Lower Colorado River
Multi-Species Conservation Program

Balancing Resource Use and Conservation

Lake Mohave Razorback Sucker Monitoring
2012 Annual Report

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

November 2012

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Lake Mohave Razorback Sucker Monitoring 2012 Annual Report

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ACRONYMS AND ABBREVIATIONS

amp	ampere
Bubbling Ponds SFH	Bubbling Ponds State Fish Hatchery
CI	confidence interval
cm	centimeter(s)
d	day(s)
h	hour(s)
kHz	kilohertz
km	kilometer(s)
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
M&A	Marsh & Associates, LLC
mm	millimeter(s)
NPS	National Pak Service
PIT	remote passive integrated
PVC	polyvinyl chloride
Reclamation	Bureau of Reclamation
RM	River Mile
TL	total length
UTM	Universal Transverse Mercator
Willow Beach NFH	Willow Beach National Fish Hatchery

Symbols

%	percent

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SUMMARY

Monitoring of repatriated razorback sucker (*Xyrauchen texanus*) in Lake Mohave has been conducted for 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, while traditional capture methods were employed to continue to collect comparable long-term monitoring data and estimate abundance of all repatriated and wild PIT-tagged razorback sucker (400 or 134.2 kHz).

Netting efforts from November 23, 2011, to September 30, 2012, resulted in the capture of 32 razorback sucker (31 captures, one short-term recapture). Sixty-five percent (%) of captures occurred in March, and 35% during November. Five fish were captured with no tags and were presumed to be repatriates; all remaining individuals were PIT-tagged repatriates. No wild razorback sucker estimate was made due to a lack of captures. The repatriated razorback sucker population for 2011 is estimated to number 2,577 (95% confidence interval [CI] from 1,139 to 6,284) with a 2% estimated survival of all repatriates released as of March 1, 2011.

Total deployment time for remote PIT scanners from January through September 2012 was 8,392.6 scan hours, resulting in a total of 46,855 PIT tag contacts representing 2,748 individual razorback sucker; 2,704 had a marking record in the Lower Colorado River Native Fish Database (as of September 30, 2012). Of the fish with a marking record, 2,685 were repatriates, 13 were wild, and 6 were recorded as unknown.

Remote PIT scanning deployments were divided among three zones: River, Liberty, and Basin. Of the repatriated razorback sucker contacted in both 2011 and 2012, very little exchange was observed between the three zones, with 94.5% of contacts (571 of 604 fish) occurring in the same zone in both years. Post-stocking dispersal between the three zones was also limited. Of the 1,070 razorback sucker that had been at large for at least 1 year and released in the River zone after October 1, 2008, 93% (994 individuals) were scanned in the River zone. Razorback sucker released in Liberty were more likely to move elsewhere, with 57% located in Basin (65 fish) and 41% in River (36 fish).

Population estimates for 134.2-kHz-tagged razorback sucker were divided among River and Basin subpopulations based on remote PIT scanning in 2011 and 2012: 1,726 (95% CI from 1,507 to 1,976) and 958 (95% CI from 815 to 112), respectively. Wild razorback sucker were also contacted in Basin and River zones. The estimated abundance of wild fish that were tagged with 134.2-kHz tags was three (number of fish marked in the initial sample [*M*] = 2, number captured in the second sample [*C*] = 2, and number of marked fish in the second sample [*R*] = 1) and 12 (*M* = 7, *C* = 11, *R* = 7), respectively. A regression

analysis of 134.2-kHz-tagged razorback sucker contacted in River from January through September 2012 was used to estimate the population there in 2012 at 2,174 (95% CI from 1,974 to 2,375).

For 2012, PIT scanning deployments in Lake Mohave increased the number of encounters with razorback sucker by more than a factor of 10 (2,748 contacted compared to 170 fish captured in March roundup), established the separation of two subpopulations, and resulted in contact with 86% of the estimated population in the River zone—1,866 razorback sucker contacted in 2012 that were released prior to 2012 out of an estimated population of 2,174 based on regression analysis. This level of annual encounter rate, if maintained for multiple years, will provide insight into the influence of stocking location, size, season, and temporal variations on post-stocking and adult survival.

INTRODUCTION

Lake Mohave once was home to the largest known population of wild razorback sucker (*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, unpublished data). A repatriation program for restoring razorback sucker in Lake Mohave was begun in the early 1990s (Mueller 1995). The program utilizes wild-produced larvae that are reared in protective captivity and then repatriated to the reservoir after growing to a nominal size of 30 centimeters (cm) in 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 50 cm has proven difficult to produce in sufficient numbers to increase population size (Mark Olson, Willow Beach National Fish Hatchery [Willow Beach NFH], personal communication), and even fish of this size are subject to predation (Karam and Marsh 2010).

The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) currently oversees and funds stocking and monitoring of razorback sucker in Lake Mohave. Stocking razorback sucker into Lake Mohave from Willow Beach NFH (LCR MSCP Work Task B2) and from lakeside ponds (LCR MSCP Work Task B7) is conducted under the Fish Augmentation component of the LCR MSCP. 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 2005), incorporate a population component that will occupy the main stem, but 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 how such a strategy should contribute to maintenance of razorback sucker 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 sucker 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. 2012). While telemetry results have generally been consistent with the mark-recapture model, telemetry also highlighted the variability in survival from year to year. Mark-recapture models that included annual variations in survival failed to provide accurate estimates due to the low recapture rate in annual roundup 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 primarily composed of individuals that contain 134.2-kilohertz (kHz) passive integrated transponder (PIT) tags; therefore, 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. 2008).

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

1. Locating and capturing adult razorback sucker.

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

3. Collecting tissue samples from adult razorback sucker for genetic analysis.

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

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 one week per month between River Miles (RM) 290–305 in November and from January through May and for 1 week per month between RM 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 data sets to the designated Bureau of Reclamation (Reclamation) Contracting Officer's Technical Representative.

METHODS

For the 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. 2012). These zones are numbered from upstream to down, with the LCR MSCP reach (i.e., 2) followed by a dash and the zone number (e.g., 2-1). Each zone has a descriptive name that represents either a specific location of focus within that zone (e.g., Liberty and Katherine), or it describes the general characteristic 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. This report relies heavily on these zone delineations for analysis and will typically refer to the description name when describing the methodological approach and results of analyses.

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 (Basin zone), near RM 298 (miles upstream of the Southern International Water Boundary). From November 28 to December 1, 2011, as many as four trammel nets (91.4 x 1.8 meters [m], 3.8-cm stretch mesh) were fished continuously along the Arizona shoreline from Pot Cove upstream to Carp Cove, and one net was set at Yuma Cove. In a similar effort, as many as six trammel nets were fished continuously along the Arizona shoreline from Pot Cove upstream to Airport Cove during the March roundup (March 12–16, 2012).

Native fishes encountered were processed and released. 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 of razorback sucker, placed in 1 milliliter of 95 percent (%) ethanol in a snap-cap tube, and returned to the laboratory for genetic analysis (Objective 3, reported elsewhere). All relevant data were entered into the comprehensive Lower Colorado River Native Fishes PIT Tag Database maintained by M&A.

Remote Monitoring

Remote PIT scanning systems were deployed between January and September 2012 on shallow gravel bars that extend 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 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 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 "OtterBox®" or a 10.4 amp-h lithium-ion battery pack contained in a watertight, 2-inch acrylonitrile butadiene styrene pipe. Submersible units scanned continuously with either battery for up to 24 h. Six to 12 submersible units were employed through the monitoring season.

The use of completely submersible units, which are not easily retrieved from the surface of the water without proper equipment, allowed the deployment of units in relatively high watercraft traffic areas such as Lone Palm, Boy Scout, Ringbolt, Bighorn Canyon, and Black Bar (figure 2). The larger shore-based unit was deployed in one fixed location, typically at Black Bar. The location varied between trips depending on fish concentrations. Scanner units monitored fish presence monthly between January and September for 3 nights and 2 days (approximately 65 continuous h) each trip.

Routine remote PIT scanning information was recorded on waterproof paper as follows: general location or site name, Universal Transverse Mercator (UTM) 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, riverflows, etc., were recorded on field sheets or data books.

Remote PIT scanning in Basin and Liberty (figure 1) was conducted by Jon Nelson (Reclamation) with support from M&A personnel (Objective 5). Scanning data along with location and effort information were provided by Mr. Nelson, 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/). Access to summary reports of scanning data as well as all raw data files can be obtained through a password-protected section of the M&A Web site (http://www.nativefishlab.net) Objective 9).

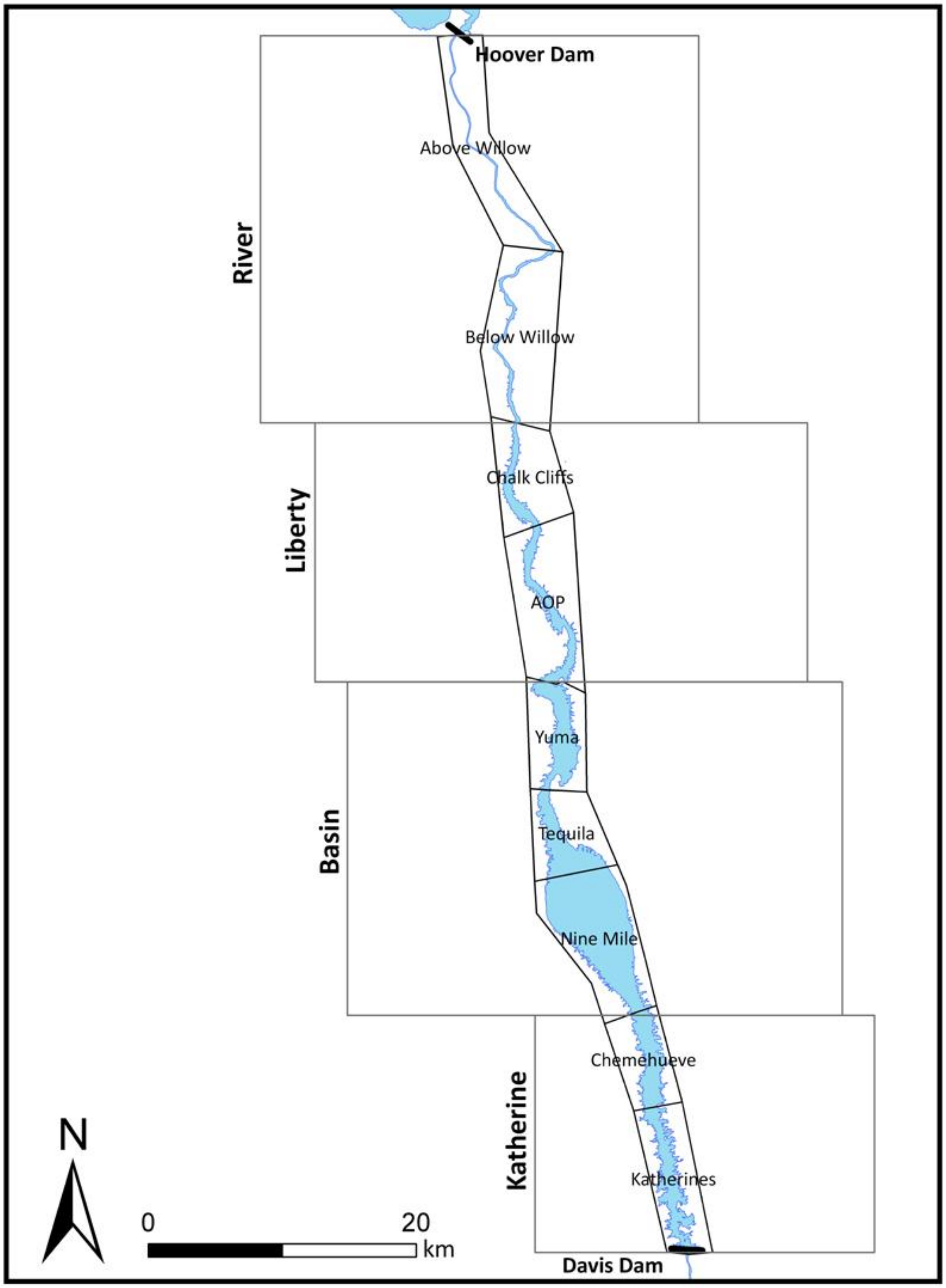

Figure 1.—Map of Lake Mohave, Arizona and Nevada, depicting two zoning schemes: general (large boxes) and specific (smaller boxes).
(Note: only the former are used in this report.)

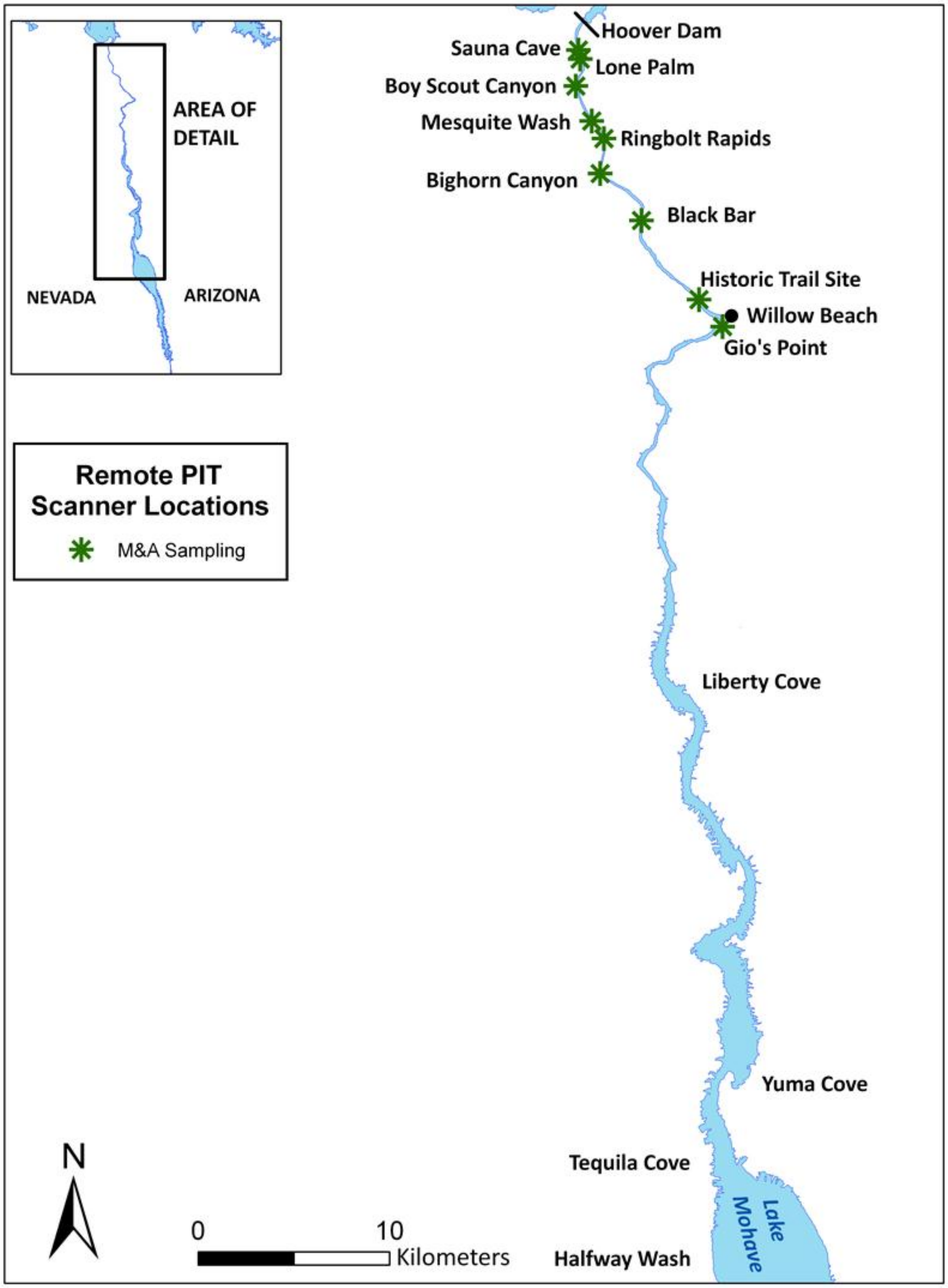

Figure 2.—Location of M&A remote PIT scanners between January and September 2012 razorback sucker census sampling between Willow Beach and Hoover Dam in Lake Mohave, Arizona and Nevada.

Remote PIT scanning data were also used to describe post-stocking dispersal in 2012 by tabulating and comparing release zone to scan zone. Razorback sucker released after October 1, 2008, were assigned to a release zone and contact zone. Fish that were contacted in more than one zone in 2012 were removed from tabulation.

Remote PIT scanners also detected razorback sucker released in 2008 and 2009 as part of the acoustic telemetry study.[1] Telemetry study fish contacted via remote PIT scanners in 2012 were assigned to the general zones. The general zone of encounter by remote PIT scanning was then tabulated to compare the short (6-month post-release) and long-term dispersal patterns of these fish.

Post-stocking fate and the influence of size at release for PIT-tagged repatriated razorback sucker that were released between October 1, 2008, and December 31, 2011, was also analyzed. All database records of razorback sucker release and scanning were assigned to a zone based on their recorded location. Release records were then grouped into cohorts based on zone and month of release. Contact data within each cohort were tabulated for all fish contacted by remote PIT scanning between January 1 and September 20, 2012. The proportion of each cohort that was contacted in 2012 was calculated as a relative index of long-term survival of each cohort.

Population Estimates

The razorback sucker population in Lake Mohave was estimated from two data sources (Objective 6). Routine monitoring data (March roundup) combined from all participants were used to estimate the overall population of wild and repatriated fish in Lake Mohave using mark-recapture (Objective 8). Data for population estimates were restricted to encounters in March because the highest number of encounters with razorback sucker 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). Remote PIT scanning data were used to estimate the size of River and Basin subpopulations of repatriated razorback sucker stocked with 134.2-kHz PIT tags in 2011 using mark-recapture, and the 2012 River subpopulation was estimated by linear regression. No estimate of the Liberty subpopulation was possible due to the low number of contacts. Routine monitoring data were required for the wild population estimate because few wild fish have been tagged with 134.2-kHz tags. Remote PIT

[1] Between 2006 and 2010, acoustic telemetry was conducted in Lake Mohave to determine post-stocking survival and movement patterns for razorback sucker (see Kesner et al. 2008, 2010). Stocking events took place in 2006, 2007, 2008, and 2009, during which a total of 106 acoustic-tagged razorback sucker were repatriated into the reservoir between Fortune Cove and Hoover Dam. All fish were marked with 134.2-kHz PIT tags. Of the 106 fish stocked, the cumulative number of acoustic-tagged fish presumed living at the end of all the studies was 55 individuals.

scanning and routine monitoring data were treated separately for repatriate estimates because some repatriate razorback sucker contain only a 400-kHz tag, which is rarely 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:

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

For each mark-recapture estimate, the number of individual PIT tags contacted in 2011 was the mark (*M*); the number contacted in 2012, the capture (*C*); and the number in common between 2011 and 2012, the recaptures (*R*). For population estimates based on PIT scanning data, only contacts in March were used for the mark, but data from the entire scan year were used for the capture.

Regression analysis was used to estimate the current (2012) size of the River subpopulation (with 134.2-kHz PIT tags) by regressing the proportion of new contacts with total unique fish contacted in the current year. This approach is analogous to a removal study in which the rate of captures (new tag encounters for PIT scanning) declines as the total number of fish removed (total unique tag contacts for PIT scanning) increases. For each scanning trip, the total number of unique PIT-tagged razorback sucker encountered prior to the trip was tallied as the independent variable, and the proportion of unique PIT-tagged razorback sucker encountered during the trip (number of newly encountered PIT tags in a given trip/total number of PIT tags encountered in a given trip) as the dependent variable. The x-intercept was set at one (1; 100% of PIT tags encountered on the first trip were unique), and the best-fit slope was determined by minimizing the sum of squared residuals (least squares, Sokal and Rohlf 1981). The population estimate was the y-intercept, the point at which no unique PIT tags would be scanned. The regression coefficient (slope), r^2, x-intercept, and 95% confidence intervals were calculated by the linear regression module provided in The R Project for Statistical Computing (http://www.r-project.org/). Razorback sucker released after 1 January 2012 were excluded from the regression because new releases would artificially increase the number of new PIT tags contacted on any trip after a stocking.

RESULTS

Routine Monitoring

We handled 32 razorback sucker during 2011 and 2012 monitoring events, with March (2012) and November (2011) monitoring activities respectively, accounting for 65% (n = 20) and 35% (n = 11) of the captures (table 1); one fish captured in

Table 1.—Adult razorback sucker monitoring summary by capture month, PIT tag, history, and sex during November 2011 and March 2012 monitoring events, Lake Mohave, Arizona and Nevada
(One fish captured in March was a short-term recapture and 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 (2011)	11 (35)	7 (23)	4 (13)	11 (35)	0	10 (32)	1 (3)
March (2012)	20 (65)	19 (61)	1 (3)	20 (65)	0	17 (55)	3 (10)
Total (% of total)	31	26 (84)	5 (16)	31	0	27 (87)	4 (13)

March was a short-term recapture and omitted from table 1 and any further analysis. Five fish were captured with no PIT tags, and these were presumed to be repatriates. All remaining individuals (n = 26) were PIT-tagged repatriates; no wild adults were captured during our monitoring events. Only four males were captured, with the remaining 28 all identified as female.

Of the 26 fish with paired capture data (i.e., fish with stocking and capture data), three fish were shorter than 30 cm at release (11%), six fish were 33 to 39 cm TL at release (23%), and 17 fish were greater than 41 cm TL at release (65%; table 2). All fish were greater than or equal to 45 cm at capture. The average TL at release was 41 cm, while the average TL at capture was 56 cm. Sex was determined for all fish at the time of capture. Males (n = 4) appeared to exhibit faster growth over their time at large, ranging from less than 1 to 7 cm/month, while females (n = 22) appeared to have slower growth, ranging from less than 1 to 2 cm/month. The average growth rate of all fish was approximately 1 cm/month. Years at large for all fish ranged from less than 1 to 15 with the average time at large of 4 years. The fish at large for less than 1 year were at large 2–5 months prior to their capture. Twenty-one fish (81%) were captured during 2011 or 2012 monitoring for the first time since their release into Lake Mohave. One fish was at large 10 years before its first capture, while another fish spent 12 years at large between captures. Three fish were tagged and released in the late 1990s, while the 23 remaining fish were tagged since 2000. Twelve fish with year class information were approximately 1–7 years old at stocking.

Fifty-eight percent of captured fish (n = 15) originated from lakeside backwaters (table 3). Dandy and Davis Cove backwaters each contributed one fish, while most were from the Arizona Juvenile and Yuma Cove backwaters. Off-site rearing facilities contributed more than 38% of the total fish captured; fish were reared at Achii Hanyo Fish Hatchery, Boulder City Golf Course Ponds and Wetlands Park, Bubbling Ponds State Fish Hatchery (Bubbling Ponds SFH), Arizona, and Willow Beach NFH. One fish had unknown rearing information, although available data suggested it may have originally been from Cibola High Levee Pond and moved to Davis Cove (unpublished data, Native Fish Work

Table 2.—Adult razorback sucker monitoring summary for 26 paired release-capture data per fish PIT tag number with calculated growth rate (capture TL in cm minus release TL in cm then divided by months at large) and time at large (capture date minus release date then divided by 30 days [d] for months at large or 365 d for years at large) and capture history (Data are in order by number of captures then capture date and include year class information where available. Release date is when fish were stocked into Lake Mohave.)

	Date		TL (cm)			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
257C60A898	10/2/2006	11/28/2011	43	65	< 1	F	1,883	63	5	1	First capture in 2011
1C2D679964[a]	1/5/2010	11/29/2011	37	60	1	F	693	23	2	1	First capture in 2011
1C2D6D0D48[b]	12/7/2010	11/29/2011	39	54	1	F	357	12	1	1	First capture in 2011
1B7969CE8C	10/13/2011	11/29/2011	43	45	1	F	47	2	< 1	1	First capture in 2011
1B7969CCAE	10/13/2011	11/30/2011	43	46	2	F	48	2	< 1	1	First capture in 2011
1B796ED9BB	10/14/2011	11/30/2011	43	45	1	M	47	2	< 1	1	First capture in 2011
257C60FCBA	4/3/2009	3/13/2012	53	61	< 1	F	1,075	36	3	1	First capture in 2012
1C2C843DE5[c]	5/11/2011	3/13/2012	45	52	1	F	307	10	1	1	First capture in 2012
1C2D060BDD[d]	5/11/2011	3/13/2012	47	55	1	F	307	10	1	1	First capture in 2012
1B7969DBC4	10/13/2011	3/13/2012	43	45	< 1	M	152	5	< 1	1	First capture in 2012
1C2C36F9E0	11/20/2007	3/14/2012	54	61	< 1	F	1,576	53	4	1	First capture in 2012
1C2C83C448[e]	3/20/2009	3/14/2012	49	59	< 1	F	1,090	36	3	1	First capture in 2012
1C2D696824[f]	5/18/2010	3/14/2012	45	48	< 1	F	666	22	2	1	First capture in 2012
1C2D6B300D	10/6/2010	3/14/2012	48	59	1	F	525	18	1	1	First capture in 2012
1C2D061AF3[g]	12/17/2009	3/15/2012	41	57	1	F	819	27	2	1	First capture in 2012
1C2D05AACB[h]	5/19/2010	3/15/2012	44	59	1	F	666	22	2	1	First capture in 2012
1B796ED22E	10/28/2011	3/15/2012	43	45	< 1	F	139	5	< 1	1	First capture in 2012
521C4F3432	11/15/2001	3/16/2012	33	57	< 1	F	3,774	126	10	1	First capture in 2012
1C2C2F7E5F	10/2/2007	3/16/2012	50	62	< 1	F	1,627	54	4	1	First capture in 2012
1C2D6D91E6[i]	1/6/2011	3/16/2012	39	50	1	F	435	15	1	1	First capture in 2012
1B7969EF1A[j]	1/26/2012	3/16/2012	35	46	7	M	50	2	< 1	1	First capture in 2012
1C2D74904B	1/13/2010	11/29/2011	48	64	1	F	685	23	2	2	First capture in March 2011, second capture in 2011
52081D0803	6/4/1999	3/13/2012	27	57	< 1	F	4,666	156	13	2	First capture in 2003, second capture in 2012
7F7A08103E	7/22/1997	3/16/2012	29	67	< 1	F	5,351	178	15	2	First capture in 2000, second capture in 2012
457178402F[k]	3/30/2005	3/14/2012	35	61	< 1	F	2,541	85	7	2	First capture in 2008, second capture in 2012
521621264F	6/11/1999	3/13/2012	27	62	< 1	M	4,659	155	13	4	First capture in 2001, second capture in 2002, third capture in 2004, fourth capture in 2012
		Average	41	56	1	–	1,315	44	4	–	–

[a] 2005 and 2006 mix of year class, reared at Willow Beach NFH.
[b] 2009 year class, reared at Achii Hanyo Fish Hatchery.
[c] 2007 year class, reared at Arizona Juvenile, Lake Mohave.
[d] 2007 year class, reared at Dandy Cove, Lake Mohave.
[e] 2002, 2003 and 2004 mix of year class, reared at Bubbling Ponds SFH.
[f] 2006 year class, reared at Arizona Juvenile, Lake Mohave.
[g] 2006 year class, reared at Willow Beach NFH.
[h] 2006 year class, reared at Yuma Cove, Lake Mohave.
[i] 2007 year class, reared at Willow Beach NFH.
[j] 2008 year class, reared at Willow Beach NFH.
[k] 2000 and 2003 mix of year class, reared at Willow Beach NFH.

Table 3.—Adult razorback sucker monitoring summary for 26 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. One fish had unknown rearing information, although available data suggested it may have originally been from Cibola High Levee Pond and moved to Davis Cove. This last fish was omitted from analysis.)

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	Pot Cove (north of, cove)	AZ	31	Liberty	7	1
			AZ	24	Basin	Carp Cove (inside)	AZ	32	Liberty	8	1
			AZ	24	Basin	Cottonwood Cove East	AZ	32	Liberty	8	1
			AZ	24	Basin	Airport Cove (south of)	AZ	34	Liberty	10	1
	Dandy		NV	26	Basin	Pot Cove (north of, cove)	AZ	31	Liberty	5	1
	Davis Cove		AZ	0	Katherine	Carp Cove (north point)	AZ	34	Liberty	34	1
	North Chemehuevi Cove		NV	19	Basin	Pot Cove (north of, cove)	AZ	31	Liberty	12	1
			NV	19	Basin	Carp Cove (north point)	AZ	34	Liberty	15	1
	Yuma Cove		AZ	39	Liberty	Carp Cove (inside)	AZ	32	Liberty	5	2
			AZ	39	Liberty	Airport Cove (south of)	AZ	34	Liberty	7	2
			AZ	39	Liberty	Carp Cove (north point)	AZ	34	Liberty	5	1
			AZ	39	Liberty	Yuma Cove, Arizona	AZ	39	Liberty	0	2
Average distance traveled										9	15
Off-site facilities	Achii Hanyo	Willow Beach boat ramp	AZ	84	River	Cottonwood Cove East	AZ	32	Liberty	52	1
	Boulder City Golf Course Ponds	Cottonwood Cove	NV	37	Liberty	Pot Cove (north of, cove)	AZ	31	Liberty	6	1
	Boulder City Wetlands Park	Placer Cove	NV	64	River	Pot Cove (north of, cove)	AZ	31	Liberty	33	1
	Bubbling Ponds SFH	Princess Cove	AZ	8	Katherine	Pot Cove (north of, cove)	AZ	31	Liberty	23	1
		Cottonwood Cove	NV	37	Liberty	Carp Cove (inside)	AZ	32	Liberty	5	1
	Willow Beach NFH	Nine Miles Coves (north of)	NV	26	Basin	Pot Cove (north of, cove)	AZ	31	Liberty	5	1
		Yuma Cove	AZ	39	Liberty	Pot Cove (north of, cove)	AZ	31	Liberty	8	1
		Owl Point Cove	AZ	47	River	Pot Cove (north of, cove)	AZ	31	Liberty	16	1
		Wrong Cove	AZ	50	River	Pot Cove (north of, cove)	AZ	31	Liberty	19	1
		Six Mile Coves	NV	31	Liberty	Carp Cove (inside)	AZ	32	Liberty	1	1
Average distance traveled										17	10

Group database). Fish reared in lakeside backwaters traveled an average of 9 kilometers (km) from release to capture sites, while fish reared in off-site facilities traveled an average of 17 km.

Remote Monitoring

In the River zone, remote PIT scanning sampling trips resulted in 4,397 h of scanning; 377 with shore-based and 4,020 with submersible PIT scanning units. Mean h per deployment were 26.9 and 21.1 for shore-based and submersible scanners, respectively. Shore-based units were often downloaded on a daily basis, although they were left onsite for up to 3 days. A total of 19,813 PIT tag contacts were recorded, representing 1,934 unique razorback sucker for which 1,918 had a marking record at release in the Lower Colorado River Native Fish Database (as of September 20, 2012). Repatriates accounted for 1,904 of the unique encounters, 11 wild razorback sucker were contacted, 3 were of unknown origin, and the other 16 have missing or erroneous marking records. The total contacts available for analysis (reduced to one PIT contact per minute scanned per PIT scanner deployment) were 18,338.

Remote PIT scanning in the Liberty zone was completed with Destron (Destron Fearing™) scanners and attributed a total of 188 h scanning hours, with a mean average deployment of 47 h. A total of 27 PIT tags were contacted, representing 18 unique razorback sucker, all of which had a marking history and were repatriates. The total contacts available for analysis (reduced to one PIT contact per minute scanned per PIT scanner deployment) were 27.

Remote PIT scanners in the Basin zone were deployed for a total of 3,807.6 h of scanning: 3,320.1 with shore-based, 62.93 with submersible, and 424.6 with Destron scanning units. Mean h per deployment were 138.34 for shore-based, 62.93 for submersible, and 38.6 for Destron scanners. A total of 27,015 PIT tags were contacted, representing 836 unique razorback sucker for which 808 had a marking record in the Lower Colorado River Native Fish Database (as of September 20, 2012). Of the unique encounters, 803 were repatriates, 2 were wild, 3 were of unknown origin, and 28 have missing or erroneous marking records. The total contacts available for analysis (reduced to one PIT contact per minute scanned per PIT scanner deployment) were 25,751.

Post-stocking dispersal between the three zones was limited mostly to the zone of stocking. Remote PIT scanners contacted a total of 1,070 fish that had been at large for at least 1 year and were released in River after October 1, 2008. The vast majority of these fish, 93% (994 individuals), were scanned in River. Only five fish that were released in River were contacted in Liberty, and 71 were contacted in Basin. Only 115 fish released in Liberty were contacted. These fish were contacted in Basin 57% of the time (65 fish), in River 41% (47 fish), and in

Liberty only 3% (3 fish). Finally, fish released in Basin were contacted 90% of the time (357 individuals out of 397), 9% in River (36 individuals), and 1% (4 individuals) in Liberty. Few fish have been released in Katherine, and no PIT scanning was conducted there in 2012. However, three fish released in Katherine were contacted in Basin, and one each was contacted in River and Liberty.

The adult subpopulations in the River, Liberty, and Basin zones exchanged few individuals from 2011 to 2012 (table 4). Out of the 899 fish contacted in 2011 that were released with a 134.2-kHz tag after October 2008, 586 were contacted in 2012. Of these fish, 18 were contacted in more than one zone in either 2011 or 2012 and were excluded from analysis to remove repeated counting. Out of the 568 that remained, 553 were contacted in the same zone as their initial contact in 2011. The greatest movement was eight fish (1.4%) that moved from River to Basin.

Table 4.—Razorback sucker contacted by remote PIT scanning in 2012 that were also contacted in 2011 broken down by zone of contact, Lake Mohave, Arizona and Nevada (Fish that were contacted in more than one zone in the same year were excluded from analysis.)

2011	River	2012 Liberty	Basin
River	402	0	8
Liberty	0	1	2
Basin	4	1	150

Eighteen individual acoustic-tagged razorback sucker have been contacted through the efforts of both Reclamation and M&A using remote PIT scanners since 2010. Thirteen acoustic-tagged fish were contacted in 2012 (table 5), eight of which had not previously been contacted during prior remote PIT scanning efforts. Of all acoustic-tagged fish contacted by remote PIT scanners to date, 6 were released in 2008 and 12 during 2009. No individuals released during 2006 or 2007 were contacted. Mean TL of all acoustic tagged fish detected by remote PIT scanners was 538 millimeters (mm). Five of 18 fish (28%) were contacted in multiple years, and 6 of 18 fish (33%) were contacted at different locations within each general zone. One of 18 fish (6%) was contacted in multiple general zones (Basin and River), 1 of 18 fish (6%) was contacted exclusively in Liberty, 3 of 18 fish (17%) were contacted exclusively in Basin, and 13 of 18 fish (72%) were contacted exclusively in River.

Table 5.—Acoustic tag, rearing source, and zone of release for the 18 acoustic-tagged razorback sucker contacted by remote PIT antenna to date and the specific month and general zone of detection for 13 of those individuals that were contacted between January and September 2012

(Yellow boxes indicate 2012 was the first year a fish was detected by remote PIT scanning, while green boxes indicate the first, and in some cases only, detection was made prior to 2012.)

Acoustic Tag	Source	Zone of Release[1]	1/12	2/12	3/12	4/12	5/12	6/12	7/12	8/12	9/12
128	Willow Beach NFH	L	R								
138	Yuma Cove Backwater	L	R								
112	Yuma Cove Backwater	L									
106	Yuma Cove Backwater	L		R	R						
153	Yuma Cove Backwater	L	B	B							
107	Yuma Cove Backwater	L									
182	River near Hoover Dam	R	R								
167	River near Hoover Dam	R	R				R	R			
184	Willow Beach NFH	R			B	B	B				
201	Willow Beach NFH	R		R							R
187	Willow Beach NFH	R		R							
189	Willow Beach NFH	R		R							R
168	Willow Beach NFH	R									
155	Willow Beach NFH	R				R					
196	Willow Beach NFH	R									
169	Willow Beach NFH	R			R					R	
172	Willow Beach NFH	R									R
158	Willow Beach NFH	R									

[1] R = River, L = Liberty, and B = Basin.

Post-stocking contact rates were highly correlated with size at release, regardless of stocking zone, but rates also varied by an order of magnitude among similarly sized cohorts (table 6). In River, the highest contact rate was 38.6% for a cohort of 500 razorback sucker released in October 2011 at a mean size of 441 mm. The lowest rate was 0.8% for a cohort released in December 2009 at a mean size of 347 mm.

Population Estimates

Monitoring data from 2011 and 2012 did not provide enough recaptures to estimate the size of the wild razorback sucker population in Lake Mohave. We estimate that the repatriated razorback sucker population is 2,577 (1,139–6,284 95% CI) with a 2% estimated survival of all repatriates released as of March 1, 2011.

Based on 2011 and 2012 remote PIT scanning, the 134.2-kHz tagged repatriate subpopulation in Basin for 2011 was estimated at 805 (95% CI from 670–968), and the repatriate subpopulation in River was 1,726 (95% CI from 1,507 to 1,976). Wild fish were also contacted in the Basin and River zones, and the estimated abundance of wild fish that were tagged with 134.2-kHz tags was 3 ($M = 2$, $C = 2$, $R = 1$) and 12 ($M = 7$, $C = 11$, $R = 7$), respectively. For 2012, the regression analysis estimated the razorback sucker population in River at 2,174 (95% CI from 1,974 to 2,375, figure 3).

DISCUSSION

Lake Mohave razorback sucker management is one facet of the larger program to conserve the species in the Colorado River basin, but its role is both central and critical because it currently is the only genetic reservoir for the species throughout its range (Dowling et al. 1996a, 1996b, 2005). Unfortunately, long-term conservation goals that require establishment of self-sustaining populations cannot be met in Lake Mohave or in any other part of the lower Colorado River mainstream[2] (Schooley and Marsh 2007; Schooley et al. 2008). Instead, use of off-channel habitats that are free of non-native predators (e.g., Minckley et al. 2003; U.S. Fish and Wildlife Service 2005; Kesner et al. 2012) appears the only viable concept to fulfill such goals. The genetic legacy of razorback sucker embodied in the Lake Mohave population must be maintained while the backwater conservation strategy is developed and implemented.

[2] Razorback sucker reportedly has limited recruitment in Lake Mead, Arizona and Nevada (Albrecht et al. 2010), but data have not been critically reviewed and important questions remain to be addressed.

Table 6.—Razorback sucker repatriation cohorts (fish released in the same month and zone) from October 2008 to December 31, 2011, and their remote PIT scanning contact rates in 2012, Lake Mohave, Arizona and Nevada

Zone	Year	Month	Number released	Mean TL	Number contacted	Proportion contacted
River	2009	October	4,830	418	628	0.130
	2009	December	1,436	347	12	0.008
	2010	January	3,570	386	341	0.096
	2010	December	2,013	342	35	0.017
	2011	October	500	441	193	0.386
	2011	December	2,002	385	380	0.190
Liberty	2009	December	3,335	378	79	0.024
	2010	January	1,584	329	9	0.006
	2011	January	1,896	339	4	0.002
	2011	March	444	NA	21	0.047
Basin	2008	October	498	442	13	0.026
	2009	March	334	491	68	0.204
	2009	September	246	457	16	0.065
	2009	October	189	425	12	0.063
	2009	December	2,024	353	102	0.050
	2010	January	980	374	25	0.026
	2010	May	105	477	45	0.429
	2010	September	226	426	13	0.058
	2010	October	454	447	93	0.205
	2011	January	1,892	341	3	0.002
	2011	May	224	435	13	0.058
			28,782	374	2,105	0.073

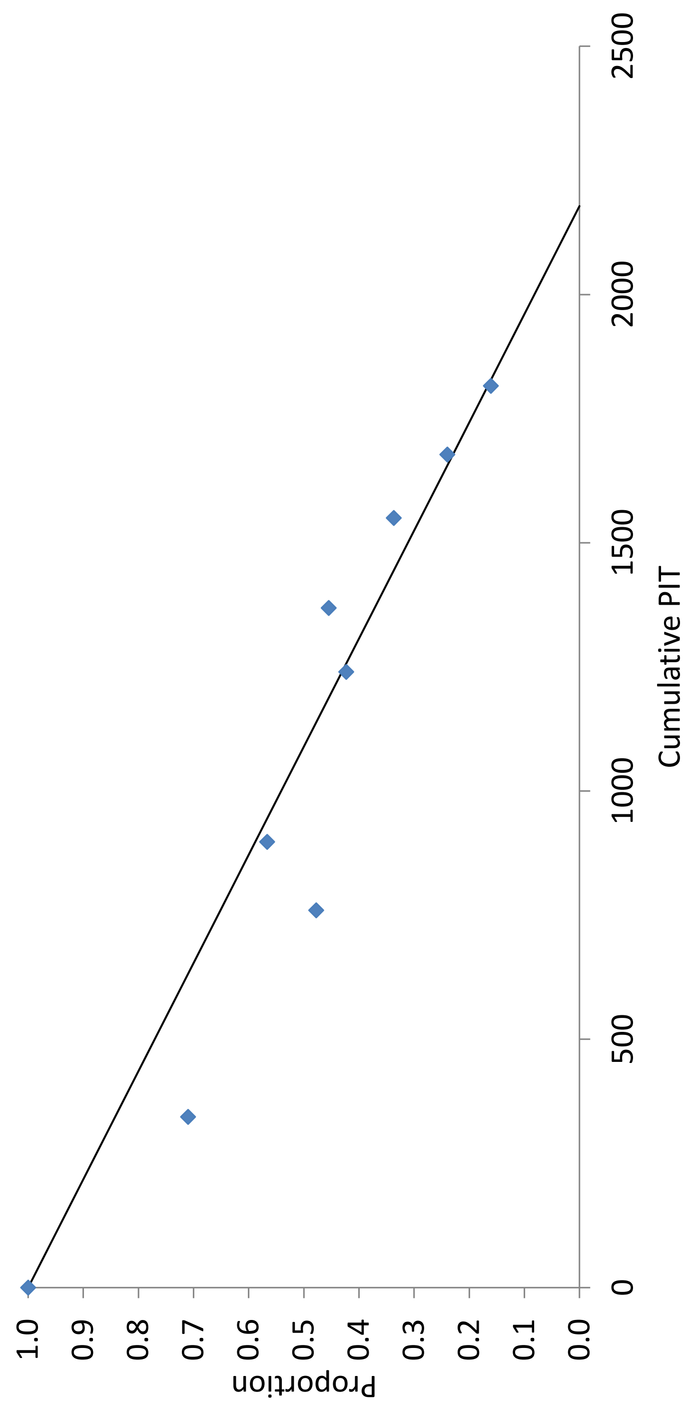

Figure 3.—Regression of the cumulative number of unique 134.2-kHz PIT tagged razorback sucker contacted in Lake Mohave, Arizona and Nevada, upstream of Willow Beach at the beginning of each scanning trip in 2012 and the proportion of newly detected PIT tags during that trip.
The slope of the regression line was fitted by minimizing the sum of square residuals with the x-intercept set at 1.0 (all contacts during the first trip were new, r^2 = 0.89). The y-intercept is the population estimate (2,174).

Razorback sucker persist in Lake Mohave with a population in the low thousands, which has been the status of the repatriate population for more than a decade (Marsh et al. 2005). While this population has been maintained by stocking, during the same period, the wild population has been reduced from more than 60,000 to fewer than 20 fish. The genetic legacy of razorback sucker is now tied into the few thousand remaining repatriate fish in Lake Mohave, and this population is completely dependent on continued stocking.

It is now apparent that razorback sucker occupying the Basin and River zones of Lake Mohave should be treated as separate demographic subpopulations because there is limited exchange of individuals from year to year among these two centers of abundance, and the majority of fish stocked into these reaches remain there years after release. The River subpopulation is apparently as large as or larger than the population in Basin, but the estimate of overall population size of razorback sucker has not increased dramatically in spite of this finding.

Similarity between combined remote PIT scanning population estimates (Basin and River) with the estimate based solely on roundup data (from mostly Basin) appears counterintuitive. One possibility is that there are additional centers of razorback sucker concentration that have yet to be identified by remote PIT scanning and are at least on a limited basis contacted by roundup efforts. Liberty was the focus of efforts to locate a third subpopulation, but given the low number of contacts and high level of dispersal out of this zone, it is likely just a site visited while razorback sucker transition from one center to another. Identification of additional population centers may eventually increase estimates of the total population in Lake Mohave.

Remote PIT scanning has dramatically improved the contact rate with razorback sucker in Lake Mohave post-stocking. More razorback sucker were contacted in 2012 than during the last eight roundups combined. The proportion of the population contacted in River reached levels only seen in populations with discrete spawning sites (Hewitt et al. 2010). This is the first year of this project, so only preliminary analyses were completed. However, the increase in data will both increase accuracy in future post-stocking survival estimates and provide estimates of temporal and geographic variation in survival. Furthermore, exchange rates between subpopulations will be estimated and incorporated into a metapopulation dynamic model of post-stocking fate.

Most razorback sucker were contacted in only one scanning location in River. This may be indicative of site fidelity among individuals, but apparent movement between sites was greatest during the suspected peak of spawning (March and April). No solid conclusions can be drawn from these results because the number of locations scanned and the choice of scanning locations per trip were not standardized. Although it is important to contact as many individuals as possible each year, standardizing a portion of PIT scanner deployments (e.g., set a number of routine sites every month) would increase confidence in these results.

Larval sampling is not routinely conducted in River and not practical there given the high water velocity and fluctuating river levels. Thus, a potential negative consequence of the metapopulation dynamics of the Lake Mohave population exists. If fish stocked into River stay there, then those individuals are essentially "wasted" if the goal is to maintain genetically diverse larval production. If so, then as long as Basin post-stocking and adult survival is equal to or higher than that in River, all fish should be stocked in Basin or other areas from which larvae are easily collected.

As we continue to move toward alternative solutions to maintaining populations of razorback sucker by stocking, it is important to continue stocking and identify and evaluate means to increase population size and improve post-stocking survival. Although it is clear alternatives to this management strategy must be pursued, any relaxing 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. 2012). Because the 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, giant Salvinia, gizzard shad, etc.) makes the probability of a shift in survival not only possible but likely.

RECOMMENDATIONS

Biannual netting operations should continue during autumn and spring roundups to collect growth, health, census, and genetic data from wild and repatriate razorback sucker in Lake Mohave. There currently is no other mechanism to acquire these data.

Once a month between January and April, locations within River and downstream from razorback sucker spawning aggregations should be sampled to identify locations where larvae can be collected. A minimum of 25 larvae should be collected each year in River for the purpose genetic analysis. Larval catch rates in River should be compared to those from specific locations in Liberty and Basin. In this way, the appropriateness of incorporating yearly sampling in this general location with ongoing larval collections elsewhere in Lake Mohave can be determined.

Razorback sucker 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. Stocking for the next fiscal year (fiscal year 2013 – October 2012 to September 2013) should be concurrent and numbers distributed equally between the three known subpopulations (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. More than 80% of the known population in River was contacted in 2012. It is anticipated that this level of contact will be maintained in 2013 for River, and additional deployments in Basin will result in a similar contact rate in Basin. Assuming 10% post-stocking survival, at least 40 razorback sucker 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. The objective of our recommendations above is to use release date and time, and contact date and time, for individual fish to determine exchange rates among subpopulations. Remote PIT scanning deployments in River will be conducted monthly. Staff at M&A will continue to work with Reclamation biologists to ensure a similar scanning effort in Basin. Effort in Liberty may be displaced to other locations if they can be identified. The location 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 (Katherine) as equipment and time permit.

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