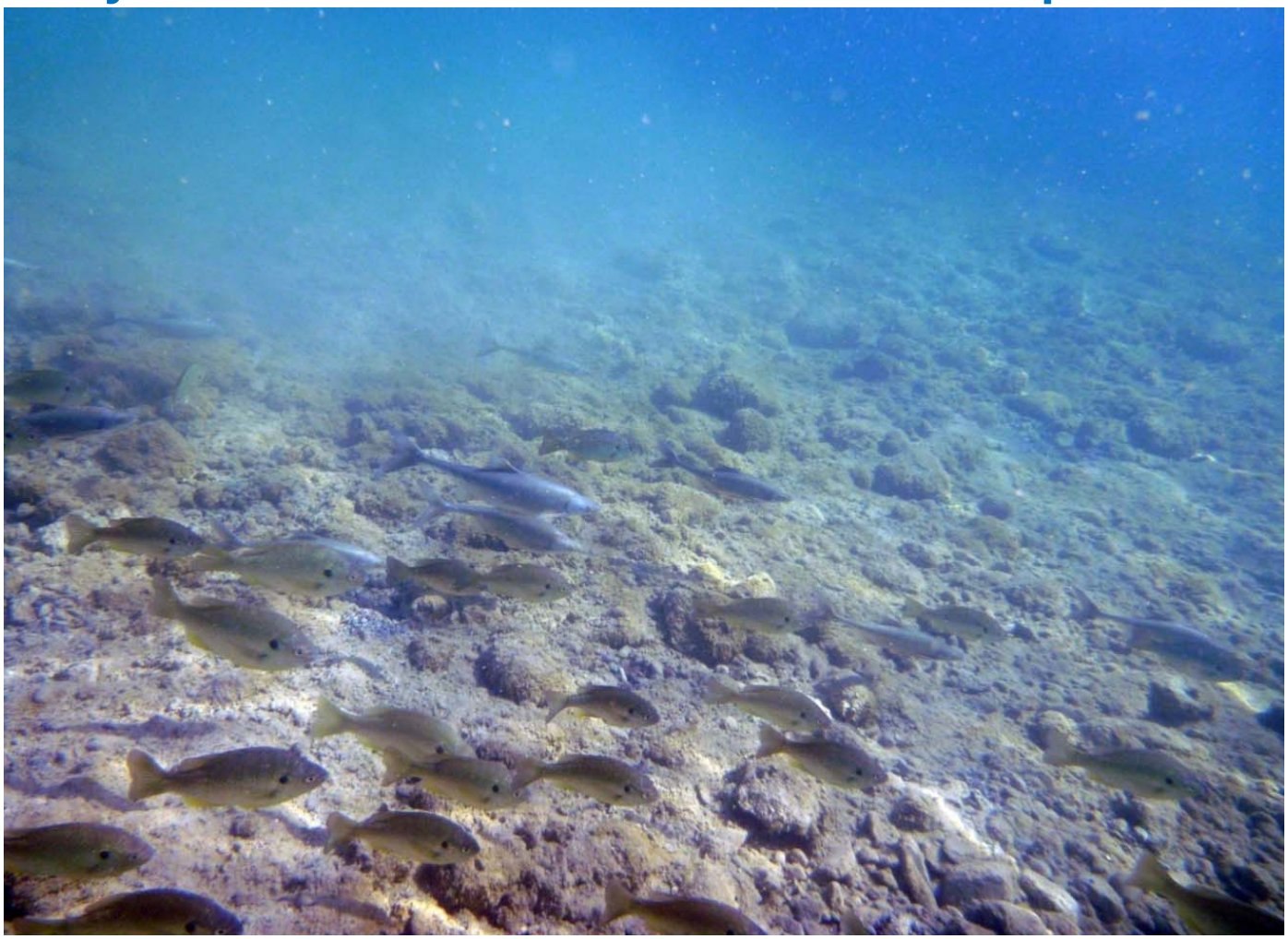
Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Distribution and Post-stocking Survival of Bonytail in Lake Havasu – 2012 Annual Report



U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

May 2013

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

Prepared by:

Abraham P. Karam, Christine M. Adelsberger,
Kristen A. Patterson, Jerry E. Warmbold, and Paul C. Marsh
Marsh & Associates, LLC
5016 South Ash Avenue, Suite 108
Tempe, Arizona 85282

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

May 2013

ACRONYMS AND ABBREVIATIONS

BLM	Bureau of Land Management
BWRNWR	Bill Williams River National Wildlife Refuge
CAP	Central Arizona Project
cm	centimeter(s)
d	day(s)
DTS	distance to shore
FIP	Lake Havasu Fishery Improvement Project
g	gram(s)
km	kilometer(s)
L	liter(s)
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
LHNWR	Lake Havasu National Wildlife Refuge
M	mass
m	meter(s)
m^3/s	cubic meters per second
M&A	Marsh & Associates, LLC
mL	milliliter(s)
mm	millimeter(s)
MWD	Metropolitan Water District of Southern California
NTU	Nephelometric Turbidity Unit
PIT	passive integrated transponder
psi	pounds per square inch
PVC	polyvinyl chloride
Reclamation	Bureau of Reclamation
SE	standard error
SNARRC	U.S. Fish and Wildlife Service Southwestern Native Aquatic Resources & Recovery Center, Dexter, New Mexico
SUR	submersible ultrasonic receivers
TL	total length
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

Symbols

%	percent

CONTENTS

Page

Executive Summary ES-1

Introduction 1
Methods 5
Study Area 5
Bill Williams River National Wildlife Refuge 5
Lake Havasu Basin 7
The Delta and Topock Gorge 7
The Colorado River 7
Outreach 7
Submersible Ultrasonic Receiver Arrangement 11
Bonytail Surgeries 12
Remote PIT Scanning 13
November 2011 Telemetry 13
SUR Deployment 14
Remote PIT Scanning 14
Surgeries and Stocking 14
Tracking Techniques and Database Management 16
2012 Lake Havasu Native Fish Roundup 19
October 2012 Telemetry 20
SUR Deployment 20
Remote PIT Scanning 20
Surgeries and Stocking 23
Tracking Techniques and Database Management 23
Results 27
November 2011 Telemetry 27
Remote PIT Scanners 27
Post-stocking Mortality and Transmitter Recovery 27
Movement Patterns and Inhabitance 30
2012 Lake Havasu Native Fish Roundup 39
October 2012 Telemetry 40
Remote PIT Scanning 40
Post-stocking Mortality and Transmitter Recovery 44
Movement Patterns and Inhabitance 44
Discussion 52
Recommendations 60
Acknowledgments 63
Literature Cited 65

Tables

Table Page

1 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 12
2 Remote PIT scanning location, contacts, and effort during the November 2011 study, Lake Havasu, Arizona and California 27
3 Table of acoustic tags that became sessile and were inspected by divers during the course of the November 2011 telemetry study, Lake Havasu, Arizona and California 29
4 SUR detections of fish stocked in BWRNWR in November 2011, Lake Havasu, Arizona and California 32
5 Submersible Ultrasonic Receiver (SUR) detections of fish stocked in Cattail Cove in November 2011, Lake Havasu, Arizona and California 34
6 Summary of telemetry data describing inhabitance (defined in "Methods") of acoustic-tagged bonytail monitored in BWRNWR between November 2011 and May 2012, Lake Havasu, Arizona and California 42
7 Summary of telemetry data describing inhabitance (defined in Methods) of acoustic-tagged bonytail monitored in Bill Williams River National Wildlife Refuge (BWRNWR) between November 2011 and May 2012, Lake Havasu, Arizona and California 43
8 Remote PIT scanning location, contacts, and effort from the October 2012 study, Lake Havasu, Arizona and California. 44
9 Table of acoustic tags that became sessile and were inspected by divers during the course of the October 2012 telemetry study, Lake Havasu, Arizona and California 45
10 SUR detections of fish stocked at BWRNWR during the October 2012 study, Lake Havasu, Arizona and California 48
11 SUR detections of fish stocked at Blankenship Bend during October 2012, Lake Havasu, Arizona and California. 49

Figures

Figure Page

1 Sketch map of the lower Colorado River between Davis Dam and Parker Dam showing Lake Havasu and the riverine portion of LCR MSCP Reach 3, Arizona, California, and Nevada..... 2
2 Map of the watercraft-accessible portion of BWRNWR at the southeast terminus of Lake Havasu, Arizona and California, and photographs of the reach. 6
3 Map indicating the basin of Lake Havasu, Arizona and California, and a photograph of the reach. 8
4 Map indicating the Colorado River delta and Topock Gorge in Lake Havasu, Arizona and California, and a photograph of a typical off-channel backwater (foreground) in the reach..... 9
5 Map indicating the Colorado River between Topock Gorge and Davis Dam on Lake Havasu, Arizona and California, and a photograph of the reach. 10
6 Example of a flyer, indicating the presence of stocked bonytail in Lake Havasu and contact information if captured, posted at a bait shop Lake Havasu City, Arizona..... 11
7 Satellite view of remote PIT scanning locations for the November 2011 and October 2012 studies, Lake Havasu, Arizona and California..... 15
8 Photos depicting bonytail implanted with an acoustic transmitter during the July 2010 transmitter retention study at SNARRC, Dexter, New Mexico, and seen at various time stages up until the November 29, 2011, surgeries at BWRNWR, Arizona. 16
9 Weekly turbidity sampling grid in Lake Havasu, Arizona and California, during December 2011. 18
10 Satellite view of remote PIT scanning locations at Blankenship Bend during October 2012, Lake Havasu, Arizona and California. 21
11 Satellite view of remote PIT scanning locations at Park Moabi during October 2012, Lake Havasu, Arizona and California. 22
12 Aerated fish transport tank in which bonytail were tempered (A) and from which fish were transferred into smaller transport tanks on Reclamation watercraft (B) before being boated to and released at Blankenship Bend, Lake Havasu, Arizona and California, on October 8, 2012..... 24
13 Turbidity sampling grid in the BWRNWR arm of Lake Havasu, Arizona and California, during October 2012. 25
14 Turbidity sampling grid in the Blankenship Bend arm of Lake Havasu, Arizona and California, during October 2012. 26

Figures (continued)

Figure Page

15 Number of bonytail available for contact during the November 2011 telemetry study, Lake Havasu, Arizona and California 28
16 Map of acoustic telemetry contacts from bonytail released at BWRNWR in November 2011, Lake Havasu, Arizona and California. 30
17 Map of acoustic telemetry contacts from bonytail released at Cattail Cove in November 2011, Lake Havasu, Arizona and California. 31
18 Satellite view of the upstream-most distributions of fish 32 and 35, which represented the upstream-most detections for all acoustic-tagged fish released at BWRNWR in November 2011, Lake Havasu, Arizona and California. 36
19 Bonytail seen from the surface of Sandpoint Marina, Arizona, during February 2012, Lake Havasu, Arizona and California. 38
20 Underwater photos of bonytail (B), redear sunfish (R), and largemouth bass (L) swimming in Sandpoint Marina, Arizona, on February 6, 2012, Lake Havasu, Arizona and California. 39
21 Turbidity (NTU) readings taken weekly during December 2011 beginning in the upstream-most watercraft-accessible portions of the Bill Williams River (water sample site 1) and ending at Lake Havasu City (water sample site 27). 40
22 Turbidity (NTU) readings taken once monthly during February (top), March (middle), and April (bottom) 2012 beginning in the upstream-most watercraft-accessible portions of the Bill Williams River (water sample site 1) and ending at Lake Havasu City (water sample site 27). 41
23 Map of acoustic telemetry contacts from fish released at BWRNWR in October 2012, Lake Havasu, Arizona and California. 46
24 Map of acoustic telemetry contacts from fish released at Blankenship Bend in October 2012, Lake Havasu, Arizona and California. 47
25 Satellite view of the location of Fish 101 and 108 utilizing an off-channel backwater near the stocking area at Blankenship Bend, Lake Havasu, Arizona and California. 50
26 Satellite view of the location of Fish 103 and 94 utilizing backwaters (defined by red outlines) in BWRNWR and the location of Fish 95 and 103, which represent the farthest upstream dispersal of fish stocked in BWRNWR during October 2012, Lake Havasu, Arizona and California. 51

Figures (continued)

Figure Page

27 Turbidity (NTU) readings on October 9 and 10, 2012, in the (A) BWRNWR arm of Lake Havasu (see figure 13) beginning in the upstream-most watercraft-accessible portions of the Bill Williams River (water sample site 1) and proceeding sequentially toward Lake Havasu City (water sample site 10) and the (B) Blankenship Bend reach of Lake Havasu (see figure 14) beginning at the delta (water sample site 11) and moving upstream (water sample site 30), Lake Havasu, Arizona and California. 53

28 Discharge in cubic meters per second from the Bill Williams River below Alamo Dam, Arizona (USGS 2013), over the course of the 3-year project period. 54

29 Photo of prolific beds of submergent aquatic vegetation found in slackwater habitats (backwaters, eddies in the main river channel, and delta) throughout the Blankenship Bend reach during the October 2012 study, Lake Havasu, Arizona and California. 58

30 Photo of a flathead catfish captured by USFWS in BWRNWR during trammel net surveys in February 2010, Lake Havasu, Arizona and California. 59

EXECUTIVE SUMMARY

The presence of bonytail (*Gila elegans*) in the Colorado River Basin relies entirely on stocking programs, and Lake Havasu, Arizona, California, and Nevada, is one of the release locations and sites where individuals are occasionally captured. Most of the information regarding the basic ecology of this critically endangered species is limited to past field observations acquired from the now extirpated wild population and to studies conducted on isolated stocks reared in hatchery or backwater ponds. The results from an earlier telemetry project 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 fate and habitat use of hatchery-reared bonytail.

In 2013, we completed the third and final year of a 3-year comprehensive project that was initiated in March 2010. Acoustic telemetry was used to describe and characterize inhabitance and dispersal of hatchery-reared bonytail by monitoring their movement and survival after release into Lake Havasu. The results from an April 2010 investigation during the first year of the project established up to 95 percent (%) of bonytail implanted with 3-month acoustic transmitters and stocked at Bill Williams River National Wildlife Refuge (BWRNWR), Arizona, 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 the U.S. Fish and Wildlife Service Southwestern Native Aquatic Resources & Recovery Center, Dexter, New Mexico (formerly Dexter National Fish Hatchery & Technology Center) that demonstrated bonytail implanted with 3- and 6-month acoustic transmitters remained healthy and active.

Based on results from these first two investigations, longer life (6-month) transmitters were utilized during a December 2010 study. The results established that only 50% of acoustic-tagged bonytail were available for contact after 3 months, which was strikingly less than the April 2010 study. However, by the end of 6 months, up to 40% of the bonytail stocked in December 2010 still remained active. Dispersal and habitat use largely resembled patterns displayed by bonytail stocked during April 2010. Dispersal was largely confined to habitats in and near BWRNWR (97% of all contacts) where fish spent significantly (Mann-Whitney test) more time than elsewhere in Lake Havasu. Mean Secchi depth readings taken at points of active contact were more than two times greater during December 2010 (2.1 meters [m]) compared to April 2010 (1.0 m). Subsequent analysis of water discharged from Bill Williams River at Alamo Dam, Arizona, indicated a large-scale water release (~ 87 square meters per second [m^3/s]) occurred 2 weeks prior to the April 2010 study, which was the cause for lower water clarity conditions during that study. Normal discharge (~ 0.3 m^3/s)

was observed prior to and throughout the December 2010 study. All immobile tags from both in situ studies were recovered by scuba divers. No fish remains were located near the sites of recovery.

During February 2011, Marsh & Associates, LLC (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; one each from the April and December 2010 telemetry studies. The catch of 68 bonytail was more than four times the capture total from the previous 2 years of netting events combined. The mean total length (TL) of captured bonytail (446 millimeters [mm]; range = 345–500 mm) was likely too large for most individuals to have originated from the December 2010 stocking (mean TL = 335 mm; all passive integrated transponder [PIT] tagged), indicating a majority of bonytail had survived from the April 2010 stocking (not PIT tagged) and were still occupying habitat in BWRNWR.

Collectively, the aforementioned telemetry and netting results indicated bonytail showed preference for habitats found in BWRNWR. To determine whether dispersal and survival were related to stocking location or habitat availability, separate dual stocking events were implemented during the final year of this project. During the first stocking in November 2011, 15 acoustic-tagged bonytail (10 implanted with 6-month battery life transmitters and 5 with 45-day battery life depth-sensing transmitters) and about 2,000 PIT-tagged bonytail (mean TL = 376 mm) were released at each of BWRNWR and Cattail Cove, Arizona. Remote PIT scanning antennas deployed throughout both stocking locations scanned for 102,898 minutes and contacted 230 unique PIT-tagged bonytail, all of which contained a stocking history in the Lower Colorado River Native Fishes Database. Contacts occurred exclusively along the riprap shore of BWRNWR and in Sandpoint Marina north of Cattail Cove. Passive and active tracking data indicate depth-tagged bonytail released at BWRNWR and Cattail Cove were contacted on average at 78% and 79% of the available water column depth, respectively. Fish depth was greater during the day than at night. The mean turbidity readings taken at fixed locations in Lake Havasu and BWRNWR reflected higher water clarity found in the reservoir proper when compared to BWRNWR. Turbidity readings in Nephelometric Turbidity Units (NTUs) were more than five times greater for actively tracked fish released at Cattail Cove (5.1 NTU ± 0.6 standard error [SE]) than for fish released at BWRNWR (1.0 NTU ± 0.2 SE). 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, 10% of those individuals utilized habitats found in BWRNWR longer than those found in Lake Havasu. The extent of detectable fish dispersal was 2.4 times greater for bonytail stocked at Cattail Cove

(35.4 kilometers [km]) than BWRNWR (14.4 km). At the end of this study, 21 of 22 sessile tags were recovered by scuba divers, and the number of fish available for contact during any given week was back-calculated. Mortality of BWRNWR stocked fish was 100%. All 10 fish tagged with 6-month transmitters were dead by 65 days after stocking. Mortality for Cattail Cove stocked fish also was high, but the decline less severe; 2 of 10 fish implanted with 6-month tags were available for contact 180 days after being stocked.

During February 2012, 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 14 bonytail, 12 of which were captured near the Bill Williams River delta and 2 between BWRNWR and Cattail Cove. Three individuals were recaptures from the November 2011 stocking, and one was a recapture from the 2011 roundup. The mean TL of bonytail captured was 447 mm (range 314–541 mm), indicating the remaining untagged fish likely originated from the April 2010 stocking because all subsequent stockings were PIT tagged prior to release.

A final split stocking was enacted during October 2012 to further explore dispersal, habitat use, and mortality differences between two separate stocking locations: Blankenship Bend (riverine habitat) and BWRNWR. Fifteen acoustic-tagged bonytail (10 implanted with 3-month battery life transmitters and 5 with 45-day battery life depth-sensing transmitters) and about 2,000 PIT-tagged bonytail were released at each location. Remote PIT scanning antennas deployed throughout Blankenship Bend and BWRNWR scanned for 95,435 minutes and contacted 85 unique PIT-tagged bonytail, all of which contained a stocking history in the Lower Colorado River Native Fishes Database. Contacts occurred exclusively along the riprap shore of BWRNWR and in the main river channel and backwaters near Blankenship Bend and in Park Moabi, California. Turbidity readings reflected the clear water conditions near Blankenship Bend relative to BWRNWR, although turbidity in the refuge was lower than previously recorded. Passive and active tracking data indicate depth-tagged bonytail released at BWRNWR and Blankenship Bend were contacted on average at 90% and 83% of the available water column depth, respectively. As a result of relatively poor success contacting fish (both actively and passively), and due to successful deployments of remote PIT scanning units in backwaters, 11 additional submersible ultrasonic receivers were acquired from the Bureau of Reclamation in November 2012 and placed in backwater habitats near both stocking areas for the remainder of the study. Two acoustic-tagged fish were contacted exclusively at night in a backwater near Blankenship Bend and a third fish in a backwater at BWRNWR. The extent of detectable fish dispersal was 3.2 times greater for bonytail stocked at Blankenship Bend (22.0 km) than BWRNWR (6.9 km). At the end of the study, four of five sessile tags were recovered by scuba divers, and the number of fish available for contact during any given week was

back-calculated. While mortality of BWRNWR stocked fish was lower than the December 2010 and November 2011 studies, it still remained relatively high; 6 of 10 fish were still being tracked at the end of the study. Mortality for Blankenship Bend appeared lower; 9 of 10 fish were still available for contact by the end of the study.

INTRODUCTION

Lake Havasu is a main stem lower Colorado River reservoir, which extends 132 kilometers (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 (LCR 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 meters [m]) and encompasses approximately 45 river km between its downriver terminus at Parker Dam and the northern limits of Lake Havasu City. Upstream from this point, the river portion of Reach 3 continues for another 87 km, through Topock Gorge to its boundary at Davis Dam.

Prior to European settlement, the main stem 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). Physical alterations also 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; Mueller and Marsh 2002). Today, Lake Havasu is populated primarily by introduced non-native fishes that support a popular recreational and sport fishery. Three species of Colorado River endemics, 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 from Davis Dam occurred during the early 1970s (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 (LCR MSCP 2004; Minckley and Thorson 2007), and Lake Havasu is one of a 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[1] (0.1 percent [%]) 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 250 millimeters [mm] total length [TL]) was reached in 2003 (Minckley and

[1] Estimate based on data from 2010.

Figure 1.—Sketch map of the lower Colorado River between Davis Dam and Parker Dam showing Lake Havasu and the riverine portion of LCR MSCP Reach 3, Arizona, California, and Nevada.

Thorson 2007), although annual monitoring continues under the FIP as the LCR MSCP has transitioned into directing Reach 3 stockings (4,000 bonytail per year greater than 300 mm TL) for the next 50 years (LCR MSCP 2004).

Monitoring by personnel from the U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), Bureau of Reclamation (Reclamation), Bureau of Land Management (BLM), California Department of Fish and Game, Arizona Game and Fish Department, Nevada Department of Wildlife, and public volunteers typically occurs in February (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 (see figure 1). Bonytail captures made during past monitoring efforts have been infrequent (19 recaptures between 1994 and 2007) (Minckley and Thorson 2007), although bonytail are occasionally contacted by recreational anglers (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 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 riprap 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 in Lake Havasu indicated a majority of fish contacts were along shorelines or in coves (Minckley 2006). 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 LCR MSCP, we completed the third and final year of a multi-year (2010–2013) research project that continues to document in detail the post-stocking distribution, habitat use, and mortality of bonytail in Lake Havasu. Results from our initial April 2010 study demonstrated a successful increase in the number of post-stocking bonytail contacts using acoustic telemetry. By the end of that study, up to 95% of bonytail implanted with 3-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 (Karam et al. 2011). In a separate transmitter retention study performed during 2010 at the USFWS Southwestern Native Aquatic Resources & Recovery Center, Dexter, New Mexico (SNARRC) (formerly Dexter National Fish Hatchery & Technology Center), it was demonstrated that bonytail implanted with 3-month

(27 x 9 mm; 4.2 grams [g]) and 6-month (42 x 11 mm; 7.8 g) acoustic transmitters remained healthy, active, and showed no significant changes in growth from control fish (Karam et al. 2011).

Based on this information, a longer term (6-month) acoustic telemetry tag was used during our second telemetry study to further describe patterns of survival and inhabitance (modified from Wingate et al. 2011) by bonytail stocked in BWRNWR and elsewhere in Lake Havasu. Because occupancy is a coarse descriptor of inhabitance by stocked fish, inferences regarding habitat use were made based on where fish are contacted over time. BWRNWR exhibits physical and biological characteristics (turbidity, depth, shoreline substrate, and littoral zone physiography) that differ from those found elsewhere in Lake Havasu. Inhabitance data from the 6-month December 2010 telemetry study and capture data from 2011 Lake Havasu Native Fish Roundup indicated bonytail showed a strong preference for habitats found in BWRNWR (USFWS 2011). Only one-half of the bonytail released in December 2010 were active at the end of 3 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 6 months, up to 40% of the bonytail stocked in December 2010 still remained active (Karam et al. 2011). Mean Secchi depth readings taken at points of active contact were more than two times greater during the December 2010 study than those taken during April 2010, 2.1 vs. 1.0 m (Karam et al. 2011). Subsequent analysis of water discharged from the Bill Williams River at Alamo Dam, Arizona, indicated a large-scale water release (~ 87 cubic meters per second [m^3/s]) occurred 2 weeks prior to the April 2010 study and was the cause for lower water clarity conditions during that study (Wiele et al. 2009). Normal discharge (~ 0.3 m^3/s) was observed throughout the December 2010 study (USGS 2013). All immobile tags from both in situ studies were recovered by scuba divers. No fish remains were located near the sites of recovery.

This report documents the final 16 months (November 2011 to February 2013) of post-stocking bonytail monitoring and research efforts conducted at Lake Havasu. The goal of the multi-year research project was to guide future bonytail stocking endeavors in the reservoir and ultimately aid in the long-term survival of this critically endangered species. Specific objectives from the reported study period include:

1. Continue to provide educational outreach to local anglers about bonytail stockings.

2. Use remote passive integrated transponder (PIT) scanning arrays in various habitats conducive to their deployment to determine if bonytail can be contacted using that technology.

3. Provide detailed post-stocking dispersal information for acoustic-tagged bonytail.

4. Provide detailed habitat descriptions in areas where bonytail were released and located.

5. Describe patterns of inhabitance for acoustic-tagged fish released at BWRNWR and Cattail Cove.

6. Document and confirm mortality of acoustic-tagged bonytail using scuba divers.

7. Participate in annual native fish monitoring surveys using trammel nets.

METHODS

Study Area

Lake Havasu (see figure 1) is impounded by Parker Dam, which was constructed by Reclamation and closed in 1938. The dam creates a 7.98 x 10^8 cubic meter storage capacity reservoir and generates hydroelectric power for MWD and for utilities in Arizona, California, and Nevada.

Bill Williams River National Wildlife Refuge

Bill Williams River National Wildlife Refuge occupies the southeast terminus of Lake Havasu and is characterized by the Bill Williams River and its delta (figure 2). Discharge in the Bill Williams River is primarily controlled by the operation of Alamo Dam, which lies approximately 62 km upstream of the delta. At base flows (< 2.83 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 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 dramatically with increased flow from the river (Dill 1944; Wiele et al. 2009, 2011). Even at base flows, however, water clarity within the refuge remains comparably low to elsewhere in Lake Havasu because of the shallow delta, soft benthic sediments, and windblown wave action. Shoreline stands of salt cedar (*Tamarix* sp.) and cottonwood (*Populus fremontii*) line the upstream-most watercraft-accessible portions of Bill Williams River, while cattail (*Typha domingensis*) and sedges (*Cyperaceae*) dominate nearly all other available shoreline habitat in BWRNWR. Large riprap lines the narrow peninsula that separates the southern portion of the refuge from the CAP intake canal. Thick beds of aquatic plants such as pondweed (*Potamogeton* spp.) and bushy pondweed (*Najas guadulupensis*) flourish in the spring, summer, and autumn months, and they are seasonally harvested to prevent blockage of the CAP Canal intake at Mark Wilmer Pumping Station (M. Thorson, USFWS, personal communication).

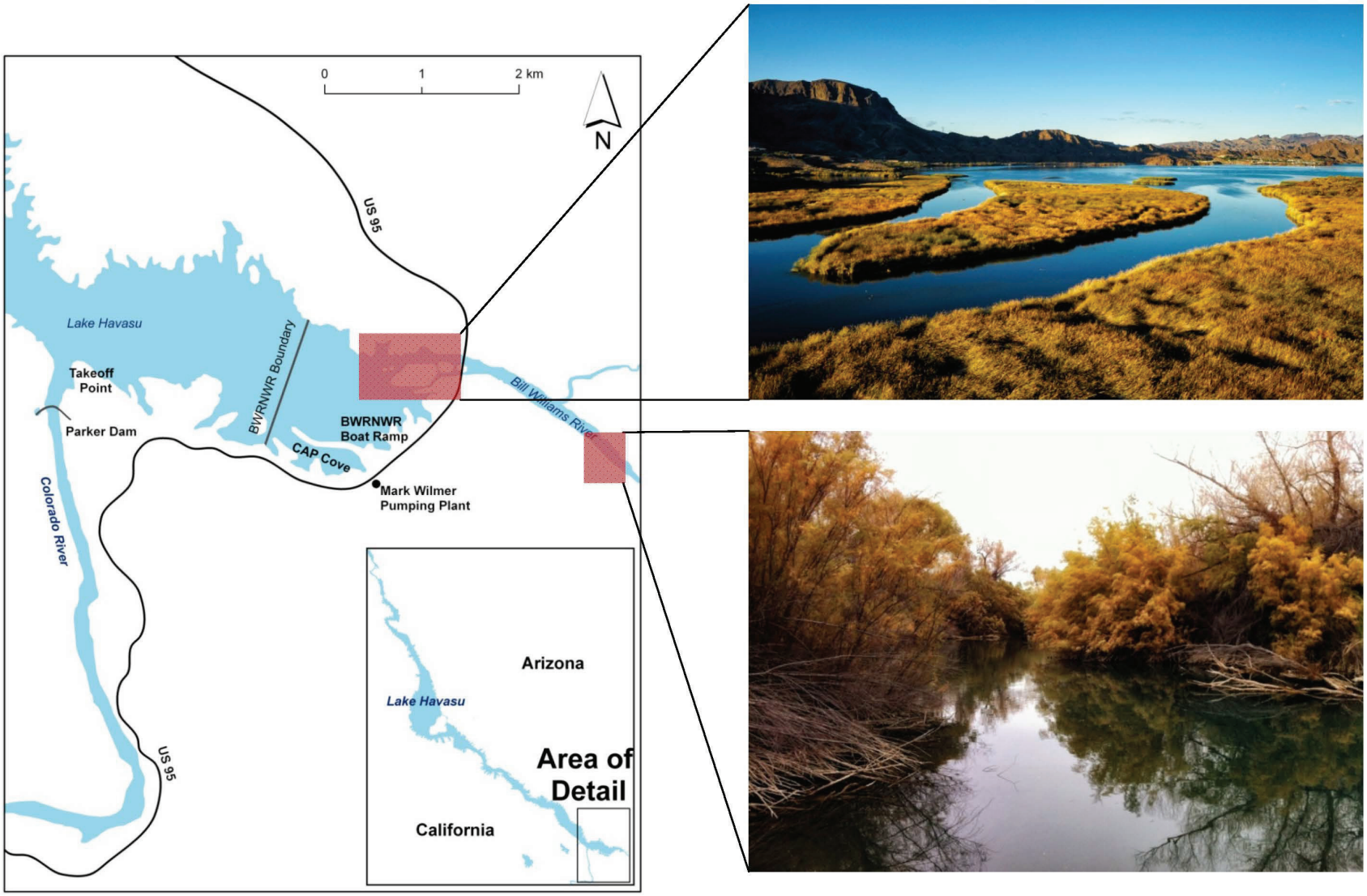


Figure 2.—Map of the watercraft-accessible portion of BWRNWR at the southeast terminus of Lake Havasu, Arizona and California, and photographs of the reach.

Lake Havasu Basin

Uplake of the refuge, Lake Havasu Basin (figure 3) extends to the northern reach of Windsor Basin at the Colorado River inflow near Lake Havasu City. Relative to BWRNWR, water clarity and depth are high (Wiele et al. 2009, 2011), and the rocky shoreline becomes sparsely lined with *Tamarix* sp., mesquite (*Prosopis* spp.), 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).

The Delta and Topock Gorge

Upstream of Windsor Basin, the Colorado River forms a braided channel for approximately 10 km. An extensive network of backwaters (predominated by rushes, *Juncaceae*) line either side of the river channel, which continues through Topock Gorge (figure 4). Most of this reach lies within the boundaries of Lake Havasu National Wildlife Refuge (LHNWR). The area is characterized by high water clarity, a relatively shallow river channel with sandy substrate, and backwaters that retain narrow or open connections to the main river channel. Thick beds of aquatic plants persist in slackwater habitats throughout the summer and autumn.

The Colorado River

Between Topock Gorge and Davis Dam, the Colorado River is sinuous and channelized as it runs through urban areas and farmlands surrounding Laughlin, Nevada, Mohave Valley, and Needles, California (figure 5). Aside from Topock Marsh and the occasional oxbows or former river channel, the river is characterized by its sand, gravel, and cobble substrate, and it maintains comparably higher water velocities as a result of Davis Dam operations (for a review of this area, see Patterson et al. 2012).

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 (figure 6). 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, three-fold pamphlets were printed and hand distributed to anglers encountered during the study. There was no followup to determine the effectiveness of this effort.

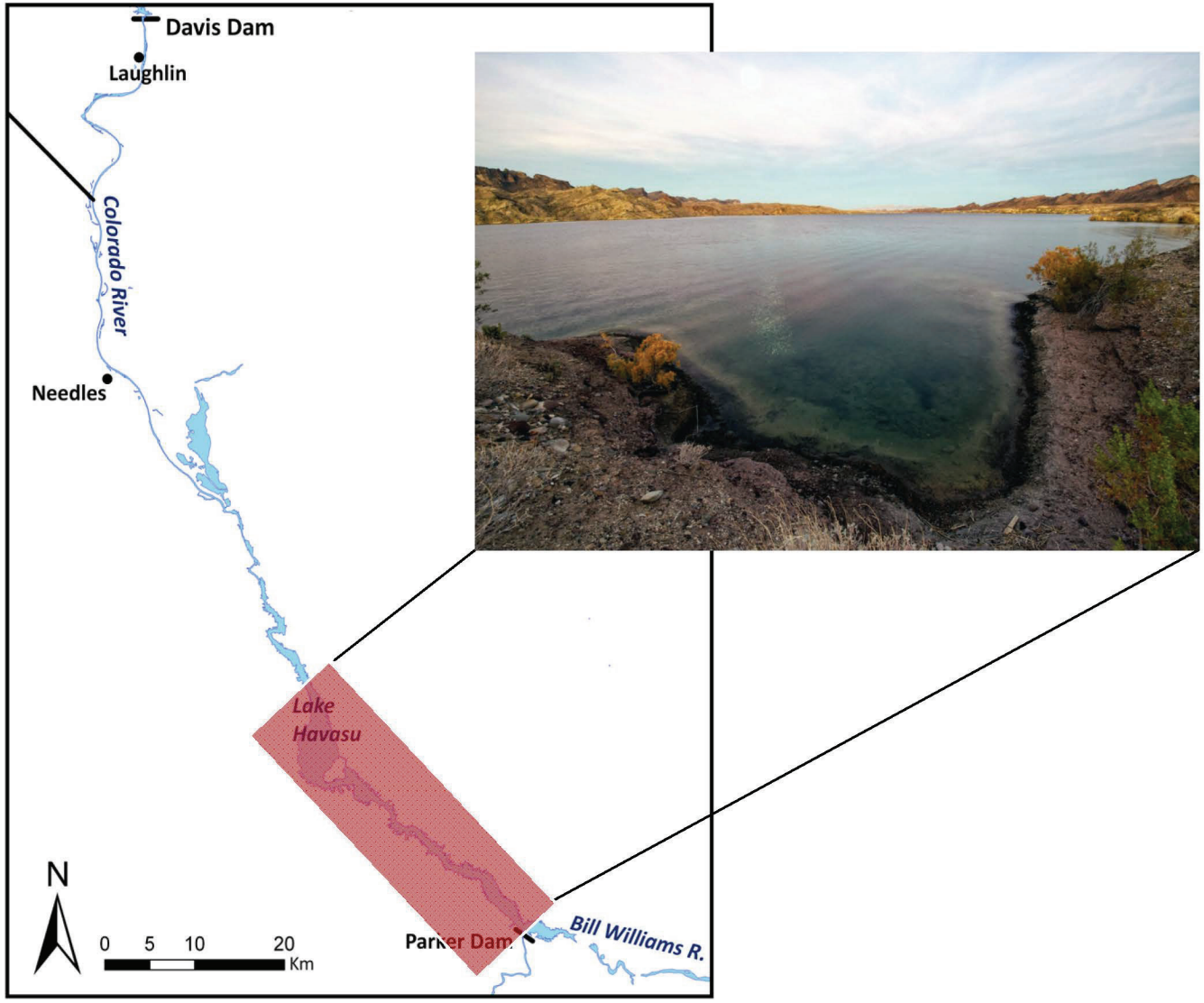


Figure 3.—Map indicating the basin of Lake Havasu, Arizona and California, and a photograph of the reach.

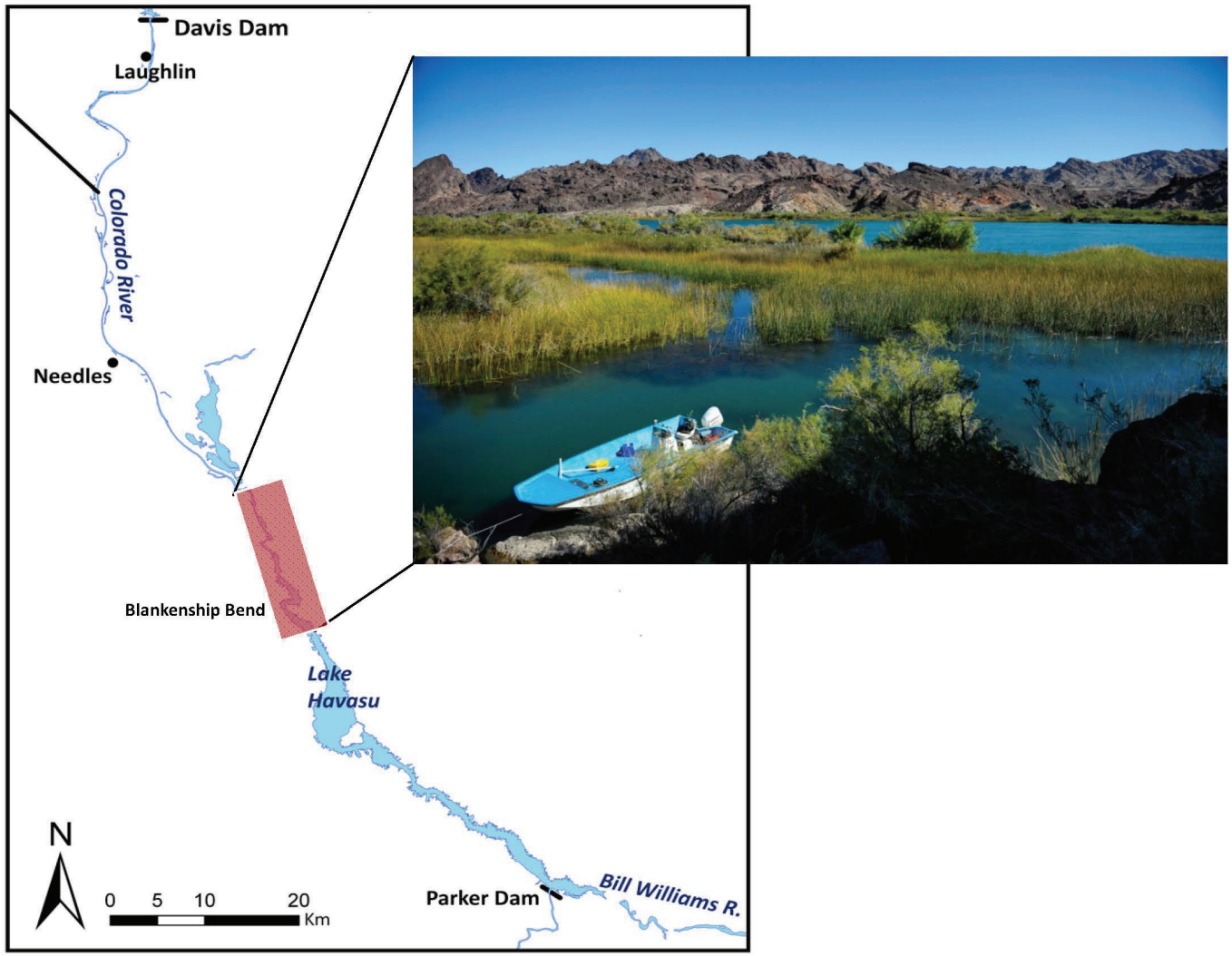


Figure 4.—Map indicating the Colorado River delta and Topock Gorge in Lake Havasu, Arizona and California, and a photograph of a typical off-channel backwater (foreground) in the reach.

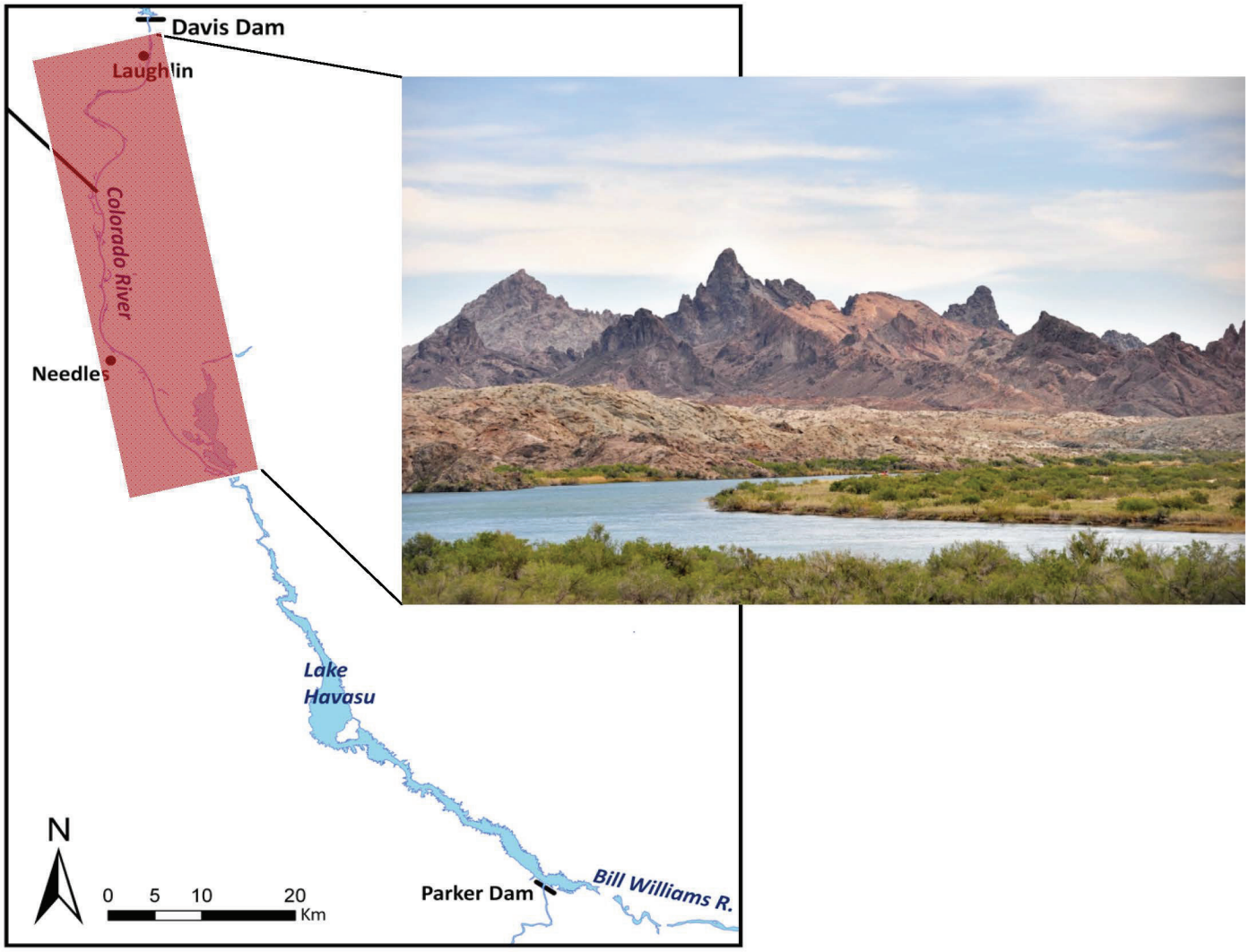


Figure 5.—Map indicating the Colorado River between Topock Gorge and Davis Dam on Lake Havasu, Arizona and California, and a photograph of the reach.

Figure 6.—Example of a flyer, indicating the presence of stocked bonytail in Lake Havasu and contact information if captured, posted at a bait shop, Lake Havasu City, Arizona.

Submersible Ultrasonic Receiver Arrangement

All submersible ultrasonic receivers (SURs) deployed throughout the study area were affixed to a camouflage-weighted rope and tethered to shore, a navigation buoy, or a subsurface float. To prevent wave/rock abrasion on the ropes attached to shore, a 6-m piece of galvanized cable provided a link to its point of attachment (usually a tree root). After deployment, the cable was buried under rocks up to the water's edge to reduce the probability of theft or vandalism. All units were programmed to continuously scan select frequencies during 60-second intervals. Detection radii extended 200 m around individual SURs and, in some cases, enabled complete shore-to-shore "gate" coverage in places where the river channel was sufficiently narrow. Units deployed in open water were tethered to a subsurface float, which increased their effective detection radius, but required scuba or surface diving to retrieve the SUR.

Bonytail Surgeries

On stocking days, acoustic tags were activated with an external magnet and tested for functionality using a directional hydrophone (DH-4; Sonotronics, Inc., Tucson Arizona) and receiver (USR-08; Sonotronics, Inc.). A surgical station was erected near the hatchery transport truck. A dual-chamber (1893-L) holding tank was filled with water from the hatchery truck and then supplied with oxygen via a split-valve regulator and air stones. Two aerated "recovery" tanks (946-L) were filled with a 50:50 mixture of lake:hatchery water and placed in the bed of a pickup truck or transport boat near the surgical station. The largest bonytail were visually selected, captured in hand-held dip nets, and transferred from the transport truck to the dual-chamber holding tank. Dissolved oxygen and water temperature levels were monitored with a hand-held Hannah Instruments® 9829 multi-parameter water quality probe.

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 milligrams per liter) until it lost equilibrium. Individuals were measured (TL; nearest mm), weighed (mass [M], nearest g), and then placed in a surgery trough. A short incision (20 mm) was made using a scalpel anterior to the pelvic fin on the left side of each fish. An acoustic transmitter sanitized in 70% ethanol was inserted into the abdominal cavity, and if not already implanted, a sanitized PIT tag was also inserted into the abdominal cavity. The incision was closed with 3-knot sutures using 4/0 Polypro®blue monofilament polypropylene non-absorbable sutures and a 17-mm NRB-1 tapered cutting needle (CP Medical, Inc., Portland Oregon). 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-milligram-per-milliliter solution) as a preventative measure for post-surgery infection (Martinsen and Horsberg 1995). Individual injections ranged from 0.1–0.3 milliliter (mL) and were based on a categorical chart that identified appropriate dosage based on the M of each fish (Kesner et al. 2008) (table 1). Tagged fish were placed in a recovery tank and monitored until they oriented themselves upright and were swimming independently.

Table 1.—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 (grams)	459	689	919	1,149	1,379	1,609
Baytril dose (mL)	0.1	0.2	0.3	0.4	0.5	0.6

Remote PIT Scanning

Remote PIT scanning systems, developed in-house at Marsh & Associates, LLC (M&A) were successfully used to monitor razorback sucker populations in Lake Mohave (Kesner et al. 2012) and in Reach 3 (Patterson et al. 2012). To assess their effectiveness at detecting the presence of PIT-tagged bonytail, those systems were deployed throughout the Lake Havasu study areas. Two models of PIT scanners were utilized: shore-based and submersible. The shore-based units were comprised of an antenna and scanner housed in a 2.3 x 0.7 m polyvinyl chloride (PVC) frame connected by 45.7 m of cable to a waterproof box that protects the logger and battery (55 amp-hours) and was 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 submersible units were 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. These latter units scanned continuously for up to 24 hours.

Remote PIT scanning units were operated for up to 4 consecutive days at a limited number of locations during most active tracking telemetry trips. Information was recorded on waterproof paper as follows: general location or site name, Universal Transverse Mercator (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 data sheets was entered into the database and associated with the scanning data for the given effort.

November 2011 Telemetry

Based on bonytail movements during the December 2010 telemetry (see Karam et al. 2011), 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 Cattail Cove as a second stocking location. Relative to conditions found in BWRNWR (high turbidity, < 6 m depth, cattail-lined shore, uniform littoral zone; see figure 2), those in Cattail Cove were representative of the aquatic habitat found elsewhere in the Lake Havasu basin (low turbidity, > 6 m depth, rocky shoreline, defined littoral zone; see figure 3).

SUR Deployment

From November 18–21, 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 December 21, 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 subsurface buoys and anchored to the bottom of the reservoir near mid-channel.

Remote PIT Scanning

From November 29, 2011, to May 3, 2012, submersible and shore-based units were tethered to the shoreline and deployed at up to nine different locations (1.0–2.4 m deep) within BWRNWR (figure 7). Submersible units were deployed along the riprap shore near the stocking area and at one location next to the cattail shoreline in Bill Williams River. A shore-based unit was deployed at approximately mid-channel under the US 95 Bridge and another under the floating dock at the BWRNWR boat ramp.

From February 6 to 9, 2012, submersible units were tethered to the shoreline and deployed at two locations (2.0 and 2.4 m deep) at Cattail Cove (figure 7). From February 6 to May 3, 2012, submersible units were placed under docks and shore-based units tethered to the shore (1.5–2.5 m deep) within Sandpoint Marina at up to four different locations. Remote PIT scanning began at Sandpoint Marina after tracking an acoustic-tagged bonytail (Fish 19) into the harbor (see Results below). Because the area was heavily utilized by people, extra precaution was taken to hide electronic boxes among shoreline vegetation.

Surgeries and Stocking

On November 28, 2011, the depth function of a subset of acoustic depth transmitters was tested for accuracy in Lake Havasu at Havasu Springs Marina. The following day, SNARRC staff transported 3,907 bonytail (mean TL = 376 mm) to BWRNWR. Bonytail were released at two separate locations in Lake Havasu: 2,111 fish were stocked at the BWRNWR boat ramp, and 1,796 fish were stocked at Cattail Cove boat ramp. While the batch stockings were in progress, 30 bonytail (mean TL = 424 mm; range = 392–460 mm and mean mass = 609 g; range = 480−812 g) were each implanted with an acoustic transmitter; 20 individuals received a 6-month battery life acoustic transmitter (Sonotronics, Inc.; IBT-96-6; 42 x 11 mm; 7.8 g), and 10 individuals received a 45-day (d) battery life[2] depth-sensing acoustic transmitter (Sonotronics, Inc.; IBDT-97-2; 47 x 10 mm; 6.8 g). Surgery fish were removed from a group of

[2] Although the depth-sensing tags were technically rated as having 45-d battery life expectancy, battery life could reasonably be expected to last for approximately 90 d (Dale White, Sonotronics, Inc., personal communication).

Figure 7.—Satellite view of remote PIT scanning locations for the November 2011 and October 2012 studies, Lake Havasu, Arizona and California.
(Image: Google Earth®)

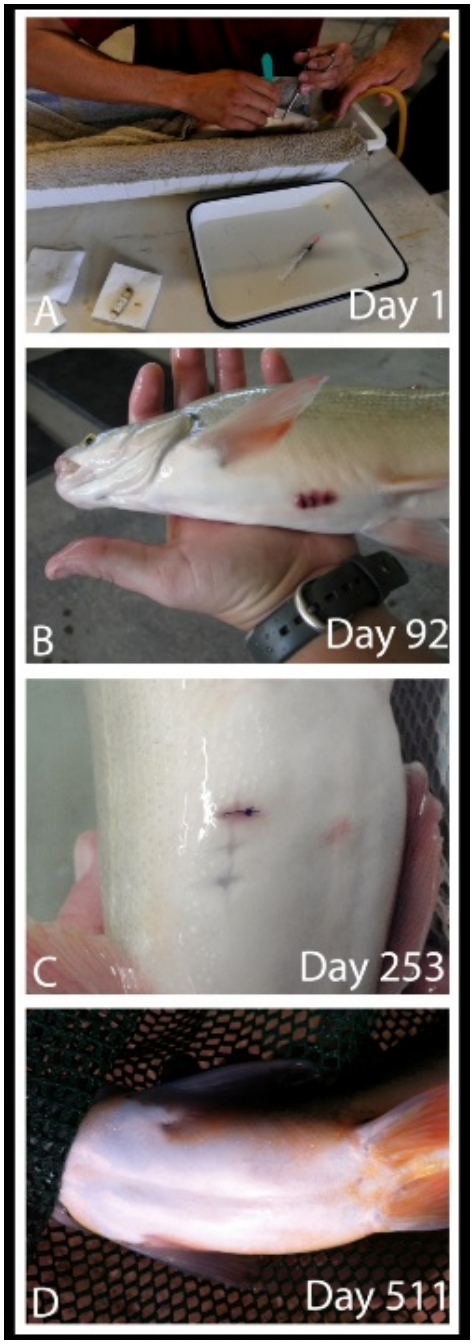


Figure 8.—Photos depicting bonytail implanted with an acoustic transmitter during the July 2010 transmitter retention study at SNARRC, Dexter, New Mexico, and seen at various time stages up until the November 29, 2011, surgeries at BWRNWR, Arizona.

the largest bonytail reserved by SNARRC. Due to faint surgical scars in the abdominal region, it was discovered that 5 of the approximately 50 allotted fish were in fact holdovers from the July 2010 tag retention study at SNARRC (Karam et al. 2011) (figure 8). Those fish were released with all other surgery fish.

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 the BWRNWR boat ramp along with all remaining bonytail.

Tracking Techniques and Database Management

Surveys followed a fixed grid (modeled after Mueller et al. 2000; Karam et al. 2008) of listening locations (750-m intervals; $N = 204$) to account for the smaller detection range of the depth-sensing tags. Two watercraft were utilized on most given dates to provide sufficient coverage to both stocking areas. Acoustic signals were detected using a hand-held directional hydrophone and ultrasonic receiver. Occasional shoreline and cove surveys were conducted using an omnidirectional towable hydrophone (TH-2; Sonotronics, Inc.). Individual fish positions were triangulated to their approximate locations where date, time, surface water temperature, depth, and distance to shore (DTS) were recorded. DTS was measured using a Bushnell® Yardage Pro Sport 450 Laser Rangefinder. Turbidity was measured at the location of each

bonytail contacted with an acoustic depth tag. A water sample was collected with a 2.2-liter Van Dorn horizontal sampling bottle at the depth where a tagged fish was contacted, and turbidity was measured using a calibrated LaMotte 2020we/wi turbidimeter.

During 3 of 4 weeks in December 2011, additional manual tracking took place at both stocking locations after dark. During nighttime tracking, two watercraft were deployed (one to each stocking location). Surveys started 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, and the aforementioned habitat parameters were recorded.

When re-contacts were made in the same location, a scuba diver was deployed to investigate with an underwater diver receiver (Sonotronics, Inc.) 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 were detected. Because SURs are not 100% reliable, and fish could have dispersed without being detected by a SUR, periodic surveys of the entire study area covered by SURs took place to ensure no fish had dispersed undetected.

Additional turbidity measurements were made along a predetermined grid at 27 sites between the easternmost watercraft-accessible portion of the Bill Williams River and Lake Havasu City (figure 9). The grid was sampled every week through December, after which the odd numbered sample sites in the sampling grid were sampled once per month in February, March, and April. Turbidity was measured in water samples collected at three depths from each site: 1 m from the reservoir bottom, mid-water column (depth/2), and 0.3 m below the surface. Each sample bottle was washed three times before turbidity was measured. Depth was determined using a Lowrance® HDS7 GPS Fish Finder.

All data were entered into a Microsoft Access® database. Raw SUR data were examined using SURsoft Stand Alone Data Processing Center v6.8.8 (Sonotronics, Inc.) prior to being exported into Access. 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). Data were pared down based on the following criteria: (1) a fish was only considered a “true contact” if it was detected twice within a 5-minute period; all other data points were considered questionable and discarded (SURs pick up noise from watercraft depth finders, which is the primary source of erroneous signals), and (2) because depth-sensing tags were prone to logging erroneous data points on SURs, maximum depth at each SUR site was determined, and depth tag contacts that were recorded deeper than the maximum lake depth at that site were excluded.

Figure 9.—Weekly turbidity sampling grid in Lake Havasu, Arizona and California, during December 2011.
Turbidity samples were taken beginning at the upstream-most watercraft-accessible portion of the Bill Williams River (1) and proceeded sequentially toward Lake Havasu City (27). At each location, a sample was taken from the surface, mid-column, and bottom.

Depth tags had to present their frequency and depth information in an alternating pattern to be considered true data in a SUR file. Sometimes a depth-tagged fish appeared to be contacted by a SUR, but only presented depth data (which was obviously erroneous to an experienced eye). In order for depth contacts to be considered reliable, they had to display an alternating pattern of the frequency, then subsequent depth, frequency, subsequent depth, etc. Data were removed in those cases in which only a string of depths was recorded. The shoreline habitat in BWRNWR is extensively lined with a mosaic of cattails that were not represented by spatial layers in ArcGIS. The true river channel was most accurately displayed in Google Earth® satellite imagery. To determine the extent of dispersal for stocked fish, curvilinear distances that followed the river channel thalweg were measured from the stocking location to the farthest respective fish detection points using Google Earth®.

Patterns of inhabitance in BWRNWR and Lake Havasu were analyzed using an ArcGIS (ESRI® ArcMap; v 9.1) 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 BWRNWR was defined as the first detection by any receiver, and exit was defined as the last detection in BWRNWR at least 1 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 the differences in continuous inhabitance spent between BWRNWR and Lake Havasu.

2012 Lake Havasu Native Fish Roundup

M&A participated in the multi-agency Native Fish Roundup on Lake Havasu from February 6 to 10, 2012. 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 2012, four to six trammel nets (45.7 m x 1.8 m, 3.8-centimeter [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 4 consecutive nights. All fish were removed and processed (enumerated, measured to total length [mm], weighed

[M, in grams], sexed, scanned for a wire or 134-kilohertz PIT tag if native, and tagged if none was present, daily. For a detailed description of the entire group's methods, see USFWS 2012.

October 2012 Telemetry

In addition to stocking at BWRNWR, a new stocking location was chosen at Blankenship Bend (see figure 4) where the corresponding habitat differs from both BWRNWR (see figure 2) and Cattail Cove (see figure 3). BWRNWR was retained as a "control" stocking location whereby results could be compared with previous (and subsequent) releases. The Blankenship Bend stocking represented the first time during the 3-year study that bonytail were exposed to river current, so a prevailing question centered on whether fish would move upstream, downstream, or seek cover in backwater habitats. Furthermore, the narrow river channel at Blankenship Bend provided a confined stocking area relative to other stocking areas utilized during recent stocking events (BWRNWR and Cattail Cove), which presumably would allow for more efficient tracking of acoustic-tagged fish.

SUR Deployment

From October 3 to 5, 2012, 30 SURs were deployed throughout the project study area: 15 between the downstream portion of Windsor Basin and the upstream-most watercraft-accessible portions of the Bill Williams River and 15 between the Colorado River delta and the river channel near Laughlin, Nevada. Of the 30 SURs deployed, only 1 was tethered to a subsurface buoy and anchored to the bottom of the reservoir near mid-channel. From November 13 to 16, 11 additional SURs were acquired on loan from Reclamation and were deployed exclusively in backwaters surrounding Blankenship Bend ($N = 8$) and the Bill Williams River delta ($N = 3$).

Remote PIT Scanning

From October 7 to 12, 2012, submersible and shore-based units were tethered to the shoreline, and docks and deployed at up to 12 different locations (1.0–3.3 m deep) within BWRNWR (see figure 7). Submersible units were deployed along the riprap shore and under the fishing dock located 400 m west of the BWRNWR boat ramp. A single shore-based unit was deployed under the dock located at BWRNWR boat ramp.

From November 6 to 8, 2012, submersible and shore-based units were placed at up to 15 locations (up to 2.5 m deep) in the river and surrounding backwaters near Blankenship Bend (figure 10). Between November 6, 2012, and February 14, 2013, up to 11 units were placed within Park Moabi and the river connection to Topock Marsh (figure 11).

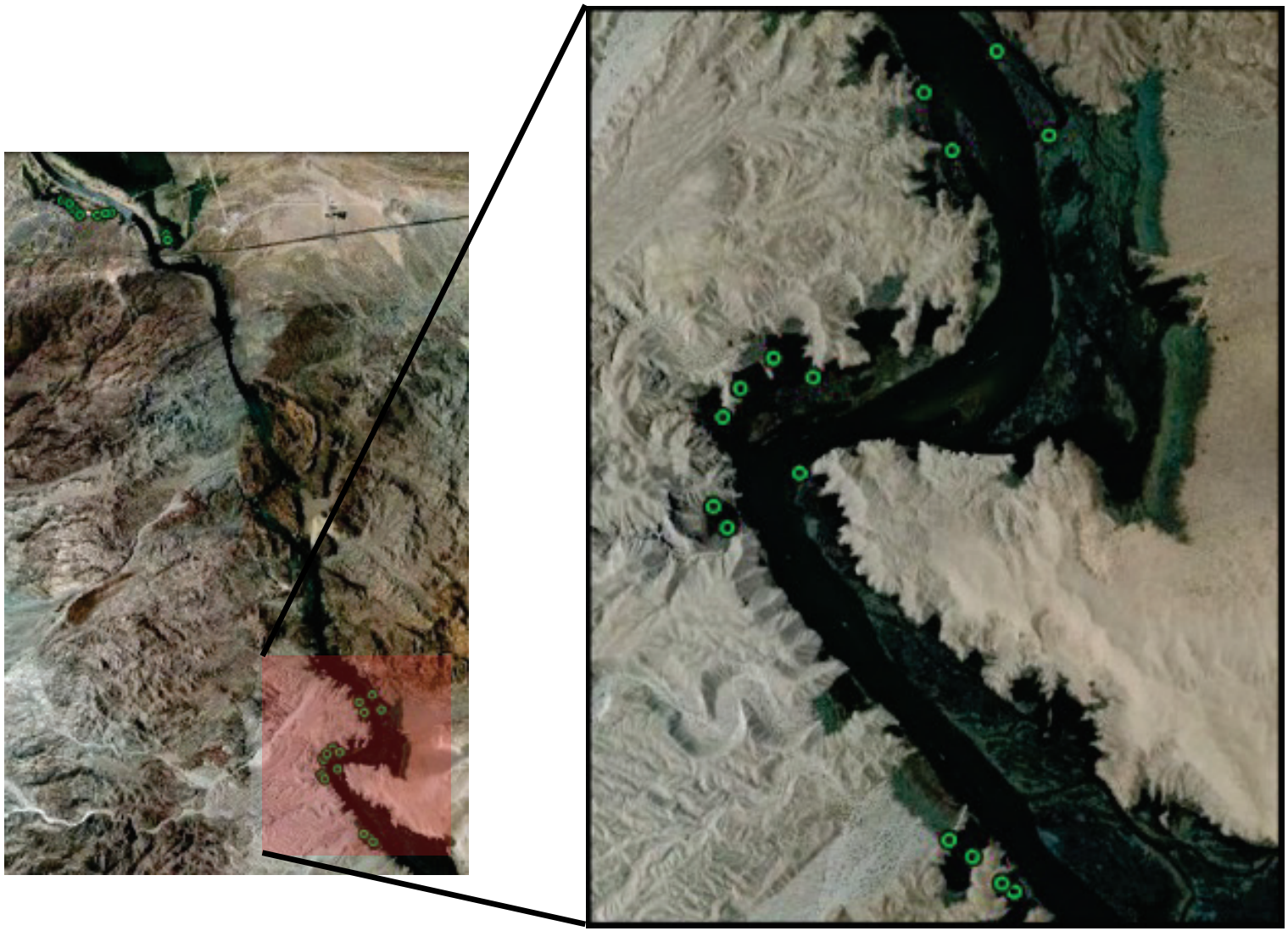


Figure 10.—Satellite view of remote PIT scanning locations at Blankenship Bend during October 2012, Lake Havasu, Arizona and California.
(Image: Google Earth®)

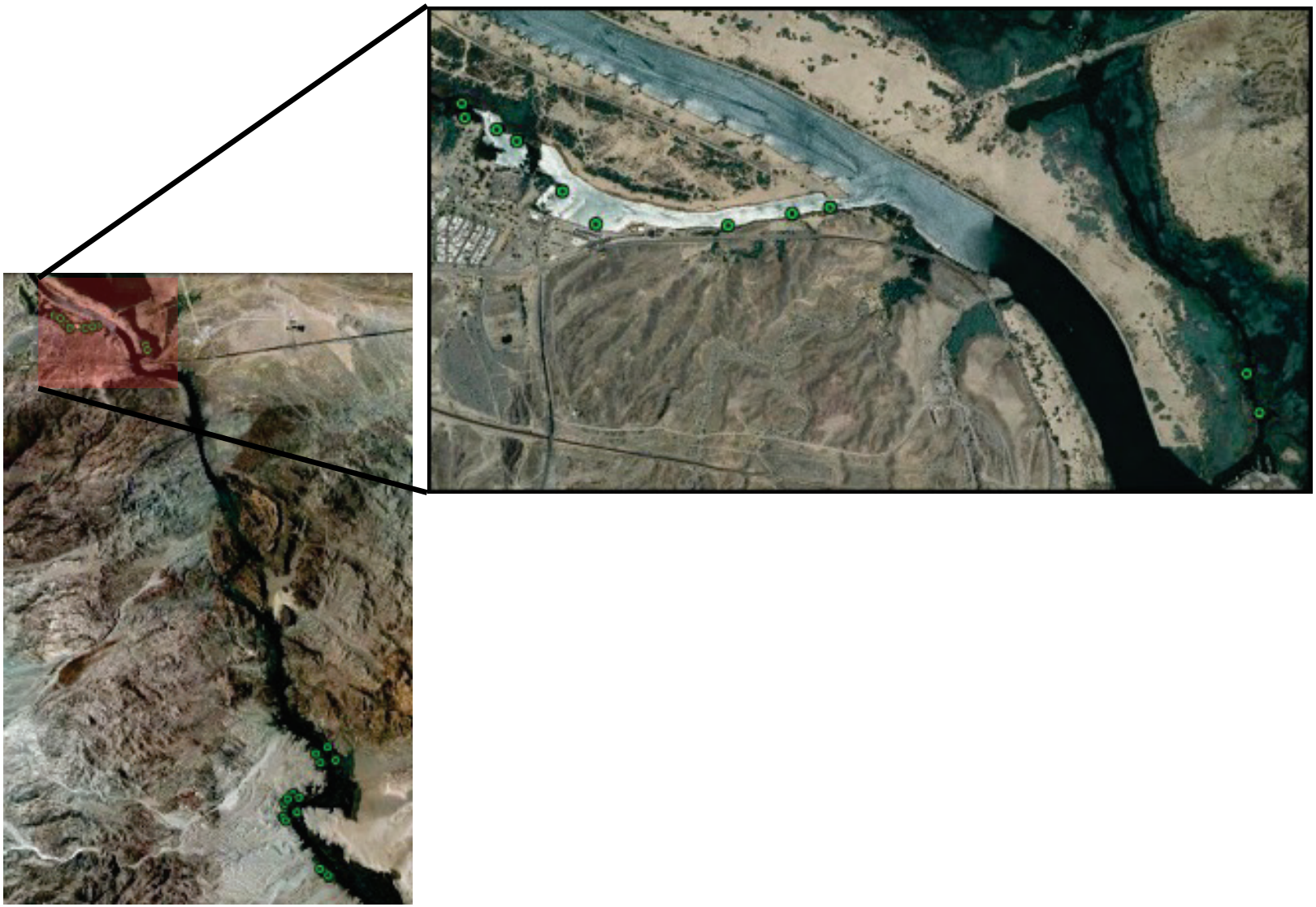


Figure 11. Satellite view of remote PIT scanning locations at Park Moabi during October 2012, Lake Havasu, Arizona and California. (Image: Google Earth®)

Surgeries and Stocking

On October 8, 2012, SNARRC staff transported 3,991 bonytail (mean TL = 320 mm) to Lake Havasu. Bonytail were released by USFWS staff at two separate locations: 1,998 fish were stocked at the BWRNWR boat ramp, and 1,993 fish were stocked at Blankenship Bend. Because the water temperatures near Blankenship Bend were considerably colder than the transport water inside the hatchery truck, bonytail first were tempered in a separate holding tank at the Windsor Beach boat ramp (figure 12). The fish were then loaded into aerated tanks secured inside boats (figure 12), transported to Blankenship Bend (a distance of approximately 13 km), and released.

While the batch stockings were in progress, 30 bonytail were each implanted with an acoustic transmitter (mean TL = 366 mm; range = 320–430 mm and mean mass = 398 g; range = 270−697 g); 20 individuals received a 3-month battery life acoustic transmitter (Sonotronics, Inc.; PT-4; 27 x 9 mm; 4.2 g in air), 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. The first 15 surgeries took place at a surgical station next to a boat ramp at Windsor Beach State Park. Ten bonytail implanted with the IBT-96-6 transmitters and five implanted with the IBDT-97-2 transmitters were then driven by boat to Blankenship Bend and released. Fifteen bonytail were then similarly implanted with acoustic transmitters at a surgical station next to the BWRNWR boat ramp and subsequently released as a group.

Tracking Techniques and Database Management

A watercraft was staged at Blankenship Bend, and tracking began immediately after the release of acoustic-tagged fish. Due to the amount of time it took to complete all 30 surgeries, manual tracking in BWRNWR did not commence until the following day. Tracking techniques generally followed those previously outlined for November 2011 with two exceptions: (1) additional tracking took place inside backwater habitats of the Blankenship Bend reach, which was not accounted for by the sampling grid, and (2) tracking efforts at Blankenship Bend ceased at the opening to Windsor Basin and at the upstream-most SUR that did not contain contact data. During two nighttime tracking events, one watercraft was deployed to each stocking area, and surveys covered both areas over the course of 4 nights (2 nights total at each stocking area). Occasional shoreline and cove surveys were conducted using a towable hydrophone throughout the study. A survey conducted in mid-December 2012 covered all 204 listening stations (Davis Dam to BWRNWR). Individual fish positions were triangulated to their exact location where the date, time, water temperature, Secchi depth, reservoir depth, and fish depth (if applicable) were recorded. Turbidity was measured at the exact location of each bonytail contacted with an acoustic depth tag. A water sample was collected with a 2.2-liter Van Dorn horizontal sampling bottle tethered to a rope at the depth where a tagged fish was contacted.

Figure 12.—Aerated fish transport tank in which bonytail were tempered (A) and from which fish were transferred into smaller transport tanks on Reclamation watercraft (B) before being boated to and released at Blankenship Bend, Lake Havasu, Arizona and California, on October 8, 2012.

Immediately after, a second sample was taken at mid-depth from the water column. Turbidity in each sample was measured using a calibrated LaMotte 2020we/wi turbidimeter.

Additional turbidity measurements were made along a predetermined grid at 30 sites; 10 of which were located between the upstream-most watercraft-accessible location in Bill Williams River and Cattail Cove (figure 13) and 20 between the Colorado River delta near Windsor Basin and Topock Gorge (figure 14). The grid was sampled on October 9–10, 2012. Turbidity was measured in water samples collected at mid-water column (depth/2). Each sample bottle was washed three times before turbidity was measured. Depth was determined using a Lowrance® HDS7 GPS Fish Finder.

All shore-based SURs were downloaded on December 11, 2012, and February 5, 2013. The single SUR tethered to a subsurface float was retrieved and downloaded on February 6, 2013. Raw SUR data were examined and pared down using a beta version of SURsoft Stand Alone Data Processing Center v 1.0.0 (Sonotronics, Inc.) prior to being imported into a Microsoft Access® database along with all other data. The new version of SURsoft enabled batch processing and provided a confidence scan feature that produced internally generated values indicating tag identification matches, thereby enhancing the ability to delete erroneous data prior to exporting those data into Access.

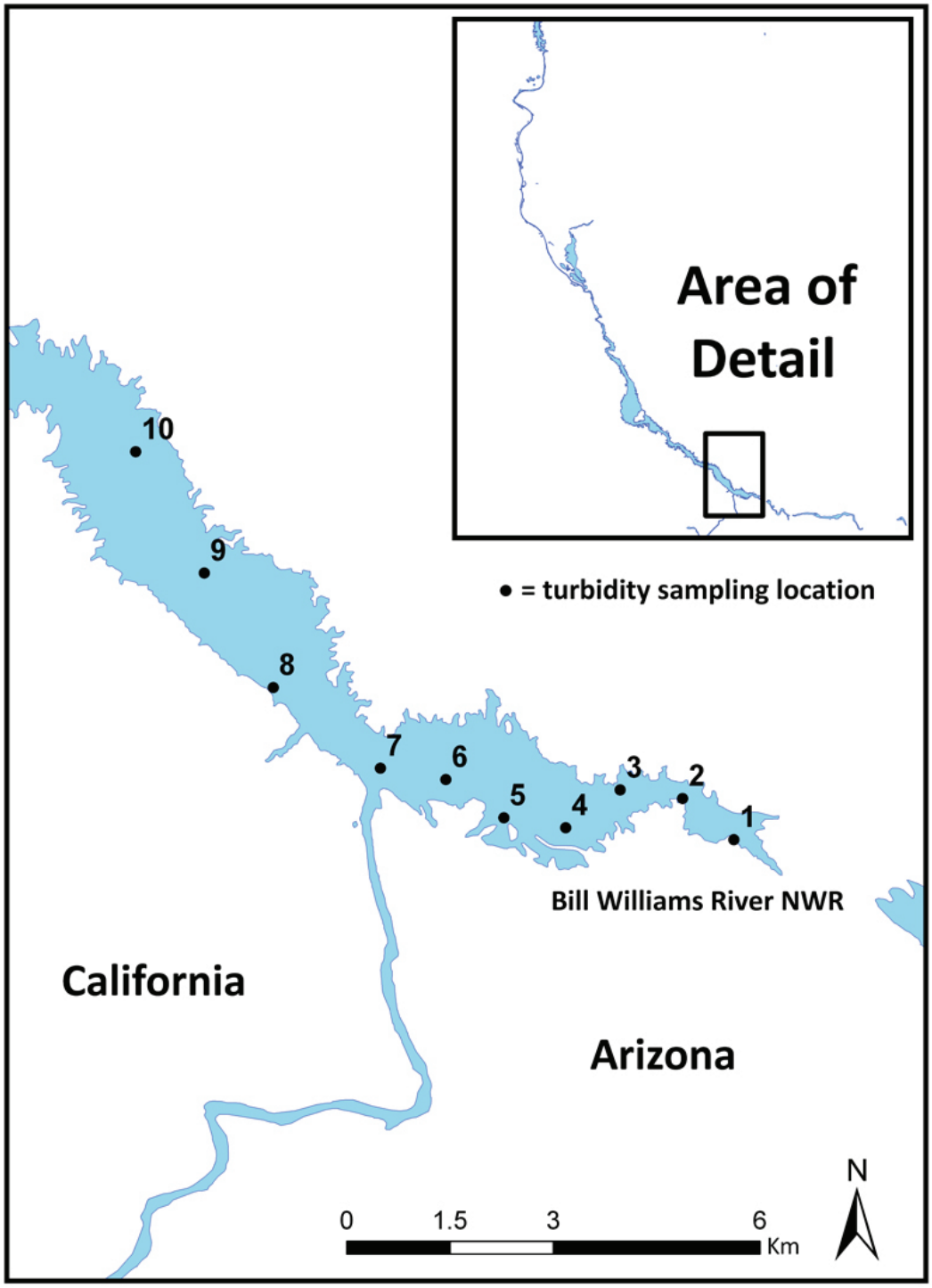


Figure 13.—Turbidity sampling grid in the BWRNWR arm of Lake Havasu, Arizona and California, during October 2012.
Turbidity samples were taken beginning at the upstream-most watercraft-accessible portion of the Bill Williams River (1) and proceeded sequentially toward Lake Havasu City, Arizona (10). At each location, a sample was taken from the mid-column.

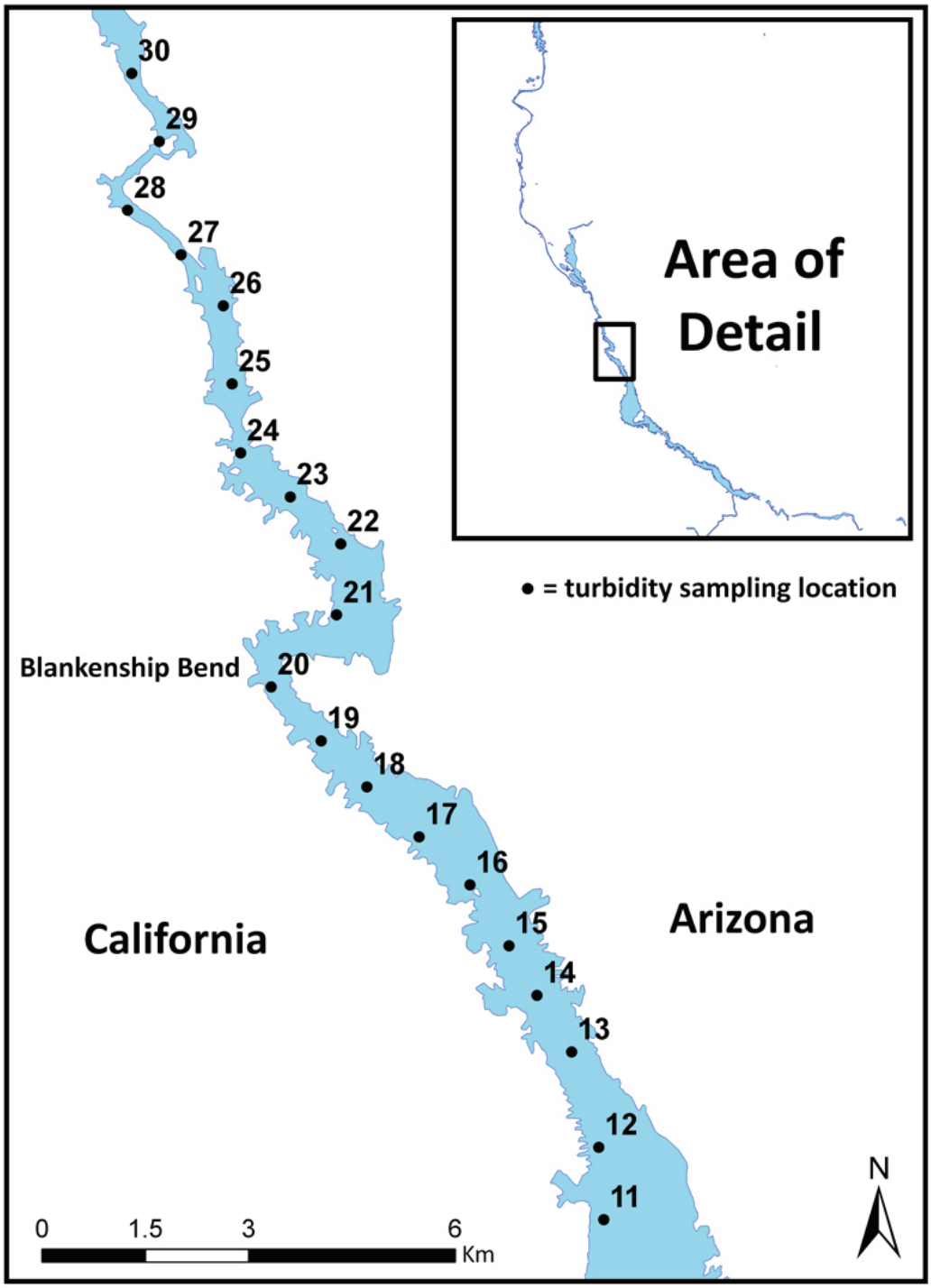


Figure 14.—Turbidity sampling grid in the Blankenship Bend arm of Lake Havasu, Arizona and California, during October 2012.
Turbidity samples were taken beginning at the delta (11) and proceeded sequentially upstream (30). At each location, a sample was taken from the mid-column.

RESULTS

November 2011 Telemetry

Remote PIT Scanners

Remote PIT antennas deployed at BWRNWR scanned for a total of 50,137 minutes. The shore-based unit deployed under the US 95 Bridge between November 29 and December 1 was compromised by a leak and did not collect any data, although a subsequent deployment at that site was successful. Over the course of the study, 189 unique bonytail were contacted by submersible scanners positioned in the immediate stocking area (table 2), all of which had marking records in the Lower Colorado River Native Fishes Database. All of the fish had been released at BWRNWR on November 29, 2011. No fish were contacted by scanners deployed upstream of the Bill Williams River delta.

Table 2.—Remote PIT scanning location, contacts, and effort during the November 2011 study, Lake Havasu, Arizona and California

Scanning location	Unique contacts	Effort (minutes)
BWRNWR	0	3,776
BWRNWR boat ramp	189	40,965
US 95 Bridge – Bill Williams River	0	5,396
Cattail Cove	0	4,332
Sandpoint Marina	41	48,429
Total	230	102,898

Remote PIT antennas deployed at Cattail Cove and Sandpoint Marina scanned for a total of 52,761 minutes. Over the course of the study, 41 unique bonytail were contacted by the submersible scanners positioned exclusively in Sandpoint Marina (see table 2), all of which had marking records in the Lower Colorado River Native Fishes Database. All of the fish had been released at Cattail Cove on November 29, 2011. No bonytail were contacted by antennae deployed at Cattail Cove.

Post-stocking Mortality and Transmitter Recovery

Mortality for the 10 bonytail implanted with 6-month battery life transmitters and stocked at BWRNWR in November 2011 was high; 5 of 10 fish (50%) were dead after 1 month, and 10 of 10 fish (100%) were dead at the start of the third month (figure 15). No acoustic-tagged fish stocked at BWRNWR were alive during the

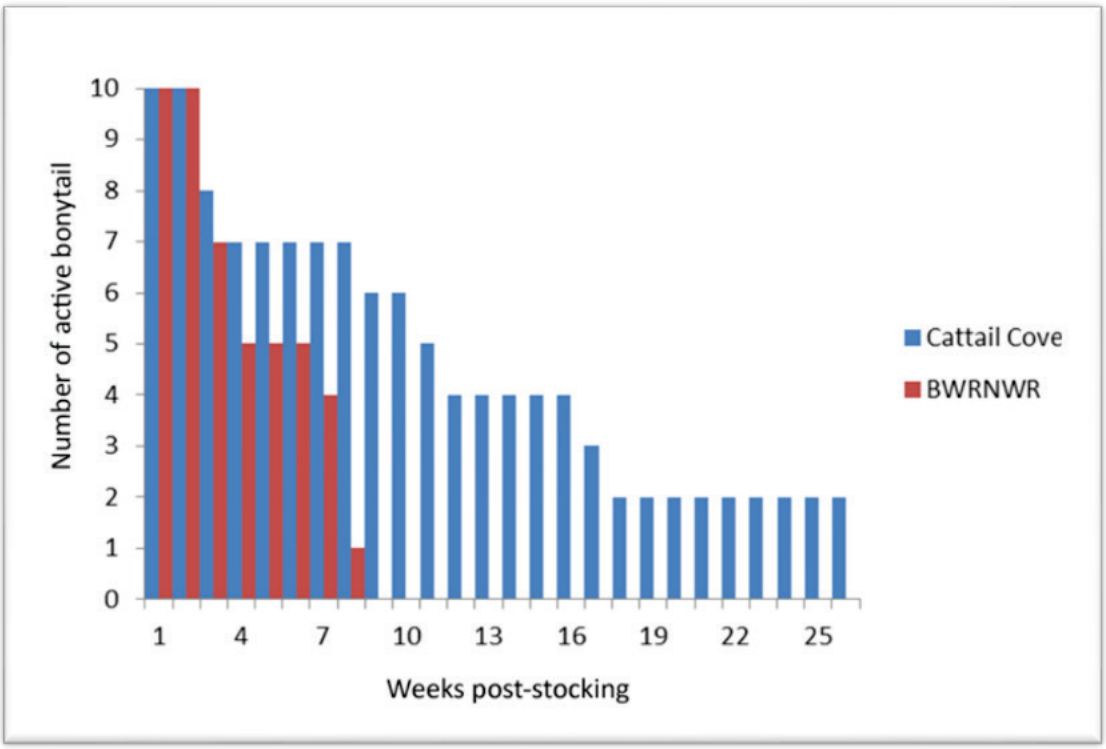


Figure 15.—Number of bonytail available for contact during the November 2011 telemetry study, Lake Havasu, Arizona and California.

last 3 months of this study. Additionally, two of five depth-tagged fish died during the study—one each during the first and fifth weeks post-stocking.

Mortality was likewise high for the 10 bonytail implanted with 6-month battery life transmitters and stocked at Cattail Cove in November 2011; 6 of 10 fish (60%) were dead after 3 months, and 8 of 10 fish (80%) were dead at the end of the 6-month study (see figure 15). One of five depth-tagged fish died during the second week post-stocking.

Over the course of the study, 22 immobile transmitters (nineteen 6-month tags and three 45-d depth tags) were inspected using a mask and snorkel or scuba gear, and 21 were recovered (table 3). No fish remains were observed near any of the transmitters. One fish (Fish 19)[3] was thought to be dead in Sandpoint Marina during January 2012, but upon inspection by a skin diver, the fish was found to be alive and actively moving. The tag was recovered four coves to the north of the marina on a later date (see table 3). The 12 immobile tags that originated in bonytail stocked at BWRNWR were located and recovered within a 5.4-km linear distance surrounding the stocking area (figure 16). Five transmitters were recovered upstream of the Bill Williams River delta (0.9–2.8 m deep), five were

[3] Fish identification numbers were between 2 and 53 as assigned by the manufacturer (see tables 6 and 7).

Table 3.—Table of acoustic tags that became sessile and were inspected by divers during the course of the November 2011 telemetry study, Lake Havasu, Arizona and California

Gray boxes indicate fish stocked at BWRNWR. Coordinates (easting and northing) are UTM, Zone 11S, NAD83/WGS84 datum.

Tag ID	Dive date	Number of days alive	Recovery depth (m)	Easting	Northing	Recovery location
7	02/01/2012	8	9.1	765519	3799939	North end of the BWRNWR buoy line
21	01/31/2012	10	2.4	765350	3798332	CAP Cove
23	01/31/2012	10	4.3	765176	3798418	West of the BWRNWR buoy line
49	02/01/2012	10	5.8	765695	3799350	Near the BWRNWR buoy line
35	03/28/2012	21	0.9	769394	3797831	Bill Williams River
51	03/28/2012	21	2.1	768982	3798155	Bill Williams River
9	01/31/2012	37	3.9	766468	3798469	Near kayak launch at BWRNWR
32	06/06/2012	42	2.1	768699	3798449	Bill Williams River
53	03/28/2012	50	3.1	766549	3798746	North of boat launch in BWRNWR
34	03/28/2012	50	2.8	768541	3798617	Bill Williams River
22	03/28/2012	50	1.5	767794	3799153	Bill Williams River
24	03/28/2012	51	4.8	765945	3798220	CAP Cove
48	03/27/2012	8	14.4	759017	3805081	Uplake of Sandpoint Marina
18	01/31/2012	8	4.9	758801	3804059	Across lake from Cattail Cove, California, shore
20	01/31/2012	9	15.9	762403	3800557	Near Gene Wash Cove
50	03/27/2012	17	3.4	757036	3806546	Near Redrock Point
33	06/06/2012	51	1.2	767418	3799261	US 95 Bridge
19	06/06/2012	64	2.1	758668	3805701	North of Cattail Cove on Arizona side
37	06/06/2012	73	4.9	752250	3809897	Steamboat Cove
47	03/28/2012	92	5	758943	3805629	Uplake of Cattail Cove
38	06/06/2012	106	5.4	762937	3800733	Near Gene Wash Cove

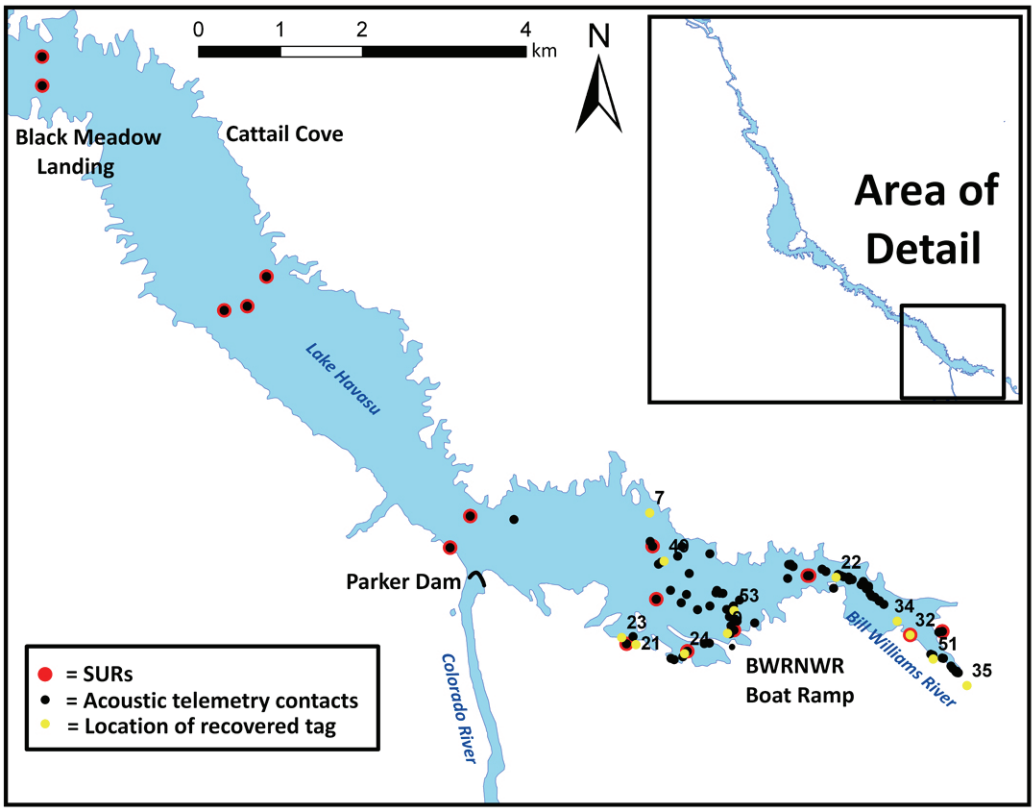


Figure 16.—Map of acoustic telemetry contacts from bonytail released at BWRNWR in November 2011, Lake Havasu, Arizona and California.

recovered between the delta and the BWRNWR buoy line (3.9–9.1 m deep), and two were recovered within 300 m of the western boundary of the BWRNWR buoy line (2.4 and 4.3 m deep). Mortalities for bonytail stocked at BWRNWR occurred at an average of 30 d (range = 8−51 d) after stocking (see table 3). The nine immobile tags from bonytail stocked at Cattail Cove were located within a 21.6-km linear distance surrounding the stocking area (figure 17). Eight of those transmitters were recovered (2.1–15.9 m deep) in Lake Havasu between Steamboat Cove and Gene Wash, and one transmitter was recovered (1.2 m deep) upstream of the Bill Williams River delta. Mortalities for bonytail stocked at Cattail Cove occurred at an average of 48 d (range 8–106 d) after stocking (see table 3).

Movement Patterns and Inhabitance

All acoustic-tagged bonytail ($N = 30$) were contacted during this study for a total of 161,262 contacts up to 143 d after stocking, of which 154 contacts occurred using manual tracking. Twenty-six of 29 SURs detected acoustic-tagged bonytail; 16 SURs contacted fish stocked at BWRNWR (table 4), and 24 SURs contacted fish stocked at Cattail cove (table 5). No fish were detected in Windsor Basin.

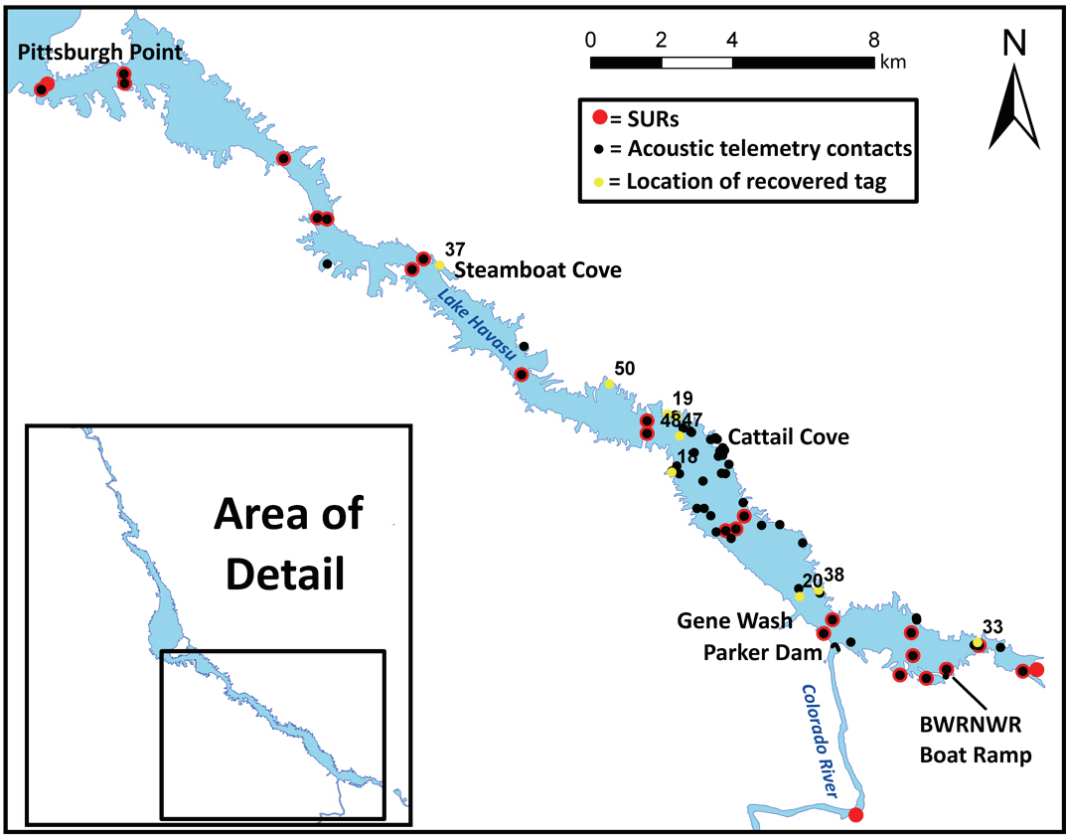


Figure 17.—Map of acoustic telemetry contacts from bonytail released at Cattail Cove in November 2011, Lake Havasu, Arizona and California.

Fish tagged with acoustic transmitters and released at the BWRNWR boat ramp dispersed into the upstream-most watercraft-accessible portion of the Bill Williams River (Fish 35; 3.8 km from the boat ramp), including a small side channel that measured no more than 4 m in width (Fish 32; 3.4 km from boat ramp). The extent of upstream fish dispersal appeared to be limited by the lack of water and available habitat beyond those points of detection (figure 18). Uplake dispersal into Lake Havasu extended to approximately Black Meadow Landing (Fish 21; 11.0 km) or a cumulative curvilinear distance of 14.4 km surrounding the stocking site (see figure 16). The SUR "gate" near Gene Wash (approximately 2.5 km uplake of the BWRNWR buoy line) recorded the presence of two fish released at BWRNWR (Fish 21 and 23). Fish released at Cattail Cove dispersed between the Bill Williams River (Fish 33; 12.1 km) approximately 1.5 km upstream of the US 95 Bridge and Pittsburg Point (Fish 4; 23.3 km) or a cumulative curvilinear distance of 35.4 km surrounding the stocking site (see figure 17).

Remote PIT scanning began at Sandpoint Marina after tracking an acoustic-tagged bonytail (Fish 19) to the harbor. After triangulating its position during three separate tracking trips in the same location, a diver was sent down to locate and

Table 4.—SUR detections of fish stocked in BWRNWR in November 2011, Lake Havasu, Arizona and California
Gray boxes indicate SURs located inside BWRNWR. Coordinates (easting and northing) are UTM, Zone 11S, NAD83/WGS84 datum.

Location	Easting	Northing	SUR	Number of contacts	Tag ID detected
Downstream Parker Dam	763994	3794397	315	0	No detections
Bill Williams River, side channel	769092	3798492	416	949	32
Bill Williams River	768699	3798449	468	11,303	21, 22, 32, 34, 35, 51
Bill Williams River at US 95 Bridge, north	767449	3799172	317	13,421	2, 3, 21, 22, 32, 34, 35, 51
Bill Williams River at US 95 Bridge, south	767466	3799173	467	4,615	3, 21, 22, 32, 34, 35, 51
BWRNWR boat ramp	766547	3798507	10230	15,069	2, 3, 5, 7, 9, 21, 22, 23, 24, 32, 34, 35, 49, 51, 53
CAP intake	765979	3798249	10228	10, 369	21, 24, 49, 53
BWRNWR buoy line, north	765554	3799532	10236	9,206	3, 5, 7, 21, 22, 23, 24, 34, 35, 49, 53
BWRNWR buoy line, south	765599	3798886	10231	27,497	2, 3, 5, 7, 9, 21, 22, 23, 24, 32, 34, 35, 49, 51, 53
Rose Cove	765236	3798341	10237	4,624	3, 5, 7, 21, 22, 23, 24, 34, 35, 49, 51, 53
Gene Wash, California	763081	3799515	10240/316	277	23
Gene Wash, Arizona	763327	3799900	10353	1,431	21, 23
Cattail Cove, Arizona	760839	3802823	10350	213	21
Cattail Cove, mid-channel	760604	3802462	10352	363	21
Cattail Cove, California	760322	3802410	10356	220	21
Black Meadow, Arizona	758096	3805507	10233	212	21
Black Meadow, California	758099	3805153	10357	297	21
Mohave Point	754558	3806808	10226	0	No detections

Table 4.—SUR detections of fish stocked in BWRNWR in November 2011, Lake Havasu, Arizona and California
Gray boxes indicate SURs located inside BWRNWR. Coordinates (easting and northing) are UTM, Zone 11S, NAD83/WGS84 datum.

Location	Easting	Northing	SUR	Number of contacts	Tag ID detected
Steamboat Cove, Arizona	751793	3810067	10173/10238	0	No detections
Steamboat Cove, California	751470	3809775	10415	0	No detections
Pilot Rock, Arizona	749069	3811194	10238	0	No detections
Pilot Rock, California	748800	3811229	10206	0	No detections
Copper Canyon	747846	3812897	10232	0	No detections
Thompson Bay, mid-channel	743344	3815285	595	0	No detections
Thompson Bay, California	743362	3815019	10119	0	No detections
Pittsburg Point	741181	3815000	10225	0	No detections
Pittsburg Point, California	741012	3814840	10239	0	No detections
London Bridge	742742	3818064	10235	0	No detections
Blankenship Bend	735142	3831101	10234	0	No detections

Table 5.—SUR detections of fish stocked in Cattail Cove in November 2011, Lake Havasu, Arizona and California
Gray boxes indicate SURs located inside BWRNWR. Coordinates (easting and northing) are UTM, Zone 11S, NAD83/WGS84 datum.

Location	Easting	Northing	SUR	Number of contacts	Tag ID detected
Downstream Parker Dam	763994	3794397	315	0	No detections
Bill Williams River, side channel	769092	3798492	416	0	No detections
Bill Williams River	768699	3798449	468	1,316	33
Bill Williams River at US 95 Bridge, north	767449	3799172	317	13,101	33
Bill Williams River at US 95 Bridge, south	767466	3799173	467	1,932	33
BWRNWR boat ramp	766547	3798507	10230	259	33, 38, 50
CAP intake	765979	3798249	10228	117	4, 38, 50
BWRNWR buoy line, north	765554	3799532	10236	950	4, 17, 33, 38, 50
BWRNWR buoy line, south	765599	3798886	10231	994	4, 17, 33, 38, 50
Rose Cove	765236	3798341	10237	247	4, 17, 33, 38, 50, 52
Gene Wash, California	763081	3799515	10240/316	2	37
Gene Wash, Arizona	763327	3799900	10353	1,013	4, 17, 33, 37, 38, 50
Cattail Cove, Arizona	760839	3802823	10350	6,524	4, 6, 8, 17, 18, 19, 20, 33, 36, 38, 47, 48, 50, 52
Cattail Cove, mid-channel	760604	3802462	10352	7,661	4, 6, 8, 17, 19, 18, 20, 33, 36, 37, 38, 47, 50, 52
Cattail Cove, California	760322	3802410	10356	3,792	4, 6, 8, 17, 20, 33, 36, 37, 38, 47, 50
Black Meadow, Arizona	758096	3805507	10233	1,616	4, 6, 8, 17, 18, 19, 20, 33, 37, 38, 47, 50, 52
Black Meadow, California	758099	3805153	10357	3,505	4, 6, 8, 17, 18, 19, 20, 33, 37, 38, 47, 48, 50, 52

Table 5.—SUR detections of fish stocked in Cattail Cove in November 2011, Lake Havasu, Arizona and California
Gray boxes indicate SURs located inside BWRNWR. Coordinates (easting and northing) are UTM, Zone 11S, NAD83/WGS84 datum.

Location	Easting	Northing	SUR	Number of contacts	Tag ID detected
Mohave Point	754558	3806808	10226	705	4, 8, 37, 50, 52
Steamboat Cove, Arizona	751793	3810067	10173/10238	43	4, 8, 37
Steamboat Cove, California	751470	3809775	10415	1,990	4, 8, 37
Pilot Rock, Arizona	749069	3811194	10238	0	No detections
Pilot Rock, California	748800	3811229	10206	5	4
Copper Canyon	747846	3812897	10232	72	4
Thompson Bay, mid-channel	743344	3815285	595	22	4
Thompson Bay, California	743362	3815019	10119	9	4
Pittsburg Point	741181	3815000	10225	305	4
Pittsburg Point, California	741012	3814840	10239	116	4
London Bridge	742742	3818064	10235	0	No detections
Blankenship Bend	735142	3831101	10234	0	No detections

Figure 18.—Satellite view of the upstream-most distributions of Fish 32 and 35, which represented the upstream-most detections for all acoustic-tagged fish released at BWRNWR in November 2011, Lake Havasu, Arizona and California. Note the lack of available habitat beyond the distribution points.
(Image: Google Earth®)

inspect the sessile tag and discovered the fish was alive and in the same proximity of a larger school of bonytail. The school of bonytail was visible from the surface (figure 19) and was found to intermingle with redear *Lepomis microlophus* and largemouth bass *Micropterus salmoides* (figure 20).

Passive and active tracking data indicate depth-tagged bonytail released at BWRNWR were contacted on average at 78% of the available water column depth; fish depth (5.1 m ± 0.03; mean ± standard error [SE]) was greater during the day (6.1 m ± 0.04) than at night (4.5 m ± 0.03). Similarly, bonytail released at Cattail Cove were contacted on average at 79% of the available water column depth; mean fish depth (7.0 m ± 0.09) was nearly 2 m greater than fish released in BWRNWR. Depths at which Cattail Cove released fish were located were similarly greater during the day (9.1 m ± 0.17) than at night (5.7 ± 0.10). 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 1.0 Nephelometric Turbidity Unit (NTU) (± 0.2 SE), while mean turbidity for contact locations at the Bill Williams River boat ramp was 5.1 NTU (± 0.6 SE).

Mean ambient turbidity readings taken over the course of the project were higher in BWRNWR than elsewhere in Lake Havasu. During December 2011, mean turbidity readings taken at mid-column were highest at Point 5 in BWRNWR (7.23 NTU ± 0.26 SE) and lowest at Point 22 in Lake Havasu (0.50 NTU ± 0.06 SE). Turbidity readings were generally higher at the bottom than at the surface or mid-water column (figure 21). Turbidity readings from February, March, and April 2012 followed similar trends (figure 22).

Based on all acoustic-tagged bonytail released at BWRNWR (N = 15) and contacted during this study, mean sum continuous inhabitance spent in BWRNWR was 33.5 d (range = 6–77 d) compared to 0.3 d (range = 0 –3 d) spent in Lake Havasu (table 6). The single longest interval of continuous inhabitance in BWRNWR was 77 d (Fish 5; for all fish, mean = 33.1 d), while the longest continuous inhabitance in Lake Havasu was 2 d (Fish 21 and 23; for all fish, mean = 0.3 d). All bonytail stocked at BWRNWR remained, with few exceptions in habitats found within the refuge.

Based on all acoustic-tagged bonytail released at Cattail Cove (N = 15) and contacted during this study, mean sum continuous inhabitance spent in BWRNWR was 3.7 d (range = 0 –48 d) compared to 46.9 d (range = 3–142 d) spent in Lake Havasu (table 7). The longest interval of continuous inhabitance in BWRNWR was 48 d (Fish 33; for all fish, mean = 3.5 d), while the longest inhabitance in Lake Havasu was 142 d (Fish 52; for all fish, mean = 42.2 d). One of 15 individuals (7%) stocked at Cattail Cove inhabited BWRNWR for more continuous days than habitats found in Lake Havasu.

Figure 19.—Bonytail seen from the surface of Sandpoint Marina, Arizona, during February 2012, Lake Havasu, Arizona and California.
(Photo credit: Megan Nichols)

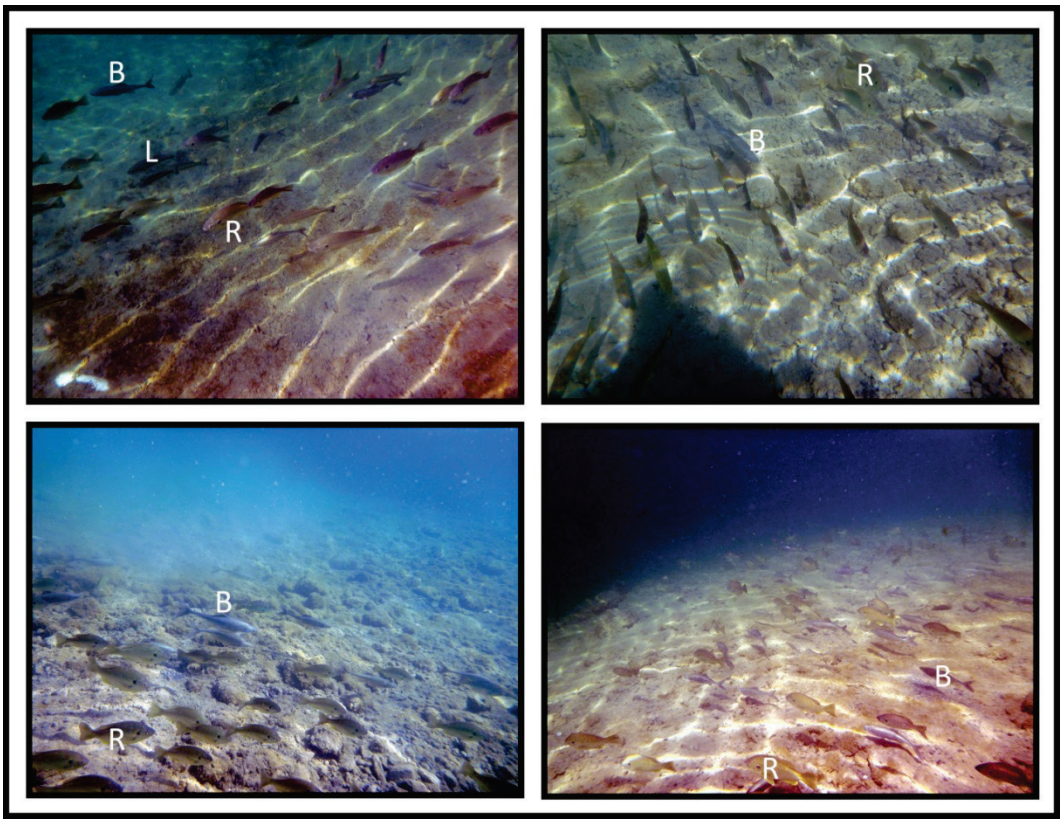


Figure 20.—Underwater photos of bonytail (B), redear sunfish (R), and largemouth bass (L) swimming in Sandpoint Marina, Arizona, on February 6, 2012, Lake Havasu, Arizona and California.
(Photo credit: Wade Massure)

2012 Lake Havasu Native Fish Roundup

A general summary of the results are presented below and focus primarily on bonytail. For a thorough review of the results and analysis from all participating members of the Lake Havasu Native Fish Roundup, see USFWS 2012. Over the course of the roundup, 1,683 fishes were captured, representing 15 non-native and 2 native species (razorback sucker and bonytail). Of those, 14 total bonytail were captured, 12 of which were near the delta of the Bill Williams River within the boundary of BWRNWR and two between the boundary of BWRNWR and Cattail Cove. The mean TL of captured bonytail was 447 mm (range 314−541 mm). Three of the captured individuals were identified from the November 2011 stocking, and an additional bonytail previously recaptured in February 2011 was again recaptured in 2012. Information regarding the origin and history of the remaining eight bonytail captured in 2012 was not reported (USFWS 2012).

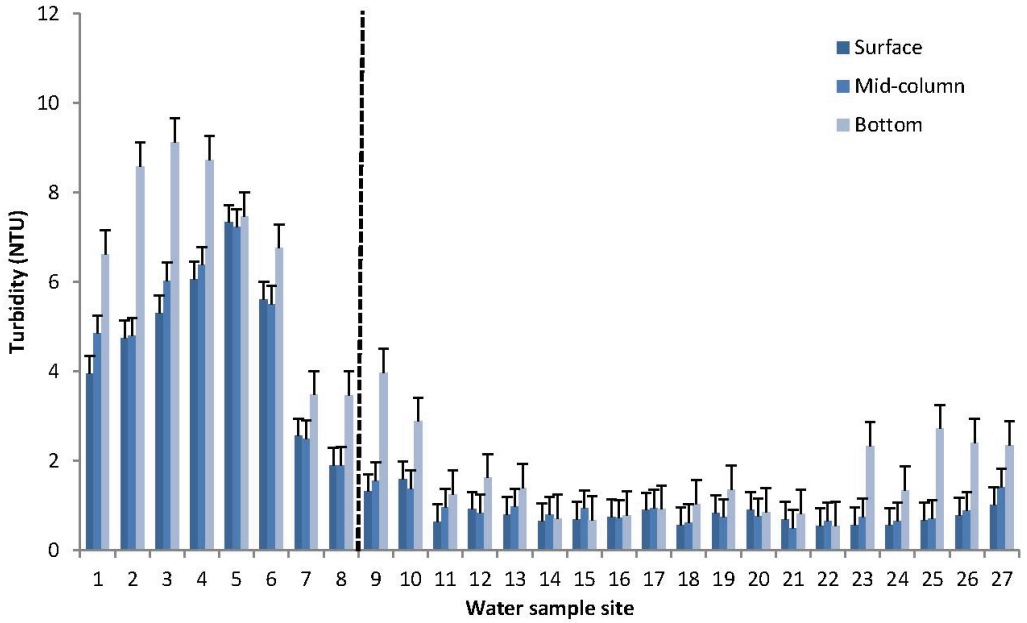


Figure 21.—Turbidity (NTU) readings taken weekly during December 2011 beginning in the upstream-most watercraft-accessible portions of the Bill Williams River (water sample site 1) and ending at Lake Havasu City (water sample site 27). Error bars represent standard error. The dashed vertical line represents the boundary of BWRNWR, Lake Havasu, Arizona and California; see figure 2.

October 2012 Telemetry

Remote PIT Scanning

Remote PIT antennas deployed at BWRNWR scanned for a total of 57,380 minutes. Over the course of the study, 67 unique bonytail were contacted by the submersible scanners positioned in the immediate stocking area (table 8), all of which had marking records in the Lower Colorado River Native Fishes Database. All of the fish had been released at BWRNWR on October 8, 2012.

Remote PIT antennas deployed at Blankenship Bend scanned for a total of 35,885 minutes. Over the course of the study, 18 unique bonytail were contacted by the submersible scanners positioned in the immediate stocking area, all of which had marking records in the Lower Colorado River Native Fishes Database. Three of 18 fish were contacted in the main river channel and the rest in off-channel backwaters (table 8). All of the fish had been released at Blankenship Bend on October 8, 2012.

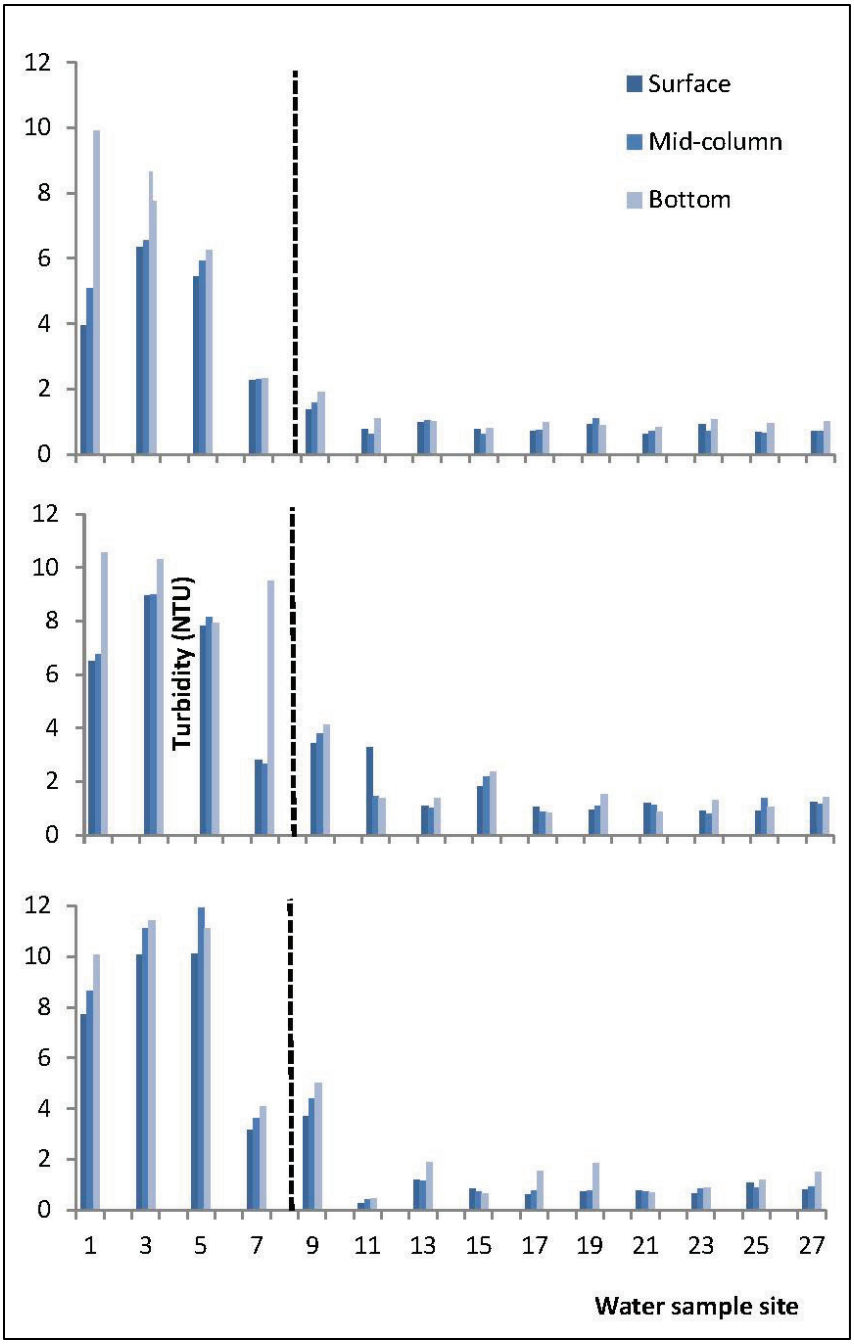


Figure 22.—Turbidity (NTU) readings taken once monthly during February (top), March (middle), and April (bottom) 2012 beginning in the upstream-most watercraft-accessible portions of the Bill Williams River (water sample site 1) and ending at Lake Havasu City (water sample site 27).
The dashed vertical line represents the refuge boundary for BWRNWR, Lake Havasu, Arizona and California; see figure 2.

Table 6.—Summary of telemetry data describing inhabitance (defined in “Methods”) of acoustic-tagged bonytail monitored in BWRNWR between November 2011 and May 2012, Lake Havasu, Arizona and California

An asterisk (*) indicates a depth-sensing tag.

Fish number	Stocking location	Date of stocking	Date of last detection	Number of active days	Summed continuous inhabitance in BWRNWR (d)	Summed continuous inhabitance in Lake Havasu (d)	Longest continuous inhabitance event in BWRNWR (d)	Longest continuous inhabitance event in Lake Havasu (d)
2*	BWRNWR	11/29/2011	02/02/2012	66	65	0	65	0
3*	BWRNWR	11/29/2011	01/17/2012	50	49	0	49	0
5*	BWRNWR	11/29/2011	02/14/2012	78	77	0	77	0
7*	BWRNWR	11/29/2011	12/06/2011	8	7	0	7	0
9*	BWRNWR	11/29/2011	01/04/2012	37	36	0	36	0
21	BWRNWR	11/29/2011	12/08/2011	10	7	2	4	2
22	BWRNWR	11/29/2011	01/17/2012	50	49	0	49	0
23	BWRNWR	11/29/2011	12/08/2011	10	6	3	3	2
24	BWRNWR	11/29/2011	01/18/2012	51	50	0	50	0
32	BWRNWR	11/29/2011	01/09/2012	42	41	0	41	0
34	BWRNWR	11/29/2011	01/17/2012	50	49	0	49	0
35	BWRNWR	11/29/2011	12/19/2011	21	20	0	20	0
49	BWRNWR	11/29/2011	12/08/2011	10	9	0	9	0
51	BWRNWR	11/29/2011	12/19/2011	21	20	0	20	0
53	BWRNWR	11/29/2011	01/17/2012	50	18	0	18	0

Table 7.—Summary of telemetry data describing inhabitance (defined in “Methods”) of acoustic-tagged bonytail monitored in BWRNWR between November 2011 and May 2012, Lake Havasu, Arizona and California

An asterisk (*) indicates a depth-sensing tag.

Fish number	Stocking location	Date of stocking	Date of last detection	Number of active days	Summed continuous inhabitance in BWRNWR (d)	Summed continuous inhabitance in Lake Havasu (d)	Longest continuous inhabitance event in BWRNWR (d)	Longest continuous inhabitance event in Lake Havasu (d)
4*	Cattail Cove	11/29/2011	12/20/2011	22	1	20	1	16
6*	Cattail Cove	11/29/2011	12/17/2011	19	0	18	0	18
8*	Cattail Cove	11/29/2011	02/18/2012	82	0	81	0	81
17*	Cattail Cove	11/29/2011	01/18/2012	51	3	47	2	27
18*	Cattail Cove	11/29/2011	12/07/2011	9	0	8	0	8
19	Cattail Cove	11/29/2011	02/01/2012	65	0	64	0	64
20	Cattail Cove	11/29/2011	12/08/2011	10	0	9	0	9
33	Cattail Cove	11/29/2011	01/19/2012	52	48	3	48	3
36	Cattail Cove	11/29/2011	12/19/2011	21	0	20	0	20
37	Cattail Cove	11/29/2011	02/10/2012	74	0	73	0	73
38	Cattail Cove	11/29/2011	03/14/2012	107	2	103	1	71
47	Cattail Cove	11/29/2011	02/29/2012	93	0	92	0	92
48	Cattail Cove	11/29/2011	12/07/2011	9	0	8	0	8
50	Cattail Cove	11/29/2011	12/16/2011	18	1	16	1	10
52	Cattail Cove	11/29/2011	04/19/2012	143	0	142	0	142

Table 8.—Remote PIT scanning location, contacts, and effort from the October 2012 study, Lake Havasu, Arizona and California

Gray boxes indicate scanners and contacts took place in off-channel backwaters

Scanning location	Unique contacts	Effort (minutes)
Blankenship Bend	2	7,377
Golden Shores near mouth of Topock Gorge	0	2,681
Mohave Rock	1	3,993
Park Moabi	5	17,408
Rearing Cove	0	2,198
Two Lobe Cove	10	2,228
BWRNWR boat ramp	67	57,380
Total	85	93,265

Post-stocking Mortality and Transmitter Recovery

Four of 10 bonytail (40%) stocked with 3-month battery life transmitters in BWRNWR were dead by the end of the study. Conversely, mortality for the 10 bonytail stocked with 3-month battery life transmitters at Blankenship Bend in October 2012 was low; 1 of 10 fish (10%) was assumed dead at the end of the study, although the single immobile tag could not be recovered by scuba divers. Over the course of the study, five immobile transmitters (all 3-month battery life tags) were inspected by scuba divers (table 9), four of which were recovered within 1.1 km of their respective stocking location at BWRNWR. Three transmitters were recovered in BWRNWR between the buoy line and delta (4.0–5.5 m deep), while one transmitter was recovered in a small backwater (2.3 m deep) east of the boat ramp (figure 23). One transmitter was located next to Mohave Rock approximately 3 km upstream of Blankenship Bend, but could not be recovered (figure 24). No fish remains were observed near any of the search and recovery sites. Mortalities in BWRNWR stocked fish occurred an average of 19 d (range 11–23) after stocking, while the one suspected mortality in Blankenship Bend stocked fish occurred 6 d after stocking.

Movement Patterns and Inhabitance

Twenty-eight of 30 acoustic-tagged bonytail were contacted during this study for a total of 83,813 contacts up to 119 d after stocking. Sixty-eight (68) of these contacts were made by manual tracking, and the remaining 83,763 contacts were recorded by remote sensors. Twenty-two of 41 SURs detected acoustic-tagged bonytail; 10 of 15 SURs deployed around both stocking areas and 2 of 11 supplemental SURs deployed during November 2012 recorded fish contacts (tables 10 and 11). Most batteries in the supplemental SURs prematurely expired prior to the end of the study. Both supplemental SURs containing fish contacts

Table 9.—Table of acoustic tags that became sessile and were inspected by divers during the course of the October 2012 telemetry study, Lake Havasu, Arizona and California
Gray boxes indicate tags were recovered in BWRNWR.

Tag ID	Dive date	Number of days alive	Recovery depth (m)	Easting	Northing	Recovery location
96	03/06/2013	11	2.3	766832	3798635	Cove west of the BWRNWR boat ramp
93	03/06/2013	23	5.5	766003	3799150	BWRNWR buoy line
104	03/07/2013	19	4.1	766411	3798675	Near BWRNWR boat ramp
105	03/07/2013	23	4	766598	3798491	Near BWRNWR boat ramp
98	03/06/2013	6	5.2	736065	3833086	Mohave Rock

were located in backwaters within 1 km of each respective stocking location. SURs grouped around both stocking areas never detected the presence of fish stocked elsewhere (i.e., BWRNWR fish were never detected by Blankenship Bend SURs and vice versa). No fish were detected in Windsor Basin during the dam-to-dam survey.

Fish tagged with acoustic transmitters and released at the BWRNWR boat ramp dispersed between the upstream-most watercraft-accessible portion of the Bill Williams River (Fish 95 and 103; 3.9 km) and the SUR "gate" in Lake Havasu near Gene Wash (Fish 82, 86, 92, 94, 95, 96, 102, 103, and 107; 4.0 km) or a cumulative curvilinear linear distance of 6.9 km surrounding the stocking site (figure 23). Fish released at Blankenship Bend dispersed upstream between Topock Gorge (Fish 110; 14.1 km) and downstream to the lower delta (Fish 80, 97, and 110; 7.9 km) or a cumulative curvilinear linear distance of 22.0 km surrounding the stocking site (figure 24).

Bonytail stocked at Blankenship Bend were contacted in the main river channel, secondary channels, and backwaters. Fish 101 and 108 both were detected in a small off-channel backwater with a narrow connection (less than 2.5 m width) to the main river channel (figure 25), although their detections were made exclusively with SURs during nighttime hours. Fish 101 was detected on consecutive dates from January 26 to 30, 2013 and from February 1 to 4, 2013 while Fish 108 was detected on December 10, 2012. Likewise, bonytail dispersed into backwater habitats in BWRNWR. Fish 94 and 103 both were contacted in backwaters found in the Bill Williams River delta (figure 26).

Passive and active tracking data indicate depth-tagged bonytail released at BWRNWR were contacted on average at 90% of the available water column depth. Mean fish depth was 8.0 m ± 1.1 SE, all of which were taken during daylight hours. Bonytail released at Blankenship Bend were contacted on average at 83% of the available water column depth. Mean fish depth was 3.2 m ± 0.5 SE, all of which were taken during daylight hours.

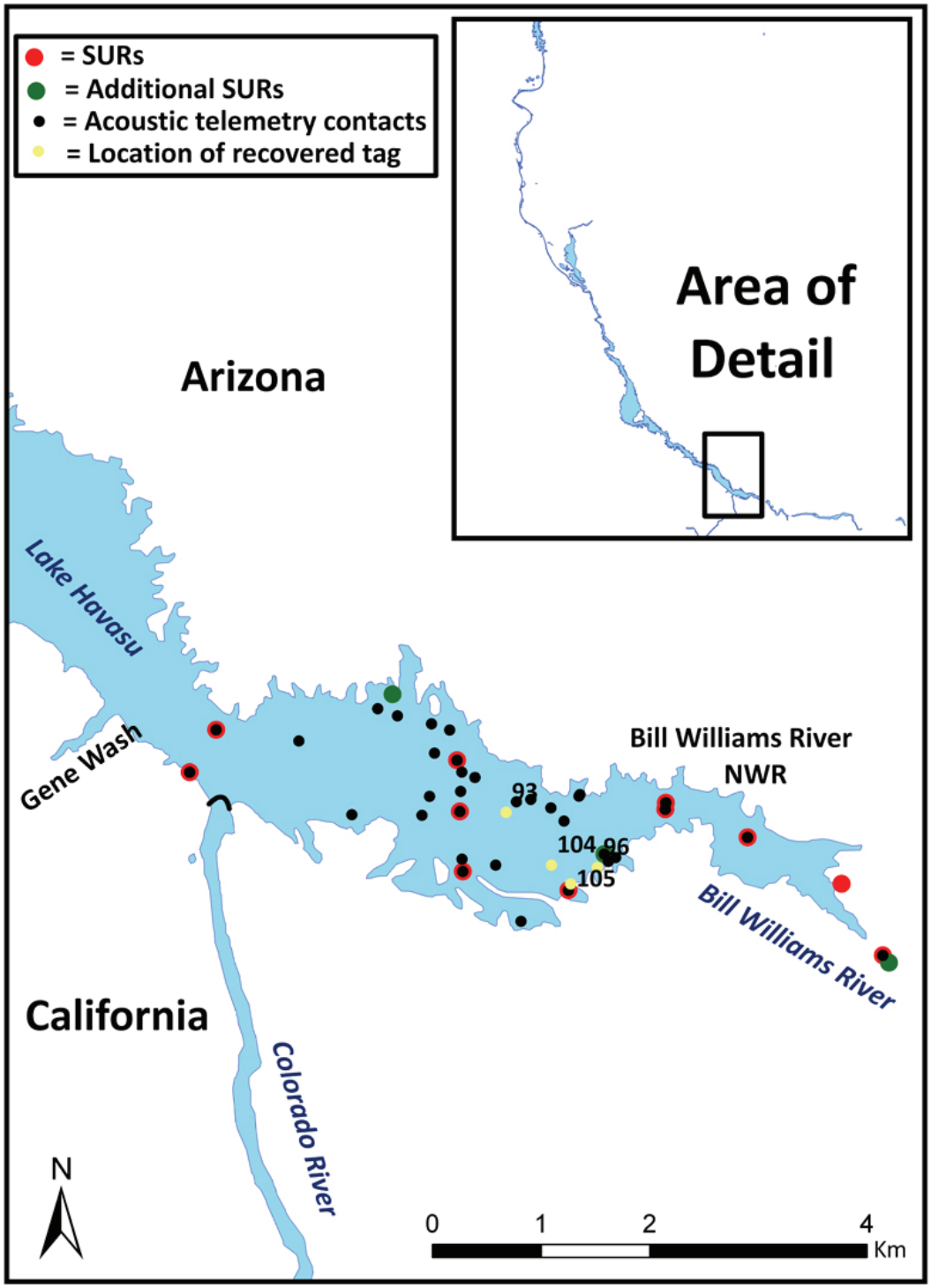


Figure 23.—Map of acoustic telemetry contacts from fish released at BWRNWR in October 2012, Lake Havasu, Arizona and California.

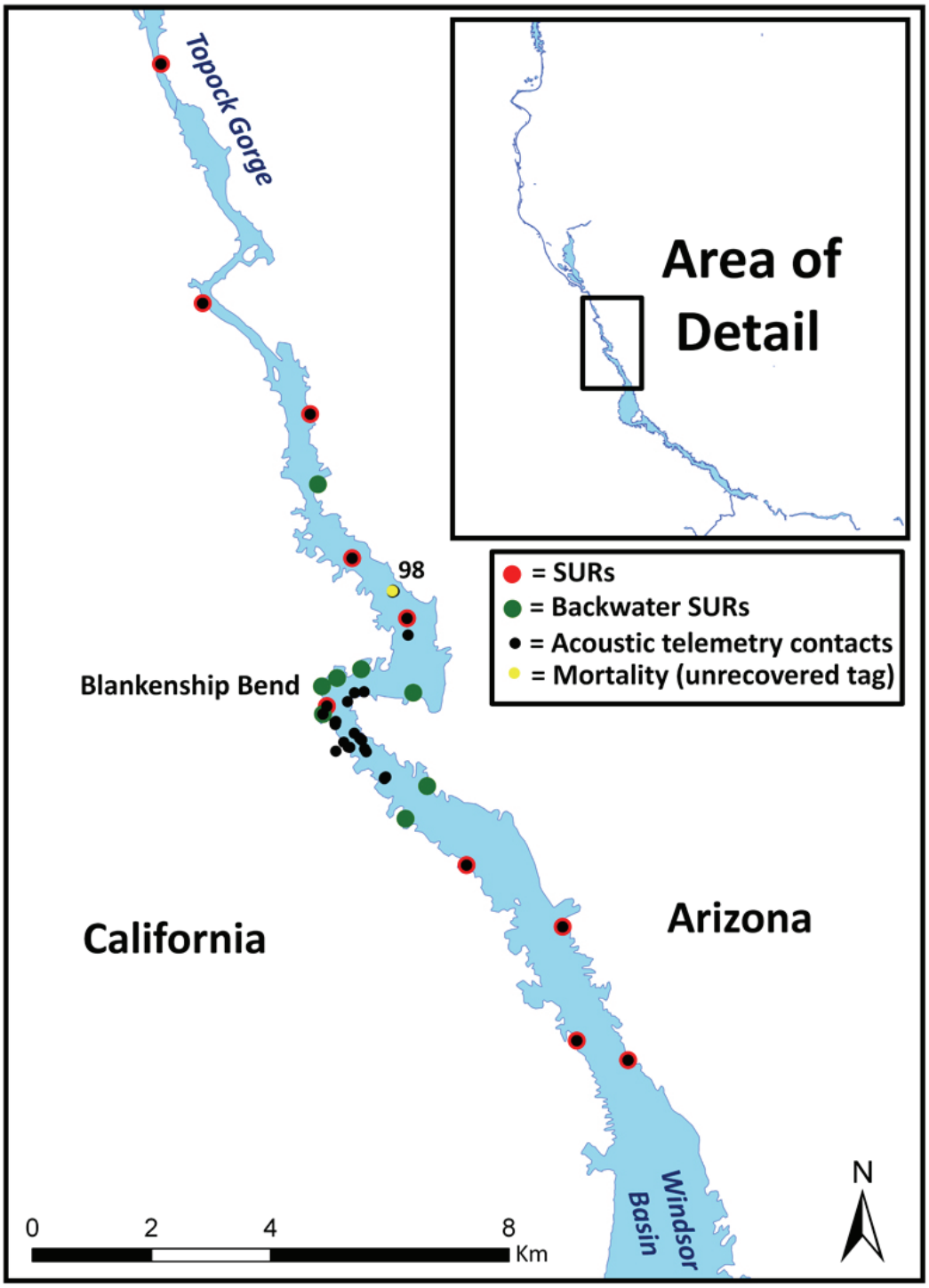


Figure 24.—Map of acoustic telemetry contacts from fish released at Blankenship Bend in October 2012, Lake Havasu, Arizona and California.

Table 10.—SUR detections of fish stocked at BWRNWR during the October 2012 study, Lake Havasu, Arizona and California
Gray boxes indicate SURs located inside BWRNWR.

Location	Easting	Northing	SUR	Number of contacts	Tag ID detected
Bill Williams River, log jam	769471	3797834	10238	66	95, 103
Bill Williams River, side-channel	769092	3798492	10206		No detections
Bill Williams River	768226	3798919	10240	670	95, 103, 107
Bill Williams River at US 95 Bridge, north	767474	3799239	10415	1,137	95, 103, 107
Bill Williams River at US 95 Bridge, south	767469	3799178	10353	580	95, 103, 107
BWRNWR boat ramp	766577	3798434	10233	23,836	82, 83, 84, 86, 92, 93, 94, 95, 96, 102, 103, 104, 105, 107
BWRNWR buoy line, north	765605	3798605	10350	8,132	82, 84, 86, 92, 93, 94, 95, 96, 102, 103, 104, 107
BWRNWR buoy line, mid-channel	765579	3799158	10231	27,199	82, 84, 86, 92, 93, 94, 95, 96, 102, 103, 104, 107
BWRNWR buoy line, south	765552	3799629	10357	15,843	82, 84, 86, 92, 93, 94, 95, 96, 102, 103, 104, 107
Gene Wash, California	763091	3799519	10119	480	86, 92, 94, 95, 96, 102, 103, 107
Gene Wash, Arizona	763336	3799909	10239	1,471	82, 86, 92, 94, 95, 102, 103, 107
Steamboat Cove, Arizona	751715	3810161	317		No detections
Steamboat Cove, California	751461	3809741	10352		No detections
Thompson Bay, California	743358	3814973	467		No detections
Thompson Bay, Arizona	743279	3815467	468		No detections
Bill Williams River, upstream log jam	769529	3797765	10536		No detections
BWRNWR backwater	766908	3798765	10269	1,247	94
Question Mark Cove	764959	3800235	10284		No detections

Table 11.—SUR detections of fish stocked at Blankenship Bend during October 2012, Lake Havasu, Arizona and California. CR = Colorado River, CRB = Colorado River backwater.

Location	Easting	Northing	SUR	Number of contacts	Tag ID detected
CR, side channel	740012	3825200	10234	14	110
CR, main channel, south	739150	3825528	595	145	80, 97, 110
CR, side channel at Castle Rock	738914	3827438	10173	17	110
CR, main channel, north	737302	3828472	10225	25	80, 97, 110
CR, Blankenship Bend	734958	3831141	10236	361	77, 80, 81, 97, 98, 100, 101, 108, 110
CR, Mohave Rock, south	736304	3832613	316	1,460	91, 98, 99, 110
CR, Mohave Rock, north	735381	3833623	10235	142	81, 98, 110
CR, Sand Dunes	734677	3836041	10226	46	81, 110
CR, River Island	732872	3837900	10228	21	80, 110
CR, Topock Gorge	732170	3841915	10230	18	110
CR, Needles Bridge	729789	3845468	10232	0	No detections
South entrance of Needles Marsh	730420	3845164	10535	0	No detections
CR, Needles, south	722708	3851957	10237	0	No detections
CR, Needles, north	717470	3859778	10356	0	No detections
CR, Razorback Island	714489	3886553	315	0	No detections
CRB, California Blankenship north 1	734874	3831474	10534	0	No detections
CRB, California Blankenship north 2	735128	3831613	416	0	No detections
CRB, California Blankenship north 3	735532	3831761	10270	0	No detections
CRB, Arizona Blankenship east 1	736406	3831366	10245	0	No detections
CRB, California Double Lobe Cove	736277	3829251	10429	0	No detections
CRB, California Blankenship south 1	734890	3831009	10431	837	101, 108
CRB, Arizona secret channel	736639	3829798	10271	0	No detections
CRB, Arizona south of big dune	734806	3834862	10430	0	No detections

Figure 25.—Satellite view of the location of Fish 101 and 108 utilizing an off-channel backwater near the stocking area at Blankenship Bend, Lake Havasu, Arizona and California.
(Image: Google Earth®)

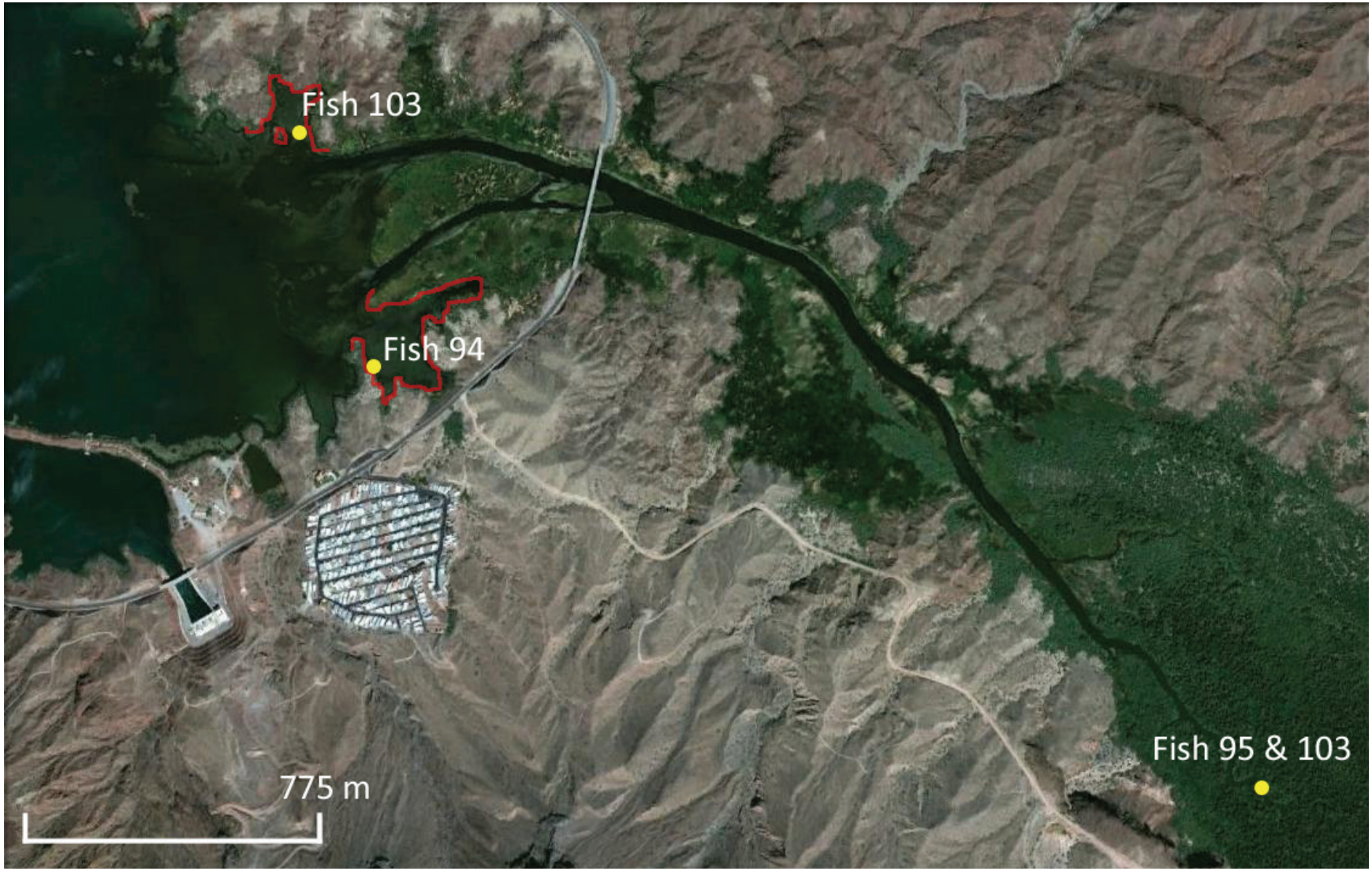


Figure 26.—Satellite view of the location of Fish 103 and 94 utilizing backwaters (defined by red outlines) in BWRNWR and the location of Fish 95 and 103, which represent the farthest upstream dispersal of fish stocked in BWRNWR during October 2012, Lake Havasu, Arizona and California.
(Image: Google Earth®)

Turbidity readings taken at points of contact for depth-tagged fish only and Secchi depth measurements taken at points of contact for all fish reflect variable water clarity conditions between both stocking locations. The mean turbidity at Blankenship Bend fish contact locations was 0.48 NTU (± 0.13 SE) and 0.50 NTU (± 0.22 SE) taken at mid-column depth. The mean turbidity at BWRNWR fish contact locations was 4.81 NTU (± 1.78 SE) and 1.04 NTU (± 0.13 SE) at mid-column depth. The mean Secchi depth readings taken at Blankenship Bend fish contact locations was 4.5 m (range = 4.0−6.5 m). The mean Secchi depth readings taken at BWRNWR fish contact locations was 2.3 m (range = 0.5−3.5 m).

The mean ambient turbidity readings taken over the course of the study reflect the higher turbidity in BWRNWR and lower turbidity found elsewhere in Lake Havasu and surrounding Blankenship Bend (figure 27). During October 2012, Secchi depth readings were highest at Point 2 in BWRNWR (3.74 NTU) and lowest at Point 9 in Lake Havasu (0.08 NTU). In the area surrounding Blankenship Bend, Secchi depth readings were highest at Point 22 (1.28 NTU) and lowest at Point 26 (0.27 NTU).

DISCUSSION

High mortality of acoustic-tagged fish monitored during three of four bonytail stocking events at BWRNWR reaffirmed the crucial role of stocking, without which the species will not persist in the wild. During those stockings (December 2010, November 2011, and October 2012), 40–100% of acoustic-tagged bonytail were confirmed dead at the conclusion of 3 months post-release (Karam et al. 2012). Mortality was not a result of our surgical procedures (Karam et al. 2011) and was likely due to fish and/or bird predation. The LCR MSCP has a clear role in the future management of bonytail, although it appears for now that stocking will only maintain low numbers of the species because the predation risk in Lake Havasu (Karam et al. 2012) and elsewhere in the lower Colorado River (Mueller and Marsh 2002; Schooley et al. 2008; Karam and Marsh 2010) is not conducive to long-term survival of adult bonytail. However, the post-stocking picture provided by acoustic telemetry is far from complete. The successful implementation of remote PIT scanning arrays assures their practicality and usefulness in helping to monitor PIT-tagged bonytail and the habitats they utilize, which potentially becomes more powerful when used in conjunction with acoustic or other telemetry. Additionally, two stocking events provided a glimmer of optimism concerning future stockings and warrant further investigation: (1) the April 2010 stocking at BWRNWR during which high discharge in the Bill Williams River (figure 28) produced lower water clarity conditions throughout BWRNWR, which indirectly may have improved bonytail survival by helping the fish avoid predation (Karam et al. 2012), and (2) the October 2012 stocking event at Blankenship Bend where fish appeared to survive better than other stocking

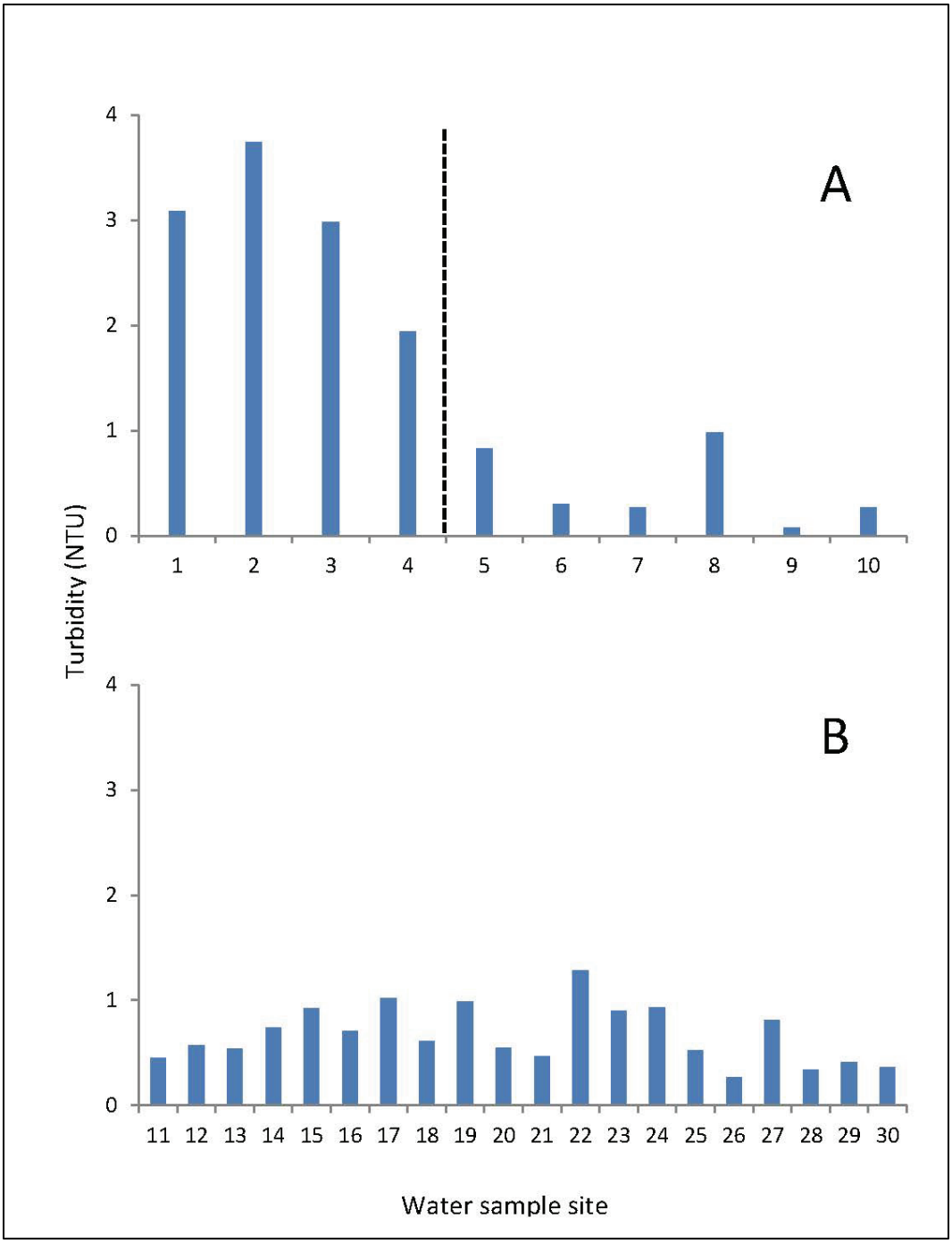


Figure 27.—Turbidity (NTU) readings on October 9 and 10, 2012, in the (A) BWRNWR arm of Lake Havasu (see figure 13) beginning in the upstream-most watercraft-accessible portions of the Bill Williams River (water sample site 1) and proceeding sequentially toward Lake Havasu City (water sample site 10) and the (B) Blankenship Bend reach of Lake Havasu (see figure 14) beginning at the delta (water sample site 11) and moving upstream (water sample site 30), Lake Havasu, Arizona and California.

The dashed vertical line in (A) represents the refuge boundary for BWRNWR; see figure 2.

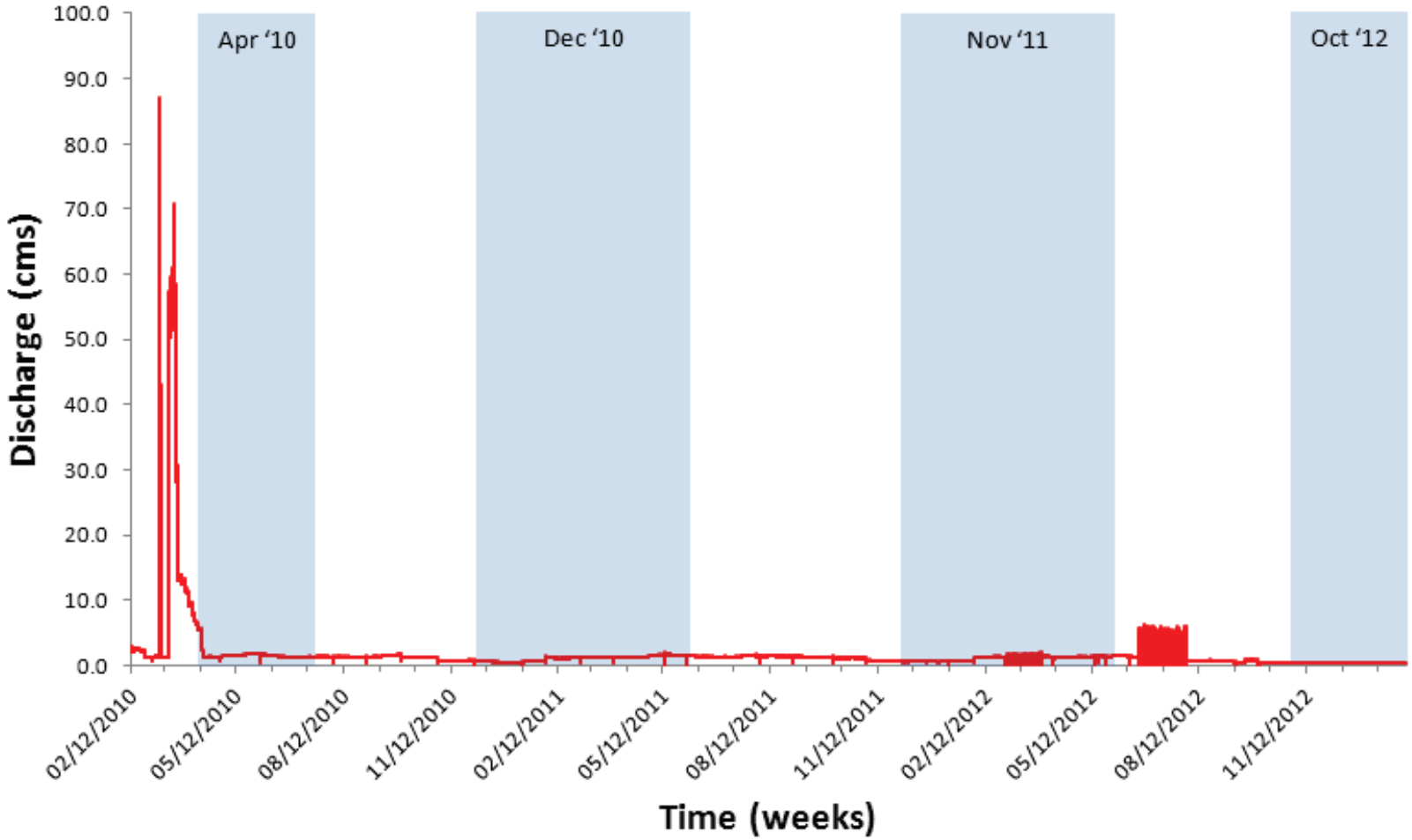


Figure 28.—Discharge in cubic meters per second from the Bill Williams River below Alamo Dam, Arizona (USGS 2013), over the course of the 3-year project period.
Shaded boxed indicate periods during which acoustic telemetry studies were conducted.

locations possibly due to their utilization of off-channel backwaters near Blankenship Bend. The role of increased turbidity prior to and during stocking events at BWRNWR and deciphering the extent of habitat utilization of off-channel backwaters within LHNWR should be explored in further detail.

The results of our study of the distribution and fate of acoustic-tagged fish stocked at BWRNWR and Cattail Cove were consistent with those of concurrent netting efforts that documented the capture of adult bonytail in BWRNWR and few elsewhere in Lake Havasu (USFWS 2010, 2011, 2012). Inhabitance data from both the December 2010 and November 2011 studies clearly indicate that a majority of bonytail stocked inside BWRNWR remain in that habitat. Dispersal was limited, and few fish were tracked outside the refuge boundaries (Karam et al. 2012) (see table 4). During November 2011, the extent of detectable fish dispersal was 2.4 times greater for bonytail stocked at Cattail Cove (35.4 km) than for fish stocked at BWRNWR (14.4 km). However, only 10% of fish stocked at Cattail Cove remained in BWRNWR for longer than they did in Lake Havasu proper. Results from the October 2012 study similarly indicated bonytail stocked in BWRNWR had limited dispersal when compared to fish stocked at Blankenship Bend. The extent of measured fish dispersal was 3.2 times greater for bonytail stocked at Blankenship Bend (22.0 km) compared to BWRNWR (6.9 km). Clear water conditions may be associated with broader bonytail dispersal; stocking locations at Blankenship Bend and Cattail Cove similarly had high water clarity compared with lower water clarity found in BWRNWR.

During October 2012, the 3-month mortality of fish stocked in BWRNWR was 40%, and the mean Secchi depth was 2.3 m at contact points of active fish. These figures are similar to the December 2010 stocking during which 50% of fish were dead after 3 months, and the mean Secchi depth at points of active contact was 2.1 m (Karam et al. 2012). Higher water clarity conditions observed during these two studies[4] was attributed to the lack of discharge into the Bill Williams River from Alamo Dam (see figure 28). The lowest detectable mortality observed during the entire 3-year study period was only 5% during the April 2010 study, which also coincided with the highest discharge from the Bill Williams River and the lowest mean Secchi readings (1.0 m) at points of actively contacted fish. Humpback chub (*Gila cypha*), a species closely related to bonytail, has been shown to utilize turbidity as cover (Valdez et al. 1992) to reduce predation risks (Stone 2010).

While the most recent release at BWRNWR (October 2012) provided results similar to previous stockings at that location, the results from the concurrent Blankenship Bend stocking provided more questions than answers. Bonytail released at Blankenship Bend were tracked between the Colorado River delta and Topock Gorge (PIT scanning efforts located fish further upstream in Park Moabi)

[4] No Secchi depth readings were taken during the November 2011 study although water clarity was similarly high and 3-month mortality was 100%.

where an extensive network of backwaters lines both sides of the river channel. The potential for locating fish in that habitat therefore presents a formidable challenge.

During October 2012, a paucity of passive and active contacts were made after the first 4 weeks of tracking, at which time remote PIT scanning antennas (deployed for the first time since stocking) detected bonytail activity in Double-lobe (Two-lobe) Cove, a backwater approximately 2.1 km downstream from Blankenship Bend. This event prompted the opportunistic deployment of 11 additional SURs into nearby backwaters that were not originally a part of the study design. Prior to the batteries on those units prematurely expiring, two acoustic-tagged fish (Fish 101 and 108) were subsequently found to be utilizing an unnamed backwater (see figure 25) at Blankenship Bend exclusively at night. Those fish inexplicably eluded detection by a nearby SUR located in the main river channel. One of the fish (Fish 101) was never detected by another SUR during the course of the study. Furthermore, five additional bonytail were detected in a backwater located directly north of Blankenship Bend by USGS remote PIT scanning antennas during February 2013; all were PIT-tagged fish from the October 2012 release, but none carried an acoustic tag (R. Wydoski, USGS, personal communication). Bonytail are clearly using these habitats, and further investigations are warranted.

A lack of contacts (both passive and active) was generated during the October 2012 study; eight individuals (four from each stocking area) were only contacted once using manual tracking. When fish were located manually in the main river channel at Blankenship Bend, they were at times located in deeper holes along eddy lines, often in the same location for consecutive days. Occasionally, however, they were found to utilize heavy cover such as shoreline vegetation. One individual (Fish 79) was located near shore on 2 consecutive days, but its signal was audibly weak, which is an indication that the tag was being obstructed. During consecutive tracking trips, another individual (Fish 111) was triangulated immediately next to shore in a dense stand of rushes. Considerable attempts were made to disturb the area to see if the fish was alive. During a subsequent visit, the fish was found to have relocated. Similarly, bonytail stocked at BWRNWR were contacted in some of the heaviest cover near the upstream extent of available habitat (see figures 18 and 26). Bonytail have been found to utilize cover along the riprap shore at Cibola High Levee Pond during daylight hours, then move into open waters during night (Marsh et al. in press[a]), presumably to feed (Marsh et al. in press[b]). Bonytail at Blankenship Bend similarly may be utilizing localized, heavy cover during day—and thus avoiding our detection—then emerging at night in backwaters.

Depth tag data indicate fish were most often found near the bottom, which creates potential obstructions with submergent vegetation when present. The signal from acoustic tags is negatively affected by obstructions (Marsh et al., in press[a]), especially if tagged fish are using that material as cover. Dense beds of

submergent aquatic vegetation were present in all slackwater habitats of both stocking areas, although it appeared to be most abundant near the mouth of the Colorado River delta (figure 29), Bill Williams River delta, in backwaters, and along the margins of the river at Blankenship Bend. When not visible from the surface, vegetation often encased the weights used to sink SURs. In some cases, backwaters were shallow enough to visually deploy SURs in a manner that prevented them from being obstructed by vegetation. When SURs were not visible following their deployment, every effort was made to tether the buoyant receiver far enough from the bottom to prevent potential obstructions due to benthic vegetation.

While mortality was determined to be cautiously low at Blankenship Bend, it cannot be assumed that fish had not died because contacts were so infrequent. If predation occurred and transmitters eventually fell to the bottom amidst heavy cover, it is doubtful the tag could be heard during manual surveys, and its location would never have been detected.[5] Blankenship Bend lies within the boundary of LHNWR where large piscivorous birds, including American white pelican (*Pelecanus erythrorhynchos*), cormorants (*Phalacrocorax* spp.), and osprey (*Pandion haliaetus*), are abundant during winter. A pair of bald eagles (*Haliaeetus leucocephalus*) was frequently observed hunting from a cliff band less than 1 km upstream of the stocking area at Blankenship Bend. Bird predation attempts of razorback sucker stocked in the lower Colorado River have been thoroughly documented (Schooley et al. 2008). Marsh and Minckley (1991) found a transmitter previously associated with a tagged razorback sucker in a raptor nest above the Gila River in eastern Arizona.

Another logical source of mortality is piscivorous fishes. However, fish species composition surrounding Blankenship Bend is notably different from elsewhere in Lake Havasu. No flathead catfish were captured at Blankenship Bend during 2011 and 2012 trammel net sampling, while they were present at Cattail Cove and relatively abundant at BWRNWR (USFWS 2011 and 2012). Flathead catfish have been implicated as a major predator of razorback sucker in the lower Colorado River (Barkstedt et al. 2008; Marsh and Brooks 1989), and individual fish can attain remarkable size in Lake Havasu, particularly in BWRNWR (figure 30) where bonytail mortality is high. If this predatory threat is absent or less prevalent at Blankenship Bend, higher bonytail stocking success is possible. Other predators, such as largemouth bass, are abundant throughout Lake Havasu (USFWS 2011 and 2012). Past surveys in the lower Colorado River demonstrated largemouth bass are capable of killing razorback sucker, although only the largest individuals were considered a threat (Barkstedt et al. 2008).

Bonytail were successfully contacted in the vicinity of all three stocking locations (BWRNWR, Cattail Cove, and Blankenship Bend) using remote PIT scanning antennas. Antennas were deployed in habitats that were accessible by boat in an attempt to maximize contacts with bonytail (Kesner et al. 2012). Arrays were not

[5] Mortality at other stocking areas was confirmed when tags were recovered by scuba divers.

Figure 29.—Photo of prolific beds of submergent aquatic vegetation found in slackwater habitats (backwaters, eddies in the main river channel, and delta) throughout the Blankenship Bend reach during the October 2012 study, Lake Havasu, Arizona and California.

Figure 30.—Photo of a flathead catfish captured by USFWS in BWRNWR during trammel net surveys in February 2010, Lake Havasu, Arizona and California.

deployed in a repeated grid to compare habitat utilization, although future deployments may include this approach. While effort was not uniform at all locations, the goal of deploying the antennas was to determine if PIT-tagged fish could in fact be contacted using this technology. Data clearly support these observations. While no fish were directly contacted at Cattail Cove (minimal effort), an acoustic-tagged bonytail (Fish 19) was tracked into Sandpoint Marina approximately 2 months after being stocked at Cattail Cove. After divers were deployed to investigate the tag (it was a suspected mortality due to perceived inactivity), the living fish was located and was found among a large school of bonytail and other non-native fishes (see figure 20). Remote PIT scanners were subsequently deployed in the vicinity of the fish and over the next few months contacted 41 uniquely PIT-tagged bonytail from the Cattail Cove stocking. The combination of using telemetry to locate other bonytail that can subsequently be scanned with remote PIT antennas appears promising and could be applied to future monitoring efforts.

Data from remote PIT scanning units deployed in BWRNWR and Cattail Cove appear to reflect the high mortality we observed with acoustic telemetry. While fish could have moved to other locations, acoustic tags recovered by scuba divers indicate that mortality was a common fate. A fisherman who frequented the facilities at Sandpoint Marina, and was familiar with the school of bonytail utilizing the cover provided by the docks, reported to have witnessed loons (*Gavia* spp.) chasing the school of bonytail. The piscivorous behavior of loons is well documented; one pair of loons rearing two chicks can remove about 423 kilograms of fish during 5.5 months on a territory (Barr 1996). Clearly, this potential predatory risk should not be overlooked.

RECOMMENDATIONS

The following recommendations are suggested to enhance bonytail stockings in Lake Havasu:

1. PIT tag all bonytail stocked into Lake Havasu.

2. Utilize acoustic telemetry to monitor post-stocking distribution and survival. Utilize smaller batches of fish (3−5 tagged fish total) to generate finer-scale assessments of habitat use and temporal distribution within those habitats.

3. Use remote PIT scanning in conjunction with small-scale acoustic telemetry to better evaluate and understand bonytail habitat use.

4. Study the role of turbidity on post-stocking survival particularly during high discharge events in the Bill Williams River.

5. Study further the utilization of backwater habitats near Blankenship Bend.

6. Continue yearly net monitoring of bonytail and outreach to the general public.

ACKNOWLEDGMENTS

Collections were permitted under the authorization of USFWS and the States of Arizona and California. Arizona State University 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 SNARRC and Achii Hanyo Native Fish Facility; M. Thorson, T. Knecht, and R. Randall from the Arizona Fish and Wildlife Conservation Office – Parker; D. Gilbert and staff from BWRNWR, Parker, Arizona; J. Lantow from the Lower Colorado River MSCP Office, R. Clarkson, B. Contreras, J. Anderson, and A. Montony from Reclamation; D. Gray from CAP; K. Koch from BLM; J. Guthrie from Arizona State Parks; B. Kesner, C. Ehlo, and W. Massure from M&A; T. Dowling and M. Saltzgiver from Arizona State University; and E. Lester and M. Nichols (volunteers). 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 p.

Barkstedt, J.M., J.R. Campbell, B.R. Kesner, J.D. Schooley, and P.C. Marsh. 2008. Survival of razorback sucker stocked into the lower Colorado River. Final 2007 Annual Report. Reclamation Agreement No. 06-FC-30-0002. Arizona State University, Tempe. 28 p. + figures, tables.

Barr, J.F. 1996. Aspects of Common Loon (*Gavia immer*) feeding biology on its breeding ground. Hydrobiologia 321:119–144.

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. Bureau of Land Management, Lake Havasu City, Arizona. 23 p.

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. 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.

Karam, A.P., C.A. Adelsberger, and P.C. Marsh. 2011. Distribution and post-stocking survival of bonytail in Lake Havasu. 2010 Annual Report. Marsh & Associates, LLC. Tempe, Arizona. 58 p.

_____. 2012. Distribution and post-stocking survival of bonytail in Lake Havasu. 2011 Annual Report. Marsh & Associates, LLC. Tempe, Arizona. 75 p.

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

Kesner, B.R., A.P. Karam, C.A. Pacey, J.W. Warmbold, and P.C. Marsh. 2012. Lake Mohave razorback sucker monitoring 2012 annual report. Marsh & Associates, LLC. Tempe, Arizona. 35 p.

Lower Colorado River Multi-Species Conservation Program (LCR MSCP). 2004. Lower Colorado River Multi-Species Conservation Program, Volume II: Habitat Conservation Plan. Final. December 17. Sacramento, California. 506 p.

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

_____. 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 p. + figures.

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

Marsh, P.C. and J.E. Brooks. 1989. Predation by ictalurid catfishes as a deterrent to re-establishment of hatchery-reared razorback suckers. The Southwestern Naturalist 34:188–195.

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., G.A. Mueller, and M.R. Schwemm. In press[a]. Diel cover use and local site fidelity of a large southwestern cyprinid, bonytail *Gila elegans*, in a lower Colorado River backwater. The Great Basin Naturalist.

Marsh, P.C., G.A. Mueller, and J.D. Schooley. In press[b]. Springtime foods of bonytail (Cyprinidae: *Gila elegans*) in a lower Colorado River backwater. The Southwestern Naturalist.

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 10 °C. 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 p.

Minckley, W.L. 1979. Aquatic habitats and fishes of the lower Colorado River, Southwestern United States. Final Report, 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.

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.

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

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 p.

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. 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 p.

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 p.

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 p. + tables, appendices.

Patterson, K.A., B.R. Kesner, A.P. Karam, and P.C. Marsh. 2012. Comparative survival of repatriated razorback sucker in lower Colorado River Reach 3. 2012 Final Annual Report. Marsh & Associates, LLC. Tempe, Arizona. 28 p.

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

Schooley, J.D., B.R. Kesner, J.R. Campbell, J.M. Barkstedt, 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 p. + figures, tables.

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.

U.S. Fish and Wildlife Service (USFWS). 2010. FWS AZFWCO Tenth annual native fish roundup on Lake Havasu. U.S. Fish and Wildlife Service, Parker, Arizona. 13 p.

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

_____. 2012. FWS AZFWCO 12th Annual Lake Havasu Round Up. U.S. Fish and Wildlife Service, Parker, Arizona. 23 p.

U.S. Geological Survey (USGS). 2013. USGS Water Data for USA. Available at: http://waterdata.usgs.gov/nwis. Accessed March 2013.

Valdez, R.A., W.J. Masslich, and W.C. Leibfried. 1992. Characterization of the life history and ecology of the humpback 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 p.

Wiele, S.M., R.J. Hart, H.L. Darling, 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 p. http://pubs.usgs.gov/sir/2009/5195/. Accessed April 2012.

Wiele, S.M., J.P. Macy, H.L. Darling, R.J. Hart, and A.B. Hautzinger. 2011. Discharge and sediment concentration in the Bill Williams River and turbidity in Lake Havasu during and following high releases from Alamo Dam, Arizona in March and April 2010: U.S. Geological Survey Open-File Report 2011-1129, 10 p. http://pubs.usgs.gov/of/2011/1129/. Accessed March 2013.

Wingate, R.L., D.H. Secor, 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.