Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

2015–2019 FINAL REPORT
Demographics and Monitoring of Repatriated Razorback Sucker in Lake Mohave

U.S. DEPARTMENT OF THE INTERIOR
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Lower Colorado River Multi-Species Conservation Program Steering Committee Members

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National Park Service
Bureau of Land Management
Bureau of Indian Affairs
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Lower Colorado River Multi-Species Conservation Program

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ACRONYMS AND ABBREVIATIONS

AIC – Akaike's Information Criterion
amp-h – ampere hour
AZFWCO – Arizona Fish and Wildlife Conservation Office
CI – confidence interval
cm – centimeter(s)
FY – fiscal year
FWS – Fish and Wildlife Service
h – hour(s)
kHz – kilohertz
km – kilometer(s)
LCR – Lower Colorado River
LCR MSCP – Lower Colorado River Multi-Species Conservation Program
M&A – Marsh & Associates, LLC
m – meter(s)
M, C, R – mark, capture, recapture
mL – milliliter(s)
mm – millimeter(s)
NFH – National Fish Hatchery
PIT – passive integrated transponder
PVC – polyvinylchloride
QAICc – quasi-likelihood
Reclamation – Bureau of Reclamation
RM – river mile(s)
rkm – reservoir kilometer(s)
SY – sample year
TL – total length
UTM – Universal Transverse Mercator

Symbols

c – recapture
n – number
p – capture
% – percent
ĉ – c-hat, variance inflation factor
γ – gamma

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EXECUTIVE SUMMARY

Repatriated razorback suckers (*Xyrauchen texanus*) in Lake Mohave have been monitored for more than 25 years, but low recapture rates have inhibited evaluation of factors contributing to highly variable post-stocking survival. In 2010, deployment of remote passive integrated transponder (PIT) scanners able to detect 134.2 kilohertz (kHz) PIT tags was initiated to increase the number of encounters with marked fish. The program was expanded in 2012 and 2013, while traditional capture methods (i.e., trammel nets) continued to be employed to collect comparable long-term monitoring data and estimate abundance of all repatriated and wild razorback suckers marked with either 400 or 134.2 kHz PIT tags. Lake Mohave was split into four distinct zones, listed from upstream to downstream as: River, Liberty, Basin, and Katherine.

Trammel netting efforts at Carp Cove from October1, 2014 to September 30, 2019 resulted in capture of 83 PIT-tagged repatriated razorback suckers that had single captures during the monitoring period and one fish that had two captures. Sex was determined at time of capture for all fish and most were female (n=68) along with 15 males and one juvenile. Of the 84 repatriates, 80 had paired stocking-capture data (i.e., fish with stocking and capture data). Overall total length (TL) at release ranged from 265–531 millimeters (mm) and TL at capture ranged from 342–741 mm with an overall mean TL at release and capture of 426 and 595 mm, respectively. The shortest time at large, from stocking to capture, was 10 days, and years at large ranged from less than one to 22 with an overall mean of 6. Year classes ranged from 2001–2016; the 2004-year class was not represented. Mean growth rate of females was 6 mm TL per month and for males approximately 4 mm TL per month. Most captured fish were released in Basin (n=59), followed by Liberty (n=12), River (n=7), and Katherine (n=2); 36 were raised in lakeside backwaters and 44 in offsite facilities.

Based on routine monitoring data (i.e., trammel netting) from the last 5 years we estimate there is no self-sustaining wild razorback sucker population remaining in Lake Mohave. The repatriated razorback sucker population in 2014, based on 2014 and 2015 March monitoring data, was estimated at 2,230 fish (95% confidence interval [CI] from 922 to 5,963), which was more than double the current (2018) estimate, based on 2018 and 2019 March monitoring data, for razorback sucker in Lake Mohave of 994 fish (95% CI from 602 to 1,639).

Total deployment time for PIT scanners (remote monitoring) from October 1, 2018 through September 30, 2019 was 37,257 scan hours resulting in 96,575 PIT tag contacts, representing 4,408 unique PIT tags for which 4,225 had a razorback sucker marking record (i.e., implanted with a PIT tag and associated data recorded), and 60 had a bonytail (*Gila elegans*) marking record in the Native Fish Database (as of September 30, 2019). Among razorback suckers with a marking record, 4,165 were repatriates, 10 were wild, and 50 were of unknown origin. All bonytail with a marking record were repatriates.

Total deployment time for remote PIT scanners from October 1, 2014 through September 30, 2019 was 201,382 scan hours resulting in 627,411 PIT tag contacts, representing 6,304 unique PIT tags for which 5,876 had a razorback sucker marking record (i.e., implanted with a PIT tag and associated data recorded), and 106 had a bonytail marking record in the Native Fish Database (as of September 30, 2019). Among razorback suckers with a marking record, 5,799 were repatriates, 13 were wild, and 64 were of unknown origin. All bonytail with a marking record were repatriates.

Based on 2018 and 2019 remote PIT scanning, the 134.2 kHz PIT tagged Lake Mohave repatriate population for 2018 was estimated at 3,649 individuals (95% CI from 3,552 to 3,745). Population estimates using zone specific scanning for 2018 estimated Basin population at 1,963 (1,904 to 2,021) and River at 2,120 (2,012 to 2,227). Too few wild fish with 134.2 kHz PIT tags were contacted to estimate Basin and River subpopulations separately (four and seven contacts in 2019, respectively). Wild fish continue to be contacted by PIT scanners, although the majority were originally tagged with 400 kHz tags. The lake-wide estimates calculated from PIT scanning data likely underestimate the wild population due to PIT scanners only contacting 134.2 kHz tags. Still, an estimated nine (5 to 19) wild razorback suckers with 134.2 kHz tags survive in Lake Mohave in 2018.

Lake-wide repatriate population estimates based on PIT scanning increased each year from 2010 (coinciding with increased scanning effort) until peaking in 2016 at 3,871 fish. The population of

razorback sucker with unknown history (tagged at capture) has increased from a low of 7 in 2013 to a high of 32 in 2018. No estimate was calculated for 2015 due to low recaptures (3).

A robust mark-recapture model was applied to accumulated PIT scanning data from sample years 2013 to 2019 to estimate annual survival for River and Basin subpopulations of razorback sucker. Estimates of adult survival were similar between River and Basin, with all but one annual estimate (Basin 2016 to 2017) more than 95%. Emigration rates were more disparate with all but one estimate lower than 6% for Basin, and all but one estimate more than 6% in River. This suggests that temporary emigration out of River is slightly higher than out of Basin. Capture probability ranged from a low of 0.0012 on the last sampling occasion in May of 2019 (Basin) to 0.508 on the first sampling occasion in January 2013 (Basin). All years had at least one occasion with capture probability above 0.250, with the highest value for a given year typically in February in Basin and December, January or February in River.

Stocking displacement was examined to determine distance traveled from stocking locations and to identify movement between zones. Fish that were released in River or Basin zones were mostly contacted exclusively within their zone of release (64.3% and 69% of contacted fish, respectively). However, a considerable portion of fish released in River or Basin zones were detected in the other zone (33.1% and 29.5% of contacted fish, respectively). Razorback suckers released in Liberty zone were mostly contacted upstream in River zone or downstream in Basin zone in approximately equal proportions and fish stocked in Katherine zone all were contacted upstream of their release location.

Deployment of remote PIT scanners to monitor the two known subpopulation centers (River and Basin) will continue to be an effective means of contacting razorback sucker aggregates. Additional PIT scanning efforts have continued in Liberty to determine if other aggregations exist and to further evaluate the dynamics of razorback sucker dispersal and distribution. Bi-annual routine monitoring efforts in Basin zone continue to collect essential growth, health, census, and genetic data for razorback sucker. These data continue to provide long-term insight into population dynamics and demographics. Together, these efforts continue to contribute to the maintenance of this endangered species.

INTRODUCTION

Lake Mohave in the latter half of the twentieth century was home to the largest known population of wild razorback suckers (*Xyrauchen texanus*), an endangered "big river" fish endemic to the Colorado River basin. The population was estimated at 60,000 – 75,000 in the 1980s, declining to fewer than 25,000 in the mid- 1990s (Marsh et al. 2003) and fewer than 50 wild individuals by 2010 (Dowling et al. 2014). Since 2010, wild razorback suckers are rarely encountered, and the population is functionally extirpated.

Although wild fish are nearly gone, a genetically diverse adult razorback sucker population persists in Lake Mohave because of a repatriation program initiated by the Native Fishes Workgroup in the early 1990's (Dowling et al. 2005, Marsh et al. 2015). The program gradually developed into a system of wild larvae collection, protective rearing, and repatriation to the reservoir after growing to a minimum size of 300 millimeters (mm) in total length (TL) (Mueller 1995). There have been several adjustments to the program that incorporate new information to increase survival of stocked fish, primarily an increased size of stocked fish to reduce predation mortality but results thus far have not met expectations (Marsh et al. 2005, 2015).

In 2006, management of the Lake Mohave repatriation program shifted to the Lower Colorado River Multi-Species Conservation Program (LCR MSCP), which currently oversees and funds stocking and monitoring of razorback sucker in Lake Mohave. Stocking razorback suckers into Lake Mohave from the Willow Beach National Fish Hatchery (NFH) (LCR MSCP 2015b, 2018, Work Task B2), Achii Hanyo Native Fish Rearing Facility (LCR MSCP 2015b, 2018, Work Task B3), Lake Mead Fish Hatchery (LCR MSCP 2015b, 2018, Work Task B6), and from lakeside ponds (LCR MSCP 2015b, 2018, Work Task B7) is conducted under the Fish Augmentation component of the program (LCR MSCP 2006, 2015a). The Lake Mohave repatriation program is one element of an overall conservation plan for razorback sucker within the LCR MSCP. This program and other conservation plans upon which it was based (Minckley et al. 2003, U.S. Fish and Wildlife Service [FWS] 2005), incorporate a population component that will occupy the lower Colorado River mainstem; however, absent changes in the non-native fish community, it may be impractical or impossible to accommodate that component.

Efforts to enhance the population size of razorback sucker have included assessing the relationship between size and survival, which has led to a recommended minimum stocking TL of 500 mm (Marsh et al. 2005, Kesner et al. 2008, Kesner et al. 2012). However, increasing individual size while maintaining sufficient stocking numbers was difficult (M. Olson, Willow Beach NFH, January 2009, personal communication), which led to a change in rearing strategy at Willow Beach NFH in February 2015.

The new strategy included holding between 8,000 to 10,000 fish on station for five years and releasing them as one cohort, regardless of size (smaller fish will not be culled). The goal was to increase mean fish size, likely to greater than 400 mm TL (LCR MSCP 2015a). Unfortunately, in November 2016, approximately 30,000 razorback suckers at Willow Beach NFH were lost due to a catastrophic outbreak of the parasitic protozoan *Ichthyophthirius multifiliis* ("ich"). Due to this loss, the number of fish available for stocking into Lake Mohave over the next several years has dramatically decreased, and the larval goal was increased to 30,500 and 43,000 individuals in 2018 and 2019, respectively (LCR MSCP 2019).

Traditionally, management of the Lake Mohave razorback sucker population relied entirely on data acquired during trammel net surveys (i.e., routine monitoring) to derive population and survivorship estimates (Marsh et al. 2005), but in 2010 the use of portable remote passive integrated transponder (PIT) scanners was initiated. This technological advance has expanded the study area into riverine portions, while traditional capture methods centered around the main basin continue to provide important comparative health and dispersal information, samples for genetics monitoring, data on untagged or older 400 kHz tagged fish, and temporal dynamics of the non-native fish community.

Overall, the objective of ongoing monitoring and research for razorback suckers in Lake Mohave is to provide information needed to determine how the repatriation program should contribute to the maintenance of this endangered species in Lake Mohave and throughout the lower Colorado River. Moreover, results of this research provide critical demographic information and inform management to help ensure long-term persistence of a genetically viable stock of adult razorback sucker in Lake Mohave.

Thirteen specific objectives were outlined to achieve the goals of this research:

1 Locating and capturing adult razorback sucker

2 Recording biological data (e.g., sex, TL, weight), documenting the PIT tag number, and examining the general health and condition of captured razorback sucker

3 Collecting tissue samples from adult razorback sucker for genetic analysis

4 Marking of captured adult razorback sucker with 134.2 kHz PIT tags for individual identification (only if fish have not been previously tagged)

5 Using mobile remote PIT tag scanners capable of deployment in both slack water and riverine sections of Lake Mohave (it is anticipated that most remote sensing will occur in River Miles 330–342 for one week of every month during the contract year. An alternate monitoring schedule of equivalent time and effort may be proposed based on contractor expertise)

6 Participating in a maximum of two annual, weeklong, multi-agency, survey events to take place in the autumn (November or December) and spring (March) of each contract year (most of the effort related to these events will be restricted to River Miles 290-305). In the event these surveys do not take place the contractor may conduct additional remote scanning during these periods

7 Estimating current repatriate, and if possible, wild razorback sucker populations

8 Assimilating Lake Mohave razorback sucker capture/contact data collected by other federal and nonfederal entities into population estimates

9 Providing monthly progress reports summarizing all field, laboratory, or office work completed during this effort

10 Providing copies of all data sets generated during this work to the designated Reclamation Contracting Officer's Technical Representative

11 Providing a draft annual report during each contract year for review by LCR MSCP staff

12 Providing a final annual report for each completed contract year

13 Attending the annual Colorado River Aquatic Biologist meeting and presenting monitoring results

This report summarizes data collected under the five-year contract as part of ongoing demographic and post-stocking survival studies of repatriated razorback sucker in Lake Mohave. Population estimates for wild and repatriate populations were updated based on results from routine monitoring. Repatriate, wild, and unknown population estimates were developed from remote PIT scanning data collected across all years available in the basin and riverine portions of the lake. In addition, remote PIT scanning data were used to update annual adult survival estimates within a robust mark-recapture model, to illustrate post-stocking dispersal through violin plots and tables, and to assess factors that influence the availability of adult razorback sucker to remote monitoring.

METHODS

For the purposes of this study, Lake Mohave (LCR MSCP Reach 2) was divided into four distinct zones: River zone, Liberty zone, Basin zone, and Katherine zone (listed from upstream to downstream), hereafter referred to as River, Liberty, Basin, and Katherine, respectively (figure 1; Kesner et al. 2012). These demarcations are based on geographic features of the river system and razorback sucker demographics as determined from previous studies. Remote PIT scanning was primarily conducted in River, Liberty, and Basin, and to a lesser extent in Katherine.

Annual sampling followed the federal fiscal year (FY), October 1 to September 30, which coincides with annual spawning behavior, i.e., the annual sampling event in autumn is reported together with the following March monitoring data each year representing a single spawning season. Sample year (SY) refers to a single calendar year based on the fiscal year schedule (e.g., October 1, 2018 to September 30, 2019 is SY 2019). Unless otherwise stated, SY data in this report represent the entire SY.

Routine Monitoring

Objectives 1, 2, 3, 4, and 6 were accomplished through participation in the December and March multi-agency survey events. During all events from 2015 through 2019, Marsh & Associates, LLC (M&A) personnel occupied a field camp for five days on Lake Mohave at Carp Cove, Arizona (Basin), near River Mile (RM) 298 (miles upstream of the Southern International

Boundary). For each sampling event, up to six trammel nets (91.4 meters [m] long x 1.8 m high, with 3.8 centimeter [cm] stretch mesh) were fished continuously along the Arizona shoreline from Cottonwood East Area upstream to Carp Cove (figure 2).

Figure 1.—Map of Lake Mohave, Arizona and Nevada, illustrating the zoning scheme used for this project; location map inset.

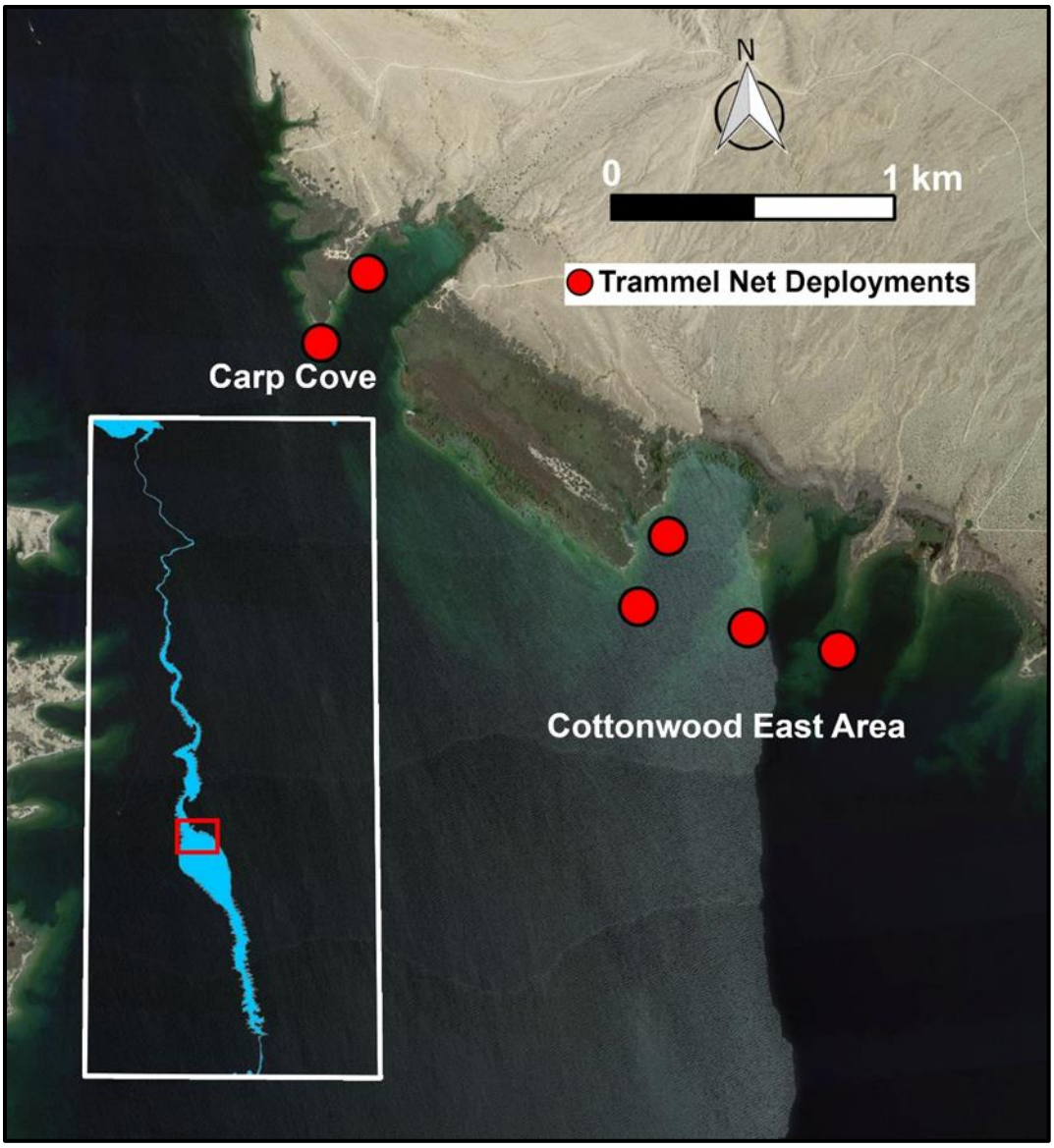

Figure 2.—General locations of trammel nets deployed by Marsh and Associates during routine monitoring events at Lake Mohave, Arizona and Nevada; location map inset.

Native fish encountered were processed and released (Objective 1). Nets were run and cleared, and fish processed twice daily, once each in the morning and evening. Processing included measuring TL, assessing sex and spawning condition (expression of gametes), scanning for a PIT tag and tagging if none was present (Objective 4), and examining the fish for general health and condition (Objective 2). A fin clip was taken from each razorback sucker, placed in 1 milliliter (mL) of 95% ethanol in a labeled snap-cap tube, and returned to the laboratory for genetic analysis (Objective 3; results reported elsewhere by others). All relevant data were entered into the comprehensive Lower Colorado River (LCR) Native Fish Database maintained by M&A. Beginning in 2007, razorback suckers that were captured without a PIT tag were implanted with a 134.2 kHz PIT tag and labeled as "unknown" in the database to denote an unknown history of origin. Also, PIT tags that do not have original capture or release data associated with them are labeled as "unknown."

Remote Monitoring

Remote PIT scanning units were deployed one week of every month during each sampling season on shallow gravel bars that extend into the Colorado River upstream of Willow Beach (River, Objective 5). Four models of PIT scanners were employed. One type of unit (shore-based) was comprised of an antenna and scanner housed in a 2.3 x 0.7 m polyvinylchloride (PVC) frame connected by 45.7 m of cable to a waterproof box that protected the logger and battery and was secured to shore. A six-volt, 12 ampere-hour (amp-h) sealed lead acid battery and a solar panel provided power to the scanner, eliminating the need for manually removing and charging the battery more than once per month. Three models of submersible PIT scanners were employed (0.8 x 0.8 m and 1.2 x 0.8 m [standard power] and 1.2 x 0.8 m [decreased power consumption]). Submersible PIT scanning units were comprised of a polyvinyl chloride (PVC) frame that housed a scanner and logger. Power to submersible units was provided by a 20.8 or 28 ampere amp-h lithium-ion battery pack contained in a watertight, 2-inch (5.08 cm) PVC pipe. Batteries were changed on a routine basis during sampling trips by checking battery voltage during daily downloads; generally, if a battery was at 7.4 volts or less, a new battery was installed. Five to 19 submersible units were employed throughout the monitoring seasons.

Five locations established in 2013 as fixed sites listed from downstream to upstream were Gio's

Point, Black Bar, Ringbolt Rapids, Boy Scout Canyon, and Sauna Cave. These locations were initially examined and evaluated in 2011, PIT scanned periodically in 2011 and 2012, and determined to be utilized by razorback sucker at different times of year. These five locations were established as fixed sites to test the hypothesis that razorback sucker aggregation sites change temporally (i.e., seasonally), with large aggregates on Black Bar during spawning, then shifting upstream toward Hoover Dam as the spawning season ends. Due to seasonal variation in contact rates, deployment of scanners not at fixed sites varied between trips depending on observed or reported fish concentrations. Fixed sites were scanned continuously each sampling trip and data typically were downloaded daily. However, instances occurred when fixed sites were scanned for multiple days without data being downloaded. For the purpose of analyses, these multi-day efforts were split into daily sub-efforts. PIT scanners were deployed 4 to 5 continuous days during every month of the year, except in SY 2015 when sampling only took place from January (when the contract was initiated) through September 2015.

One or two PIT scanning units were deployed between trips throughout each season in River above Willow Beach and scanned continuously for up to 673 h. In SY 2015 and SY 2016 this was a shore-based unit deployed at Boy Scout Canyon that started scanning at 1800 hours, ran for 24 h, and stopped scanning for 24 h. This cycle was repeated three weeks per month. During the week of active PIT scanning in River, this unit scanned continuously (24 h per day). This shore-based scanner was replaced in SY 2017, and subsequent sample years, with a battery-powered submersible unit with twice the wire turns as standard units, which resulted in lower power consumption and a longer runtime. This type of scanner was deployed at Black Bar (in addition to Lone Palm Hot Spring in SY 2017) during scanning trips and retrieved the next month. In SY 2019, one double-wound submersible PIT scanner at Black Bar was vandalized in May; M&A redeployed the scanner in July.

In SYs 2017 through 2019, additional PIT scanning was conducted downstream of Willow Beach to determine if any additional spawning aggregates existed, and to assess spatiotemporal movement. M&A deployed up to 10 submersible PIT scanners per trip within a section of the reservoir between Willow Beach and Aztec Wash. Each month a different reservoir section was selected for PIT scanner deployments by subjectively targeting suspected razorback sucker

habitat that was shallow enough for PIT scanner deployment (e.g., shallow wash fans or coves). In SY 2018 submersible units were deployed in Liberty Cove (Liberty zone) every month except August. Reclamation deployed up to 10 submersible units per trip working in one to two-mile increments moving upstream each sample trip from Basin to Liberty Cove. These areas included shallow gravel bars and cobble substrates, as well as cattail/bulrush stands where razorback sucker have been observed in the past (J. Stolberg, Bureau of Reclamation, July 2016, personal communication).

Reclamation conducted remote PIT scanning in Basin with support from M&A personnel (Objective 5). Semi-permanent shore-based units were deployed November/December through May for continuous scanning to coincide with the spawning season. Shore-based PIT scanners were deployed at Tequila Cove SYs 2015 through 2019, Yuma Cove SYs 2015 through 2019, and Half-Way Wash SYs 2016 through 2019. Continuous power was provided to these units using a combination of lead-acid batteries and solar panels. All sites with semi-permanent shore-based units were known spawning aggregation sites and had been part of March monitoring efforts since collections began in 1974 (Minckley 1983).

In SY 2017, Reclamation expanded their PIT scanning efforts to Katherine and conducted seven sampling trips from December 2016 to June 2017. Reclamation crews worked downstream in four sections, scanning both sides of the river, and deployed units in almost every cove in Katherine, subjectively targeting cattail/bulrush stands. No PIT scanning was conducted in Katherine other than in SY 2017.

Information downloaded from PIT scanning units was recorded as follows: general location or site name, Universal Transverse Mercator (UTM) coordinates, water depth in meters, time and date of deployment and retrieval, logger and battery numbers, logger start and stop times, and scanning interval. Narrative descriptions of weather, river flows, etc. were recorded on field sheets or data books.

Remote PIT scanning data and associated deployment information were provided by Reclamation and all data acquired from PIT scanning on Lake Mohave were incorporated into a MySQL database, maintained by M&A, and hosted by Hostgator.com

(http://www.hostgator.com/). Access to summary reports of scanning data as well as all raw data files are available through a password protected website (http://www.ncreased.net/, Objective 10).

SY 2019

In SY 2019, PIT scanners were deployed in Lake Mohave for a total scan time of 37,258 h (figure 3); 8,186 h using shore-based devices and 29,072 h with submersible units. Remote PIT scanning in River resulted in a total scan time of 9,480 h, all with submersible units. Mean deployment time for submersible units was 41 h. Remote scanners in Liberty were deployed for a total scan time of 8,964 h, all with submersible units. The mean deployment time for submersible scanners was 57 h. Both shore-based and submersible units were deployed in Basin and accumulated 18,814 total h of scanning: 8,186 h with shore-based and 10,628 h with submersible units. Mean deployment times for shore-based and submersibles were 264 h and 177 h, respectively. PIT scanner deployments ranged from near Hoover Dam south to Halfway Wash (figures 4 and 5).

SY 2015–2019

From SY 2015 through SY 2019 PIT scanners were deployed in Lake Mohave for a total scan time of 201,382 h; 54,384 h using shore-based units and 146,998 h with submersible units. Deployment distribution covered much of the shoreline of Lake Mohave (figure 6) but known spawning grounds received the most scanning effort. PIT scanning in River resulted in a total scan time of 44,653 h; 2,209 h using shore-based units and 42,444 h with submersible units. Mean deployment times for shore-based and submersibles were 79 h and 31 h, respectively. PIT scanners in Liberty were deployed for a total scan time of 25,892 h, all with submersible units. The mean deployment time for submersible PIT scanners was 51 h. Both shore-based and submersible units were deployed in Basin and accumulated 125,386 total h of scanning: 52,175 h with shore-based and 73,211 h with submersible units. Mean deployment times for shore-based and submersible units were 213 h and 121 h, respectively. PIT scanners in Katherine were deployed for a total scan time of 5,451 h, all with submersible units. The mean deployment time for submersible PIT scanners was 80 h. The spatial distribution of PIT scanners was greatest in SY 2017 with deployments in all zones (figure 4). In 2010, the technology was in its infancy and scanning only occurred in Basin and Liberty. Since then, deployment distribution expanded into

River and Liberty. Deployment distribution of PIT scanners in Liberty was greatest in SY 2017 through SY 2019.

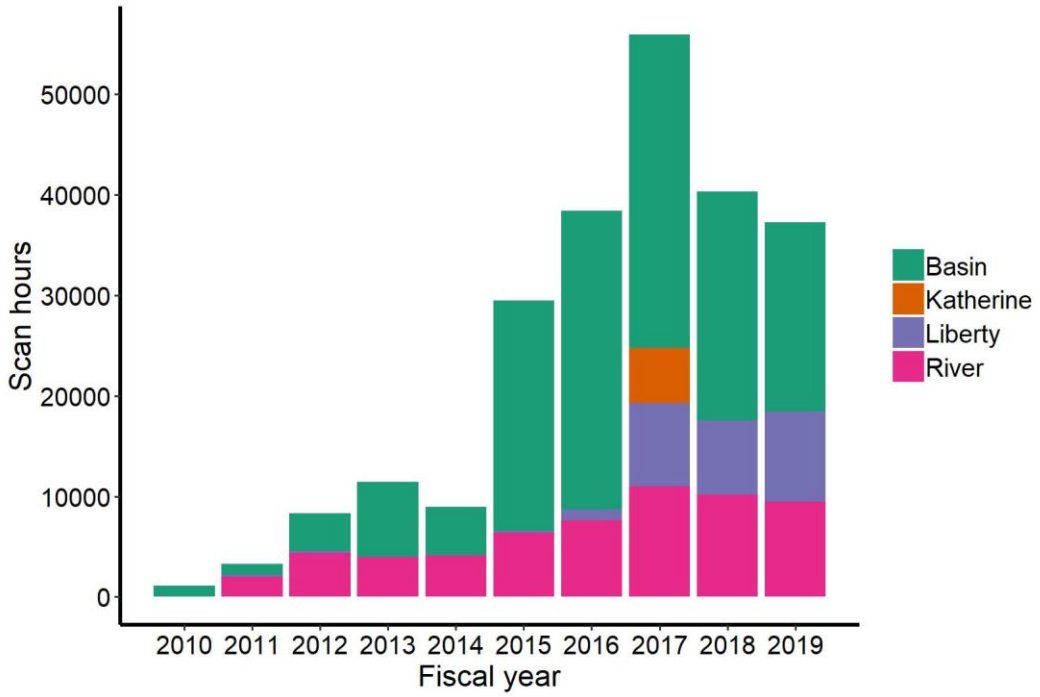

Figure 3.—Relationship between total scan hours and fiscal year for submersible and shore-based PIT scanners for each zone.

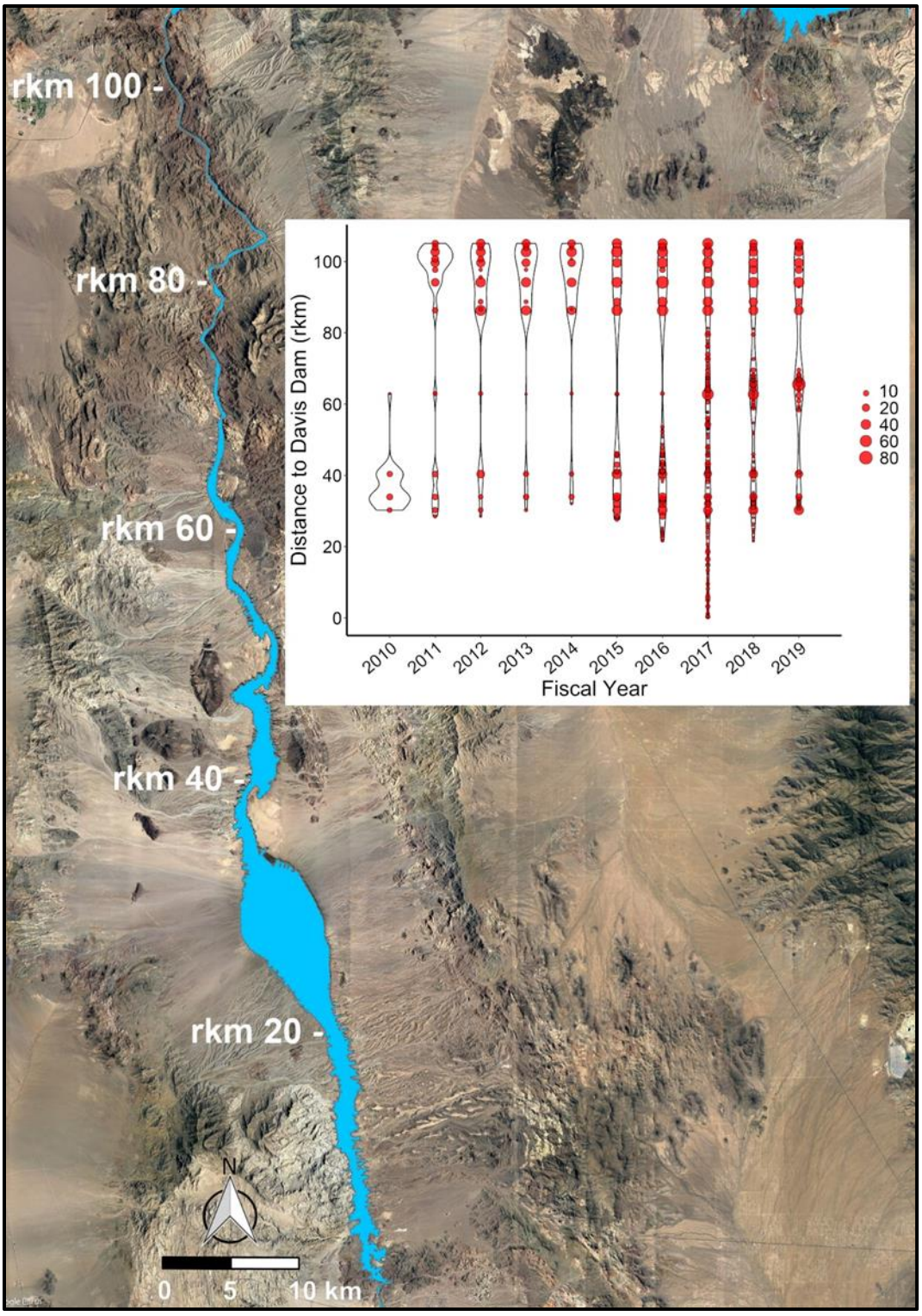

Figure 4.—Relationship between number of submersible and shore-based PIT scanners deployed (red circles) and distance to Davis Dam (rkm) from SY 2010–19 in Lake Mohave, Arizona and Nevada

Figure 5.— Locations of M&A and Reclamation remote PIT scanners in River, Liberty, and Basin zones of Lake Mohave, Arizona and Nevada, SY 2019; location map inset.

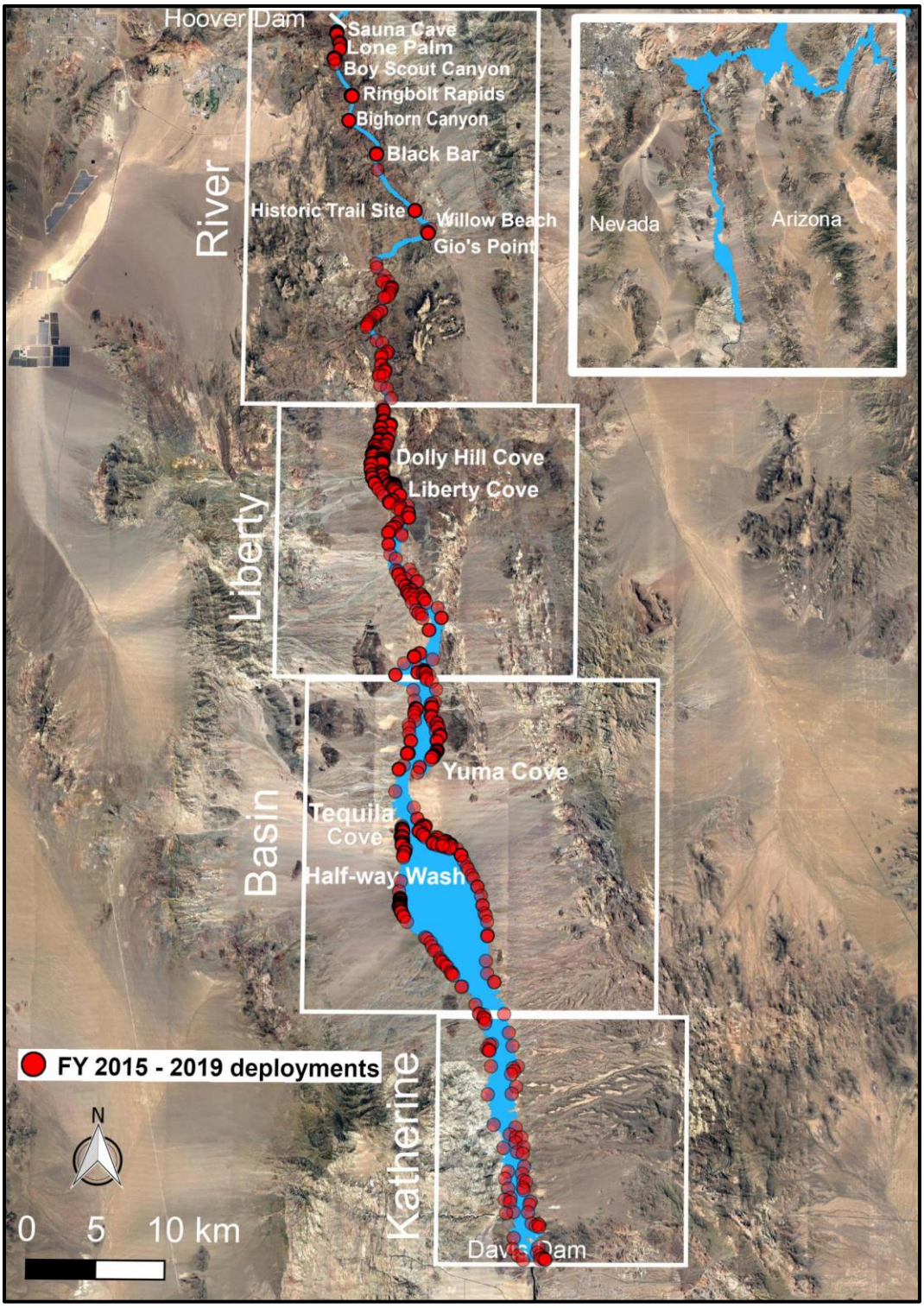

Figure 6.— Locations of M&A and Reclamation remote PIT scanners in River, Liberty, and Basin zones of Lake Mohave, Arizona and Nevada, SY 2015–19; location map inset.

Population Estimates

The razorback sucker population in Lake Mohave was estimated from two data sources (Objective 7). First, netting data[1] from all agencies participating in the spring survey were used to estimate overall populations of wild and repatriated fish in Lake Mohave using mark-recapture (Objective 8). Second, remote PIT scanning data were used to estimate repatriate population size for the lake-wide population as well as River and Basin subpopulations of repatriated razorback suckers with 134.2 kHz PIT tags. Remote PIT scanning and routine monitoring data were treated separately for repatriate estimates because some repatriate razorback sucker contain only a 400 kHz tag, which is rarely detected by remote PIT scanners. Combining the two sources would not accurately estimate the repatriate population.

Regardless of data source, mark-recapture estimates were based on the modified Peterson formula,

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

Capture data for population estimates were restricted to encounters in March of each SY because the highest number of captures with razorback suckers occurs then and the marking event must be short relative to the interval between marking and capturing events to meet assumptions of the estimate (Ricker 1975). For population estimates based on remote PIT scanning, the number of individual PIT tags contacted in a two-month scanning period encompassing the peak of razorback sucker spawning (January 1 through the end of February) in the previous SY was the mark (*M*), the number contacted between October 1 and April 30 in the current SY was the capture (*C*), and the number in common between both years the recaptures (*R*). Any contacts with PIT tags released after May 31 of the year prior to the marking year were removed from population estimates. Confidence intervals (CIs) were derived using Poisson approximation tables using *R* as the entering variable when recaptures were 50 or less (Ricker 1975, Appendix II), or they were based on the normal distribution for 51 or more recaptures (Seber 1973). Estimates with fewer than four recaptures were not reported. The Chapman estimate of large sample variance (Ricker 1975) was used for normal distribution-based confidence intervals.

[1] March data include the entire month of March although March monitoring occurs during a single week

In an effort to standardize razorback sucker population estimates based on remote PIT scanning data throughout the reservoirs in the lower Colorado River basin, the date ranges of marking and capture periods used to estimate the population in this report are different compared to previous annual reports (see Kesner et al. 2012, Kesner et al. 2014, Wisenall et al. 2015, Wisenall et al. 2016, and Leavitt et al. 2017). This change was reported in the 2018 annual report and updated estimates for all available years (SYs 2010–2017) were provided (Burgad et al. 2019). These estimates were updated to include an estimate for SY 2018 in this final report.

Adult Survival

In 2018, a robust mark-recapture model was developed to increase the amount of remote sensing data that can be incorporated into mark-recapture models and to improve model fit by including temporary emigration into the model (Burgad et al. 2019). The inclusion of temporary emigration improved model fit and up to 8% of the population was estimated to emigrate out of the observable spawning areas per year. The data included in the initial model were restricted to adult repatriate razorback sucker known to be alive over the modeled period, i.e., the fish were known to be alive and present in Lake Mohave during all years of the robust model analysis (SYs 2012–1017), because they all were contacted in 2018 and released prior to 2010. This limited dataset reduced complexity of the mark-recapture model for initial evaluation. In this final report, we extended this model to all adult razorback sucker and used accumulated scanning data from SY 2013 to SY 2019 to estimate annual survival for River and Basin subpopulations.

Robust mark-recapture models combine closed sessions, repeated sampling occasions during which no mortality or migration occurs, with open periods between sessions with mortality and temporary migration (Kendall et al. 1997). Capture and recapture rates are estimated from the demographically closed sampling occasions within each session. Survival and temporary emigration rates are estimated from data collected over multiple SYs. There are 13 different parameterizations of the robust model in the computer program MARK (Cooch and White 2016). Most of these are based on variations in closed mark-recapture parameterizations (see Otis et al. 1978). The "Huggin's p and c" model was selected for this analysis. This model removes population estimation from the likelihood, but it is still calculated as a ‘derived’ parameter and

allows for differences in capture probabilities within a session (i.e., SY). The model also includes separate parameters for first time capture (p) and recapture (c). The gamma′ (γ') and gamma″ (γ'') parameters in the model allow for individuals to temporarily emigrate out of and immigrate back into the scanning area between sessions. γ' is the probability a fish emigrates away from the scanning area, and γ'' is the probability a fish remains out of the study area once it has emigrated. The probability of a fish surviving from one session to the next is estimated by the parameter S.

Sampling occasions for Lake Mohave PIT scanning were based on monthly PIT scanning trips conducted on behalf of this contract by M&A. These trips were typically four to five days long and were conducted monthly since 2011, between January and August prior to 2015 and year-round since 2015. PIT scanning deployments on these trips were focused on razorback sucker aggregation sites upstream of Willow Beach (River zone). PIT scanning data in Basin were predominately collected with shore-based PIT scanners running continuously through the spawning season (typically November through April). To establish discrete capture (scanning) occasions for the robust model, contacts recorded outside the week of River scanning trips were removed from capture histories (i.e., regardless of contact location, only contacts collected during the date range of monthly River PIT scanning trips were included). PIT scanning occasions were grouped by SY to represent a sample session. To allow enough time between sessions for mortality and migration, only PIT scanning occasions between December and May of each SY (session) were included.

Separate capture history files were derived for PIT scanning contacts in River and Basin. Therefore, an individual PIT tag could occur in both River and Basin contact histories if the fish moved across zones within the seven years analyzed, and temporary immigration as assessed separately for River and Basin contact histories could represent movement between zones as well as movement to an unobserved subpopulation. In general, a PIT tag contact was included in the contact history if it met these criteria: the contact occurred during the modeled sample week, the contact occurred in the zone being modeled (Basin or River), and the contact occurred in a SY more than 2 years after the release SY. This last requirement was used to meet the assumption that the model was assessing adult survival.

Capture (p) and recapture (c) rates were set equal for any given sample occasion (hereon referred to as contact rates) because the likelihood of either is equivalent when both are represented by PIT scanning contacts. Contact rates varied with time (occasion) in all models because PIT scanning effort varied from month to month and contact rates were higher during peak spawning months (January through March) compared to other sampling months. Different migration parameterizations were modeled to represent three potential temporary emigration patterns; no temporary emigration (γ'' and γ' fixed at 0), random emigration (γ'' equals γ' for each between session period), and Markovian emigration (γ'' and γ' independent and time varying); see Kendall et al. (1997) for further explanation. In all models with time varying migration and survival, the last parameter values of both migration rates (γ'' and γ') were constrained to equal values from the penultimate period to eliminate confounding of parameters (Kendall et al. 1997).

Models were ranked within MARK based on Akaike's Information Criterion (AIC) score (Akaike 1974). This value reported in MARK is a modified value (AICc) that adjusts for small sample sizes (Burnham and Anderson 2002). No estimate of $\hat{c}$ was available in the current version of MARK for robust models; however, the Fletcher estimate of $\hat{c}$ (Fletcher 2012) based on the known adult population from last year's model was approximately one (Burgad et al. 2019). Values of $\hat{c}$ near one indicated good model fit, so AICc was not adjusted for over-dispersion. Reported parameter values were based on the highest ranked model (lowest AICc or quasi-likelihood [QAICc]) if QAICc weight for the top model was greater than 0.9 (Johnson and Omland 2004). Otherwise estimates were based on model averaging of all tested models.

Post-Stocking Fate

Displacement

Stocking displacement was examined by calculating distance traveled from stocking locations and tallying movement between zones. The analysis included hatchery-reared individual razorback sucker stocked from October 1, 2008 through September 30, 2013 that were implanted with a 134.2 kHz PIT tag. The beginning of this interval marks the year when all razorback sucker being repatriated to Lake Mohave were injected with a 134.2 kHz PIT tag and the end of this interval denotes a "moving window" to allow enough time for fish to disperse. Razorback suckers stocked from lakeside backwaters were excluded from this analysis because these events

occurred only in Basin. The inclusion of lakeside stockings would result in a confounding factor that could not be isolated from the effects of release zone. Individuals with less than ten contacts were removed from analyses to reduce the probability that contacts were due to chance alone.

Analyses were performed separately for fish stocked in each zone (i.e., River, Liberty, Basin, and Katherine) by pooling data across all stocking locations within each zone (figure 7) and then tabulating all contact history combinations. To investigate transitional razorback suckers that were released in Basin and contacted in River, and those that were released in River and contacted in Basin, unique contacts per scanning SY were analyzed and contact proportions, by zone, were calculated and graphed. Stocking displacement was calculated by measuring the distance traveled in reservoir kilometers (rkm) from the locality of contact to Davis Dam (i.e., river mouth) for every individual. A combination of QGIS version 2.18.16 (QGIS Development Team 2017) and R version 3.4.3 (R Development Core Team 2017) was used to calculate displacement. First, polyline data were obtained from the National Hydrography Dataset Plus (NHDPlus), which represented the river network and allowed calculating distance as the path along the watercourse instead of straight-line distance (i.e., Euclidean). Next, the river was clipped to the extent of the study area and a dissolve was performed to expedite calculations in R. The "mouthdistbysurvey" function in the "riverdist" package was used to calculate distance between subsequent dates of contact for every individual (Tyers 2017). By default, the "mouthdistbysurvey" function only allowed distance computation when an individual moved between two different locations (i.e., unique coordinates). Stocking displacement was visualized by plotting the distance contacted from Davis Dam across all individuals for each year with violin plots. Violin plots are similar to box plots but incorporate a rotated kernel density plot on each side to illustrate the abundance of contacts (more contacts equals wider plots), thus providing a spatially explicit illustration.

Repatriate Recruitment

Beyond providing population estimates and monitoring the overall health and distribution of the population in Lake Mohave, the monitoring program provides analysis of factors that impact stocking survival, which informs the repatriation program. Remote sensing of PIT tagged razorback suckers through the deployment of PIT scanners has provided orders of magnitude more contact data than previous methods (e.g., routine monitoring). In previous reports, the data

were used to assess post-stocking survival and the factors influencing survival within a mark-recapture framework. However, PIT scanning data as collected must be reduced and manipulated to fit the mark-recapture models, the results of which rarely go beyond the "bigger is better" paradigm (Wisenall et al. 2015). A different approach outside the mark-recapture methodology was therefore utilized in this comprehensive report.

The repatriation program is best served by optimizing the number of stocked individuals that survive to eventually produce larvae and thereby contribute to the repatriation program. We assumed that stocked razorback suckers have fully recruited to the repatriate population when they participate in spawning aggregations at locations where larvae can be collected for the program. These locations are also locations where PIT scanners are deployed consistently and extensively throughout the spawning season. Based on estimates of population size and the number of unique PIT tags contacted on an annual basis (e.g., Burgad et al. 2019), a majority of available (i.e., recruited) razorback suckers in Lake Mohave are contacted annually. Therefore, the proportion of a release "cohort" that is contacted via PIT scanners after they have matured to adulthood is directly proportional to the actual recruitment rate for that release cohort, and these contact proportions could be used directly to provide post-stocking analysis for the repatriation program.

Release data for all fish released with a 134.2 kHz PIT tag between SY 2008 and SY 2014 were divided into release cohorts based on pre-release factors of interest; size class (TL in 10 mm bins), release SY, and pond rearing (yes for backwater or pond hatchery rearing sites and no for raceway hatcheries). Release cohorts were also separated by month of release to allow for multiple data points among size class, release year, and pond rearing factors. To ensure the contact was with a fully recruited adult fish, the contacted PIT tag was included only if it was matched with a razorback sucker released more than two SYs prior to the contact. Also, release cohorts only included fish that were measured (TL in mm) and tagged with 134.2 kHz PIT tag prior to that release.

Due to the requirement that fish were at large for more than two SYs, only fish released through SY 2014 were analyzed. This gave all release cohorts at least three full years of PIT scanning to

be counted as “recruited.” Based on previous mark-recapture analysis on a known population of adult razorback sucker (Burgad et al. 2019), an individual razorback sucker available to PIT scanning has a greater than 90% probability of being contacted at least once after three years of availability. This is likely only true for razorback sucker released in River and Basin, so only razorback suckers released in River and Basin were included. To reduce the impact of low sample size on variation in capture proportions cohorts with less than 20 fish released were excluded.

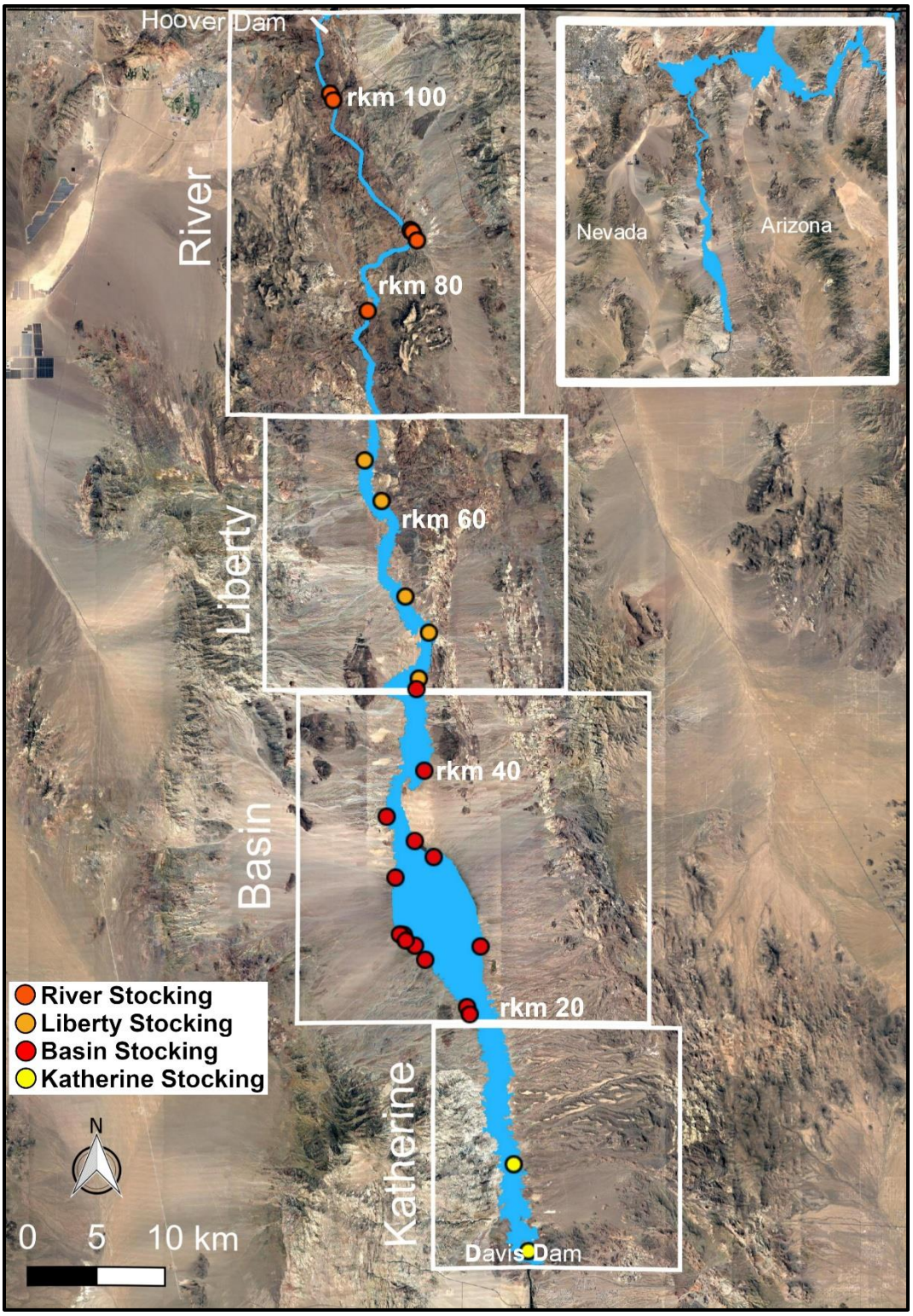

Figure 7.—Stocking locations of razorback sucker from October 1, 2008 to September 30, 2013 in River, Liberty, Basin, and Katherine zones of Lake Mohave, Arizona and Nevada; location map inset.

RESULTS

Routine Monitoring

Trammel netting efforts near Carp Cove from Oct 1, 2014 to Sep 30, 2019 (SY 2015 through SY 2019) resulted in capture of 102 razorback suckers (Appendix 1). Fish with unknown histories (n=12), one wild fish, and five fish with same-trip captures were removed from further analysis; remaining individuals (n=84) all were PIT tagged repatriates (table 1). Sex was determined at time of capture and most fish captured were female (n=68); there were 15 males and one juvenile. More females than males were captured during both March (43 females, 14 males) and Nov/Dec (25 females, 1 male) monitoring events.

Table 1.—Razorback sucker monitoring summary from Mar, Nov and Dec monitoring events, Oct 2014 through Sep 2019, Lake Mohave, Arizona and Nevada
Data presented by number of fish by capture date and sex.

Capture date	n fish by sex			Total
	F	M	J	
Mar				
2015	16	6	1	23
2016	7	3		10
2017	4			4
2018	7	3		10
2019	9	2		11
Total	43	14	1	58
Nov				
2017	8			8
2018	1			1
Total	9			9
Dec				
2014	11	1		12
2016	5			5
Total	16	1		1704
Grand total	68	15	1	84

Four fish did not have paired stocking-capture data (i.e., fish with both a stocking and capture record in the database matched by PIT tag) and were excluded from further analysis. The remaining 80 fish had a TL that ranged from 265 to 531 mm at stocking and from 342 to 741 mm at capture with overall mean TLs at stocking and capture at 426 and 595 mm, respectively (table 2). Four fish had individual TLs at release less than 300 mm TL, 18 fish had individual TLs ranging from 300 to 399 mm TL, and 58 fish had individual TLs from 400 mm TL or greater while individual TLs at capture ranged from less than 400 to greater than 600 mm TL (table 3). A list of paired stocking-capture data is provided in Appendix 1.

Table 2.—Razorback sucker monitoring summary from Mar, Nov and Dec monitoring events, Oct 2014 through Sep 2019, Lake Mohave, Arizona and Nevada

Summary statistics for 80 PIT tagged fish captured near Carp Cove with paired stocking-capture data: number of fish per capture date, mean (SD; range) of TL(mm) at stocking and capture, time at large in days, months, and years. Time at large is capture date minus stocking date divided by 30 days for months at large or 365 days for years at large. Stocking date is when fish were stocked into Lake Mohave.

		TL (mm)		Time at large		
		Stocking	Capture	Days	Months	Years
Capture date	n fish	Mean (SD; range)	Mean (SD; range)	Mean (SD; range)	Mean (SD; range)	Mean (SD; range)
Mar						
2015	21	415 (56; 306–500)	577 (97; 342–675)	2,250 (1935; 10–6,719)	75 (64; < 1–224)	6 (5; < 1–18)
2016	9	427 (77; 265–520)	611 (44; 530–665)	1,986 (1,326; 419–4912)	66 (44; 14–164)	5 (4; 1–13)
2017	4	532 (66; 350–490)	655 (25; 626–685)	3,800 (738; 2,918–4,654)	127 (25; 97–155)	10 (2; 8–13)
2018	9	427 (43; 345–500)	593 (87; 401–660)	2,853 (2,321; 87–8,150)	95 (77; 3–272)	8 (6; < 1–22)
2019	11	424 (72; 280–531)	573 (118; 419–741)	2,177 (2,510; 40–7,903)	72 (84; 1–263)	6 (7; < 1–22)
Total	54	422 (60; 265–531)	590 (90; 342–741)	2,406 (1,986; 10–8,150)	80 (66; < 1–272)	6 (5; < 1–22)
Nov						
2017	8	449 (52; 355–510)	631 (9; 620–643)	2,504 (1,136; 1,489–4,911)	83 (38; 50–164)	7 (3; 4–13)
2018	1	458	561	203	7	< 1
Total	9	450 (49; 355–510)	623 (25; 561–643)	2,249 (1,310; 203–4,911)	75 (44; 7–164)	6 (4; < 1–13)
Dec						
2014a	12	424 (36; 350–470)	589 (46; 475–645)	1,178 (863; 322–3,465)	39 (29; 11–116)	3 (2; <1–9)
2016	5	425 (86; 285–510)	613 (54; 543–671)	2,208 (1,898; 327–5,247)	74 (63; 11–175)	6 (5; <1–14)
Total	17	424 (53; 285–510)	596 (48; 475–671)	1,408 (1,283; 322–5,247)	49 (43; 11–175)	4 (3; <1–14)
Grand Total	80	426 (58; 265–531)	595 (78; 342–741)	2,192 (1,815; 10–8,150)	73 (60; <1–272)	6 (5; <1–22)

[a]One fish missing TL

Table 3.—Razorback sucker monitoring summary from Mar, Nov and Dec monitoring events, Oct 2014 through Sep 2019, Lake Mohave, Arizona and Nevada

Summary statistics for 80 PIT tagged fish captured near Carp Cove with paired stocking-capture data: number of fish per capture date, and TL (mm) at stocking and capture.

		TL at stocking (mm)			TL at capture (mm)		
Capture date	**n fish**	**200–299**	**300–399**	**> = 400**	**300–399**	**400–599**	**> = 600**
Mar							
2015	21	0	9	12	3	7	11
2016	9	1	1	7	0	2	7
2017	7	0	1	3	0	0	4
2018	9	0	2	7	0	3	6
2019	11	1	2	8	0	5	6
Total	54	2	15	37	3	17	34
Nov							
2017	8	0	1	7	0	0	8
2018	1	0	0	1	0	1	0
Total	9	0	1	8	0	1	8
Dec							
2014[a]	12	1	2	9	0	8	4
2016	5	1	0	4	0	2	3
Total	17	2	2	13	0	10	7
Grand total	80	4	18	58	3	28	49

[a] One fish missing TL

The shortest time at large, from stocking to capture, was presented by 12 fish that were at large for less than 1 year (table 4). Years at large for the other 68 fish ranged from 1 to 22 years (figure 8) with overall mean years at large for all fish approximately 6 years (tables 2 and 4).

Table 4.—Razorback sucker monitoring summary from Mar, Nov and Dec monitoring events, Oct 2014 through Sep 2019, Lake Mohave, Arizona and Nevada

Summary statistics for 80 PIT tagged fish captured near Carp Cove with paired stocking-capture data: number of fish, capture date, and years at large.

Capture date	n fish	Years at large																	
		< 1	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	18	22
Mar																			
2015	21	3	1	2	3	2	2	1			1	1	2		1		1	1	
2016	9	0	1		1	4		1			1			1					
2017	4	0								1		1	1	1					
2018	9	2					1			5									1
2019	11	4			1	1		1	2							1			1
Total	54	9	2	2	5	7	3	3	2	6	2	2	3	2	1	1	1	1	2
Nov																			
2017	8	0				3		2		2				1					
2018	1	1																	
Total	9	1				3		2		2				1					
Dec																			
2014	12	1		5	2	2	1				1								
2016	5	1			1		1		1						1				
Total	17	2		5	3	2	2		1		1				1				
Grand total	80	12	2	7	8	12	5	5	3	8	3	2	3	3	2	1	1	1	2

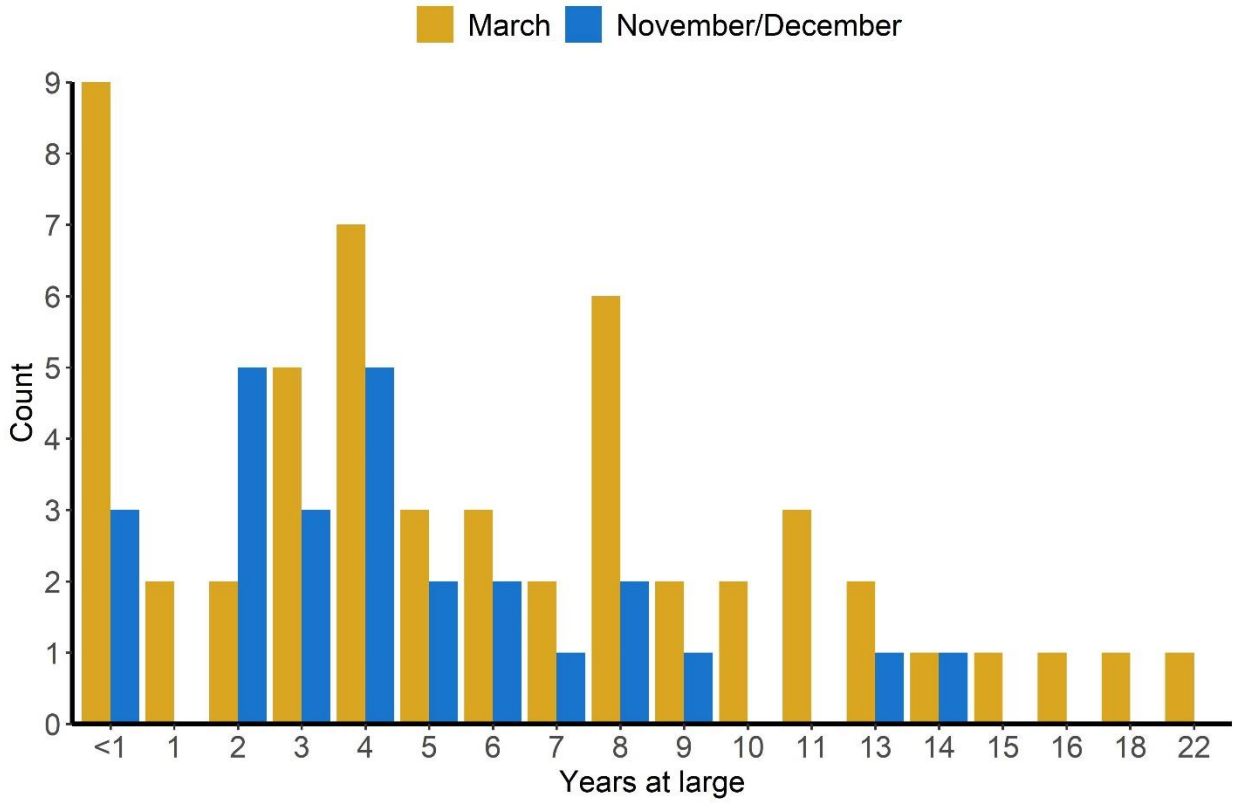

Figure 8.—Years at large at time of capture for 80 razorback suckers captured during November/December and March monitoring periods 2015-2019.

Sixty-one fish were captured the first time since their stocking during the monitoring period (table 5) and their time at large ranged from approximately 1 to 22 years before their first captures (Appendix 2). The remaining 19 fish had more than two captures with time between first and second captures ranging from 1 to 9 years; of these, three fish had three captures, one fish had four captures and one fish had five captures (table 5 and Appendix 2).

Table 5.—Razorback sucker monitoring summary from Mar, Nov and Dec monitoring events, Oct 2014 through Sep 2019, Lake Mohave, Arizona and Nevada

Summary statistics for 80 PIT tagged fish captured near Carp Cove with paired stocking-capture data: number of fish, capture date, and number of captures since stocking.

Capture date	n fish	n captures				
		1	2	3	4	5
Mar						
2015	21	14	5	2	0	0
2016	9	6	2	1	0	0
2017	4	3	1	0	0	0
2018	9	6	3	0	0	0
2019	54	38	12	3	1	0
Total						
Nov						
2017	8	7	0	0	0	1
2018	1	1	0	0	0	0
Total	9	8	0	0	0	1
Dec						
2014	12	10	2	0	0	0
2016	5	5	0	0	0	0
Total	17	15	2	0	0	0
Grand total	80	61	14	3	1	1

Year class data were missing from 26 fish (Appendix 2). Of the remaining 54 fish, year classes ranged from 2001 to 2016; the 2004-year class was not represented. Most fish were one to six years old at stocking (n=52); year class could not be determined for two fish with multiple year data provided (Appendix 2).

Two females and two males had growth rates less than 1 mm/month, which likely was due to measurement error; one juvenile had zero growth rate (Appendix 2). Of the remaining 62 females, growth rate ranged from 1 to 15 mm/month, and of the remaining 11 males, growth rate ranged from 1 to 11 mm/month (table 6). Mean growth rate of all females was 6 mm TL/month and for all males approximately 4 mm TL/month.

Table 6.—Razorback sucker monitoring summary from Mar, Nov and Dec events, Oct 2014 through Sep 2019, Lake Mohave, Arizona and Nevada.

Summary statistics for 80 PIT tagged fish captured near Carp Cove with paired stocking-capture data: sex and capture date, mean growth rate, and growth rate per month. Growth rate/month is mean capture TL (mm) minus mean stocking TL (mm) divided by mean months at large. (Table 6 is continued on the next page.)

Sex and capture date	n fish	Mean growth rate (mm/month)	Growth rate (mm/month)														
			0	< 1	1	2	3	4	5	6	7	8	9	10	11	12	15
Female																	
March																	
2015	14	6	0	0	0	1	0	2	3	4	1	1	0	2	0	0	0
2016	6	6	0	0	0	0	0	2	0	1	3	0	0	0	0	0	0
2017	4	7	0	0	0	0	0	1	0	1	0	0	1	1	0	0	0
2018	6	8	0	0	0	0	0	0	0	1	2	1	1	1	0	0	0
2019	9	7	0	2	1	0	1	1	0	0	1	0	1	0	1	0	1
Total	39	7	0	2	1	1	1	6	3	7	7	2	3	4	1	0	1
November																	
2017	8	6	0	0	0	0	0	2	2	0	3	0	1	0	0	0	0
2018	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Total	9	6	0	0	0	0	1	2	2	0	3	0	1	0	0	0	0
December																	
2014[a]	11	5	0	0	0	0	0	2	4	3	0	1	0	0	0	0	0
2016	5	6	0	0	0	1	0	1	1	0	0	1	0	0	0	1	0
Total	16	6	0	0	0	1	0	3	5	3	0	2	0	0	0	1	0
Grand total	64	5	0	2	1	2	2	11	10	10	10	4	4	4	1	1	1

(Table 6 continued)

Sex and capture date	n fish	Mean growth rate (mm/month)	Growth rate (mm/month)														
			0	< 1	1	2	3	4	5	6	7	8	9	10	11	12	15
Male																	
March																	
2015	6	7	0	2	0	0	0	1	1	0	1	0	0	0	1	0	0
2016	3	7	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
2018	3	2	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
2019	2	7	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Total	14	7	0	4	0	1	1	1	2	1	2	0	0	1	1	0	0
December																	
2014	1	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Total	1	6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Grand total	15	6	0	4	0	1	1	2	2	1	2	0	0	1	1	0	0

[a]One fish missing TL

Most captured fish were stocked in Basin (n=59) with 36 reared in lakeside backwaters and 23 in off-site facilities (table 7). Rearing locations that contributed the most repatriates during the monitoring period were Willow Beach NFH, Yuma Cove and Arizona Juvenile lakeside backwaters, and Achii Hanyo NFH.

Table 7. —Razorback sucker monitoring summary from Mar, Nov and Dec monitoring events, Oct 2014 through Sep 2019, Lake Mohave, Arizona and Nevada.

Summary statistics for 80 PIT tagged fish captured near Carp Cove with paired stocking-capture data: number of fish by rearing type and location, and release zone.

Rearing	n fish	Release zone			
		River	Liberty	Basin	Katherine
Lakeside backwater					
Arizona Juvenile	12	0	0	12	0
Dandy Cove	5	0	0	5	0
North Chemehuevi Cove	4	0	0	4	0
Willow backwater	1	0	0	1	0
Yuma Cove	14	0	0	14	0
Total	36	0	0	36	0
Off-site facility					
Achii Hanyo	10	2	0	8	0
Boulder City Wetlands Park	3	0	1	2	0
Bubbling Ponds FH	7	5	0	2	0
Dexter NFH (SNARRC)	1	0	0	0	1
Lake Mead Fish Hatchery	3	0	0	3	0
Overton Wildlife Management Area, Center Pond	2	0	0	2	0
Willow Beach NFH	18	0	11	6	1
Total	44	7	12	23	2
Grand Total	80	7	12	59	2

Remote Monitoring

SY 2019

SY 2019 PIT scanning efforts (figure 3) resulted in 96,575 total contacts (all species), 4,408 of which were unique PIT tags, with 4,285 of those having a marking history in the Native Fish Database (i.e., have a marking record). This excludes fish that were in the database but did not have a proper marking record, and fish that were marked and released in a backwater but did not have a record of release into the reservoir. Among fish with a marking record, 4,225 were razorback suckers (4,165 repatriates, 10 of wild origin, and 50 of unknown origin), and 60 were bonytail (all repatriates).

River PIT scanner deployments resulted in a total of 23,330 contacts from 2,237 unique PIT tags of which 2,169 had a marking record. Among fish with a marking record, all were razorback suckers (2,155 repatriates, seven wild, and seven of unknown origin). In Liberty, a total of 302 PIT tag contacts were recorded representing 101 unique PIT tags, all of which had a marking record in the Native Fish Database. Of the unique fishes contacted in Liberty, 81 were razorback suckers (80 repatriates and one of unknown origin) and 20 were bonytail (all repatriates). In Basin, a total of 72,943 contacts were recorded representing 2,462 unique PIT tags for which 2,366 had a marking record in the Native Fish Database. Of the unique fishes contacted in Basin, 2,326 were razorback suckers (2,274 repatriates, four of wild origin, and 48 of unknown origin) and 40 were bonytail (all repatriates).

SY 2015–2019

For the entire contract period a total of 598,503 PIT tag contacts were recorded, 6,308 of which were unique PIT tags, with 5,957 of those having a marking history in the Native Fish Database. Among fish with a marking record, 5,851 were razorback suckers (5,774 repatriates, 13 of wild origin, and 64 of unknown origin), and 106 were bonytail (all repatriates).

Among 107,625 contacts in River over the contract period, 3,554 were unique PIT tags and of those 3,398 had a marking record in the Native Fish Database. Among fish with a marking record, all were razorback suckers (3,374 repatriates, 10 of wild origin, and 14 of unknown origin). No bonytail were detected in River. In Liberty, a total of 681 PIT tag contacts were recorded representing 241 unique PIT tags, 238 of which had a marking record in the Native Fish

Database. Among fishes with a marking record, 193 were razorback suckers (190 repatriates and three of unknown origin) and 45 were bonytail (all repatriates). In Basin, a total of 518,734 contacts were recorded representing 3,722 unique PIT tags for which 3,523 had a marking record in the Native Fish Database. Of the unique fishes contacted, 3,462 were razorback suckers (3,396 repatriates, five of wild origin, and 61 of unknown origin) and 61 were bonytail (all repatriates). In Katherine, a total of 371 PIT tag contacts were recorded representing 59 unique PIT tags, 54 of which had a marking record in the Native Fish Database. Among fish with a marking record, all were repatriated razorback suckers. In general, unique contact rates have increased over time, along with increased scanning effort, for the three zones scanned on an annual basis: River, Liberty, and Basin (figures 3 and 9).

PIT scanning contacts at fixed sites in River were compared during the entire duration of scanning from January 2013 to September 2019. The spawning period was evident as most contacts were recorded at Black Bar from November through April, becoming fewer in subsequent months and scattered at different locations (figure 10). The next largest spawning aggregation site was at Boy Scout Cove. After the spawning season, PIT scanning contacts with razorback suckers declined at Black Bar and Boy Scout Cove with no evident increase at other fixed sites.

Figure 9.—Total number of unique contacts in each zone from SY 2010–2019 in Lake Mohave, Arizona and Nevada.
N is the number of unique contacts in Liberty; Katherine is overlapping with Liberty in 2017 and the total number of unique contacts (n=59) is not visible.

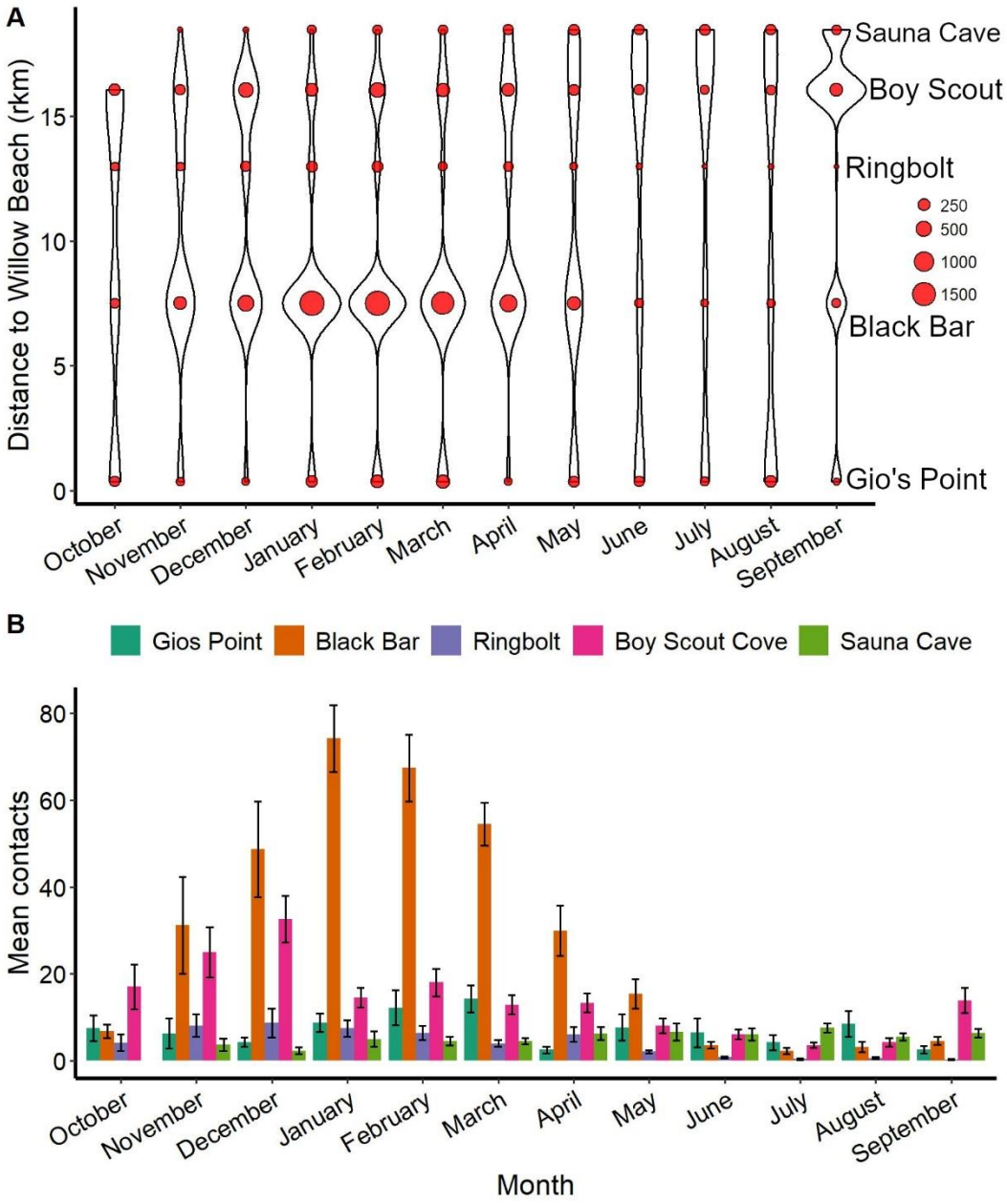

Figure 10.—Spatial distribution of contacts (red circles; A) and mean unique razorback sucker PIT tag contacts (B) recorded January 2013 to September 2019 at five fixed stations in River zone, Lake Mohave, Arizona and Nevada.
Error bars represent ±1 SE.

Population Estimates

Routine Monitoring

Too few wild razorback suckers have been encountered during routine monitoring from SY 2015 through SY 2019 to estimate their abundance. The repatriated razorback sucker population in

2014, based on 2014 and 2015 March monitoring data, was estimated at 2,230 fish (95% confidence interval [CI] from 922 to 5,963) which was more than double the current (2018) estimate, based on 2018 and 2019 March monitoring data, for razorback sucker in Lake Mohave of 994 fish (95% CI from 602 to 1,639) (table 8).

Table 8.—Repatriated RASU population estimates, Lake Mohave, Arizona and Nevada, 2015–2019, using annual single census population estimate, N* (Chapman modification of the modified Peterson Method; Seber 1973)

Marking year	Sampling year	*N**	95% CI		Source
			Lower	Upper	
2018	2019	994[a]	602	1,639	Pacey (unpublished)
2017	2018	841[a]	694	4,487	Pacey, Marsh, and Kesner 2018
2016	2017	1,291[a]	531	3,436	Pacey, Marsh, and Kesner 2017
2015	2016	1,707[a]	603	3,897	Pacey, Marsh, and Kesner 2016
2014	2015	2,230 [a]	922	5,963	Pacey and Marsh 2015

[a]Estimate adjusted to exclude fish captured in March of marking year that were released in March of marking year, as well as fish released after March 1 of marking year and captured in March of sampling year.

Remote Monitoring

Based on SY 2018 and SY 2019 remote PIT scanning, the 134.2 kHz PIT tagged Lake Mohave repatriate population for 2018 was estimated at 3,649 individuals (95% CI from 3,552 to 3,745; figure 11, table 9). Population estimates using zone specific scanning for 2018 estimated Basin population at 1,963 (95% CI from 1,904 to 2,021) and River at 2,120 (95% CI from 2,012 to 2,227; figure 11, table 10). Too few wild fish were contacted to estimate Basin and River subpopulations separately (four and seven contacts, respectively). The lake-wide estimates of wild and unknown populations based on PIT scanning in 2018 and 2019 were 9 and 32 fish, respectively.

Lake-wide repatriate population estimates based on PIT scanning were low in the initial years of PIT scanning (figure 3) but increased each year until peaking in 2016 at 3,871 fish, thereafter, declining slightly in 2017 and 2018 (figure 11 and table 9). Repatriate subpopulation estimates for River and Basin have followed a similar trend over time, with peaks of 2,243 and 1,894 fish

in 2016, respectively (table 10). Repatriate population estimates have remained close for both subpopulations. Lake-wide population estimates of wild fish have steadily declined from a high in 2012 of 15 fish and low in 2018 of 9 fish (table 9). The unknown population has increased from a low of 7 in 2013 and 2014 to a high of 32 in 2018; no unknown estimate was calculated for 2015 due to low recaptures (3).

Table 9.—Repatriate, Wild, and Unknown lake-wide population estimates based on remote PIT scanning data

History	Year	M	C	R	Estimate (95% CI)
Repatriate	2010	103	130	27	486 (339–725)
	2011	295	1,424	181	2,317 (2,003–2,630)
	2012	1,119	1,979	824	2,688 (2,547–2,828)
	2013	1,843	2,030	1,209	3,095 (2,984–3,205)
	2014	1,644	2,465	1,185	3,420 (3,279–3,560)
	2015	2,033	2,743	1,520	3,669 (3,545–3,792)
	2016	2,140	3,030	1,675	3,871 (3,747–3,994)
	2017	2,011	3,028	1,677	3,631 (3,514–3,747)
	2018	2,341	3,050	1,957	3,649 (3,552–3,745)
Unknown	2012	4	7	4	8 (4–20)
	2013	6	6	6	7 (3–15)
	2014	6	4	4	7 (3–18)
	2016	10	10	9	12 (7–24)
	2017	16	16	14	19 (12–33)
	2018	22	26	18	32 (21–53)
Wild	2012	11	9	7	15 (8–32)
	2013	9	10	9	11 (6–22)
	2014	8	9	6	12 (6–28)
	2015	8	10	7	12 (6–26)
	2016	6	8	5	10 (5–24)
	2017	4	8	4	9 (4–23)
	2018	7	8	7	9 (5–19)

Table 10.—Repatriate subpopulation estimates based on remote PIT scanning data

Zone	Year	M	C	R	Estimate (95% CI)
River	2011	225	870	136	1,436 (1,215–1,656)
	2012	560	980	354	1,550 (1,421–1,678)
	2013	897	1,062	506	1,882 (1,763–2,000)
	2014	703	1,305	465	1,973 (1,829–2,116)
	2015	1,001	1,311	637	2,060 (1,945–2,174)
	2016	793	1,742	616	2,243 (2,100–2,385)
	2017	823	1,619	635	2,098 (1,970–2,225)
	2018	1,017	1,622	778	2,120 (2,012–2,227)
Basin	2010	103	76	27	286 (199–426)
	2011	61	566	44	781 (586–1,065)
	2012	560	1,077	472	1,278 (1,191–1,364)
	2013	981	1,017	706	1,413 (1,355–1,470)
	2014	956	1,263	722	1,673 (1,593–1,752)
	2015	1,068	1,542	892	1,847 (1,768–1,925)
	2016	1,388	1,457	1,068	1,894 (1,835–1,952)
	2017	1,208	1,638	1,052	1,881 (1,813–1,948)
	2018	1,421	1,671	1,210	1,963 (1,904–2,021)

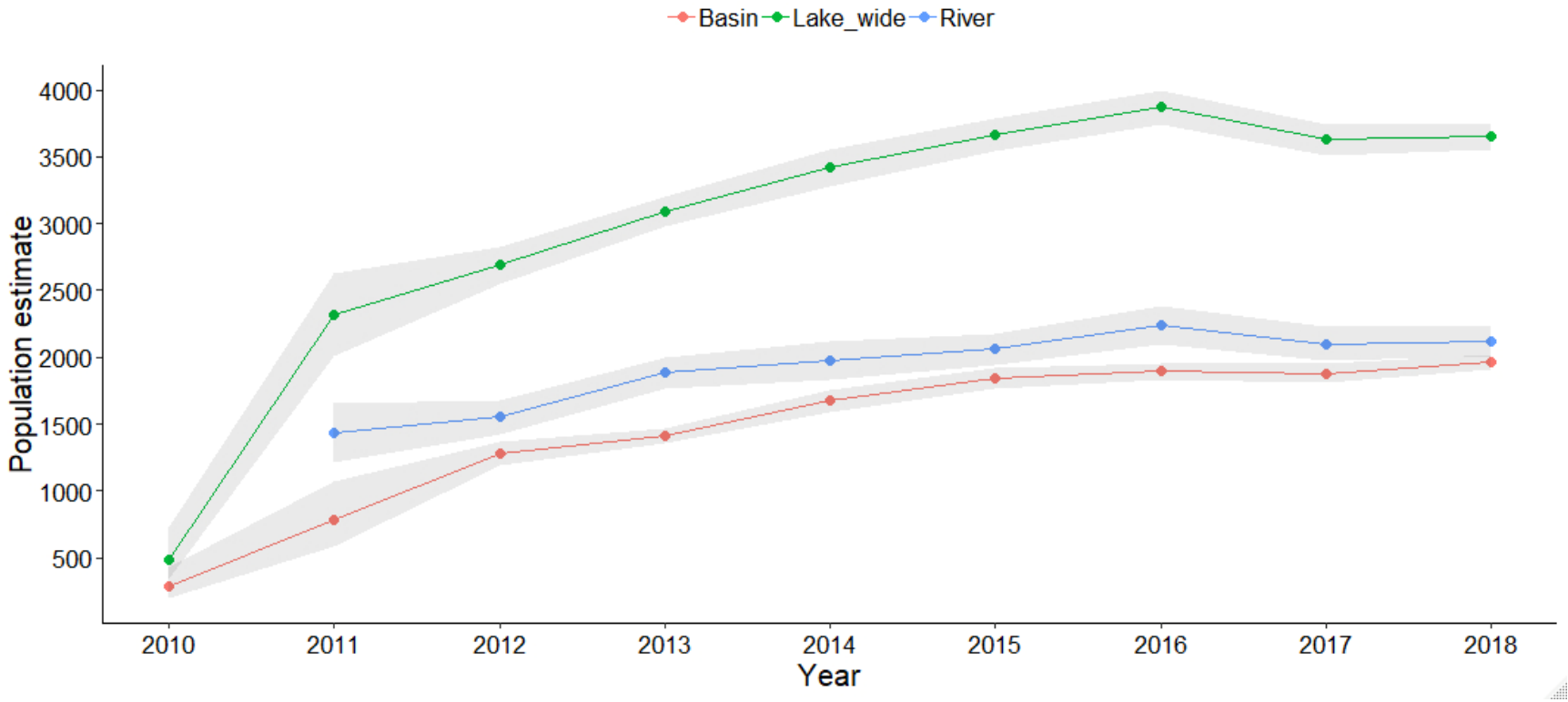

Figure 11.—Repatriate razorback sucker population estimates derived from PIT scanning data from 2010 to 2019 in Lake Mohave, Arizona and Nevada.
The shaded area represents lower and upper 95% confidence intervals.

Adult Survival

The top robust model based on AIC weight for River and Basin PIT scanning was not the global model and was different for the two subpopulations (tables 11 and 12). In River, the top model with over 67% of AIC weight had fixed survival, fixed immigration, and time varying emigration. In Basin, the no temporary emigration model was the top-ranking model, but with a low AIC weight of about 25%. The next five models with a combined weight of 64% had temporary emigration in the model.

Estimates of adult survival were similar between River and Basin, greater than 0.95 estimated probability (table 13), except for one estimate (Basin 2016 to 2017). Estimates of temporary emigration (γ'') between zones were dissimilar with all but one estimate below 0.06 for Basin, and all but one estimate above 0.06 in River. However, paired (same time interval) 95% confidence intervals of emigration estimates between Basin and River overlap. Contact rates (probabilities) ranged from a low of 0.0012 on the last sampling occasion in May of 2019 (Basin) to 0.508 on the first sampling occasion in January 2013 (Basin). All years had at least one occasion with contact rates above 0.250, with the highest value for a given year typically in February in Basin and December, January or February in River. Estimates of razorback suckers returning to the population ($1-\gamma'$) were lower in River than in Basin.

Table 11.—Results of robust model parameterizations used in Program MARK for River PIT scanning. N = 1,773 contact histories.

Model	AICc	AICc Weight	No. parameters	Deviance
S(.) p(t)=c(t) γ″(t) γ′ (.)	45,039.83	0.67428	46	92,667.41
S(t) p(t)=c(t) γ″(.) γ′ (.)	45,043.99	0.08420	46	92,671.57
S(.) p(t)=c(t) γ″(.) γ′ (.)	45,044.05	0.08187	41	92,681.72
S(t) p(t)=c(t) γ″(t) γ′ (.)	45,044.50	0.06537	50	92,664.00
S(.) p(t)=c(t) γ″(.) γ′ ′ (t)	45,045.62	0.03741	45	92,675.22
S(.) p(t)=c(t) γ″(t) γ′ ′ (t)	45,046.03	0.03048	50	92,665.52
S(t) p(t)=c(t) γ″(.) γ′ ′ (t)	45,046.70	0.02176	49	92,668.22
S(t) p(t)=c(t) γ″(t) γ′ ′ (t)	45,049.79	0.00463	53	92,663.23
S(t) p(t)=c(t) γ″(.)=γ′ ′ (.)	45,097.92	0.00000	45	92,727.52
S(t) p(t)=c(t) γ″(t)=γ′ ′ (t)	45,102.91	0.00000	49	92,724.43
S(.) p(t)=c(t) γ″(.)=γ′ ′ (.)	45,103.80	0.00000	40	92,743.49
S(.) p(t)=c(t) γ″(t)=γ′ ′ (t)	45,105.77	0.00000	45	92,735.37
S(t) p(t)=c(t) γ″(0)=γ′ ′ (0)	45,110.37	0.00000	44	92,741.99
S(.) p(t)=c(t) γ″(0)=γ′ ′ (0)	45,126.72	0.00000	39	92,768.43

Table 12.—Results of robust model parameterizations used in Program MARK for Basin PIT scanning. N = 1,027 contact histories.

Model	AICc	AICc Weight	No. parameters	Deviance
S(t) p(t)=c(t) γ″(0)=γ′ ′ (0)	15,708.37	0.25376	44	30,087.24
S(.) p(t)=c(t) γ″(t) γ′ ′ (.)	15,708.93	0.19188	46	30,083.70
S(.) p(t)=c(t) γ″(t) γ′ ′ (t)	15,709.72	0.12887	50	30,076.27
S(t) p(t)=c(t) γ″(t) γ′ ′ (.)	15,709.79	0.12450	50	30,076.34
S(t) p(t)=c(t) γ″(.) γ′ ′ (.)	15,710.10	0.10657	46	30,084.87
S(t) p(t)=c(t) γ″(.)=γ′ ′ (.)	15,710.42	0.09100	45	30,087.24
S(t) p(t)=c(t) γ″(t) γ′ ′ (t)	15,712.05	0.04017	53	30,072.43
S(.) p(t)=c(t) γ″(.) γ′ ′ (t)	15,712.77	0.02812	45	30,089.59
S(t) p(t)=c(t) γ″(t)=γ′ ′ (t)	15,713.84	0.01647	49	30,082.44
S(t) p(t)=c(t) γ″(.) γ′ ′ (t)	15,714.96	0.00938	49	30,083.57
S(.) p(t)=c(t) γ″(.) γ′ ′ (.)	15,715.28	0.00802	41	30,100.29
S(.) p(t)=c(t) γ″(0)=γ′ ′ (0)	15,719.81	0.00083	39	30,108.92
S(.) p(t)=c(t) γ″(.)=γ′ ′ (.)	15,721.83	0.00030	40	30,108.89
S(.) p(t)=c(t) γ″(t)=γ′ ′ (t)	15,723.60	0.00012	45	30,100.42

Table 13.—Repatriated adult razorback robust model estimates of survival, emigration, and immigration

Parameter	Interval	River	Basin
Survival (S)	2013 to 2014	0.973 (0.894–0.993)	0.985 (0.747–0.999)
	2014 to 2015	0.973 (0.897–0.993)	0.954 (0.795–0.991)
	2015 to 2016	0.974 (0.885–0.994)	0.995 (0.96–1.03)
	2016 to 2017	0.974 (0.897–0.994)	0.917 (0.693–0.982)
	2017 to 2018	0.963 (0.844–0.992)	0.957 (0.715–0.995)
	2018 to 2019	0.955 (0.759–0.993)	0.961 (0.652–0.997)
Emigration (γ")	2013 to 2014	0.119 (0.074–0.187)	0.069 (0.007–0.431)
	2014 to 2015	0.051 (0.014–0.172)	0.045 (0.002–0.472)
	2015 to 2016	0.07 (0.032–0.146)	0.008 (-0.036–0.052)
	2016 to 2017	0.092 (0.057–0.145)	0.055 (0.004–0.453)
	2017 to 2018	0.095 (0.045–0.188)	0.058 (0.009–0.305)
	2018 to 2019	0.123 (0.054–0.256)	0.054 (0.007–0.31)
Immigration (1-γ′)	2014 to 2015	0.216 (0.062–0.537)	0.454 (0.02–0.962)
	2015 to 2016	0.24 (0.104–0.464)	0.6 (0.058–0.973)
	2016 to 2017	0.237 (0.102–0.458)	0.486 (0.021–0.977)
	2017 to 2018	0.228 (0.095–0.454)	0.484 (0.03–0.966)
	2018 to 2019	0.23 (0.097–0.452)	0.516 (0.042–0.963)

Table 14.—Repatriated adult razorback robust model estimates of capture probability

Year	Month	River	Basin
2013	January	0.302 (0.273–0.333)	0.508 (0.419–0.597)
	February	0.345 (0.313–0.378)	0.295 (0.23–0.369)
	March	0.314 (0.284–0.345)	0.222 (0.167–0.289)
	April	0.184 (0.161–0.209)	0.064 (0.037–0.106)
	May	0.083 (0.068–0.101)	0.023 (0.009–0.054)
2014	January	0.211 (0.184–0.24)	0.237 (0.187–0.296)
	February	0.254 (0.224–0.286)	0.312 (0.252–0.379)
	March	0.267 (0.237–0.3)	0.224 (0.176–0.28)
	May	0.092 (0.075–0.112)	0.014 (0.006–0.033)
2015	January	0.186 (0.165–0.208)	0.169 (0.131–0.215)
	February	0.477 (0.447–0.508)	0.28 (0.227–0.34)
	March	0.323 (0.297–0.35)	0.125 (0.093–0.164)
	April	0.108 (0.093–0.126)	0.033 (0.02–0.056)
	May	0.079 (0.066–0.095)	0.013 (0.006–0.03)
2016	December	0.206 (0.185–0.229)	0.054 (0.039–0.073)
	January	0.221 (0.199–0.244)	0.3 (0.264–0.338)
	February	0.305 (0.279–0.331)	0.476 (0.431–0.521)
	March	0.184 (0.164–0.205)	0.098 (0.078–0.123)
	April	0.094 (0.08–0.11)	0.012 (0.006–0.023)
	May	0.049 (0.039–0.061)	0.013 (0.007–0.025)
2017	December	0.28 (0.255–0.306)	0.081 (0.063–0.103)
	January	0.297 (0.272–0.324)	0.107 (0.087–0.132)
	February	0.234 (0.212–0.259)	0.334 (0.297–0.373)
	March	0.253 (0.229–0.278)	0.192 (0.164–0.223)
	April	0.088 (0.074–0.104)	0.043 (0.031–0.06)
	May	0.053 (0.042–0.067)	0.019 (0.011–0.031)
2018	December	0.289 (0.262–0.317)	0.059 (0.044–0.077)
	January	0.202 (0.18–0.227)	0.132 (0.109–0.159)

(Table 14 continued.)

Year	Month	River	Basin
2018	February	0.191 (0.169–0.214)	0.28 (0.244–0.318)
	March	0.196 (0.174–0.22)	0.204 (0.175–0.237)
	April	0.108 (0.091–0.126)	0.044 (0.032–0.06)
	May	0.032 (0.023–0.043)	0.006 (0.001–0.011)
2019	December	0.147 (0.125–0.171)	0.074 (0.057–0.095)
	January	0.294 (0.262–0.328)	0.318 (0.28–0.358)
	February	0.297 (0.264–0.331)	0.428 (0.383–0.474)
	March	0.17 (0.146–0.196)	0.116 (0.095–0.142)
	April	0.103 (0.086–0.124)	0.073 (0.056–0.093)
	May	0.031 (0.022–0.043)	0.001 (-0.001–0.004)

Post-Stocking Fate

Displacement

A total of 53,315 hatchery-reared razorback suckers were stocked into Lake Mohave from October 2008 to September 2013[2]. From these fish, a total of 311,966 contacts were recorded from SY 2014–2019, of which 2,597 were unique. After removal of individuals with fewer than 10 contacts, 1,997 unique fish remained with a total of 307,894 contacts. Of the 1,997 unique fish contacted, 1387 (69.5%) were contacted in one zone, 575 (28.8%) were contacted in two zones, 35 (1.8%) were contacted in three zones, and none were contacted in four.

In River, there were five stocking locations from which 22,922 razorback sucker were released from October 2008 to September 2013. A total of 98,122 contacts were recorded from fish released in River, of which 1,345 were unique. Of the total 98,122 contacts, 66,354 (1,284 unique) were in River, 92 (59 unique) were in Liberty, 31,672 (445 unique) were in Basin, and four (three unique) were in

[2] Total releases are based on records of release in the Lower Colorado River Native Fish Database. These numbers may be lower than actual numbers released due to errors in data collection and data entry.

Katherine. Most River releases were contacted exclusively in River (64.3%; table 15), however, a substantial proportion of razorback suckers were detected in Basin (33.1%). Yearly stocking displacement analysis indicated a consistent pattern across all years, with most contacts in River but with fish also dispersing to Basin (figure 12).

Table 15.—Summary of contact histories for unique razorback suckers stocked in River zone from October 2008 to September 2013 in Lake Mohave, Arizona and Nevada
(Combination refers to each scenario for contact histories; if fish were contacted in a particular zone it is denoted [X] and summarized by number contacted [n] and percent for each contact history combination.)

Combination	River	Liberty	Basin	Katherine	n	Percent (%)
1	-	-	X	-	61	4.5
2	X	-	-	-	865	64.3
3	X	-	-	X	1	0.07
4	X	-	X	-	357	26.5
5	X	-	X	X	2	0.1
6	X	X	-	-	34	2.5
7	X	X	X	-	25	1.9
				Total	1,345	100

In Liberty, there were five stocking locations from which 11,087 razorback suckers were released from October 2008 to September 2013. A total of 31,614 contacts were recorded from fish released in Liberty, of which 209 were unique. Of the total 31,614 contacts, 5,255 (139 unique) were in River, 56 (13 unique) were in Liberty, 26,298 (139 unique) were in Basin, and five (one unique) were in Katherine. A small percentage of fish were detected exclusively in Liberty (0.5%) and most fish were not contacted in Liberty at all (93.7%). Detection of fish in River (30.1%), Basin (30.6%), and both River and Basin (32.5%) were analogous (table 16). Yearly stocking displacement analysis indicated a consistent pattern across all years, with fish dispersing upstream and downstream from stocking localities (figure 13).

Table 16.—Summary of contact histories for unique razorback suckers stocked in Liberty zone from October 2008 to September 2013 in Lake Mohave, Arizona and Nevada

Combination refers to each scenario for contact histories; if fish were contacted in a particular zone it is denoted [X] and summarized by number contacted [n] and percent for each contact history combination.)

Combination	River	Liberty	Basin	Katherine	n	Percent (%)
1	-	-	X	-	64	30.6
2	-	-	X	X	1	0.5
3	-	X	-	-	1	0.5
4	-	X	X	-	4	1.9
5	X	-	-	-	63	30.1
6	X	-	X	-	68	32.5
7	X	X	-	-	6	2.9
8	X	X	X	-	2	1
				Total	209	100

In Basin, there were nine stocking locations from which 12,214 fish were released from October 2008 to September 2013. A total of 168,984 contacts were recorded from fish released in Basin, of which 407 were unique. Of the 168,984 total contacts, 3,261 (120 unique) were in River, nine (eight unique) were in Liberty, 165,700 (387 unique) were in Basin, and 14 (two unique) were in Katherine. Most Basin releases were contacted exclusively in Basin (69.5%; table 17), however, a substantial proportion of razorback suckers were detected in River (29.5%). Yearly stocking displacement analysis indicated a consistent pattern across all years, with most contacts in Basin but with fish also dispersing to River (figure 14).

For razorback suckers that were stocked in River or Basin and contacted in both River and Basin, contact proportions were roughly equal between the two zones (figure 16).

Table 17.—Summary of contact histories for unique razorback suckers stocked in Basin zone from October 2008 to September 2012 in Lake Mohave, Arizona and Nevada

Combination refers to each scenario for contact histories; if fish were contacted in a particular zone it is denoted [X] and summarized by number contacted [n] and percent for each contact history combination.)

Combination	River	Liberty	Basin	Katherine	n	Percent (%)
1	-	-	X	-	283	69.5
2	-	-	X	X	1	0.2
3	-	X	X	-	3	0.7
4	X	-	-	-	20	4.9
5	X	-	X	-	94	23.1
6	X	-	X	X	1	0.2
7	X	X	X	-	5	1.2
				Total	407	100

In Katherine, there was one stocking location from which 7,092 fish were released from October 2008 to September 2013. A total of 9,174 contacts were recorded from fish released in Katherine, of which 36 were unique. Of the 9,174 contacts, 1,444 (8 unique) were in River, none were in Liberty, 7729 (33 unique) were in Basin, and one was in Katherine. Most Katherine releases were detected exclusively in Basin, followed by a small portion of fish detected in both River and Basin (13.9%; table 18). Yearly stocking displacement analysis indicated a consistent pattern, with fish dispersing to Basin and River, except in SY 2014 when fish were only detected in Basin (figure 15).

Table 18.—Summary of contact histories for unique razorback suckers stocked in Katherine zone from October 2008 to September 2012 in Lake Mohave, Arizona and Nevada

Combination refers to each scenario for contact histories; if fish were contacted in a particular zone it is denoted [X] and summarized by number contacted [n] and percent for each contact history combination.)

Combination	River	Liberty	Basin	Katherine	n	Percent (%)
1	-	-	X	-	27	75
2	-	-	X	X	1	2.8
3	X	-	-	-	3	8.3
4	X	-	X	-	5	13.9
				Total	36	100

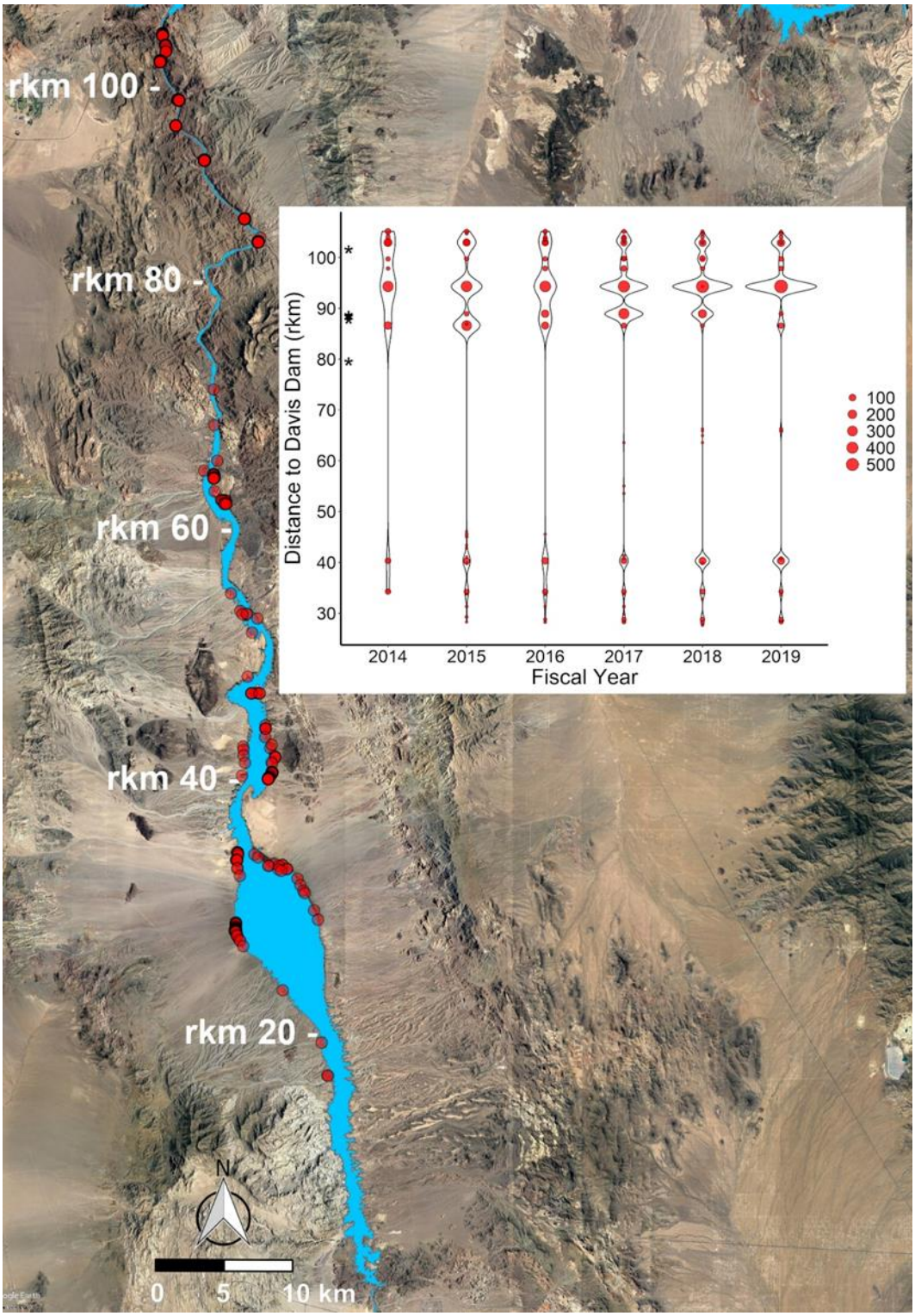

Figure 12.—Relationship between number of contacts (red circles) and distance to Davis Dam (rkm) for razorback suckers stocked in River zone from October 2008 to September 2013, Lake Mohave, Arizona and Nevada.
Asterisks along y-axis represent stocking locations.

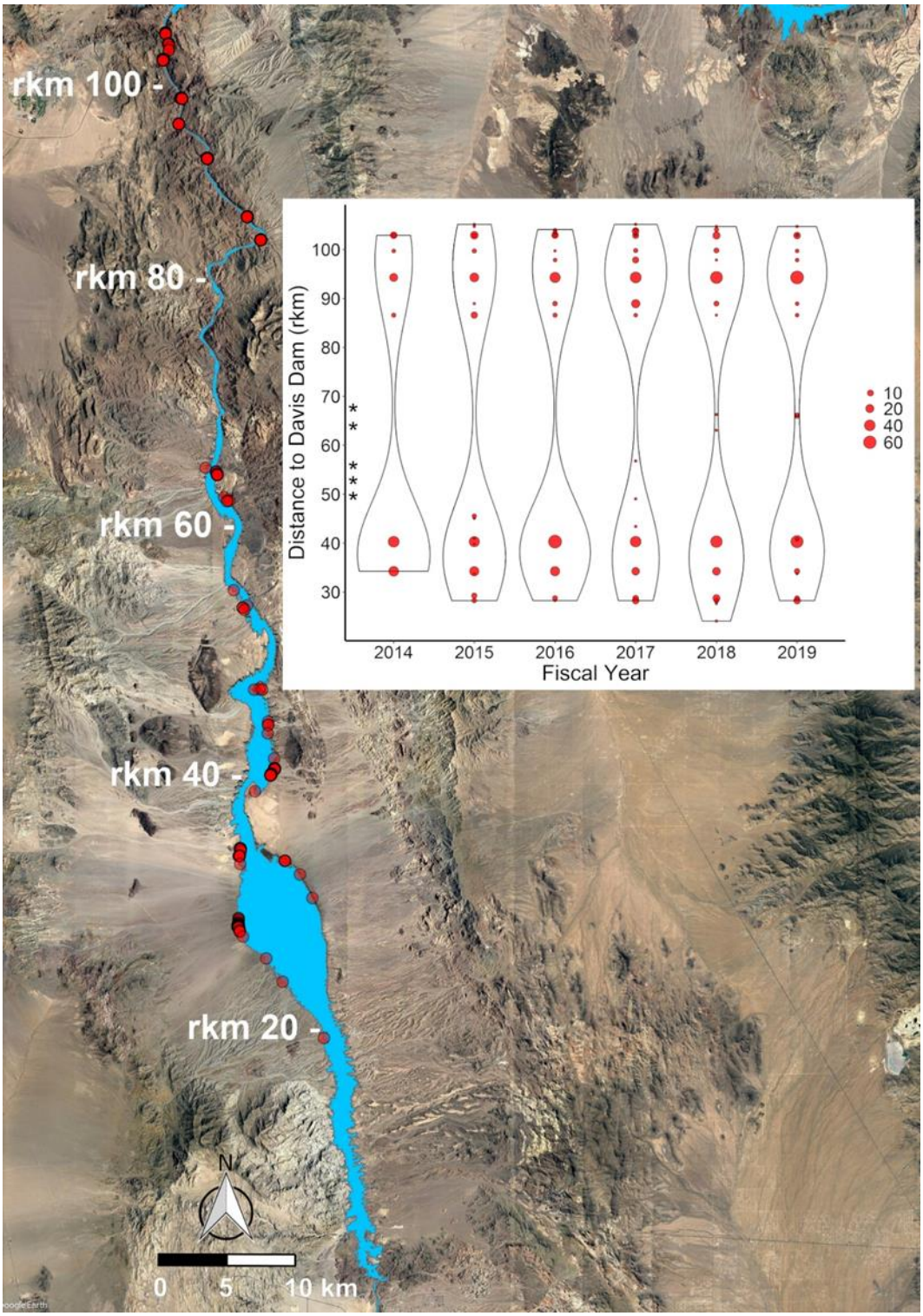

Figure 13.—Relationship between number of contacts (red circles) and distance to Davis Dam (rkm) for razorback suckers stocked in Liberty zone from October 2008 to September 2013, Lake Mohave, Arizona and Nevada.
Asterisks along y-axis represent stocking locations

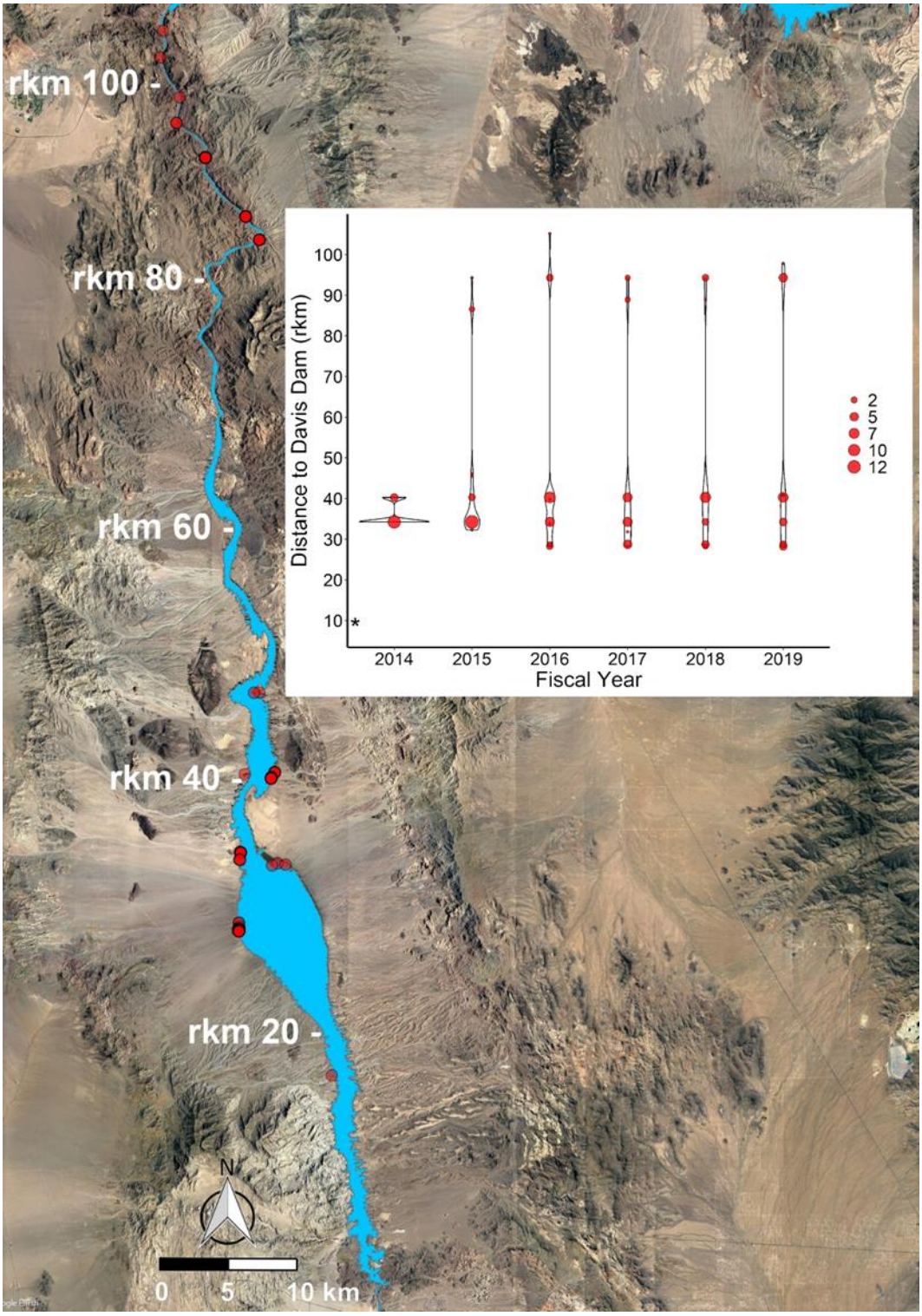

Figure 14.—Relationship between number of contacts (red circles) and distance to Davis Dam (rkm) for razorback suckers stocked in Basin zone from October 2008 to September 2013, Lake Mohave, Arizona and Nevada.
Asterisks along y-axis represent stocking locations.

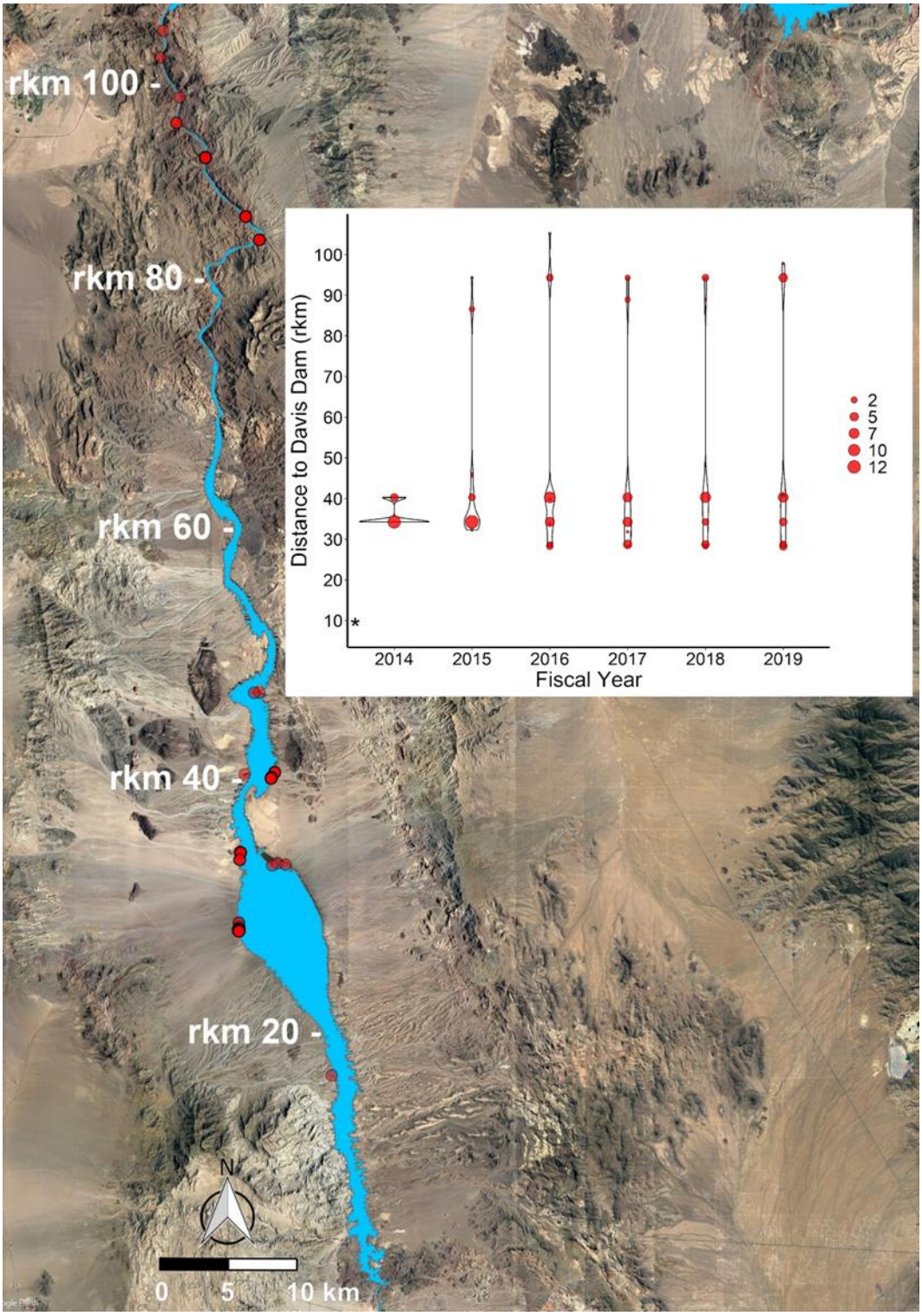

Figure 15.—Relationship between number of contacts (red circles) and distance to Davis Dam (rkm) for razorback suckers stocked in Katherine zone from October 2009 to September 2013, Lake Mohave, Arizona and Nevada.
Asterisk along y-axis represent stocking locations
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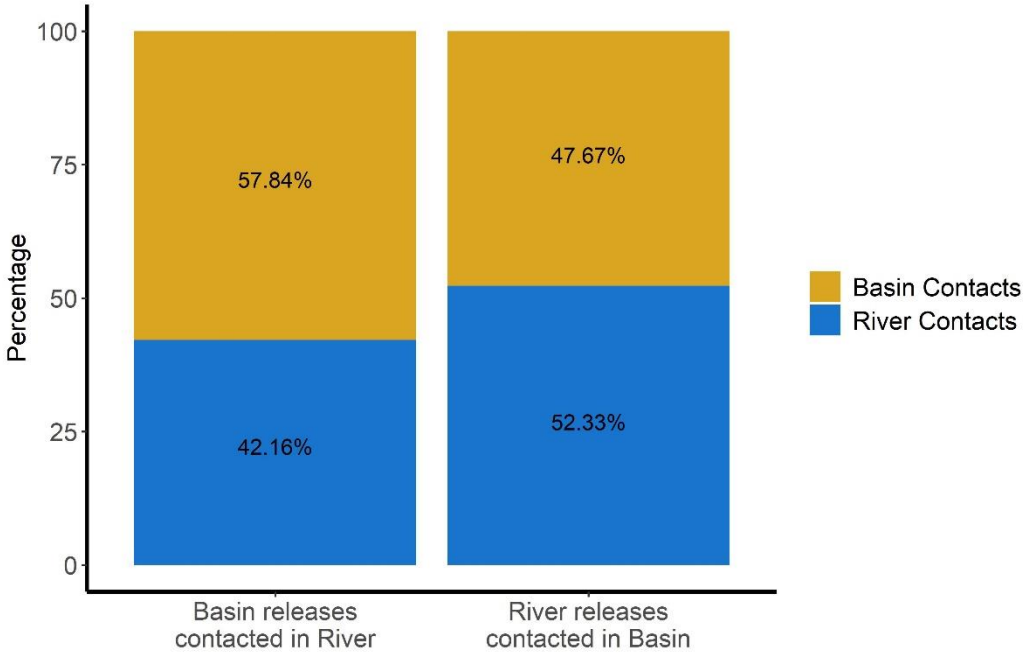

Figure 16.—Contact proportions of unique razorback sucker PIT tags that were released in Basin and contacted in River, and released in River and contacted in Basin, for fish stocked from October 2008 to September 2013 in Lake Mohave, Arizona and Nevada.

Repatriate Recruitment

Cohorts released at longer TL had higher contact rates for all years and there were few to no contacts for cohorts released at shorter than 400 mm TL (figure 17 and 18). This pattern is consistent between cohorts raised in ponds or raceways and across years. Other than size at release, release SY appears to account for the largest variation in cohort availability. The range of release sizes was also not consistent among years and zones. Cohorts released in River from 2010 through 2012 included cohorts of large fish (greater than 450 mm TL), whereas cohorts from SY 2013 and 2014 included no large fish. In Basin, for all release years available for analysis (SY 2009 through SY 2014) no fish larger than 430 mm TL was released from raceways, whereas fish released from ponds ranged from 340 to 500 mm TL (Appendix 3). The cohort with the highest contact rate (0.80, 20 out of 25 fish released) was released in October of 2010 from a lakeside backwater with a TL bin of 480 mm TL (480 to 489 mm TL).

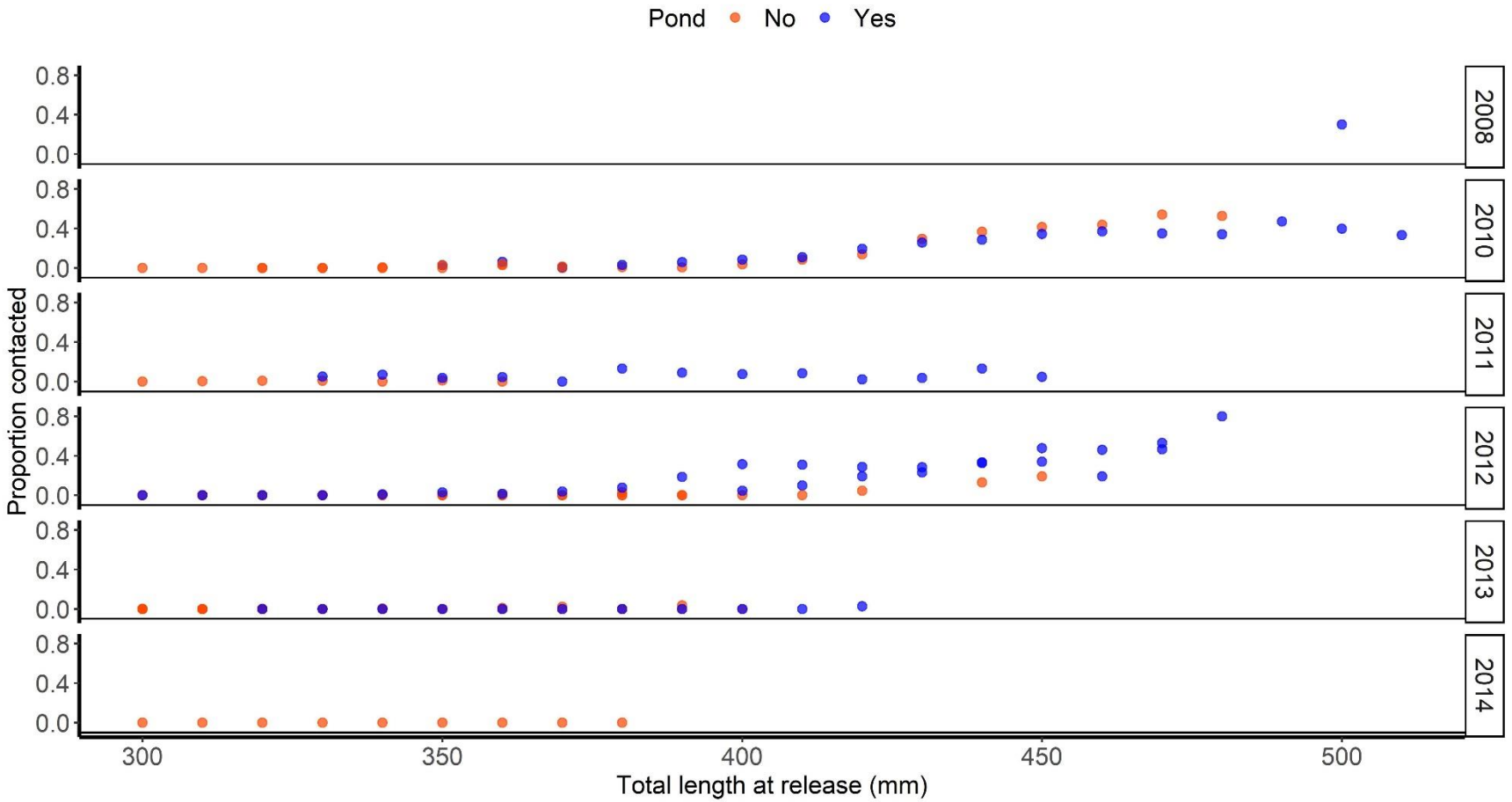

Figure 17.—Proportion of razorback sucker released in River contacted at least once between SY 2017 through SY 2019, grouped into cohorts based on release SY, size at release (10 mm bins), and pond rearing (yes or no).
Each point represents a group of fish released at the reported SY, size (10 mm bin), zone (River or Basin), and month (individual points).

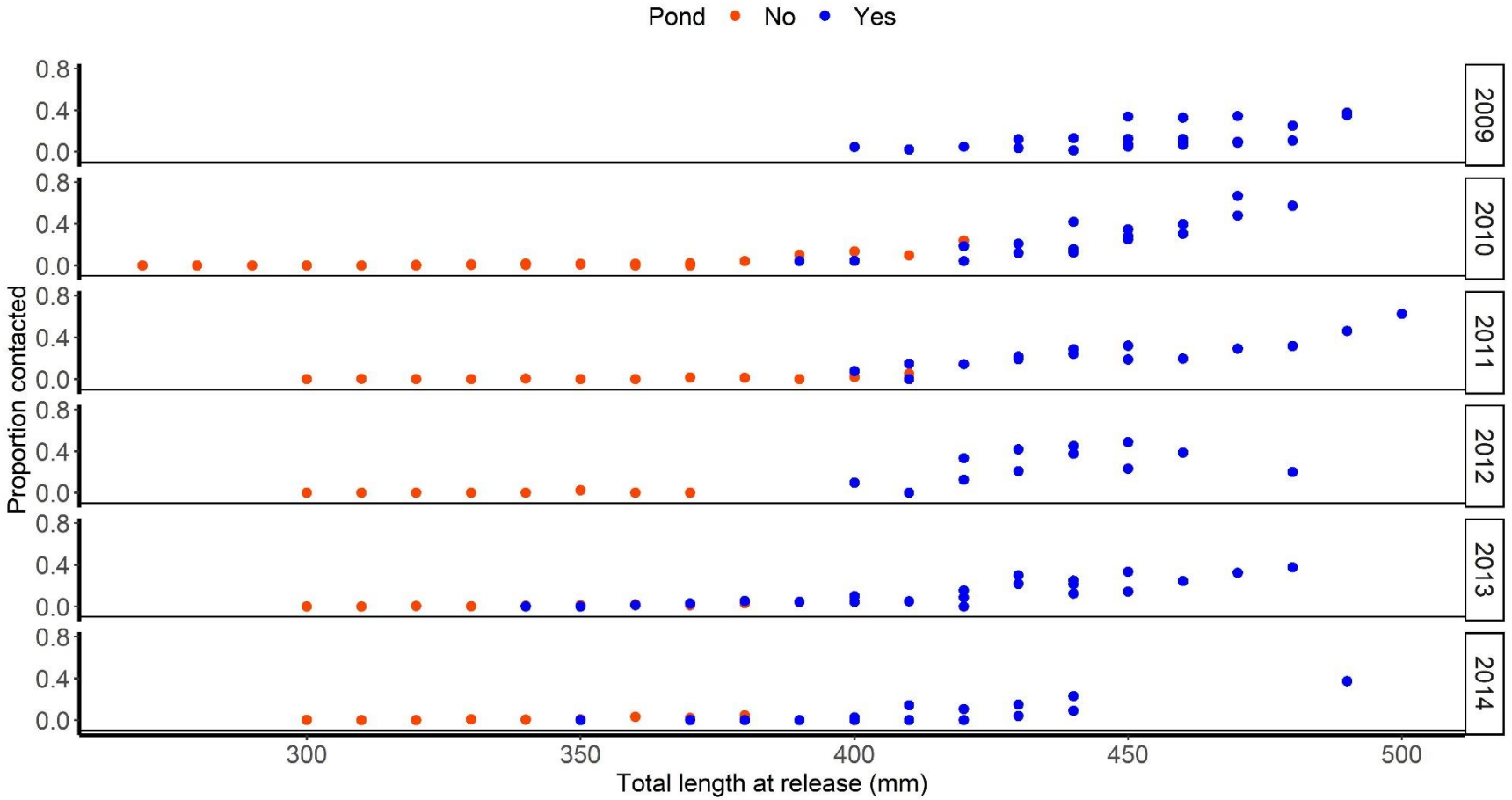

Figure 18.—Proportion of razorback sucker released in Basin contacted at least once between SY 2017 through SY 2019, grouped into cohorts based on release SY, size at release (10 mm bins), and pond rearing (yes or no).

Each point represents a group of fish released at the reported SY, size (10 mm bin), zone (River or Basin), and month (individual points).

DISCUSSION

The long-term monitoring program for razorback suckers in Lake Mohave continues to evolve as data provide new information and insight on population dynamics and demographics. As new technologies develop, the data available to inform the program expands. Remote sensing via deployment of PIT scanners has increased the number of contacts with repatriated razorback suckers by at least one order of magnitude. However, the need for continued long-term basic biological data has not been eliminated. The consistent application of the same techniques and analyses for more than four decades has provided a context for which new data collected by new techniques can be compared.

Continued deployment of PIT scanning units has increased the spatial extent of the study area from the Basin to River where traditional methods were ineffective, adding information on large-scale dispersal patterns to the program. Previous reports based on preliminary PIT scanning data concluded that only a small proportion of fish dispersed from their zone of release in River and Basin (e.g., Wisenall et al. 2015, Burgad et al. 2019). Most razorback suckers stocked in River or Basin continue to remain in their zone of release, but a considerable portion (roughly one third) of fish released in River are contacted in Basin, and vice versa. This suggests that more movement exists between River and Basin than previously thought. Contact proportions between River and Basin were roughly equal for these multi-zone fish, thereby suggesting that time spent in the zone of destination was substantial, assuming that fish in each zone have equal probability of being contacted. This could be a sex-linked trait, males or females may be more likely to move from zone to zone, but currently sex is not known for most fish released.

Most razorback suckers released in Liberty are contacted upstream or downstream in River or Basin subpopulations in nearly equal numbers. This may suggest that habitat quality in Liberty is low, alternatively, aggregations of razorback sucker may have yet to be discovered in the zone, although this prospect seems

increasingly unlikely with each year of PIT scanning effort in this zone. Less is known about the fate of fish released in Katherine; they are contacted in River and Basin in low numbers, but little to no PIT scanning effort has been conducted there except in 2017.

PIT scanning also has provided additional estimates of population size, subpopulation size, and subpopulation adult survival using mark-recapture models. PIT scanning estimates of subpopulations in River and Basin have remained stable over the last five years, but the routine monitoring estimate has declined. The temporal constraints of the routine monitoring estimate (March data only) may no longer be adequate to estimate the entire Basin subpopulation. This could be due to the age of the repatriation program, i.e., a shift in behavior or timing of spawning in Basin as the population shifts from a young population to a more mature age structure as the repatriation program ages. Further analysis of PIT scanning data using "known" populations of razorback sucker that include shifting temporal windows to estimate population size would increase our understanding of this widening discrepancy.

Adult survival in River and Basin is substantially higher than previously reported based on capture data (Kesner et al. 2012, Marsh et al. 2005). Adult survival also is substantially higher than other locations in the Colorado River (e.g., Zelasko et al. 2010). This increase in estimated annual survival likely is not due to the addition of temporary emigration in the mark-recapture model, because the highest-ranking model in Basin included no temporary emigration. More likely, the additional spatial coverage and sheer volume of data that PIT scanning provides has improved accuracy and precision of adult estimates. It therefore is possible that adult survival estimates elsewhere will increase as PIT scanning is incorporated into models for those reaches. Regardless, it is not unusual for large, long lived catostomids to have annual survival over 90% (e.g., Scoppettone et al. 2015).

The clear relationship between size and survival continues to dominate post-stocking analysis. Based on analysis of post-release contacts evaluated for release cohorts, there is little to no difference in future availability (recruitment) of fish raised in ponds or raceways. In Basin, most of the fish available were raised in ponds, but the discrepancies in release size between pond and raceway raised fish may account for the lack of raceway raised fish in Basin. In River, the lack of releases at larger sizes (greater than 420 mm TL) after SY 2012 results in few fish contributing to the subpopulation there.

Year to year variation in the relationship between size at release and recruitment may be due to condition of fish prior to release. Cohort variation within SY and size class in Basin appears highest among pond reared fish (figure 18 and Appendix 3). Most if not all razorback suckers released in Basin and recorded as "pond reared" were released into Lake Mohave from a lakeside backwater. Therefore, differences in apparent recruitment based on cumulative remote PIT scanning data within a SY and size class are likely due to variations in recruitment between lakeside backwaters. Identification of particularly low or high recruitment from individual backwater cohorts in combination with information on condition of fish from those cohorts may provide additional clues to factors influencing post-stocking survival.

The first repatriations of razorback sucker to Lake Mohave were in 1992 when a few adults reared in the Yuma Cove backwater were transferred into the reservoir at Arizona Bay to augment a dwindling population of wild fish. The wild population now is gone and in the nearly 30 years since its inception the repatriation program has grown in size, scope, and complexity and a population of several thousand stocked fish now exists only because of its implementation. Moreover, although important questions remain, we now know many details of razorback sucker population dynamics and factors that influence post-stocking and long-term survival. The return on stocking can be high when fish are repatriated at appropriate size. The importance of the relationship between fish

size at stocking and post-stocking survival is well understood and cannot be overemphasized but logistical constraints to rearing large fish have proven difficult to overcome. Nonetheless the razorback sucker should benefit from future program enhancements informed by additional experience, data acquisition and population modelling, and implementation of novel strategies.

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Appendix 1. – Razorback sucker monitoring summary by capture month, year, PIT tag, history, and sex during monitoring events Oct 2014 through Sep 2019, Lake Mohave, Arizona and Nevada. Data in order by Pit tag, and within Pit tag, by Capture date.

Pit tag	Capture date	Capture location	Sex	TL	WT	Recap	Same trip	Hist	Rearing location	Year class
000B0DA8F7	15-Mar-18	Waterwheel Cove	F	710		N	N	U	Unknown	
000B0DA910	12-Mar-18	Waterwheel Cove	M	602		N	N	U	Unknown	
000B0DA925	15-Mar-18	Waterwheel Cove (north of)	F	690		Y	N	R	Unknown	
000B0DA92D	12-Mar-19	Cottonwood Cove East	F	620	2700	N	N	U	Unknown	
000B0DA935	03-Dec-14	Cottonwood Cove East (1st point south of north point)	F	640		Y	Y	R	Unknown	
000B0DA935	03-Dec-14	Cottonwood Cove East (1st point south of north point)	F	640		N	N	U	Unknown	
000B0DA93D	12-Mar-19	Cottonwood Cove East	F	651	3345	N	N	U	Unknown	
003BA62D5A	05-Dec-16	Carp Cove	F	670		N	N	U	Unknown	
003BA62D65	20-Mar-15	Waterwheel Cove	M	360		Y	N	R	Lake Mead Fish Hatchery	2010
003BA62D97	19-Mar-15	Waterwheel Cove	M	342		Y	N	R	Lake Mead Fish Hatchery	2010
003BA63ECB	02-Dec-14	Cottonwood Cove East (1st point south of north point)	M	475		Y	N	R	Willow Beach NFH	2011
003BA7448C	17-Mar-15	Waterwheel Cove	F	525		Y	Y	R	Arizona Juvenile	2011
003BA7448C	17-Mar-15	Carp Cove (north point)	F	525		Y	Y	R	Arizona Juvenile	2011
003BA744A2	17-Mar-15	Waterwheel Cove	F	522		Y	N	R	Willow Beach NFH	2011
003BA744A2	20-Mar-15	Cottonwood Cove East	F	522		Y	Y	R	Willow Beach NFH	2011
003BCB88F9	13-Mar-19	Cottonwood Cove East	F	630	2951	Y	N	R	Dandy Cove	2011
003BCC5C34	18-Mar-15	Carp Cove	J	390		Y	N	R	Willow Beach NFH	2012
003BCC66EA	15-Mar-16	Cottonwood Cove East (100 m inside, north shore)	M	530		Y	N	R	Willow Beach NFH	2013
003BE5B93B	05-Dec-16	Carp Cove	F	543		Y	N	R	Willow Beach NFH	2014
003BEA19E8	15-Mar-18	Waterwheel Cove (north of)	M	525		Y	N	R	Dandy Cove	2014
003BF31E7E	12-Mar-19	Cottonwood Cove East	F	419	726	Y	N	R	Willow Beach NFH	2016
003BF31E8C	12-Mar-19	Cottonwood Cove East	F	460	895	Y	N	R	Willow Beach NFH	2016
003BF32067	12-Mar-19	Cottonwood Cove East	F	444	935	Y	N	R	Willow Beach NFH	2016
003BF323EB	12-Mar-19	Cottonwood Cove East	M	419		Y	N	R	Willow Beach NFH	2016
003C06CAA5	12-Mar-18	Carp Cove (inside)	M	401		Y	N	R	Lake Mead Fish Hatchery	2015
003C06CCCA	28-Nov-18	Cottonwood Cove East (north point)	F	561		Y	N	R	Arizona Juvenile	2014
1B7969D55B	17-Mar-16	Cottonwood Cove East (2nd point south of north point)	F	660		Y	N	R	Yuma Cove	
1B7969E303	15-Mar-19	Cottonwood Cove East	F	701	3730	Y	N	R	Yuma Cove	

Demographics and monitoring of repatriated razorback suckers in Lake Mohave

Pit tag	Capture date	Capture location	Sex	TL	WT	Recap	Same trip	Hist	Rearing location	Year class
1B796B41D9	18-Mar-15	Carp Cove	M	579		Y	N	R	North Chemehuevi Cove	2008
1B796B4797	13-Mar-19	Cottonwood Cove East	F	620	290	Y	N	R	Achii Hanyo	2010
1B796B5742	18-Mar-16	Cottonwood Cove East (north point)	F	617		Y	N	R	Achii Hanyo	2010
1B796ED720	28-Nov-17	Cottonwood Cove East	F	643		Y	N	R	North Chemehuevi Cove	2009
1B796ED90F	20-Mar-15	Waterwheel Cove	F	595		Y	N	R	Yuma Cove	
1B796ED99D	04-Dec-14	Cottonwood Cove East (1st point south of north point)	F	585		Y	N	R	Arizona Juvenile	2009
1B796EE3DB	28-Nov-17	Cottonwood Cove East (2nd point south of north point)	F	643		Y	N	R	Arizona Juvenile	2009
1B796EE831	04-Dec-14	Cottonwood Cove East (1st point south of north point)	F	580		Y	N	R	Arizona Juvenile	2009
1B796EEC75	29-Nov-17	Cottonwood Cove East	F	620		Y	N	R	Dandy Cove	2009
1B796EECA8	03-Dec-14	Cottonwood Cove East (1st point south of north point)	F	589		Y	N	R	Yuma Cove	
1B796EEFF9	17-Mar-15	Waterwheel Cove	F	575		Y	N	R	North Chemehuevi Cove	2009
1B796EF477	03-Dec-14	Cottonwood Cove East (1st point south of north point)	F	585		Y	N	R	Arizona Juvenile	2009
1C2C3435B7	16-Mar-17	Cottonwood Cove East (100 m inside, north shore)	F	626		Y	N	R	Bubbling Ponds FH	2002, 2003 and 2004
1C2C7F410E	04-Dec-14	Cottonwood Cove East (1st point south of north point)	M	577		N	N	U	Unknown	
1C2C7F472D	15-Mar-18	Waterwheel Cove (first point south of)	F	620		N	N	U	Unknown	
1C2C7F72A3	20-Mar-15	Waterwheel Cove	M	550		N	N	U	Unknown	
1C2C7FE9B4	19-Mar-15	Waterwheel Cove	F	640		Y	N	R	Bubbling Ponds FH	2005
1C2C7FECE7	04-Dec-14	Cottonwood Cove East (1st point south of north point)	F	680		N	N	U	Unknown	
1C2C840A18	04-Dec-14	Cottonwood Cove East (1st point south of north point)	F	645		Y	N	R	Willow Beach NFH	2007
1C2C84482D	12-Mar-19	Cottonwood Cove East	F	676	3780	N	N	U	Unknown	
1C2C856E15	16-Mar-16	Cottonwood Cove East (100 m inside, north shore)	M	610		Y	N	R	Yuma Cove	
1C2C857464	20-Mar-15	Cottonwood Cove East	F	645		Y	N	R	Unknown	
1C2D067132	19-Mar-15	Waterwheel Cove	F	625		Y	N	R	Arizona Juvenile	2007
1C2D06BA6D	29-Nov-17	Carp Cove (north point)	F	628		Y	N	R	Willow backwater	2007
1C2D25D516	28-Nov-17	Cottonwood Cove East (1st point south of north point)	F	624		Y	N	R	Bubbling Ponds FH	2005
1C2D265EC1	03-Dec-14	Cottonwood Cove East (1st point south of north point)	F	595		Y	N	R	Bubbling Ponds FH	2005
1C2D267788	05-Dec-16	Carp Cove	F	634		Y	N	R	North Chemehuevi Cove	2008
1C2D269177	18-Mar-15	Waterwheel Cove	F	560		Y	N	R	Bubbling Ponds FH	2005

Pit tag	Capture date	Capture location	Sex	TL	WT	Recap	Same trip	Hist	Rearing location	Year class
1C2D26933A	15-Mar-18	Waterwheel Cove	F	650		Y	N	R	Bubbling Ponds FH	2008
1C2D60F707	05-Dec-16	Carp Cove	F	671		Y	N	R	Achii Hanyo	2008
1C2D610A0A	13-Mar-19	Carp Cove (north point)	F	681	3691	Y	Y	R	Achii Hanyo	2008
1C2D6188C7	29-Nov-17	Carp Cove (north point)	F	634		Y	N	R	Achii Hanyo	2008
1C2D61A3F9	15-Mar-18	Carp Cove (inside)	F	627		Y	N	R	Bubbling Ponds FH	2005
1C2D635C66	15-Mar-18	Carp Cove (inside)	F	655		Y	N	R	Willow Beach NFH	2006
1C2D63A268	20-Mar-15	Cottonwood Cove East	F	635		Y	N	R	Achii Hanyo	2008
1C2D642F9E	14-Mar-18	Waterwheel Cove	F	635		Y	N	R	Willow Beach NFH	2006
1C2D64311A	14-Mar-19	Cottonwood Cove East	F	614	2660	Y	N	R	Overton Wildlife Management Area, Center Pond	2008
1C2D69590E	20-Mar-15	Waterwheel Cove (north of)	F	645		Y	N	R	Dandy Cove	2006
1C2D697D4D	05-Dec-16	Carp Cove	F	572		Y	N	R	Overton Wildlife Management Area, Center Pond	2008
1C2D698C52	16-Mar-18	Cottonwood Cove East (north point)	F	640		Y	N	R	Achii Hanyo	2008
1C2D6C0076	16-Mar-16	Carp Cove (inside)	F	650		Y	N	R	Unknown	
1C2D6C0D3F	30-Nov-18	Carp Cove (north point)	F	646		N	N	U	Unknown	
1C2D6C6741	28-Nov-17	Cottonwood Cove East (2nd point south of north point)	F	634		Y	N	R	Yuma Cove	
1C2D6C6905	19-Mar-15	Cottonwood Cove East	F	641		Y	N	R	Yuma Cove	
1C2D6CD55A	02-Dec-14	Cottonwood Cove East (1st point south of north point)	F	640		Y	N	R	Yuma Cove	
1C2D6D1839	16-Mar-16	Cottonwood Cove East (100 m inside, north shore)	F	606		Y	N	R	Arizona Juvenile	2008
1C2D8C1D62	14-Mar-16	Carp Cove (inside)	F	619		Y	N	R	Arizona Juvenile	2008
1C2D8C9FEB	20-Mar-15	Waterwheel Cove (north of)	F	627		Y	N	R	Arizona Juvenile	2008
2037246223	14-Mar-18	Waterwheel Cove	F	660		Y	N	R	Yuma Cove	
2241216911	17-Mar-15	Carp Cove	M	625		Y	N	R	Yuma Cove	
257C60995F	14-Mar-17	Cottonwood Cove East (100 m inside, north shore)	F	665		Y	N	R	Arizona Juvenile	
257C60B28B	16-Mar-16	Carp Cove (north point)	F	665		Y	N	R	Arizona Juvenile	
257C61D63E	03-Dec-14	Cottonwood Cove East (1st point south of north point)	F	625		Y	N	R	Yuma Cove	2005
36F2B263D5	14-Mar-18	Waterwheel Cove	M	548		Y	N	R	Yuma Cove	
36F2B263D6	15-Mar-16	Cottonwood Cove East (100 m inside, north shore)	F	635		Y	N	R	Yuma Cove	
36F2B5A1F3	02-Dec-14	Cottonwood Cove East (1st point south of north point)	F	541		Y	N	R	Achii Hanyo	2010
36F2B5A66F	03-Dec-14	Cottonwood Cove East (1st point south of north point)	F	590		Y	N	R	Achii Hanyo	2010
36F2B5A67A	20-Mar-15	Carp Cove (north point)	M	520		Y	N	R	Achii Hanyo	2010

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Pit tag	Capture date	Capture location	Sex	TL	WT	Recap	Same trip	Hist	Rearing location	Year class
36F2B5A67A	14-Mar-19	Cottonwood Cove East	M	591	2441	Y	N	R	Achii Hanyo	2010
42403A6F62	20-Mar-15	Waterwheel Cove	F	670		Y	N	R	Boulder City Wetlands Park	
424108294D	14-Mar-16	Cottonwood Cove East (1st point south of north point)	M	554		Y	N	R	Arizona Juvenile	
436478455A	20-Mar-15	Waterwheel Cove	M	570		Y	N	R	Willow Beach NFH	
4645566F2C	02-Dec-14	Cottonwood Cove East (1st point south of north point)	M	580		Y	N	W	Not applicable	
46466C1A49	20-Mar-15	Waterwheel Cove	F	620		Y	N	R	Yuma Cove	
4646761253	17-Mar-15	Waterwheel Cove	F	675		Y	N	R	Willow Beach NFH	2001/2003
46486F1069	03-Dec-14	Cottonwood Cove East (1st point south of north point)	F	620		Y	N	R	Dandy Cove	
4648701437	15-Mar-17	Cottonwood Cove East (between north point and 1st)	F	685		Y	N	R	Willow Beach NFH	2003
5216245249	17-Mar-15	Carp Cove	F	574		Y	N	R	Boulder City Wetlands Park	
5324140160	05-Dec-16	Carp Cove	F	646		Y	N	R	Dexter NFH (SNARRC)	
532F2A1140	12-Mar-19	Cottonwood Cove East	F	670	3650	Y	N	R	Willow Beach NFH	
5333403056	19-Mar-15	Carp Cove (north point)	F	642		Y	N	R	Willow Beach NFH	
5335245B2C	28-Nov-17	Cottonwood Cove East (100 m inside, north shore)	F	624		Y	N	R	Willow Beach NFH	
53453C2E26	16-Mar-17	Carp Cove	F	645		Y	N	R	Willow Beach NFH	
7F7A082D4E	13-Mar-19	Carp Cove	F	741	4501	Y	N	R	Boulder City Wetlands Park	

Appendix 2. – Razorback sucker monitoring summary by capture month, year, PIT tag, history, and sex during monitoring events Oct 2014 through Sep 2019, Lake Mohave, Arizona and Nevada. Data are from 80 paired stocking-capture data per fish PIT tag. Data in order by Recap, and within Recap, data in order by Same trip capture and History.

Pit tag	Release	Capture	Release	Capture	Growth/ month	Sex	Days at large	Months at large	Years at large	Number of captures	Comments
36F2B5A66F	06-Dec-12	03-Dec-14	430	590	5	F	727	24	2	1	First capture in 2014
36F2B5A1F3	06-Dec-12	02-Dec-14	430	541	4	F	726	24	2	1	First capture in 2014
257C61D63E	19-May-10	03-Dec-14	470	625	5	F	1,659	55	5	1	First capture in 2014
1C2D6CD55A	12-Oct-11	02-Dec-14	445	640	6	F	1,147	38	3	1	First capture in 2014
1C2C840A18	16-Mar-11	04-Dec-14		645	ND	F	1,359	45	4	1	First capture in 2014
1B796EF477	06-May-13	03-Dec-14	455	585	4	F	576	19	2	1	First capture in 2014
1B796EECA8	28-Oct-11	03-Dec-14	440	589	5	F	1,132	38	3	1	First capture in 2014
1B796EE831	06-May-13	04-Dec-14	430	580	5	F	577	19	2	1	First capture in 2014
1B796ED99D	06-May-13	04-Dec-14	420	585	6	F	577	19	2	1	First capture in 2014
003BA63ECB	14-Jan-14	02-Dec-14	350	475	4	M	322	11	1	1	First capture in 2014
5333403056	17-Jun-04	19-Mar-15	330	642	10	F	3,927	131	11	1	First capture in 2015
5216245249	13-Aug-99	17-Mar-15	360	574	7	F	5,695	190	16	1	First capture in 2015
4646761253	29-Mar-05	17-Mar-15	390	675	10	F	3,640	121	10	1	First capture in 2015
46466C1A49	26-Apr-06	20-Mar-15	490	620	4	F	3,250	108	9	1	First capture in 2015
436478455A	14-Apr-04	20-Mar-15	355	570	7	M	3,992	133	11	1	First capture in 2015
42403A6F62	22-May-01	20-Mar-15	420	670	8	F	5,050	168	14	1	First capture in 2015
2241216911	23-Oct-96	17-Mar-15	306	625	11	M	6,719	224	18	1	First capture in 2015
1C2D269177	23-Oct-09	18-Mar-15	435	560	4	F	1,972	66	5	1	First capture in 2015
1C2D067132	11-May-11	19-Mar-15	465	625	5	F	1,408	47	4	1	First capture in 2015
1B796ED90F	28-Oct-11	20-Mar-15	455	595	5	F	1,239	41	3	1	First capture in 2015
1B796B41D9	16-Oct-12	18-Mar-15	430	579	5	M	883	29	2	1	First capture in 2015
003BCC5C34	05-Jan-15	18-Mar-15	390	390	0	J	72	2	0	1	First capture in 2015
003BA62D97	09-Mar-15	19-Mar-15	350	342	< 1	M	10	0	0	1	First capture in 2015
003BA62D65	09-Mar-15	20-Mar-15	355	360	< 1	M	11	0	0	1	First capture in 2015
5324140160	25-Jul-02	05-Dec-16	285	646	12	F	5,247	175	14	1	First capture in 2016
36F2B263D6	22-Oct-12	15-Mar-16	520	635	4	F	1,240	41	3	1	First capture in 2016

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Pit tag	Release	Capture	Release	Capture	Growth/ month	Sex	Days at large	Months at large	Years at large	Number of captures	Comments
257C60B28B	13-Jun-07	16-Mar-16	460	665	7	F	3,199	107	9	1	First capture in 2016
1C2D8C1D62	16-May-12	14-Mar-16	489	619	4	F	1,398	47	4	1	First capture in 2016
1C2D697D4D	19-Feb-14	05-Dec-16	510	572	2	F	1,020	34	3	1	First capture in 2016
1C2D60F707	03-Dec-09	05-Dec-16	445	671	8	F	2,559	85	7	1	First capture in 2016
1C2D267788	05-Oct-11	05-Dec-16	475	634	5	F	1,888	63	5	1	First capture in 2016
1C2C856E15	19-May-10	16-Mar-16	470	610	5	M	2,128	71	6	1	First capture in 2016
1B796B5742	08-Dec-11	18-Mar-16	410	617	7	F	1,562	52	4	1	First capture in 2016
003BE5B93B	13-Jan-16	05-Dec-16	410	543	4	F	327	11	1	1	First capture in 2016
003BCC66EA	21-Jan-15	15-Mar-16	355	530	6	M	419	14	1	1	First capture in 2016
5335245B2C	18-Jun-04	28-Nov-17	355	624	9	F	4,911	164	13	1	First capture in 2017
4648701437	25-Jan-06	15-Mar-17	410	685	9	F	4,067	136	11	1	First capture in 2017
257C60995F	13-Jun-07	14-Mar-17	480	665	6	F	3,562	119	10	1	First capture in 2017
1C2D6C6741	04-Nov-11	28-Nov-17	435	634	7	F	2,216	74	6	1	First capture in 2017
1C2D6188C7	03-Dec-09	29-Nov-17	435	634	7	F	2,918	97	8	1	First capture in 2017
1C2D25D516	23-Oct-09	28-Nov-17	470	624	5	F	2,958	99	8	1	First capture in 2017
1C2D06BA6D	11-May-11	29-Nov-17	405	628	7	F	2,394	80	7	1	First capture in 2017
1C2C3435B7	20-Mar-09	16-Mar-17	490	626	4	F	2,918	97	8	1	First capture in 2017
1B796EEC75	21-Oct-13	29-Nov-17	492	620	4	F	1,500	50	4	1	First capture in 2017
1B796EE3DB	22-May-13	28-Nov-17	492	643	5	F	1,651	55	5	1	First capture in 2017
36F2B263D5	23-Oct-12	14-Mar-18	500	548	2	M	1,968	66	5	1	First capture in 2018
2037246223	20-Nov-95	14-Mar-18	345	660	10	F	8,150	272	22	1	First capture in 2018
1C2D642F9E	17-Dec-09	14-Mar-18	430	635	7	F	3,009	100	8	1	First capture in 2018
1C2D635C66	06-Jan-10	15-Mar-18	390	655	9	F	2,990	100	8	1	First capture in 2018
1C2D61A3F9	23-Oct-09	15-Mar-18	455	627	6	F	3,065	102	8	1	First capture in 2018
003C06CCCA	09-May-18	28-Nov-18	458	561	3	F	203	7	1	1	First capture in 2018
003BEA19E8	02-May-17	15-Mar-18	434	525	3	M	317	11	1	1	First capture in 2018
532F2A1140	17-Jun-04	12-Mar-19	340	670	11	F	5,381	179	15	1	First capture in 2019
1C2D64311A	07-Nov-14	14-Mar-19	531	614	3	F	1,588	53	4	1	First capture in 2019

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Pit tag	Release	Capture	Release	Capture	Growth/ month	Sex	Days at large	Months at large	Years at large	Number of captures	Comments
1B796B4797	08-Dec-11	13-Mar-19	400	620	7	F	2,652	88	7	1	First capture in 2019
1B7969E303	13-Oct-11	15-Mar-19	430	701	9	F	2,710	90	7	1	First capture in 2019
003BF323EB	31-Jan-19	12-Mar-19	425	419	< 1	M	40	1	0	1	First capture in 2019
003BF32067	31-Jan-19	12-Mar-19	447	444	< 1	F	40	1	0	1	First capture in 2019
003BF31E8C	31-Jan-19	12-Mar-19	446	460	< 1	F	40	1	0	1	First capture in 2019
003BF31E7E	31-Jan-19	12-Mar-19	453	419	1	F	40	1	0	1	First capture in 2019
003BCB88F9	30-Sep-15	13-Mar-19	520	630	4	F	1,260	42	3	1	First capture in 2019
424108294D	02-Oct-02	14-Mar-16	265	554	10	M	4,912	164	13	2	First capture in 2007, second capture in 2016
46486F1069	08-Jun-05	03-Dec-14	365	620	8	F	3,465	116	9	2	First capture in 2009, second capture in 2014
1C2D265EC1	23-Oct-09	03-Dec-14	430	595	6	F	1,867	62	5	2	First capture in 2010, second capture in 2014
1C2C7FE9B4	26-Mar-09	19-Mar-15	450	640	6	F	2,184	73	6	2	First capture in 2012, second capture in 2015
1C2D698C52	03-Dec-09	16-Mar-18	425	640	7	F	3,025	101	8	2	First capture in 2012, second capture in 2018
53453C2E26	18-Jun-04	16-Mar-17	350	645	10	F	4,654	155	13	2	First capture in 2013, second capture in 2017
1C2D26933A	23-Oct-09	15-Mar-18	425	650	8	F	3,065	102	8	2	First capture in 2013, second capture in 2018
1C2D63A268	03-Dec-09	20-Mar-15	445	635	6	F	1,933	64	5	2	First capture in 2014, second capture in 2015
1C2D8C9FEB	16-May-12	20-Mar-15	473	627	5	F	1,038	35	3	2	First and second captures in 2015
1B7969D55B	13-Oct-11	17-Mar-16	450	660	7	F	1,617	54	4	2	First capture in 2015, second capture in 2016
36F2B5A67A	06-Dec-12	14-Mar-19	390	591	7	M	2,289	76	6	2	First capture in 2015, second capture in 2019
36F2B5A67A	06-Dec-12	20-Mar-15	390	520	4	M	834	28	2	2	First capture in 2015, second capture in 2019
1C2D6C6905	12-Oct-11	19-Mar-15	450	641	6	F	1,254	42	3	2	First capture in 2015, second capture in 2019
003C06CAA5	15-Dec-17	12-Mar-18	445	401	< 1	M	87	3	0	2	First capture in 2018, second capture in 2019
1C2D69590E	29-Sep-10	20-Mar-15	480	645	6	F	1,633	54	4	3	First capture in 2011, second capture in 2012, third capture in 2015
1C2D6D1839	16-May-12	16-Mar-16	429	606	6	F	1,400	47	4	3	First capture in 2012, second capture in 2013, third capture in 2016
1B796EEFF9	31-Oct-13	17-Mar-15	500	575	2	F	502	17	1	3	First capture in 2015, second capture in 2018, third capture in 2019
7F7A082D4E	23-Jul-97	13-Mar-19	280	741	15	F	7,903	263	22	4	First capture in 2005, second capture in 2006, third capture in 2007, fourth capture in 2019
1B796ED720	31-Oct-13	28-Nov-17	510	643	4	F	1,489	50	4	5	First, second and third captures in 2015, fourth and fifth captures in 2017

Appendix 3. Contact data for release cohorts of razorback sucker released in River and Basin from SY 2008 through 2014. Release cohorts with less than 20 releases were removed from analysis and contact with a fish must have occurred two SY after release.

Release Zone	Release SY	Release Month	Pond	TL bin (mm)	Releases	Contacts	Proportion
Basin	2009	3	Yes	490	20	7	0.350
River	2008	4	Yes	500	20	6	0.300
Basin	2009	3	Yes	480	20	5	0.250
Basin	2012	10	Yes	480	20	4	0.200
Basin	2011	10	Yes	410	20	3	0.150
Basin	2013	5	Yes	400	20	2	0.100
River	2011	12	Yes	330	20	1	0.050
Basin	2009	5	Yes	450	20	1	0.050
Basin	2011	1	No	410	20	1	0.050
River	2012	3	No	370	20	0	0.000
River	2013	1	No	400	20	0	0.000
River	2013	4	No	340	20	0	0.000
Basin	2010	12	No	370	20	0	0.000
Basin	2011	5	Yes	410	20	0	0.000
Basin	2012	5	Yes	410	20	0	0.000
Basin	2010	5	Yes	470	21	14	0.667
Basin	2010	1	No	420	21	5	0.238
River	2012	3	No	450	21	4	0.190
River	2012	12	Yes	460	21	4	0.190
Basin	2011	5	Yes	420	21	3	0.143
Basin	2009	9	Yes	470	21	2	0.095
River	2011	12	Yes	450	21	1	0.048
River	2012	3	No	380	21	0	0.000
River	2012	4	No	380	21	0	0.000
Basin	2013	10	Yes	420	21	0	0.000
Basin	2010	1	No	270	22	0	0.000
Basin	2013	12	Yes	340	22	0	0.000
Basin	2014	12	Yes	380	22	0	0.000
Basin	2010	5	Yes	450	23	8	0.348
Basin	2010	9	Yes	460	23	7	0.304
River	2011	12	Yes	440	23	3	0.130
River	2012	3	No	440	23	3	0.130
Basin	2009	9	Yes	440	23	3	0.130
Basin	2010	10	Yes	400	23	1	0.043
Basin	2011	10	Yes	500	24	15	0.625
Basin	2009	9	Yes	490	24	9	0.375
Basin	2012	5	Yes	440	24	9	0.375
Basin	2013	10	Yes	480	24	9	0.375
Basin	2014	10	Yes	490	24	9	0.375
Basin	2010	9	Yes	450	24	6	0.250
Basin	2012	5	Yes	430	24	5	0.208
Basin	2012	5	Yes	420	24	3	0.125
Basin	2010	10	Yes	390	24	1	0.042
Basin	2010	10	Yes	420	24	1	0.042
River	2012	3	No	400	24	0	0.000
River	2014	1	No	380	24	0	0.000
River	2012	10	Yes	480	25	20	0.800
Basin	2009	9	Yes	430	25	3	0.120
Basin	2014	12	Yes	370	25	0	0.000
Basin	2011	10	Yes	490	26	12	0.462
Basin	2012	10	Yes	460	26	10	0.385
Basin	2012	5	Yes	450	26	6	0.231
Basin	2014	5	Yes	440	26	6	0.231

Release Zone	Release SY	Release Month	Pond	TL bin (mm)	Releases	Contacts	Proportion
Basin	2011	10	Yes	430	26	5	0.192
Basin	2013	5	Yes	420	26	4	0.154
River	2011	12	Yes	400	26	2	0.077
Basin	2011	5	Yes	400	26	2	0.077
River	2012	3	No	360	26	0	0.000
River	2012	12	Yes	310	26	0	0.000
River	2010	10	Yes	510	27	9	0.333
Basin	2012	10	Yes	420	27	9	0.333
River	2011	12	Yes	350	27	1	0.037
River	2012	1	No	390	27	0	0.000
Basin	2010	12	Yes	480	28	16	0.571
Basin	2011	5	Yes	450	28	9	0.321
Basin	2013	5	Yes	440	28	6	0.214
Basin	2009	9	Yes	480	28	3	0.107
River	2011	12	Yes	340	28	2	0.071
River	2011	12	Yes	430	28	1	0.036
River	2013	2	No	390	28	1	0.036
River	2013	1	No	390	28	0	0.000
River	2013	4	No	330	28	0	0.000
Basin	2012	1	No	360	28	0	0.000
Basin	2012	1	No	370	28	0	0.000
Basin	2011	10	Yes	440	29	7	0.241
River	2012	12	Yes	470	30	14	0.467
Basin	2013	5	Yes	450	30	10	0.333
Basin	2013	5	Yes	430	30	9	0.300
Basin	2009	9	Yes	460	30	2	0.067
Basin	2013	10	Yes	470	31	10	0.323
River	2012	1	No	380	31	1	0.032
Basin	2014	12	Yes	350	31	0	0.000
Basin	2013	12	Yes	440	32	8	0.250
Basin	2011	5	Yes	430	32	7	0.219
Basin	2010	9	Yes	440	32	5	0.156
Basin	2009	9	Yes	450	32	4	0.125
Basin	2010	10	Yes	440	32	4	0.125
Basin	2013	10	Yes	460	33	8	0.242
Basin	2014	12	Yes	440	33	3	0.091
River	2013	4	No	320	33	0	0.000
Basin	2010	1	No	280	33	0	0.000
Basin	2010	9	Yes	430	34	4	0.118
River	2012	3	No	310	34	0	0.000
River	2012	3	No	390	34	0	0.000
River	2012	3	No	410	34	0	0.000
River	2013	4	No	310	34	0	0.000
Basin	2014	12	Yes	390	34	0	0.000
Basin	2009	3	Yes	470	35	12	0.343
Basin	2011	5	Yes	440	35	10	0.286
Basin	2013	10	Yes	450	35	5	0.143
River	2011	12	Yes	370	35	0	0.000
River	2011	12	Yes	410	36	3	0.083
Basin	2012	10	Yes	450	37	18	0.486
River	2012	10	Yes	460	37	17	0.459
Basin	2011	10	Yes	450	37	7	0.189
River	2010	10	Yes	350	37	1	0.027
Basin	2014	5	Yes	400	37	1	0.027
River	2011	12	Yes	380	38	5	0.132
River	2013	12	Yes	420	38	1	0.026
Basin	2012	1	No	350	38	1	0.026

Release Zone	Release SY	Release Month	Pond	TL bin (mm)	Releases	Contacts	Proportion
River	2010	1	No	480	40	21	0.525
Basin	2013	10	Yes	440	40	5	0.125
Basin	2011	10	Yes	470	41	12	0.293
Basin	2012	5	Yes	400	41	4	0.098
River	2013	4	No	300	41	0	0.000
Basin	2012	10	Yes	430	43	18	0.419
River	2010	10	Yes	500	43	17	0.395
Basin	2010	12	Yes	420	43	8	0.186
River	2012	3	No	420	43	2	0.047
Basin	2014	1	No	380	43	2	0.047
River	2013	2	No	380	43	0	0.000
River	2012	10	Yes	450	44	21	0.477
River	2012	12	Yes	450	44	15	0.341
River	2011	12	Yes	360	44	2	0.045
River	2011	12	Yes	420	44	1	0.023
Basin	2011	1	No	400	44	1	0.023
River	2012	3	No	320	44	0	0.000
River	2011	12	Yes	390	45	4	0.089
Basin	2011	10	Yes	460	46	9	0.196
River	2012	12	Yes	320	46	0	0.000
Basin	2011	10	Yes	480	47	15	0.319
Basin	2009	10	Yes	470	47	4	0.085
River	2013	2	No	370	47	1	0.021
Basin	2009	10	Yes	410	47	1	0.021
Basin	2014	12	Yes	400	47	0	0.000
Basin	2010	12	Yes	470	48	23	0.479
River	2012	10	Yes	440	48	16	0.333
Basin	2010	1	No	290	48	0	0.000
River	2012	10	Yes	470	49	26	0.531
River	2010	10	Yes	490	49	23	0.469
Basin	2012	10	Yes	440	49	22	0.449
River	2012	3	No	350	49	0	0.000
River	2011	12	No	360	50	0	0.000
River	2013	1	No	380	50	0	0.000
Basin	2013	12	Yes	430	51	11	0.216
Basin	2010	1	No	410	51	5	0.098
Basin	2014	12	Yes	430	51	2	0.039
River	2012	12	Yes	440	52	17	0.327
Basin	2010	12	Yes	430	53	11	0.208
Basin	2013	1	No	400	54	5	0.093
River	2012	12	Yes	300	54	0	0.000
River	2013	12	Yes	410	54	0	0.000
Basin	2010	12	Yes	440	55	23	0.418
Basin	2013	12	Yes	350	55	0	0.000
Basin	2014	12	Yes	410	56	0	0.000
River	2013	12	Yes	320	57	0	0.000
Basin	2009	3	Yes	450	59	20	0.339
River	2010	12	No	320	59	0	0.000
Basin	2014	12	Yes	420	59	0	0.000
Basin	2010	12	Yes	450	60	17	0.283
River	2012	10	Yes	410	60	6	0.100
Basin	2009	10	Yes	420	60	3	0.050
River	2012	3	No	330	60	0	0.000
River	2012	10	Yes	430	61	14	0.230
Basin	2011	1	No	390	62	0	0.000
Basin	2009	3	Yes	460	64	21	0.328
Basin	2009	10	Yes	460	65	8	0.123

Release Zone	Release SY	Release Month	Pond	TL bin (mm)	Releases	Contacts	Proportion
Basin	2009	10	Yes	400	65	3	0.046
River	2012	3	No	340	65	0	0.000
River	2010	10	Yes	360	66	4	0.061
River	2012	10	Yes	400	66	3	0.045
River	2010	12	No	370	69	1	0.014
Basin	2009	10	Yes	440	72	1	0.014
River	2012	1	No	370	72	0	0.000
Basin	2010	12	Yes	460	73	29	0.397
River	2012	10	Yes	420	73	14	0.192
Basin	2009	10	Yes	450	73	5	0.068
Basin	2013	1	No	390	73	3	0.041
River	2012	12	Yes	430	74	21	0.284
Basin	2014	5	Yes	430	74	11	0.149
River	2012	12	Yes	330	74	0	0.000
River	2014	1	No	370	77	0	0.000
Basin	2011	1	No	380	78	1	0.013
River	2013	12	Yes	400	79	0	0.000
Basin	2010	12	No	360	83	0	0.000
Basin	2012	1	No	340	83	0	0.000
Basin	2009	10	Yes	430	85	3	0.035
Basin	2010	1	No	400	89	12	0.135
River	2011	12	No	350	89	1	0.011
River	2010	10	Yes	480	91	31	0.341
River	2012	12	Yes	420	91	26	0.286
Basin	2014	5	Yes	420	93	10	0.108
Basin	2012	1	No	330	94	0	0.000
Basin	2013	1	No	380	97	3	0.031
River	2010	1	No	470	102	55	0.539
Basin	2014	5	Yes	410	105	15	0.143
Basin	2013	12	Yes	420	105	9	0.086
River	2013	2	No	360	105	1	0.010
River	2012	1	No	360	106	0	0.000
River	2013	1	No	370	106	0	0.000
River	2012	12	Yes	340	111	1	0.009
River	2013	12	Yes	330	111	0	0.000
River	2010	1	No	370	115	0	0.000
River	2010	10	Yes	370	116	1	0.009
River	2010	10	Yes	470	117	41	0.350
Basin	2011	1	No	370	117	2	0.017
Basin	2010	1	No	390	118	12	0.102
Basin	2010	1	No	380	120	5	0.042
Basin	2012	1	No	300	120	0	0.000
Basin	2010	12	No	350	121	2	0.017
Basin	2013	12	Yes	410	123	6	0.049
Basin	2010	12	No	300	123	0	0.000
Basin	2012	1	No	320	129	0	0.000
River	2010	1	No	300	131	0	0.000
Basin	2010	1	No	300	133	0	0.000
River	2011	12	No	340	136	0	0.000
River	2010	1	No	460	138	60	0.435
River	2013	2	No	350	138	0	0.000
River	2013	12	Yes	340	138	0	0.000
Basin	2012	1	No	310	143	0	0.000
River	2012	12	Yes	350	144	4	0.028
River	2012	12	Yes	360	144	2	0.014
Basin	2014	1	No	370	145	3	0.021
Basin	2013	12	Yes	360	147	2	0.014

Release Zone	Release SY	Release Month	Pond	TL bin (mm)	Releases	Contacts	Proportion
River	2013	1	No	360	149	0	0.000
River	2010	1	No	360	151	4	0.026
River	2010	1	No	380	151	1	0.007
River	2013	12	Yes	390	159	0	0.000
Basin	2013	1	No	370	161	2	0.012
River	2013	12	Yes	380	162	0	0.000
River	2012	12	Yes	410	165	51	0.309
Basin	2011	1	No	360	165	0	0.000
Basin	2011	1	No	300	167	0	0.000
River	2010	10	Yes	380	169	5	0.030
Basin	2010	1	No	310	172	0	0.000
River	2010	1	No	390	176	1	0.006
Basin	2013	12	Yes	370	178	5	0.028
River	2012	1	No	350	181	0	0.000
River	2010	10	Yes	460	182	67	0.368
Basin	2013	12	Yes	400	184	8	0.043
River	2012	12	Yes	370	184	7	0.038
River	2010	1	No	350	184	0	0.000
River	2013	12	Yes	350	188	0	0.000
River	2013	2	No	340	190	1	0.005
River	2014	1	No	360	191	0	0.000
Basin	2011	1	No	350	191	0	0.000
Basin	2013	1	No	360	193	4	0.021
River	2010	1	No	450	194	80	0.412
River	2010	1	No	400	194	7	0.036
Basin	2010	1	No	370	198	4	0.020
River	2012	12	Yes	400	203	64	0.315
River	2010	12	No	360	203	7	0.034
River	2013	1	No	350	205	0	0.000
River	2010	1	No	440	210	77	0.367
Basin	2010	12	No	340	212	1	0.005
River	2010	1	No	430	214	63	0.294
River	2013	12	Yes	370	214	0	0.000
River	2011	12	No	330	215	2	0.009
River	2013	12	Yes	360	219	0	0.000
Basin	2013	12	Yes	390	223	10	0.045
River	2012	1	No	340	223	0	0.000
Basin	2011	1	No	340	237	1	0.004
Basin	2011	1	No	310	244	1	0.004
River	2012	1	No	300	245	0	0.000
River	2010	1	No	340	251	0	0.000
River	2010	1	No	410	252	21	0.083
Basin	2010	1	No	360	252	4	0.016
Basin	2010	1	No	320	252	0	0.000
River	2014	1	No	300	254	0	0.000
River	2010	1	No	310	256	0	0.000
River	2010	1	No	420	257	35	0.136
Basin	2014	1	No	360	259	8	0.031
River	2012	12	Yes	380	260	20	0.077
River	2012	12	Yes	390	262	49	0.187
Basin	2013	12	Yes	380	262	14	0.053
River	2010	1	No	330	262	0	0.000
River	2013	2	No	330	263	0	0.000
River	2010	1	No	320	265	0	0.000
River	2013	2	No	300	273	0	0.000
River	2011	12	No	300	275	0	0.000
Basin	2011	1	No	320	275	0	0.000

Release Zone	Release SY	Release Month	Pond	TL bin (mm)	Releases	Contacts	Proportion
River	2010	10	Yes	450	277	95	0.343
River	2013	1	No	340	278	0	0.000
River	2012	1	No	330	279	0	0.000
Basin	2010	12	No	310	285	0	0.000
Basin	2011	1	No	330	285	0	0.000
Basin	2013	1	No	350	288	4	0.014
River	2010	12	No	330	288	0	0.000
River	2012	1	No	310	298	0	0.000
River	2012	1	No	320	299	0	0.000
Basin	2010	1	No	350	303	3	0.010
River	2013	2	No	320	304	1	0.003
River	2011	12	No	320	317	3	0.009
River	2013	2	No	310	317	0	0.000
Basin	2014	1	No	300	325	1	0.003
River	2010	10	Yes	390	329	19	0.058
Basin	2010	12	No	330	339	2	0.006
Basin	2010	1	No	330	348	3	0.009
River	2013	1	No	330	359	0	0.000
Basin	2010	1	No	340	360	6	0.017
River	2014	1	No	350	364	0	0.000
River	2010	10	Yes	440	371	106	0.286
River	2010	12	No	350	378	10	0.026
Basin	2013	1	No	340	378	3	0.008
Basin	2013	1	No	300	379	0	0.000
River	2011	12	No	310	395	1	0.003
River	2010	12	No	340	418	2	0.005
Basin	2010	12	No	320	424	2	0.005
River	2010	10	Yes	430	448	115	0.257
River	2013	1	No	320	458	0	0.000
River	2014	1	No	340	460	0	0.000
Basin	2014	1	No	350	472	4	0.008
Basin	2013	1	No	330	472	1	0.002
River	2013	1	No	310	484	0	0.000
Basin	2013	1	No	310	509	0	0.000
River	2013	1	No	300	510	1	0.002
Basin	2014	1	No	310	520	0	0.000
River	2014	1	No	330	522	0	0.000
River	2010	10	Yes	420	528	102	0.193
River	2014	1	No	310	530	0	0.000
River	2014	1	No	320	551	0	0.000
River	2010	10	Yes	410	553	60	0.108
Basin	2013	1	No	320	555	3	0.005
Basin	2014	1	No	340	639	3	0.005
Basin	2014	1	No	330	666	5	0.008
Basin	2014	1	No	320	694	0	0.000
River	2010	10	Yes	400	1380	113	0.082