Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Comparative Survival of Repatriated Razorback Sucker in Lower Colorado River Reach 3

2014 Annual Report

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

February 2015

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Lower Colorado River Multi-Species Conservation Program

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February 2015

Ehlo, C.A. B.R. Kesner, and P.C. Marsh. 2015. Comparative Survival of Repatriated Razorback Sucker in Lower Colorado River Reach 3, 2014 Annual Report. Prepared by Marsh & Associates, LLC, for the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

ACRONYMS AND ABBREVIATIONS

CI	confidence interval
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
M&A	Marsh & Associates, LLC
m	meter(s)
mm	millimeter(s)
NFWG	lower Colorado River Native Fish Work Group
PIT	passive integrated transponder
PVC	polyvinyl chloride
Reclamation	Bureau of Reclamation
RKM	Reservoir Kilometer
RM	Reservoir Mile
TL	total length
UTM	Universal Transverse Mercator

Symbols

>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to
%	percent

CONTENTS

Tables

Figures

EXECUTIVE SUMMARY

Razorback sucker (*Xyrauchen texanus*) is a fish endemic to the Colorado River drainage. It was once abundant throughout its range, but populations have steadily declined, and the species now is listed as endangered. Under guidance of the Lower Colorado River Multi-Species Conservation Program (LCR MSCP), 51,000 razorback suckers have been stocked into Reach 3 since 2006. Contact rates of stocked fish have been low using traditional fisheries sampling methods (i.e., electrofishing and trammel nets); however, the use of remote passive integrated transponder (PIT) scanning technology has proven effective at contacting a large proportion of the population.

Remote PIT scanners were deployed in Reach 3 for 4 months from January to April 2014, from Davis Dam downstream to Park Moabi Regional Park, California, to target spawning aggregates of razorback sucker. In addition, data were compiled from other projects and entities that scanned in Reach 3 from October 2013 to May 2014. These collective efforts resulted in the contact of 2,324 individual fish.

A total of 2,442 native fish were contacted through a combination of remote PIT scanning and standard sampling methodologies in 2014. Of these, 1,730 individual razorback suckers were included in a 2013 population estimate that produced an estimate of 4,456 (4,089–4,855; 95-percent [%] confidence interval [CI]) individuals.

Relative capture rates of razorback sucker were directly related to the size of the fish at release. Contact rates (95% CI) were lowest at 0.01 (0.003–0.03) for fish released at < 299 millimeters (mm), increased at each size class, and were highest at 0.11 (0.803–0.15) for fish released at > 500 mm. As elsewhere throughout the lower Colorado River, size at release is strongly associated with post-release survival in Reach 3. Contact rates differed between stocking location and were significantly lower in Zone 3-4 at 0.01 (0.005–0.01) and highest for fish stocked in Zone 3-2 at 0.05 (0.044–0.051). Contact rates were similar between Zone 3-1 at 0.03 (0.026-0.031) and Zone 3-3 at 0.03 (0.024–0.032). Contact rates were higher for fish released in the spring months at 0.04 (0.039–0.043) than in the autumn months at 0.01 (0.009–0.013).

PIT scanning continues to provide increased contacts of fish compared to traditional means such as electrofishing and trammel netting. Monitoring of razorback sucker in LCR MSCP Reach 3 should continue with both remote PIT scanning and biannual netting trips. As more data are collected, a more indepth analysis of post-stocking dynamics will provide additional information to assess post-stocking survival of razorback sucker in Reach 3.

INTRODUCTION

Razorback sucker (*Xyrauchen texanus*) is a fish endemic to the Colorado River that was once abundant and widespread throughout the drainage (Minckley 1973). Its distribution and numbers have dwindled, and the species is currently listed as endangered under the Endangered Species Act (U.S. Fish and Wildlife Service 1991). Population decline is largely attributed to habitat alterations associated with dam construction and direct and indirect interactions with introduced non-native fish species (Joseph et al. 1977; Minckley 1979; Bestgen 1990; Minckley et al. 1991; Mueller and Marsh 2002).

The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) was implemented in 2005 to balance the use of water resources and conservation of native species and their habitat in compliance with the Endangered Species Act (Bureau of Reclamation [Reclamation] 2004). The lower Colorado River has been subdivided into designated planning areas and river reaches to address these goals. LCR MSCP Reach 3 is the 135-kilometer section along the Arizona-Nevada and Arizona-California borders between Davis and Parker Dams. The reach includes an 87-kilometer riverine section immediately downstream from Davis Dam and the entirety of Lake Havasu proper, which is impounded by Parker Dam (figure 1).

Minckley (1983) hypothesized that razorback sucker populations experienced highly successful recruitment events immediately following impoundment of reservoirs in the lower Colorado River Basin. Lake Havasu was impounded in 1938, but recruitment events became rare due to negative interactions with non-native sport fishes. As a result, populations began to decline, and the last documented capture of wild adults was in Laughlin Lagoon in 1986 (Marsh and Minckley 1989). A population persists today only because of annual stocking efforts that began with larval stocking in 1986 (Marsh and Minckley 1989) and continued with nearly 500,000 mostly small razorback sucker stocked between 1986 and 2005 (Schooley and Marsh 2007, unpublished data).

Under guidance of the LCR MSCP, 51,000 larger razorback sucker (> 300 millimeters [mm]) have been stocked into Reach 3 since 2006. Post-stocking research and monitoring activities have resulted in the capture of very few fish from early stockings, and while individuals from more recent stockings have comparatively higher contact rates, absolute capture rates using standard fisheries gear (i.e., electrofishing and trammel nets) have remained low (< 3 percent [%]) (Patterson et al. 2014). Therefore, calculating accurate population estimates and isolating specific factors affecting survival of repatriated razorback sucker in Reach 3 presents a challenge.

Razorback sucker have been found to aggregate in major spawning areas from Laughlin, Nevada, downstream to Needles, California (Wydoski and Mueller 2006; Wydoski and Lantow 2012). Remote passive integrated transponder (PIT)

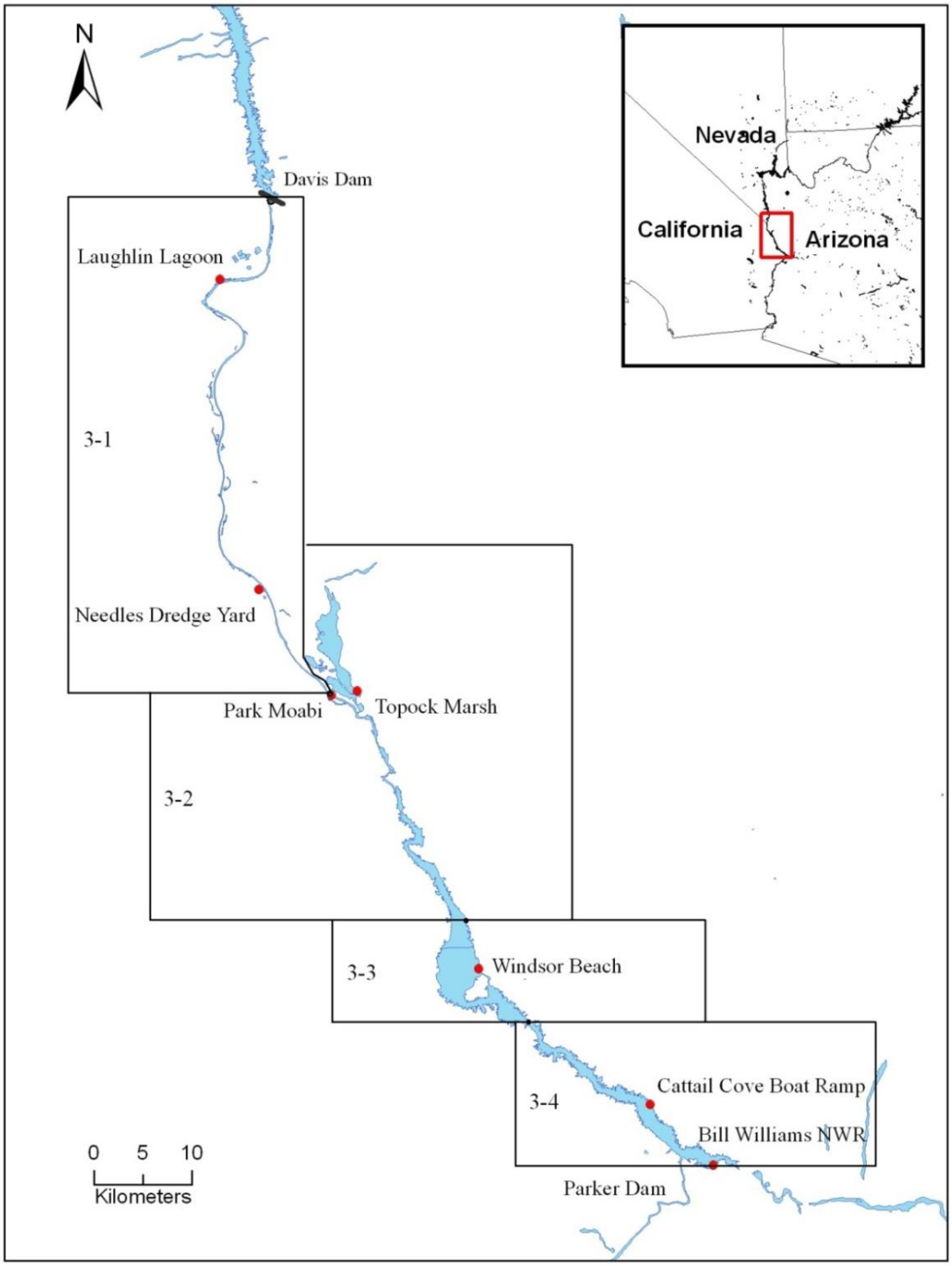

Figure 1.—Overview map of the study area depicting LCR MSCP Reach 3, including general remote PIT scanning and stocking locations, and general Zones 3-1 to 3-4 established in the "Methods" section, lower Colorado River, Arizona-California-Nevada.

scanning of spawning aggregates has proven successful in Reach 3 as well as in Lake Mohave, which occupies LCR MSCP Reach 2 (Kesner et al. 2014; Patterson et al. 2014). Because of the success of these previous studies, we continued with remote PIT scanning in Reach 3 from January to April 2014. In addition, we compiled PIT scanning and capture data collected from other projects from October 2013 to May 2014 to be used for this study.

Here we report the results and conclusions of remote PIT scanning, assess the current Reach 3 razorback sucker population, and evaluate the effects of size, location, and timing of release on post-stocking survival. This information is integral in formulating a cost-effective, efficient method to restore the razorback sucker population in Reach 3. Specific objectives from the study period include:

1. Contact razorback sucker using remote PIT scanning units in Zones 3-1 and 3-2

2. Assimilate all Reach 3 razorback sucker release and capture data collected by any entity

3. Estimate the current repatriate razorback sucker population

4. Estimate the survival of razorback sucker released in Reach 3 based on size, location, and season of release since 2005

5. Participate in annual multi-agency native fish surveys

This information will aid in completion of LCR MSCP Work Task C33: Comparative Survival of 500-mm Razorback Sucker Released in Reach 3.

METHODS

Study Area

Lake Havasu is impounded by Parker Dam, constructed by Reclamation and began impounding water in 1938. The reservoir has a 7.98 x 108 cubic meter storage capacity regulated by releases at the upstream terminus (Davis Dam), downstream terminus (Parker Dam), and less significantly through releases into the Bill Williams River from Alamo Dam. For this study, Reach 3 (including Lake Havasu) has been separated into four distinct zones based largely on habitat types (see figure 1). Moving downstream from Davis Dam, the first zone, Zone 3-1, encompasses clear, fast- flowing waters of the riverine section from the dam downstream to Reservoir Kilometer (RKM) 70.6 (Reservoir Mile, [RM] 43.9). The shoreline is low lying and relatively well developed. Zone 3-2 is characterized by slower waters, rocky canyon-like shoreline, and contains the highest concentration of backwater habitat in Reach 3. It encompasses Park Moabi, Topock Marsh, and the Lake Havasu delta region from RKM 70.6 (RM 43.9) downstream to RKM 39.7 (RM 24.7). Zone 3-3 has gently sloping surrounding shoreline and is the open water portion of the reservoir from the bottom of the delta, RKM 39.7 (RM 24.7) to immediately upstream of Copper Canyon, where the reservoir once again narrows at RKM 23.3 (RM 14.5). The fourth zone, Zone 3-4, extends from Copper Canyon downstream to Parker Dam and includes the Bill Williams River National Wildlife Refuge.

Remote PIT Scanning

Remote PIT scanning units were deployed from January 21 to April 24, 2014, between Davis Dam and Needles, California. Three models of PIT scanners were utilized: two large, shore-based units; eight completely submersible units; and one prototype neutrally buoyant submersible unit. Shore-based units were comprised of a 1.9 x 0.8 meter (m) polyvinyl chloride (PVC) antenna frame with a built-in scanner connected to a shore-based, waterproof box housing. The waterproof housing was equipped with either a "mini logger" or "black box logger." One shore-based unit was connected to a 21 amp-hour battery with a 12-watt solar panel to maintain the battery's charge. The other shore-based unit was connected to a 12 amp-hour 6-volt battery and 3-watt solar panel. Both battery-solar panel units were capable of continuously powering the scanner for at least 72 hours. These units were deployed the first afternoon we arrived to the field site and left to run until retrieved the last morning of sampling before departing the site. The submersible units consisted of a 0.8 x 0.8 m PVC antenna frame with a scanner, "mini logger," and 10.4 amp-hour battery contained in PVC/acrylonitrile butadiene styrene piping. A sandbag was attached to each unit to keep it in place under water. Units were retrieved approximately every 24 hours and downloaded on site; the battery was replaced before redeployment. The prototype antennae was comprised of a 1.2 x 0.8 m PVC frame antenna attached to a scanner, logger, and a 20.8 amp-hour battery contained in watertight PVC piping. This unit could be equipped with weights so it could be oriented to lie flat along the bottom (bottom flat) or to stand upright in the water column (bottom long). It was deployed the first afternoon we arrived to the field site and left to run until retrieved the last morning of sampling before departing the site. Eight to 11 of these units were deployed throughout the scanning season; each unit was assigned and labeled with a four-character alpha-numeric code (unit ID, e.g., RT03) for individual identification, which allowed data downloads to be matched with deployment locations.

Shore-based units were deployed at three locations: Razorback Island, Laughlin Lagoon, and Topock Marsh (figures 2 and 3). The waterproof boxes could be easily hidden in these areas and were accessible only by boat. Submersible units

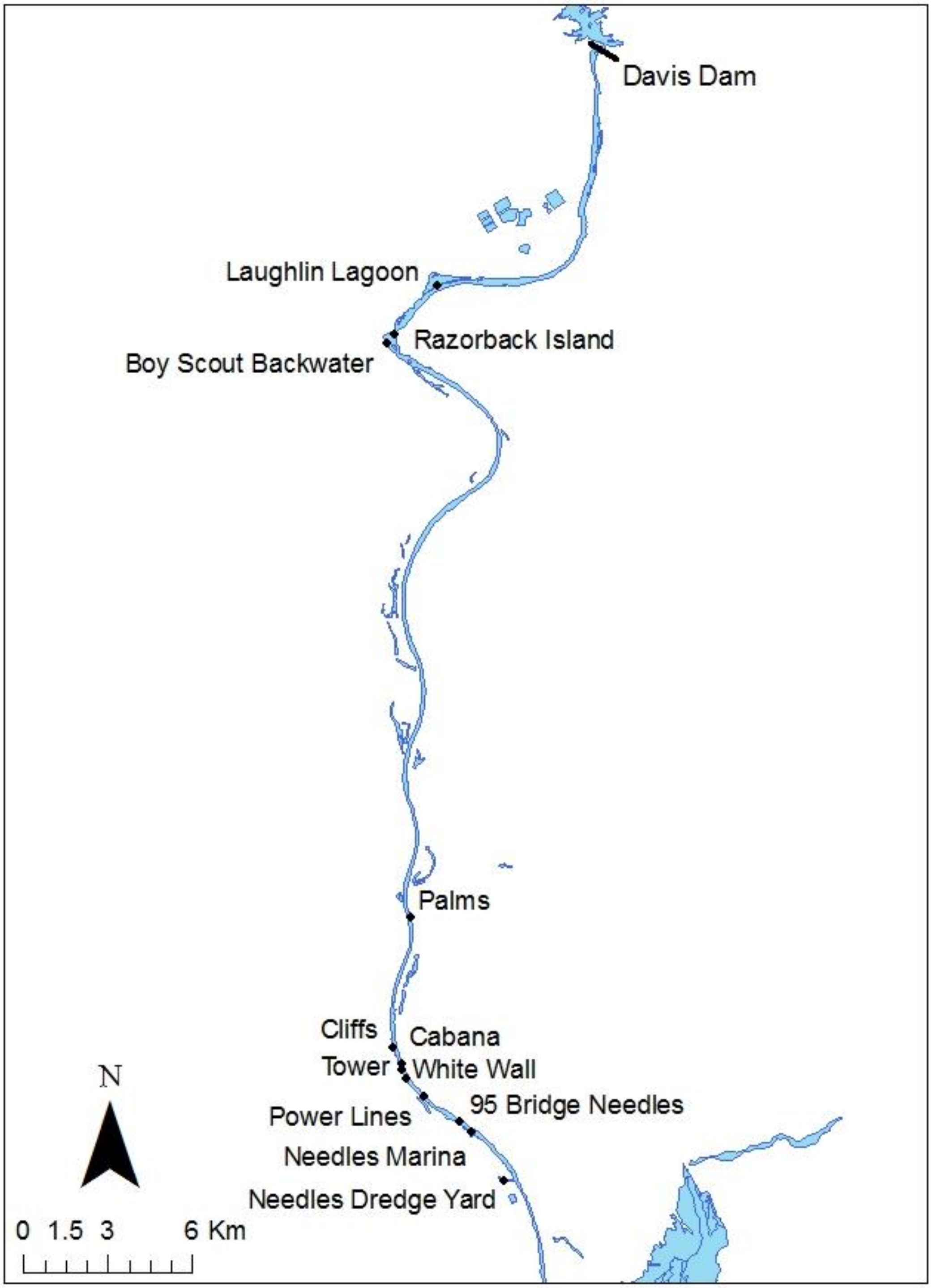

Figure 2.—Location of remote PIT scanning deployment by any entity in LCR MSCP Reach 3, Zone 3-1, between October 1, 2013, and May 31, 2014, lower Colorado River, Arizona-California-Nevada.

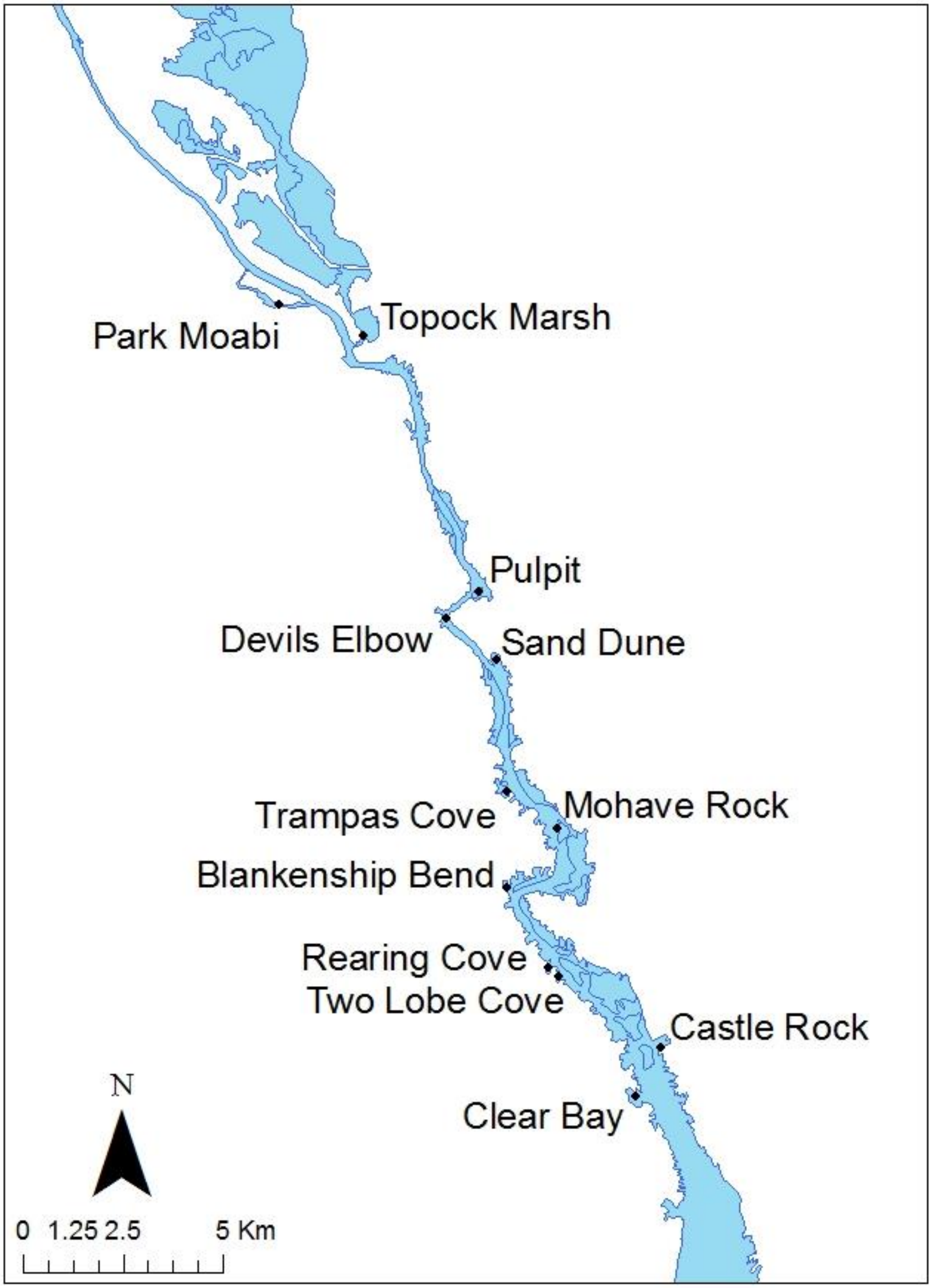

Figure 3.—Location of remote PIT scanning deployment by any entity in LCR MSCP Reach 3, Zone 3-2, between October 1, 2013, and May 31, 2014, lower Colorado River, Arizona-California-Nevada.

were deployed at nine different general areas, moving downstream: Laughlin Lagoon near Laughlin, Nevada; and Palms, Cliffs, Cabana, Tower, White Wall, Power Lines, Needles Dredge Yard, and Topock Marsh near Needles, California (see figures 2 and 3). The prototype submersible unit was deployed at two locations: Laughlin Lagoon and Needles Dredge Yard. Locations monitored varied from trip to trip based on fish concentrations, but each trip consisted of 3 nights and 2 days of continuous scanning.

Remote PIT scanning information for each individual deployment was recorded on waterproof datasheets as follows: location, river right or river left, unit deployed, battery deployed, Universal Transverse Mercator (UTM) zone, UTM easting, UTM northing, depth (m) of deployed unit, date and time deployed, date and time retrieved, start time of scanner, end time or run interval of scanner, stop interval, scan time (minutes), unit orientation in water, purpose of scanning, comments, and a check box to indicate if any equipment malfunctioned. All information, including downloaded contact data, was incorporated into a MySQL database maintained by Marsh & Associates, LLC (M&A) and hosted by Hostmonster.com (http://www.hostmonster.com/) using an online form within a password-protected section of the M&A Web site (http://www.nativefishlab.net). Microsoft® Access 2010 was used for data management.

Electrofishing and Routine Monitoring

Potential razorback sucker habitat was electrofished at Laughlin Lagoon and Razorback Island (see figure 2) to seek out potential subpopulations for scanning in those areas. These efforts occurred at night under supervision of the project's Contracting Officers Representative with three netters present. All razorback sucker captured were measured for total length (mm) and weight (grams), sexed, assessed for sexual ripeness, scanned for a wire tag, scanned for a 125- or 134.2 (hereafter 134)-kHz PIT tag, and tagged with a 134-kHz PIT tag if no tag was detected. A right pectoral fin clip was taken from each individual, preserved in a 1-milliliter snap-cap tube with 95% ethanol, and sent to the Conservation Genetics Laboratory at Wayne State University, Detroit, Michigan, for analysis. All fish were then returned to their point of capture.

Biologists from M&A assisted with trammel netting in Zone 3-2 from Clear Bay upstream to Park Moabi on February 10 to February 14, 2014 (see figure 3). Multifilament trammel nets (45.7 or 91.4 m x 1.8 m, 3.8-centimeter stretch mesh, 30.5-centimeter bar outer wall) were deployed in overnight sets and redeployed for four consecutive nights. All razorback sucker and bonytail (*Gila elegans*) captured were processed as described above. Non-native fish were identified to species and enumerated. All fish were then returned to their point of capture. Electrofishing and monitoring data were entered into the comprehensive lower

Colorado River Native Fish Work Group (NFWG) PIT tag and stocking database maintained by M&A on behalf of all partners engaged in conservation activities for big-river fishes in the lower Colorado River.

Population Estimate

We employed the modified Petersen formula (Ricker 1975) on paired census data (January 1 through March 31) to calculate a single census population estimate (N^*) for razorback sucker in 2013:

$$N\hat{}^* = ((M+1)\ (C+1))/(R+1)$$

Fish to be included in the estimate (M, C, and R) must have been released or tagged prior to the sampling year, before January 1, 2013, for the 2013 estimate. Only fish with a 134-kHz PIT tag release or capture record in the NFWG PIT tag database were included in the estimate (i.e., fish tagged with a 125- and 134-kHz PIT tag were not included). All releases were into the main stem or reservoir or into backwaters connected to the river; none were into habitats permanently isolated from the river.

Definitions for M, C, and R from Ricker (1975) have been modified for our purposes. M is not the number of fish tagged and placed into a water body but the number of fish contacted in the designated mark period (January 1 to March 31, 2013). Catch, C, is the number of fish contacted in the second period of the paired data, extended to include all scanning data in the current year through August (January 1 to August 31, 2014). Recapture, R, is the number of fish contacted in both mark and catch periods for the 2013 estimate. Fish contacted more than once in mark or catch periods were only included in the analysis for their first encounter event in each time frame. Confidence intervals (CIs) were derived using the normal distribution, valid when recaptures are > 30 (Seber 1973).

To be unbiased, a model should meet three assumptions when applying the Chapman modified Petersen estimate (Pollock et al. 1990): (1) the population is closed to both deletions and additions, (2) no tags are lost or omitted, and (3) equal catchability of all individuals. All of these assumptions are met under the current application.[1] This study only includes known individuals added to the system with a 134-kH PIT tag before the period of the mark (M) and individuals

[1] Tag loss and emigration are distinct possibilities, but they both can be considered losses to the population just as natural mortality. The lost tag issue is only important if fish that lost tags were improperly counted as part of C and not R when they actually were recaptures. Because we do not include fish without tags in either M or C, if a fish loses a tag between mark and capture, it would be the same as if the fish died between M and C. These factors all have the same effect on the population estimate and make no difference except to validate the estimate for the marking period.

that were captured without a 134-kH tag but had one implanted before January 1, 2013. Emigration out of Lake Havasu by passing through Parker Dam or deletion of fish through water intake structures is negligible in this system because razorback sucker have only been found to occupy regions of the reservoir upstream of these structures (Wydoski et al. 2010). PIT tags are considered a permanent tag (Zydlewski et al. 2003); thus, deletion due to natural mortality is the only factor present, and this does not bias the estimate. Efforts employed to sample razorback sucker are diverse both methodologically and geographically, which imparts equal catchability of individuals.

Post-Stocking Survival

Remote PIT scanning contact rates were used as an index to post-stocking survival. Size at release for this study was assessed by dividing up the stocked fish and the contacted fish (by remote PIT scanning, trammel netting, and electrofishing) into six size classes or cohorts based on TL at release: one (≤ 299 mm), two (300–349 mm), three (350–399 mm), four (400–449 mm), five (450–499 mm), and six (≥ 500 mm). Only fish with a TL measurement at stocking were included in the analysis. Cohorts and number of fish scanned in each cohort were tabulated by year. Relative capture rates (number contacted/number released) were evaluated for each size class. Ninety-five percent binomial CIs were calculated for each contact rate. CIs that did not overlap were determined as significant.

The location and season of release were evaluated by dividing the location of release into four zones (Zones 3-1, 3-2, 3-3, and 3-4) and the seasons into spring (January – May) and autumn (October – December). The number of fish stocked in each location and season, as well as the number of fish contacted from each stocking and the relative capture rates, were tabulated. Only fish with a location or date of stocking were used in the analysis. Ninety-five percent binomial CIs where calculated for each contact rate. CIs that did not overlap were determined as significant.

RESULTS

Remote PIT Scanning

Remote PIT scanning in Reach 3 was performed by two entities in 2013–14: M&A and Reclamation. M&A scanning was implemented in Reach 3, Zones 3-1 and 3-2. Seven trips were taken in Zone 3-1 (see figure 2) from January to April 2014 and primarily focused on razorback sucker scanning directly related to this study. Seven trips were taken for a separate project in Zone 3-2 (see figure 3) from October 2013 to February 2014 and primarily focused on bonytail scanning. Efforts in Zone 3-1 resulted in 3,820 hours of scanning and 1,518 individual fish contacted. Efforts in Zone 3-2 resulted in 6,958.4 hours of scanning and 463 individual fish contacted. Reclamation scanning was done over seven trips from November 2013 to May 2014 in Reach 3, Zones 3-1 and 3-2, with the majority of efforts in Zone 3-2 (see figure 3). Their efforts resulted in 2,599.3 hours of scanning and 414 individual fish contacted. Razorback sucker data collected from both the bonytail and Reclamation efforts were incorporated into the analysis for this report. Overall, 2,324 individual fish were contacted. Of these, 2,291 have a tagging record. The majority of the fish (1,972) were razorback sucker; however, 314 bonytail and 5 flannelmouth sucker (*Catostomus latipinnis*) were scanned as well. Of the 1,972 razorback sucker, 1,923 were released with a 134-kHz tag.

Electrofishing and Routine Monitoring

Electrofishing efforts resulted in 1,926 seconds of electrofishing and the capture of 37 razorback sucker in Laughlin Lagoon and 500 seconds of electrofishing and the capture of 13 fish at Razorback Island. TL ranged from 431–700 mm, with an average length of 528 mm. Eleven of the fish in Laughlin Lagoon were untagged, and each was implanted with a 134-kHz PIT tag; four of these untagged fish had missing pectoral fins, presumably from fin clipping. The untagged razorback suckers were likely small fish harvested from Lake Mohave backwaters and were not implanted with PIT tags prior to being stocked into Laughlin Lagoon (J. Lantow, 2014, personal communication). All recaptured fish had 134-kHz PIT tags.

A total of 614 fish of all species were captured in trammel nets during routine annual monitoring. Of these, 27 were razorback sucker, and 5 were bonytail. TL of razorback sucker ranged from 385–600 mm, with an average length of 512 mm. Sixteen of the razorback suckers were sexed as female, nine were male, and two were not sexed. Three of the fish were untagged, and each was implanted with a 134-kHz PIT tag. All recaptured fish had 134-kHz PIT tags.

Population Estimate

Population estimates for Reach 3 were calculated with scanning data alone and scanning data combined with capture data. For scanning alone, the estimated 134-kHz PIT-tagged razorback sucker population in 2013 for Reach 3 was 4,196 individuals (3,850–4,573; 95% CI); 1,313, 1,653, and 517 for mark, capture, and recapture, respectively. Combining scanning and capture data resulted in an estimated population of 4,456 (4,089–4,855; 95% CI); 1,335, 1,730, and 518 for mark, capture, and recapture, respectively.

Post-Stocking Survival

A total of 51,066 razorback sucker with 134-kHz PIT tags were released into Reach 3 between January 1, 2006, and December 31, 2013. The majority of fish (96%) were released in size classes two (300–349 mm), three (350–399 mm), and four (400–449 mm) (table 1). A combined total of 2,442 individual repatriated fish were contacted by scanning, netting, and electrofishing from October 1, 2013, to May 31, 2014. A portion of the contacts included fish contacted in electrofishing and trammel netting efforts in which M&A did not participate, and therefore, those individual numbers are not stated in this report. The majority of contacts (90%) were fish released in size classes two, three, and four (table 1). Relative contact rates (95% CI) were significantly lowest for fish released at ≤ 299 mm at 0.01 (0.003–0.03) and fish released at 300–349 mm at 0.02 (0.022–0.026). Relative contact rates increased as size increased. Fish released at 350–399 mm had a contact rate of 0.04 (0.035–0.041), and fish released at 400–449 mm had a contact rate of 0.06 (0.054–0.065). The relative contact rate was significantly highest for fish released at 450–499 mm and fish released at > 500 mm at 0.08 (0.069–0.096) and 0.11 (0.803–0.15), respectively (table 2; figure 4).

The majority of fish were stocked into Zone 3-1. However, relative contact rates (95% CI) were highest for fish stocked in Zone 3-2 at 0.05 (0.044–0.051). Contact rates were lowest for fish stocked in Zone 3-4 at 0.007 (0.005–0.01) and similar for fish stocked in Zone 3-1 at 0.03 (0.026–0.031) and Zone 3-3 at 0.03 (0.024–0.032). By season, the majority of fish (77 %) were stocked in the spring, and the majority of scanned fish (93%) came from spring stockings. Relative contact rates (95% CI) were also higher in the spring at 0.04 (0.039–0.043) than in the autumn at 0.01 (0.009–0.013).

DISCUSSION

Population estimates were higher for 2012 and 2013 compared to 2011 (Patterson et al. 2014) (table 3). Utilization of PIT scanning technology began in 2012, which increased detectability of fish and, therefore, increased the number of captures for the 2011 estimate. The prior year fish were sampled with only traditional means (i.e., electrofishing and trammel netting). This reliance on capturing fish may bias the estimate (trap happy response). The number of "recaptures" produced through remote PIT scanning likely reduces the potential for bias, and there was no noticeable change in the population from 2012 to 2013 (table 3). Contact rates increased from the 2012 to 2013 estimates and may continue to increase in subsequent years as remote PIT scanning technology evolves and more spawning aggregates are identified and sampled.

Table 1.—Number and proportion of 134-kHz PIT-tagged razorback sucker released between January 1, 2006, and December 31, 2013, by year and size class (top) and individuals contacted by any means between October 1, 2013, and May 31, 2014 by year and size class (bottom), LCR MSCP Reach 3, lower Colorado River, Arizona-California-Nevada

(Fish were divided into the following six size classes based on TL at release: one (≤ 299 mm), two (300–349 mm), three (350–399 mm), four (400–449 mm), five (450–499 mm), and six (≥ 500 mm.)

Stocking year	Size class						
	One	Two	Three	Four	Five	Six	Proportion
2006	109	2,122	1,738	77	0	0	0.08
2007	18	3,279	2,603	690	128	0	0.13
2008	64	2,707	334	10	4	19	0.06
2009	25	4,456	1,278	94	1	4	0.12
2010	10	2,032	2,686	677	58	2	0.11
2011	0	4,605	4,396	1,360	318	161	0.21
2012	112	3,600	3,073	1,080	286	89	0.16
2013	1	1,047	2,209	2,443	967	65	0.13
Proportion	0.01	0.47	0.36	0.13	0.04	0.01	1.00

Stocking year	Size class						
	One	Two	Three	Four	Five	Six	Proportion
2006	1	21	51	2	0	0	0.04
2007	0	12	62	17	1	0	0.05
2008	3	80	16	1	0	0	0.06
2009	0	150	101	10	0	1	0.14
2010	0	30	45	20	0	0	0.05
2011	0	133	179	91	23	17	0.24
2012	0	107	151	96	20	7	0.21
2013	0	24	92	143	94	13	0.20
Proportion	0.002	0.31	0.38	0.21	0.08	0.02	1.00

The majority of the fish released and scanned in this study were between 300 and 450 mm long (table 1). Although fewer fish are stocked at larger sizes (> 450 mm), relative contact rates have shown that potential survival of the larger fish is greater than that of smaller fish (figure 4). The size-survival relationship has been documented in other portions of the river. Marsh et al. (2005) stated that TL at release was the most important determinant of post-stocking survival of razorback sucker in Lake Mohave. Effect of size at release on survival for razorback sucker in Lake Havasu was assessed in a previous report as well (Patterson et al. 2014). Although size at release was found to be a significant contributor to survival, accuracy for post-stocking estimates was poor due to a lack of immediate post-stocking contact data for releases prior to 2011

Table 2.—Number and proportion of 134-kHz PIT-tagged razorback sucker released between January 1, 2006, and December 31, 2013, by size class (mm), location (zone), and season and individuals contacted by any means between October 1, 2013, and May 31, 2014), LCR MSCP Reach 3, lower Colorado River, Arizona-California-Nevada

	Number stocked	Proportion stocked	Number contacted	Proportion of contacts	Relative contact rate (95% CI)
Size class					
≤ 299	339	0.01	4	0.002	0.01 (0.003–0.03)
300–349	23,848	0.47	557	0.31	0.02 (0.022–0.025)
350–399	18,317	0.36	697	0.38	0.04 (0.035–0.041)
400–449	6,431	0.13	380	0.21	0.06 (0.054–0.065)
450–499	1,762	0.04	144	0.08	0.08 (0.069–0.096)
≥ 500	340	0.01	80	0.02	0.11 (0.803–0.15)
Location					
Zone 3-1	21,586	0.44	617	0.39	0.03 (0.026–0.031)
Zone 3-2	15,051	0.31	719	0.45	0.05 (0.044–0.051)
Zone 3-3	7,999	0.16	222	0.14	0.03 (0.024–0.032)
Zone 3-4	4,536	0.09	33	0.02	0.01 (0.005–0.01)
Season					
Spring	39,470	0.77	1,612	0.93	0.04 (0.039–0.043)
Autumn	11,579	0.23	122	0.07	0.01 (0.009–0.013)

(i.e., prior to remote PIT scanning). The data will be reassessed at the end of this study, restricting releases to the period since the initiation of remote PIT scanning in the reach.

It is unclear if there is any significant effect of stocking location on survival. However, relative contacts and subsequent survival were significantly higher in Zone 3-2. This zone is characterized by numerous backwaters and side channels, and it encompasses the most complex habitat in Reach 3. Striped bass (*Morone saxatilis*) has been found to be the primary cause of mortality of stocked razorback suckers in Lake Mohave (Karam et al. 2008; Karam and Marsh 2010). Striped bass are an important sportfish in open waters of Lake Havasu, but are relatively uncommon in the river reach; thus, these backwaters could provide valuable refugia for newly stocked razorback sucker from predation. Contact rates and survival appear to be lowest for those fish stocked in Zone 3-4. Zone 3-4 occurs in the lower area of Reach 3, while the majority of the scanning occurs in the upper areas of Reach 3. Relatively few fish have been stocked in Zone 3-4 compared to other zones. Given sufficient time, telemetry studies have shown that fish stocked into the lower reaches of Lake Havasu can move

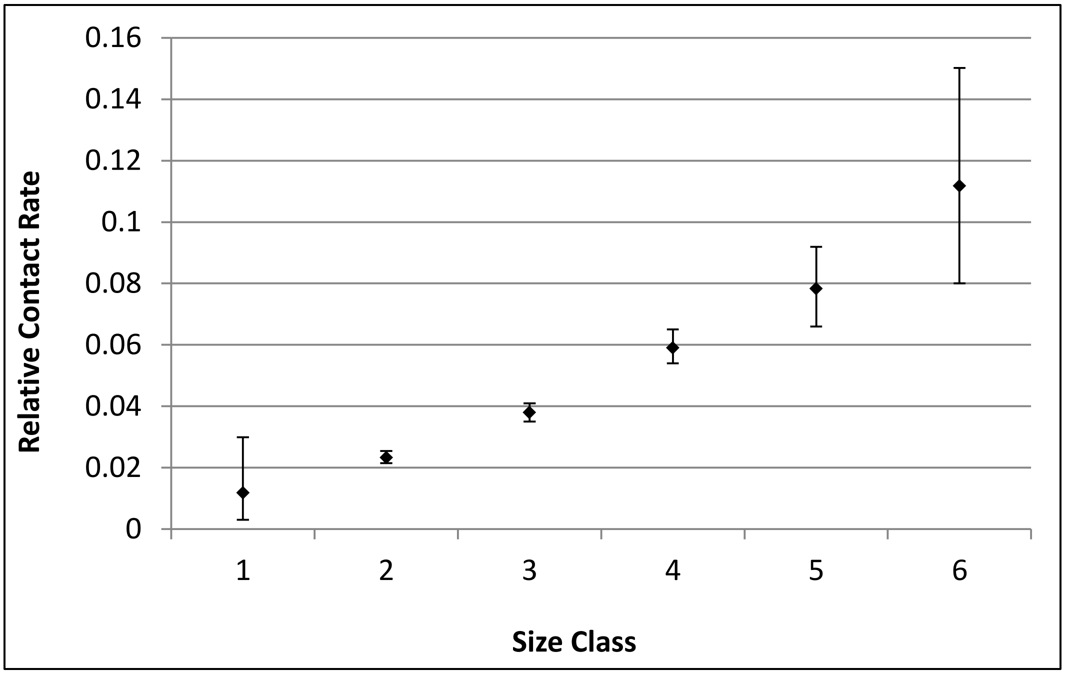

Figure 4.—Relative capture proportion of repatriated razorback sucker released between January 1, 2006, and December 31, 2013, and contacted between October 1, 2013, and May 31, 2014, LCR MSCP Reach 3, lower Colorado River, Arizona-California-Nevada.
Fish were divided into the following six size classes based on TL at release: one (≤ 299 mm), two (300–349 mm), three (350–399 mm), four (400–449 mm), five (450–499 mm), and six (≥ 500 mm). Error bars represent 95% binomial CIs.

Table 3.—Population estimates of razorback sucker over 3 years in LCR MSCP Reach 3, lower Colorado River, Arizona-California-Nevada
(Population estimates for 2011 and 2012 were derived from Patterson et al. [2014])

Year	Number marked	Number captured	Number recaptured	Population estimate (95% CI)
2011	228	642	59	2,496 (1,935–3,220)
2012	934	1373	284	4,524 (4,027–5,081)
2013	1335	1730	518	4,456 (4,089–4,855)

upstream to spawning areas in Zone 3-1 (Wydoski and Lantow 2012). Even though adults will move upstream to the spawning area, the combination of fewer fish stocked and a greater distance to the known spawning areas may account for the lack of contacts of fish stocked in Zone 3-4.

Stocking season appears to play an important role in razorback sucker survival. Contact rates were significantly higher for fish stocked in the spring rather than in the autumn. This pattern has also been observed with razorback sucker stockings in the Green and San Juan Rivers (Bestgen et al. 2009; Zelasko et al. 2011). One hypothesis is that stocking fish at the beginning of the growing season rather than at the end allows fish to increase length and weight significantly prior to the winter season and, in turn, increase survival.

Overall, the use of remote PIT scanning continues to provide increased contacts of fish compared to traditional means such as electrofishing and trammel netting. The majority of trammel netting occurs in backwater habitats with little to no flow and requires substantial equipment and many man hours (Wydoski and Mueller, 2006). Moreover, remote PIT scanning allows two biologists to efficiently sample fast-flowing riverine habitats where trammel netting is not feasible and electrofishing is relatively inefficient. While netting and electrofishing are ideal to collect such information as growth, health, and genetic information, remote PIT scanning provides a non-invasive method to monitor the population as a whole and continues to help meet the goals of this and other projects.

RECOMMENDATIONS

We recommend that remote PIT scanning continue to be utilized and expanded in Reach 3. While this technology is not perfect, it provides a more comprehensive look at the razorback sucker population in the lower Colorado River than traditional methods. However, netting and electrofishing efforts should continue in order to collect health, growth, and genetic data from repatriated razorback suckers.

It was clear that relative contact rates were much lower from fish stocked in Zone 3-4. Given this difference in contact rates and evidence that fish stocked in Zone 3-4 will migrate to the upper reaches to spawn, we recommend that stocking efforts focus on Zones 3-1 and 3-2.

Continued scanning will further build on the existing remote sensing database and will allow for a more complex analysis of the data using program MARK. With a more complex analysis in the final report, we will be able to make more specific recommendations to enhance post-stocking survival of repatriated razorback sucker in Reach 3.

ACKNOWLEDGEMENTS

This study benefitted from the participation and cooperation of J. Lantow and staff from the LCR MSCP Office; staff at Big Bend National Recreational Area, Nevada; staff at Park Moabi Regional Park; and S.H. Gehrke, K.G. Humphrey, and J.B. Wisenall from M&A. This work was supported under Reclamation Agreement Number R14PD00027.

Cover photo of LCR MSCP Reach 3 near Needles, California, by A.P. Karam.

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