Lower Colorado River
Multi-Species Conservation Program

Balancing Resource Use and Conservation

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

U.S. Department of the Interior
Bureau of Reclamation

October 2012

Lower Colorado River Multi-Species Conservation Program
Steering Committee Members

Federal Participant Group

Bureau of Reclamation
U.S. Fish and Wildlife Service
National Park Service
Bureau of Land Management
Bureau of Indian Affairs
Western Area Power Administration

Arizona Participant Group

Arizona Department of Water Resources
Arizona Electric Power Cooperative, Inc.
Arizona Game and Fish Department
Arizona Power Authority
Central Arizona Water Conservation District
Cibola Valley Irrigation and Drainage District
City of Bullhead City
City of Lake Havasu City
City of Mesa
City of Somerton
City of Yuma
Electrical District No. 3, Pinal County, Arizona
Golden Shores Water Conservation District
Mohave County Water Authority
Mohave Valley Irrigation and Drainage District
Mohave Water Conservation District
North Gila Valley Irrigation and Drainage District
Town of Fredonia
Town of Thatcher
Town of Wickenburg
Salt River Project Agricultural Improvement and Power District
Unit "B" Irrigation and Drainage District
Wellton-Mohawk Irrigation and Drainage District
Yuma County Water Users' Association
Yuma Irrigation District
Yuma Mesa Irrigation and Drainage District

Other Interested Parties Participant Group

QuadState County Government Coalition
Desert Wildlife Unlimited

California Participant Group

California Department of Fish and Game
City of Needles
Coachella Valley Water District
Colorado River Board of California
Bard Water District
Imperial Irrigation District
Los Angeles Department of Water and Power
Palo Verde Irrigation District
San Diego County Water Authority
Southern California Edison Company
Southern California Public Power Authority
The Metropolitan Water District of Southern California

Nevada Participant Group

Colorado River Commission of Nevada
Nevada Department of Wildlife
Southern Nevada Water Authority
Colorado River Commission Power Users
Basic Water Company

Native American Participant Group

Hualapai Tribe
Colorado River Indian Tribes
Chemehuevi Indian Tribe

Conservation Participant Group

Ducks Unlimited
Lower Colorado River RC&D Area, Inc.
The Nature Conservancy

Lower Colorado River Multi-Species Conservation Program

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

Prepared by:

Kristen A. Patterson, Brian R. Kesner, Abraham P. Karam, and Paul C. Marsh
Marsh & Associates, LLC
5016 South Ash Avenue, Suite 108
Tempe, Arizona 85282

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

October 2012

ACRONYMS AND ABBREVIATIONS

ANCOVA	analysis of covariance
BWRNWR	Bill Williams River National Wildlife Refuge
cm	centimeter(s)
g	gram(s)
kHz	kilohertz
km	kilometer(s)
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
mm	millimeter(s)
NFWG	Native Fish Work Group
PIT	passive integrated transponder
PVC	polyvinyl chloride
Reclamation	Bureau of Reclamation
RKM	reservoir kilometer
RM	reservoir mile
SE	standard error
TL	total length
UTM	Universal Transverse Mercator
W	weight

Symbols

%	percent

CONTENTS

Tables

Tables (continued)

Figures

SUMMARY

Persistence of sucker (*Xyrauchen texanus*) in the lower Colorado River relies almost entirely upon stocking programs in place today. Only a small proportion of fish stocked are ever encountered in the wild through annual or biannual sampling efforts. In Lake Havasu, recent telemetry studies have found large spawning aggregations of razorback sucker outside of habitat suitable for the standard net-based sampling that occurs in this reach. Contacting a greater proportion of the population is vital to assess the current at large population and the factors that affect their survival once stocked.

The use of remote passive integrated transponder (PIT) scanning has been a successful tool in both riverine and slack waters throughout the lower Colorado River. This technology was deployed biweekly for the spawning period (January–early April 2012) in the fast flowing waters from Davis Dam downstream to Needles, California. We contacted 763 individual razorback sucker, 651 of which had a release with a 134-kilohertz tag record.

The combination of remote PIT scanning and regular sampling methodologies totaled 1,006 fish contacts in 2012. Of these, 675 individuals met criteria to be included in a 2011 population estimate, which produced an estimate of 2,659 (2,069 to 3,414, 95-percent confidence interval) individuals.

The relative capture rates of razorback sucker were directly related to the size of fish at release. Fish released in the higher size classes, ≥ 500 millimeters (mm), were contacted at a rate of 3.2 to 10.3 times greater than fish released in any other individual size class of fish ≤ 449 mm. Individuals were also significantly more likely to be contacted if released in the spring months than the autumn.

Monitoring of the MSCP River Reach 3 razorback sucker stocking program should continue and emphasize seasonal application of remote PIT tag scanning augmented by biannual physical sampling that utilizes electrofishing and netting. Recommendations to improve post-release survival should accrue after multiple iterations of data collection, analysis, and interpretation.

INTRODUCTION

Razorback sucker is one of the four "big river" fishes endemic to the Lower Colorado River and was once abundant and widespread throughout the system (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 [USFWS] 1991). The decline in populations is largely attributed to dam construction and direct and indirect interactions with non-native species introduced into the main stem (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 (LCR MSCP 2004). The lower Colorado River has been subdivided into designated planning areas and river reaches in which to address these goals. Reach 3 is the 135-kilometer (km) section along the Arizona-Nevada and Arizona-California borders between Davis and Parker Dams. The reach includes an 87-km riverine section immediately downstream from Davis Dam and the entirety of Lake Havasu, which is impounded by Parker Dam (figure 1).

Minckley (1983) hypothesized that razorback sucker populations experienced highly successful recruitment events immediately following the impoundment of reservoirs in the lower Colorado River basin. Lake Havasu was impounded in 1938, and the last documented capture of wild adults was in Laughlin Lagoon in 1986 (Marsh and Minckley 1989). A population persists 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 the guidance of the LCR MSCP, 38,000 larger razorback sucker (> 300 millimeters [mm]) have been stocked into Reach 3 since 2006. Research and monitoring activities have resulted in the capture of very few fish from early stockings, and while individuals from more recent stockings have increased contact rates comparatively, absolute capture rates remain low. Recently released fish have been found to aggregate in major spawning areas from Laughlin, Nevada, downstream to Needles, California (Wydoski and Mueller 2006; Wydoski and Lantow 2012). Capture rates are less than 3 percent (%) of cumulative fish released (table 1), so calculating accurate population estimates and isolating specific factors affecting survival of repatriated razorback sucker in Reach 3 presents a challenge. The purpose of this study was to use a combination of remote passive integrated transponder (PIT) scanning and capture data to assess the current razorback sucker population and to 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 population in Reach 3 and will be addressed initially by analyzing the assimilated razorback

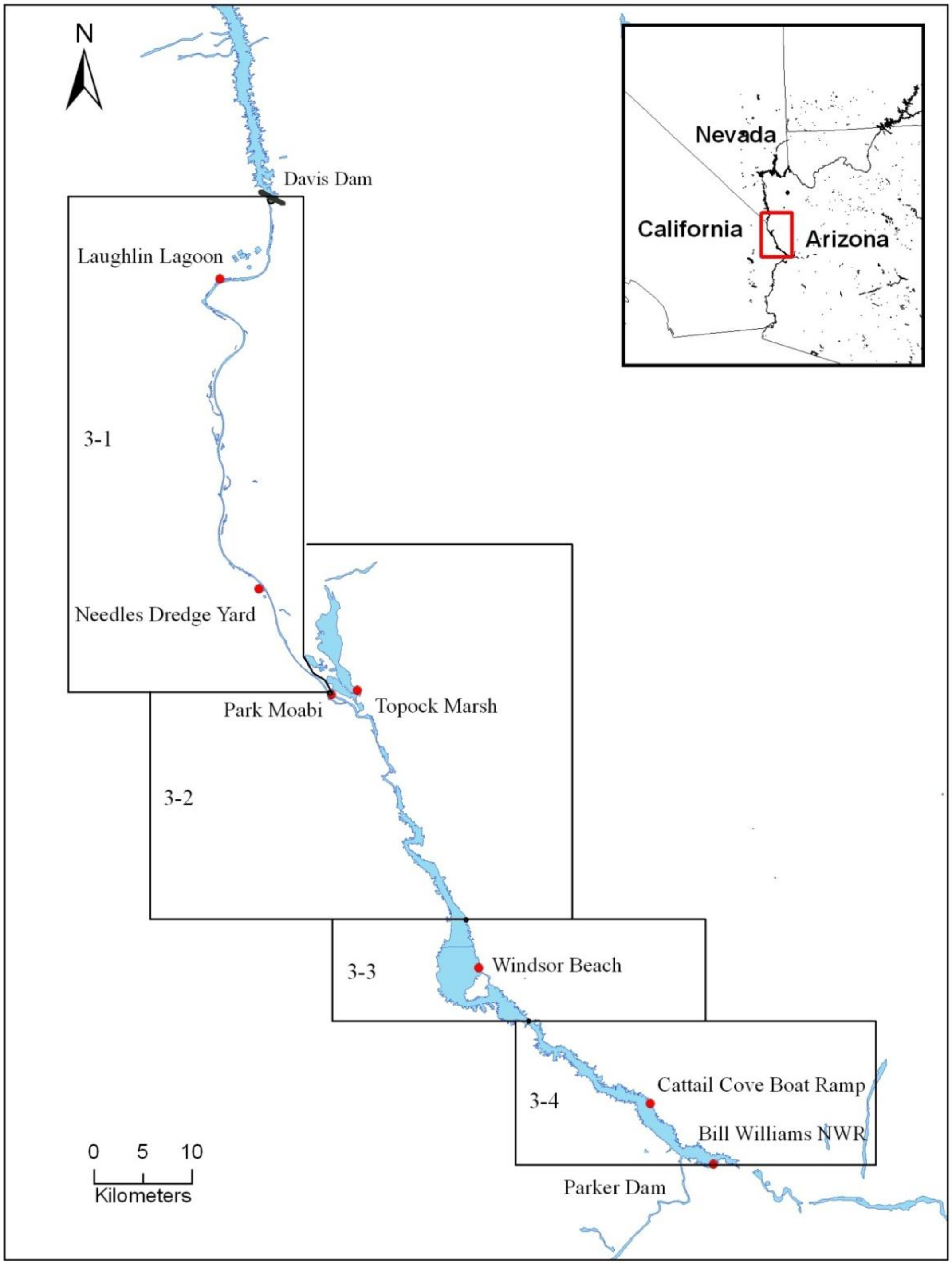

Figure 1.—Overview map of the study area depicting MSCP River Reach 3, including general remote PIT scanning and stocking locations, and general Zones 3-1 to 3-4 established in the "Methods" section below, lower Colorado River, Arizona-California-Nevada.

Table 1.—Proportion of fish captured in each year based on the cumulative number of fish released up to the previous year's end, MSCP River Reach 3, lower Colorado River, Arizona-California-Nevada (from the Native Fish Work Group PIT tag database)

Release year	Number released	Cumulative number released	Capture year	Number captured	Proportion captured
2006	4,120	4,120	2007	94	0.022
2007	6,937	11,057	2008	75	0.007
2008	3,207	14,264	2009	135	0.009
2009	5,936	20,200	2010	216	0.011
2010	5,453	25,653	2011	261	0.010
2011	10,866	36,519	2012	252	0.007
2012	7,248	43,767			

sucker data from all participating parties. This information will aid in the 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, which was constructed by the Bureau of Reclamation (Reclamation), and closed in 1938. The reservoir has a 7.98×10^8 cubic meters storage capacity regulated by releases at the upstream terminus (Davis Dam), downstream (Parker Dam), and less significantly through releases into the Bill Williams River from the Alamo Dam. For this work, 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, 3-1, encompasses clear moving 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, 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 directly upstream of Copper Canyon, where the reservoir once again narrows at RKM 23.3 (RM 14.5). The fourth zone (3-4) extends from Copper Canyon downstream to Parker Dam and includes the Bill Williams River National Wildlife Refuge (BWRNWR).

Electrofishing

Potential razorback sucker habitat between Davis Dam and Needles, California, was electrofished to assess the proportion of razorback sucker occupying the area where PIT scanning was to take place. These efforts targeted native fish, and no non-native species were netted. Night electrofishing events occurred under supervision of the project Contracting Officers Representative with up to four netters present. All suckers captured (flannelmouth sucker [*Catostomus latipinnis*] and razorback sucker) were enumerated, measured for total length (TL) (mm) and weight (W) (grams [g]), sexed, assessed for sexual ripeness, scanned for a wire tag, scanned for a 125- or 134-kilohertz (kHz) PIT tag, and tagged with a 134-kHz PIT tag if either a wire tag or no tag was detected. A right pectoral fin clip was taken from all razorback sucker, placed in 1 milliliter of 95% ethanol in a snap-cap tube, and sent to the Conservation Genetics Laboratory at Arizona State University for analysis. All fish were returned close to their point of capture. Data were entered into the comprehensive lower Colorado River Native Fish Work Group (NFWG) PIT tag and stocking database maintained by Marsh & Associates, LLC, on behalf of all partners engaged in conservation activities for big river fishes in the lower Colorado River. This razorback sucker capture data will be used in assessing the 2012 population estimates.

Remote PIT Scanning

Remote PIT scanning units were deployed from January 9 to April 5, 2012, between Davis Dam and Needles, California. Two models of PIT scanners were utilized: one large, shore-based unit and seven completely submersible units. The shore-based unit was comprised of a 1.9 x 0.8 meter (m) polyvinyl (PVC) antenna frame with a built-in scanner connected to a shore-based, waterproof box housing a “black box” logger and 21 amp-hour battery by 27.4 m of cable. The battery was capable of continuously powering the scanner for up to 68 hours, and this unit was deployed the first afternoon we arrived at the field site and left to run until retrieved the last morning of sampling before departing. The submersible units consisted of a 0.8 x 0.8 m PVC antenna frame with a scanner and “mini logger” contained in PVC/acrylonitrile butadiene styrene piping and a 9 amp-hour battery held in a watertight OtterBox® with a 24-hour powering capacity. The battery box was secured in one-half of a dual-sided sandbag holder used to keep the unit in place under water. These antennas were retrieved approximately every 24 hours and downloaded onsite; the battery was replaced before re-deployment. Five to seven of these units were employed 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. This allowed data downloads to be matched with deployment locations.

The shore-based unit was deployed at a single location all season, Razorback Island (figure 2), where the waterproof box was easily hidden and accessible only by boat. The submersible units were deployed at 10 different general areas (moving downstream): Laughlin Bridge, Laughlin Lagoon, Razorback Island, and Razorback Riffle near Laughlin, Nevada, and Palms, Cliffs, Cabana, Tower, White Wall, and Power Lines near Needles, California (figure 2). The 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 (S), end time or run interval of scanner (E), stop interval (I), scan time (min), 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, and hosted by Hostmonster.com (http://www.hostmonster.com/) using an online form within a password protected section of the Marsh & Associates, LLC, Web site (http://www.nativefishlab.net). Microsoft® Access 2010 was used for data management.

Routine Monitoring

Biologists from Marsh & Associates, LLC, assisted with trammel netting in six and electrofishing in two of nine fixed reaches (USFWS 2011) during the multi-agency Native Fish Roundup on Lake Havasu. Up to four multi-filament nylon trammel nets (45.7 or 91.4 m x 1.8 m, 3.8-centimeter [cm] stretch mesh, 30.5-cm bar outer wall) were deployed in overnight sets and then retrieved the following morning and re-deployed in new locations for 4 consecutive nights. All fish were removed and processed. At a minimum, non-native species were enumerated, and TL was measured (mm). Native species were processed as described above, and a fin clip was taken from a subsample of razorback sucker for genetic examination (see above). For detailed methods of the Native Fish Roundup on Lake Havasu, see USFWS 2011.

Data Analysis

Population Estimation

We employed the Chapman 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 2011.

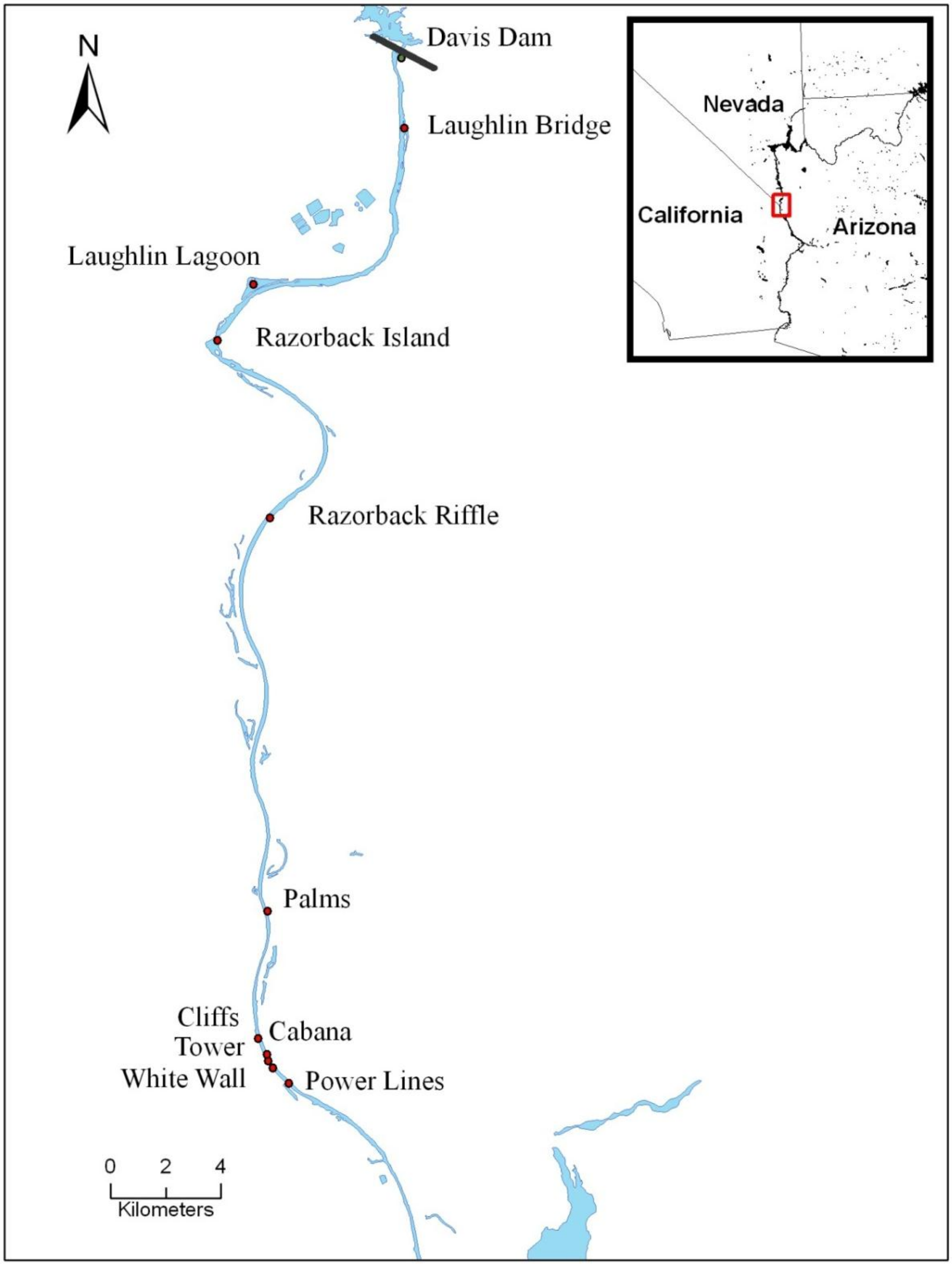

Figure 2.—Location of remote PIT scanning deployment (red circles) in MSCP River Reach 3 between January 9 and April 5, 2012, lower Colorado River, Arizona-California-Nevada.

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

Fish to be included in the estimate must have been released any year previous to the sampling year used as the mark (in this case, before January 1, 2011). We included both fish released with a 134-kHz PIT tag in the NFWG PIT tag database and fish that did not have a release record but were captured for the first time on record and tagged with a 134-kHz tag before January 1, 2011. All releases were into the main stem or reservoir, or into backwaters connected to the river; none were released into habitats isolated from the river. Stocking locations and numbers of fish released used in this analysis can be found in table 2.

The 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, 2011). The catch, C, is the number of fish contacted in the second period of the paired data, (January 1 to March 31, 2012). R is the number of fish contacted in both the mark and catch periods. Fish contacted more than once in the mark or catch period were only included in the analysis for their first encounter event in each timeframe. Confidence intervals were derived using Poisson approximation tables using R as the entering variable (Seber 1973).

To be unbiased, the 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. These assumptions are met under the current application.[1] This project only includes known individuals added to the system with a 134-kHz PIT tag before the period of the mark (M) and individuals that were captured without a 134-kHz tag, and had one implanted before January 1, 2011. 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 thus does not bias the estimate. The efforts employed to sample razorback are diverse both methodologically and geographically, which imparts equal catchability of 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.

Table 2.—Stocking location and number of fish released into MSCP River Reach 3, lower Colorado River, Arizona-California-Nevada, used in the 2011 razorback sucker population estimation

Stocking location	Number of fish stocked
24 RM	1
Avi	2
Avi Hotel	6
Avi to Willow Valley	4
Below Davis Dam	33
Big Bend State Park to Avi	1
Bill Williams River National Wildlife Refuge	439
Blankenship Bend	1
Bureau of Land Management Partner's Point Work Camp	26
Boyscout Camp Lagoon	10
Boyscout Point	1
Bulkhead Cove	1
Catfish Bay Cove	1
Catfish Paradise in Topock Marsh	3,243
Cattail Cove Boat Ramp	1,971
Clear Bay Cove	1
Davis Dam to Riverside launch	1
Fort Mojave	1
Lake Havasu	2
Laughlin Lagoon	6,151
Mesquite Bay (north of)	2
Needles	282
Needles (north of)	38
Needles Bridge (south of)	1
Needles Dredge Yard	4,215
Needles to Laughlin	16
Office Cove	4
Office Cove and Bill Williams National Wildlife Refuge	2,124
Park Moabi	2,912
Park Moabi and Topock Gorge	1
Park Moabi Marina	1
Parker Dam (north of)	1
Pulpit Rock Cove	3
Standard Wash Cove	5
Takeoff Point	1
Trampas Cove	2
Willow Valley	3
Windsor Beach State Park	4,156

Factors Affecting Survival

The effect of size at release on survival was evaluated for all razorback sucker released with a 134-kHz PIT tag between January 1, 2006, and January 1, 2012. Fish were divided into the following size classes based on TL at release: One – ≤ 299 mm, Two – 300 to 349 mm, Three – 350 to 399 mm, Four – 400 to 449 mm, Five – 450 to 499 mm, Six – 500 to 549 mm, and Seven – ≥ 550 mm. Fish released without a TL measurement were excluded from analysis. Razorback sucker released between January 1, 2006, and January 1, 2012, and razorback sucker contacted between January 1 and April 30, 2012, were tabulated (two separate tables) with total fish count per size class by year. Relative capture rates (number contacted/number released) were evaluated for each size class. The correlation between size at release and relative capture rates was estimated by calculating Pearson correlation coefficient (r):

$$r = \frac{\sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n} (X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n} (Y_i - Y)^2}}$$

Where:

X = Size class at release
Y = Relative capture rate of fish in each size class

To address the effect of stocking location and season on survival of razorback sucker, fish release records were separated into cohorts based on general zone, year, and month of stocking. Individuals included in survival assessment based on release zone and season were: (1) released before the detection period of the estimate year, January 1, 2012, (2) detected in the sample year, (3) released with a 134 kHz PIT tag, and (4) measured for TL at release. Only release groups larger than 100 individuals were included as cohorts to simulate a typical stocking event that occurs in Reach 3. These data were tabulated by release zone, date (month, year), mean TL, and counts for released and contacted fish. Using an analysis of covariance (ANCOVA), controlling for mean TL at release, the influence of stocking location was assessed by comparing the relative capture rates of fish released within each of the four zones. Excluding location as a variable, and controlling for mean TL at release, relative capture rates of razorback sucker released in spring (January through May) were compared to those released in autumn (October through November) with an ANCOVA to assess the influence of seasonality.

RESULTS

Electrofishing

Electrofishing efforts between January 9 and March 7, 2012, resulted in the capture of 60 razorback sucker and 16 flannelmouth sucker. Efforts were conducted in seven events encompassing potential scanning habitats ranging geographically from directly below Davis Dam downstream to Needles, California, for a total of 12,941 seconds. The average output ranged between 9.2 and 10 amps.

Mean TL and W for razorback sucker was 597 mm (range 461–721 mm) and 2,538 g (range 1,195–4,380 g), respectively. A majority (65%) of razorback sucker captured had a detectable 134-kHz PIT tag, 8 of 60 contained 125-kHz PIT tags, and 13 had no PIT tag and received a 134-kHz tag before release. The proportion of razorback sucker that would be undetectable with remote PIT scanners at the beginning of our sampling period was (21/60) = 0.35[2].

Remote PIT Scanning

Scanning effort in Reach 3 consisted of 2243.9 scan hours. The actual time to deploy/retrieve an antenna, download the logger, and change the battery was minimal (approximately 10 minutes per unit) and totaled 18 hours of effort (excluding travel time). This effort resulted in contact with 763 individual razorback sucker. Although flannelmouth sucker tagged with 134-kHz tags were captured in Reach 3 (see above), none were detected with remote PIT scanners.

Of all razorback sucker scanned, 651 had a release record with a 134-kHz PIT tag. The majority of individuals scanned were in size classes Two (300 to 349 mm, 41.0%) and Three (350 to 399 mm, 44.0%) at release (table 3).

Routine Monitoring

A general summary from Native Fish Roundup on Lake Havasu is reported here with a focus on razorback sucker capture. During February 6 to 10, 2012, a total of 1,683 fish were captured. Of those, 109 were razorback sucker captured from Willow Valley, RKM 93.3 (RM 58) downstream to Mesquite Bay, RKM 38.6 (RM 24). The mean TL of razorback sucker sampled was 523 mm (range 247 to 711 mm).

---

[2] This is the proportion of untagged fish (21) in the electrofishing sample of 60 razorback sucker.

Table 3.—Number and proportion of 134-kHz PIT tagged razorback sucker released by year and size class (top) and individuals contacted between January 1 and April 30, 2012 (bottom), MSCP River Reach 3, lower Colorado River, Arizona-California-Nevada

Fish were divided into the following size classes based on TL at release: One – ≤ 299 mm, Two – 300 to 349 mm, Three – 350 to 399 mm, Four – 400 to 449 mm, Five – 450 to 499 mm, Six – 500 to 549 mm, and Seven – ≥ 550 mm

Year	One	Two	Three	Four	Five	Six	Seven	Proportion
2006	109	2,122	1,738	77	0	0	0	0.112
2007	18	3,279	2,603	690	128	0	0	0.187
2008	64	2,707	334	10	4	6	13	0.087
2009	25	4,456	1,278	94	1	2	2	0.163
2010	10	2,032	2,686	670	17	0	0	0.150
2011	0	4,605	4,396	1,360	318	145	18	0.301
Proportion	0.006	0.533	0.362	0.081	0.013	0.004	0.001	

Year	One	Two	Three	Four	Five	Six	Seven	Proportion
2006	0	25	62	2	0	0	0	0.106
2007	0	18	74	17	6	0	0	0.137
2008	2	65	10	1	0	0	1	0.094
2009	0	149	74	6	0	1	0	0.273
2010	0	20	46	17	2	0	0	0.101
2011	0	68	104	40	15	14	2	0.289
Proportion	0.002	0.410	0.440	0.099	0.027	0.018	0.004	

Population Estimation

Data used for the mark (M) were all razorback sucker with a release record and sampled in Reach 3 by netting or electrofishing between January 1 and March 31, 2011. The capture period data included razorback sucker sampled by all methods (including remote PIT scanning) between January 1 and March 31, 2012, totaling 118 individuals from netting/electrofishing and 557 detected through remote PIT scanning.

Of the 763 individuals scanned remotely, 597 had a release record before January 1, 2011. The remainder (166 fish) either had a release record after January 1, 2011 (148), did not have a release or initial capture record (10), or did not have any record in the NFWG database (8) and were not included in this analysis. Contacts of fish released before the marking event (January 1, 2011) and sampled between January 1 and March 31, 2011, with a release record were used as the mark (M).

The estimated population of 134-kHz PIT tagged repatriated razorback sucker in Reach 3 in 2011 was 2,659 (2,069 to 3,414, 95% confidence interval) individuals (235, 675, and 59 for M, C, and R, respectively). This estimate can be expanded to include the proportion of the population that is untagged or tagged with a 125-kHz tag in 2011 that would have been excluded from the estimate. Capture data from January 1 to March 31, 2011, found 313 of 326 (96%) fish handled had a 134-kHz tag only. If this proportion holds true for the entire population, then an estimate of the entire population in Reach 3 would be 2,770 fish (2,659/0.96).

Factors Affecting Survival

Between January 1, 2006, and December 31, 2011, 36,017 razorback sucker were released with 134-kHz PIT tags and available for contact in Reach 3 in 2012. The generalized percent survival of fish released up to 2011 (N*/cumulative number of fish released*100) was estimated at 10.8 percent. The distribution among fish across size classes was not even, with < 1% of fish being released in the smallest (≤ 299 mm) and largest (≥ 550 mm) size classes (see table 3). The majority of fish released were in size classes Two (53%) and Three (36%, see table 3).

In the 2012 sampling period between January 1 and April 30, 2012, 841 repatriated razorback sucker were contacted through netting, electrofishing, and PIT scanning efforts combined. Comparable to the release data, < 1% of contacted fish were from the smallest and largest size classes, and a majority of contacts were fish released between 300 and 350 mm (41%) and 350 to 400 mm (44%, see table 3). Relative catch rates were strongly correlated (r = 0.93) to size class at release, ranging from 0.008 in fish released ≤ 299 to 0.09 for fish released ≥ 550 mm (figure 3).

Zone of release did not affect the probability of being contacted in 2012 (ANCOVA: P = 0.32, F-value = 1.07, table 4). Razorback sucker released in spring were significantly more likely to be contacted post-release than fish released in autumn (mean relative capture rate ± 1 SE; spring: 0.038 ± 0.006; autumn: 0.014 ± 0.005, ANCOVA: P = 0.03, F-value = 5.99).

DISCUSSION

During the initial years of repatriated razorback sucker monitoring, recapture was rare, making population estimates or understanding the influence of factors such as release season and location on survival challenging. Year-to-year capture rates of cumulative fish released have remained low (0.7% to 2.2%, see table 1) since inception of the LCR MSCP stocking program. Use of remote PIT scanning has allowed increased contact rate of released fish. In 2012, there was a 3.1 fold increase in contacts of razorback sucker, detecting 763 individuals with the

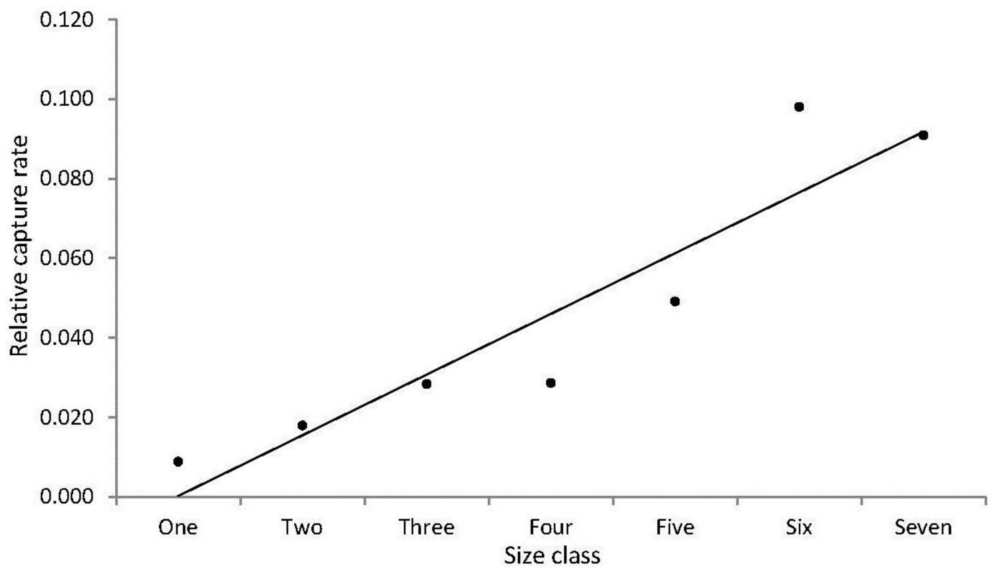

Figure 3.–Relative capture rates of repatriated razorback released between January 1, 2006, and January 1, 2012, and contacted between January 1 and April 30, 2012, MSCP River Reach 3, lower Colorado River, Arizona-California-Nevada.

Fish were divided into the following size classes based on TL at release:
One – ≤ 299 mm, Two – 300 to 349 mm, Three – 350 to 399 mm, Four – 400 to 449 mm, Five – 450 to 499 mm, Six – 500 to 549 mm, and Seven – ≥ 550 mm.

inclusion of PIT scanners. This method of contact does have limitations in that questions regarding the general health or growth of released fish cannot be addressed. It does, however, provide a cost-effective and efficient method of contact that meets the goals of this and similar projects.

Previous estimates of razorback sucker in Reach 3 were based on few recaptures (e.g., R = 2), resulting in questionable accuracy (Wydoski and Mueller 2006). In contrast, combining capture and remote PIT scanning data in 2012 provided 59 fish sampled in both mark and capture period (R) and removed the likelihood of statistical bias in the Chapman modified Petersen estimate (Ricker 1975). The base estimate for 2011 of 2,659 (2,069 to 3,414, 95% confidence interval) is almost double the estimate of 1,400 reported in 2010 (J. Lantow, personal communication) and lies outside of that estimate's confidence interval (894 to 2,196, 95% confidence interval).

In agreement with mark-recapture size-survival relationships of repatriated razorback sucker elsewhere in the lower Colorado River (Marsh et al. 2005; Kesner et al. 2011), size class at release was positively correlated with contact rate (see figure 3) and could be an explanatory variable attributable to the increase in recent population estimates. Size of fish stocked into Reach 3 have generally

Table 4.—Proportion and mean TL of razorback sucker released into Zones 3-1 to 3-4 with a 134-kHz PIT tag that were scanned with remote PIT scanners in Zone 3-1 between January 1 and April 30, 2012, MSCP River Reach 3, lower Colorado River, Arizona-California-Nevada

Zone	Release date	Number released	Mean TL (mm)	Number contacted	Proportion contacted
3-1	October 2006	2,011	325	19	0.009
	November 2006	2,009	365	70	0.035
	April 2007	1,045	380	77	0.074
	November 2007	3,113	343	19	0.006
	March 2008	1,160	320	30	0.026
	October 2008	1,014	324	5	0.005
	January 2011	3,229	366	54	0.017
3-2	March 2008	937	329	42	0.045
	March 2009	1,903	340	113	0.059
	January 2010	3,243	349	31	0.010
	February 2011	3,496	368	109	0.031
	November 2011	250	420	7	0.028
3-3	May 2009	1,985	326	90	0.045
	February 2010	2,171	376	54	0.025
	February 2011	1,308	361	13	0.010
	March 2011	2,192	343	58	0.026
	October 2011	327	324	1	0.003
3-4	October 2007	439	435	11	0.025
	November 2007	2,124	339	1	0.000
	February 2009	1,966	330	26	0.013

been larger year to year, with a decrease in fish stocked in the lowest size classes particularly from 2008 onwards (figure 4). Most notable is the increase in fish stocked between 400 and 449 mm (size class Four), which has increased to approximately 12% of fish stocked in the last 2 years. The proportion of fish contacted in this size class, as well as size class Three, was consistently higher than the proportion released (figure 4).

The contact rate of razorback sucker was not dependent on the zone into which fish were originally stocked, even when the zone of stocking was 92 RKM (57 RM) away in Zone 3-4. This contradicted a result of zero detections in

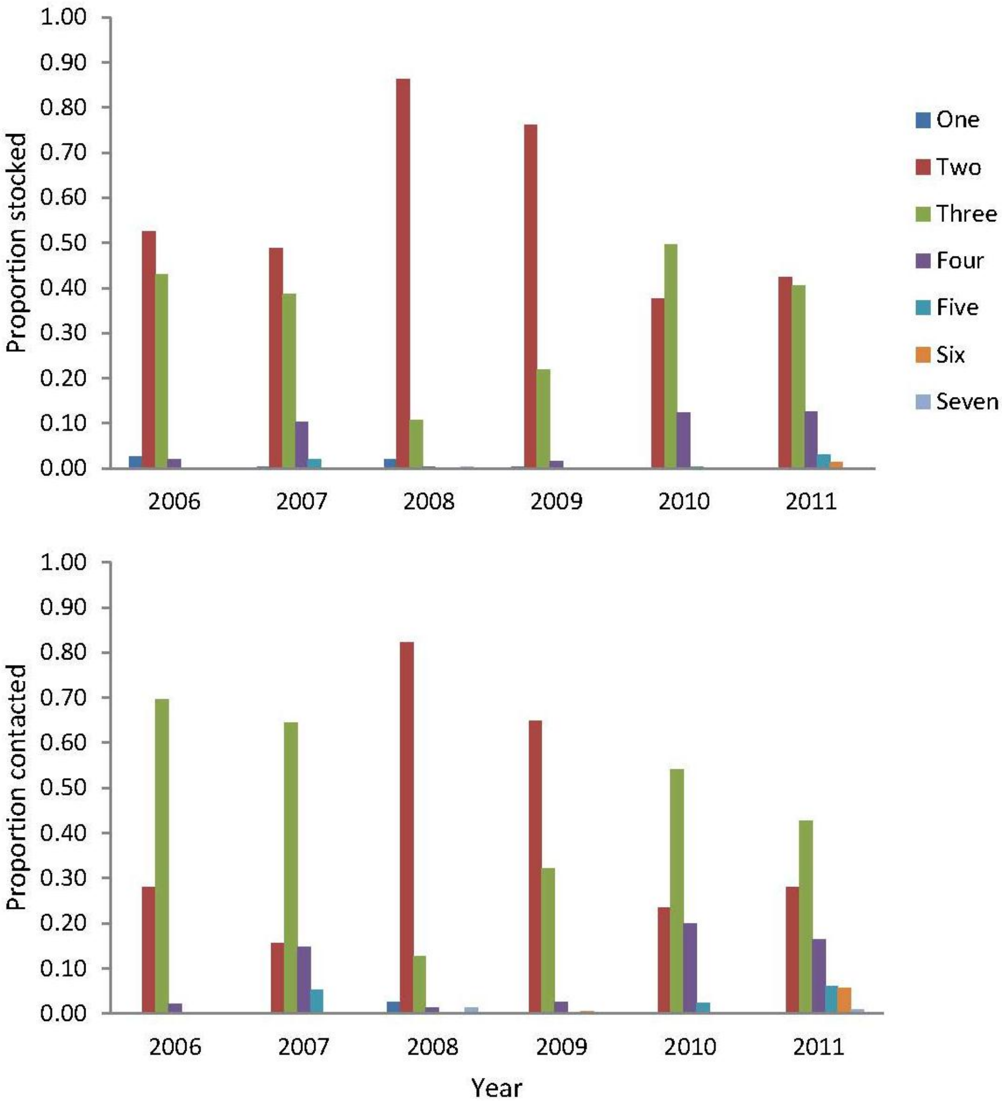

Figure 4.—Proportion of fish stocked (top) that were contacted (bottom) between January 1 and April 30, 2012, separated by size class at release, MSCP River Reach 3, lower Colorado River, Arizona-California-Nevada.

Fish were divided into the following size classes based on TL at release:
One – ≤ 299 mm, Two – 300 to 349 mm, Three – 350 to 399 mm, Four – 400 to 449 mm, Five – 450 to 499 mm, Six – 500 to 549 mm, and Seven – ≥ 550 mm.

Zone 3-1 of razorback sucker released between 1999–2005 at the downstream most portion of the reservoir (Zone 3-4) Wydoski and Mueller (2006). Although their sampling area covered a larger portion of the reservoir (Laughlin downstream to Cattail Cove), Wydoski and Mueller (2006) failed to contact any fish that had been released into the lower end of the reservoir. Their netting efforts were primarily focused in backwaters off the main channel and, to a lesser degree, in eddy fences with low current in the main channel. Our sampling efforts included the center and side of the main channel with higher flow rates where aggregates of spawning razorback sucker occur, thus increasing contact rates. Telemetry studies of razorback sucker released into the downstream end of Lake Havasu proper found that, given sufficient time (approximately 1 year), fish can move upstream to spawning areas near Needles, California (Wydoski and Lantow 2012). Razorback sucker are capable of travelling upwards of 20 km per day in Lake Mohave, the reservoir directly upstream of Davis Dam (Mueller and Marsh 1998; Mueller et al. 2000).

Studies in both the lower and upper Colorado River system have noted reduced first year survival attributed in part to razorback sucker being poorly prepared to live in riverine conditions (Marsh et al. 2005; Bestgen et al. 2009). However, contact rates for razorback sucker in Reach 3 were not significantly different if released in the lotic (Zones 3-1 and 3-2) or more lentic portions (Zones 3-3 and 3-4).

The time of year in which fish are introduced into a system can affect their ability to adapt and survive. Similar to razorback sucker releases in the Green and San Juan Rivers (Bestgen et al. 2009; Zelasko et al. 2011), fish in our study had a higher likelihood of contact when released in spring than autumn. Our seasonal analysis grouped fish into only two "seasons" based on the concentration of stocking events in January through May (spring), and October through November (autumn).

RECOMMENDATIONS

We recommend continuing the monitoring of repatriated razorback sucker in Reach 3 with the increased implementation of remote PIT scanner deployment. This methodology, like any other, has limitations, but it has proven to be an effective means to contact razorback sucker in the riverine portion of this reach especially in the spawning season. The continuation of biannual netting and electrofishing efforts to collect health, growth, census, and genetic data from repatriate razorback suckers should also continue to create a more complete picture of the status of razorback sucker in the reach.

Previous telemetry studies in Lake Havasu have shown the movement of razorback sucker upstream of the main basin, regardless of where they were released, and remaining near the Lake Havasu delta region, upstream to Davis Dam. Although the zone in which fish were released and then contacted was not significant between zones, relative rates of contact were at least two-fold lower in Zone 3-4, compared to the other zones of release. If fish move into these reaches regardless of stocking location and are not contacted by any methodology downstream from the delta, we suggest future stocking events focus on Zones 3-1 through 3-3.

Future availability of multiple seasons of remote PIT scanning data will allow us to make interyear comparisons and provide an opportunity to perform more complete data analysis. Our expectation is that results of these additional analyses will form a foundation upon which to base recommendations to adjust the Reach 3 stocking program in ways that will enhance post-release survival of repatriated fish.

ACKNOWLEDGEMENTS

This project benefitted from the participation and cooperation of J. Lantow from the Lower Colorado River Multi-Species Conservation Program Office; staff at Big Bend National Recreational Area, Nevada; staff at Havasu National Wildlife Refuge; and W.A. Massure, C.A. Pacey, and J.W. Warmbold from Marsh & Associates, LLC. This work was supported by Reclamation Agreement Number R12PD30013. The cover photo of MSCP River Reach 3 near Needles, California, was provided by Abraham P. Karam.

LITERATURE CITED

Bestgen, K.R. 1990. Status review of the razorback sucker, *Xyrauchen texanus*. Contribution 44. Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado. 92 p.

Bestgen, K.R., K.A. Zelasko, and G.C. White. 2009. Survival of hatchery-reared razorback suckers *Xyrauchen texanus* stocked in the San Juan River Basin, New Mexico, Colorado, and Utah. Final Report. Larval Fish Laboratory, Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins, Colorado. 46 p.

Joseph, T.W., R.J. Sinning, R.J. Behnke, and P.B. Holden. 1977. An evaluation of the status, life history, and habitat requirements of endangered and threatened fishes of the upper Colorado River system. U.S. Fish and Wildlife Service, Fort Collins, Colorado. FWS/OBS Rep. 24, part 2. 183 p.

Kesner, B.R., A.P. Karam, C.A. Pacey, K.A. Patterson, and P.C. Marsh. 2011. Demographics and post-stocking survival of repatriated razorback sucker in Lake Mohave. Final Report. Bureau of Reclamation Agreement No. R09AP30002, Boulder City, Nevada. Marsh & Associates, LLC, Tempe, Arizona. 79 p.

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

_____. 2012. Final implementation report, fiscal year 2013 work plan and budget, fiscal year 2011 accomplishment report. LCR MSCP Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada. 404 p.

Marsh, P.C. and W.L. Minckley. 1989. Observations on recruitment and ecology of razorback sucker: lower Colorado River, Arizona-California-Nevada. Great Basin Naturalist 49:71–78.

Marsh, P.C., B.R. Kesner, and C.A. Pacey. 2005. Repatriation as a management strategy to conserve a critically imperiled fish species. North American Journal of Fisheries Management 25:547–556.

Minckley, W.L. 1973. The Fishes of Arizona. Arizona Game and Fish Department, Phoenix. 273 p.

_____ 1979. Aquatic habitats and fishes of the lower Colorado River, southwestern United States. Final Report, Bureau of Reclamation, Contract No. 14-06-300-2529, Boulder City, Nevada. 478 p.

_____. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the Lower Colorado River Basin. The Southwestern Naturalist 28:165–187.

Minckley, W.L., P.C. Marsh, J.E. Brooks, J.E. Johnson, and B.L. Jensen. 1991. Management toward recovery of the razorback sucker. Chapter 17, pp. 303–358 in W.L. Minckley and J.E. Deacon, editors. Battle Against Extinction: Native Fish Management in the American West. University of Arizona Press, Tucson.

Mueller, G.A. and P.C. Marsh. 1998. Post-Stocking dispersal, habitat use, and behavioral acclimation of juvenile razorback suckers (*Xyrauchen texanus*) in two Colorado River reservoirs: U.S. Geological Survey Open-File Report 98–301. 24 p.

_____. 2002. Lost, a desert river and its native fishes: a historical perspective of the lower Colorado River. Information and Technology Report USGS/BRD/ITR—2002—0010: U.S. Government Printing Office, Denver, Colorado. 69 p.

Mueller, G.A., P.C. Marsh, G. Knowles, and T. Wolters. 2000. Distribution, movements, and habitat use of razorback sucker (*Xyrauchen texanus*) in a lower Colorado River reservoir, Arizona-Nevada. Western North American Naturalist 60:180–187.

Pollock, K.H., J.D. Nichols, C. Brownie, and J.E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs 107:1–97.

Ricker, W.E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin of the Fisheries Research Board of Canada, No. 191. Department of the Environment Fisheries and Marine Service. 382 p.

Schooley, J.D. and P.C. Marsh. 2007. Stocking of endangered razorback suckers into the lower Colorado River basin over three decades: 1974–2004. North American Journal of Fisheries Management 27:43–51.

Seber, G.A.F. 1973. The Estimation of Animal Abundance and Related Parameters. Griffin, London. 506 p.

U.S. Fish and Wildlife Service (USFWS). 1991. Endangered and threatened wildlife and plants: the razorback sucker (*Xyrauchen texanus*) determined to be an endangered species. Federal Register 56:54957–54967.

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

Wydoski, R. and G. Mueller. 2006. The status of razorback sucker in the Colorado River between Davis and Parker Dams (Lake Havasu), 2003 to 2005. U.S. Geographical Survey Technical Memorandum 86-68220-06-19, Denver, Colorado. 31 p.

Wydoski, R., E. Best, and J. Lantow. 2010. Movements of sonic tagged razorback suckers between Davis and Parker Dams (Lake Havasu). Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada. 27 p.

Wydoski, R. and J. Lantow. 2012. Movements of sonic tagged razorback suckers between Davis and Parker dams (Lake Havasu), 2007–2010. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada. 35 p.

Zelasko, K.A., K.R. Bestgen, and G.C. White. 2011. Survival rate estimation of hatchery-reared razorback sucker *Xyrauchen texanus* stocked in the upper Colorado River basin, Utah and Colorado, 2004–2007. Final Report. Colorado River Implementation Program Project Number 159. 96 p.

Zydlewski, G., C. Winter, E. McClanahan, J. Johnson, and J. Zydlewski. 2003. Evaluation of fish movements, migration patterns, and population abundance with stream width PIT tag interrogation systems. Bonneville Power Administration, Report 00005464, Portland, Oregon. 74 p.