Lower Colorado River
Multi-Species Conservation Program

Balancing Resource Use and Conservation

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

December 2013

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Lower Colorado River Multi-Species Conservation Program

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

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Summary

Persistence of razorback sucker (*Xyrauchen texanus*) in the lower Colorado River below Hoover Dam now relies entirely upon stocking programs. Even so, only a small proportion of stocked fish are ever encountered in the wild. In Lake Havasu (MSCP Reach 3), recent telemetry studies have found large spawning aggregations of razorback sucker in the upstream, riverine portion outside of reservoir habitat that is unsuitable for standard net based sampling that occurs in the lake. Contacting a greater proportion of the population is vital to assess the current at large population and the factors that affect individual survival.

Remote PIT scanning has been a successful tool for contacting tagged fish in both riverine and slack waters throughout the lower Colorado River, and this technology was deployed for the razorback sucker spawning periods in January-April 2012 and December-April 2013 in the fast flowing waters of Reach 3 from Davis Dam downstream to Moabi Regional Park, CA. We contacted 652 and 2092 razorback sucker released with a 134 kHz PIT tag in 2012 and 2013 respectively.

The combination of remote PIT scanning and standard fisheries sampling methodologies produced population estimates for 134 kHz PIT tagged razorback sucker of 2496 (1935 to 3220, 95% confidence interval) and 4524 (4027 to 5081, 95% confidence interval) for 2011 and 2012 respectively.

Season of release and size at release were found to be significant factors in post-stocking survival of razorback sucker released into Reach 3 in an assessment of mark-recapture models using the software package MARK. Actual estimates of survival varied significantly among competing models, and year to year variation of post-release survival was significant. Still, post-release survival estimates for razorback sucker released in the spring were twice as high on average compared to autumn releases in all models, and models that incorporated size at release as a covariate were always ranked higher by AIC_C (small sample Akaike's Information Criterion) than models that did not.

Monitoring of the MSCP Reach 3 razorback sucker stocking program should continue and emphasize seasonal application of remote PIT tag scanning augmented by bi-annual physical sampling that utilizes electrofishing and netting. Although remote PIT scanning has significantly increased contact rates for razorback sucker in the reach, precise post-release survival estimates have remained elusive. The variability in post-stocking survival (year to year and season to season) combined with the seasonality and temporal proximity of employing PIT scanning results in imprecise post-stocking survival estimates. Because contacting released razorback sucker in the season after release is required to assess survival during this critical period, PIT scanning will need to continue for multiple years and across seasons. Recommendations to improve post-release survival should accrue after multiple iterations of data collection, analysis, and interpretation.

Introduction

Razorback sucker is one of the four "big-river" fishes endemic to the Colorado River that were once abundant and widespread throughout the system (Minckley 1973). Its distribution and numbers have dwindled and the species is currently listed as endangered under the Endangered Species Act (USFWS 1991). Population decline is largely attributed to dam construction and direct and indirect interactions with non-native species introduced into the main stem (Joseph *et al.* 1977; Minckley 1979; Bestgen 1990; Minckley *et al.* 1991; Mueller and Marsh 2002).

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

Minckley (1983) hypothesized that razorback sucker populations experienced highly successful recruitment events immediately following impoundment of reservoirs in the lower Colorado River basin. Lake Havasu was impounded in 1938, and the last documented capture of wild adults was in Laughlin Lagoon, 1986 (Marsh and Minckley 1989). A population persists today only because of annual stocking efforts that began with larval stocking in 1986 (Marsh and Minckley 1989), and continued with nearly 500,000 mostly small razorback sucker stocked between 1986 and 2005 (Schooley and Marsh 2007, unpublished data).

Under guidance of the LCR MSCP, 49,000 larger razorback sucker (>300 millimeters [mm]) have been stocked into Reach 3 since 2006. Post-stocking research and monitoring activities have resulted in capture of very few fish from early stockings, and while individuals from more recent stockings have increased contact rates comparatively, absolute capture rates remain low. Recently released fish have been found to aggregate in major spawning areas from Laughlin, Nevada, downstream to Needles, California (Wydoski and Mueller 2006; Wydoski and Lantow

2012). Capture rates are less than 3 percent (%) of cumulative fish released (Table 1), so calculating accurate population estimates and isolating specific factors affecting survival of repatriated razorback sucker in Reach 3 presents a challenge.

Here we report the final results and conclusions on the use of a combination of remote Passive Integrated Transponder (PIT) scanning and capture data (December 2011-2013) to assess the current Reach 3 razorback sucker population and evaluate the effects of size, location, and timing of release on post-stocking survival. This information is integral in formulating a cost-effective, efficient method to restore the population in Reach 3. Specific objectives from the study period include:

1. Contact razorback sucker using remote PIT scanning units in zone 3-1 and 3-2
2. Assimilate all Reach 3 razorback sucker release and capture data collected by any entity
3. Estimate the current repatriate razorback sucker population
4. Estimate survival of razorback sucker released in Reach 3 based on size, location, and season of release since 2005
5. Participate in annual multi-agency native fish survey

This information will aid in completion of LCR MSCP Work Task C33: comparative survival of 500-mm razorback sucker released in Reach 3.

Methods

Study area

Lake Havasu is impounded by Parker Dam, constructed by U.S. Bureau of Reclamation (Reclamation) and closed in 1938. The reservoir has a 7.98×10^8 cubic meter (m^3) storage capacity regulated by releases at the upstream terminus (Davis Dam), downstream terminus (Parker Dam), and less significantly through releases into the Bill Williams River from Alamo Dam. For this work, Reach 3 has been separated into four distinct zones based largely on habitat types (Figure 1). Moving downstream from Davis Dam the first zone, 3-1, encompasses clear moving waters of the riverine section from the dam downstream to reservoir kilometer (RKM) 70.6 (reservoir mile, [RM] 43.9). The shoreline is low lying and relatively well developed.

Zone 3-2 is characterized by slower waters, canyon-like shoreline, and contains the highest concentration of backwater habitat in Reach 3. It encompasses Moabi Regional Park, Topock Marsh and the Lake Havasu delta region from RKM 70.6 (RM 43.9) downstream to RKM 39.7 (RM 24.7). Zone 3-3 has gently sloping surrounding shoreline and is the open water portion of the reservoir from the bottom of the delta, RKM 39.7 (RM 24.7), to directly upstream of Copper Canyon where the reservoir once again narrows at RKM 23.3 (RM 14.5). The fourth zone, 3-4, extends from Copper Canyon downstream to Parker Dam and includes the Bill Williams River National Wildlife Refuge (BWRNWR).

Electrofishing

Potential razorback sucker habitat between Davis Dam and Needles, CA was electrofished during the period 9 January to 7 March 2012 to assess the proportion of razorback sucker occupying the area where PIT scanning was to take place. These electrofishing efforts targeted native fish, and were located in areas where no non-native species were previously netted. Night electrofishing events occurred under supervision of the project Contracting Officers Representative (COR) with up to four netters present. All suckers captured (flannelmouth sucker [*Catostomus latipinnis*] and razorback sucker) were enumerated, measured for total length (TL, mm) and weight (W, grams [g]), sexed, assessed for sexual ripeness, scanned for a wire tag, scanned for a 125 or 134 kilohertz (kHz) PIT tag, and tagged with a 134 kHz PIT tag if either a wire tag or no tag was detected. A right pectoral fin clip was taken from all razorback sucker, placed in 1 milliliter (mL) of 95% ethanol in a snap-cap tube, and sent to the Conservation Genetics Laboratory at Arizona State University (ASU) for analysis. All fish were returned to the water close to their point of capture. Data were entered into the comprehensive lower Colorado River Native Fish Work Group (NFWG) PIT tag and stocking database maintained by Marsh & Associates (M&A) in behalf of all partners engaged in conservation activities for big-river fishes in the lower Colorado River. These razorback sucker capture data were used for population estimation.

Remote PIT scanning

2012

Remote PIT scanning units were deployed from 9 January to 5 April 2012 between Davis Dam and Needles, CA. Two models of PIT scanners were utilized: one large, shore-based unit and seven completely submersible units. The shore-based unit was comprised of a 1.9 x 0.8 meter (m) polyvinyl chloride (PVC) antenna frame with a built-in scanner connected by 27.4 m of cable to a shore-based, waterproof box housing a "black box" logger and 21 ampere (amp)-hour battery. The battery was capable of continuously powering the scanner for up to 68 hours, and this unit was deployed the first afternoon we arrived to the field site and retrieved the last morning of sampling before departing the field site. Submersible units consisted of a 0.8 x 0.8 m PVC antenna frame with a scanner and "mini logger" contained in PVC/acrylonitrile butadiene styrene (ABS) piping, and a 9 amp-hour battery held in a water tight OtterBox® with a 24 hour powering capacity. The battery box was secured in one half of a dual-sided sand bag holder used to keep the unit in place under water. These antennas were retrieved approximately every 24 hours and downloaded on site; the battery was replaced before redeployment. Five to seven of these units were employed throughout the scanning season; each unit was assigned and labeled with a four character alpha-numeric code (unit ID, e.g., RT03) for individual identification. This allowed data downloads to be matched with deployment locations.

The shore-based unit was deployed at a single location, Razorback Island, all season (Figure 2). At this location, the waterproof box was easily hidden and was accessible only by boat. Submersible units were deployed at ten different general areas (moving downstream): Laughlin Bridge, Laughlin Lagoon, Razorback Island, and Razorback Riffle near Laughlin, NV, and Palms, Cliffs, Cabana, Tower, White Wall, and Power Lines near Needles, CA (Figure 2). The locations that were monitored varied from trip to trip based on fish concentrations, but each trip consisted of 3 nights and 2 days of continuous scanning.

2013

Eight to thirteen units were deployed across six scanning events. Remote PIT scanners were deployed from 10 December 2012 to 11 April 2013 between Davis Dam and Moabi Regional

Park, CA. In addition to the two models of scanner employed in the early 2012 monitoring, a modified submersible unit with a 10.4 amp-hour lithium-ion battery pack contained in a watertight, 2-inch ABS pipe also was employed.

The shore-based unit was deployed in Moabi Regional Park. Submersible units were deployed at the same locations as in early 2012, with addition of eight new locations between Moabi Regional Park, CA and Big Bend of the Colorado State Recreational Area, NV (Figure 2).

Remote PIT scanning information for each individual deployment was recorded on waterproof datasheets as follows: location, river right or river left, unit deployed, battery deployed, Universal Transverse Mercator (UTM) zone, UTM easting, UTM northing, depth (m) of deployed unit, date & time deployed, date & time retrieved, start time of scanner (S), end time or run interval of scanner (E), stop interval (I), scan time in minutes (min), unit orientation in water (horizontal or vertical), purpose of scanning, comments, and a check box to indicate if any equipment malfunctioned.

PIT scanning in zone 3-2 (Figure 3) was conducted by Reclamation (Rick Wydoski). Scanning data along with location and effort information were provided by the COR and all data acquired from PIT scanning on Reach 3 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 and all raw data files are available through a password protected section of the M&A website (http://www.nativefishlab.net). Microsoft® Access 2010 was used for data management.

Routine monitoring

M&A biologists assisted with trammel netting in six of nine fixed reaches (USFWS 2012) and with electrofishing in two of nine reaches during the multi-agency Native Fish Roundup on Lake Havasu on 6-9 February and 5-8 November 2012. In conjunction with roundup efforts in zones 3-2 and 3-3, M&A associates deployed PIT scanners throughout zone 3-1 on 11-14 February 2013 in replacement of electrofishing efforts usually carried out in that section. Up to four multi-filament nylon trammel nets (45.7 or 91.4 m x 1.8 m, 3.8 centimeter (cm) stretch mesh, 30.5 cm bar outer wall) were deployed in overnight sets in reach 3-2, retrieved the following morning and redeployed in new locations within the reach for four consecutive nights according to a standard protocol reported elsewhere by Reclamation. In general, nets are subjectively set based on historic catch and accessible backwaters and placed a minimum of 50 m apart (J. Lantow, Reclamation, personal communication). All fish were removed and processed. At minimum, non-native species were enumerated and TL was measured (mm). Native species were processed as described above, and a fin clip was taken from a sub-sample of razorback sucker for genetic examination (see above). For detailed methods of the Native Fish Roundup, see USFWS (2012).

Data analysis

Population estimation

We employed the modified Petersen formula (Ricker 1975) on paired census data (1 January through 31 March) to calculate a single census population estimate (N^*) for razorback sucker in 2011.

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

Fish to be included in the estimate must have been released any year previous to the sampling year used as the mark, that is, before 1 January 2011 for the 2011 estimate, and before 1 January 2012 for the 2012 estimate. We included both fish released with a 134 kHz PIT tag in the NFWG PIT tag database and fish that did not have a release record, but were captured for the first time on record and tagged with a 134 kHz tag before the beginning of the mark period. All releases were into the main stem or reservoir, or into backwaters connected to the river; none were into habitats permanently isolated from the river. Stocking locations and numbers of fish released used in this analysis are in Table 2.

Definitions for M, C, and R from Ricker (1975) have been modified for our purposes. M is not the number of fish tagged and placed into a water body, but the number of fish contacted in the designated mark period (1 January to 31 March 2011). Catch, C, is the number of fish contacted in the second period of the paired data, (1 January to 31 March 2012), and R is the number of fish contacted in both mark and catch periods for the 2011 estimate. For the 2012 population estimate mark and catch periods were 1 December 2011 to 30 April 2012 and 1 December 2012 to 30 April 2013, respectively. Fish contacted more than once in mark or catch periods were only included in the analysis for their first encounter event in each time frame. Confidence intervals were derived using Poisson approximation tables using R as the entering variable (Seber 1973).

To be unbiased the model should meet three assumptions when applying the Chapman modified Petersen estimate (Pollock *et al.* 1990): (1) the population is closed to both deletions and additions, (2) no tags are lost or omitted, and (3) equal catchability of all individuals, and these all are met under the current application[1]. This project only includes known individuals added to the system with a 134kH PIT tag before the period of the mark (M) and individuals that were captured without a 134kH tag, and had one implanted before 1 January 2011. Emigration out of Lake Havasu by passing through Parker Dam or deletion of fish through water intake structures is negligible in this system because razorback sucker have only been found to occupy regions of the reservoir upstream of these structures (Wydoski *et al.* 2010). PIT tags are considered a permanent tag (Zydlewski *et al.* 2003), thus, deletion due to natural mortality is the only factor present and this does not bias the estimate. Efforts employed to sample razorback are diverse both methodologically and geographically, which imparts equal catchability of individuals.

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

Factors affecting survival

Effect of size at release on survival was evaluated for all razorback sucker released with a 134 kHz PIT tag between 1 January 2006 and 1 January 2012. Fish were divided into the following six size classes based on TL at release: One - ≤299 mm, Two - 300 to 349 mm, Three - 350 to 399 mm, Four - 400 to 449 mm, Five - 450 to 499 mm, and Six - ≥500. Fish released without a TL measurement were excluded from analysis. Razorback sucker released between 1 January 2006 and 1 January 2012 and contacted in 2012 (1 January 2012 and 30 April 2012) and 2013 (1 December 2012 and 30 April 2013) were tabulated.

Relative capture rates (number contacted/number released) were evaluated for each size class. The correlation between size at release and relative capture rates was estimated by calculating Pearson correlation coefficient (r):

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

Where *X* represents the size class at release, and *Y* represents the relative capture rate of fish in each size class. Due to the non-linear nature of the relationship (exponential), data were log transformed before correlation analysis.

The influence of release size and zone of release was examined by tabulating the number of fish released, mean release size (TL), and number of fish contacted through remote PIT scanning per release cohort (razorback sucker released within the same zone and month). Cohorts released with a 134 kHz PIT tag between October 2006 and May 2012 were included. PIT scanning data included were collected in 2012 (1 January 2012 and 30 April 2012) and 2013 (1 December 2012 and 30 April 2013).

Ecological Modeling

An analysis was conducted using mark-recapture data to test for the effect of size (TL at release) and season on post-release survival of repatriated razorback sucker. The Cormack-Jolly-Seber

(CJS) open population model was the basis for the analysis assessed by the computer program MARK (Cooch & White 2013). Zone (location) of release was not included as a factor due to a lack of consistent stockings among the four zones since 2006. Release and capture data were separated into 'seasons' based on whether they were released/captured in January through June (spring) or July through December (autumn). TL at release was significantly correlated with encounter rate in this study, and is a consistent factor for survival of razorback sucker elsewhere (Marsh *et al.* 2005). Therefore, TL at release was included as a covariate in this analysis (any fish released without a release TL was excluded from this analysis).

Both release and capture histories were generated for all razorback sucker released with a 134 kHz PIT tag from the comprehensive NFWG database and consisted of fish released from 1 July 2006 through 30 December 2012, and captured from 1 January 2007 through 30 June 2013. Contact histories from remote PIT scanning were generated from the online remote sensing database and included alongside capture data from the NFWG database for a complete post release 'capture' history of each razorback sucker released. Each history was expressed as a series of zeros and ones with the initial non-zero value representing the release, e.g., history '1000000100001' represents a fish released in the first time period, and captured in the 9th and 14th time period. Each time period represented a year and season starting with autumn 2006 and ending with spring 2013. Further details on the derivation of these captures can be provided upon request.

The model structure of the 'live recaptures only' CJS model within MARK is based on two groups of 'real' parameters; Φ_i – the probability of an individual surviving from interval *i*-1 to *i*, and p_i – the probability of being recaptured in interval *i*. Each parameter group is a half matrix of parameters, with the number of rows and columns equaling the number of recapture occasions (13). Rows represent different release occasions and columns represent recapture occasions. The original CJS model of time varying survival and recapture rates can be coded by varying each parameter group by column, but any combination or parameters can be modeled. The first diagonal of the matrix represents the first time period after release for each release group (year and season) or cohort, and is the key parameter for assessing immediate post-stocking survival. The 'real' parameters are probability values that are constrained between 0 and 1, but the models are assessed based on beta parameters that are back-transformed to provide the 'real' estimates. This connection between the beta and 'real' parameters is represented as a matrix that is typically an identity matrix for most general models (time varying, age structured). Complexity to this parameter matrix is added for this study to include TL at release as an individual covariate. TL at release was modeled as a linear regression within the parameter matrix (one parameter for the y-intercept and one for the slope). The back transformation of the y-intercept and slope into real estimates of probability results in a sigmoidal curve of survival probability between 0 and 1 for a range of TL at release values.

For the Reach 3 analysis, recapture rates were set to vary by time for all models (we assumed time varying recapture probability, i.e., stocked fish have unequal probability of being recaptured in any period post release across all models). Potential factors affecting survival, season of release, cohort and the individual covariate (release TL), were evaluated within MARK. The effect of season was evaluated by comparing models with a seasonal component in the first two periods post-release with either a fixed (one parameter) model or a time varying (different parameters for each release cohort) model. Age structure was also modeled similar to the structure used for Lake Mohave (Marsh *et al*. 2005) and in the upper Colorado River basin (Zelasko *et al*. 2011); separate parameters of survival for the first (two age model), or for the first and second (three age model) time period after release in addition to an adult survival parameter group. Models with release TL as a covariate of survival in the first period after release were compared to models without to determine the significance of size. Sampling was grouped into six month time periods and estimates of adult survival were converted to annualized rates by raising the bi-annual rate to the second power. Post-release survival for the first time period (two age model) or for the first two time periods (three age model) were reported as is (six month survival estimates) making them directly comparable to results from Lake Mohave studies (e.g., Kesner *et al*. 2011). Model selection was based on Akaike's Information Criterion (AIC) score (Akaike 1974) as calculated within MARK. This value reported in MARK is a modified value (AIC_c) that adjusts for small sample sizes (Burnham and Anderson 2002). The lowest AIC_c value represents the most parsimonious model, but model averaging was considered if AIC_c values of competing 'best' models were similar (Johnson and Omland 2004).

Results

Electrofishing

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

Mean TL and Wt for razorback sucker was 597 mm (range 461-721 mm) and 2538 g (range 1195-4380 g), respectively. A majority (65%) of razorback sucker captured had a detectable 134 kHz PIT tag, 8 of 60 contained 125 kHz PIT tags, and 13 had no PIT tag and received a 134 kHz tag before release. The proportion of razorback sucker that would be undetectable with remote PIT scanners at the beginning of our sampling period was (21/60) = 0.35[2].

Remote PIT scanning

2012

Scanning effort in Reach 3 consisted of 2243.9 scan hours. The actual time to deploy/retrieve an antenna, download the logger, and change the battery was minimal (approximately 10 minutes per unit), and totaled 18 hours of effort (excluding travel time). Scanning resulted in contact with 763 individuals. Of all fish scanned, 652 had a release record with a 134 kHz PIT tag. The majority (74.5%) of individuals scanned were in size classes Two (300 to 349 mm, 34.9%) and Three (350 to 399 mm, 39.6%) at release.

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

2013

Scanning efforts in Reach 3 were undertaken by two entities in 2012-2013, M&A and Reclamation. M&As scanning effort in Reach 3 consisted of six trips from December 2012 through April 2013 in Reach 3 zones 3-1 and 3-2, with a majority of efforts in 3-1 (Figure 2). This effort resulted in 3250.6 hours of scanning, and the contact of 1414 individual fish.

Scanning efforts by Reclamation included in this report consisted of nine trips from December 2012 through April 2013 in Reach 3 zones 3-1 and 3-2, with a majority of efforts in 3-2 (Figure 3). Their efforts resulted in 3466.1 hours of scanning, and the contact of 994 individual fish (excludes scanning in waters disconnected from the mainstem river).

The combined total of unique fish scanned was 2168 individuals. Of these, 2142 had a marking record. A majority of these were razorback sucker (2131) although bonytail (10) and flannelmouth sucker (1) were also scanned.

Of the 2148 razorback sucker with a marking record, 2110 individuals were released with a 134 kHz tag. The majority of individuals scanned were spread across size classes Two (300 to 349, 28.7%), Three (350 to 399, 34.5%) and Four (400 to 449, 21.9%) at release.

Routine monitoring

A general summary from the Lake Havasu Native Fish Roundup is reported here with a focus on razorback sucker capture. During 6-10 February 2012, a total of 1683 fish were captured. Of those, 109 (6.5%) were razorback sucker captured from Willow Valley, RKM 93.3 (RM 58) downstream to Mesquite Bay RKM 38.6 (RM 24). Mean TL of razorback sucker sampled was 523 mm (range 247 to 711 mm). For full report see USFWS (2012).

During the survey conducted between 5-8 November 2012, 40 razorback sucker were captured with a mean TL of 466.6 mm (range 405-480). These fish were captured in trammel nets between Moabi Regional Park, RKM 70.0 (RM 43.5) and Castle Rock, RKM 44.3 (RM 27.5). All scanning data collected from efforts associated with the February 2013 native fish round up have been included in the subsequent results and analyses unless otherwise noted.

Population estimation

2011 estimate

Data used for the mark (M) were all razorback sucker with a release record and sampled in Reach 3 by netting or electrofishing between 1 January and 31 March 2011 for the 2011 estimate. Capture period data included razorback sucker sampled by all methods (including remote PIT scanning) between 1 January and 31 March 2012. A total of 116 individuals were included in the estimate from netting/electrofishing. Of the 692 individuals scanned remotely, 559 had a release record before 1 January 2011. The remainder (133 fish) either had a release record after 1 January 2011 (112), did not have a release or initial capture record (10), or did not have any record in the NFWG database (11), and were not included in this analysis. Thirty-three fish were both scanned and contacted making the capture total for the 2011 estimate 642 (559+116-33).

The estimated population of 134 kHz PIT tagged repatriated razorback sucker in Reach 3 in 2011 was 2496 (1935 to 3220, 95% confidence interval) individuals (228, 642, and 59 for M, C, and R, respectively). The estimate from capture data alone (228, 116, 10 for M, C, and R, respectively) was 2679, similar to the combined estimate, but the 95% confidence interval was much wider (1456 to 5701). The combined estimate was expanded to include razorback sucker that were untagged or tagged with a 125 kHz tag in 2011. Capture data from 1 January to 31 March 2011 found 313 of 326 (96%) fish handled had a 134 kHz tag only. If this proportion holds true for the entire population, then an estimate of the entire population in Reach 3 would be 2770 fish (2659/0.96).

2012 estimate

Data used for the mark (M) and capture (C) periods were all razorback sucker released with a 134 kHz tag and contacted by any means in Reach 3 between 1 December 2011 and 30 April

2012 (M) and the same period for 2012-2013 (C). Only individuals marked/released before 1 December 2011 were included in the 2012 population estimate. Of the 763 individuals remotely scanned between 1 December 2011 and 30 April 2012, 726 were released before the mark (1 December 2011). The remaining fish were released after the mark (16), had a capture record but no associated release record (10), or lacked any record in the NFWG database (11).

Scanning efforts between 1 December 2012 and 30 April 2013 resulted in scanning of 2168 individuals. Fish were excluded from the population estimate for not meeting the following criteria: incorrect species (11), razorback sucker released after the mark (820), had capture record with no associated release record (27). This left 1310 fish to be included in the capture (C). Applying the same criteria to fish sampled through netting and electrofishing efforts as was in place for scanning, 247 and 85 razorback sucker were contacted during the mark and capture periods. There were 39 and 22 razorback sucker captured and scanned during the marking and capture periods respectively.

The estimated population of 134 kHz PIT tagged repatriated razorback sucker in Reach 3 in 2012 was 4524 (4027 to 5081, 95% confidence interval) individuals (934, 1373, and 284 for M, C, and R, respectively). Netting and electrofishing data alone did not provide enough recaptures (2) to reliably estimate the population size. The combined estimate was expanded to include untagged or 125 kHz tagged fish. Electrofishing data from 2012 found 65% of fish had a detectable 134 kHz tag. This would expand the population estimate to 6960 (4524/0.65).

Factors affecting survival

Between 1 January 2006 and 1 January 2012, 36,015 razorback sucker were released with 134 kHz PIT tags and available for contact in Reach 3 during the 2012 and 2013 sampling seasons. Distribution among fish across size classes was not even, with <1% of fish being released in the smallest (≤299 mm) and largest (≥500 mm) size classes (Table 3). A majority of fish were released in size classes Two (53%) and Three (36%, Table 3).

In the 2012 (1 Dec 2011 to 30 April 2012) and 2013 (1 Dec 2012 to 30 April 2013) sampling periods, 2247 repatriated razorback sucker with release histories before 1 January 2012 were contacted through netting, electrofishing, and PIT scanning efforts combined. Comparable to the release data, <1% of contacted fish were from the smallest size class, while 2% of fish contacted were in the largest size class. A majority of contacts were fish released between 300 and 350 mm (41%), and 350 to 400 mm (43%, Table 3). Relative catch rates were strongly correlated (r=0.93) to size class at release, ranging from 0.048 in fish released between 300 and 350 mm to 0.239 for fish released ≥500 mm (Figure 4).

The release cohort with the highest proportion of contacts through remote PIT scanning also had the highest mean release TL (613 mm, zone 3-1, February 2007), but the relationship between mean release TL and contact proportion was highly variable (Table 4). The top five contact proportions (excluding recent releases in 2012) were all from spring releases in zones 3-1 and 3-4 whereas the five lowest contact proportions represented all four zones with the majority released in autumn (4 of 5).

Ecological modeling

For the mark-recapture model a total of 44,255 released fish from autumn 2006 (Jan-June) through autumn 2012, and 3069 captures or contacts from spring 2007 (Jul-Dec) through spring 2013 were included (Table 5). The best fit model with an AIC weight of nearly one (0.996) was a two age structured model with time varying 1st (post-release) and 2nd (adult) age survival parameters and release TL as a covariate. Each model with a seasonal 1st period survival parameter group (separate parameters for spring and autumn) fit better than the comparable model with fixed 1st period survival (single parameter), but not better than the comparable model with time varying 1st period survival (see Appendix A for complete model comparison). Post-release survival estimates (first season after release) based on release TL were back-calculated and then plotted for 10 of 13 cohorts from the best fit model (Figure 5). Two cohorts, autumn 2009 and autumn 2010, were eliminated due to a lack of releases, 0 and 1 respectively, and one cohort, autumn 2008, was eliminated due to a lack of post-release contacts (0 for first four periods post-release). Post-release survival was highest for spring releases from 2006 through 2009. Generally, spring releases had better survival for a given size at release compared to autumn, and cohorts before 2010 had higher survival than cohorts after 2010. The cohort with the lowest survival was for the most recent spring release in 2012, this low estimate may be due to the low number of recapture opportunities.

Discussion

Use of remote PIT scanning during this study increased contact rate of released razorback sucker in Reach 3 by factors of 3.6 and 10.1 for 2012 and 2013, respectively, compared with standard physical sampling methods such as electrofishing and netting. Scanning was employed in both slack and quickly moving waters and provided a cost-effective and efficient method of contact that meets the goals of this and similar projects. This increase in contacts resulted in more precise population estimates, and new insights into factors affecting post-stocking survival. Previous estimates of razorback sucker in Reach 3 were based on relatively few recaptures (e.g., R=2), resulting in questionable accuracy (Wydoski and Mueller 2006). In contrast, combining capture and remote PIT scanning data in 2012 provided a substantial number of fish sampled in both mark and captures period (R=59), which removed the likelihood of statistical bias (due to low recaptures) in the Chapman modified Petersen estimate (Ricker 1975). The base population estimate for 2011 of 2659 (2069 to 3414, 95% confidence interval) is almost double the estimate of 1400 (894 to 2196, 95% confidence interval) reported in 2010 (J. Lantow, Reclamation, personal communication), but confidence intervals overlap broadly and so estimates are not significantly different. The increased number of fish contacted in 2013 resulted in 279 recaptures boosting the population estimate to 4156 (3698 to 4671, 95% confidence interval). However, the expanded population estimate that includes fish without a 134 kHz PIT tag based on the percentage of 134 kHz tagged fish encountered during electrofishing is likely suspect given the observed year to year variation in the percentage of 134 kHz PIT tagged fish. The difference between the 2011 electrofishing percentage of captured fish that contained a 134 kHz tag (96%) and the 2012 percentage (65%) cannot be explained by release records or an average amount of tag loss, but instead may indicate potential bias in estimates due to non-random fish assortment and sampling.

Random assortment of fishes between capture events is an assumption of the modified Peterson population estimate as well as the mark-recapture estimates of survival in MARK (Seber 1973, Cooch and White 2013). An examination of the summary data used in mark-recapture analysis (Table 5) illustrates the apparent lack of random assortment. The final sampling event (spring 2013) resulted in substantially more PIT scanning contacts compared to the previous spring (2012), which was the first year PIT scanning was employed. However, when the number of contacts is compared on a per cohort (release season) basis, the number of contacts decreased from spring 2012 to spring 2013 for older cohorts (autumn 2006 and spring and autumn 2007). The relative increase in total contacts for spring 2013 is mostly attributable to a more than 2.5-fold-increase between spring 2012 and spring 2013 in contacts of fish from the spring 2011 cohort. This increase may represent fish reaching sexual maturity two years after release, as a similar trend can be seen for spring 2007 and spring 2008 releases. Regardless of the cause, this nonrandom contact rate from one year to the next will bias both population estimates and mark-recapture estimates of survival.

Besides the potential for bias, post-release survival estimates presented in this report suffer from a lack of precision due to sparse data. Although there was a substantial increase in the number of contacts from PIT scanning in spring 2012 and 2013, post-release survival estimates for fish released in spring rely on contacts made in the first autumn after release. Without a significant number of contacts in the autumn, estimates of post-release survival and adult survival varied widely among relatively similar models, and especially-so in models with unique values for all cohorts (i.e., time varying survival). The lack of precision was also evident within the 'best fit' model parameter estimates (Table 6). First season post-release survival (Age 1) for a fish released at mean size (352 mm TL) in the spring of 2012 was estimated at 4.4% with a confidence interval between 3.7% to 5.1%, but the second season survival for this same cohort has a confidence interval between 0 and 100%. When survival for the first two seasons (Age 1 and Age 2) is combined, only spring of 2010 and autumn of 2011 appear to have acceptable levels of precision. Although actual post-release survival estimates fluctuated between and within models, post-release survival for razorback sucker released in spring was significantly higher than for autumn releases in all seasonal models. Razorback sucker released in the Green and San Juan rivers had similar seasonal trends (Bestgen *et al.* 2009; Zelasko *et al.* 2011). Seasonal analysis for this study was restricted to only two "seasons" based on the majority of stockings occurring from January through May (spring), and October through November (autumn).

Release location was not found to be a statistically significant confounding factor in assessing population size and post-stocking survival, even when the zone of stocking was 92 RKM (57 RM) away in zone 3-4, but relative rates of contact were at least half in zone 3-4, compared to the other zones of release. Relatively low replication in zones 3-3 and 3-4 likely resulted in low statistical power and a lack of statistical significance. The results from this study should be considered in the context of previous work as well. Telemetry studies of razorback sucker released into the downstream end of Lake Havasu proper found that, given sufficient time (approximately one year), fish can and do move upstream to spawning areas near Needles, CA (Wydoski and Lantow 2012). Razorback sucker are capable of travelling substantial distances at rates upwards of 20 km/day in Lake Mohave, the reservoir directly upstream of Davis Dam (Mueller and Marsh 1998; Mueller *et al.* 2000), and elsewhere (Tyus 1987, Tyus and Karp 1990). However, extensive netting efforts in the reservoir (Laughlin downstream to Cattail Cove) have generally failed to contact fish released in the lower portion of the reservoir (zone 3-4; Wydoski and Mueller 2006). These netting efforts were primarily focused in backwaters adjacent to the main channel, and to a lesser degree in eddy fences with low current in the main channel. Our remote sensing sampling efforts included the center and side of the main channel with higher current where aggregates of spawning razorback sucker occur, thus increasing contact rates.

Recommendations

We recommend continued monitoring of repatriated razorback sucker in Reach 3, with increased implementation of remote PIT scanner deployment. This methodology, like any other, has limitations, but it has proven to be a far more effective means than standard physical sampling in contacting razorback sucker in the riverine portion of this reach and especially-so during the reproductive season. This benefit became more evident during our second season of remote PIT scanning throughout the reach, when the number of fish contacted by remote sensing was three fold greater than conventional methods. Continuation of such efforts in the coming years should provide a data set with enough clarity to adequately discern the factors affecting survival of razorback stocked into Reach 3. Bi-annual netting and electrofishing efforts to collect health, growth, census, and genetic data from repatriate razorback suckers should also continue to create a more complete picture of the status of razorback sucker in the reach.

Although the zone in which fish were released and later contacted was not found to be statistically significant between zones, relative rates of contact were at least half in zone 3-4, compared to the other zones of release. Given this difference in contact rates and evidence from previous netting efforts, we suggest future stocking events focus on zones 3-1 through 3-3.

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

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

Release year	Number released	Cumulative number released	Capture year	Number captured	Proportion captured
2006	4082	4120	2007	89	0.022
2007	6721	10803	2008	69	0.006
2008	3167	13970	2009	109	0.008
2009	5868	19838	2010	141	0.007
2010	5415	25253	2011	186	0.007
2011	10842	36095	2012	213	0.006
2012	8267	44362	2013	7	0.000
2013	6595	46875			

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

Stocking location	No. fish stocked
Avi	2
Avi Hotel	6
Avi to Willow Valley	4
Below Davis Dam	33
Big Bend State Park to Avi	1
Bill Williams River NWR	439
Blankenship Bend	2
BLM Partner's Point Work Camp	26
Boyscout Camp Lagoon	10
Boyscout Point	1
Catfish Bay Cove	1
Catfish Paradise in Topock Marsh	3243
Cattail Cove Boat Ramp	1971
Clear Bay Cove	1
Davis Dam to Riverside launch	1
Fort Mojave	1
Golden Shores/mouth of Topock Gorge	2
Lake Havasu	1
Laughlin Lagoon	6151
Laughlin Lagoon and Needles Dredge Yard	3229
Mesquite Bay (north of)	2
Needles	299
Needles (north of)	38
Needles Bridge (south of)	1
Needles Dredge Yard	4215
Needles to Laughlin	16
Office Cove area and bridge at Bill Williams NWR	2124
Moabi Regional Park	6447
Moabi Regional Park Marina	1
Parker Dam (north of)	1
Pulpit Rock Cove	3
Razorback Riffle to Willow Valley	4
Standard Wash Cove	5
Topock Marina boat launch	250
Trampas Cove	2
Willow Valley	3
Windsor Beach State Park	7983

Table 3. Number and proportion of 134 kHz PIT tagged razorback sucker released between January 1, 2006 and December 31, 2011 by year and size class (top) and individuals contacted by any means between 1 January 2012 and 30 April 2012 and 1 December 2012 and 30 April 2013 (bottom), MSCP Reach 3, lower Colorado River, Arizona-California-Nevada. Fish were divided into the following six size classes based on TL at release: One - ≤299 mm, Two - 300 to 349 mm, Three - 350 to 399 mm, Four - 400 to 449 mm, Five - 450 to 499 mm, and Six - ≥500.

Year	One	Two	Three	Four	Five	Six	Proportion
2006	109	2122	1738	77	0	0	0.112
2007	18	3279	2603	690	128	0	0.187
2008	64	2707	334	10	4	19	0.087
2009	25	4456	1278	94	1	4	0.163
2010	10	2032	2686	670	17	0	0.150
2011	0	4605	4396	1360	318	161	0.301
Proportion	0.006	0.533	0.362	0.081	0.013	0.005	1.000

Year	One	Two	Three	Four	Five	Six	Proportion
2006	0	54	165	7	0	0	0.101
2007	0	35	138	48	8	0	0.102
2008	11	201	36	1	0	0	0.111
2009	0	335	190	19	1	1	0.243
2010	0	33	89	44	2	0	0.075
2011	0	261	350	141	34	43	0.369
Proportion	0.005	0.409	0.431	0.116	0.020	0.020	1.000

Table 4. Date, number, and mean TL of razorback sucker released into zones 3-1 to 3-4 with a 134 kHz PIT tag and number and proportion of number released that were scanned with remote PIT scanners in zone 3-1 between 1 January 2012 and 30 April 2012 or 1 December 2012 and 30 April 2013, MSCP Reach 3, lower Colorado River, Arizona-California-Nevada.

zone	Release date	Number released	Mean TL (mm)	Number contacted	Proportion contacted
3-1	October 2006	2011	325	22	0.011
	November 2006	2009	365	118	0.059
	February 2007	145	613	29	0.200
	April 2007	1045	380	115	0.110
	November 2007	3113	343	23	0.007
	March 2008	1160	320	55	0.047
	October 2008	1014	324	6	0.006
	January 2011	3229	366	106	0.033
	March 2012	4125	366	38	0.009
3-2	March 2008	937	329	94	0.100
	March 2009	1903	340	255	0.134
	January 2010	3243	349	32	0.010
	February 2011	3496	368	439	0.126
	November 2011	250	420	14	0.056
	February 2012	2887	344	131	0.045
	April 2012	917	364	45	0.049
	May 2012	123	345	0	0.000
3-3	May 2009	1985	326	130	0.065
	February 2010	2171	376	86	0.040
	February 2011	1308	361	18	0.014
	March 2011	2192	343	119	0.054
	October 2011	327	324	0	0.000
3-4	October 2007	439	435	12	0.027
	November 2007	2124	339	17	0.008
	February 2009	1966	330	30	0.015

Table 5. Numbers of razorback sucker with a release TL released and/or contacted by any means (netting, electrofishing, scanning) by season from 1 July 2006 through 30 June 2013 in MSCP Reach 3, lower Colorado River, Arizona-California-Nevada. Releases or contacts from January through June were denoted as Spring (S), and from July through December as Autumn (A). Contacts made within the season of release were removed from analysis.

Release season	Number released	S 2007	A 2007	S2008	A 2008	S 2009	A 2009	S 2010	A 2010	S 2011	A 2011	S 2012	A 2012	S 2013	Total contacts
A 2006	4046	31	13	18	3	21	3	5	4	15	1	86	26	74	300
S 2007	1045		14	11	3	17	2	8	1	16	0	75	34	60	241
A 2007	5673			10	2	1	1	2	0	10	0	38	5	20	89
S 2008	2108				52	10	7	17	13	16	0	71	19	100	305
A 2008	1030					0	0	0	0	2	0	5	1	2	10
S 2009	5858						23	54	27	71	2	223	60	268	728
A 2009	0							0	0	0	0	0	0	0	0
S 2010	5414								8	30	3	66	12	62	181
A 2010	1									1	0	0	0	0	1
S 2011	10263										18	217	121	551	907
A 2011	577											6	2	11	19
S 2012	8191												69	199	268
A 2012	49													20	20
Totals	44255	31	27	39	60	49	36	86	53	161	24	787	349	1367	3069

Table 6. Parameter estimates from the best fit mark-recapture model “2 age, time, time, yes” (see Appendix A) evaluated in MARK. Survival estimates are for a fish released at the overall mean size (TL) of 352 mm.

	Parameter	Estimate	SE	95% Confidence interval Lower	Upper
Survival					
	Age 1 - Autumn 2006	0.26530	0.04130	0.19250	0.35370
	Age 1 - Spring 2007	0.77670	0.17520	0.32440	0.96180
	Age 1 - Autumn 2007	0.05920	0.01240	0.03910	0.08860
	Age 1 - Spring 2008	0.74620	0.10740	0.49180	0.89940
	Age 1 - Autumn 2008	0.01720	0.00680	0.00790	0.03710
	Age 1 - Spring 2009	0.26760	0.02310	0.22480	0.31520
	Age 1 - Autumn 2009	0.00180	0.00000	0.00180	0.00180
	Age 1 - Spring 2010	0.06450	0.00700	0.05210	0.07980
	Age 1 - Autumn 2010	1.00000	0.00000	1.00000	1.00000
	Age 1 - Spring 2011	0.13390	0.00720	0.12050	0.14860
	Age 1 - Autumn 2011	0.05420	0.01150	0.03560	0.08170
	Age 1 - Spring 2012	0.04350	0.00340	0.03730	0.05080
	Age 1 - Autumn 2012	0.24790	0.30520	0.01310	0.89080
	Age 2 - Autumn 2006	1.00000	0.00000	1.00000	1.00000
	Age 2 - Spring 2007	0.80640	0.19090	0.27500	0.97860
	Age 2 - Autumn 2007	1.00000	0.00080	0.00000	1.00000
	Age 2 - Spring 2008	0.38600	0.07790	0.24820	0.54490
	Age 2 - Autumn 2008	1.00000	0.00000	0.00000	1.00000
	Age 2 - Spring 2009	1.00000	0.00000	0.00000	1.00000
	Age 2 - Autumn 2009	1.00000	0.00010	0.00000	1.00000
	Age 2 - Spring 2010	0.76030	0.06800	0.60410	0.86830
	Age 2 - Autumn 2010	0.99930	0.01670	0.00000	1.00000
	Age 2 - Spring 2011	1.00000	0.00000	0.00000	1.00000
	Age 2 - Autumn 2011	0.59810	0.03960	0.51860	0.67270
	Age 2 - Spring 2012	0.73190	0.55610	0.01050	0.99860
Recapture					
	Spring 2007	0.03030	0.00710	0.01920	0.04770
	Autumn 2007	0.01410	0.00340	0.00880	0.02250
	Spring 2008	0.02070	0.00510	0.01280	0.03330
	Autumn 2008	0.01880	0.00420	0.01210	0.02910
	Spring 2009	0.03930	0.00630	0.02860	0.05370
	Autumn 2009	0.01420	0.00260	0.00990	0.02030
	Spring 2010	0.03400	0.00450	0.02620	0.04390
	Autumn 2010	0.01810	0.00280	0.01330	0.02460
	Spring 2011	0.07250	0.00630	0.06100	0.08580
	Autumn 2011	0.00620	0.00130	0.00410	0.00930
	Spring 2012	0.20080	0.01020	0.18150	0.22150
	Autumn 2012	0.12670	0.00900	0.11000	0.14550
	Spring 2013	0.66810	0.50680	0.02230	0.99440

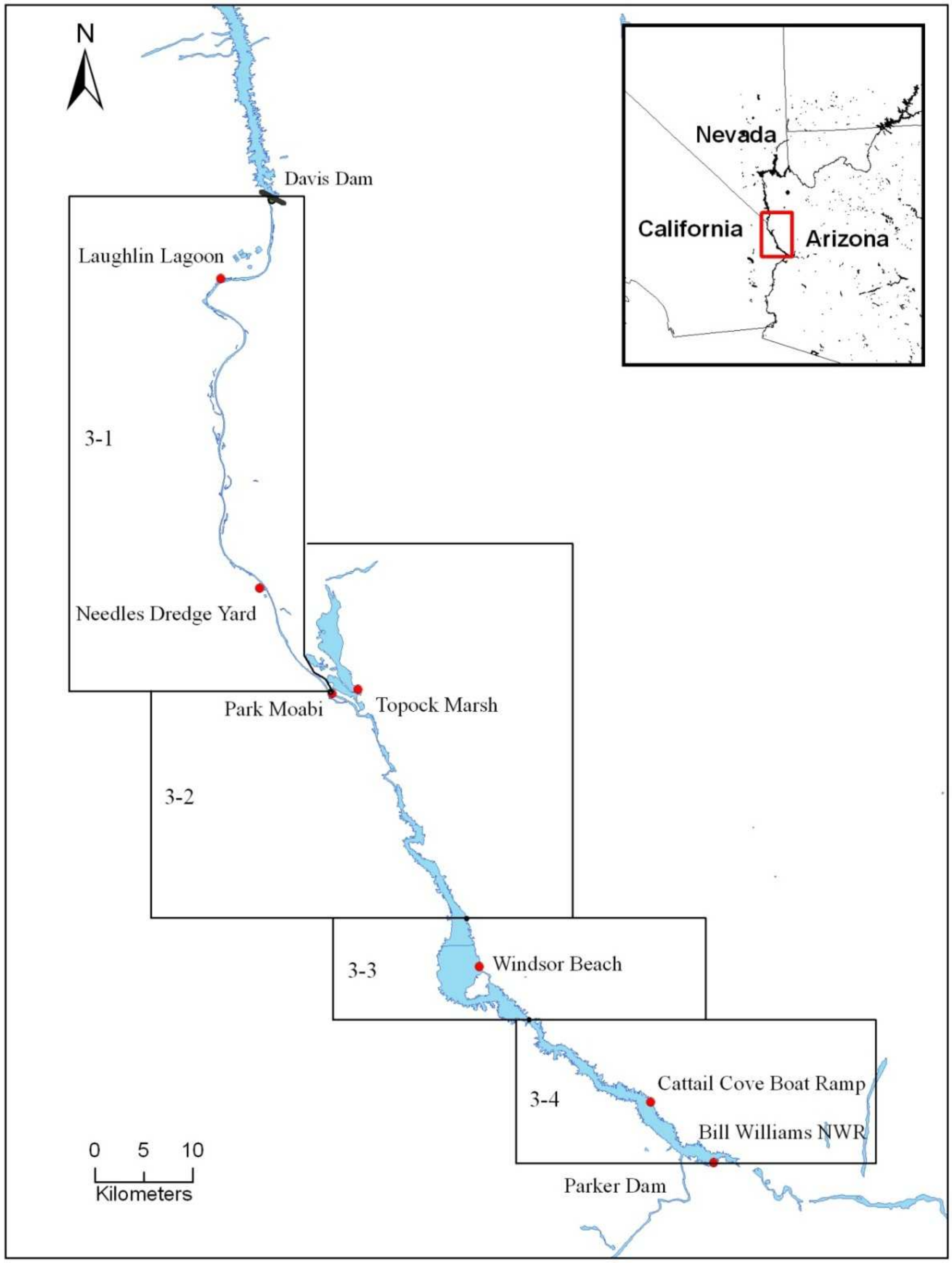


Figure 1. Overview map of the study area depicting MSCP Reach 3 including general remote PIT scanning and stocking locations, and general zones 3-1 to 3-4 established in methods, lower Colorado River, Arizona-California-Nevada.

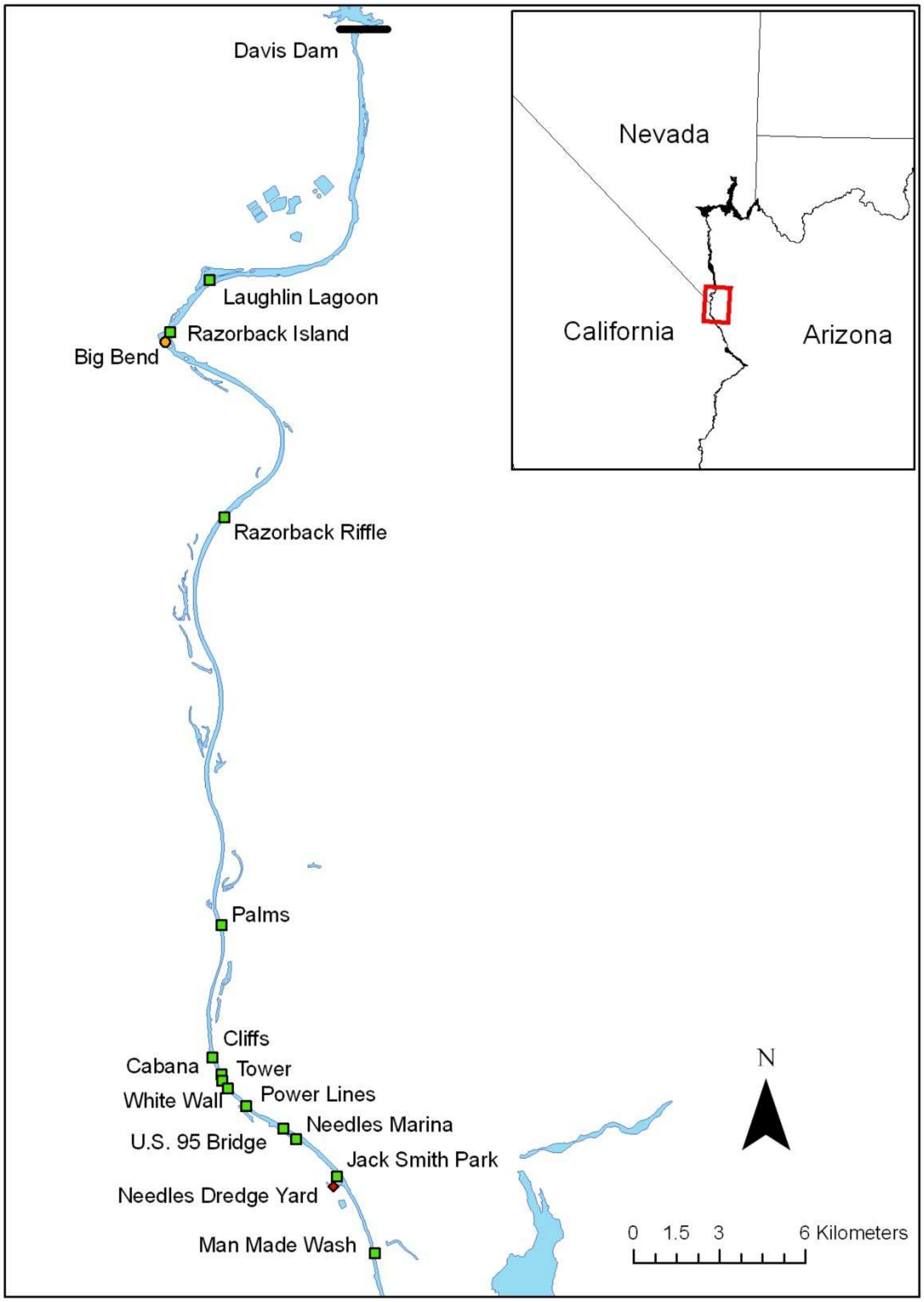


Figure 2. Location of remote PIT scanning deployment by M&A (green square), Reclamation (red diamond) or both (orange circle) in MSCP Reach 3, zone 3-1 between 1 January 2012 and 30 April 2012 and 1 December 2012 and 30 April 2013, lower Colorado River, Arizona-California-Nevada.

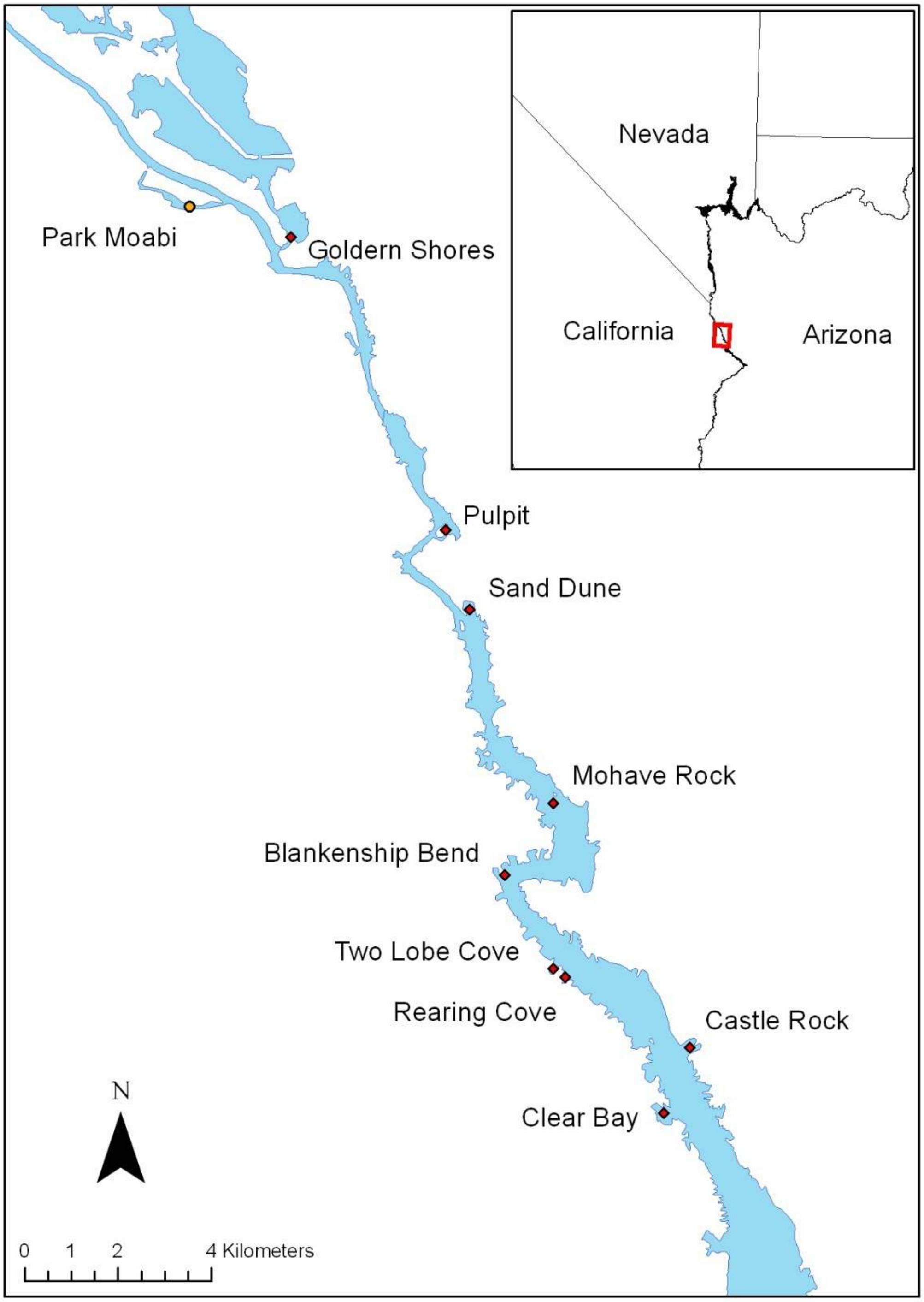


Figure 3. Location of remote PIT scanning deployment by Reclamation (red diamond) or both Reclamation and M&A (orange circle) in MSCP Reach 3, zone 3-2 between 1 January 2012 and 30 April 2012 and 1 December 2012 and 30 April 2013, lower Colorado River, Arizona-California-Nevada.

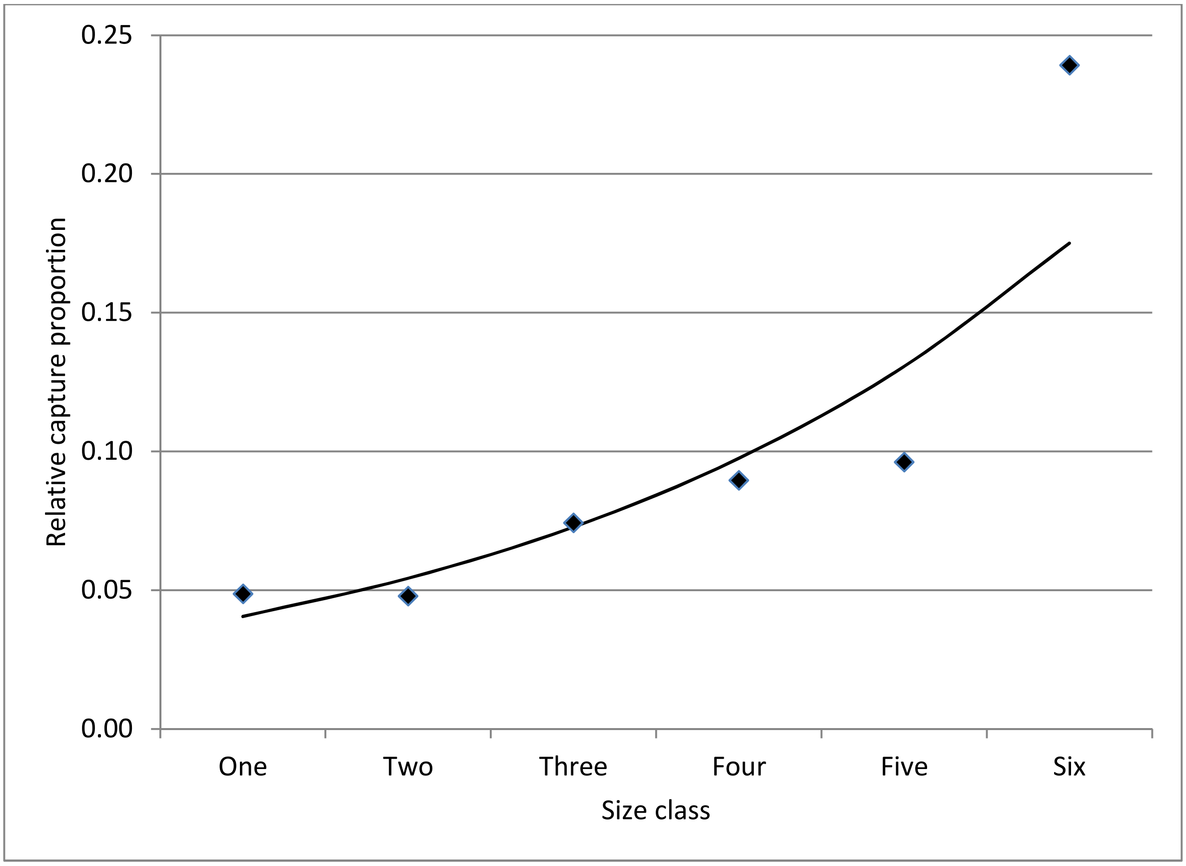
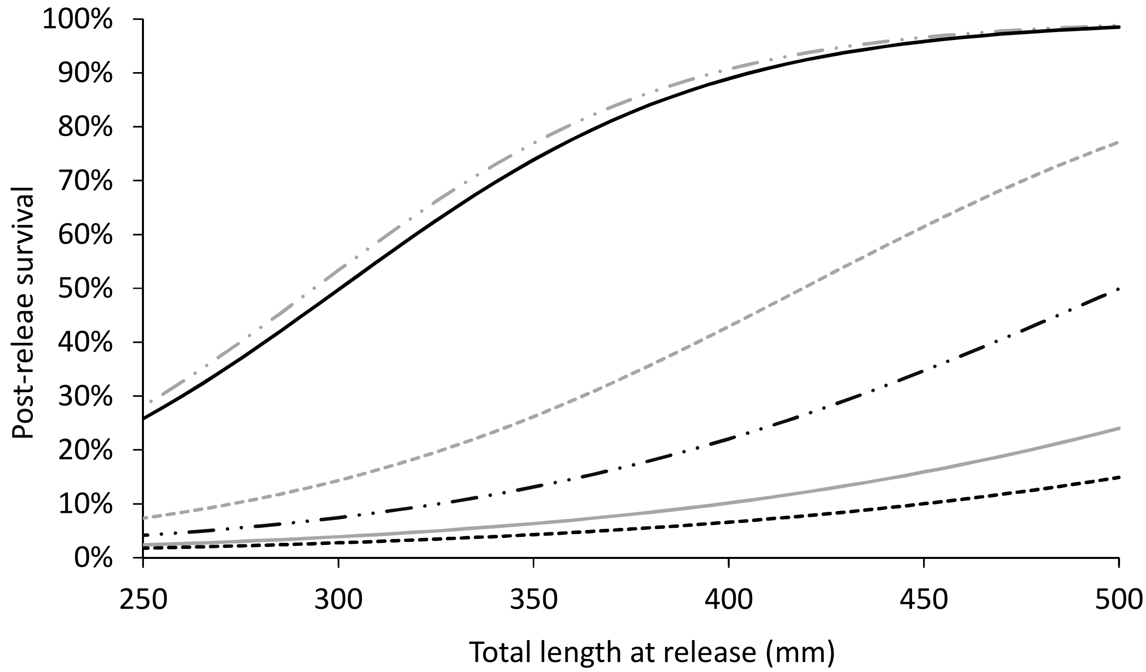


Figure 4. Relative capture proportion of repatriated razorback released between 1 January 2006 and 1 January 2012, and contacted between 1 January 2012 and 30 April 2012 or 1 December 2012 and 30 April 2013, MSCP Reach 3, lower Colorado River, Arizona-California-Nevada. Fish were divided into the following seven six classes based on TL at release: One - ≤299 mm, Two - 300 to 349 mm, Three - 350 to 399 mm, Four - 400 to 449 mm, Five - 450 to 499 mm, and Six - ≥500 mm. Regression line is the best fit (least mean squares) of log transformed capture proportions (r^2 = 0.858).



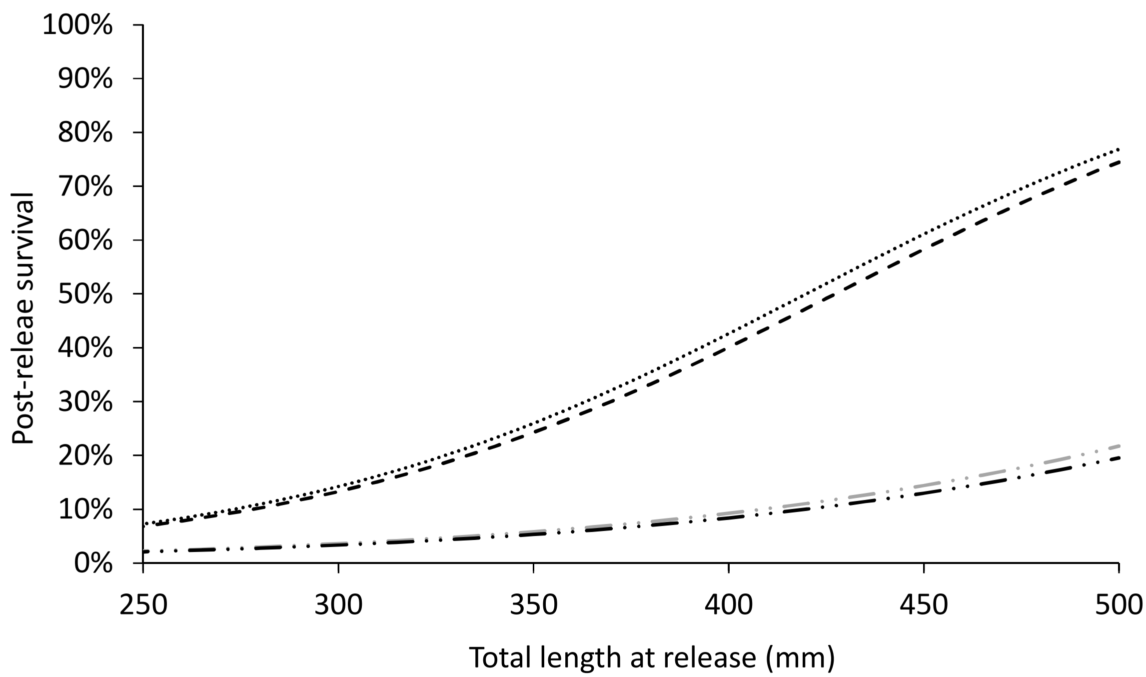


Figure 5. Post-release (six month) survival for razorback sucker stocked into Reach 3 in spring (top) and autumn (bottom) from autumn 2006 through spring 2012; 2006 (black dot), 2007 (grey dash dot), 2008 (solid black), 2009 (grey dash), 2010 (solid grey), 2011 (black dash dot), 2012 (black dash). Missing year-season combinations had fewer than ten fish released or post-release contacts.

Appendix A. Model comparison results from the mark-recapture program MARK. Model structure summarized by number of ages, variation in parameterization of ages, and inclusion of release TL as a covariate in model; e.g. model – {2 age, time, time, yes} = a two age structure model with time varying parameters for the 1st and 2nd ages and release TL as a covariate).

Model	AICc	AICc Weight	No. of Parameters	Deviance
{2 age, time, time, yes}	27636.60	0.9965	31	27574.56
{3 age, time, fixed, seasonal, yes}	27647.87	0.0036	27	27593.84
{2 age, time, seasonal, yes}	27677.98	0.0000	26	27625.95
{2 age, time, fixed, yes}	27683.47	0.0000	25	27633.45
{3 age, time, fixed, time, yes}	27690.94	0.0000	35	27620.88
{3 age, time, fixed, fixed, yes}	27706.70	0.0000	25	27656.67
{3 age, time, time, time, yes}	27712.51	0.0000	28	27656.47
{3 age, time, fixed, time, no}	27934.28	0.0000	37	27860.22
{3 age, time, time, fixed, yes}	27944.96	0.0000	23	27898.94
{3 age, time, time, seasonal, yes}	27971.26	0.0000	25	27921.23
{3 age, time, fixed, seasonal, no}	27976.18	0.0000	28	27920.15
{2 age, time, time, no}	27980.26	0.0000	37	27906.20
{3 age, time, fixed, fixed, no}	27983.62	0.0000	27	27929.59
{2 age, time, seasonal, no}	28001.88	0.0000	27	27947.85
{2 age, time, fixed, no}	28008.04	0.0000	26	27956.01
{3 age, time, time, time, no}	28049.81	0.0000	36	27977.75
{3 age, time, time, fixed, no}	28132.07	0.0000	25	28082.04
{3 age, time, time, seasonal, no}	28135.62	0.0000	27	28081.59
{2 age, seasonal, time, yes}	28472.89	0.0000	19	28434.88
{3 age, seasonal, fixed, seasonal, yes}	28482.23	0.0000	17	28448.22
{3 age, seasonal, fixed, time, yes}	28482.26	0.0000	19	28444.24
{3 age, seasonal, fixed, fixed, yes}	28487.33	0.0000	18	28451.32
{2 age, seasonal, seasonal, yes}	28545.50	0.0000	16	28513.49
{2 age, seasonal, fixed, yes}	28547.51	0.0000	17	28513.49
{3 age, seasonal, seasonal, fixed, yes}	28561.93	0.0000	16	28529.92
{3 age, seasonal, seasonal, seasonal, yes}	28561.93	0.0000	16	28529.92
{3 age, seasonal, seasonal, time, yes}	28561.93	0.0000	16	28529.92
{2 age, fixed, time, yes}	28616.19	0.0000	21	28574.17
{2 age, seasonal, time, no}	28663.74	0.0000	27	28609.71
{3 age, seasonal, fixed, seasonal, no}	28677.46	0.0000	16	28645.45
{3 age, fixed, fixed, time, yes}	28678.91	0.0000	18	28642.90
{3 age, seasonal, fixed, fixed, no}	28679.46	0.0000	17	28645.45
{3 age, seasonal, fixed, time, no}	28719.88	0.0000	25	28669.85
{2 age, seasonal, fixed, no}	28739.86	0.0000	16	28707.85
{2 age, seasonal, seasonal, no}	28741.55	0.0000	17	28707.54
{3 age, seasonal, seasonal, fixed, no}	28759.29	0.0000	16	28727.28
{3 age, seasonal, seasonal, seasonal, no}	28759.30	0.0000	16	28727.29
{3 age, seasonal, seasonal, time, no}	28772.37	0.0000	26	28720.34
{3 age, fixed, fixed, seasonal, yes}	28805.37	0.0000	17	28771.35
{2 age, fixed, seasonal, yes}	28813.23	0.0000	17	28779.21
{2 age, fixed, fixed, yes}	28846.21	0.0000	16	28814.20
{2 age, fixed, time, no}	28854.87	0.0000	26	28802.84
{3 age, fixed, fixed, fixed, yes}	28856.28	0.0000	17	28822.26
{3 age, fixed, fixed, time, no}	28931.26	0.0000	26	28879.23
{3 age, fixed, fixed, seasonal, no}	29023.71	0.0000	17	28989.70
{2 age, fixed, seasonal, no}	29024.15	0.0000	16	28992.14
{3 age, fixed, fixed, fixed, no}	29047.90	0.0000	16	29015.89
{2 age, fixed, fixed, no}	29065.10	0.0000	15	29035.09