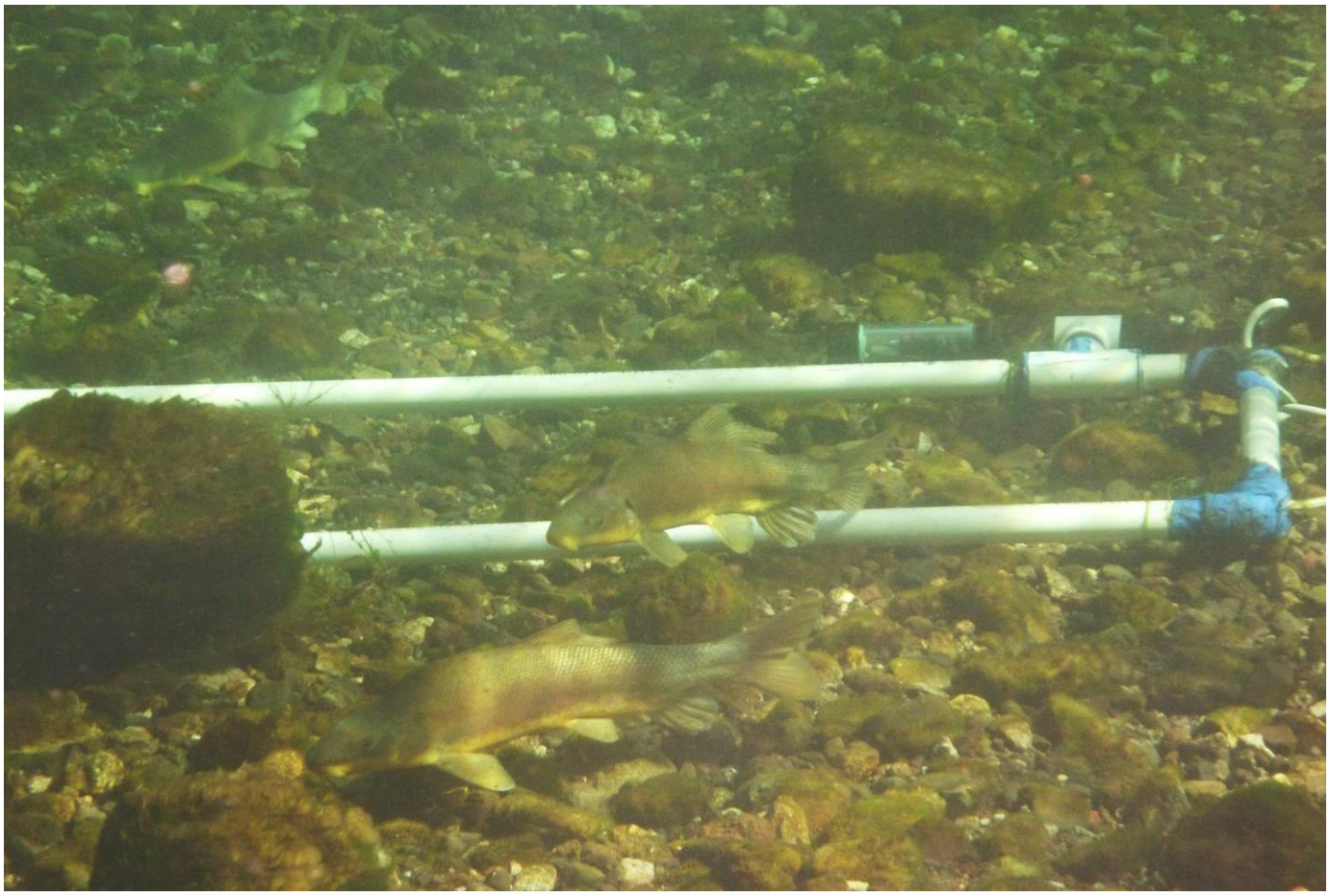
Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Lake Mohave Razorback Sucker Monitoring

2013 Annual Report



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Lake Mohave Razorback Sucker Monitoring

2013 Annual Report

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ACRONYMS AND ABBREVIATIONS

amp	ampere
CI	confidence interval
cm	centimeter(s)
h	hour(s)
kHz	kilohertz
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
M&A	Marsh & Associates, LLC
mm	millimeter(s)
PIT	passive integrated transponder
PVC	polyvinyl chloride
Reclamation	Bureau of Reclamation
TL	total length
USFWS	U.S. Fish and Wildlife Service
Willow Beach NFH	Willow Beach National Fish Hatchery

Symbols

>	greater than
>	less than
%	percent

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EXECUTIVE SUMMARY

Monitoring of repatriated razorback sucker (*Xyrauchen texanus*) in Lake Mohave has been conducted for more than 20 years, but low recapture rates have inhibited evaluation of factors contributing to highly variable post-stocking survival. To increase the number of encounters, deployment of remote passive integrated transponder (PIT) scanners able to detect 134.2-kilohertz (kHz) PIT tags was initiated in 2011, and expanded in 2012 and 2013, while traditional capture methods were employed to continue to collect comparable long-term monitoring data and estimate abundance of all repatriated and wild razorback suckers PIT tagged with either 400- or 134.2-kHz tags.

Netting efforts from October 1, 2012, to September 30, 2013, resulted in the capture of 22 razorback suckers. Seventy-seven percent (%) of captures occurred in March and 23% during November. Two fish were captured with no tags and were presumed to be repatriates that lost their tags; all remaining individuals were PIT-tagged repatriates. No wild razorback sucker estimate was made due to a lack of wild fish captures. The repatriated razorback sucker population for 2012 was estimated to number 1,854 (95% confidence interval [CI] from 941 to 3,782), with a 1% estimated survival of all repatriates released as of March 1, 2012.

Total deployment time for remote PIT scanners from November 2012 through September 2013 was 8,392.6 scan hours, resulting in a total of 475,334 PIT tag contacts representing 3,216 unique PIT tags for which 3,171 had a razorback sucker marking record in the Lower Colorado River Native Fish Database (as of September 30, 2013). Of the fish with a marking record, 3,151 were repatriates, 11 were wild, and 9 were recorded as unknown.

Remote PIT scanning detected little movement of razorback suckers among the three zones scanned in 2012 and 2013, river, Liberty, and basin, with 96.6% of individuals (1,543 out of 1,596) contacted in the same zone both years. Post-stocking dispersal from zone to zone also was limited. The majority (> 80%) of fish released in the river and basin zones were contacted in their zone of release regardless of release year. Razorback suckers released in Liberty were generally contacted elsewhere (the river and basin zones); however, these fish accounted for 5.6% of the total contacted (129 of 2,289).

Post-stocking contact rates, the percentage of total fish released from a given stocking that were contacted in 2013, were highly correlated with size at release ($r = 0.83$) regardless of stocking zone. The cohorts with the highest contact rates in the river (29.6%) and basin (45.5%) zones had mean total lengths (TL) at release of 441 and 478 millimeters (mm), respectively, markedly higher than the overall mean of 419 mm for all releases. In stark contrast, no fish were contacted from a cohort consisting of 1,778 razorback suckers with a mean TL of 332 mm released on January 4, 2012, in the river zone. The three lowest contact rates all came from cohorts released at or near Ringbolt Rapids in the river zone; these

cohorts also represented some of the smallest fish released with a mean TL at release of 324 to 332 mm. The mean contact rate for all stockings was 17.9% regardless of mean release TL (overall mean = 419 mm; overall range = 324 to 508 mm), but the highest contact rate at Liberty was 5.9% for a cohort released into Liberty Cove on March 3, 2011, with a mean TL of 414 mm.

Based on 2012 and 2013 remote PIT scanning, the 134.2-kHz tagged Lake Mohave repatriate population was estimated at 3,588 individuals (95% CI from 3,259–3,950). Subpopulation estimates based on zone-specific scanning in 2012 and 2013 were also calculated. The basin zone population was estimated at 1,598 (95% CI from 1,390–1,836), in Liberty at 55 (95% CI from 17–100; one recapture), and in the river zone at 2,188 (95% CI from 1,908–2,509). The river zone estimate was nearly identical to the estimate of 2,174 from a regression analysis conducted in 2012 (Kesner et al. 2012b). Wild fish also were contacted in the basin and river zones, but no estimate was calculated because only one recapture was recorded in the river zone.

Results from the current monitoring year demonstrate that annual census estimates calculated from March capture data exclude a significant portion of the population that resides upstream of Willow Beach. Depending on the dynamics of the limited exchange between subpopulations, the river zone subpopulation may not contribute to the reproductive output collected by the repatriation program. Additional monitoring years will be required to determine the dynamics of the lake-wide metapopulation.

INTRODUCTION

Lake Mohave once was home to the largest known population of wild razorback suckers (*Xyrauchen texanus*), an endangered "big river" fish endemic to the Colorado River Basin. Historically, this population contained more than 100,000 fish, but numbers have dwindled dramatically in recent years, and it currently is made up of fewer than 25 wild individuals (Marsh et al. 2003; Turner et al. 2007, Reclamation, unpublished data). A repatriation program for restoring razorback suckers in Lake Mohave began in the early 1990s (Mueller 1995). The program utilized wild larvae that were produced naturally in the lake, reared in protective captivity, and then repatriated to the reservoir after growing to a nominal size of 300 millimeters (mm) total length (TL) or more. There have been a number of adjustments to the program that incorporate new information in an attempt to increase survival of stocked fish, but results thus far have not met expectations (Marsh et al. 2005). A recommended minimum stocking TL of 500 mm has proven difficult to produce in sufficient numbers to increase population size (M. Olson 2012, personal communication), and even fish of this size are subject to predation (Karam and Marsh 2010).

Stocking and monitoring of razorback suckers in Lake Mohave from the Willow Beach National Fish Hatchery (Willow Beach NFH) is currently overseen and funded under the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) (LCR MSCP 2013 – Work Tasks B2 and B7) and is conducted under the "Fish Augmentation" component of the program (Bureau of Reclamation [Reclamation] 2006). The Lake Mohave repatriation program is one component of an overall conservation plan for razorback sucker within the LCR MSCP. This program, as well as other conservation plans upon which it was based (Minckley et al. 2003; U.S. Fish and Wildlife Service [USFWS] 2005), incorporates augmentation and maintenance of a population component that will occupy the lower Colorado River main stem; however, it may be impractical or impossible to accommodate that component. It is an objective of the research and monitoring component of the Lake Mohave razorback sucker program, the subject of this report, to provide information needed to determine the effectiveness of the repatriation program as well as how such an augmentation strategy should contribute to maintenance of razorback suckers in Lake Mohave and throughout the lower Colorado River. Moreover, the results of this research provide critical demographic information and management recommendations to help ensure the long-term persistence of a genetically viable stock of adult razorback suckers in Lake Mohave.

In prior years, estimates of post-stocking survival based on multiple years of telemetry were used to evaluate predictions of mark-recapture models that relied extensively on data generated from routine monitoring (Kesner et al. 2012a). While telemetry results have generally been consistent with the mark-recapture model, survival for subadult razorback suckers (mean TL 380 mm) varied from 7 percent (%) – 1 of 15 fish (Kesner et al. 2008a) to 67% – 6 of 9 fish (Kesner

et al. 2012a) released just 1 year apart. Mark-recapture models that included annual variations in survival failed to provide accurate estimates due to the low recapture rate in annual March data (Marsh et al. 2005). Traditional sampling approaches, such as more intensive trammel netting, are not reasonable strategies due to budget and personnel limitations, habitat constraints, and the potential to repeatedly capture the same individuals. The repatriate population is now composed primarily of individuals that contain 134.2-kilohertz (kHz) passive integrated transponder (PIT) tags, so remote PIT scanning can be used to accurately estimate population size and answer fundamental demographics questions that will improve ongoing conservation strategies (Kesner et al. 2008b).

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

1. Locating and capturing adult razorback sucker.

2. Marking captured adult razorback suckers with 134.2-kHz PIT tags for individual identification (only if fish have not been previously tagged).

3. Collecting tissue samples from adult razorback suckers for genetic analyses.

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

5. Using mobile remote PIT tag sensing units capable of deployment in both slack water and riverine sections of Lake Mohave (it is anticipated that remote sensing will occur 1 week per month between River Miles 290–305 in November and from January through May and for 1 week per month between River Miles 330–342 from June through August). An alternate monitoring schedule of equivalent time and effort may be proposed based on contractor expertise.

6. Estimating current repatriate and wild razorback sucker populations.

7. Participating in up to three annual, weeklong, multi-agency survey events to take place in November, March, and May (the majority of the effort related to these events will be restricted to River Miles 290–305).

8. Assimilating Lake Mohave razorback sucker capture data collected by other Federal and non-Federal entities into population estimates.

9. Providing copies of all datasets to the designated Reclamation Contracting Officer's Technical Representative.

METHODS

For purposes of this study, Lake Mohave (LCR MSCP Reach 2) has been divided into four distinct zones based on geographic features of the lake and razorback sucker demographics as determined from previous studies (figure 1) (Kesner et al. 2012a). Each zone has a descriptive name that represents either a specific location of focus within that zone (e.g., Liberty and Katherine) or describes the general characteristics of that zone (e.g., basin and river). Remote PIT scanning was conducted in the river, Liberty, and basin zones. Katherine was excluded due to a lack of known razorback sucker aggregation sites in that zone.

Routine Monitoring

Objectives 1, 2, 3, 4, and 7 were accomplished through participation in the November and March multi-agency survey events. During both events, Marsh & Associates, LLC (M&A) personnel occupied a field camp on Lake Mohave at Carp Cove, Arizona (the basin zone), near River Mile 298 (miles upstream of the Southern International Boundary). From November 26–30, 2012, as many as six trammel nets (four 91.4 meter [m] x 1.8 m, 3.8-centimeter [cm] stretch mesh and two 45.7 m x 1.8 m, 3.8-cm stretch mesh) were fished continuously along the Arizona shoreline from Pot Cove upstream to Carp Cove. In a similar effort, as many as six trammel nets (91.4 m x 1.8 m, 3.8-cm stretch mesh) were fished continuously along the Arizona shoreline from Pot Cove upstream to Carp Cove from March 11–15, 2013.

Native fishes encountered were processed and released (objective 1). Nets were run and cleared, and fish were processed twice daily in the morning and evening. Processing included measuring for TL, assessing sex and spawning condition (expression of gametes), scanning for PIT tag and tagging if none was present (objective 2), and examining the fish for general health and condition (objective 4). A fin clip was taken from a subsample[1] of razorback suckers, placed in 1 milliliter of 95% ethanol in a snap-cap tube, and returned to the laboratory for genetic analyses (objective 3, results reported elsewhere by others). All relevant data were entered into the comprehensive Lower Colorado River Native Fishes Database maintained by M&A.

[1] Fin clips were not taken from some razorback suckers by inadvertent omission or because necessary supplies were exhausted or unavailable.

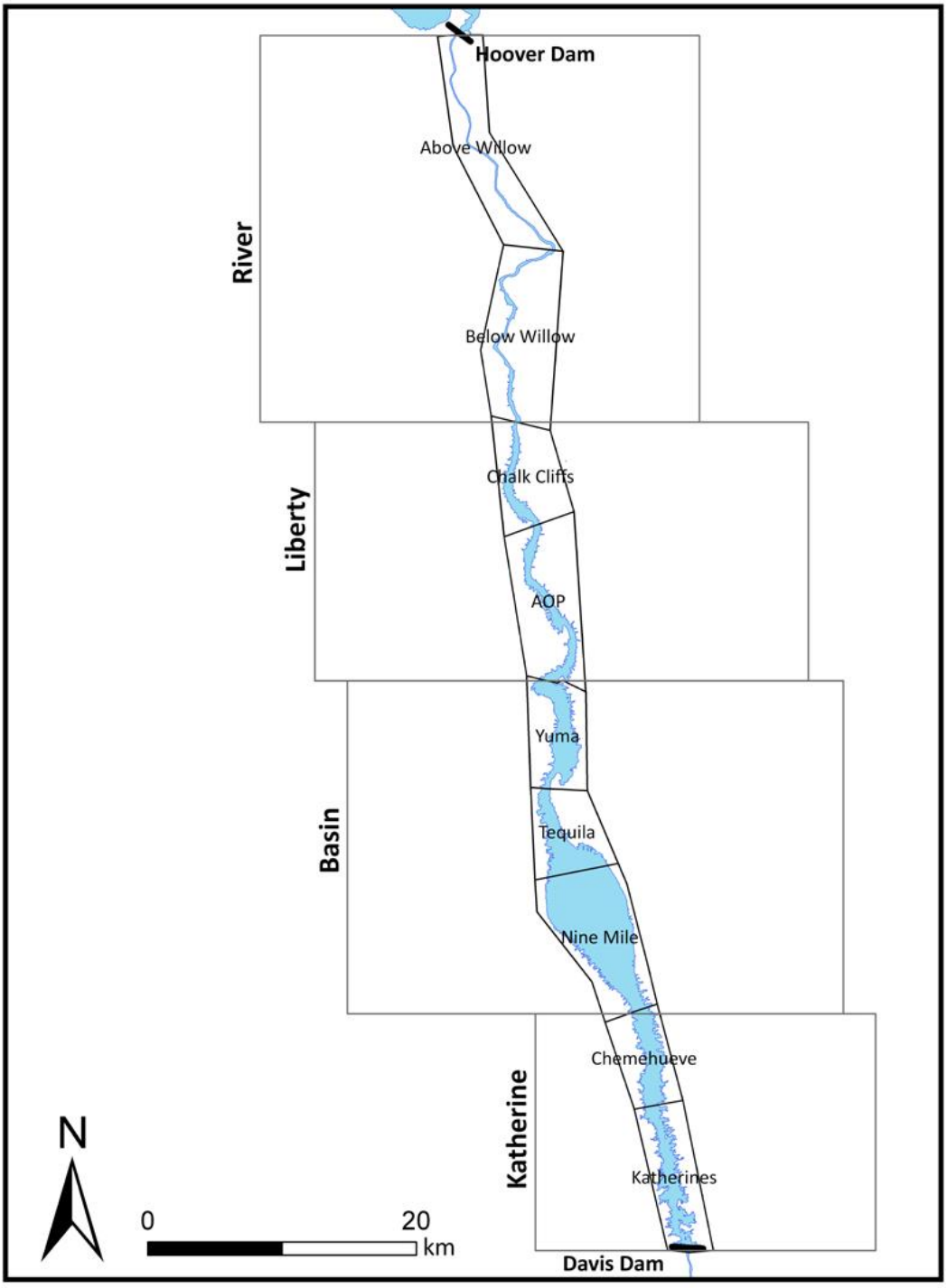

Figure 1.—Map of Lake Mohave, Arizona and Nevada, depicting two zoning schemes, general (large boxes) and specific (smaller boxes); only the former are used in this report.

Remote Monitoring

Remote PIT scanning systems were deployed from January through September 2013 on shallow gravel bars that extended into the Colorado River upstream of Willow Beach (river zone, objective 5). Two models of PIT scanners were utilized. One type of unit (shore based) was comprised of an antenna and scanner housed in a 2.3 m x 0.7 m polyvinyl chloride (PVC) frame connected by 45.7 m of cable to a waterproof box that protected the logger and battery and was secured to shore. The 55 ampere (amp)-hour (h) battery provided power to the scanner continuously for 72 h, eliminating the need for manually removing and charging batteries. The other unit (submersible) was comprised of a 0.8 m x 0.8 m PVC frame antenna attached to a scanner and logger contained in watertight PVC piping. Power to submersible units was provided either by an 8 amp-h sealed lead-acid battery contained in a waterproof "Otter Box®" or a 10.4 amp-h lithium-ion battery pack contained in a watertight, 2-inch acrylonitrile butadiene styrene pipe. Submersible units with either battery scanned continuously for up to 24 h. Five to six submersible units were employed through the monitoring season.

Five locations established as fixed sites for 2013, Gio's Point, Black Bar, Sauna Cave, Ringbolt Rapids, and Boy Scout Canyon (figure 2) received at least one submersible deployment per day each sampling trip. These fixed deployments were set up to test the hypothesis that razorback sucker aggregation sites change over the course of the year, centering around Black Bar during spawning but shifting upstream toward Hoover Dam as the spawning season ends. The sites were all initially scouted in 2011, PIT scanned periodically in 2011 and 2012, and determined to be utilized by razorback suckers at different times of years. One or two shore-based units were deployed in only a few locations: Black Bar, Boy Scout Canyon, and Sauna Cave. Deployment locations of additional scanners not set at fixed sites varied among trips depending on observed or reported fish concentrations. Scanner units monitored fish presence monthly from January through September for 3 nights and 2 days (approximately 65 continuous h) each trip.

Routine remote PIT scanning information was recorded as follows: general location or site name, Universal Transverse Mercator coordinates, water depth (m), time and date of deployment and retrieval, logger number, logger start and stop times, and the scanning interval. Narrative descriptions of weather, river flows, etc., were recorded on field sheets or in data books.

Remote PIT scanning in Basin and Liberty (see figure 1) was conducted by Reclamation with support from M&A personnel (objective 5). Semipermanent shore-based units were deployed in the basin for continuous scanning from November 2012 through May 2013. One shore-based PIT scanner was deployed at Tequila Cove. The unit operated continuously from December 2012 through

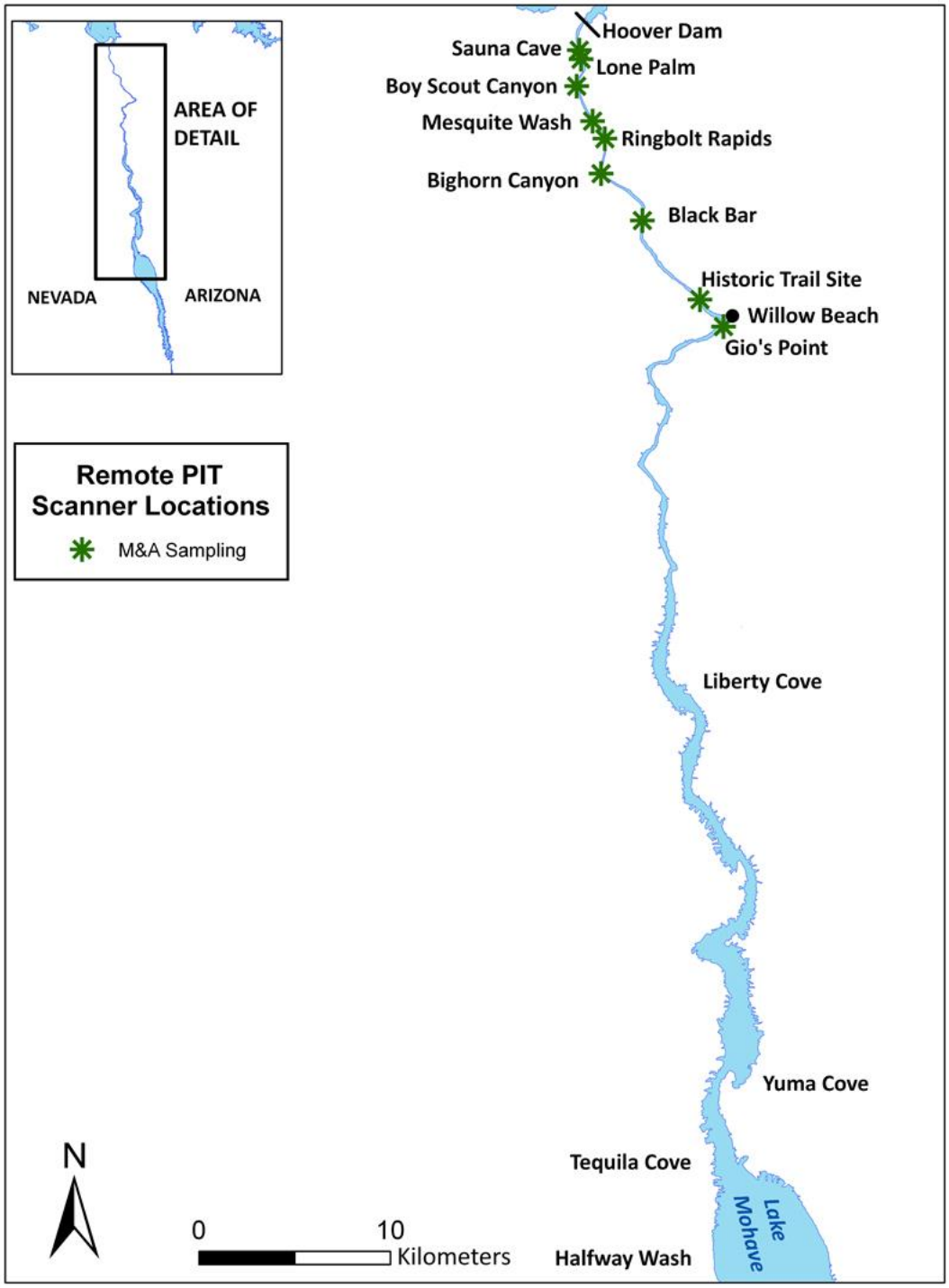

Figure 2.—Location of M&A remote PIT scanners between November 1, 2012, and September 30, 2013, razorback sucker census sampling between Willow Beach and Hoover Dam in Lake Mohave, Arizona and Nevada.

May 2013 and was powered by a deep-cycle marine battery and a 60-watt solar panel. Two shore-based units were also deployed in the lake at Yuma Cove (one in November 2012 and one in January 2013) and attached to the solar aeration system for power. All sites with semipermanent shore-based units represented known spawning aggregation sites and have been collections sites for the March Roundup since collections began. Scanning data along with location and effort 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 Hostmonster.com (http://www.hostmonster.com/).

Remote PIT scanning data were used to describe post-stocking dispersal within a zone in 2013 by tabulating and comparing release zone to scan zone. Razorback suckers contacted from November 1, 2012, through September 30, 2013, with remote PIT scanners and released from October 1, 2008, through September 30, 2012, were assigned a release and contact zone based on locations recorded. Razorback suckers released after September 30, 2008, all contained a 134.2-kHz PIT tag, whereas some or all of the fish released prior to this date contained older 400-kHz PIT tags, which have little to no remote detection capability. Zone and year of release were treated as categorical variables, and the proportion of fish contacted in each zone was presented in stacked bar graphs.

Movement between zones from 2012 to 2013 was also tabulated from remote PIT scanning data. Razorback suckers released after October 1, 2008, and contacted by remote PIT scanning in 2012 (January 1, 2012, to September 30, 2012) and in 2013 (November 1, 2012, to September 30, 2013) were assigned a zone of contact for each year based on recorded location.

Post-stocking survival and the influence of size at release for PIT-tagged repatriated razorback suckers that were released from October 1, 2008, through September 30, 2012, were also analyzed. All database records of razorback sucker release and scanning were assigned to a zone based on their recorded location. Release records were grouped into cohorts based on location and date of release. Cohorts that were released after September 30, 2012, were excluded from analysis to give fish at least a month to disperse prior to initiation of PIT scanning. Contact data within each cohort were tabulated for all fish contacted by remote PIT scanning between November 1, 2012, and September 30, 2013. The proportion of each cohort that was contacted in 2013 was calculated as a relative index of long-term survival of each cohort. This comparison assumes that all razorback suckers alive in Lake Mohave with a 134.2-kHz PIT tag have an equal probability of encountering a PIT scanner over the course of the scanning year. These fish are considered “available” to PIT scanning equipment. Cohorts with fewer than 100 fish released were excluded from tabulation to reduce the probability that differences in contact proportion were due to chance alone.

Population Estimates

The razorback sucker population in Lake Mohave was estimated from two data sources (objective 6). First, March monitoring data were used to estimate the overall population of wild and repatriated fish in Lake Mohave using mark-recapture (objective 8). Data for population estimates from capture data were restricted to encounters in March because the highest number of encounters 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). Second, remote PIT scanning data were used to estimate the size of the lake-wide population as well as the river, Liberty, and basin subpopulations of repatriated and wild razorback suckers with 134.2-kHz PIT tags in 2012 using mark-recapture. PIT scanning data for the marking period were restricted to March, but the capture period was extended to include the entire scan year with the assumption that only deletions (mortality and emigration) occur. Remote PIT scanning and routine monitoring data were treated separately for repatriate estimates because some repatriate razorback suckers contain only a 400-kHz tag, which is rarely recorded 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)

For each mark-recapture estimate, the number of individual PIT tags contacted in March 2012 was the mark (M), the number contacted in 2013 was the capture (C), and the number in common between 2012 and 2013 was the recapture (R). Any contacts with razorback suckers released after the initiation of the marking year (January 1, 2012) were removed from population estimates.

RESULTS

Routine Monitoring

Twenty-two razorback suckers were handled during 2012 and 2013 monitoring events, with March (2013) and November (2012) monitoring activities accounting for 77% (n = 17) and 23% (n = 5) of the captures, respectively (table 1). Two fish captured in March were short-term recaptures by other agencies, with one fish having its first capture by the Nevada Department of Wildlife and National Park Service on March 13, 2013, then its recapture by M&A on March 15, and the other fish had its first capture by the USFWS on March 13, 2013, then its

Table 1.—Adult razorback sucker monitoring summary by capture month, PIT tag, history, and gender during November 2012 and March 2013 monitoring events, Lake Mohave, Arizona and Nevada.

(Two fish captured in March were short-term recaptures, and their capture data from other agencies were omitted from analysis.)

Capture month (year)	Total (% of total)	PIT tag? (% of total)		History (% of total)		Sex (% of total)	
		Yes	No	Repatriate	Wild	Female	Male
November (2012)	5 (23)	5 (23)	–	5 (23)	0	5 (23)	–
March (2013)	17 (77)	15 (68)	2 (9)	17 (77)	0	11 (50)	6 (27)
Total (% of total)	22	20 (91)	2 (9)	22	0	16 (73)	6 (27)

recapture by M&A on March 15; neither fish had any previous captures since release. Two fish were captured with no PIT tags and were presumed to be repatriates that lost their tag; all remaining individuals (n = 20) were PIT-tagged repatriates. No wild adults were captured during the monitoring events. Sex was determined for all fish at the time of capture; the majority of fish captured were female (16; 73%), and the other six (27%) were male. Both females and males were captured in March (n = 11 and 6, respectively), while only females were captured in November (n = 5).

Of the 20 fish with paired captured data (i.e., fish with both stocking and capture data), 2 were shorter than 350 mm TL at release (10%), 12 were 350–499 mm TL at release (60%), and 6 were 450 mm or greater TL at release (30%; table 2). The average TL at release was 420 mm, and the average TL at capture was 510 mm. At capture, 1 fish was shorter than 350 mm (5%), 6 were less than 450 mm TL (30%), and 13 were 450 mm TL or larger (65%) (table 2). Males (n = 5) appeared to exhibit less growth over their time at large, ranging from 0 to 7 mm per month, while females (n = 15) appeared to have more growth, ranging from 0 to 16 mm per month. The average growth rate of all fish was approximately 5 mm per month. Years at large for all fish ranged from less than 1 to 14 years, with an average time at large of almost 2 years (median = 0.6 year). The fish at large for less than 1 year were at large less than 1 to 7 months prior to their capture. Eighteen fish (90%) were captured during 2012/2013 monitoring for the first time since their release into Lake Mohave. One of these fish was at large for 7 years before its first capture. The two remaining fish had 1 and 2 years between their releases and first captures (as reported above), then it was almost 2 and 12 years, respectively, until they were captured again. Seventeen fish with year class information were approximately 1 to 5 years old at stocking.

Table 2.—Adult razorback sucker monitoring summary, November 2012 and March 2013

(Data are for 20, paired release-capture data per fish PIT tag number and include: calculated growth rate (capture TL in mm minus release TL in mm divided by months at large), time at large (capture date minus release date divided by 30 days [for months at large] or 365 days [for years at large]), and capture history. Data are in order by number of captures and capture date, and include year class information where available. Release date is when fish were stocked into Lake Mohave.)

	Date		TL (mm)			Capture history						
PIT tag	Release	Capture	Release	Capture	Growth rate/month	Sex	Days at large	Months at large	Years at large	Number of captures	Comments
1C2D6C6EBD	10/12/2011	11/29/2012	450	560	8	F	414	14	1	1	First capture in 2012
1C2D8DAFFA[a]	5/15/2012	11/29/2012	480	550	10	F	198	7	< 1	1	First capture in 2012
1C2D8C2AF6[b]	5/16/2012	11/29/2012	470	570	16	F	197	7	< 1	1	First capture in 2012
1C2D679787[c]	1/7/2010	11/30/2012	470	570	3	F	1,058	35	3	1	First capture in 2012
1C2D6D1839[b]	5/16/2012	11/30/2012	430	510	13	F	198	7	< 1	1	First capture in 2012
36F2B5A414[d]	12/5/2012	3/12/2013	370	370	0	M	97	3	< 1	1	First capture in 2013
36F2B5A7D6[d]	12/6/2012	3/12/2013	390	400	2	M	96	3	< 1	1	First capture in 2013
4646642132[e]	1/26/2006	3/12/2013	430	670	3	F	2,602	87	7	1	First capture in 2013
003B9F6612[f]	2/28/2013	3/12/2013	370	370	7	M	12	< 1	< 1	1	First capture in 2013
36F2B5A811[d]	12/6/2012	3/13/2013	380	380	0	M	97	3	< 1	1	First capture in 2013
36F2B59FC8[g]	12/5/2012	3/13/2013	450	450	0	F	98	3	< 1	1	First capture in 2013
003B9F6EC4[h]	1/24/2013	3/13/2013	330	330	2	M	48	2	< 1	1	First capture in 2013
1B796B4E44[d]	12/8/2011	3/13/2013	400	520	8	F	461	15	1	1	First capture in 2013
1C2D6CD9F6	10/12/2011	3/13/2013	420	570	9	F	518	17	1	1	First capture in 2013
36F2B5A693[d]	12/6/2012	3/14/2013	390	400	4	F	98	3	< 1	1	First capture in 2013
1B796B590E[d]	12/12/2011	3/14/2013	410	570	11	F	458	15	1	1	First capture in 2013
36F2B5A80A[d]	12/6/2012	3/15/2013	430	440	2	F	99	3	< 1	1	First capture in 2013
1C2C36A31C[i]	10/18/2010	3/15/2013	530	610	3	F	879	29	2	1	First capture in 2013
5210351932	11/10/1998	3/12/2013	330	700	2	F	5,236	175	14	2	First capture in 2001, second capture 2013
1C2D685AB7[j]	12/3/2009	3/13/2013	430	600	4	F	1,196	40	3	2	First capture in 2011, second capture in 2013
		Average	420	510	6	–	703	23	2	–	–

[a] 2008 year class, reared at Dandy Cove backwater.
[b] 2008 year class, reared at Arizona Juvenile backwater.
[c] 2005 year class, reared at Willow Beach NFH.
[d] 2010 year class, reared at Achii Hanyo State Fish Hatchery.
[e] 2003 year class, reared at Willow Beach NFH.
[f] 2010 year class, reared at Willow Beach NFH.
[g] 2007 year class, reared at Achii Hanyo State Fish Hatchery.
[h] 2009 year class, reared at Willow Beach NFH.
[i] 2006 year class, reared at Yuma Cove backwater.
[j] 2008 year class, reared at Achii Hanyo State Fish Hatchery.

Table 3.—Adult razorback sucker monitoring summary, November 2012 and March 2013, for 20 paired release-capture data by rearing type and location, and release and capture locations

(Data are in alphabetical order of rearing type and rearing location. Release location is where fish were stocked into Lake Mohave.)

Rearing		Release				Capture				Distance Traveled (change km)	n fish
Type	Location	Location	State	River km	Zone	Location	State	River km	Zone		
Lakeside backwaters	Arizona Juvenile		AZ	24	Basin	Waterwheel Cove	AZ	32	Basin	8	2
	Dandy Cove		NV	26						6	1
	Yuma Cove		AZ	39	Basin	Carp Cove (inside)				7	1
						Carp Cove (north point)		34		6	1
						Waterwheel Cove		32		7	1
									Avg distance traveled	7	6
Off-site facilities	Achii Hanyo	Cottonwood Cove	NV	37	Basin	Carp Cove (inside)	AZ	32	Basin	4	1
						Carp Cove (north point)		34		3	1
						Cottonwood Cove East		32		5	2
						Cottonwood Cove East (100 m inside, north shore)				5	1
		Princess Cove	AZ	8	Katherine	Cottonwood Cove East				24	1
						Cottonwood Cove East (100 m inside, north shore)				24	1
		Willow Beach boat ramp	AZ	84	River	Cottonwood Cove East				51	1
						Cottonwood Cove East (100 m inside, north shore)				51	1
	Boulder City Wetlands Park	Placer Cove	NV	64	Liberty	Carp Cove (inside)				32	1
	Willow Beach NFH	Antelope Cove		50						18	1
		Cottonwood Cove East	AZ	32	Basin	Cottonwood Cove East (100 m inside, north shore)				0	1
		Liberty Cove		62	Liberty	Cottonwood Cove East				30	1
		Willow Beach NFH		85	River	Waterwheel Cove				53	1
									Avg distance traveled	22	14

Thirty percent of fish (n = 6) captured originated from lakeside backwaters (table 3). Dandy Cove backwater contributed one fish, while Arizona Juvenile and Yuma Cove backwaters contributed two and three fish, respectively. Offsite rearing facilities, including Achii Hanyo State Fish Hatchery, Boulder City Wetlands Park, and Willow Beach NFH contributed more than 70% of the total fish captured (n = 14). Fish reared in lakeside backwaters traveled an average of 7 kilometers from their release to their capture site, while fish reared in offsite facilities traveled an average of 22 kilometers.

Remote Monitoring

In the river zone, remote PIT scanning sampling trips resulted in 3,842 h of scanning: 544 h with shore-based and 3,298 h with submersible PIT scanning units. Mean deployment times were 25.9 and 20.9 h for shore-based and submersible scanners, respectively. Shore-based units were often downloaded on a daily basis, although they were left on site for up to 3 days. A total of 12,900 PIT tag contacts were recorded, representing 1,686 unique PIT tags for which 1,680 had a marking record in the Lower Colorado River Native Fish Database (as of September 30, 2013). Repatriated razorback suckers accounted for 1,669 of the unique encounters, 8 were wild razorback suckers, and 3 were of unknown origin.

Remote PIT scanning in the Liberty zone was completed with a single deployment of a Destron (Destron FearingTM) PIT scanner for 39.4 h. A total of 97 PIT tag contacts were recorded, representing 15 unique razorback suckers, all of which had a marking history and were repatriates.

Remote PIT scanners in the basin zone were deployed for a total of 7,412 h of scanning: 7,301 with shore-based and 111 with Destron scanning units. Mean deployment times were 429.5 h for shore-based and 55.5 h for Destron scanners. A total of 462,337 PIT tag contacts were recorded, representing 1,620 unique PIT tags for which 1,581 had a marking record in the Lower Colorado River Native Fish Database (as of September 30, 2013). Repatriated razorback suckers accounted for 1,572 of the unique encounters, 3 were wild, and 6 were of unknown origin.

Post-stocking dispersal out of the zone of release was minimal for two of the three main stocking zones. Razorback suckers released into the river zone accounted for 61.7% (1,413) of the 2,289 fish contacted there, excluding 88 fish (3.7%) of the total contacted in multiple zones. The majority (> 80%) of these fish were contacted in the river zone regardless of release year (figure 3). Razorback suckers released in the Liberty zone in 2012 were contacted in Liberty (figure 4), but for other release years, they were contacted elsewhere (the river and basin zones). Basin zone released fish accounted for 31.8% (727) of razorback suckers contacted, and as with the river zone released fish, more than 80% were contacted in their zone of release regardless of release year (figure 5). No pit scanning was

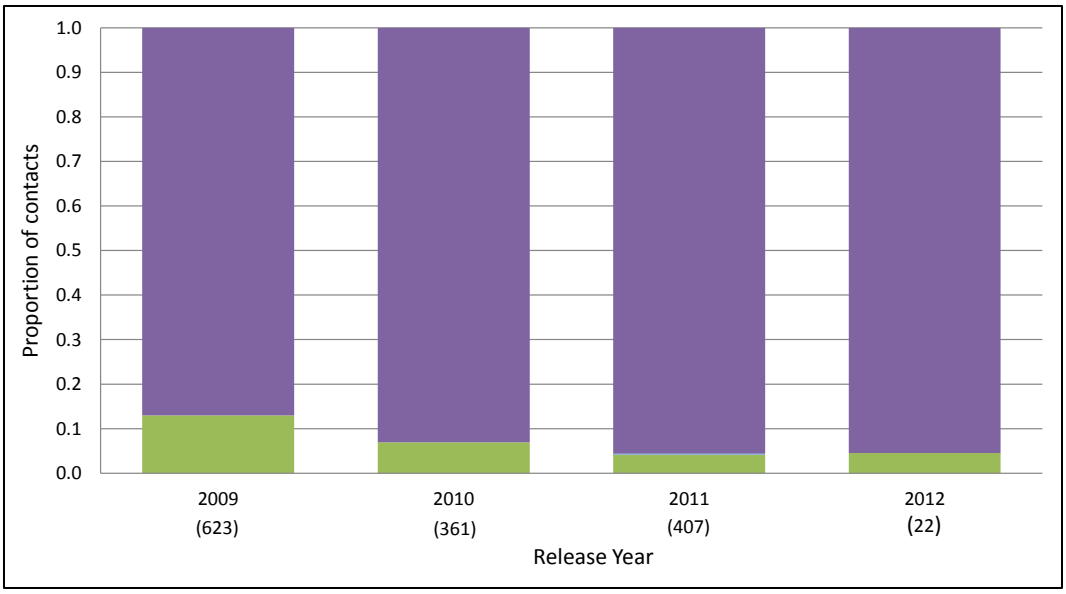

Figure 3.—Proportion of razorback sucker PIT tag contacts among three scanning zones in Lake Mohave, basin (green), Liberty (blue), and river (purple), for fish released in the river zone.
Fish were released between November 1, 2008, and October 31, 2012, and contacted during PIT scanning activities from November 1, 2012, to September 30, 2013. The number of contacts is in parentheses.

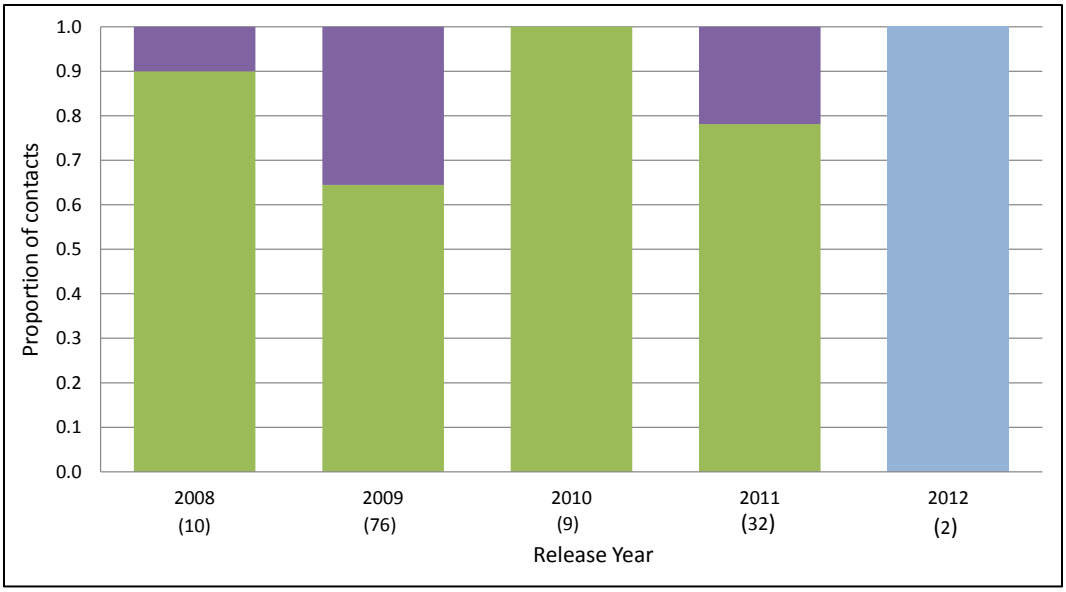

Figure 4.—Proportion of razorback sucker PIT tag contacts among three scanning zones in Lake Mohave, basin (green), Liberty (blue), and river (purple), for fish released in the Liberty zone.
Fish were released between November 1, 2008, and October 31, 2012, and contacted during PIT scanning activities from November 1, 2012, to September 30, 2013. The number of contacts is in parentheses.

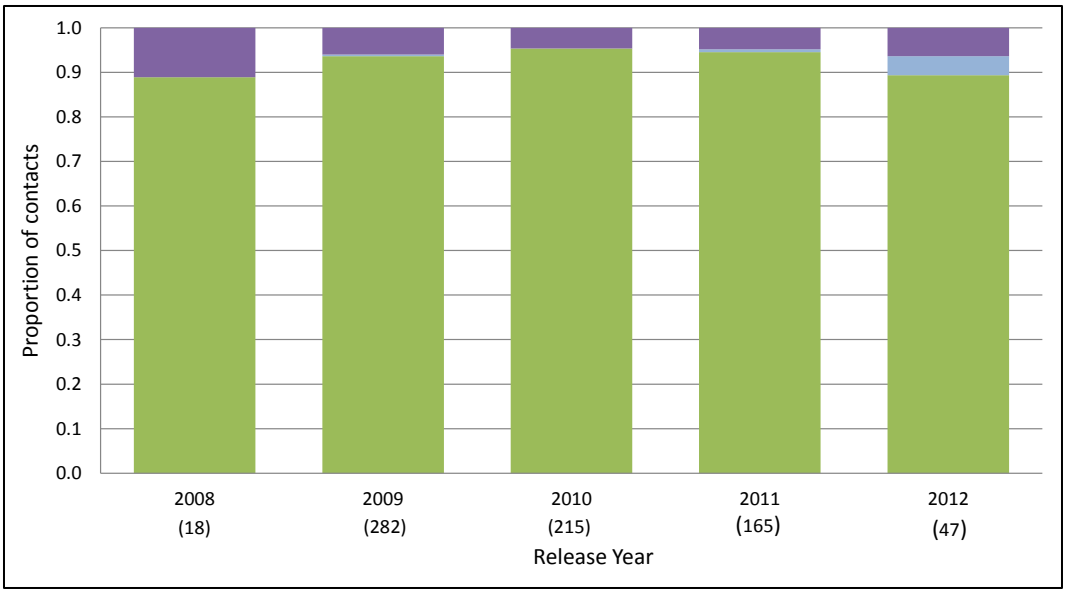

Figure 5.—Proportion of razorback sucker PIT tag contacts among three scanning zones in Lake Mohave, basin (green), Liberty (blue), and river (purple), for fish released in the basin zone.
Fish were released between November 1, 2008, and October 31, 2012, and contacted during PIT scanning activities from November 1, 2012, to September 30, 2013. The number of contacts is in parentheses.

conducted in Katherine because few fish have been released there between October 1, 2008, and September 30, 2012, and only one release cohort in that time period contained more than 100 fish (1,689 fish released at Princess Cove in 2012) (table 4). However, 17 fish released in Katherine were contacted in the basin zone, and three were contacted in the river zone.

The adult subpopulations in the river, Liberty, and basin zones exchanged few individuals from 2012 to 2013 (table 5). Out of the 1,671 fish that were contacted in both years, 1,543 (92.3%) were contacted in only one zone (no detectable movement between zones). For fish contacted in a different zone each year, but only one zone per year, the greatest detectable movement was 39 fish (2.3%) that moved from the river to the basin zone. Twelve fish moved from the basin to the river zone, and 2 fish moved from Liberty to the basin zone. The remaining fish were contacted in multiple zones in a year; 18 fish were contacted in multiple zones in 2012, 52 were contacted in multiple zones in 2013, and five fish were contacted in multiple zones both years.

Post-stocking contact rates were highly correlated with size at release ($r = 0.83$), regardless of stocking zone, but rates also varied by as much as a factor of five among similarly sized cohorts (table 4). In the river zone, the highest contact rate was 29.6% for a cohort of 500 razorback sucker released on October 4, 2011, at a mean size of 441 mm. This cohort had the highest contact rate in 2012 as well at

Table 4.—Razorback sucker repatriation cohorts (fish released at a given location on the same date) from October 1, 2008, to October 31, 2012, and their remote PIT scanning contact rates in 2013, Lake Mohave, Arizona and Nevada

Release zone	Release location	Release date	Releases	Mean TL (mm)	Contacted	Percent contacted
River	Willow Beach NFH	10/4/2011	500	441	148	29.6%
	Willow Beach boat ramp	10/23/2009	2234	421	441	19.7%
	Willow Beach boat ramp	12/8/2011	1,594	394	260	16.3%
	Willow Beach NFH	1/7/2010	2,077	423	338	16.3%
	Willow Beach boat ramp	10/13/2009	2,588	416	185	7.1%
	Willow Beach boat ramp	12/7/2010	504	398	34	6.7%
	Willow Beach NFH	3/8/2012	549	375	21	3.8%
	Willow Beach boat ramp	12/12/2011	408	351	5	1.2%
	Painted 8 Cove	12/18/2009	1,436	347	16	1.1%
	Willow Beach NFH	4/4/2012	119	373	1	0.8%
	Ringbolt Cove	1/6/2010	1,493	334	3	0.2%
	Ringbolt Rapids	12/16/2010	1,509	324	3	0.2%
	Ringbolt Rapids	1/5/2012	1,778	332	0	0.0%
Liberty	Liberty Cove	3/16/2011	444	414	26	5.9%
	Wrong Cove	12/17/2009	917	374	38	4.1%
	Red Tail Cove	12/17/2009	897	382	18	2.0%
	Liberty Cove	12/17/2009	1,521	379	27	1.8%
	Six Mile Coves	1/5/2010	1,584	329	9	0.6%
	Liberty Cove	1/5/2011	1,896	339	7	0.4%
	Liberty Cove	1/5/2012	1,920	330	3	0.2%
Basin	Yuma Cove	5/19/2010	101	478	46	45.5%
	Cottonwood Cove	3/26/2009	125	463	44	35.2%
	Cottonwood Cove	3/20/2009	209	508	72	34.4%
	Cottonwood Cove	12/3/2009	413	448	119	28.8%
	Chemehuevi Cove North	10/14/2008	176	451	7	4.0%
	Dandy Cove	10/8/2008	158	438	6	3.8%
	Nine Mile Coves	1/6/2010	980	374	36	3.7%
	Nine Mile Coves (north of)	1/6/2011	1,892	341	7	0.4%
	Yuma Cove	12/18/2009	1,611	329	5	0.3%
	Owl Point Cove	1/26/2012	1,022	324	2	0.2%
	Yuma Cove	1/18/2012	693	328	1	0.1%
Katherine	Princess Cove	1/18/2012	1,689	335	4	0.2%
Totals			35,037	419 (mean)	1,932	17.9% (mean)

Table 5.—Razorback suckers contacted by remote PIT scanning in 2013 (November 1, 2012, through September 30, 2013) that were also contacted in 2012 (January 1, 2012, through September 30, 2012) broken down by zone of contact, Lake Mohave, Arizona and Nevada

(Fish that were contacted in more than one zone in the same year [18 in 2012, 52 in 2013, and 5 in both years] were excluded from this table.)

	2013		
2012	**River**	**Liberty**	**Basin**
River	1,063	0	39
Liberty	0	1	2
Basin	12	0	479
	1,075	1	520

38.6%. In stark contrast, no fish were contacted from a cohort consisting of 1,778 razorback sucker with a mean TL of 332 mm released on January 5, 2012, at Ringbolt Rapids. The three lowest contact rates (0.0 to 0.2%) all came from cohorts released at or near Ringbolt Rapids, and these cohorts also represented some of the smallest fish released (mean TL at release of 324 to 334 mm; table 4). The mean contact rate for all stockings was 17.9%, but the highest contact rate in Liberty was 5.9% for a cohort released at Liberty Cove on March 3, 2011, with a mean TL of 414 mm. The basin zone had four of the top five cohort contact rates (45.5, 35.2, 34.4, and 28.8%). Mean TLs of these four cohorts were 448 to 508 mm — much greater than the mean TL for all cohorts (419 mm) — and were relatively small in numbers (between 101 and 413 fish).

Population Estimates

Monitoring data from 2012 and 2013 did not provide enough recaptures to estimate the size of the wild razorback sucker population in Lake Mohave. The repatriated razorback sucker population estimate for 2012 was 1,854 fish (95% confidence interval [CI] from 941 to 3,782), with a 1% estimated survival of all repatriates released as of March 1, 2012.

Based on 2012 and 2013 remote PIT scanning, the 134.2-kHz tagged Lake Mohave repatriate population was estimated at 3,588 individuals (95% CI from 3,259–3,950). Subpopulation estimates based on zone-specific scanning in 2012 and 2013 also were calculated. The basin zone population was estimated at 1,598 (95% CI from 1,390–1,836), the Liberty zone was estimated at 55 (95% CI from 17–100; one recapture), and the river zone was estimated at 2,188 (95% CI from 1,908 to 2,509). The river zone estimate was nearly identical to the estimate

of 2,174 from a regression analysis conducted in 2012 (Kesner et al. 2012b). Wild fish also were contacted in the basin and river zones, but no estimate was calculated because only one recapture was recorded in the river zone.

DISCUSSION

For over a decade, the repatriated population of razorback suckers in Lake Mohave has been maintained at a few thousand fish by stocking nearly 200,000 fish. The razorback sucker repatriation program is one facet of a broader strategy, but it plays a critical role in maintaining Lake Mohave as the only genetic reservoir for the species throughout its range (Dowling et al. 1996a, 1995b, 2005) and, thus, requires continuation. The genetic legacy of razorback suckers embodied in the Lake Mohave population must be maintained while a backwater conservation strategy (Minckley et al. 2003; USFWS 2005) or an alternative is developed and implemented. That genetic legacy depends not just on maintaining a genetically diverse population but also on the collection of the reproductive output (i.e., naturally produced larvae) of that population. Results from the current monitoring year demonstrate that annual census estimates calculated from March capture data exclude a significant portion of the population that resides upstream of Willow Beach, and that a majority of this "river" subpopulation likely is not contributing to the reproductive output collected by the repatriation program.

Remote PIT scanning data indicate razorback suckers in the river and basin zones act as separate demographic subpopulations. Fewer than 10% of fish are contacted in more than one zone, and even 5 years after release, more than 80% remain in their release zone. From a genetics perspective, a few individuals per generation can be enough to homogenize the genetics (Wright 1931; Mills and Allendorf 1996). However, this assumes natural recruitment and exchange of random individuals between subpopulations. The contribution of the river zone subpopulation to the genetics of the repatriation program depends on the dynamics of exchange between the basin and river zone subpopulations. If the same individuals move from the river to basin zone each year, then the remaining subpopulation in the river zone does not contribute to the available larval production used in the repatriation program, under which larvae are collected exclusively downstream from Willow Beach. On the other hand, if each year a random assortment of the river zone subpopulation moves from the river to basin zone, then over the course of a generation, much of the river zone subpopulation would contribute to the repatriation program. Determination of which situation exists would determine the appropriate population metric to track with the genetic analysis that is conducted concurrently. This determination can be done with current levels of effort but will require additional years of monitoring.

The increased contact rate provided by remote PIT scanning compared with traditional capture methods has provided near complete post-release data. More razorback suckers were contacted in 2013 (3,171) than the estimated population size based on March 2012 and March 2013 monitoring data, and it is likely that this estimate largely ignores the subpopulation in the river zone. Still, there is strong evidence that the vast majority of razorback suckers available for remote PIT scanning in Lake Mohave were contacted in 2013. First, 2,760 of the fish contacted in 2013 were repatriated razorback suckers released before January 1, 2012. This represents 77% of the lake-wide estimate based on 2012 and 2013 PIT scanning data (3,588). Second, out of the 2,355 razorback suckers released after September 30, 2008, and scanned in 2012, 1,671 were contacted in 2013 (71%; unpublished data). Given that adult survival is estimated to be about 75% annually (Marsh et al. 2005), most razorback suckers that were released after September 30, 2008, and survived through 2013, were scanned in 2013.

The additional data continue to support the paradigm that fish released at TLs of 450 mm or greater have nearly an order of magnitude higher survival than fish released at 300 mm. However, year-to-year and within-year fluctuations in survival also are dramatic. For example, stockings without a known pre-release factor discrepancy that differ by as little as a month in release dates can differ by a factor of five in post-release contact rates (release cohorts at Willow Beach in March and April 2012) (see table 5). The survival discrepancy among years may be due to depressed numbers of large striped bass (*Morone saxatilis*), and within year discrepancies may represent a shift in striped bass occupation of release sites. There also may be unidentified and unevaluated pre-release factors (e.g., health and condition of fish prior to release) that impact post-release survival. Investigation of both possibilities should be pursued to maximize post-release survival and stocking efficiency.

As we continue to move toward alternative solutions to maintaining populations of razorback sucker by stocking, it is important to continue stocking and to identify and evaluate means to improve post-stocking survival and increase population size. Although it is clear that alternatives to this management strategy must be pursued, any relaxation of the Lake Mohave stocking program could have serious consequences for the species within a few years. There are also unknown factors and continued threats that require continued monitoring of this population given that post-stocking survival can fluctuate nearly ten-fold from year to year (Kesner et al. 2008a, 2012a). Because the Lake Mohave population is dependent on a large number of fish recruiting to the adult population every year, relative to the overall population size, any dramatic downward shift in post-stocking survival of razorback sucker must be identified as soon as it occurs so that diagnostic and remedial action can be taken if feasible. The continued changing environment in reservoirs throughout the Colorado River Basin (e.g., introductions of quagga mussel [*Dreissena rostriformis bugensis*], giant salvinia [*Salvinia molesta*], gizzard shad [*Dorosoma cepedianum*], etc.) makes the probability of a shift in survival not only possible but likely.

RECOMMENDATIONS

Biannual netting operations should continue during autumn and spring monitoring to collect growth, health, census, and genetic data from wild and repatriate razorback suckers in Lake Mohave. There currently are no other mechanisms to acquire these critical data.

Razorback suckers stocked into Lake Mohave should be at the largest individual size possible and in the greatest number possible. Stockings should be directed spatially and temporally, with the goal of assessing razorback sucker metapopulation dynamics and effect of stocking location on these dynamics. Stockings for the next Federal fiscal year (fiscal year 2014 – October 2013 to September 2014) should continue to be distributed equally among the three monitoring zones (river, Liberty, and basin). Fish repatriated at each location should be as close as possible to the same mean size and total number, and releases among the three zones should be within a few days to at most a few weeks of each other. Based upon available data, releases of at least 500 fish per location and stocking event should result in adequate future PIT scanning contacts to support sound analysis. Contact rates in the basin and river zones likely exceeded 80% of available fish in 2013. Assuming 10% post-stocking survival, at least 40 razorback suckers will be contacted from each stocking cohort.

The goal of the Lake Mohave razorback sucker repatriation program is to maintain or increase the genetic diversity of the adult population for the purpose of species conservation. One objective of the recommendations above is to use release date and time, as well as contact date and time, for individual fish to determine exchange rates among subpopulations. Remote PIT scanning deployments in the river zone should be conducted at least monthly. M&A staff should continue to work with Reclamation biologists to ensure a similar scanning effort in the basin zone. Effort in the Liberty zone may be displaced to other suitable locations if they can be identified based on presence of razorback suckers. Locations of deployments would be based on past results and continued input from visual surveys as well as supplemental PIT scanner deployments in new locations and zones (i.e., Katherine) as equipment, personnel, and time permit.

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