Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Demographics and Post-stocking Survival of Repatriated Razorback Sucker in Lake Mohave 2008 Final Report

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Summary

Four general areas of inquiry were pursued relative to razorback sucker in Lake Mohave during the period January 2006 to September 2008: (1) post-stocking dispersal and fate determined by sonic telemetry (2) routine monitoring, (3) creel census, and (4) ecological modeling. This report documents results and implications of those investigations.

In autumn 2006, 20 subadult razorback sucker (approximately 38 cm total length [TL]) were implanted with sonic transmitters, released at Fortune Cove, and tracked for six months. Dispersal was generally confined to the northern half of the reservoir (upstream of Painted Canyon Lights). At the conclusion of the project, three of 19 (16%) study fish remained active. Thirteen transmitters from immobile fish were recovered from the bottom of the reservoir by a SCUBA diver. No fish remains were observed near any recovered transmitters. Concurrently, 20 subadult razorback sucker were implanted with sonic transmitters and maintained in a raceway at Willow Beach NFH for three months. No transmitters were shed and all fish remained healthy throughout the study. Manual tracking and submersible ultrasonic receiver (SUR) data from Lake Mohave telemetry, in addition to the captive fish experiment results, indicate that subadult fish face almost certain mortality in a relatively short amount of time after being repatriated into Lake Mohave. This is most likely due to the consumption of repatriated fish by striped bass.

A second telemetry study was initiated in autumn 2007 to compare survival estimates based on telemetry between two size classes of razorback sucker repatriates: subadult razorback sucker similar in size to fish released in 2006 and adult razorback sucker approximately 50 cm TL. Fifteen subadult and 17 adult razorback sucker were implanted with sonic transmitters and released at Fortune Cove on 19 October 2007. Over the six month study, no subadult repatriate dispersed downstream of Sheep Trail Light, but an adult was contacted in Cottonwood Basin. At the conclusion of this study, one of 15 (7%) tagged subadult fish and five of 14 (36%) tagged adult fish were active. Fourteen transmitters from immobile subadults and eight transmitters from immobile adults were inspected by a SCUBA diver and were subsequently recovered from the bottom of the reservoir; one transmitter from an adult fish was observed from the surface and was therefore not recovered. Similar to the 2006 study, both groups of fish displayed high rates of mortality, but the proportion of active adults was always greater than that of subadults.

Routine monitoring during the months of March, May and November in 2006 and 2007, and in March and May of 2008 resulted in the capture of 74 razorback sucker (75 captures, one short-term recapture). Population estimates from March roundup data have declined for both wild and repatriate fish. Wild population estimates have declined from 507 fish (263-1,067 95% confidence interval [CI]) in 2005 to 47 fish (24-175 95% CI) in 2007, and repatriated razorback sucker estimates have declined from an all-time high in 2005 of 4,221 fish (954-35,071 95% CI) to 1,232 fish (662-2,318 95% CI) in 2007. The total population estimate has decreased from 4,728 fish to 1,279 fish in 2 years.

Eleven striped bass and two channel catfish have been scanned for PIT tags by NVDOW creel census personnel since January 2006; none have contained PIT tags. Increases in size at release for repatriated razorback sucker may be reducing striped bass consumption, but this has not been confirmed independently by examination of striped bass stomachs.

A total of 1,120 razorback sucker capture histories were analyzed in a multi-site mark-recapture model, but only 212 capture records represented fish recaptures. Spatial transition rates from the best fit mark-recapture model varied from zone to zone with 7% of fish leaving the Yuma area within one month to 90% leaving Nine Mile area in the same time period. Razorback sucker in the Tequila area experienced the highest rate of survival at 91.7% annually, followed by Yuma (76.3%) and Nine Mile (70.1%).

Although low recapture rates reduce resolution and limit model choice in mark-recapture models, single-census population estimates and post-release survival estimates based on telemetry and mark-recapture data are largely in agreement with the model results. Initial survival is low enough that few fish recruit to the adult population, and the adult population has approximately 75% annual survivorship. Repatriate population size will continue to remain in the 2,000 to 4,000 range unless strategies are implemented to increase post-stocking survival. The most viable option to obtain that result under the current scenario in Lake Mohave is to repatriate larger fish, which already is being implemented.

Introduction

Lake Mohave once was home to the largest known population of wild razorback sucker *Xyrauchen texanus*. Historically, this population contained more than one hundred thousand fish, but numbers have dwindled dramatically in recent years and it currently is made up of fewer than 100 individuals (Marsh et al. 2003, Turner et al. 2007, this report). 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 cm 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). The current (2008) recommended minimum size for stocking is 50 cm.

Razorback sucker like many other native fishes of the region is on a trajectory that soon will lead to its extirpation in the wild in the lower Colorado River. Conservation plans for big-river fishes in the lower Colorado River (Minckley et al. 2003, U.S. Fish and Wildlife Service 2005) incorporate a population component that will occupy the main stream, but it may be impractical or impossible to accommodate that plan. If main channel populations cannot be developed and maintained, conservation of razorback sucker in the lower river may depend entirely on populations in off-channel habitats that are free of non-native fishes. It is an objective of this research 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, our results 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.

This report is the concluding document of a three year study. Two rounds of sonic telemetry were conducted to evaluate post-repatriation mortality for two size classes of released fish (35 cm and 50 cm target release sizes). Population and survival estimates for wild and repatriate populations were updated based on results from standard monitoring. Creel census data on large striped bass abundance and impact on razorback sucker stockings are currently being provided through collaboration with Nevada Department of Wildlife (NDOW).

Methods

Post-stocking Dispersal and Fate

2006-07 Sonic Telemetry and Experimental Stocking

Prior to the release of study fish into Lake Mohave, ten monofilament gill nets (45.7 x 3.1 m, 20.3 cm stretch mesh) were set in and around the stocking site. The large net mesh size was chosen to target large-bodied piscivorous fish (specifically striped bass *Morone saxatillis*) but allow smaller subadult razorback sucker and other non-target fish to pass through the net without becoming entangled.

During both release dates at Fortune Cove, up to five members of the Bureau of Reclamation (BR) Lower Colorado Region Dive Team were positioned underwater near the release boat with writing slates and digital video recording equipment to document the dispersal behavior and potential predation of razorback sucker as they were released. Divers took notes on fish schooling behavior and direction of travel: inshore into the cove or offshore into the reservoir, surface or bottom.

Methods regarding sonic transmitter implantation, and release and tracking of study fish are thoroughly described by Karam et al. (2008) and are therefore only summarized here. Twenty subadult razorback sucker (mean TL = 38 cm, range 36 to 46 cm) were implanted with sonic transmitters at Willow Beach NFH on 25 September 2006. Two days later, sonic tagged fish were transported downriver and released with 480 additional subadults into Fortune Cove near river mile (RM)[1] 41 (Fig. 1). These fish were released as a part of an experimental, two-day stocking event in which a total of 1,034 razorback sucker were repatriated to Lake Mohave. All fish contained 400 KHz PIT tags. Sonic tagged fish were tracked using stationary SURs, as well as manually tracked by boat at regular intervals. When re-contacts were made in the same location, a SCUBA diver was deployed with an Underwater Diver Receiver (UDR) to locate and attempt to recover the sonic transmitter. Contact locations and transmitter recoveries were used to illustrate dispersal and estimate survival, respectively.

[1] River miles (RM) are measured upriver (north) from Davis Dam.

Captive Fish Experiment

A captive fish study was implemented to estimate the impact of post-surgical transmitter retention and mortality. A total of 43 razorback sucker were randomly selected from a hatchery stock of subadults on 10 January 2007 and placed in an indoor raceway at Willow Beach NFH. Twenty individuals (mean TL = 38 cm, range 37 to 40 cm) were selected from the group to approximate the size of fish used in the telemetry study and implanted with a transmitter (see Karam et al. 2008).

Between 10 January and 12 April 2007 study fish were fed weekly. No antibiotics or prophylaxis were administered. In-depth monitoring of experimental fish was conducted bi-monthly throughout the study. During each visit, the raceway was swept and inspected for dropped transmitters and mortalities. On 12 April 2007 all captive fish were measured (TL) and scanned for a PIT tag. PIT tag number, TL, and sexual condition were recorded for each fish. Fish growth (delta TL) was calculated as the difference in TL from initial measurements on 10 January 2007 to measurements made on 12 April 2007. Seven experimental fish (five males, two females) were randomly selected and sacrificed to locate and retrieve the implanted transmitters. All others were returned to the hatchery raceway.

2007-08 Sonic Telemetry

This second telemetry study was designed to compare survivorship estimates based on telemetry between two size classes of released razorback sucker: subadult razorback sucker similar in size to fish released in 2006 and adult razorback sucker of approximately 50 cm TL. Methods regarding sonic transmitter implantation, and release and tracking of study fish are thoroughly described within the 2007 Lake Mohave annual report (Kesner et al. 2007) and are therefore only summarized here.

Thirty-two razorback sucker (15 subadults [average TL = 38 cm, range 36 to 41 cm] and 17 adults [average TL = 50 cm, range 48 to 51 cm]) were collected from two different brood stocks at Willow Beach NFH and surgically implanted with sonic transmitters on 17 October 2007. Two days later, sonic tagged fish were transported downriver along with 485 additional subadult razorback sucker and released into Fortune Cove. All fish contained 134 KHz PIT tags. Manual and SUR tracking techniques, and transmitter observations and recovery all followed the methods as previously reported (Kesner et al. 2007).

Sonic Telemetry Data Analysis

A survival history for each fish was developed from the contact database and tag recovery or visual observation data. A live contact with a fish was one in which the subsequent contact was in a different location (i.e., the fish was moving). If a transmitter was recovered or visually observed, all contacts for the corresponding fish in that location were considered dead contacts. If a transmitter was never recovered or observed, but never moved from a location where it was contacted multiple times for a time period spanning more than a month, all contacts at that location were considered dead contacts.

Estimates of survival were calculated separately for three groups of released razorback sucker: subadult fish from 2006-07 study, subadult fish from 2007-08 study, and adult fish from 2007-08 study. Initially, a weekly survival rate was estimated from known time intervals of survival and mortality. The known time interval a fish survived (t_a) was calculated as the interval, in weeks, between release and last live contact with that fish. The known time interval a fish died (t_d) was calculated as the interval, in weeks, between last live contact and first dead contact. Survivorship was modeled as an instantaneous rate (s). Therefore the probability a fish survives the time interval (t_a) was calculated from s, t_a, and e (the base of natural logarithms; approximately 2.71828):

(1) $$e^{st_a}$$

The probability that a fish died in the time interval (t_d) was calculated as:

(2) $$1 - e^{st_d}$$

The likelihood of each survival history was calculated as the multinomial of equations 1 and 2 with time in weeks. For example, for a fish that was relocated alive after two weeks, but was first located at its transmitter recovery location on the third week, the likelihood would be:

(3) $$e^{2s}(1-e^{s})$$

Equation 1 made up the entire likelihood for fish that purportedly survived the entire study period (i.e., the transmitter was not located repeatedly at the same site).

Maximum likelihood estimates of the instantaneous survival rate were calculated by minimizing the negative log-likelihood of all survival histories for each study group, and a 95% confidence interval was calculated using profile likelihood (Cormack 1992). Values for survival rate and confidence intervals were converted to weekly survival probabilities by taking the natural exponent. These weekly rates were converted to estimates of survival for the entire study period by raising them to the power of the number of weeks in each study.

Other mathematical models have been used for estimating survivorship from telemetry data (e.g., Pollock et al. 1989, Hightower et al. 2001), but were inadequate for this study due to low number of relocations during manual tracking events, varying time intervals in which fish were located, and a desire to use SUR contact data to extend known live time intervals. Our simplified model requires no calculation of nuisance parameters such as relocation probabilities, but relies on knowing the fate of a large proportion of fish in the study. Otherwise assumptions for this model are similar to other telemetry models of mortality (see Pollock et al. 1995).

The proportion of active subadult and adult repatriates from the 2007-08 study were compared at three- and six-month post-stocking intervals using a 2 x 2 contingency table and a Fisher exact probability test (Sokal & Rohlf 1981). Similarly, differences in the proportion of active subadults were compared between the 2006-07 and 2007-08 studies. If no significant differences were detected between subadult groups from both studies, those data were pooled and compared to the proportion of active adults from 2007-08.

Routine Monitoring

Routine monitoring was conducted during the months of March, May and November in 2006 and 2007, and in March and May of 2008. Generally, five to seven trammel (91.4 x 1.8 m, 3.8-cm stretch mesh) nets were allowed to fish continuously for 4 to 5 days in the area of Carp Cove (area bounded by Waterwheel and Airport coves) along the Arizona shoreline of Lake Mohave. Effort was divided in March 2008 with one crew setting nets in the vicinity of Carp Cove, and a second crew sampling the nine downstream-most miles from Sidewinder Cove, Arizona, to Davis Dam.

Nets were checked in the morning and evening daily and natives were removed and processed (measured, sexed, scanned for a PIT tag and tagged if none was present, and examined for general health and condition) and released. A fin clip was taken from a sub-sample of razorback sucker, placed in 1 ml of 95% ethanol in a snap-cap tube, and returned the laboratory for genetic analysis (reported elsewhere). All relevant data were entered into the comprehensive lower river native fishes PIT tag database maintained by Arizona State University (ASU).

Creel Census Data

Creel census data were collected periodically by a NDOW biologist at Cottonwood Landing, Nevada and Willow Beach, Arizona. All striped bass greater than 80 cm in total length encountered were scanned for PIT tags. If a PIT tag was found, the stomach was to be removed and sent to the Native Fish Lab at ASU for gut content analysis.

Ecological Modeling

In 2006, a simple contingency analysis of spatially explicit mark-recapture data demonstrated statistically significant site fidelity for wild and repatriate razorback sucker in Lake Mohave (Kesner et al. 2007). For that analysis, capture data were spatially distributed among four general zones within Lake Mohave, designated as follows, down- to upstream: Lower Lake, Basin, Arizona Bay, and River (Fig. 2). In 2007, these general zones were used in a multi-site mark-recapture model to estimate survivorship and transition rates (movement rates between zones) between the four general zones for wild and repatriate fish (Kesner et al. 2008). The multi-site model fit was consistently poorer than standard mark-recapture models as determined by Akaike's information criterion (AIC) score (Akaike 1974). In addition, the inclusion of multiple sites into the mark-recapture model did not significantly change parametric estimates of survival for wild or repatriate razorback sucker.

If site-fidelity of repatriate razorback sucker biases estimates of survival from simple mark-recapture models, then a multi-site mark-recapture model that incorporates movement and location data should provide significantly different estimates of survival. Although the model in 2007 did not result in differing survival estimates, a second multi-site mark-recapture model was developed in 2008 to verify those results. This model focused on a subset of specific zones on Lake Mohave (Fig. 3): Yuma (5), Tequila (6), and Nine Mile (7). These three zones account for the majority of repatriate captures, and effort is often applied to these three zones concurrently. The data were restricted to captures only, release data were not used due to low initial survival and the resulting difficulty in parameter estimates. This model represents survival and transition (movement from zone to zone) of repatriated fish at large among the three zones and excludes immediate post-stocking mortality. Sampling periods were defined by year and month, and restricted to 26 combinations in which all three zones were sampled, i.e., had capture records (Table 1). Each capture history was expressed as a series of zeros and 5, 6, or 7s representing the zone of capture (Yuma, Tequila, and Nine Mile respectively) in a given time period. If fish were less than 40 cm TL upon capture, then those captures were removed from analysis. This was done in an attempt to limit the analysis to adult repatriated fish. Full details of the derivation of these capture histories can be provided upon request.

As with previous multi-site mark-recapture models (e.g., Kesner et al. 2007) the structure is made up of three parameter groups: Φ_i^{x} – the probability of an individual surviving from year *i* to year *i*+1 in zone *x*, p_i^{x} – the probability of being recaptured in zone *x* in year *i*, and Ψ_i^{xy} – the probability of moving from zone *x* to zone *y* during the period *i* to *i*+1. Each parameter group can vary by time, age, site (zone), cohort, and individual covariate. The total number of models examined was limited due to the low number of recaptures; models with more than one parameter group varying by time results in models with more than 100 parameters. Each parameter group was examined independently to determine if varying the parameter group by time significantly improved fit from the basic model of constant values across time. In addition, survival amongst zones was combined to determine if survival amongst zones was significantly different. Likelihood ratio tests (LRTs) were used to determine significant differences in model fit (Kendall & Stuart 1979). Test statistics and parameter estimates were evaluated by the computer program MARK (Cooch & White 2008). Because sampling occasions represented combinations of year and month, time steps in the model were calculated in months. Consequently, model estimates of survival and transition were estimates of monthly rates. Survival rates were converted to annualized rates by raising the monthly rate to the 12^{th} power for comparison to previously reported models that used annual March data. Transition rates were similarly treated, although annualized transition rates are representative only, not accurate estimates of complex fish transitions between zones over the course of one year. An annual estimate of site-fidelity was calculated as the proportion of fish remaining within a zone per year. This was done by first calculating the monthly retention of fish within a zone (e.g. proportion remaining in zone A = 100% - transition rate from A to B - transition rate from A to C) and raising this value to the 12^{th} power.

To date, size at release (TL) is the only release variable that has been successfully incorporated into a mark-recapture model of survival. An alternative approach to identifying release variables that influence survival was sought because of a general lack of parameter resolution in the mark-recapture models (e.g., Kesner et al. 2008). Standard statistical analyses such as correlation and analysis of covariance (ANCOVA) along with graphical approaches were used on capture data derived in the following manner:

Release data were grouped by date and location. Each release date-location was considered a "cohort." Total number of fish released for each cohort was summed (cohort size) and mean TL at release was calculated per cohort. Captures of fish were linked to release cohorts by PIT tag and the total number of captures, including recaptures but not short-term (same-trip) recaptures, were summed for each release cohort. Fish were given one year to assimilate into the adult population and so captures within the first year post-release were not counted. Because fish released earlier have a greater number of years at large than fish released recently (increasing their capture probability), captures were limited to five years after release. Therefore, capture totals were limited for each cohort to fish captured between one and five years post-release. Cohorts released after March of 2003 were excluded from the analysis since these fish had not been at large for five years.

Cohort size, mean TL at release, release month, release year, and "specific zone" of release (specific zones, Fig. 3) were analyzed for their relationship with each other using bivariate correlation or with capture proportion (number of captures/cohort size) using ANCOVA (Sokal & Rohlf 1981). All statistical analyses were conducted in the statistical software package SPSS 16.0 (SPSS Inc., Chicago).

Results

Post-stocking Dispersal and Fate

2006-07 Sonic Telemetry and Experimental Stocking

Gill nets near Fortune Cover were fished continuously for 72 hours post-stocking. Nets were checked daily at sunrise, mid-day, and again after dark. Total effort was 720 net-hours and catch was zero fish.

SCUBA observations from both dates indicated the vast majority of stocked razorback sucker swam at a steep angle toward the bottom, and to the back of Fortune Cove immediately following their release. Divers estimated between 20-27% of released fish swam outward, towards the open waters of the reservoir. Most of the fish that dispersed into the cove took cover in the extensive weed beds that blanketed the bottom. Following the stocking events on both dates, few fish were observed throughout the cove, which led divers to theorize fish remained hidden in the submerged vegetation.

Over the six month study, all 20 sonic tagged fish were contacted, for a total of 247 individual detections. Of the 247 total contacts, 82 (33%) were made remotely with SURs. With the exception of one individual that briefly entered the open basin south of RM 24 (Painted Canyon Lights), tagged fish movements were confined to the northern half of the reservoir. Active fish contacts were made between RM 52 (near Shallow Rapids) and RM 21.5 (near Cottonwood Cove). Immobile transmitters were documented between RM 63 (near Hoover Dam) and RM 26 (between Owl Point and Arizona Bay). On two separate trips, the entire reservoir was surveyed (all 148 listening stations) confirming that no fish had moved past the downstream-most SUR deployed at Painted Canyon Lights. One individual was contacted immediately after stocking but was never contacted again for the remainder of the study. This individual was subsequently removed from further analysis.

At the conclusion of the study, three of 19 (16%) tagged fish remained active (Fig. 4). Thirteen transmitters were recovered from the bottom of the reservoir by a SCUBA diver. No fish remains were observed near any recovered transmitters. No SCUBA observations were made for three fish that stopped moving, but those individuals remained motionless for the remainder of the study and those fish were presumed dead. Of the sixteen sessile transmitters, fourteen were located in the main channel (mean distance was 10 km from the release site [range 2 to 30 km], mean depth was 10 m [range 3 to 21 m]) and two transmitters were found in shallow coves (mean distance was 7 km from the release site [range 4 to 10 km], mean depth was 4 m [range 2 to 5 m]). All 16 deceased fish had a history of actively swimming and were frequently contacted by manual and SUR tracking prior to becoming stationary. The median number of active swim days for fish whose transmitters were recovered was 42 d (range 2 to 154 d).

Based on survival histories of the 19 fish tracked during the 2006-2007 study, weekly survivorship was estimated at 91.8% (95% CI, 87.4 to 95.1%). Based on this estimate, survival for the entire study, 27 September 2006 to 16 March 2007, was 12.6% (95% CI, 3.8 to 29.7%).

Captive Fish Experiment

Throughout the three month duration of the captive fish study, all 43 individuals (20 experimental, 23 control) remained active and healthy and no transmitters were shed. All incisions in experimental fish had healed, and there were no signs of infection. Minor irritation was observed at the site of some sutures. At the conclusion of the study, both male and female fish showed visible signs of milt or egg production. Transmitters from sacrificed fish were located near the incision site; either between the ventral abdominal wall and gut lumen or between folds of the intestine. There was no evidence of transmitter encapsulation by connective tissue or intestinal loops.

Growth regressions for control and experimental fish were not significant (linear regression $r^2 = 0.09$, $p>0.1$ and $r^2 = 0.03$, $p>0.1$, respectively), therefore growth rates could not be compared. Fish growth was positive for both groups but variability was high among individuals. Experimental fish grew 2 to 9 mm (mean Δ TL = 6 mm) while control fish grew 0 mm to 11 mm (mean Δ TL = 5 mm).

2007-08 Sonic Telemetry

Over the six month study, all 15 subadult razorback sucker were contacted, for a total of 213 detections, 81 (38%) of which were made remotely by SURs. Active subadult contacts were made between RM 49.5 (49 Mile Light) and RM 31.5 (Sheep Trail Light). Immobile transmitters were documented between RM 54 (near the USGS stream gauge upstream of Willow Beach) and RM 37 (near Plateau Cove).

All 17 adult razorback sucker were contacted for a total of 446 detections, 329 (74%) of which were made remotely by SURs. Active adult contacts were documented between RM 60.5 (upstream of Ringbolt Rapid) and RM 20 (near the Arizona shore in Cottonwood Basin). Immobile transmitters were documented between RM 50 (near 50 Mile Light) and RM 3.5 (Arrowhead Cove). On two separate trips, the entire reservoir was surveyed (all 148 listening stations) confirming that unaccounted fish (both adult and subadult) had not dispersed downstream of the SUR positioned at Painted Canyon Lights. Three adult individuals were contacted within the first seven days post-release but were never contacted again for the remainder of the study. These individuals were subsequently removed from further analysis

At the conclusion of this study, one of 15 (7%) tagged subadult razorback sucker remained active (Fig. 5). All 14 inactive transmitters were inspected by a SCUBA diver and were subsequently recovered from the bottom of the reservoir. No fish remains were present near any recovered transmitter. Of the 14 sessile transmitters, 12 were located in the main channel (mean distance was 7 km from the release site [range 1 to 19 km], mean depth was 8 m [range 3 to 18 m]) and two were located in coves (both located 3 km from the release site, average depth was 4 m [range 3 to 4 m]). The median number of active swim days for subadults whose transmitters were recovered was 21 d (range 4 to 141 d).

Five of 14 (36%) tagged adult razorback sucker remained active (Fig. 5). Eight of nine immobile transmitters were inspected by a SCUBA diver and were subsequently recovered from the bottom of the reservoir. The remaining immobile transmitter was located and inspected from the surface of the reservoir in shallow water (Fig. 6). No fish remains were present near any recovered transmitter. Of the nine sessile transmitters, seven were located in the main channel (mean distance was 13 km from the release site [range 1 to 29 km], mean depth was 8 m [range 2 to 19 m]) and two were located in coves (mean distance was 29 km from the release site [range 3 to 54 km], mean depth was 24 km [range 3 to 21 m]). The median number of active swim days for adults whose transmitters were recovered was 102 d (range 22 to 154 d).

For the 15 subadult fish tracked during 2007-2008, weekly survivorship was estimated at 81.7% (95% CI, 71.8 to 89.3%). Based on this estimate, survival for the entire study, 19 October 2007 to 14 April 2008, was 0.6% (95% CI, 0.02 to 5.6%). For the 14 adult fish tracked during 2007-2008, weekly survivorship was estimated at 95.3% (95% CI, 91.7 to 97.7%). Based on this estimate, survival for the entire study was 28.9% (95% CI, 11.1 to 55.9%).

Analysis of the contingency table revealed a significant difference ($p<0.002$) in the proportion of adult and subadult repatriates (2007-08 fish only) that were active three months after stocking. However, by the conclusion of the study no significant difference ($p = 0.069$) was detected between adult and subadult fish.

Subadults from the 2006-07 and 2007-08 studies could not be pooled three months post-stocking because the proportion of active fish was significantly different ($p<0.019$) between years. After six months, however, no significant difference ($p = 0.340$) was detected between subadults from both studies. Subadults were pooled and compared to adults from the 2007-08 study, but no significant difference ($p = 0.067$) was detected between groups.

Routine Monitoring

Routine monitoring from 2006 to May 2008 resulted in the capture of 74 razorback sucker (75 captures, 1 short-term recapture). There were 63 PIT-tagged repatriates, 3 PIT-tagged fish with unknown capture histories, 5 wild PIT-tagged fish, and 3 untagged fish.

All of the PIT tagged repatriates had known capture histories; 29 were reared in lakeside backwaters while 34 were reared in off-site facilities (Table 2). Most of the lakeside-reared fish were reared in Yuma Cove (*N*=11) while North Chemehueve and Arizona Juvenile tied for second position (*N*=5 each rearing location). Willow Beach NFH fish contributed 65% (*N*=22) of fish from off-site facilities, and 35% of total PIT tagged repatriates. Repatriates were from 23 different release locations around Lake Mohave (Table 3) and their time at large ranged from less than one year to 13 years with an overall average TL at release of 37.7 cm (Table 4).

Wild population estimates have declined from 507 fish (263-1,067 95% CI) in 2005 (Kesner et al. 2007) to 47 fish (24-175 95% CI) in 2007 based on 2007 and 2008 March capture data. Repatriated razorback sucker population estimates have also declined from an all-time high in 2005 of 4,221 fish (954-35,071 95% CI) to 1,232 fish (662-2,318 95% CI) in 2007 based on 2007 and 2008 March capture data. The total population estimate has decreased from 4,728 fish to 1,279 fish in 2 years.

Creel Census Data

No PIT tags have been identified in the stomachs of large predatory fish in Lake Mohave during this study period. Since NDOW began providing creel census data in 2006, 12 large striped bass and two large channel catfish have been scanned for PIT tags. No tags have been detected. NDOW recorded one anecdote of an angler catching a 30 lb striped bass with a razorback sucker in its stomach on 23 November 2007.

Ecological modeling

For the multi-site mark-recapture model, a total of 1,120 repatriate capture histories were analyzed, 212 of which represent fish recaptured during the period of March 1996 to March 2008. Recapture rate differed significantly among capture occasions (χ^2 = 305.599, df = 72, p<<0.01), while the survival rate did not (χ^2 = 72.083, df = 61, p = 0.157). The model with time varying spatial transition rates could not be resolved numerically. This was likely due to the large number of parameters (over 150) in comparison to the number of data points (212 recaptures). Survival was significantly different among zones (χ^2 = 913.864, df = 2, p<<0.01), therefore, the ‘best’ model included time varying recapture rates, and constant survival and transition rates per zone.

Transition and survival rates for adult (>40 cm), at-large repatriate razorback sucker varied considerably from zone to zone (Table 5). Approximately 90% of fish transitioned out of the Nine Mile zone within one month, compared to about 7 and 12% out of Yuma and Tequila zones respectively. Annual estimates of site fidelity are low with few fish exhibiting strong ties to the zone of first capture. Nearly all fish transitioned out of Nine Mile (99.9%), 77% transitioned out of Tequila, and 56% transitioned out of Yuma. Repatriate razorback sucker in Tequila experienced the highest rate of survival, 91.7% annually, according to the best mark-recapture model (Table 5), followed by Yuma (76.3%) and Nine Mile (70.1%).

Several significant correlations ($p<0.01$) in release variables illustrate the evolution of the NFWG repatriation program (Table 6). An increase in target release size for repatriated razorback sucker since the program began is evident in the significant positive correlation between release year and average TL at release. Release year was also negatively correlated with release zone, indicating an uplake (upstream) movement of stockings (zones were numbered from Hoover Dam downlake [downstream] 1-9, see Fig. 3). Release year was also negatively correlated with cohort size indicating that the upper lake zones typically have larger cohort sizes. These correlations illustrate the shift from lakeside backwater releases to releases from Willow Beach NFH, which are often stocked in zones uplake of lakeside backwater sites and in bigger cohorts.

Two correlations indicate variables that influence survival. Release year was negatively correlated with capture proportion indicating a decline in survivorship with time (Table 5). Average release TL was positively correlated with capture proportion indicating a positive effect of size on survivorship.

Based on significant correlations of release year and average release TL with capture proportion, an ANCOVA (Analysis of Covariance) was used to test for statistical significance of zone and month of release on capture proportion while treating release year and average release TL as covariates. The effect of both covariates was significant ($F = 42.9$, $df = 1$, $p<<0.01$ and $F = 62.9$, $df = 1$, $p<<0.01$ respectively). A significant interaction between release zone and release month indicates that the effect of release month varies by zone ($F = 1.99$, $df = 61$, $p<<0.01$).

Discussion

Post-stocking Dispersal and Fate

Two years of sonic telemetry data and a captive fish study that tested the impact of our surgical methods on study fish have provided a clearer understanding of post-stocking survival of razorback sucker in Lake Mohave. High subadult mortality observed during both telemetry studies provides strong evidence, which corroborates poor repatriate survival observed during past years of reservoir-wide monitoring efforts (Marsh et al. 2005). Results from the 2007-08 telemetry study indicate adult repatriates appear to survive better than subadults, but additional data using a larger sample of adults—in addition to larger fish (>55 cm)—are needed to portray a clearer depiction of size-based differences in post-stocking survival of razorback sucker.

2006-07 Sonic Telemetry

The lack of striped bass captures in large-mesh gill nets suggests trivial predation pressure on razorback sucker repatriates in the vicinity of Fortune Cove immediately after and during the three day post-stocking period. However, this could be a result of seasonal factors or serendipity, for example, if larger striped bass were dispersed to other parts of the reservoir during the stocking period. Catch data and creel results unequivocally demonstrate the presence of large striped bass, to longer than a meter, in Lake Mohave, and these fish must prey on razorback sucker. Additional directed and opportunistic sampling may be needed to further address this issue.

Visual surveys conducted by SCUBA divers indicated a majority of stocked razorback sucker initially swam to the back of Fortune Cove and took cover in the extensive submergent weed beds following their release. Subsequent analysis of underwater video footage recorded by divers confirmed this dispersal trend toward submergent cover and did not indicate the presence of any large-bodied piscivorous fish loitering in the stocking area. If a majority of stocked fish immediately found cover and remained out of view of potential pelagic predators, as suggested by the dive team, and no large striped bass were cued in by the two stocking events, it is reasonable to conclude predation of repatriated fish in the close vicinity of the stocking site was negligible. Instead, we suggest that fish became vulnerable to striped bass predation and were consumed after they left the protective cover and departed from the area. We do not know if channel catfish, which have a benthic habit, also occupied the weed beds sought by razorback sucker, where they could pose a predation threat to suitably-size, newly stocked fish.

The loss of one sonic tagged fish early on could represent transmitter failure or bird predation (e.g., Jepsen et al. 1998, Marsh & Minckley 1991), or actual emigration out of Lake Mohave. There are records of individual razorback sucker released into Lake Mohave that have been recaptured in the Colorado River downstream from Davis Dam (NFWG database, unpublished). However, the possible emigration of one fish (5% of total released) is minor in comparison to the 16 fish that died during the 6 month telemetry study. In addition, the dispersal patterns of sonic tagged fish do not support a general hypothesis that repatriated fish migrate out of the reservoir via Davis Dam.

Manual tracking and SUR data, in addition to the captive fish experiment results, indicate that telemetry fish face almost certain mortality in a relatively short period of time after being repatriated into Lake Mohave. While recovered transmitters alone are not definitive indicators, 100% tag retention in captive fish suggests that recovered transmitters represented fish mortality. The captive fish study also demonstrated that surgical procedures in no way compromised fish health or behavior. In fact, at the conclusion of the experiment fish showed obvious reproductive signs in both sexes, suggesting sexual development was not disturbed by the implanted transmitters. Similar observations were made in razorback sucker implanted with radio transmitters on the Green River, Utah (Tyus & Karp 1990, Modde & Irving 1998).

Based on data acquired at the time of transmitter recovery and previous studies of razorback sucker, rapid loss of telemetered fish from this study was most likely due to consumption by predacious fishes. Piscivory has been documented as a cause of mortality for adult and subadult razorback sucker elsewhere in the Colorado River basin (Marsh & Brooks 1989, Tyus & Nikirk 1990). Absence of fish remains even when tags were recovered a relatively short time after cessation of movement suggests predation and is consistent with other studies of this population (Marsh et al. 2005).

2007-08 Sonic Telemetry

Sonic tagged adults utilized a larger area of the reservoir than did subadults. Active adults from the 2007-08 study dispersed 125% further than subadults during the same year, and 31% further than subadults from the 2006-07 study.

A significantly larger proportion of subadults from the 2006-07 study were active three months post-stocking than were subadults from the 2007-08 study during the same length of time. However, at the end of six months, mortality was high in both groups (86% and 93%, respectively) and there was no statistical difference between the proportions of active subadults between studies. Similarly, weekly survival rates calculated from survival histories have overlapping confidence intervals indicating a lack of statistical difference of survival rates between the two study years. While poor survival of subadult fish during 2007-08 was predicted following results from the previous years study, the mortality rate observed in both studies was higher than expected.

On any given week during the 2007-08 study, the proportion of active adults was always higher than the proportion of active subadults. The trend of higher adult survivorship continued through the end of the study, yet no significant difference was detected between large and small repatriates after 6 months. As the number of fish in both groups decreased over time, the small sample sizes limited the power of the analysis to detect variation between groups. However, weekly survival rate confidence intervals do not overlap, indicating a significant difference in survival between subadults and adults in the 2007-2008 study, and survival rate estimates for the entire study period indicate a nearly 50-fold increase (0.6 to 29%) in survival between subadult and adult released fish.

During the 2007-08 study, sonic tagged adult fish were contacted three times more frequently than subadult fish. One reason for this disparity was several adults frequently made movements between Fortune Cove (where an SUR was located) and other nearby coves, thereby increasing total contacts. For example, on each of 31 consecutive days in spring 2008, one adult arrived at Fortune Cove at sunrise, remained there until dusk, then moved to another nearby cove (documented by manual tracking nighttime surveys). The individual then returned to Fortune Cove at sunrise (remarkably, its return times during this time period never differed by more than 40 minutes) where it remained for the rest of each day. As a group, when SUR contacts were removed from total active contacts, adult fish were still contacted 48% more frequently than subadult fish. Because a larger proportion of adult fish was active compared with subadults between the second week post-stocking and the end of the study, more adults were available for contact. Adult fish were ultimately alive longer throughout this study than were subadult fish.

Active fish contacts combined from both studies (both size classes) were restricted to the area north of Nine Mile. While a majority of all combined active contacts occurred between Willow Beach and Owl Point, fish were contacted in higher densities upstream of Fortune

Cove (Fig. 7). During that time, immobile transmitters were recovered over a much broader area and were located in close proximity to both Davis and Hoover dams. It was impossible to tell from our data where the site of a predation event occurred and therefore which areas of the reservoir, if any are more dangerous for fish to be stocked.

Although piscivory has been considered a threat to this population for some time (Minckley 1983, Minckley et al. 2003), the high rate of losses is troublesome considering both studies account for a trivial amount of time (6 months) in the lifespan of fish that can exceed 40 years (McCarthy & Minckley 1987). In addition, the size of fish being consumed is alarming. Razorback sucker more than 50 cm long were located with predation scars (Fig. 8) and 64% of sonic tagged adults were consumed. Striped bass are the only piscivores in Lake Mohave that have a gape size large enough to ingest fish of this size (e.g., Dennerline & VanDen Avyle 2000). While 50 cm razorback sucker appear to have better survivorship than subadult fish, our data suggests that they are not large enough to evade predation by the largest striped bass that inhabit the reservoir.

Routine Monitoring

The 2007 population estimate for wild razorback sucker in Lake Mohave was dramatically lower compared to previous estimates. This marks the second year in a row where the estimate has declined by more than 50% in comparison to the previous year (Kesner et al. 2007, 2008). It appears that the wild population is near complete extirpation. Repatriates in Lake Mohave now outnumber wild adults by an order of magnitude. The new protocol which recommends a minimum stocking size of 50 cm is still not completely implemented. However, results from the 2006-2007 telemetry are encouraging (Karam et al. 2008, this document) and increases in repatriate survival and population abundance may be in the offing.

Creel Census Data

Although no PIT tags have been detected in striped bass or channel catfish stomachs during the three year study period, few small razorback sucker were released in 2007 and 2008, and creel census data that were collected at Cottonwood Cove in 2006 resulted in only 3 large striped bass scanned. The lack of tag detections is at least partially due to bad timing. Since the increase in target release size, few razorback sucker have achieved this size and have been released. In addition, the fish that have been released from Willow Beach NFH have been large, close to 50 cm, fish. This size has been targeted to avoid predation by striped bass, and therefore they are expected to be rarely ingested. However, cooperation with NDOW is expected to continue beyond this study.

Ecological Modeling

Results of multi-site mark-recapture models suggest that site fidelity may introduce some bias into population estimates given that sampling effort is not evenly distributed throughout the reservoir. However, it is doubtful that this bias would have any significant impact on population estimates. At large, adult repatriate survival estimates from the mark-recapture model are consistent with estimates from previous reservoir-wide models at approximately 75% (Kesner et al. 2007, Kesner et al. 2008). In addition, although site fidelity is statistically significant, annual spatial transition rates result in at least 50% of fish from each zone entering a different zone by the following year. These multi-site model results are in concordance with reservoir-wide release-capture data used for contingency analysis in 2006 (Figure 8), about half of the fish released in one zone were captured in a different zone.

The ANCOVA did not uncover a significant release variable beyond what was already known (release size), or beyond the control of the repatriation program (year of release). However, cohort size and/or release location appear to impact future capture probabilities. A total of 340 captures have been recorded out of the 16,667 fish released in cohorts smaller than 100 (2.0%) compared to 479 captures out of the 51,817 released in cohorts greater than or equal to 100 (0.9%). The majority of release cohorts (68%) with cohort size less than 100 are from the three central zones: Yuma, Tequila and Nine Mile, so it is difficult to determine if cohort size or release site is affecting future capture probability. The three central zones constitute the areas of the most consistent effort, and any increase in captures from fish released in these zones could be due to site fidelity of fish released in those zones, and not due to increases in survival.

Conclusions

Single-census population estimates, post-release survival estimates based on telemetry and mark-recapture data, and at large survival estimates based on multi-site mark-recapture data are all largely in agreement. Initial survival is low enough that few fish recruit to the adult population, and the adult repatriate population has approximately 75% annual survivorship. These two facts result in the maintenance of a population between 2,000 and 4,000 fish given average annual stocking numbers and sizes. For example, the nominal target size of 35 cm release should result in an at best 10% survival in the first year based on telemetry and mark-recapture data (Marsh et al. 2005, this report). If 10,000 fish are released annually at this size, 1,000 fish remain after the first year to recruit to the adult population. Meanwhile, the adult repatriate population of 4,000 loses 1,000 fish due to the adult survival rate of 75%. The end result is the maintenance of an adult repatriate population of 4,000. If released fish take 2 years to recruit to the adult population, then 750 recruit (75% second-year survival), and the population is maintained at 3,000 fish, and if it takes three years for fish to recruit, 500 fish recruit and a stable population of 2,000 fish is maintained. This range of population sizes is similar to the range of annual population estimates reported in this document and elsewhere (Marsh et al. 2005).

There is no doubt that increasing size at release increases survivorship, and telemetry results indicate a potential 50-fold increase in survival between 35 and 50 cm fish (0.6% compared to 28.9%). However, survival for both subadult and adult fish in the telemetry study was lower than predictions based on mark-recapture data (e.g., Marsh et al 2003). Mark-recapture estimates of survival appear unreliable for larger fish sizes because too few large fish have been released. According to the NFWG database, only 921 fish have been released into Lake Mohave with a TL greater than 45 cm. Seventy-three of these fish (7.9%) have been captured since being released. Until more data are available on large fish survival, the most efficient release size – the length at release that maximizes population size given the limitations of hatchery operations and cost – will remain unknown.

Finally, low recapture rates increase uncertainty in mark-recapture estimates and limit the number of models that can be analyzed, but increasing sampling effort to get higher recapture rates may be harmful to the fish and would require additional resource expenditures. Remote PIT tag sensing, deploying PIT scanning equipment underwater to detect passing PIT tags, offers an opportunity to increase sampling occasions and ‘recapture’ rates without increasing fish handling. This technique is currently being evaluated by Jon Nelson (BR), and along with sonic telemetry may reduce the role of netting for population monitoring of repatriate razorback sucker in Lake Mohave.

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Table 1. Total captures of repatriate razorback sucker in Lake Mohave Arizona-Nevada from three specific zones from March 1996 to March 2008. Year and month combinations in which captures did not occur in all three zones were excluded from this table.

		Capture Zone			
Year	**Month**	**Nine Mile**	**Tequila**	**Yuma**	**Total**
1996	March	10	9	11	30
	April	5	4	17	26
1997	March	12	8	9	29
	November	2	6	2	10
1998	February	2	1	9	12
	March	25	10	8	43
1999	March	18	26	44	88
	November	2	8	1	11
2000	February	8	6	5	19
	March	31	12	25	68
2001	March	43	54	53	150
	April	7	3	6	16
2002	February	16	21	24	61
	March	70	25	30	125
2003	February	8	7	16	31
	March	50	37	53	140
	November	21	5	31	57
2004	January	3	7	17	27
	March	53	63	33	149
	April	1	1	9	11
2005	February	1	8	27	36
	March	23	26	35	84
	November	10	12	23	45
2006	March	38	56	32	126
2007	March	29	29	37	95
2008	March	26	31	113	170
Total		514	475	670	1,659

Table 2. Rearing type and location of razorback sucker repatriates, Lake Mohave, Arizona and Nevada. Data are arranged by number of fish.

Rearing		
Type	**Location**	***N* fish**
Lakeside backwater	Yuma Cove	11
	North Chemehuevi Cove	5
	Arizona Juvenile	5
	Nevada Larvae	2
	Dandy Cove	2
	Willow Cove	1
	South Sidewinder Cove	1
	Nine Mile Cove	1
	Davis Cove	1
	Lakeside backwater total	29
Off-site facility	Willow Beach NFH	22
	Boulder City Wetlands Park	9
	Boulder City Golf Course Ponds	2
	Bubbling Ponds FH	1
	Off-site facility total	34
	Grand total	63

Table 3. Release locations of razorback sucker repatriates, Lake Mohave, Arizona and Nevada. Data are arranged by number of fish.

Release location	***N* fish**
Yuma Cove	12
Cottonwood Cove	8
Arizona Juvenile	6
Chemehuevi Cove	6
Sheeptrail Cove	4
Placer Cove	3
Pot Cove	3
Red Tail Cove	3
Dandy Cove	2
Nevada Larvae	2
Perkins Cove (south of)	2
42 RM	1
Davis Cove	1
Gold Cove	1
Great West Cove, Wrong Cove and Antelope Cove	1
Nelson's Landing	1
Nevada Bay	1
Nine Mile Coves	1
Oro, Elizabeth and Fortune Coves	1
Owl Cove	1
Sidewinder Cove	1
Willow Cove	1
Wrong Cove	1
Total	63

Table 4. Release year and average total length (TL) at release of razorback sucker repatriates, Lake Mohave, Arizona and Nevada. Data are arranged by descending release year.

Release year	***N* fish**	**TL (cm)**			
		Avg	**SD**	**Min**	**Max**
2007	6	43.7	8.3	29.0	53.0
2006	17	40.9	3.7	35.5	47.5
2005	10	40.5	4.3	35.5	50.5
2004	2	36.0	0.0	36.0	36.0
2002	2	33.5	0.7	33.0	34.0
2001	4	36.6	6.9	30.5	44.0
2000	5	41.8	5.2	35.0	48.5
1998	5	30.2	4.5	25.0	36.5
1997	1	28.0	-	28.0	-
1996	4	29.5	3.3	25.5	32.3
1995	5	32.4	3.6	26.0	34.6
1993	1	23.8	-	23.8	-
1992	1	35.5	-	35.5	-
Total	63	37.7	6.6	23.8	53.0

Table 5. Estimates of survival and transition (movement between zones) and their associated 95% confidence intervals (CI) from mark-recapture data of repatriated razorback sucker in Lake Mohave, Arizona and Nevada.

	Monthly Rate			Annual Rate		
	Estimate	**CI (Lower)**	**CI (Upper)**	**Estimate**	**CI (Lower)**	**CI (Upper)**
Survival						
Yuma	97.8%	96.5%	98.6%	76.3%	65.5%	84.1%
Tequila	99.3%	98.1%	99.7%	91.7%	79.3%	96.9%
Nine Mile	97.1%	93.2%	98.8%	70.1%	43.1%	86.3%
Transition						
Yuma to Tequila	5.6%	2.6%	11.4%	49.8%	27.5%	76.5%
Yuma to Nine Mile	1.1%	0.3%	3.7%	12.4%	3.8%	36.1%
Tequila to Yuma	6.4%	3.4%	11.8%	54.8%	33.7%	78.0%
Tequila to Nine Mile	5.2%	3.1%	8.8%	47.6%	31.4%	66.7%
Nine Mile to Yuma	28.2%	13.8%	49.1%	98.1%	83.3%	100.0%
Nine Mile to Tequila	61.6%	42.0%	78.0%	100.0%	99.9%	100.0%

Table 6. Pearson's correlation coefficients for variables of release and capture for repatriated razorback sucker in Lake Mohave, Arizona and Nevada. Significant correlations are highlighted in yellow. Values in grey represent redundant values or correlations of a variable to itself.

	Release Year	Cohort Size	Zone	Capture Proportion	Average Release TL
Release Year	1	0.088	-0.133	-0.155	0.386
Cohort Size	0.088	1	-0.148	-0.075	0.102
Zone	-0.133	-0.148	1	0.073	0.057
Capture Proportion	-0.155	-0.075	0.073	1	0.153
Average Release TL	0.386	-0.102	0.057	0.153	1

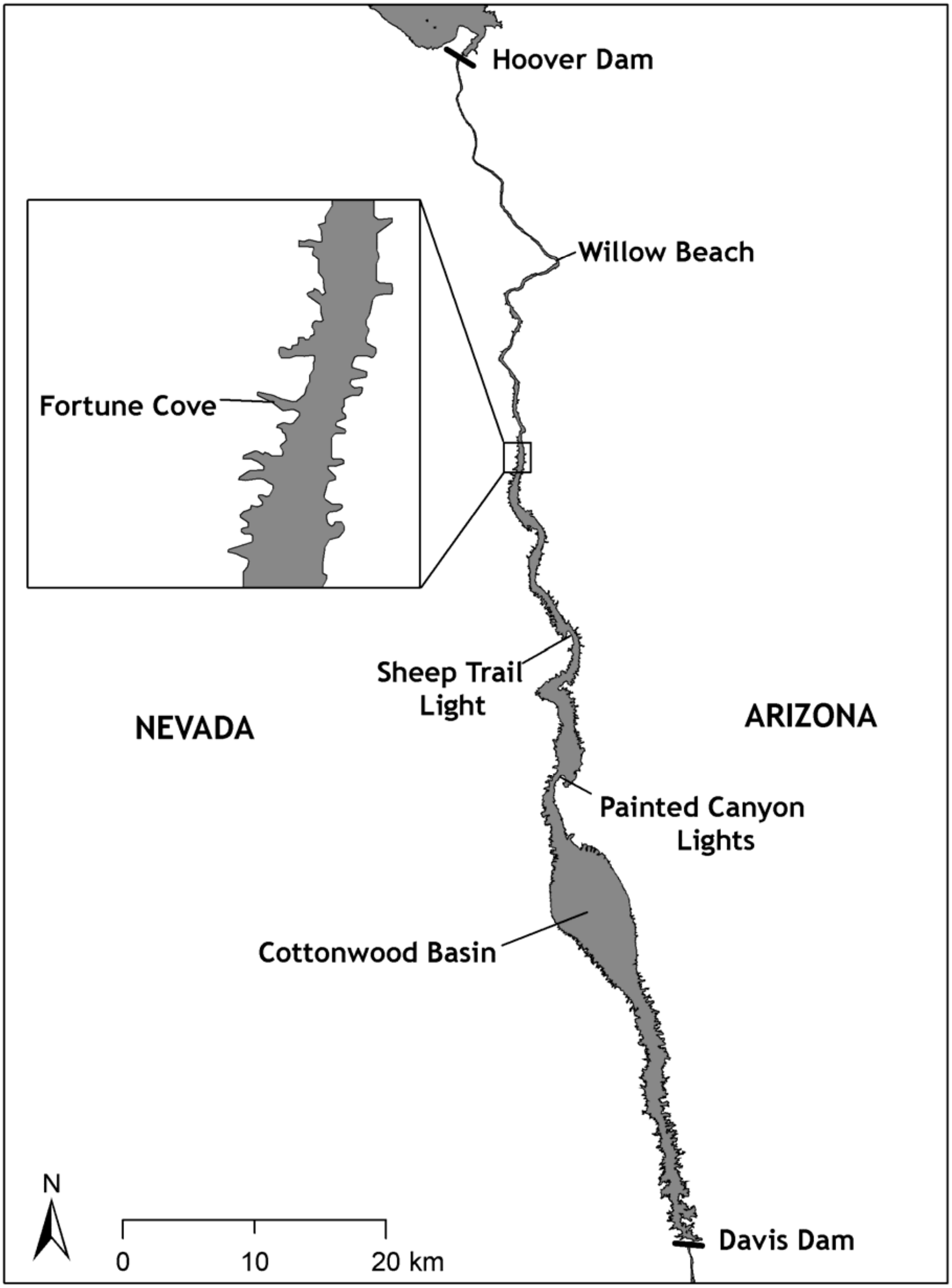

Figure 1. Sketch map of Lake Mohave and Fortune Cove where razorback sucker from the 2006-07 and 2007-08 sonic telemetry studies were repatriated into the reservoir.

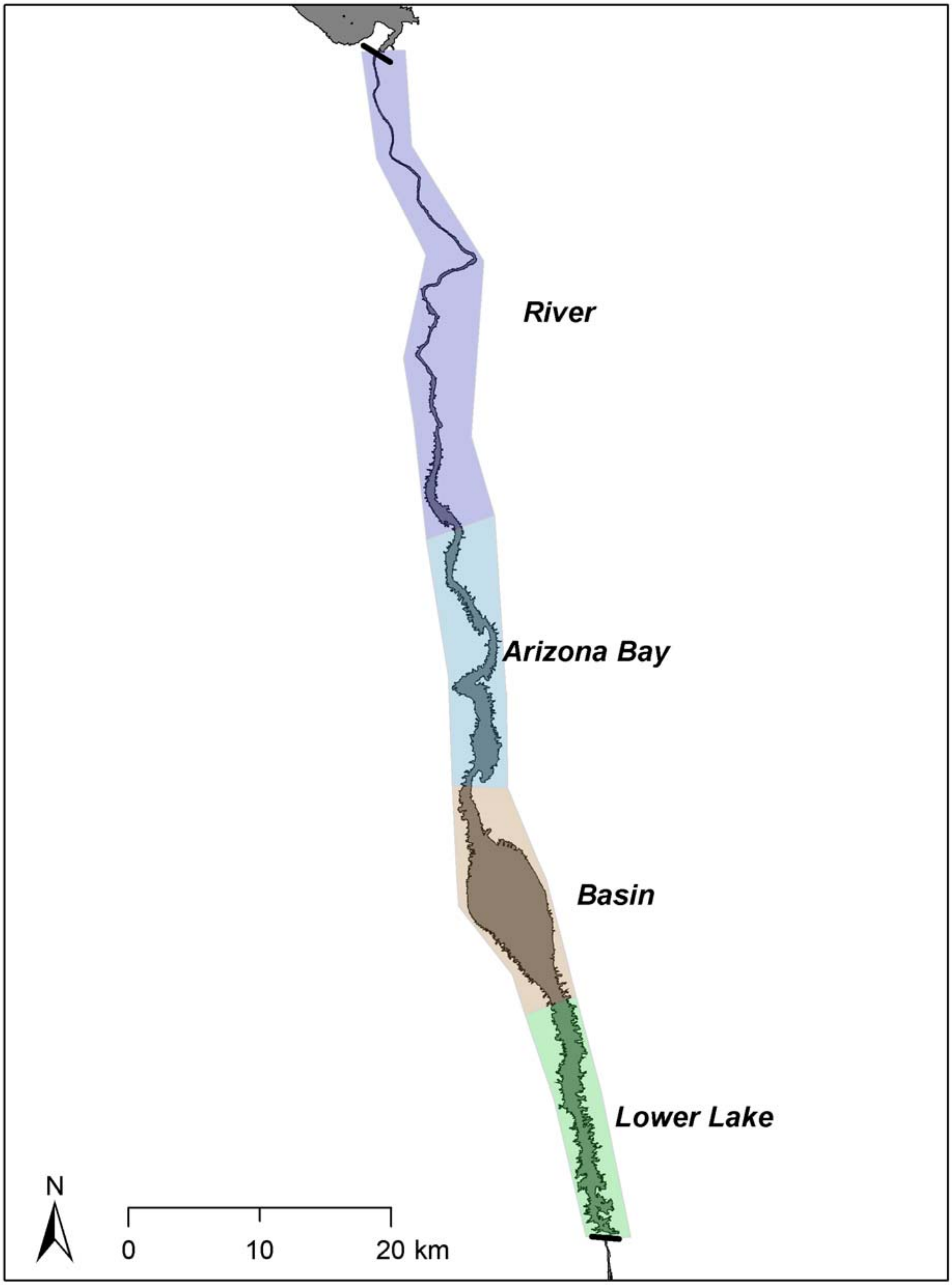

Figure 2. General zone names and boundaries used to analyze razorback sucker catch and effort data for Lake Mohave, Arizona and Nevada.

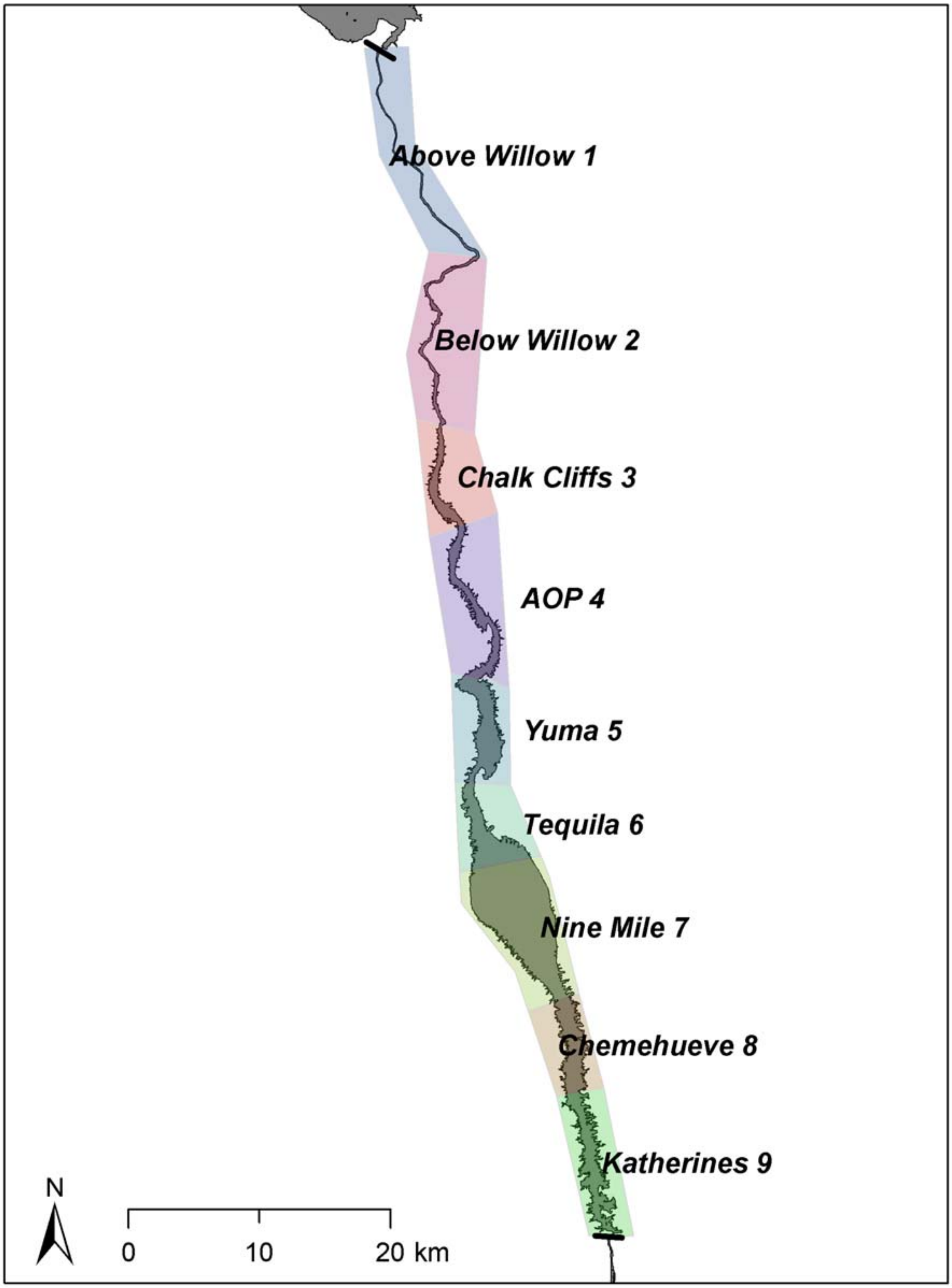

Figure 3. Specific zone names (number) and boundaries used to analyze razorback sucker catch and effort data for Lake Mohave, Arizona and Nevada. Zones were numbered sequentially from 1 to 9 for quantitative analyses.

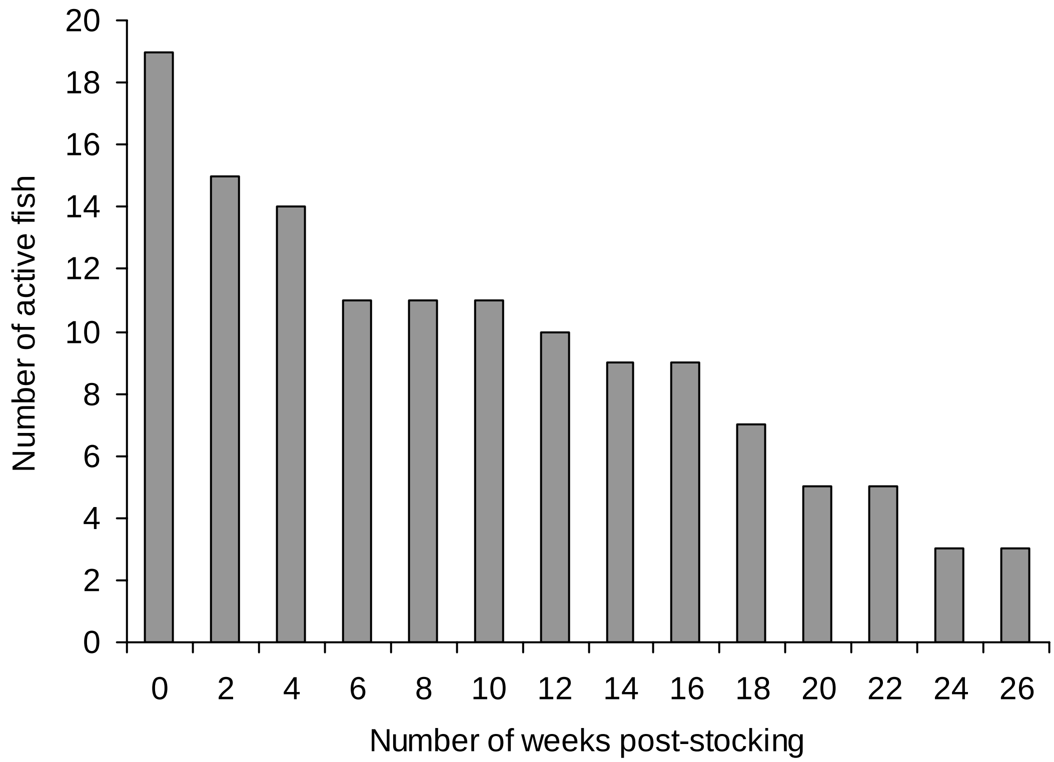

Figure 4. Summary of active tagged razorback sucker contacted between 27 September 2006 and 16 March 2007. Number of active fish is the total number of razorback sucker without a documented dead contact for a given bi-monthly survey.

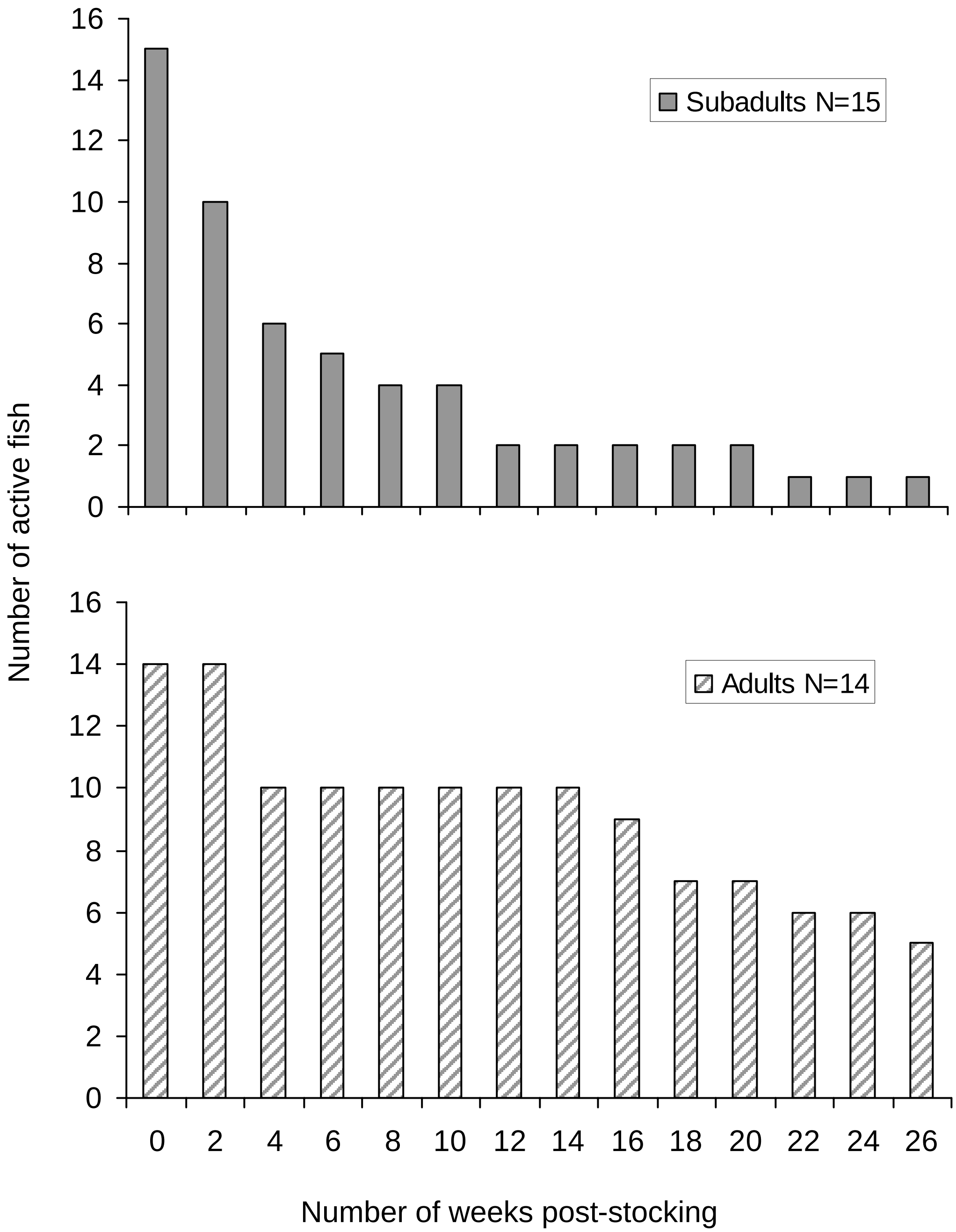

Figure 5. Summary of active tagged razorback sucker subadults and adults contacted between 19 October 2007 and 14 April 2008. Number of active fish is the total number of razorback sucker without a documented dead contact for a given bi-monthly survey.

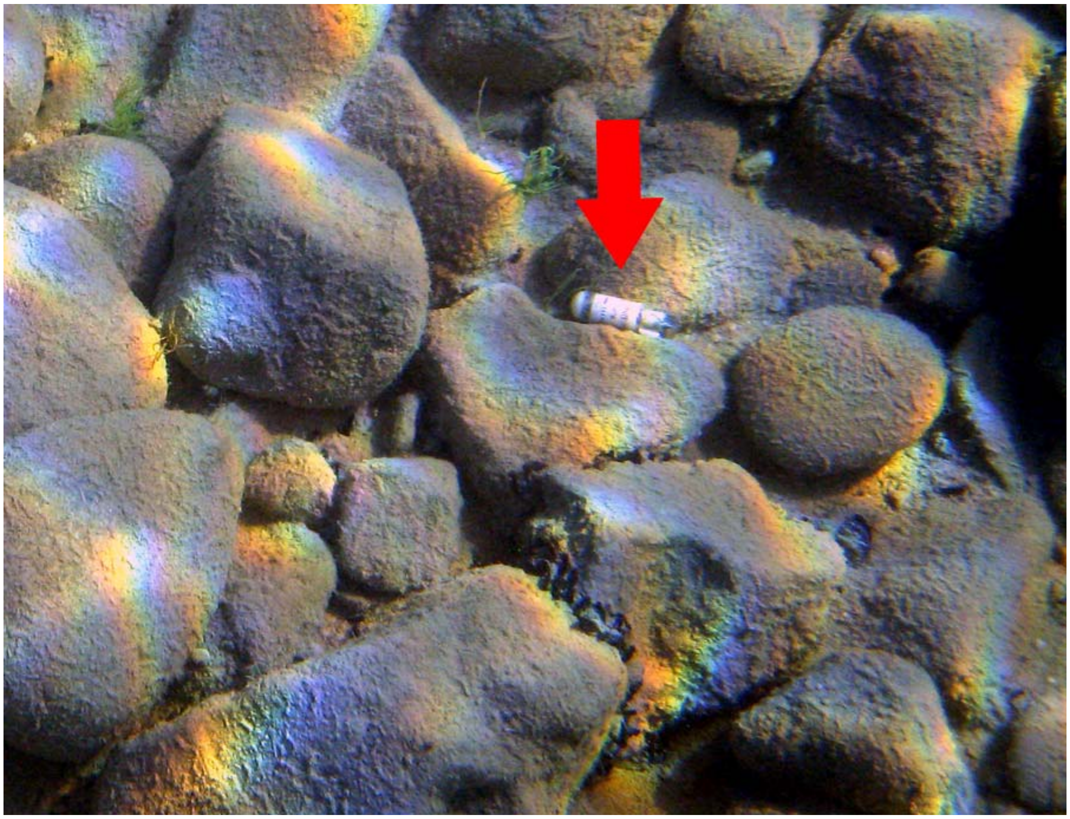

Figure 6. Photograph of a sonic transmitter taken from the surface of Lake Mohave on 5 February 2008. The transmitter was located directly across the reservoir from Cottonwood Cove at a depth of 2.5 m.

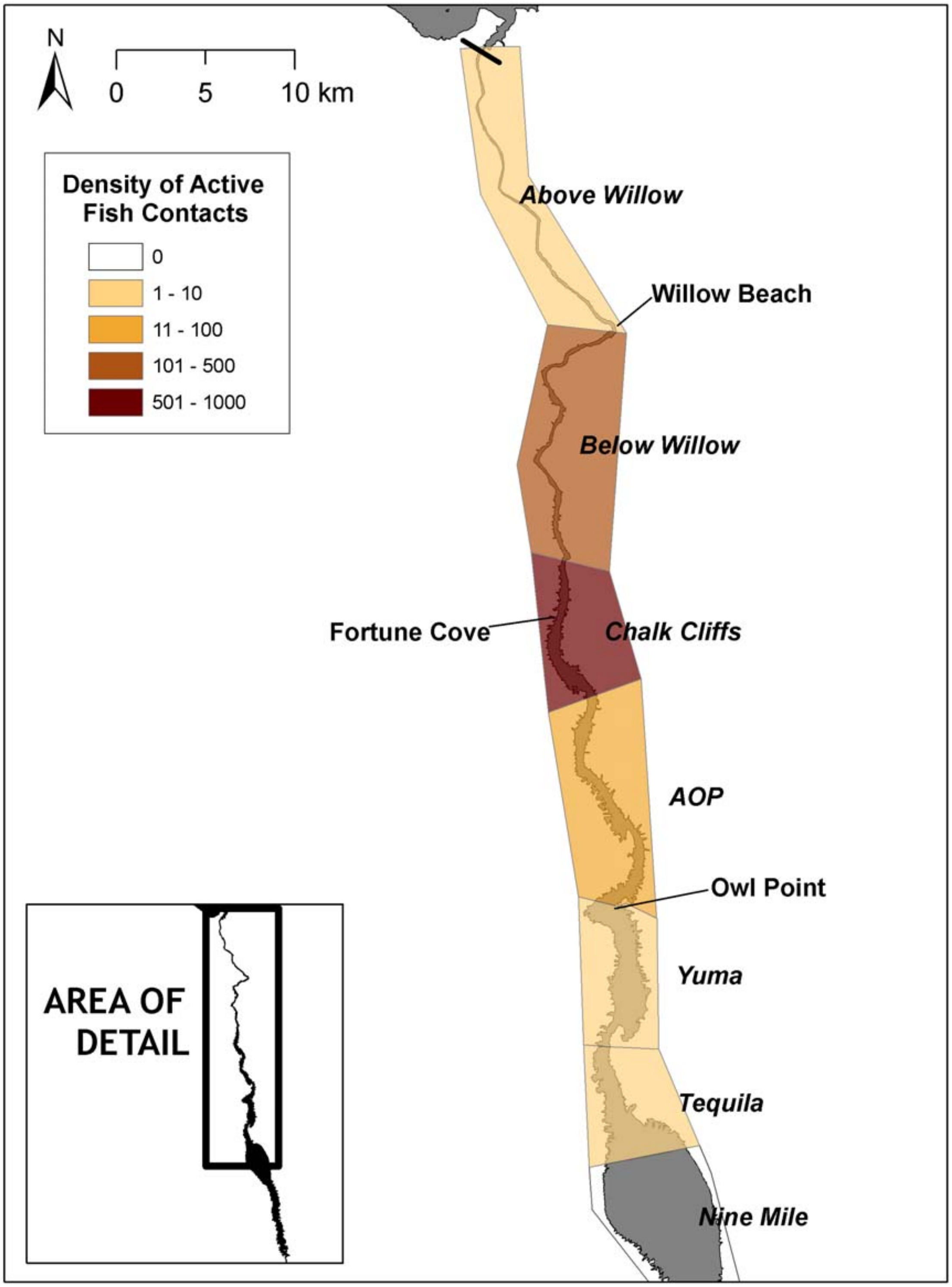

Figure 7. Density of active contacts made for all sonic tagged fish in the 2006-07 and 2007-08 telemetry studies.

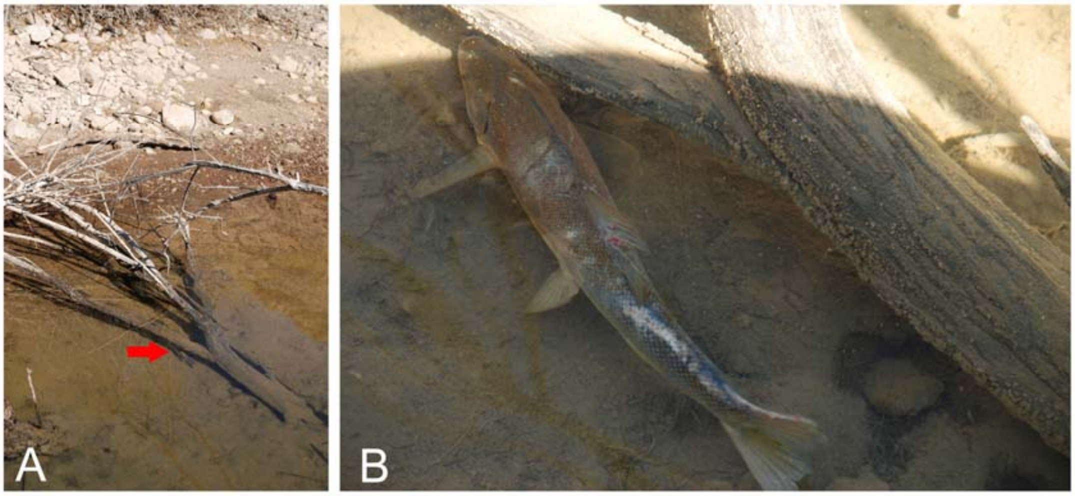

Figure 8. Photographs of a sonic tagged adult razorback sucker taken on 5 March 2008 in Techatticup Cove, Lake Mohave. A red arrow (A) points to the fish and its near-shore location under woody debris. The close-up image (B) depicts a missing piece of the dorsal fin and an abrasion potentially made by a predacious fish.