Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

2017 FINAL INTERIM REPORT Population Status and Distribution of Razorback Sucker and Bonytail Downstream of Palo Verde Dam

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

August 2017

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Lower Colorado River Multi-Species Conservation Program

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ACRONYMS AND ABBREVIATIONS

ABS – acrylonitrile butadiene styrene
AIC – Akaike's Information Criterion
amp-h – ampere hour
AZGFD – Arizona Game and Fish Department
CI – confidence interval
cm – centimeter(s)
DAL – days at large
FWS – U.S. Fish and Wildlife Service
g - grams
kHz – kilohertz
km – kilometer(s)
L – liter(s)
LCR – Lower Colorado River
LCR MSCP – Lower Colorado River Multi-Species Conservation Program
M&A – Marsh and Associates, LLC
m – meter(s)
M, C, R – mark, capture, recapture
mg L^{-1} – milligrams per liter
mL – milliliter(s)
mm – millimeter(s)
ms – millisecond(s)
MS222 – Tricaine methanesulfonate
NDOW – Nevada Department of Wildlife
NFH – National Fish Hatchery
NFWG – Native Fish Work Group
NPS – U.S. National Park Service
PIT – passive integrated transponder
PVC – polyvinylchloride
Reclamation – Bureau of Reclamation
RM – River Mile
SFH – State Fish Hatchery
SNARRC – FWS Southwestern Native Aquatic Resources and Recovery Center
SUR - Submersible Ultrasonic Receivers
SY – sample year
TL – total length
UDR – underwater diver receiver
UTM – Universal Transverse Mercator

Symbols

≥ - greater than or equal to
< - less than
% – percent
® – Registered
™ – Trademark

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EXECUTIVE SUMMARY

This is the first year of the current project to monitor the population status and distribution of razorback sucker (*Xyrauchen texanus*) and bonytail (*Gila elegans*) in the lower Colorado River downstream of Palo Verde Diversion Dam and upstream of the Imperial Diversion Dam. In support of this study, a total of 5,935 razorback sucker and 4,491 bonytail were stocked into backwaters in La Paz Co., AZ and Riverside Co., CA from October 2016 through January 2017. All fish released were implanted with a 134.2-kilohertz (kHz) passive integrated transponder (PIT) tag. Twenty subadults of each species were implanted with short-term (3 month) acoustic telemetry tags to examine dispersal patterns immediately following release. Ten adult razorback sucker were implanted with longer-term (36 month) tags to examine dispersal over a longer period. PIT tag sensing units were used to contact PIT tagged fish and were set monthly from October 2016-April 2017 for 1-2 weeks. Submersible ultrasonic receivers (SURs) were dispersed throughout the backwaters and river channel to detect fish movement.

Up to 20 PIT tag sensing units were distributed throughout backwaters and the main river channel for five days during each month from October-April. Effort between February and April was increased in the river channel in attempt to identify spawning sites and contact individuals during spawning. PIT tag sensing units were deployed for a total of 14,011.5 hours in this first year of study and recorded 671 unique contacts – 277 bonytail, 383 razorback sucker, and 11 individuals with no database record.

Based on the Lower Colorado River Native Fishes Database, totals of 15,795 razorback sucker and 11,696 bonytail were released with 134.2 kilohertz (kHz) PIT tags into the Colorado River downstream of Palo Verde Diversion Dam between 2007 and May 2017. Deployment of remote PIT tag sensing units since October 2014 (SY 2015) has resulted in contact with 900 razorback sucker and 438 bonytail from these releases, but only 186 and 76 of these contacts

respectively occurred outside of their release site. The greatest number of days at large (DAL) for a PIT tagged bonytail was 548 days, released in September 2015. A razorback sucker released October 2007 had been at large for 3,500 days.

Based on year to year PIT tag sensing contact records, a razorback sucker population estimate for SY 2016 was 216 (95% CI 173 to 271) with 130 encountered in SY 2016 (marking period October 2015 through May 2016), 130 encountered in SY 2017 (capture period October 2016 through May 2017), and 78 encountered in both periods (recaptures). More than 90% of contacts used in the population estimate were recorded in A10.

SURs were distributed throughout the backwater and river channels to detect movement of individuals implanted with an acoustic tag. Opportunistic manual tracking in backwaters was conducted to provide additional movement information. The maximum dispersal distance recorded was 20.4 kilometers (km) by an acoustic tagged adult razorback sucker released in February 2017. The greatest dispersal distance by an acoustic tagged subadult bonytail was 2.31 km, released in January 2017.

INTRODUCTION

Razorback sucker (*Xyrauchen texanus*) and bonytail (*Gila elegans*) are presently considered endangered by the U.S. Fish and Wildlife Service and both rely upon regular stocking programs to maintain a presence throughout their range in the main stem of the Colorado River. The Lower Colorado River Multi-Species Conservation Program (MSCP) has been stocking fish Reach 4 and 5 of the lower Colorado River (Parker Dam to Imperial Dam) since 2005. The program has a planned stocking effort of 6,000 razorback sucker and 4,000 bonytail per year into Reach 4/5 for 45 years, with all fish ≥305 millimeters (mm). Beginning as early as 2017 an additional 6,000 razorback sucker and 4,000 bonytail per year will be stocked for a 10-year period designated for intensive research and monitoring (Bureau of Reclamation 2015). All fish are released with a full duplex 134.2-kilohertz (kHz) passive integrated transponder (PIT) tag.

The fish community in Reach 4/5 is dominated by introduced non-native species which support a popular recreational fishery. Aside from infrequent captures of repatriated native fish, little information is available regarding their survival and distribution. A two-year study (2006-2008) of razorback sucker survival in the lower Colorado River found little evidence of long-term survival and suggested that continued augmentation would not be sufficient to establish a new population (Schooley et al. 2008).

The current project has six primary objectives:

1. Contact razorback sucker and bonytail using mobile remote PIT tag sensing units capable of detecting full duplex 134.2-kHz tags and deployable in backwater, slack water, and riverine sections of the Colorado River.

2. Conduct eight monitoring trips across multiple release sites and habitat types within Reach 4 of the MSCP from October through March of each year.
3. Conduct broad scale multi-year telemetry monitoring on 10 resident adult

razorback sucker per year to determine relative dispersal, seasonal movements, and preferred habitat types.

4. Conduct broad scale telemetry monitoring of 20 subadult razorback sucker and 20 subadult bonytail each year to determine relative dispersal and preferred habitat types after release in backwaters.

5. Assimilate and summarize all Reach 4/5 razorback sucker and bonytail contact data collected by other federal and non-federal entities into mark-recapture population estimates for each species with 95% confidence intervals.

6. If data are adequate, use mark-recapture modeling to provide estimates for adult survival (with 95% confidence intervals) and assess its dependence on a variety of factors (i.e., size at release, location of release, and season of release) for all razorback sucker and bonytail released since 2005. If data are inadequate for a model-comparison assessment of all factors, use exploratory analysis to identify their potential relationship to scanning contact rates (e.g., with graphs and/or correlation analysis).

Study Area

Reach 4 of the MSCP area extends from Parker Dam at river mile (RM) 192 downstream to the southern end of Cibola National Wildlife Refuge (RM 88). Reach 5 continues from here downstream to Imperial Diversion Dam at RM 49.2 (figure 1). The focal area of this study is from the Palo Verde Diversion Dam north of Ehrenberg, AZ downstream approximately 45 river miles to Walter’s Camp, CA. Fish were released into one of five backwaters within this zone: A7 upper, A10 upper, A10 lower, C7 (McIntyre) or C10 (Ehler’s) (figure 2). All backwaters are connected to the main river channel by way of a culvert or a boat-accessible channel (figure 3).

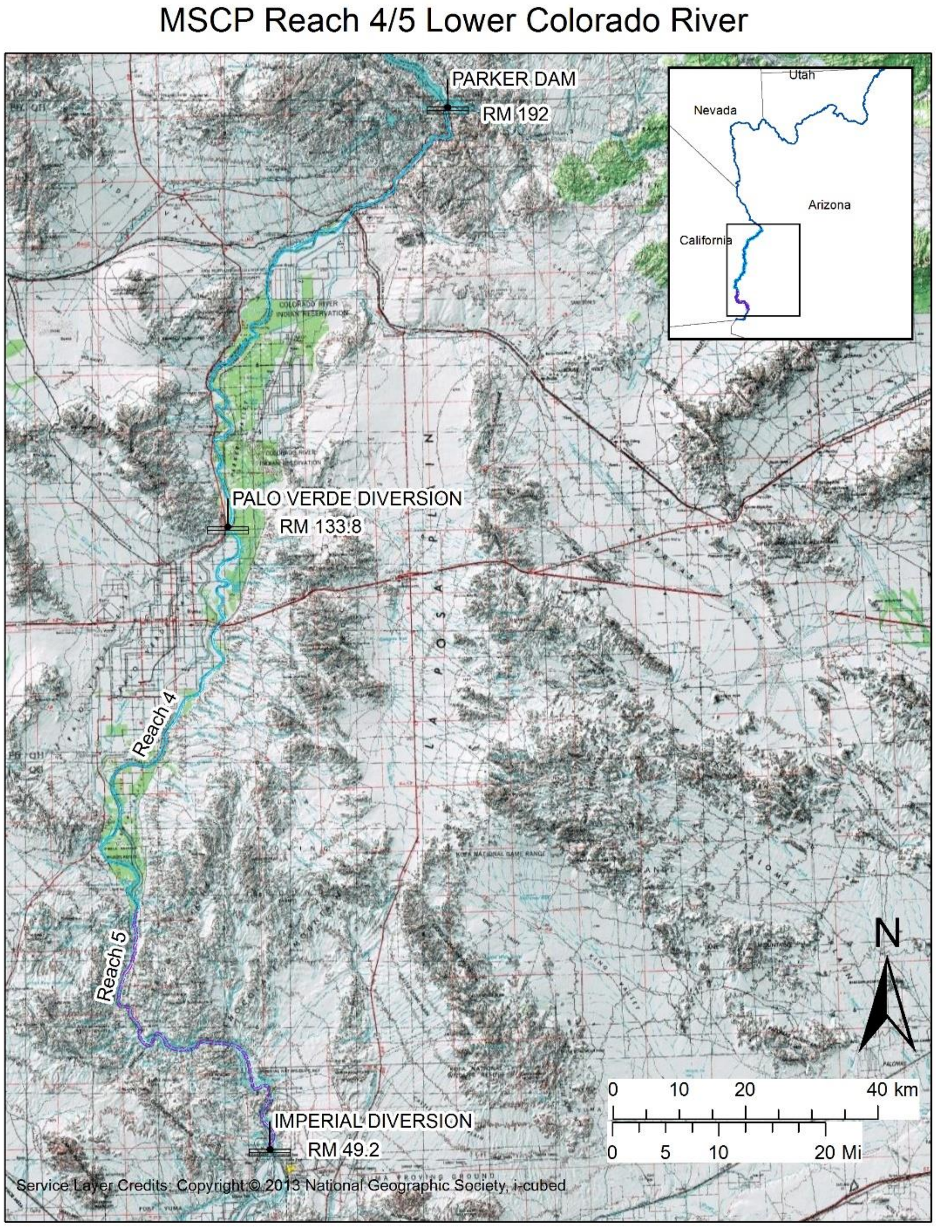

Figure 1.— MSCP Reaches 4 and 5 on the lower Colorado River.

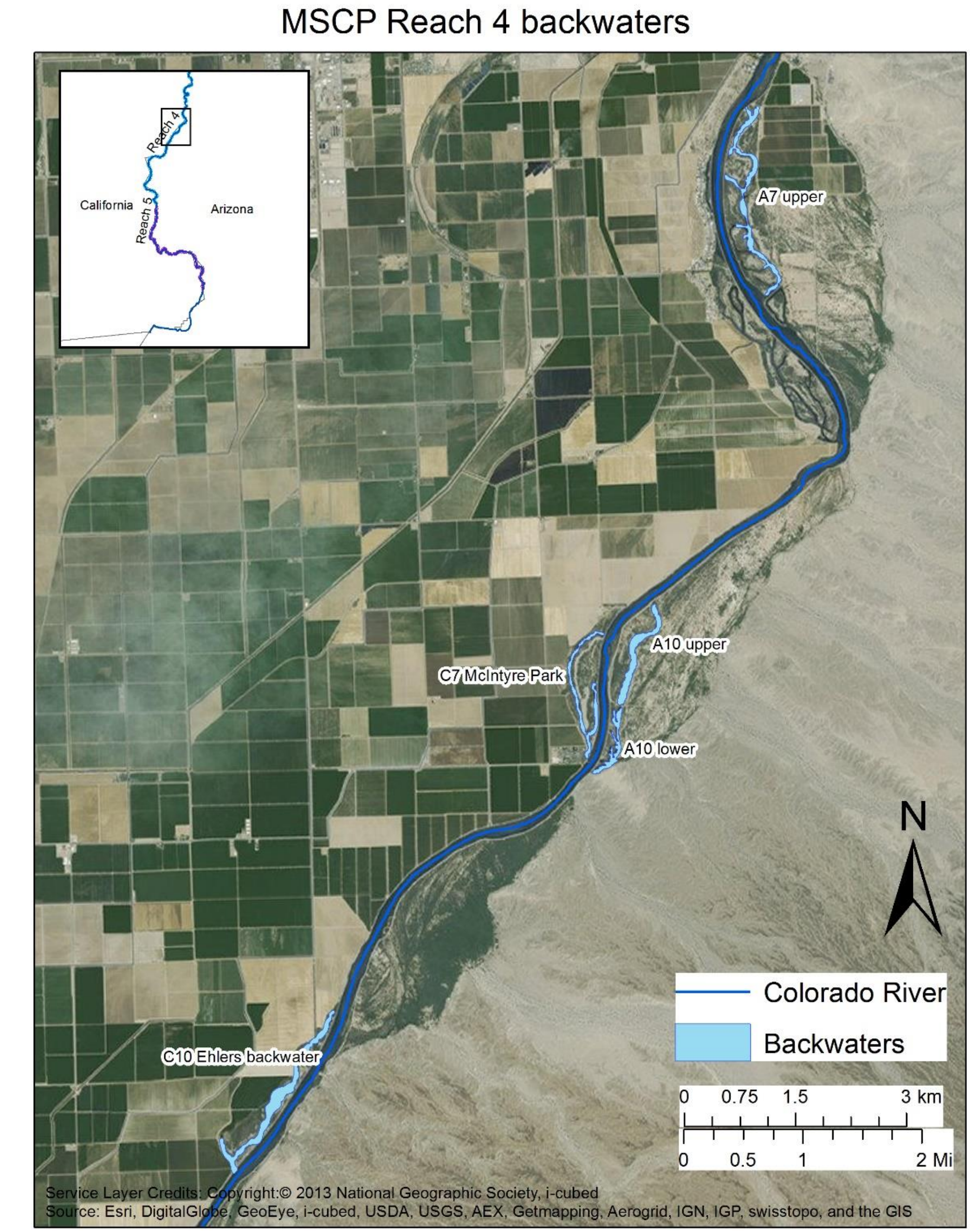

Figure 2.—Backwaters in MSCP Reach 4 on the lower Colorado River.

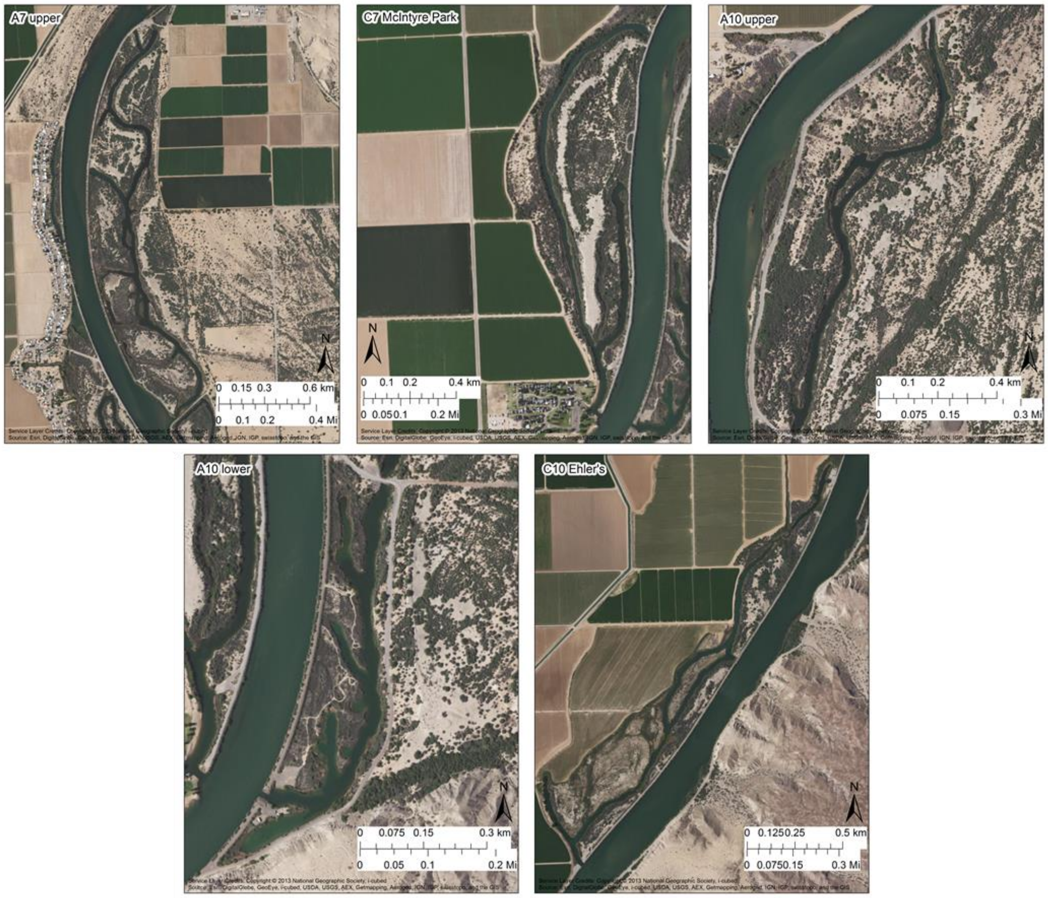

Figure 3.—Aerial imagery of backwaters in MSCP Reach 4. Backwaters from left to right, top to bottom are: A7 upper, C7 McIntyre Park, A10 upper, A10 lower and C10 Ehler's.

METHODS

Passive and active remote sensing technologies were used to contact razorback sucker and bonytail in backwater, slack water, and riverine sections of the lower Colorado River. Passive sampling was achieved using an array of Submersible Ultrasonic Receivers (SURs) and PIT tag sensing units, while active sampling was conducted by boat using a directional or towable omnidirectional hydrophone. Acoustic tags were surgically implanted using standard techniques into 20 hatchery reared subadult razorback sucker and 20 subadult bonytail and 10 adult razorback sucker captured in a backwater with boat electrofishing.

Releases

Stockings of razorback sucker and bonytail during SY2017 were to be distributed across spatial and temporal variables in order to accommodate analysis of factors influencing post-stocking survival (Objective 6). Five backwaters were identified as primary stocking locations; A10 upper, A10 lower, A7 upper, C7, and C10. At least one stocking per season (autumn, winter, and spring) was anticipated, dependent on availability of hatchery fish and crew for PIT tagging prior to release. Releasing hatchery-reared fish into backwaters provides better access to immediate cover than is available in the river channel, where the current is also faster. All backwaters provide access to the river channel.

Remote PIT tag sensing

Twenty remote PIT tag sensing units were deployed during six monthly field sampling trips (October 2016 through March 2017) (Objectives 1 and 2). Two additional sampling trips were conducted in an attempt to maximize remote PIT tag sensing contacts when needed (during peak spawning); these trips occurred in February and April. Each sampling trip was five days. Initial deployments were based on accessibility and habitat suitability (figure 4). Immediately after stocking, all deployments were in the immediate vicinity of the release site. Deployments in subsequent months depended on indications of dispersal provided by SUR contacts with acoustic tagged fish when available, otherwise they were based on past contact experience.

PIT tag sensing units were downloaded and redeployed daily initially prior to release of acoustic tagged fish. Based on the study design deployment would be shifted so that half of the units would be deployed up- and downstream when dispersal was detected outside of the release area. In the first year of the study none of the subadult acoustic tagged fish were recorded to disperse (i.e. recorded on SURS outside of release backwaters). Therefore, few PIT tag sensing units were deployed in the mainstem river, mainly in areas with possible spawning habitat. No razorback sucker or bonytail were observed in the mainstem.

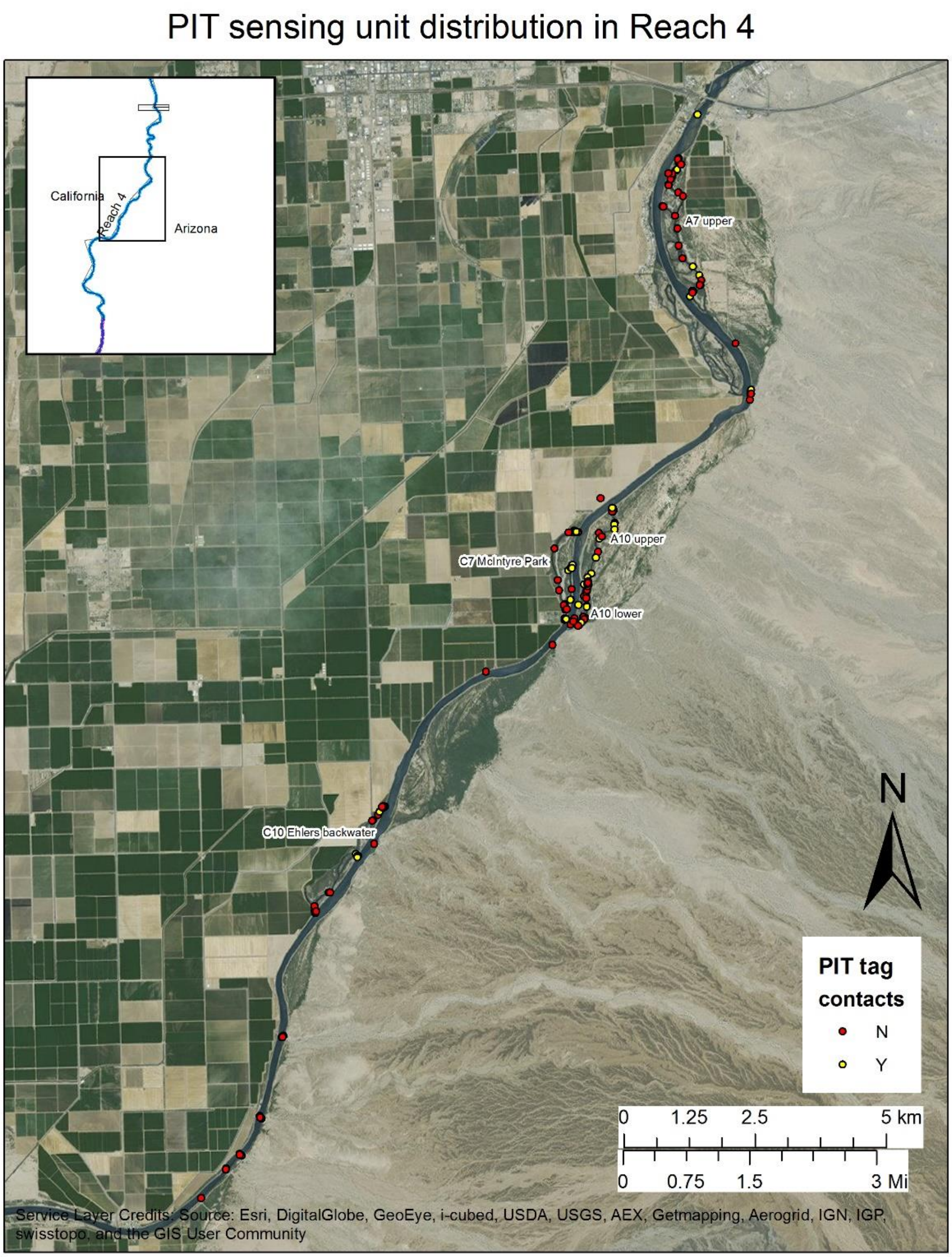

Figure 4.—Location of PIT tag sensing units deployed throughout backwaters and the main stem in Reach 4 from October 2016 – April 2017.

Release and contact records for razorback sucker and bonytail released with 134.2

kHz PIT tags downstream of Palo Verde Diversion Dam were extracted from the Lower Colorado River Native Fishes Database and the MySQL remote PIT tag sensing database and retained in a separate Access database. These records were tallied and presented in release and contact tables for this annual report. The Lower Colorado River Native Fishes Database is considered the definitive collection of release and capture records. However, remote PIT sensing was conducted prior to the initiation of the MySQL remote PIT tag sensing database in 2012. Additional efforts to incorporate remote PIT tag sensing records from 2007 to 2012 are ongoing.

This was the first year of systematic remote PIT scanner deployments and stocking, so data were inadequate to develop a mark-recapture model of post-release survival (Objective 6). Total release and remote sensing records among release sites, species, and size classes were tallied and provided in figures to illustrate potential relationships between contact availability, release size, and release location. Individual bonytail and razorback sucker released since October 1, 2014 (sample year [SY] 2015) within the study area (Palo Verde Diversion Dam to Imperial Dam) with a recorded total length (TL) at release were grouped into size classes. The size classes were based around the minimum target release size of 305 mm TL as follows; size class 1 - less than 305 mm TL, size class 2 - 305 to 354 mm TL, size class 3 - 355 mm to 404 mm TL, size class 4 - 405 mm to 454 mm TL, and size class 5 - 455 mm TL or greater at release. Contact records were filtered to include only those recorded at least 30 days after the fish was released, and figures were based on the contact proportion (number of unique contacts/number of fish released) for a given release site, size class, and species.

Surgery

All surgeries followed established procedures (Mueller et al. 2000; Karam et al. 2008). Fish reared in the hatchery were implanted with PT-4 acoustic transmitters (Sonotronics Inc., Tucson AZ). This tag is small, reliable, and has a battery life of approximately three months. Adult razorback sucker captured from a backwater were implanted with CT-05-36 (Sonotronics Inc., Tucson AZ). This is a larger tag and has a battery life of approximately 36 months.

Before surgery, an individual fish was anesthetized by immersion in a dark container with approximately 16-liters (L) of fresh water and tricaine methanesulfonate (MS222; 125 mg L^{-1}). A successfully anesthetized fish was indicated by lack of operculation, weak muscular movements, and cessation of fin movements. Once these criteria were met, the fish was removed from the container, measured (TL, in mm), weighed (nearest gram [g]), and scanned for a 134.2-kHz PIT tag. The fish was then placed on a surgery cradle ventral side up and covered in a wet towel to eliminate desiccation. Anesthesia was maintained by gently pumping MS-222 solution with a small tube (4.77 mm) via the mouth across the gills for the remainder of the surgical procedure. A short (< 2 cm) mediolateral incision was made slightly anterior and dorsal to the left pelvic fin and an acoustic transmitter sanitized in 70% ethanol was inserted into the abdominal cavity. If the fish lacked a PIT tag, a 134.2-kHz tag was implanted via the mediolateral incision. The incision was closed with 2-3 knots using 4-0 absorbable braided, coated suture and RB-1 (CV-23), 17 mm, ½ taper needle (AD Surgical, Sunnyvale, CA). Post-surgery, the fish received additional care to prevent infection (Martinsen and Horsberg 1995): the sutured wound was swabbed with Betadine and a 10 mg/kg dosage of the antibiotic Baytril® (enrofloxacin) was injected into the dorso-lateral musculature to mitigate infection.

December

On December 7, 2016 ten subadult razorback sucker and ten subadult bonytail were surgically implanted with model PT-4 acoustic transmitters at the Lake Mead Fish Hatchery (objective 4) (table 1). Fish were held for one week in the hatchery before being released into A10 upper backwater on December 14, 2016. Mean TL of razorback sucker was 456 mm, and of bonytail was 417 mm.

January

On January 25, 2017 ten subadult razorback and ten subadult bonytail were surgically implanted with model PT-4 acoustic transmitters at the A10 lower ramp (objective 4) (table 2). Five of each species were immediately released post-surgery into A10 lower with a group of 210 PIT tagged razorback sucker. Mean TL of razorback sucker was 483 mm (451-519 mm). Mean TL of bonytail was 398 mm (380-415 mm). After all surgeries were completed, the other five of each species were transferred to A7 upper and released with a group of 317 PIT tagged razorback sucker and 10 PIT tagged bonytail. Mean TL of razorback sucker was 503 mm (470-525 mm). Mean TL of bonytail was 407 mm (371-427 mm).

February

Boat electrofishing in the main river channel yielded no resident adult fish for telemetry (objective 3). Three different attempts in January and February were made at historical spawning grounds where wash fans enter the river and at other gravelly riffles and suitable habitat throughout the channel as far upstream as the Palo Verde Diversion Dam for a total of 3563 seconds. Adult razorback sucker were collected by boat electrofishing from A10 upper backwater on February 22, 2017 (1535 seconds, 13 total razorback sucker captured). All boat electrofishing was conducted using a Smith Root 7.5 GPP Boat Electrofisher at 500 volts direct current, 120 pulses per second, 20% range, 11.5 amperes. Surgeries took place at the road crossing between A10 upper and A10 lower on the same day. Ten adult razorback sucker were surgically implanted with CT-05-36 acoustic transmitters (objective 3) (table 3). Fish were released into A10 lower immediately post-surgery. Mean TL of adult razorback sucker was 529mm (485-595mm).

Table 1.—Subadult razorback sucker and bonytail released into A10 upper on December 14, 2016.

Tag ID	Freq.	Interval (ms)	Code	TL (mm)	Weight (g)	Pit tag #
Razorback sucker						
97	75	1150	4-5-5-6	457	998	3DD.003BCBF762
96	74	1120	4-4-5-7	423	940	3DD.003BCBF770
95	73	1130	4-4-5-6	464	1179	3DD.003BCBF748
94	72	1100	3-7-5-7	495	1202	3DD.003BCBF757
93	71	1110	3-7-4-8	460	949	3DD.003BCBF75B
90	83	1050	3-5-7-4	468	1059	3DD.003BCBF74C
89	82	1040	3-5-6-8	437	909	3DD.003BCBF741
81	74	960	3-3-4-4	448	979	3DD.003BCBF752
92	70	1080	3-6-4-8	467	1109	3DD.003BCBF72D
82	75	970	3-3-4-5	440	947	3DD.003BCBF73F
Bonytail						
77	70	920	4-7-7	425	848	3DD.003BCBF774
88	81	1030	3-5-3-6	421	745	3DD.003BCBF73C
87	80	1020	3-5-3-3	417	684	3DD.003BCBF764
86	79	1010	3-4-5-4	410	684	3DD.003BCBF74D
85	78	1000	3-4-4-8	414	686	3DD.003BCBF76E
84	77	990	3-3-7-7	428	833	3DD.003BCBF730
83	76	980	3-3-7-6	407	565	3DD.003BCBF74E
80	73	950	5-8-8	420	749	3DD.003BCBF733
79	72	940	5-8-7	412	595	3DD.003BCBF723
78	71	930	4-7-8	414	642	3DD.003BCBF773

Table 2.—Subadult razorback sucker and subadult bonytail released on January 25, 2017. All razorback sucker were potentially double tagged, but only the individuals with two tags were scanned for two tags. All other fish were released without being scanned for a second tag.

Tag ID	Frequency	Interval (ms)	Code	TL (mm)	Weight (g)	Pit tag #
Razorback sucker released into A10 lower						
47	70	980	3-3-6-5	485	1335	3DD.003BEA6EB4
48	71	990	3-3-6-6	519	1663	3DD.003BCBFEAB
49	72	1000	3-4-3-7	489	1346	3DD.003BEA6ED2
50	73	1010	3-4-3-8	451	905	3DD.003BCBFF3B
52	75	1030	3-4-7-5	471	1489	3DD.003BEA4D89
Razorback sucker released into A7 upper						
53	76	1040	3-5-5-7	507	1404	3DD.003BEA6EC2
54	77	1050	3-5-5-8	510	1382	3DD.003BEA4D8A 3DD.003BCBFF1D
55	78	1060	3-6-3-6	503	1241	3DD.003BCBFEEE 3DD.003BEA4DDD
56	79	1070	3-6-3-7	525	1769	3DD.003BEA6EC3 3DD.003BCBFF72
57	80	1080	3-6-7-7	470	1195	3DD.003BEA4DCB 3DD.003BCBFEE6
Bonytail released into A10 lower						
58	81	1090	3-6-7-8	410	668	3DD.003BEA6900
59	82	1100	3-8-8-8	394	599	3DD.003BEA7322
60	83	1110	4-4-4-5	380	524	3DD.003BEA6B8A
62	70	1140	4-5-4-5	394	555	3DD.003BEA6CEA
63	71	1170	4-6-4-8	415	761	3DD.003BEA68EI
Bonytail released into A7 upper						
64	72	1160	4-6-5-5	420	695	3DD.003BEA8BF5
65	73	1190	4-8-5-8	371	469	3DD.003BEA6891
66	74	1180	4-8-6-8	427	824	3DD.003BEA68E8
67	75	1210	5-6-5-7	406	775	3DD.003BEA8BDA
68	76	1200	5-6-5-8	412	755	3DD.003BEA8BE4

Table 3.—Repatriated adult razorback sucker released into A10 lower on February 22, 2017. *Fish recorded with two PIT tags; one 134.2-kHz PIT tags (first tag listed) and one 125-kHz PIT tag.

Tag ID	Frequency	Interval (ms)	Code	TL (mm)	Weight (g)	Pit tag #
137	70	1240	6-6-6-7	485	1240	3DD.003BCC0078
138	71	1250	6-6-6-8	595	2087	3D9.1C2D6BF683
139	72	860	3-3-6	515	1312	3DD.003BCC415A
140	73	870	3-3-7	536	1370	*3D9.257C61B274 44552B5143
141	74	880	3-6-8	574	1893	*3D9.1C2D6D11FC 4605473C1D
143	76	900	4-5-6	549	1635	3D9.1C2D6D0C13
144	77	930	5-5-6	509	1548	3D9.1C2C7F3DEB
145	78	920	5-5-7	518	1313	3D9.1C2D6C39B6
146	79	950	6-8-7	521	1471	3DD.003BA748FE
147	80	940	6-8-8	485	1078	3D9.1C2D6C3E99

Telemetry

Prior to stocking of acoustic tagged razorback sucker and bonytail, 12 SURs were deployed throughout the study area (figure 5, objectives 3 and 4). Five supplemental SURs were deployed later in the season. Sites were selected to ensure movement of fish up- or downstream as well as fish entering or exiting major backwaters was detected. All SURs deployed throughout the study area were attached to a camouflaged rope and connected to a 6-meter (m) piece of galvanized cable that was connected to a secure on-shore habitat (e.g., a tree root). Cable was used to avoid rope abrasion caused by waves and current on rocks in the river. Weights were attached to the cable and the SUR to ensure the SUR remained completely submerged in the water column. Each SUR has a battery life expectancy of 8 months and is programmed to scan continuously with a detection range up to 500 m. Each major backwater (A10 upper, A10 lower, A7 upper, C7, C10) had at least one SUR deployed in them. A7 upper and A10 upper each had two SURs deployed in them due to size and number of acoustic tagged fish released in them. The remaining SURs were spaced out in the river from above the interstate bridge and as far downstream as Walter's Camp. An additional SUR was placed in the river adjacent to Imperial Ponds.

Except for the SUR at Imperial Ponds, SURs were downloaded once every trip. The SUR at Imperial Ponds was downloaded by Reclamation biologists after the end of the field season. In months where two trips occurred in consecutive weeks, SURs were downloaded once during the span of the two weeks. Confidence values, as defined by the number of detections within a timed window, were calculated using Sonotronics SURsoft Stand Alone Data Processing Center software. Only records from SURs with a confidence of 5 were included in analysis. Records with a confidence of 5 were discarded when it was clear that background noise was the cause. In these isolated cases, multiple records across all frequencies with the same interval were recorded in the raw data file. This indicated that an environmental noise was the cause. In several cases this was verified by the tag being recorded prior to the release of the acoustic tagged fish. Data were imported into a Microsoft Access® database used for managing fish contact histories and SUR locations.

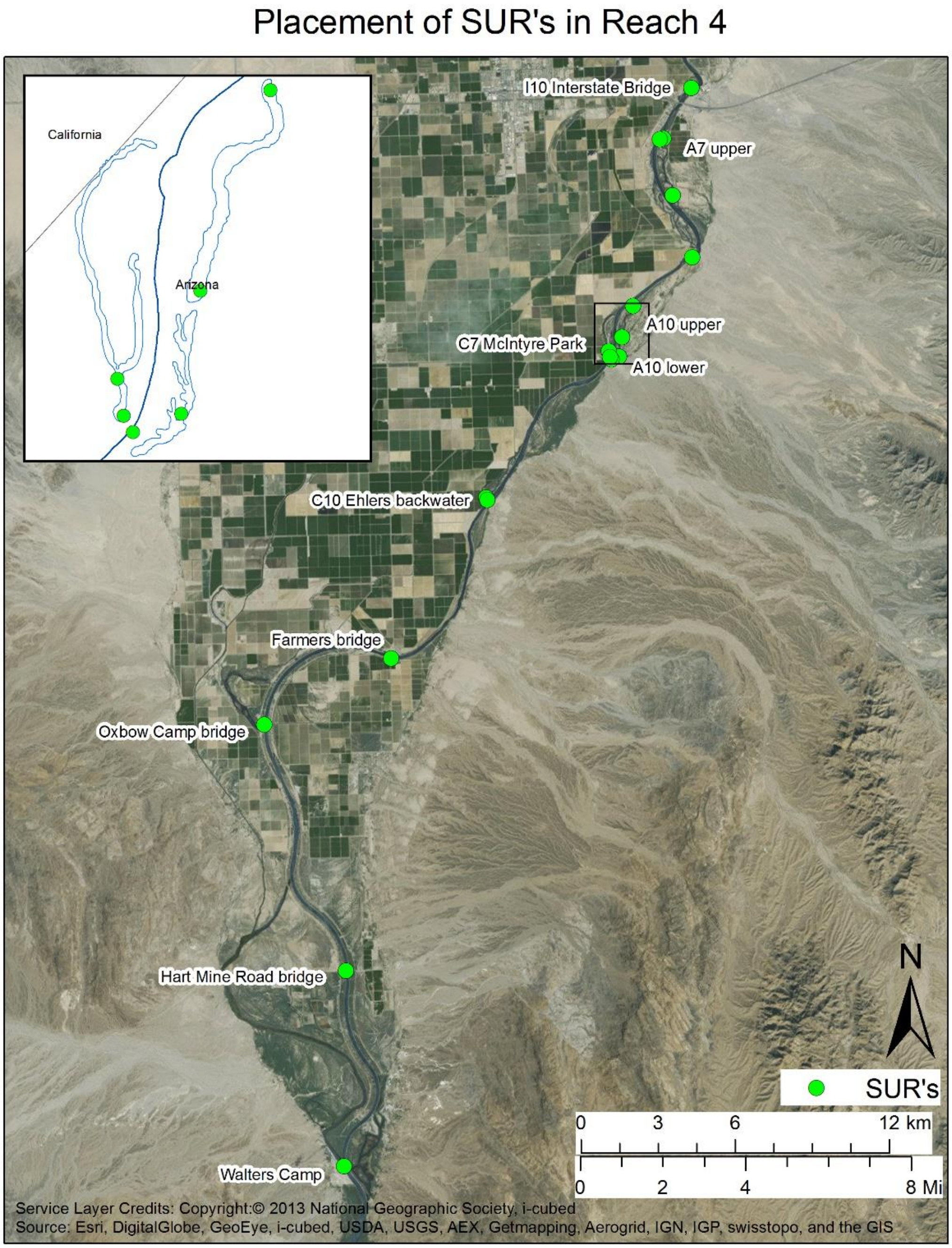

Figure 5.—Location of SURs deployed in the river and backwaters in Reach 4.

Active tracking was conducted with a directional (Model DH-4, Sonotronics, Inc.) or omnidirectional towable (Model TH-2, Sonotronics, Inc.) hydrophone and receiver. The receiver was manually set to specific tag frequencies corresponding to each tagged fish. Active tracking initially began at each release site but later varied depending on recorded fish movement. Tracking took place in backwaters each month after subadult fish were released, and in the river channel and backwaters in March and April after adult fish were released. When the towable hydrophone was used, boat speed was maintained at approximately 10 km per hour or less to reduce noise interference from the engine and to allow the device to scan for multiple frequencies within the signal's detection range. Once a fish was detected using the towable hydrophone, the directional hydrophone was used to triangulate its location and then an underwater diver receiver (UDR) was used to pin point, within 5 meters, the location of the fish.

Fish with acoustic tags exhibiting no detectable movement for three or more consecutive tracking periods were considered dead. The first date of consecutive active tracking events that a fish was found at the same location was determined as its time of death. Recovery of acoustic tags was conducted using scuba and UDR to confirm mortality once during the field season. The time of the last recorded active or passive (SUR) contact with a fish whose signal was permanently lost was determined as the time the fish was lost to the study.

Patterns of dispersal and displacement were assessed for individual fish using Esri® ArcMAP™ Version 10.1. Total straight-line displacement was assessed in ArcGIS by creating paths between tracking events for each fish with the Points to Line and Create Route tools. The total distance of these paths was calculated to provide minimum (straight line) total distance displaced between contacts for each fish and does not account for river sinuosity. Maximum dispersal was determined by calculating the Euclidian distance between Universal Transverse Mercator (UTM) coordinates from the release site and UTM coordinates from the furthest point a fish was contacted manually or by SURs.

Population Estimates

Population estimates for bonytail and razorback sucker were based on remote PIT tag sensing data when paired year to year sample data included four or more recaptures (Objective 5). Sample years were based on the fiscal year (e.g. October 1, 2015 to September 30, 2016 is SY 2016). To provide enough time between mark and capture periods, data for population estimates were further restricted to the current field season (October through April).

The mark-recapture estimate for each species was based on the modified Peterson formula,

$$N^* = \frac{(M+1)(C+1)}{R+1} \text{ (Ricker 1975)}$$

For each mark-recapture estimate, the number of individual PIT tags contacted in the field season of the previous SY was the mark (*M*), the number contacted in the current SY the capture (*C*), and the number in common between both years the recaptures (*R*). Any contacts with PIT tags released after the initiation of the marking year (October 1 of the previous SY) were removed from population estimates. Confidence intervals were derived using Poisson approximation tables using R as the entering variable when recaptures were 50 or less, or based on the normal distribution for 51 or more recaptures (Seber 1973).

RESULTS

Releases

In support of this study, a total of 5,935 razorback sucker and 4,491 bonytail were stocked into backwaters in La Paz Co., AZ and Riverside Co., CA from October 2016 through January 2017. All fish released were implanted with a 134.2-

kilohertz (kHz) passive integrated transponder (PIT) tag. These stockings were distributed among five backwaters; A7 upper, A10 upper, A10 lower, C7, and C10. Both species were stocked at least once per month during the sample season (October through March) except for February (neither species was released) and March (no razorback sucker were released). These numbers are directly from stocking records, which are slightly higher than database records (tables 4 and 5; 5,932 razorback sucker and 4,490 bonytail). Discrepancies in the database are often due to data recording errors during the tagging process.

The Lower River Native Fishes Database has recorded totals of 15,795 razorback sucker and 11,696 bonytail stocked into the five study backwaters, as well as some river locations, between 2007 and May 2017 (tables 4 and 5). Stocked fish were reared at Bubbling Ponds Fish Hatchery, Imperial National Wildlife Refuge Pond, Southwestern Native Aquatic Resources and Recovery Center (SNARRC, previously Dexter National Fish Hatchery), Lake Mead Fish Hatchery, Willow Beach National Fish Hatchery and Achii Hanyo Native Fish Rearing Facility. Release size of bonytail ranges from 223-535 mm TL and for razorback sucker 275-640 mm TL.

Contacts

A total of 438 bonytail and 901 razorback sucker unique PIT tag contacts were recorded in backwaters and the main river channel since 2014 (tables 4 and 5). A single PIT tag sensing unit deployed in C7 contacted 171 bonytail which were unexpectedly released close by on March 20, 2017, contributing the majority of the 176 bonytail contacted within the backwater. The proportion of fish released and contacted for bonytail and razorback sucker was similar, 0.037 (438 of 11,696) and 0.057 (900 of 15,795) respectively, but the proportion contacted outside their release backwater was nearly twice as high for razorback sucker 0.012 (186 of 15,795) than it was for bonytail 0.006 (75 of 11,696).

The difference between bonytail and razorback sucker PIT tag sensing contacts was more pronounced when comparing release location and size class after removing contacts that occurred within the first month after release. The highest proportion of contacts for bonytail occurred for those released into the A10 lower backwater, and for razorback sucker into A10 upper backwater (figures 6 and 7). The majority of bonytail were released at size class 2 (305-354 mm TL), with 2720 of this size released into A10 backwater (upper or lower not specified) (figure 8) but no size class of bonytail had a contact rate above 2.5%. Fifty-eight size class 4 (405-454 mm TL) bonytail were released into C7 backwater and 1.7% of these were contacted more than 30 days after release. Only nine size class 5 (455mm TL or longer) razorback sucker were released into A10 upper (figure 9) and 55.6% of these were contacted more than 30 days after release (figure 7). No bonytail or razorback sucker were released at the smallest size class (< 305 mm TL). None of the bonytail released into Ehler's backwater (C10), and none of the razorback sucker released directly in the river at Mayflower were contacted more than 30 days after release.

Table 4.—Summary of bonytail stocked into Reach 4 downstream of Palo Verde Diversion Dam and subsequent contacts. “Out contacts” refers to fish contacted outside of the release backwater. Total length (TL) is recorded in mm. Days at large (DAL) is the maximum number of days between an individual fish’s release date and the most recent contact recorded via remote PIT tag sensing unit. Due to a lack of consistency in release site descriptions provided by stocking entities for A10 backwater, movements between the two halves of A10 backwater could not be reliably assessed. Out contacts for all A10 releases are therefore restricted to contacts completely outside of A10 backwater

Date	Location	Rearing Site	Releases	Contacts	Out Contacts	TL	DAL
Released downstream Palo Verde Diversion Dam Jan 2007 through Sep 2014			150	0	0	320 (275 – 405)	NA
10-Dec-14	A10 backwater lower	Dexter NFH (SNARRC)	1996	113	5	346 (305 – 425)	30 (6 – 278)
23-Sep-15	A10 backwater	Dexter NFH (SNARRC)	2865	47	27	324 (305 – 429)	50 (20 – 548)
26-Oct-16	A10 backwater upper	Dexter NFH (SNARRC)	600	32	0	323 (305 – 392)	18 (0 – 44)
26-Oct-16	A7 backwater upper	Dexter NFH (SNARRC)	600	13	7	326 (240 – 401)	25 (12 – 149)
26-Oct-16	C7 backwater, McIntyre Park	Dexter NFH (SNARRC)	600	19	2	325 (223 – 385)	13 (0 – 44)
16-Nov-16	A10 backwater upper	Dexter NFH (SNARRC)	800	3	2	326 (305 – 395)	22 (19 – 23)
16-Nov-16	A7 backwater upper	Dexter NFH (SNARRC)	456	0	0	324 (305 – 397)	NA
16-Nov-16	C7 backwater, McIntyre Park	Dexter NFH (SNARRC)	700	3	1	326 (305 – 387)	21 (19 – 23)
16-Nov-16	Ehler's backwater	Dexter NFH (SNARRC)	700	1	0	326 (305 – 535)	20 (20 – 20)
14-Dec-16	A10 backwater upper	Lake Mead Fish Hatchery	14	0	0	415 (405 – 428)	NA
25-Jan-17	A10 backwater lower	Lake Mead Fish Hatchery	5	0	0	402 (385 – 416)	NA
25-Jan-17	A7 backwater upper	Lake Mead Fish Hatchery	15	0	0	401 (366 – 435)	NA
20-Mar-17	C7 backwater, McIntyre Park	Lake Mead Fish Hatchery	1445	206	30	349 (305 – 444)	3 (0 – 91)
25-Apr-17	A7 backwater upper	Dexter NFH (SNARRC)	750	1	1	312 (305 – 431)	31 (31 – 31)
		Totals	11696	438	75		

Table 5.—Summary of razorback sucker stocked into Reach 4 downstream of Palo Verde Diversion Dam and subsequent contacts. “Out contacts” refers to fish contacted outside of the release backwater. Total length (TL) is recorded in mm. Days at large (DAL) is the maximum number of days between an individual fish’s release date and the most recent contact recorded via remote PIT tag sensing unit. Only releases into locations with surface water connections to the mainstem Colorado River were included in this table.

Date	Location	Rearing Site	Releases	Contacts	Out Contacts	TL	DAL
Released downstream Palo Verde Diversion Dam Jan 2007 through Sep 2014			1959	22	1	364 (300 – 624)	2440 (313 – 3500)
05-Dec-14	A10 backwater lower	Imperial NWR Farm Fish Pond	30	15	4	542 (275 – 640)	90 (11 – 161)
02-Apr-15	A10 backwater lower	Bubbling Ponds FH	1019	187	37	344 (305 – 440)	47 (0 – 783)
02-Apr-15	A10 backwater upper	Bubbling Ponds FH	778	171	6	347 (305 – 420)	567 (0 – 784)
08-Dec-15	A7 backwater upper	Achii Hanyo	1212	31	20	336 (305 – 460)	16 (0 – 94)
09-Dec-15	Oxbow Recreation Area	Achii Hanyo	1160	160	31	346 (305 – 455)	3 (0 – 76)
18-Feb-16	A10 backwater lower	Bubbling Ponds FH	518	11	10	338 (305 – 470)	198 (7 – 420)
18-Feb-16	Oxbow Recreation Area	Bubbling Ponds FH	516	13	5	336 (305 – 445)	16 (5 – 119)
28-Apr-16	A10 backwater upper	Bubbling Ponds FH	1106	20	11	351 (305 – 450)	240 (46 – 419)
28-Apr-16	Oxbow Recreation Area	Bubbling Ponds FH	981	7	7	351 (305 – 445)	146 (47 – 301)
27-Oct-16	A10 backwater lower	Bubbling Ponds FH	629	47	16	358 (305 – 440)	11 (0 – 210)
27-Oct-16	A10 backwater upper	Bubbling Ponds FH	628	23	1	356 (305 – 455)	56 (12 – 209)
27-Oct-16	A7 backwater upper	Bubbling Ponds FH	630	17	10	353 (305 – 450)	20 (0 – 84)
27-Oct-16	C7 backwater, McIntyre Park	Bubbling Ponds FH	625	43	5	359 (305 – 465)	27 (0 – 236)
27-Oct-16	Ehler's backwater	Bubbling Ponds FH	633	59	3	360 (305 – 465)	12 (0 – 84)
17-Nov-16	A10 backwater upper	Bubbling Ponds FH	600	18	0	356 (305 – 465)	39 (18 – 188)
17-Nov-16	A7 backwater upper	Bubbling Ponds FH	574	3	1	354 (305 – 485)	35 (19 – 63)
17-Nov-16	C7 backwater, McIntyre Park	Bubbling Ponds FH	467	12	3	358 (305 – 480)	33 (18 – 96)
17-Nov-16	Ehler's backwater	Bubbling Ponds FH	598	8	2	354 (305 – 485)	39 (18 – 125)
14-Dec-16	A10 backwater upper	Lake Mead Fish Hatchery	11	3	0	453 (423 – 495)	71 (70 – 72)
25-Jan-17	A10 backwater lower	Lake Mead Fish Hatchery	215	0		447 (334 – 540)	NA
25-Jan-17	A7 backwater upper	Lake Mead Fish Hatchery	322	3	1	455 (362 – 550)	22 (21 – 22)
04-May-17	A10 backwater lower	Lake Mead Fish Hatchery	202	10	10	419 (320 – 539)	34 (20 – 49)
04-May-17	C7 backwater, McIntyre Park	Lake Mead Fish Hatchery	182	16	1	418 (312 – 509)	38 (21 – 49)
04-May-17	Mayflower at Hidden Beaches	Lake Mead Fish Hatchery	200	1	1	422 (318 – 530)	21 (21 – 21)
		Totals	15795	900	186		

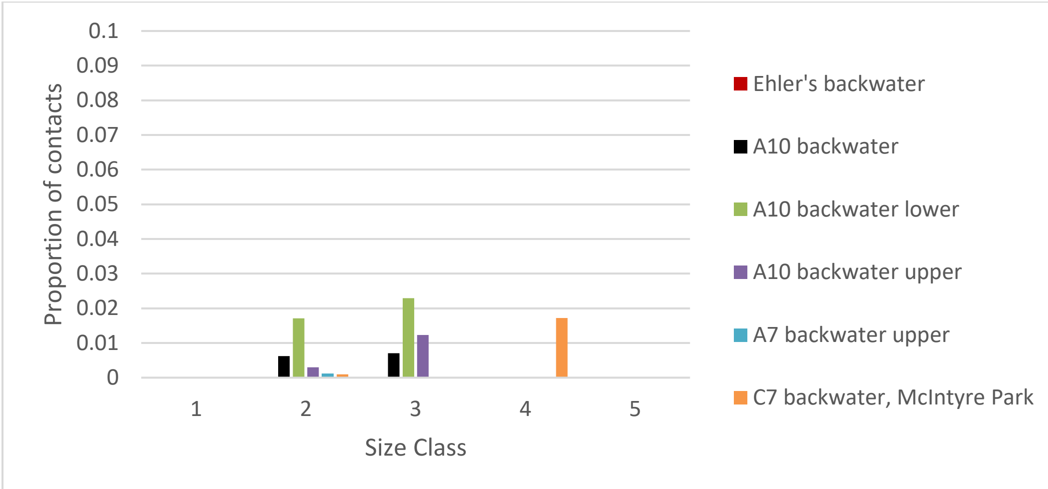

Figure 6.—Proportion of bonytail contacted more than 30 days post release by release location and size at release. Size class 1 – less than 305 mm TL; 2 – 305 to 354 mm TL; 3 – 355 to 404 mm TL; 4 – 405 to 454 mm TL; and 5 – 455 mm TL or longer. A release of bonytail on September 23, 2015 did not differentiate between A10 lower and A10 upper.

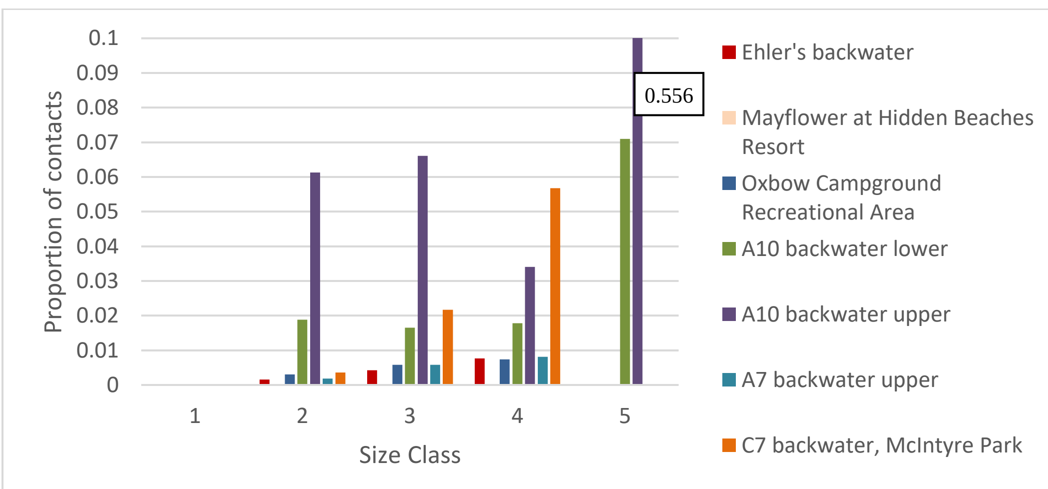

Figure 7.—Proportion of razorback sucker contacted more than 30 days post release by release location and size at release. Size class 1 – less than 305 mm TL; 2 – 305 to 354 mm TL; 3 – 355 to 404 mm TL; 4 – 405 to 454 mm TL; and 5 – 455 mm TL or longer.

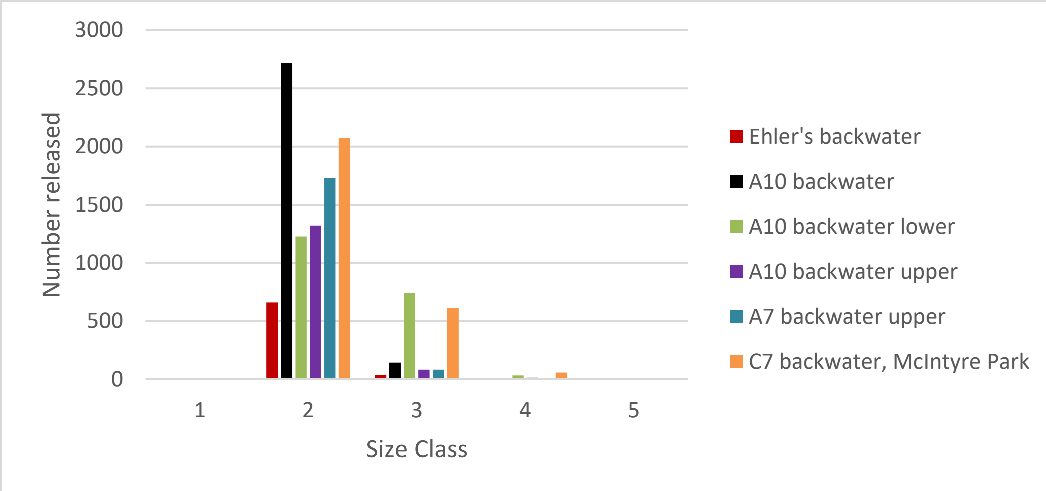

Figure 8.—Number of bonytail released by release location and size at release. Size class 1 – less than 305 mm TL; 2 – 305 to 354 mm TL; 3 – 355 to 404 mm TL; 4 – 405 to 454 mm TL; and 5 – 455 mm TL or longer.

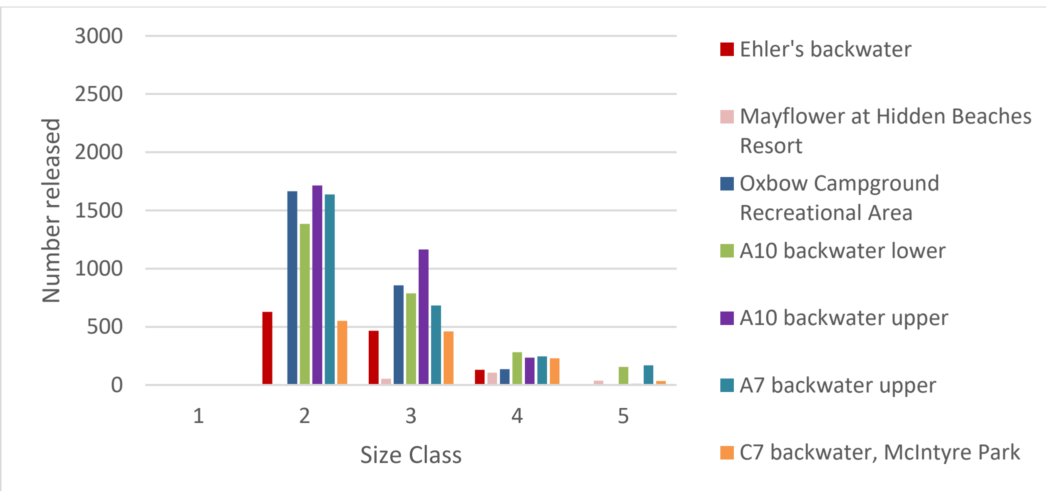

Figure 9.— Number of razorback sucker released by release location and size at release. Size class 1 – less than 305 mm TL; 2 – 305 to 354 mm TL; 3 – 355 to 404 mm TL; 4 – 405 to 454 mm TL; and 5 – 455 mm TL or longer.

Seven razorback sucker contacted via PIT tag sensing units in SY 2017 were stocked in 2007. All seven were released on October 25, 2007 into A10 upper and reared at Willow Beach National Fish Hatchery (mean TL 396 mm range 370-440 mm). Only one bonytail, released in A10 backwater in 2015, has been contacted after being at large for more than a year (548 days).

Dispersal

No general assessment of subadult dispersal out of release backwaters was possible. Except for four razorback sucker and three bonytail, acoustic tagged subadult fish were either not detected after two weeks post release or never detected outside the release backwater. The greatest dispersal distance detected for an acoustic tagged subadult bonytail (tag ID 64, 420 mm TL) was 2.31 km. Raised at Lake Mead Fish Hatchery and released into A7 upper at the boat ramp, it dispersed to the northern end of the backwater where it was detected by an SUR and tracked manually a short distance further up the backwater. The furthest dispersal distance detected for an acoustic tagged subadult bonytail outside of the release backwater was by an individual released in January into A10 lower (tag ID 63, 415 mm TL). It was manually tracked in upper A10 lower before dispersing out of the backwater and across the channel to C7 backwater, a distance of 0.55 km (figure 8). The SUR placed at the C7 entrance was deployed on March 22, subsequent to this fish's dispersal, but the fish was recorded by the SUR further upstream in the backwater.

The greatest dispersal distance detected for a subadult razorback sucker (tag ID 52, 471mm TL) was 19.71 km, also raised at Lake Mead Fish Hatchery and released in January into A10 lower backwater at the boat ramp. It dispersed outside of the backwater downstream as far as the Oxbow camp bridge where it was detected by the SUR. Two subadult razorback sucker were detected by the SUR deployed ~1 km upstream of the interstate bridge after being released in January into A7 upper and A10 lower backwaters.

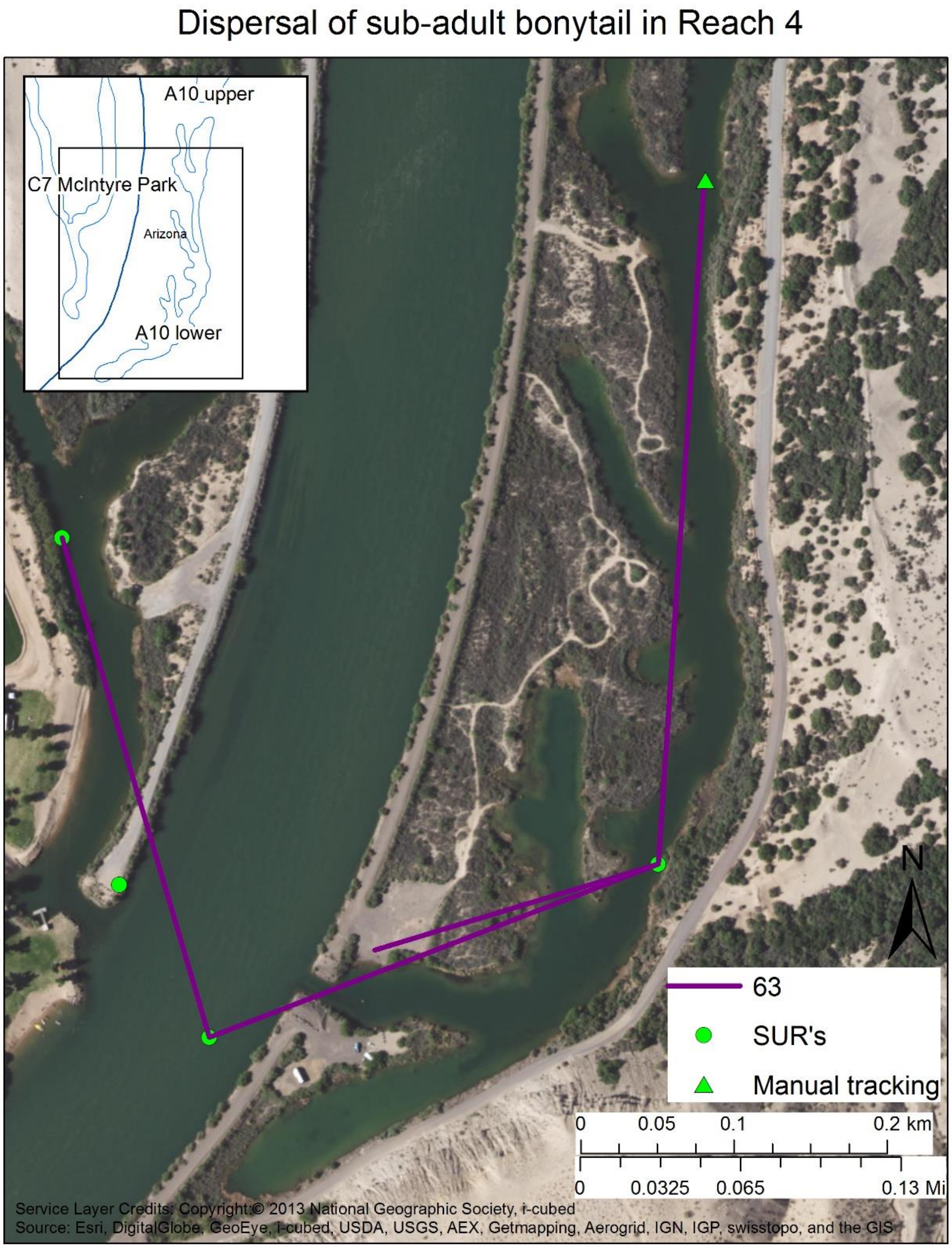

Figure 8.—Straight-line dispersal of subadult bonytail (Tag ID 63) released in A10 lower backwater at the boat ramp (southern end of map).

Ten subadult razorback sucker were released into A10 upper in December. One individual (tag ID 82) was not detected again after release and has therefore been excluded from dispersal analysis. The remaining nine individuals remained within A10 upper backwater, dispersing throughout the backwater between SURs located at either end (table 6). Displacement distances of some of these individuals appears high as there were two SURs deployed in this backwater, at the upper and the lower end, and fish were detected traveling between them. Ten subadult bonytail were released simultaneously in December and also were not detected beyond A10 upper backwater.

Table 6.—Dispersal of subadult razorback sucker and bonytail released into A10 upper on December 14, 2016. None of the released fish dispersed outside of the backwater. Displacement values demonstrate movement between SURs in the backwater and active tracking efforts. * indicates recovered tag. DAL indicates the last active contact with a fish if it was lost to the study (less than 90 days), or the day of first contact at the location of a tag recovery.

Tag	Max dispersal (km)	Displacement (km)	DAL	Displacement/day (km/day)
Razorback sucker				
81	0.88	3.03	4	0.79
82	-	-	-	-
89*	0.10	0.10	36	0.00
90	0.88	201.76	120	1.67
92	0.88	60.57	95	0.64
93*	0.88	18.61	42	0.44
94	0.88	14.52	65	0.22
95	0.94	81.88	118	0.69
96*	0.88	1.84	63	0.03
97	0.88	15.97	16	0.98
Average	**0.80**	**44.25**	**62**	**0.61**
Bonytail				
77	0.88	3.03	5	0.65
78	0.45	0.95	42	0.02
79	0.88	4.33	2	1.96
80	0.88	2.55	42	0.06
83	0.88	2.18	1	1.75
84	0.88	1.74	1	1.16
85	0.45	0.45	1	0.37
86	0.88	2.18	1	1.85
87*	0.45	0.83	42	0.02
88*	0.88	2.97	63	0.05
Average	**0.75**	**2.12**	**20**	**0.79**

Of five subadult razorback sucker released into A7 upper in January, two dispersed downstream to C10 backwater, detected by the SUR inside the entrance. The remaining three did not disperse from A7 upper. Five subadult bonytail also were released into A7 upper in January, none of which dispersed outside of the backwater. Five subadult razorback sucker were released into A10 lower in January. One individual (tag ID 47) was not detected again after release and has therefore been excluded from dispersal analysis. Only one of the four remained within the release backwater. The remaining three dispersed upstream to the interstate bridge, downstream to the Oxbow camp bridge, or were detected in the river channel just outside the release backwater. Five subadult bonytail were released into A10 lower simultaneously in January. Two were not detected outside of the release backwater, while two dispersed to C7 backwater (table 7).

Table 7.—Dispersal of subadult razorback sucker and bonytail released into A10 lower and A7 upper on 01/25/2017. Max dispersal <3 km for bonytail indicates the individual did not disperse outside of the backwater. * indicates recovered tag. DAL indicates the last active contact with a fish if it was lost to the study (less than 90 days), or the day of first contact at the location of a tag recovery.

Tag	Max dispersal (km)	Displacement (km)	DAL	Displacement/day (km/day)
Razorback sucker released into A10 lower				
47	-	-	-	-
48	10.92	10.92	11	0.99
49	0.19	0.19	1	0.21
50	0.12	0.12	3	0.04
52	19.71	39.31	31	1.27
Average	**7.74**	**12.64**	**12**	**0.63**
Razorback sucker released into A7 upper				
53	2.16	13.32	16	0.84
54	14.03	49.07	69	0.72
55	2.16	4.39	6	0.77
56	0.16	0.16	1	0.17
57	13.96	18.69	8	2.29
Average	**6.49**	**17.13**	**20**	**0.95**
Bonytail released into A10 lower				
58	0.19	0.19	2	0.08
59	0.34	0.64	3	0.20
60	0.19	0.19	2	0.12
62	1.64	1.82	78	0.02
63*	0.55	1.95	22	0.09
Average	**0.58**	**0.96**	**22**	**0.10**
Bonytail released into A7 upper				
64*	2.31	2.38	27	0.09
65	0.16	0.16	1	0.20
66*	2.16	14.98	28	0.54
67*	2.16	4.07	22	0.19
68*	2.16	2.89	28	0.10
Average	**1.79**	**4.89**	**21**	**0.23**

The maximum dispersal distance recorded by an acoustic tagged razorback sucker (Tag ID 145) was 20.4 km (table 8), which was an adult released in February 2017. Adults were captured by boat electro-fishing from A10 upper backwater and this individual measured 518 mm TL. Released into A10 lower backwater at the upper end in February, it dispersed downstream where it was detected by the SUR at Oxbow Camp bridge (figure 9). SUR contact data show that this individual was not contacted by two SURs (one at C10 entrance and another at Farmer's Bridge) in the river channel between A10 lower and Oxbow Camp bridge. All ten adults dispersed at least as far as C7 backwater. Six dispersed as far as the SUR located in the upper end of A10 upper, even after being detected throughout C7 and A10 lower backwaters (table 8, figure 10). Dispersal occurred through the culvert between A10 lower and A10 upper.

Table 8.—Dispersal of adult repatriate razorback sucker released into A10 lower on 2/22/2017. DAL indicates the last active contact with a fish if it was lost to the study (less than 90 days), or the day of first contact at the location of a tag recovery.

Tag	Max dispersal (km)	Displacement (km)	DAL	Displacement/day (km/day)
137	1.39	17.95	50	0.36
138	1.39	19.26	50	0.38
139	0.79	2.34	50	0.05
140	1.39	3.42	50	0.07
141	1.39	7.89	44	0.18
143	0.85	3.70	24	0.15
144	1.39	39.00	50	0.78
145	20.40	20.57	8	2.49
146	0.79	2.50	50	0.05
147	0.85	2.97	17	0.18
Average	**3.07**	**11.96**	**39.49**	**0.47**

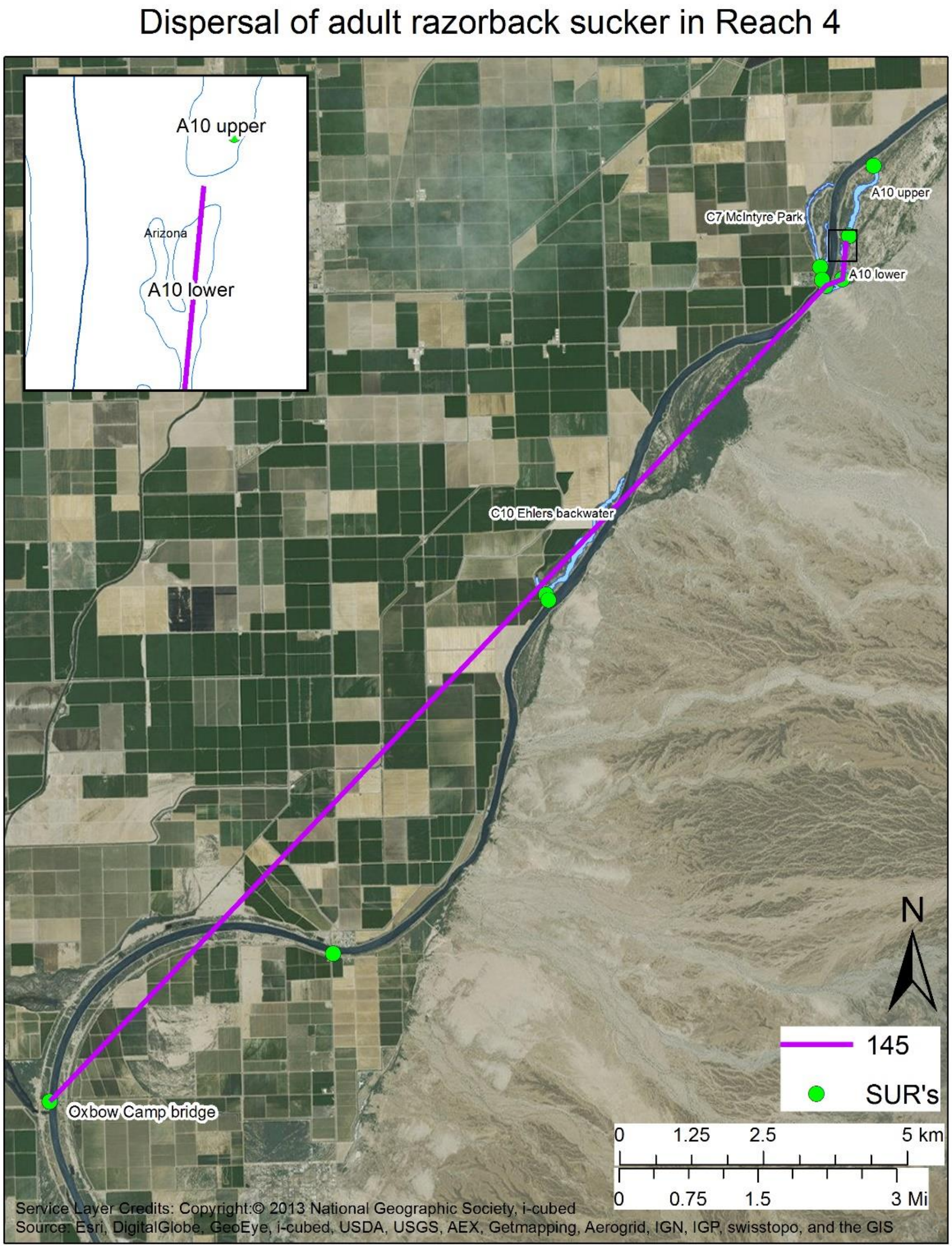

Figure 9.—Straight-line dispersal of adult razorback sucker (Tag ID 145) released in the A10 lower backwater (northern end of map).

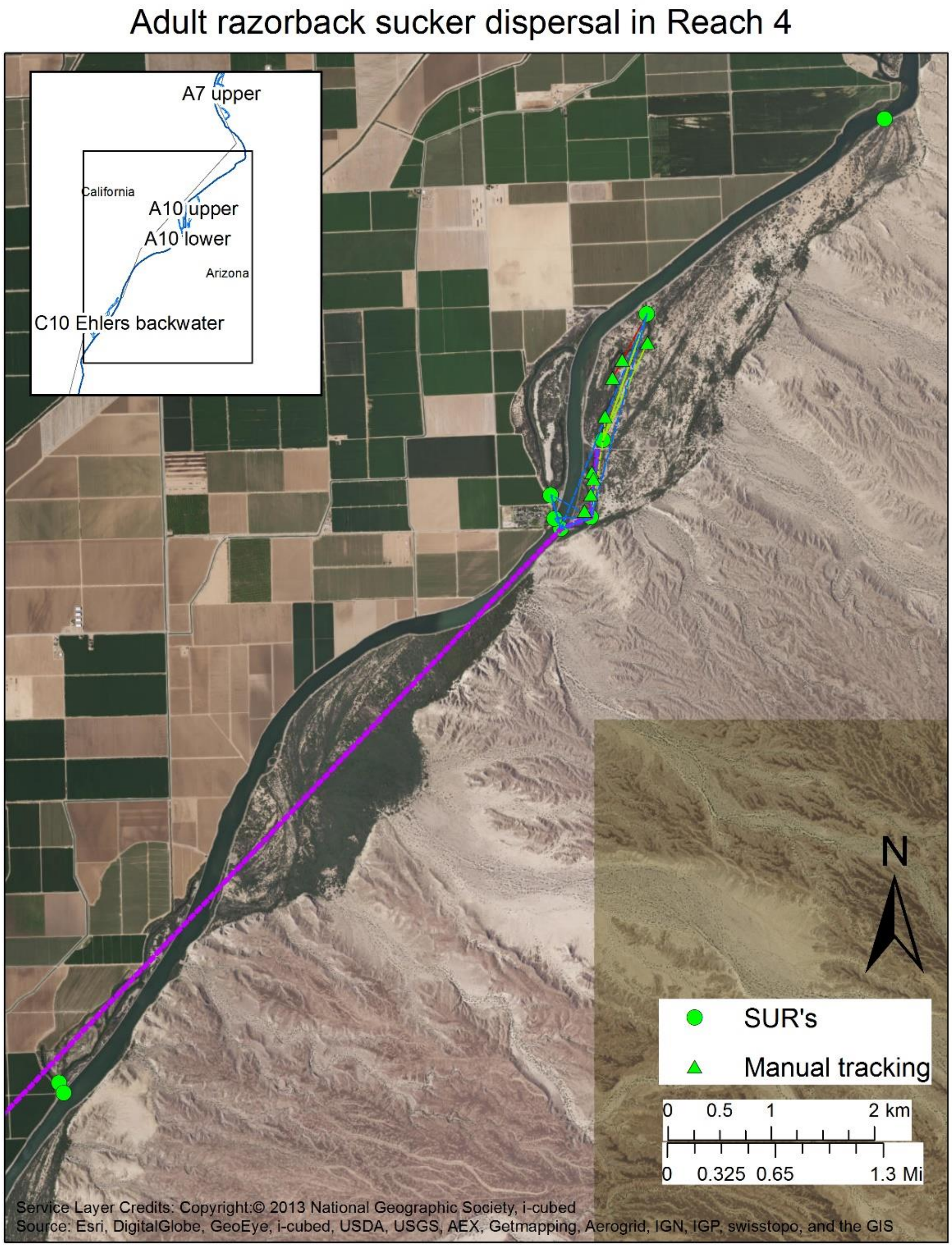

Figure 10.—Dispersal of adult razorback sucker released at A10 lower boat ramp (southern end of map). Tag ID 145 is excluded from this map as it is detailed in figure 9.

The final fate of subadult acoustic tagged razorback sucker and bonytail was determined for less than half of the 40 fish released; 7 of 20 razorback sucker and 8 of 20 bonytail (tables 6 and 7). Four subadult razorback sucker and one bonytail survived from release to the end of the monitoring period. Ten short-term tags (three razorback sucker and seven bonytail) were retrieved from A10 upper and lower, and C7 backwaters in March via scuba, presumably from deceased individuals.

Population estimate

No bonytail contacted in SY 2016 were contacted again in SY 2017, and so no population estimate was possible. Few razorback sucker were encountered in both years when the contact period was restricted from October to April. Therefore, an initial population estimate was calculated based on extending the mark and capture periods to include all contact data from October to May of each sample year. The estimate for SY 2016 was 216 (95% CI 173 to 271) with 130 encountered in SY 2016 (marking period October 2015 through May 2016), 130 encountered in SY 2017 (capture period October 2016 through May 2017), and 78 encountered in both periods (recaptures). The population estimate for razorback sucker was almost entirely based on contacts within A10 backwater (upper and lower). Out of the 130 contacted during the marking period, seven fish were contacted outside of A10 backwater (two of which were also contacted within A10 during the same period). Out of the 130 contacted during the capture period, six fish were contacted outside of A10 backwater (four of which were also contacted within A10 during the same period). An estimate based on contacts just within A10 backwater was 206 (95% CI 164 to 258) with 125, 127, and 77 for marks, captures, and recaptures respectively.

Avian predation observations

Up to two osprey (*Pandion haliaetus*) individuals were observed in Reach 4 throughout the field season. They were seen roosting close to the river and flying directly over the main channel. Double-crested cormorants (*Phalacrocorax auritus*) were observed in abundance and their numbers seemed to increase through the winter. Roosting opportunities are plentiful throughout the backwaters and they were often observed diving to feed. On numerous occasions while boating in a backwater, cormorants were seen regurgitating into the water before taking flight when approached. On one occasion the regurgitated, partially digested prey was confirmed to be a razorback sucker (figure 11). On other occasions, razorback sucker or bonytail were found deceased in the water with scratches and puncture wounds that appear to be the result of attempted predation by birds (talon or beak markings).

Figure 11.—Signs of predation on a deceased bonytail found floating on the surface (top); partially digested remains of a razorback sucker after being regurgitated by a cormorant (bottom left); deceased razorback sucker observed submerged (bottom right).

DISCUSSION

Deployment of PIT tag sensing antennas throughout the backwaters and main river channel was effective in contacting existing and recently stocked razorback sucker and bonytail implanted with full duplex 134.2-kHz PIT tags. The majority of contacts were made in backwaters because this is where effort was focused. PIT tag sensing unit effort was not redirected to any specific locations in the main channel because the majority of acoustic tagged subadult fish remained in their release backwater, perished in their release backwater, or moved into another backwater. Acoustic tagged adult razorback sucker were not actively contacted in the main channel, and no spawning aggregations were located during electrofishing events in the river. The adult razorback sucker may have been released too late in the year (February) to recover from surgery and spawn. Continued tracking of the surviving adult razorback sucker earlier in the year next year should provide more insights into spawning locations, but the availability of adult razorback sucker in the main channel for future capture and acoustic tagging is uncertain.

Few subadult bonytail and razorback sucker released into A10 upper dispersed outside the backwater. None of the acoustic tagged subadult razorback sucker and bonytail released in A10 upper dispersed outside of the backwater, and the majority of PIT tag sensing unit contacts with fish released in A10 upper occurred in A10 upper. This is a large backwater with limited access to the river channel. Fish can only disperse to the river through a culvert near the upstream terminus, or through a second culvert at the downstream end into A10 lower. The relatively 'captive' population of razorback sucker in A10 upper increases the probability that enough data will be collected there to estimate population sizes and survival in the reach over the next four years. The first population estimate of 216 fish in this report is based on more than 95% of contacts from A10 upper. However, this does not satisfy the objective of estimating the population size and survival for fish released in the entire reach.

Fish released in all other backwaters including C7, A7 upper, C10, and A10 lower dispersed more readily, as indicated by more PIT tag sensing unit contacts outside of the release site than for fish released in A10 upper. However, very few of the fish from these backwaters were contacted more than 30 days after release. This either indicates fish dispersal beyond the study area, or very high mortality of stocked fish. These results are similar to those obtained during the 2006 through 2008 studies in the same area using trammel nets and boat electrofishing (Schooley et al. 2008). At that time A10 lower did not have an open channel to the river, only a culvert, and both A10 upper and A10 lower contained 'captive' populations of razorback sucker numbering in the hundreds to thousands. Fish released in A7 upper were more likely to be contacted outside of the release backwater, but captures of razorback sucker outside the release backwater were rare. Even within A10 (upper and lower), mortality factors including avian and piscine predators resulted in annual survival for stocked razorback sucker of less than 30% (Schooley et al. 2008). The combination of high annual mortality and rapid dispersal out of the study area will make it difficult to accurately assess survival rates and population size for the entire reach. If concentrations of razorback sucker within the main channel cannot be located, estimates will likely be largely based on the fish in A10 upper backwater.

Available data for bonytail were even fewer than for razorback sucker. No recaptures of bonytail were available for a population estimate. Records of individual bonytail that survived a year or more are uncommon in the Colorado River basin (Humphrey et al. 2016; Bestgen et al. 2017), and to date there have been too few for a population estimate. When survival has been estimated, it has been only within a few months of release and very low (Bestgen et al. 2008; Humphrey et al. 2016). However, few bonytail were stocked into the reach downstream of Palo Verde Diversion Dam between 2007 and 2014, and multiple contacts with bonytail from every release since 2014 is promising. It may take several years of focused stocking to develop a small population in the reach.

Although dispersal out of a backwater is desirable, slowing that dispersal may allow for bonytail and razorback sucker to behaviorally adapt to the system and avoid moving rapidly out of the study area. The common release location in many of the backwaters is a boat ramp. Some of these boat ramps are immediately adjacent to the backwater entrance channel from the river near the downstream end (e.g., A10 lower, A7 upper, and C7). Moving the release location to the upstream end of the backwater may provide more opportunity for fish to recover from handling, find cover, and delay their dispersal into the river.

This is possible in A10 lower as there is a road that divides A10 upper and A10 lower that would provide stocking truck access to the upper terminus of A10 lower. A7 upper also contains locations further upstream in the backwater that could serve as release sites giving fish more backwater to move through prior to dispersing into the river. C7 is surrounded by a campground facility and the upstream most access point within the campground would be preferable to the boat ramp near the main channel exit. Few fish were released into C10 backwater, but the release site at the boat ramp is centrally located and provides abundant cover for released fish. At times, this backwater is unnavigable by boat due to a large floating debris field limiting boat access to the lower half of the backwater, but it can still be accessed by road, or by boating through the entrance at the south end.

LESSONS LEARNED

Some changes to the monitoring efforts based on experience from the first study period should help meet study objectives. Much of the PIT tag sensing effort in this cycle was focused in the backwaters with some deployments in the river channel (mostly later in the season). Regardless of results from subadult acoustic telemetry, deploying more sensing units in the river channel, and further downstream on a routine basis may provide better insight into the number of fish dispersing from the backwaters.

Installing PIT tag sensing units inside or around the culverts will provide data on fish dispersal through them. Initial focus should be on the A10 backwaters because that is where most fish have been contacted. Installing a PIT tag sensing unit in the culvert between A10 upper and A10 lower would provide data on movement of fish between these two backwaters. A unit in the culvert from A10 upper to the river would capture dispersal of fish out of A10 upper to the main channel.

Continued releases of bonytail and razorback sucker among the five main release backwaters (A7 upper, A10 upper, A10 lower, C7, and C10) will provide more information on native fish habitat use and survival. Stocking fish as far upstream as possible within the backwater may slow dispersal out of the backwaters and provide more data on fish activity for identifying important backwater habitat within and outside of the backwaters.

Surgeries on adult razorback sucker occurred late in this study period, after spawning had already been observed in A10 upper backwater. If adult fish cannot be collected from the river channel, they should be collected as early as possible from A10 upper or an alternate site. While no spawning was observed in the river channel, releasing and tracking telemetry fish earlier in the season will increase the opportunities to identify spawning grounds in the river if they exist. An additional SUR in the river channel on wash fans between C7 and C10 backwaters (potential spawning habitat) could confirm spawning in this section of the river.

Finally, determining boundaries for "seasons" as relevant to the stocking and survival of bonytail and razorback sucker required assessing the impact of various factors that occur seasonally on these fish species. Examples of these factors include migratory piscivorous bird activity, water temperature, and piscivorous fish activity. Although physical factors (water and air temperature) are seasonal and tend to control the biological factors (migratory birds and fish activity), they also directly impact native fishes. Increased water temperature stresses fish, and the timing or temperature thresholds of these different factors do not occur simultaneously or impact the two species of interest equally. Therefore, it may be prudent to track water and air temperatures directly, use the literature or other data sources to determine the timing of biological factors, and use them as covariates in mark-recapture models for estimating survival outcomes of both species.

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