Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Razorback Sucker (*Xyrauchen texanus*) Investigations at the Colorado River Inflow Area, Lake Mead, Nevada and Arizona

2012 Annual Report

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Lower Colorado River
Multi-Species Conservation Program

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ACRONYMS AND ABBREVIATIONS

AICc	corrected Akaike's information criterion
ANOVA	analysis of variance
asl	above sea level
BIO-West	BIO-WEST, Inc.
CI	confidence interval
CJS	Cormack-Jolly-Seber
cm	centimeter(s)
CPUE	catch per unit effort
CRI	Colorado River inflow area of Lake Mead
FL	fork length
ft	foot/feet
in	inch(es)
km	kilometer(s)
m	meter(s)
mi	mile(s)
mm	millimeter(s)
MS-222	tricaine methanesulfonate
NDOW	Nevada Department of Wildlife
PIT	passive integrated transponder
Reclamation	Bureau of Reclamation
RKM	river kilometer
RM	river mile
SL	standard length
SUR	submersible ultrasonic receiver
TL	total length
USFWS	U.S. Fish and Wildlife Service

Symbols

φ	apparent survival rate
°C	degrees Celsius
°F	degrees Fahrenheit
%	percent
ρ	recapture

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EXECUTIVE SUMMARY

In 2010, the Bureau of Reclamation (Reclamation), under the Lower Colorado River Multi-Species Conservation Program, initiated a project to evaluate razorback sucker (*Xyrauchen texanus* [Abbott]) use of the Colorado River inflow area of Lake Mead (CRI). The project is based on a biological opinion from the U.S. Fish and Wildlife Service (USFWS) that recommended Reclamation begin a project to "…examine the potential habitat in the lower Grand Canyon for the species, and institute an augmentation program in collaboration with USFWS, if appropriate" (USFWS 2007). The project was also recommended in the comprehensive review report of 10 years of razorback sucker monitoring on Lake Mead (Albrecht et al. 2008a). Several of the recommendations from this report were highlighted by the Lake Mead Work Group for inclusion in its long-term management plan (Albrecht et al. 2009), and investigating the CRI for razorback sucker presence was the first item from that plan to be implemented. This report presents the results of the third year of efforts to determine the status of razorback suckers at the CRI.

Based on research during long-term Lake Mead razorback sucker investigations, efforts involved tagging and releasing pond-reared razorback suckers into the CRI in 2010 and 2011 and tracking these fish using sonic telemetry techniques. In 2012, sonic-tagged and radio-tagged razorback suckers were followed via manual tracking (similar to long-term razorback sucker monitoring methods) and passive tracking (using submersible ultrasonic receiver [SUR] technology). In total, 17 sonic-tagged fish were contacted at the CRI in 2012, including all 16 fish released at the CRI and 1 fish released in Las Vegas Bay in 2008. The numbers of contacts totaled 213 active and 13,738 passive detections. Of these 17 fish located, 11 remain active or are presumed active to date. One sonic-tagged fish, released at the CRI in 2010, was located in Las Vegas Bay for the majority of the season and last detected at that location. Perhaps most interesting was the utilization of the Colorado River by sonic-tagged fish in 2012. Five sonic-tagged fish were located via a SUR above the Pearce Ferry Rapid in April and May 2012. SURs even detected two of these fish as far upstream as Quartermaster Canyon. These same fish have most recently been contacted near the CRI in proximity to the river/lake interface.

Using the sonic-tagged fish to locate potential spawning sites, sampling for catastomid larvae occurred on 39 nights during the 2012 spawning period (February – April). Larval sampling resulted in the capture of 10 larval razorback suckers. The presence of larval razorback suckers at the CRI helped confirm successful spawning by adult razorback suckers in 2012.

Trammel netting was used to capture adults where concentrations of razorback suckers were suspected, and fin ray specimens were obtained from razorback suckers for aging purposes. From 181 net-nights, 26 wild razorback suckers, 2 wild razorback x flannelmouth sucker hybrids, and 201 flannelmouth suckers were captured. Of these fish, 13 razorback suckers and 36 flannelmouth suckers were recaptured fish. Fourteen of the wild razorback suckers were males expressing milt, and the remaining 12 were females showing signs of spawning, which helped confirm spawning activities in the area. Ages from the 14 new, wild razorback suckers ranged from 6 to 10 years.

The goal to document the continued presence of razorback suckers at the CRI was met during 2012 sampling efforts. This was accomplished by using sonic-tagged razorback suckers to locate wild razorback suckers, mark captured razorback suckers, sample for larval fish, determine razorback sucker habitat use, and employ aging techniques to continue characterizing the age structure of the razorback sucker population at the CRI. Since 2010, a total of 51 razorback suckers (23 of which were unique and wild) and 13 razorback x flannelmouth suckers (11 of which were unique and wild) have been captured. Additionally, 82 razorback sucker larvae have been captured from multiple spawning areas at the CRI. With each study year at the CRI, more has been learned regarding Lake Mead razorback sucker populations and techniques to improve sampling effectiveness and efficiency. Many questions must still be addressed, and the study could be improved through building a larger dataset over subsequent years. Future goals for the study include continuing to study the razorback sucker population at the CRI using sonic tracking, larval sampling, and netting efforts. These efforts will enable better characterization of razorback sucker habitat at the CRI and improve our ability to locate additional groups of fish or spawning areas in the vicinity. Also of interest is investigating razorback sucker use of the Colorado River proper as well as other physicochemical and biological factors that allow for continued Lake Mead razorback sucker recruitment.

INTRODUCTION

The razorback sucker (*Xyrauchen texanus* [Abbott]) is one of four endemic, large-river fish species of the Colorado River basin presently considered endangered by the U.S. Department of the Interior (U.S. Fish and Wildlife Service [USFWS] 1991). The other three species are the Colorado pikeminnow (*Ptychocheilus lucius*), bonytail chub (*Gila elegans*), and humpback chub (*Gila cypha*). Razorback suckers were historically widespread and common throughout the larger rivers of the Colorado River basin (Minckley et al. 1991). The current distribution and abundance of razorback suckers are greatly reduced from historic levels mainly because of the construction of main stem dams and the resultant cool tailwaters and reservoir habitats that replaced a warm, riverine environment (Holden and Stalnaker 1975; Joseph et al. 1977; Wick et al. 1982; Minckley et al. 1991). Razorback suckers persisted in several reservoirs constructed in the Lower Colorado River Basin; however, these populations consisted primarily of adult fish that apparently recruited during the first few years of reservoir formation. Because of a lack of sustained recruitment, the populations of long-lived adults then disappeared 40–50 years following reservoir creation and the initial recruitment period (Minckley 1983). Riverine razorback sucker populations in the Upper Colorado River Basin also have declined, as recruitment has not occurred at significant levels since the construction of these main stem dams (Bestgen et al. 2011). It is thought that predation by bass (*Micropterus* spp.), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), sunfish (*Lepomis* spp.), and other nonnative species is the primary reason for the lack of razorback sucker recruitment throughout its original distribution (Minckley et al. 1991; Marsh et al. 2003).

It was widely believed that the trends of razorback sucker decline observed in the Colorado River were also occurring in Lake Mead. Razorback sucker numbers, initially high in Lake Mead, decreased noticeably in the 1970s, and no razorback suckers were collected during the 1980s (Minckley 1973; McCall 1980; Minckley et al. 1991; Holden 1994; Sjoberg 1995). However, in the early 1990s, Nevada Department of Wildlife (NDOW) personnel were informed by local anglers that the species was still present in two localized areas of Lake Mead: Las Vegas Bay and Echo Bay. Limited sampling efforts initiated by the NDOW soon confirmed the presence of remnant populations of razorback suckers in Lake Mead. In 1996, the Southern Nevada Water Authority, in cooperation with the NDOW, initiated the Lake Mead studies to attempt to identify some of the basic population dynamics of razorback sucker in Lake Mead. BIO-WEST, Inc. (BIO-WEST), was contracted to design and conduct the study with collaboration from the Southern Nevada Water Authority and NDOW. Other cooperating agencies included the Bureau of Reclamation (Reclamation), National Park Service, Colorado River Commission of Nevada, and USFWS. This work eventually led to the discovery of several groups of wild fish spawning and recruiting in the reservoir, and these groups currently represent the only known recruiting and naturally expanding population within the entire Colorado River basin (Albrecht et al. 2008a, 2010a, 2010c; Kegerries et al. 2009; Shattuck et al. 2011).

Larval razorback suckers were found in the Colorado River inflow area of Lake Mead (CRI) during 2000 and 2001, but despite opportunistic netting efforts, no adult razorback suckers were captured at that time (Holden et al. 2001; Abate et al. 2002; Albrecht et al. 2008a). In 2008, the Arizona Game and Fish Department captured a large, adult razorback sucker during annual gill netting efforts in Gregg Basin. The NDOW also captured two adult fish in the Virgin Basin. These captures emphasized the possibility that other razorback sucker populations may exist in areas of Lake Mead that are not being studied under the current Lake Mead razorback sucker monitoring efforts.

More recently, a comprehensive review evaluating the entire Lake Mead razorback sucker dataset obtained from 1996 to 2007 was finalized (Albrecht et al. 2008a). This report provided a summary of the methods used and cumulative findings regarding Lake Mead razorback suckers to date. The comprehensive review also provided recommendations for future monitoring and research on Lake Mead. These recommendations have been incorporated into a long-term management plan that serves as a guide for future razorback sucker studies on Lake Mead (Albrecht et al. 2009). This plan is used and updated by the Lake Mead Work Group, which comprises the various agencies involved with Lake Mead razorback suckers.

One of the major tasks of the management plan is to explore other locations in Lake Mead for existing razorback sucker populations. Based on the location of known populations, which occur in areas with some turbidity and (at times) vegetative cover, the CRI was identified as the most logical area to investigate first. In addition, a biological opinion from the USFWS on the Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead recommended Reclamation begin a project to "…examine the potential habitat in the lower Grand Canyon for the species, and institute an augmentation program in collaboration with the USFWS, if appropriate" (USFWS 2007). Thus, the Lake Mead Work Group decided to begin investigative efforts at the CRI with the goal of identifying whether an unknown population exists within the upper end of Lake Mead. This was the first new task in the management plan to be implemented and is the first step in meeting the conservation measure from the USFWS in their 2007 biological opinion (USFWS 2007; Albrecht et al. 2009).

As recently as 2009, there was an apparent surge in razorback sucker recruitment, and overall numbers of young, juvenile fish increased at known spawning areas in Lake Mead (Albrecht et al. 2008a; Kegerries et al. 2009). It was hypothesized that the potential to successfully document razorback suckers at the CRI would likely be very high at that time. Given the recent successes of monitoring fish implanted with improved sonic tags, it was concluded that renewed efforts at the CRI would help clarify whether an additional spawning population existed within

Lake Mead (Albrecht et al. 2008a; Kegerries et al. 2009). Thus, BIO-WEST proposed initiating telemetry and limited sampling efforts at the CRI in 2010. Combining stocking and tracking of sonic-tagged razorback suckers, trammel netting, and larval sampling increased the potential of finding a new spawning population of razorback suckers at the CRI. This resulted in the confirmation of a new Lake Mead spawning aggregate (Albrecht et al. 2010b). In addition to providing a greater understanding of habitat use and movement patterns within Lake Mead, sampling this additional population provided even more information regarding the overall recruitment patterns of Lake Mead razorback suckers, which will undoubtedly help identify the conditions that are conducive to these unique recruitment events.

Furthermore, the CRI provided information regarding the impact, scale, and magnitude of lake level and habitat changes in relation to razorback sucker spawning. As a result of receding lake levels, razorback sucker spawning locations and spawning habitat use have changed. Habitat at the CRI has changed during the past decade but at a much larger spatial scale than other spawning areas throughout the lake (e.g., Las Vegas Bay, Echo Bay, Muddy River/Virgin River inflow). For example, during 2001–03, BIO-WEST sampled the Pearce Ferry and Grand Wash Bay areas, which were all accessible by boat. Currently, the lentic portion of Lake Mead only extends to the mouth of Iceberg Canyon. Above that interface, several kilometers (km) of once-lentic habitats are now riverine and essentially part of the Colorado River proper. Thus, compared with the remainder of Lake Mead, the scale of change at the CRI has been fairly large (kilometers of habitat change compared with meters [m] of change at the known spawning locations). This disparity provided a unique opportunity to evaluate razorback sucker use of an area that has been drastically modified and has remained dynamic since the lake was impounded. The CRI may also provide insight as to what we can and should expect in terms of future spawning, particularly at the Muddy River/Virgin River inflow area and other known spawning locations within the lake, if lake levels decline.

The overall goal of this project was to determine the presence or absence of a razorback sucker population with the CRI. This goal was met in 2010, 2011, and 2012 by accomplishing the following objectives:

- Use sonic-tagged razorback suckers to locate and capture wild razorback suckers in various life stages and track movement patterns of any existing population

- Mark captured juvenile and adult razorback suckers for individual identification using passive integrated transponder (PIT) tags

- Use a combination of sonic telemetry data, larval razorback sucker capture-location information, and juvenile/adult razorback sucker netting data to determine habitat use of this unique population

- Use nonlethal aging techniques to characterize the age structure and potential recruitment patterns associated with a razorback sucker population at the CRI

Given the findings of wild razorback suckers at the CRI in 2010, the overall objectives remained the same for 2011 and 2012 but with twice the field effort and manpower compared to 2010. This increased effort was meant to capitalize on the sampling opportunity presented by recent razorback sucker recruitment, cover more area, and increase the likelihood of capturing more individuals. With this increased effort, more resources were spent in the Colorado River proper trying to understand the relationship between the riverine environment and lentic habitat utilization of razorback suckers during the spawning season.

This report presents the findings of the third study year at the CRI and covers the intensive field efforts conducted from January to May 2012. It also presents sonic telemetry data obtained from July 2011 to December 2012 in accordance with the results reported in other annual Lake Mead razorback sucker reports (Albrecht et al. 2008b; Kegerries et al. 2009; Albrecht et al. 2010b; Shattuck et al. 2011). Other information and data from previous studies are included when applicable. This report not only presents efforts and findings from investigations conducted at the CRI in 2012, it also serves as a companion report to the 2012 long-term Lake Mead razorback sucker monitoring report from efforts conducted at Las Vegas Bay, Echo Bay, and the Muddy River/Virgin River inflow area in 2012 (Albrecht et al. 2013).

STUDY AREAS

The 2012 CRI study activities occurred within Gregg Basin of Lake Mead and the Colorado River upstream to just below Quartermaster Canyon at Grand Canyon River Mile (RM) 260 (figure 1).

Definitions for various portions of the CRI in which the study was conducted shall be referred to using the following terms:

- Lake Mead proper begins where the flooded portion of the river channel widens and velocity is reduced.

- The Colorado River proper is simply the flowing river. Depending on conditions, this area may or may not be accessible by large boat.

- Interface is the area where the river proper meets the lake proper. This area may or may not have flow, is typically turbid, and is transitory and highly dynamic in nature.

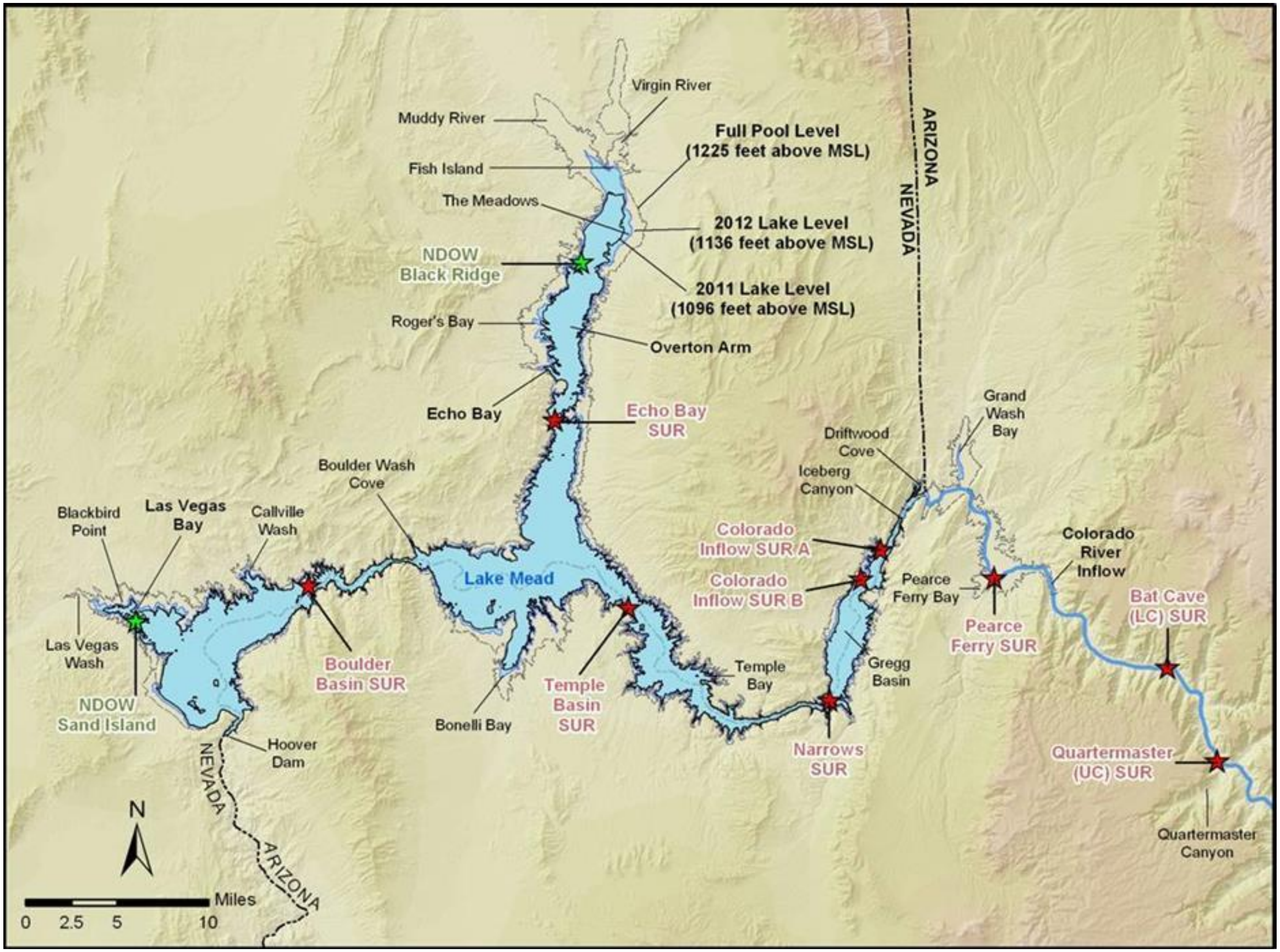

Figure 1.—Lake Mead general study areas, including locations of submersible ultrasonic receiver locations.

METHODS

Lake Elevation

Month-end lake elevations for the 2012 field season (July 1, 2011 – June 30, 2012) were measured in feet (ft) above sea level (asl) and obtained from Reclamation's Lower Colorado Regional Office Web site (Reclamation 2012). The effect of fluctuating lake levels on razorback sucker habitat was documented by written observations and/or photographs during sampling trips to the CRI.

Sonic Tagging

No sonic tagging occurred for the 2012 study year because numerous sonic-tagged fish were still present from both the 2010 and 2011 stocking events.

Active Sonic Telemetry and Tracking

During the intensive field season associated with the spawning period (January – May), sonic-tagged fish were tracked weekly (or sometimes daily) depending on the field schedule and weekly project goals. During the remainder of the year (June – December), sonic-tagged fish were typically tracked monthly. Fish searches were conducted largely along shorelines, with listening points of approximately 0.8 km (0.5 mile [mi]) apart, depending on shoreline configuration and other factors that could impact signal reception. Sonic equipment is line-of-sight, and any obstruction can reduce or block a signal. Also, telemetry signals are often reduced in shallow, turbid environments. Active tracking consisted of listening underwater for coded sonic tags using a Sonotronics USR-08 ultrasonic receiver (or earlier model) and DH4 hydrophone. The hydrophone was lowered into the water and rotated 360 degrees to detect the presence of sonic-tagged fish. Once a signal was detected, the position of the sonic-tagged fish was pinpointed by moving in the fish's direction until the signal was heard in all directions with the same intensity. The sonic tag number, Global Positioning System location, and depth information were then recorded. Combination radio- and sonic-tagged fish were tracked using similar methods or with a Lotek SRX 400a receiver and Yagi antenna.

Passive Sonic Telemetry and Submersible Ultrasonic Receiver Data Collection Efforts

Along with active tracking methods, submersible ultrasonic receivers (SURs) were deployed in various locations throughout the CRI (see figure 1). The advantage to using SURs is their ability to autonomously record continuous telemetry data day or night. With an approximate 9-month battery life and the ability to detect ultrasonic transmitters, SURs save valuable field time while collecting additional telemetry data.

A SUR was placed at the southern end of Gregg Basin, near the mouth of Hualapai Bay (see figure 1), to track fish moving in and out of the basin. This SUR has been utilized since the study began in 2010. In June 2011, an additional SUR was deployed in the Temple Basin to aid in tracking sonic-tagged fish movement between basins where little manual tracking effort is spent. Another SUR has remained near the CRI, although the exact location of this SUR has changed several times since 2010 to adjust for changing lake levels and to optimize data collection as the location of the river/lake interface changed. The Colorado inflow SUR (see figure 1) was deployed in two locations during the 2012 study year. It began the season just below the mouth of Iceberg Canyon, outside of Devil’s Cove, where it remained until May 23, 2012. Because of declining lake levels, it was moved further out into the lake proper off of an island just north of Sandy Point.

In 2012, two additional SURs were used in an effort to monitor fish movement in and out of the Colorado River proper (see figure 1). A SUR was deployed near the Pearce Ferry boat ramp at river kilometer (RKM) 450.6 (RM 280) from March 7 to April 6, 2012. On April 6, 2012, this same SUR was moved approximately 20.9 RKM (13 RM) upstream near the bat cave at RKM 429.7 (RM 267) where it currently remains. Another SUR was deployed on April 25, 2012, near Quartermaster Canyon (RKM 418.4 [RM 260]) where it remained until May 22, 2012.

All SURs were programmed to detect implanted, active, sonic tag frequencies using Sonotronic’s SURsoft software. The semibuoyant SURs were then suspended from an anchor (e.g., a rock, anchor, or block) using approximately 18 inches [in] of rope. A lead of vinyl-coated cable was secured to the anchor as the SUR was deployed and allowed to sink to the lake bottom. The cable was secured on shore and concealed. Data were retrieved from SURs frequently by pulling the SUR into the boat and downloading the data via Sonotronic’s SURsoft software. These data were then processed through Sonotronic’s SURsoftDPC software to ascertain the time, date, and frequency of positive sonic-tagged fish detections within 2 millisecond-interval units (e.g., a range of 898–902 for a 900-interval tag). To avoid any false-positive contacts due to environmental “noise” in data analysis, a minimum of two records were required within 5 minutes of one another in order for a SUR record to be considered valid.

Adult Studies

Tammel Netting

Adult fish were captured using trammel nets 274.4 m (300 ft) long by 1.8 m (6 ft) deep with internal panels of 2.54-centimeter (cm) (1-in) mesh and external panels of 30.48-cm (12-in) mesh. On occasion, shorter trammel nets, 45.7 m long (150 ft) by 1.2 m (4 ft), of the same mesh configuration were used to sample smaller habitat areas, especially within the river proper. Nets were generally set with one end near shore in 3.05–9.15 m (5–30 ft) of water, with the net stretched out into deeper areas. All trammel nets were set in the late afternoon (just before sundown) and pulled the next morning (shortly after sunrise). Netting locations were selected based on the locations of sonic-tagged fish, the location or presence of concentrated larval fish, and knowledge of previous adult razorback sucker capture locations.

Fish were taken from nets, and live fish were held in large, 94.6-liter (100-quart) coolers filled with lake water. Razorback suckers and/or flannelmouth suckers (*Catostomus latipinnis*) were isolated from other fish species and held in aerated live wells. All but the first five common carp and gizzard shad (*Dorosoma cepedianum*) were enumerated and returned to the lake, while other species (including five common carp and five gizzard shad) were identified, measured for total length (TL), weighed, and released at the capture location. Razorback sucker, flannelmouth sucker, or suspected razorback sucker x flannelmouth sucker hybrids were scanned for PIT tags. If the individuals were not recaptured fish, they were PIT tagged, measured (including TL, standard length [SL], and fork length [FL]), weighed, and released at the point of capture. Native sucker species selected for age determination were anesthetized with tricaine methanesulfonate (MS-222) and placed dorsal-side down on a padded surgical cradle for support while a segment of the second pectoral fin ray was collected. Because of the presence of hybrid suckers at the CRI, as well as other genetic work being done on Lake Mead razorback suckers, genetic material was also removed from many of the native suckers (including suspected hybrids). This consisted of a small piece of tissue obtained from the caudle fin, preserved in 95-percent (%) ethanol, and then provided to Reclamation for further laboratory analysis.

Growth

Razorback sucker annual growth information was gathered from recaptured individuals in trammel netting collections. Recaptured individuals were only measured once during the spawning season, to avoid handling stress, and only used for annual growth analysis if approximately one sampling year had passed between capture occasions. Stocked individuals were excluded from the dataset and analysis to account for discrepancies in environmental conditions (e.g., a hatchery- or pond-reared individual recently stocked into a wild environment) and to allow for the yearly cycles of gonadal and somatic growth. The annual growth for razorback suckers was calculated for each individual using the difference in TL (millimeters [mm]) between capture periods. If the data were available, the mean annual growth was calculated separately for stocked and wild individuals.

Larval Sampling

The primary larval sampling method followed that developed by Burke (1995) and other researchers on Lake Mohave. The procedure uses the positive phototactic response of larval razorback suckers to capture them. After sundown, two to four 12-volt "crappie" lights were connected to a battery, placed over each side of the boat, and submerged in 10.2–25.4 cm (4–10 in) of water. Two to four netters equipped with long-handled aquarium dip nets were stationed to observe the area around the lights. Larval razorback suckers that swam into the lighted area were dip-netted out of the water and placed into a holding bucket. The procedure was repeated for 15 minutes at 4–12 sampling sites on each night attempted. Larvae were identified and enumerated as they were placed in the holding bucket and then released at the point of capture when sampling at a site was completed.

Because of the vast sampling area, turbidity, flowing water, and the potential for larval drift at the CRI, larval light traps were also deployed as an experimental method to capitalize on efforts to collect catostomid larvae. These traps were set out either overnight or for several hours after sunset in an effort to cover more area and sample those areas that are not conducive to the method described above (i.e., flowing portions of the river). The larval light traps were deployed by tying the lead rope to the vegetation near shore in suspected spawning areas. A light stick was inserted into the trap and allowed to float freely. The light traps were collected the next morning or after the desired deployment time. The catch bowls were checked for the presence of larval fish. All larval fish present were identified, enumerated, and returned to the lake.

Because other native sucker species are present at the CRI, suspected larval razorback suckers were preserved in 10% formalin for microscopic verification using the key to catostomid fish larvae developed by Snyder and Muth (2004). It should be noted that not all larvae were preserved for identification; only those that were difficult to identify in the field were preserved for verification.

Spawning Site Identification

During the 16 years of razorback sucker monitoring on Lake Mead, it has been found that multiple methods are needed to identify and pinpoint annual razorback sucker spawning sites. The basic, most effective spawning site identification procedure has been to track sonic-tagged fish and identify the most frequented areas. Once a location is identified as heavily used by sonic-tagged fish, particularly during crepuscular hours, trammel nets are typically set in an effort to capture adult razorback suckers. Captured fish are then evaluated for signs of ripeness, which are indicative of spawning. After the initial identification of a possible spawning site through sonic-tagged razorback sucker habitat use and other, untagged juvenile or adult trammel net captures, larval sampling is conducted to validate whether successful spawning occurred. Examples of the effectiveness of these techniques are evident in the descriptions provided by Albrecht and Holden (2005) regarding the documentation of a new spawning aggregate near Fish Island in the Overton Arm of Lake Mead. This same general approach was also used effectively at the CRI in 2010, 2011, and 2012.

Age Determination

For age determinations, a nonlethal technique developed in 1999 was employed using fin ray sections on Lake Mead razorback suckers (Holden et al. 2000). As in past Lake Mead razorback sucker studies, an emphasis of our 2012 CRI efforts involved collecting fin ray sections from razorback suckers for aging purposes. Specimens were also obtained from suspected hybrid suckers and a subset of the flannelmouth suckers for age determination.

During the 2012 spawning period, previously unaged suckers captured via trammel netting were anesthetized, and a single, approximately 6.00-mm (0.25-in) long segment of the second left pectoral fin ray was surgically removed. Fish were anesthetized with a lake-water bath containing MS-222, sodium chloride, and a slime-coat protectant to reduce surgery-related stress, speed recovery, and avoid accidental injury to fish that may thrash during surgical procedures. During the surgery, standard processing was conducted (weighing, measuring, and PIT tagging), and a pectoral fin ray sample was surgically collected using custom-made bone snips originally developed by BIO-WEST. These surgical tools consist of a matched pair of finely sharpened chisels welded to a set of wire-stripping pliers. The connecting membrane between fin rays was cut using a scalpel blade, and the section was placed in a labeled envelope for drying. All surgical equipment was sterilized before use, and subsequent wounds were packed with antibiotic ointment to minimize post-surgical bacterial infections and promote rapid healing. All native suckers undergoing fin ray extraction techniques were immediately placed in a recovery bath of fresh lake water containing a slime-coat protectant and sodium chloride, allowed to recover, and released as soon as they regained equilibrium and appeared recovered from the anesthesia. Vigilant monitoring was conducted during all phases of the procedure.

In the laboratory, fin ray segments were embedded in thermoplastic epoxy resin and heat cured. This technique allowed the fin rays to be perpendicularly sectioned using a Buhler isomet low-speed saw. Resultant sections were then mounted on microscope slides, sanded, polished, and examined under a stereo-zoom microscope. Each sectioned fin ray was aged independently by at least two readers. Sections were then reviewed by all readers in instances in which the assigned age was not agreed upon. If age discrepancies remained after the second reading, a third reader viewed the structure, and all three readers collectively assigned an age to the individual. For further information regarding the evolution of our fin ray aging technique, refer to Albrecht and Holden (2005), Albrecht et al. (2006), Albrecht et al. (2008a), and other annual Lake Mead razorback sucker reports.

Population and Survival Rate Estimation

Population Estimation

In 2012, a population estimate was produced in the program MARK using mark-recapture data from 2010–12. Models produced in the program MARK are tested and ranked to produce the most precise and informative estimate.

Three population estimates were produced, which included the CRI, the CRI combined with Echo Bay and the Muddy River/Virgin River inflow area, and a lake-wide estimate, including data from all long-term monitoring (Albrecht et al. 2013). There were 41 capture events for the CRI and lake-wide estimates and 35 for the CRI combined with the Echo Bay and Muddy River/Virgin River. For the lake-wide estimate, netting efforts from the long-term monitoring were used only when efforts were taking place simultaneously at the CRI in order to maintain some semblance of consistency in effort across space and time. To date, movements of wild razorback suckers to and from the Overton Arm (reported herein) and sonic-tagged fish movement to and from Las Vegas Bay and the Overton Arm have been documented (Kegerries and Albrecht 2011). Similar movement of razorback suckers has also been documented on numerous occasions throughout other portions of Lake Mead (Albrecht et al. 2007, 2008a, 2008b, 2010c; Kegerries et al. 2009; Shattuck et al. 2011)—thus, the rationale for reporting estimates that include data from other spawning areas. Stocked fish were not used in the population estimates unless they had survived a minimum of 1 year in Lake Mead. It was assumed that an adult, stocked fish that had survived 1 year in Lake Mead was able to avoid predation and contribute progeny to the population (Albrecht and Holden 2005; Modde et al. 2005). Within the program MARK, the models where ranked according to their relative goodness-of-fit value (according to the corrected Akaike's information criterion [AICc values]) to determine which model fit the dataset best. The population model with the highest ranked AICc value is reported herein.

Survival Rate Estimation

Similar to the population estimation analyses, the program MARK was used to estimate an apparent survival rate (φ) of razorback suckers in Lake Mead from trammel netting data collected during the spawning season (February – May) from 2010 to 2012. Two models, the Cormack-Jolly-Seber (CJS) live recapture model (Cormack 1964; Jolly 1965; Seber 1965) and the Pradel survival model (Pradel 1996), were used in the program MARK to calculate apparent survival rates based on 41 capture events lake-wide (Cooch and White 2012).

Apparent survival estimates the probability of an individual being alive and available for capture from one time period to another (Zelasko and White 2011). Razorback sucker survival rate estimates have not been reported from Lake Mead in past reports; thus, this analysis may provide additional information regarding population dynamics for wild razorback suckers in Lake Mead.

Additionally, these estimates provide a means to compare Lake Mead razorback sucker apparent survival rates to those of other prominent razorback sucker populations (e.g., the Green River and upper Colorado River subbasins [Zelasko and White 2011] and Lake Mohave [Kesner et al. 2012]). Lake-wide data selection and encounter histories were identical to those used in the population estimate (described above) and were analyzed using a similar approach as described by Zelasko and White (2011). The pre-defined models of φ (apparent survival) and ρ (recapture) were used for both the CJS and the Pradel survival estimators. Within the program MARK, the models were ranked according to their relative goodness of fit value (AICc) to determine which was the best fit model for the dataset. The apparent survival rate estimate with the highest-ranked AICc value is reported for both the CJS and Pradel models for comparison purposes.

RESULTS

Lake Elevation

After a record-low lake elevation (332.8 m [1,092 ft] asl) in January 2011, the lake level rose consistently throughout 2011 and peaked in January 2012 (346.3 m [1,136 ft] asl) (figure 2). This increase in lake level of approximately 13.5 m (44 ft) created vast areas of wetted, littoral habitats, including increased amounts of inundated vegetation, and caused an upstream shift of the river/lake interface into Iceberg Canyon. Although the lake levels were higher in 2012 during the spawning season and intense sampling efforts compared to 2011, the typical trend of lake level decline was observed from January to June 2012 (figure 2). With the exception of 2011, this same trend has been observed on Lake Mead for more than a decade (figure 2). The effects of higher water levels and the inundation of littoral zone habitat was evident (based on visual observations) within the CRI, as well as at all other locations within Lake Mead, where razorback suckers spawned in 2012 (Albrecht et al. 2013).

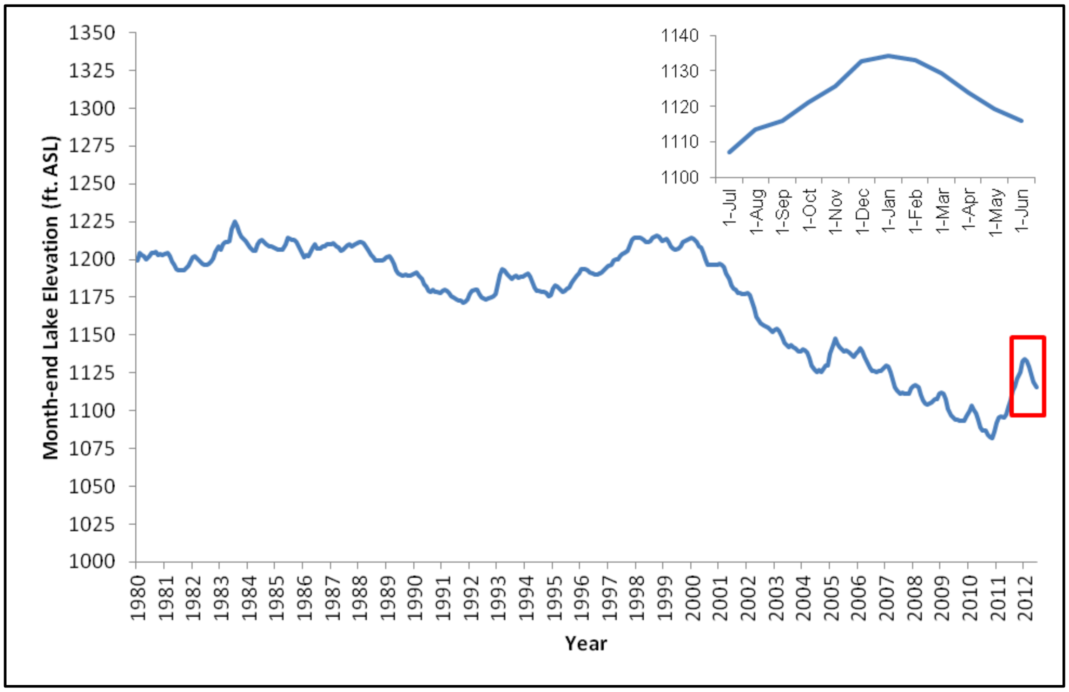

Figure 2.—Lake Mead month-end elevations, January 1980 – June 2012 (inset shows red, boxed area of graph).

Telemetry

Sixteen sonic- and radio-tagged fish have been released into the CRI since 2010 (table 1), with stocking events occurring in 2010 and 2011. For a more detailed description of fish released, release locations, and data collected in 2010 and 2011, refer to Albrecht et al. (2010b) and Kegerries and Albrecht (2011). No fish were implanted with sonic or radio tags or stocked into the CRI during the 2011–12 study year.

In total, 17 sonic-tagged fish were contacted 13,951 times (213 active and 13,738 passive) from July 2011 to December 2012 at the CRI (table 1, figure 5). Of these 17 fish, 8 were stocked in 2011, 8 were stocked in 2010, and 1 was from a 2008 stocking in Las Vegas Bay. To date, 11 of these sonic-tagged fish have functioning tags and are presumed active and detectable (table 1). One fish (6678) was confirmed to be healthy and active with an expired tag (battery no longer functioning) after its capture via trammel netting in March and April 2012. This tag was designed to transmit for only 12 months. Although unconfirmed, another sonic-tagged fish with a similar tag (5768) is presumed to have an expired battery because it has not been heard from since August 2011. Two more of the 2011 tags are expected to expire within the year. Four sonic tags have remained stationary most of the season (table 1).

Table 1.—Tagging and stocking information, location, date of last contact, and current status of sonic-tagged fish released into the CRI from 2010 to 2012 and found using CRI habitats during the 2012 study year

Capture location[a]	Tag date	Tag code	TL (mm)	Sex[b]	Stocking location[a]	Last location[a]	Last contact date	2011–12 contact[c]	Tag status	Estimated expiration
Fish tagged in 2011										
FDLB	1/5/2011	447	505	M	CRI	CRI	5/7/2012	635 total 36 active 599 passive	Stationary	01/2015
FDLB	1/5/2011	3546	496	M	CRI	CRI	12/6/2012	597 total 23 active 574 passive	Active	01/2015
FDLB	1/5/2011	3666	504	M	CRI	CRI	8/17/2011	1 total 1 active 0 passive	Stationary	01/2015
FDLB	1/5/2011	3774	509	M	CRI	CRI/ river	12/6/2012	3,206 total 29 active 3,177 passive	Active	01/2015
FDLB	1/5/2011	5578	487	M	CRI/river	CRI	11/4/2012	1,457 total 16 active 1,441 passive	Active	01/2012
FDLB	1/5/2011	5767	515	M	CRI/river	CRI	5/21/2012	1,933 total 20 active 1,913 passive	Active	01/2012
FDLB	1/5/2011	5768	530	F	CRI/river	CRI	8/17/2011	1 total 1 active 0 passive	Presumed expired	01/2012
FDLB	1/5/2011	6678	565	M	CRI/river	CRI	2/8/2012	99 total 9 active 90 passive	Expired	01/2012

Table 1.—Tagging and stocking information, location, date of last contact, and current status of sonic-tagged fish released into the CRI from 2010 to 2012 and found using CRI habitats during the 2012 study year

Capture location[a]	Tag date	Tag code	TL (mm)	Sex[b]	Stocking location[a]	Last location[a]	Last contact date	2011–12 contact[c]	Tag status	Estimated expiration
Fish tagged in 2010										
FDLB	2/23/2010	227	486	M	GB	CRI	12/6/2012	544 total 16 active 528 passive	Active	02/2014
FDLB	2/23/2010	249	511	M	CRI	CRI	12/6/2012	2,283 total 25 active 2,258 passive	Active	02/2014
FDLB	2/23/2010	258	502	M	CRI	CRI	7/18/2012	2 total 2 active 0 passive	Active	02/2014
FDLB	2/23/2010	267	534	F	GB	CRI	1/18/2012	113 total 3 active 110 passive	Presumed active	02/2014
FDLB	2/23/2010	339	501	M	CRI	CRI	4/11/2012	14 total 14 active 0 passive	Stationary	02/2014
FDLB	2/23/2010	348	516	M	GB	GB	4/11/2012	1 total 1 active 0 passive	Stationary	02/2014
FDLB	2/23/2010	357	490	M	GB	LVB	11/12/2012	484 total 2 active 482 passive	Active	02/2014
FDLB	2/23/2010	485	517	M	CRI	CRI	12/6/2012	2,580 total 14 active 2,566 passive	Active	02/2014
Fish tagged in 2008										
FDLB	12/3/2008	3355	483	M	LB	CRI	8/17/2011	1 total 1 active 0 passive	Presumed active	12/2012

[a] Locations: FDLB = Floyd Lamb Park, CRI = Colorado River inflow area, GB = Gregg Basin near Scanlon Bay, and LVB = Las Vegas Bay.
[b] Sex: M = male, and F = female.
[c] Number of contacts are presented using active sonic telemetry techniques, passive sonic telemetry techniques (i.e., SURs), and in total (the number of active and passive contacts combined). Refer to the active and passive sonic tracking methodologies in this report for details.

With a few exceptions, particularly heavy razorback sucker use was observed at or near the interface of the Colorado River and Lake Mead for the majority of these fish (figures 3 and 4). Although there was contact with some of these fish upstream into the Colorado River proper, prolonged (longer than a month) occupancy of the flowing river has not yet been observed.

Manual tracking efforts from July 2011 through the end of January 2012 and from June through December 2012 (nonspawning months) resulted in 113 contacts with 16 unique, sonic-tagged fish (figure 3). Sonic-tagged fish locations during these tracking events were concentrated primarily near the CRI in and around the river/lake interface. Fish were typically found occupying open, deeper water and showed little to no preference for any particular habitat. In fact, these fish were found in water averaging approximately 7.7 m (25.4 ft). Interestingly, during January, eight sonic-tagged fish were found in the river proper between Iceberg Canyon and Pearce Ferry Rapid (figure 3).

During the spawning period (February – June), sonic-tagged fish continued to occupy habitats close to the river/lake interface (figure 4). Eleven unique sonic-tagged fish were tracked during this period, for a total of 100 contacts. These fish were tracked in water averaging approximately 6.7 m (22.0 ft), which is not significantly shallower (analysis of variance [ANOVA], $p = 0.086$) than depths occupied by fish tracked during the nonspawning months. Many of the contacts occurred just south and west from the mouth of Iceberg Canyon near and within Devil's Cove. Movement of sonic-tagged fish into the flowing portions of the river was also found in February and March when a total of nine unique, sonic-tagged fish occupied the river from Iceberg Canyon upstream to Pearce Ferry Rapid during tracking events (figure 4). Multiple sonic-tagged fish spent days to weeks occupying slackwater or eddy habitats upstream of the inflow area and even immediately below Pearce Ferry Rapid. The number of contacts with sonic-tagged fish in the Devil's Cove area, combined with larval and netting data (reported later in this document), helped identify the areas most likely to be the primary spawning areas for razorback suckers in 2012 (figure 4).

Netting close to sonic-tagged fish locations aided in the capture of several adult razorback suckers, both wild and stocked. On February 28 and 29, 2012, three sonic-tagged fish were found along a point (which was small and shallow at the time of sampling) located just south and west of the mouth of Iceberg Canyon, along the western shoreline of the lake. Trammel netting, guided by the presence of sonic-tagged fish at this location, resulted in the capture of four adult razorback suckers, two of which were new, wild fish. The other two were fish captured for the first time and tagged earlier in January and February, respectively. This same method was used to locate other adult razorback suckers, reinforcing the idea that sonic-tagged fish are an important tool for locating wild razorback suckers.

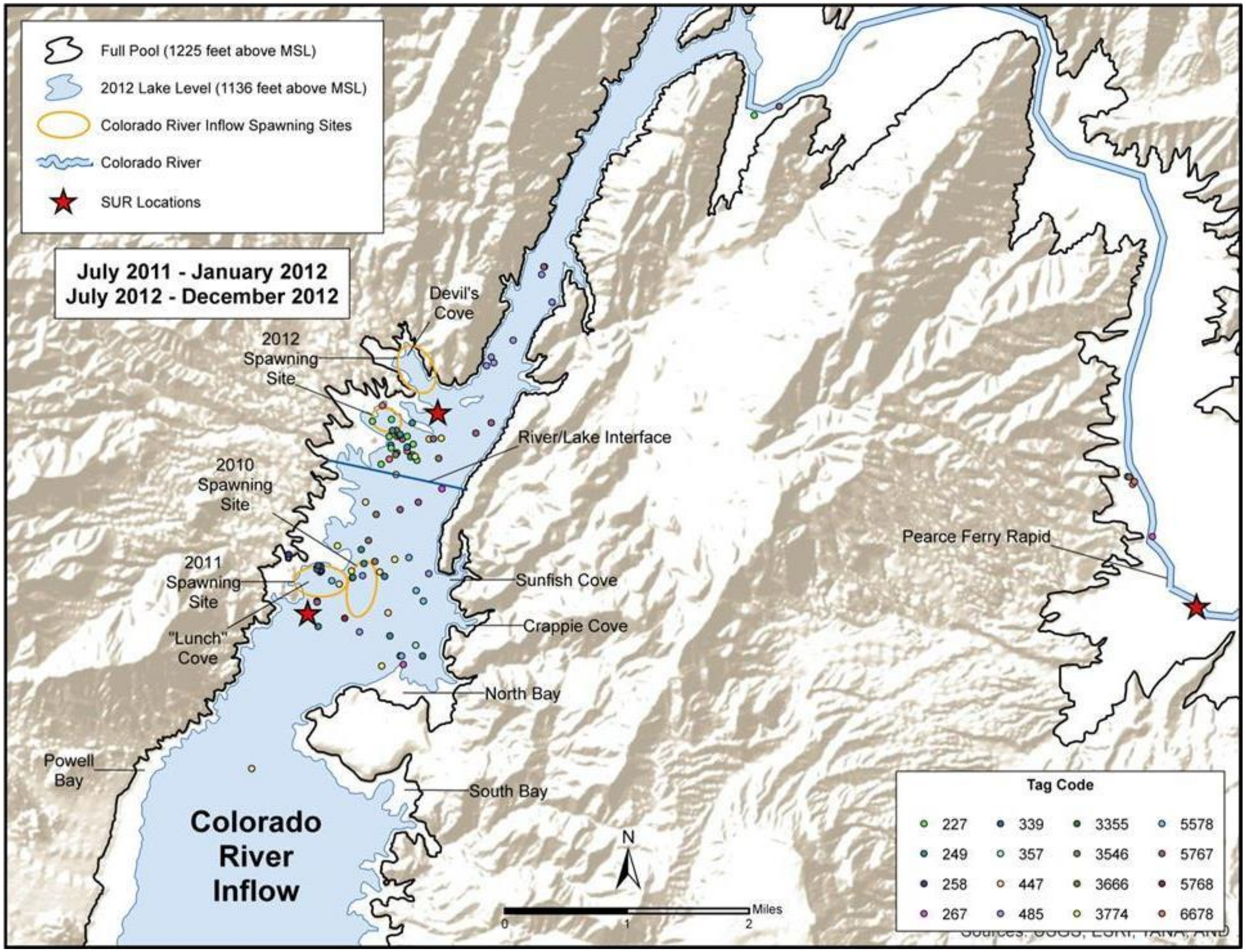

Figure 3.—Distribution of sonic-tagged fish at the CRI during the nonspawning months of July 2011 – January 2012 and July – December 2012.

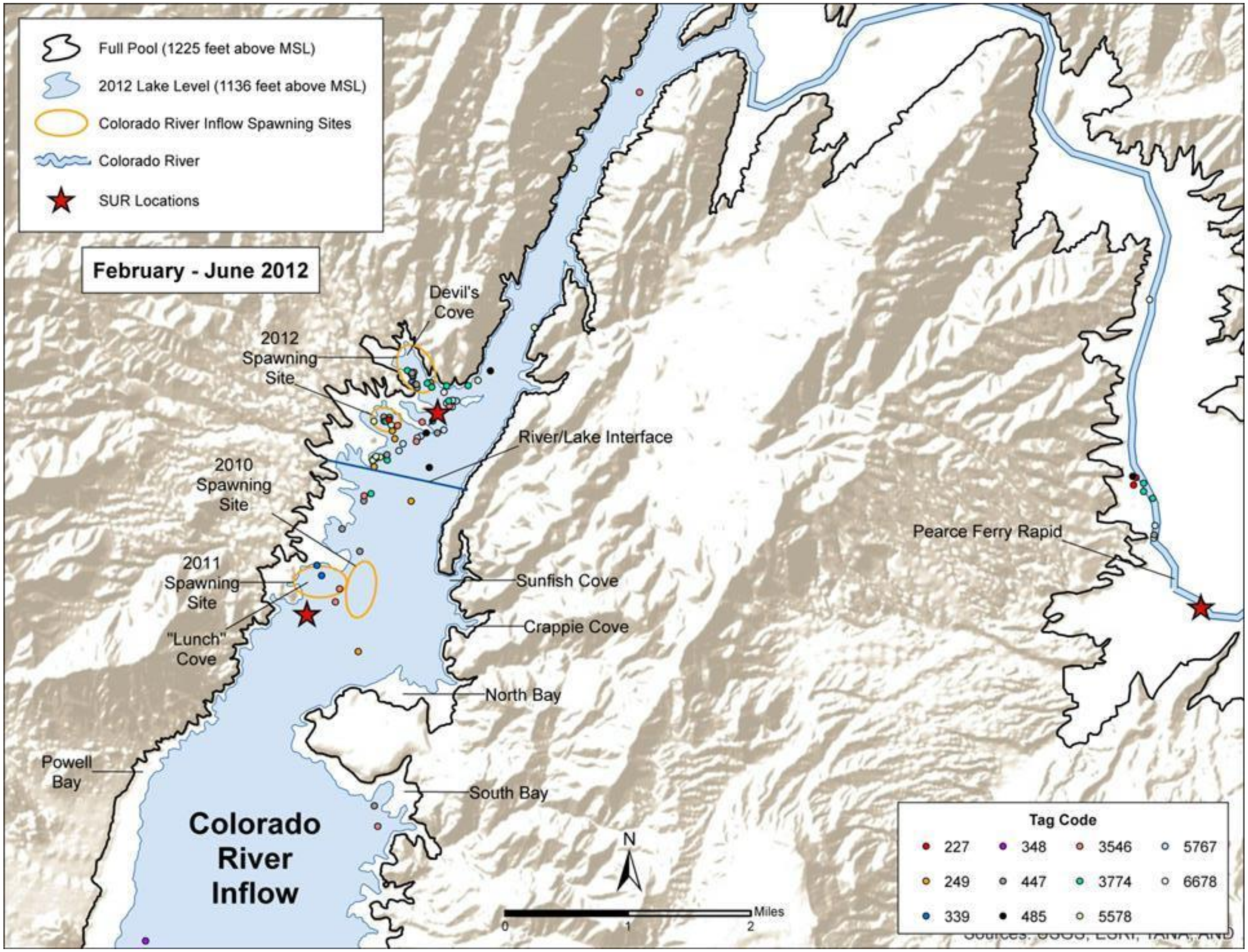

Figure 4.—Distribution of sonic-tagged fish at the CRI during the spawning months of February – June 2012.

Interesting movements from implanted fish were also documented in 2012. One interesting contact came from fish 3355 on August 17, 2011 (see table 1). This fish was originally stocked in Las Vegas Bay in 2008 and had not been contacted since August 2009 (Albrecht et al. 2013). This fish has not been contacted anywhere else in the lake since the single contact at the CRI in 2011.

Fish 357 was originally stocked at the CRI in February 2010 where it remained until August 2011. Since then, this fish was contacted via two different SURs, and eventually tracked manually in Las Vegas Bay, where it has remained since April 2012. Additional details regarding this sonic-tagged fish can be found in Albrecht et al. (2013).

Perhaps the most interesting telemetry results at the CRI in 2012 were the movement of sonic-tagged fish to and from the flowing portions of the Colorado River and the lake proper. Nearly all sonic tags, except for those that are expired or stationary (see table 1), showed some degree of upstream movement throughout the season (figure 5).

Of the 17 fish tracked at the CRI, 10 showed movement upstream to at least the Pearce Ferry Rapid, where lotic conditions exist. Further movements upstream were demonstrated by five unique, sonic-tagged fish (figure 5). Sonic-tagged fish 5578 was contacted above the Pearce Ferry Rapid near the Pearce Ferry SUR (see figure 1 for SUR locations) in early March before returning back to the CRI, when it was contacted again in early April (figure 5). Sonic-tagged fish 485 was not only detected by the Pearce Ferry SUR on April 1, 2012, but it traveled further upstream, where it was detected at the bat cave on April 9, 2012, and again near Quartermaster Canyon on May 21, 2012 (figure 5). Sonic-tagged fish 249 and 5767 were also contacted near the bat cave in April and early May 2012. Finally, sonic-tagged fish 3774 was contacted near Quartermaster Canyon on April 28, 2012, after being detected on the bat cave SUR earlier that morning (figure 5). Interestingly, all five sonic-tagged fish that traveled upstream of the Pearce Ferry Rapid in 2012 returned to the lake, where they have all been contacted after July 2012, and no sonic-tagged fish have been detected on the bat cave SUR since late May 2012.

Sonic-tagged fish 3774, 5578, 447, and 6678 all showed multiple movements to and from the Pearce Ferry Rapid and lake proper within a relatively short period of time during spring (figure 5). This same back and forth movement was also found in fish 249, with movement to and from the inflow area and bat cave SUR during late April and early May (figure 5).

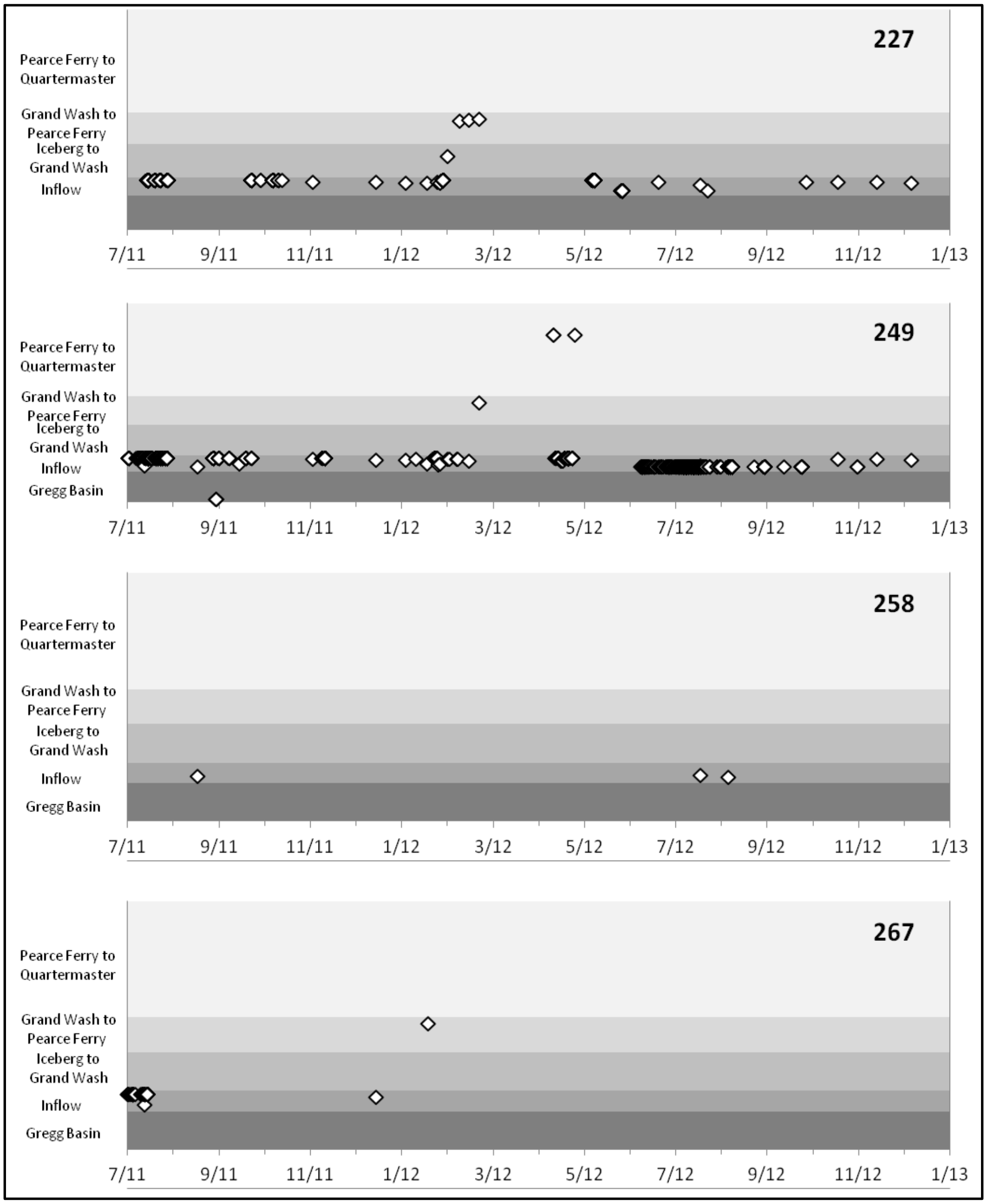

Figure 5.—Movement derived from active and passive sonic telemetry at the CRI from July 2011 to December 2012.
(Refer to Albrecht et al. 2013 for details regarding sonic-tagged fish 357.)

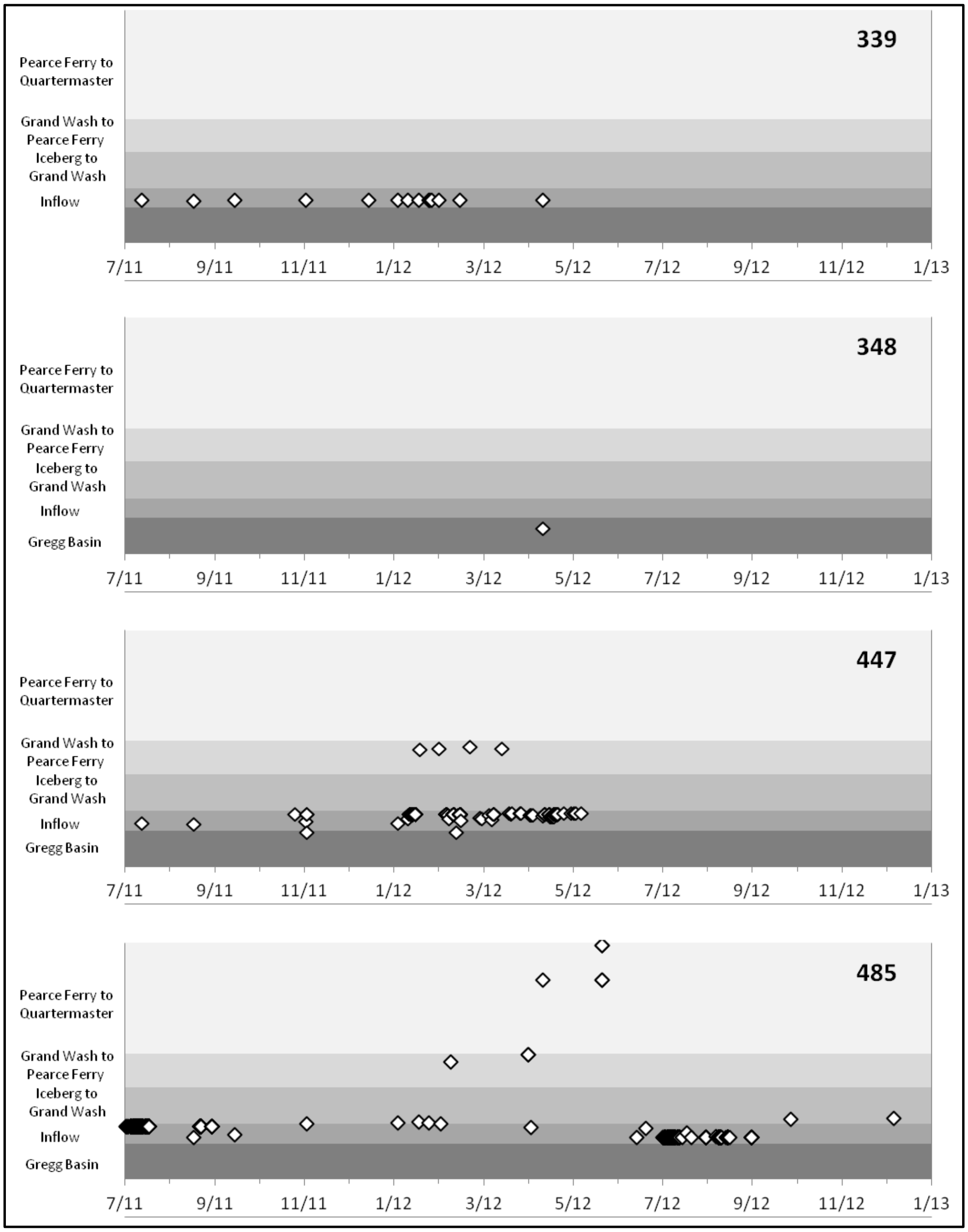

Figure 5 (continued).—Movement derived from active and passive sonic telemetry at the CRI from July 2011 to December 2012.
(Refer to Albrecht et al. 2013 for details regarding sonic-tagged fish 357 (continued).

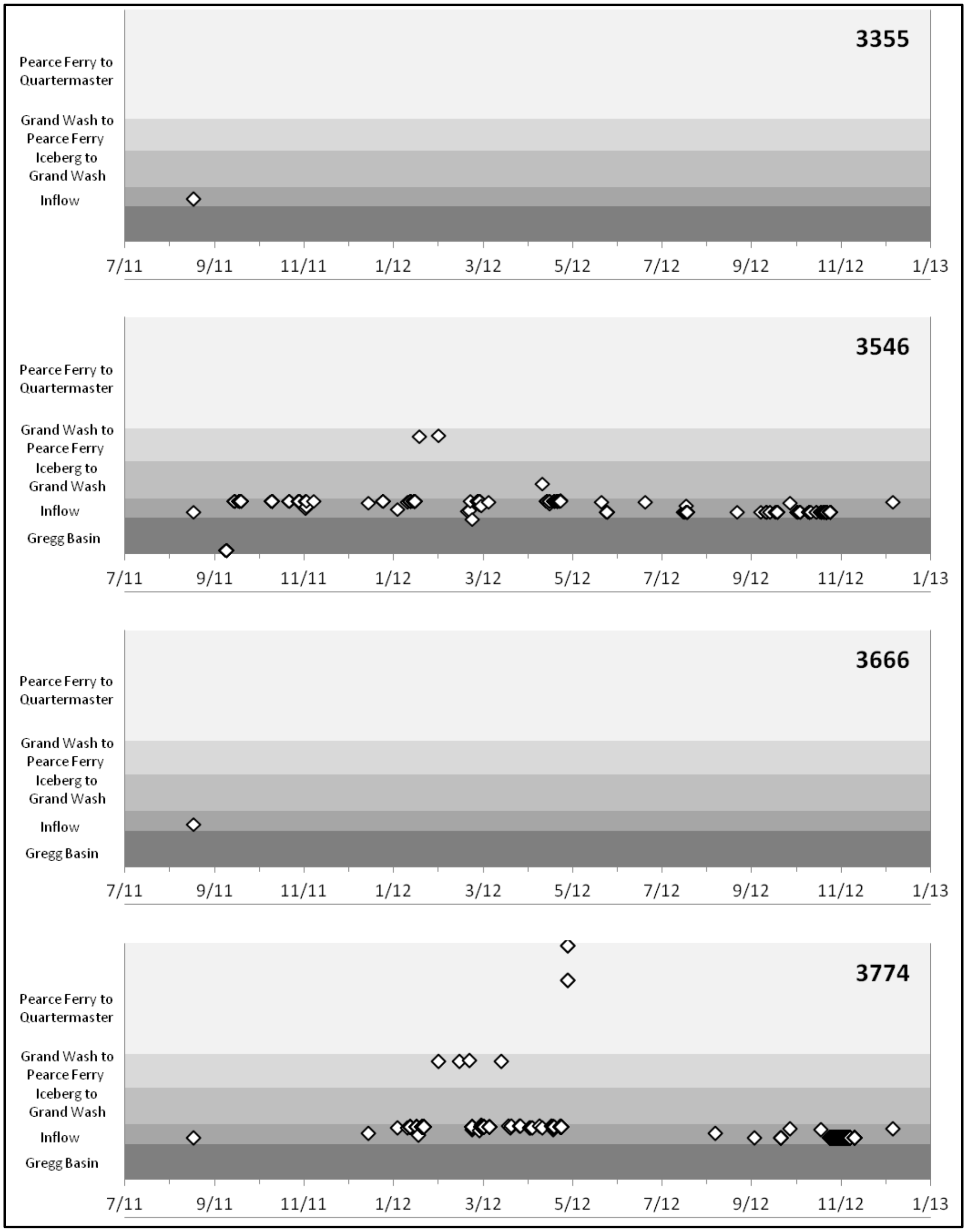

Figure 5 (continued).—Movement derived from active and passive sonic telemetry at the CRI from July 2011 to December 2012.
(Refer to Albrecht et al. 2013 for details regarding sonic-tagged fish 357 (continued).

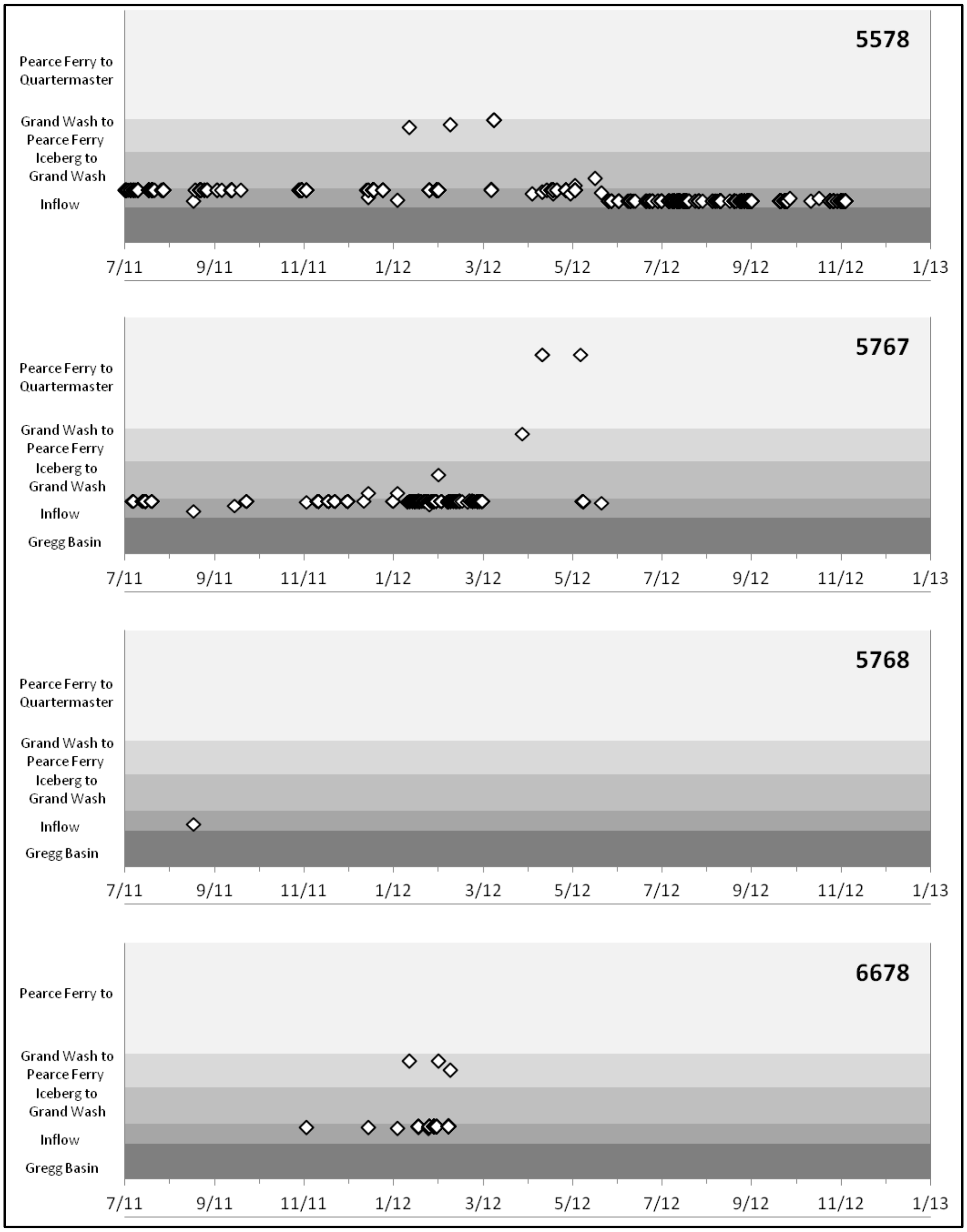

Figure 5 (continued).—Movement derived from active and passive sonic telemetry at the CRI from July 2011 to December 2012.
(Refer to Albrecht et al. 2013 for details regarding sonic-tagged fish 357 (continued).

Adult Sampling

Trammel Netting

Trammel netting was conducted for a total of 181 net-nights at the CRI from January through May 2012 (table 2). Trammel netting was generally concentrated near the river inflow because this area was frequented by sonic-tagged fish and because of previous successes capturing razorback suckers there during the 2010 and 2011 field seasons. Much of this effort was expended along the western shoreline between the mouth of Iceberg Canyon and "Lunch Cove" (figure 6).

Table 2.—Trammel netting effort (net-nights) at the CRI during 2012

Month	CRI net-nights
January	11
February	58
March	69
April	41
May	2
Total	**181**

One of the goals for the 2011 and 2012 field seasons was to increase our trammel netting effort relative to 2010 in hopes of capturing more razorback suckers from the CRI. We accomplished this goal both years by increasing our trammel netting effort by more than 600% as compared to 2010. Trammel netting resulted in the capture of 33 razorback suckers in 2012 (table 3), 26 of which were wild individuals. Thirteen of the 26 wild captures were new, unmarked fish (39.4% of total catch). Of the 51 razorback suckers captured at the CRI from 2010 to 2012, nearly 65% were captured in 2012, approximately 29% were captured in 2011, and the remaining 6% were captured in 2010. The recapture rate for razorback suckers at the CRI from 2010 to 2012 was 41.2%, which is similar to recapture rates found throughout other Lake Mead spawning areas (Kegerries et al. 2009; Albrecht et al. 2010c; Shattuck et al. 2011).

For the 2012 field season, razorback sucker catch per unit effort (CPUE), based on 33 total captures, was 0.18 fish per net-night (figure 7) compared to 0.10 and 0.08 fish per net-night in 2010 and 2011, respectively. Although catch rates have varied over the past three study years, they were not found to differ significantly (ANOVA, $p = 0.0686$). The CPUE for new, wild razorback suckers was 0.07 fish per net-night. Trammel netting resulted in perhaps the most striking evidence of razorback sucker spawning activity at the CRI in 2012. In comparison, the CPUE for razorback suckers captured at the CRI from 2010 to 2012 was greater than or

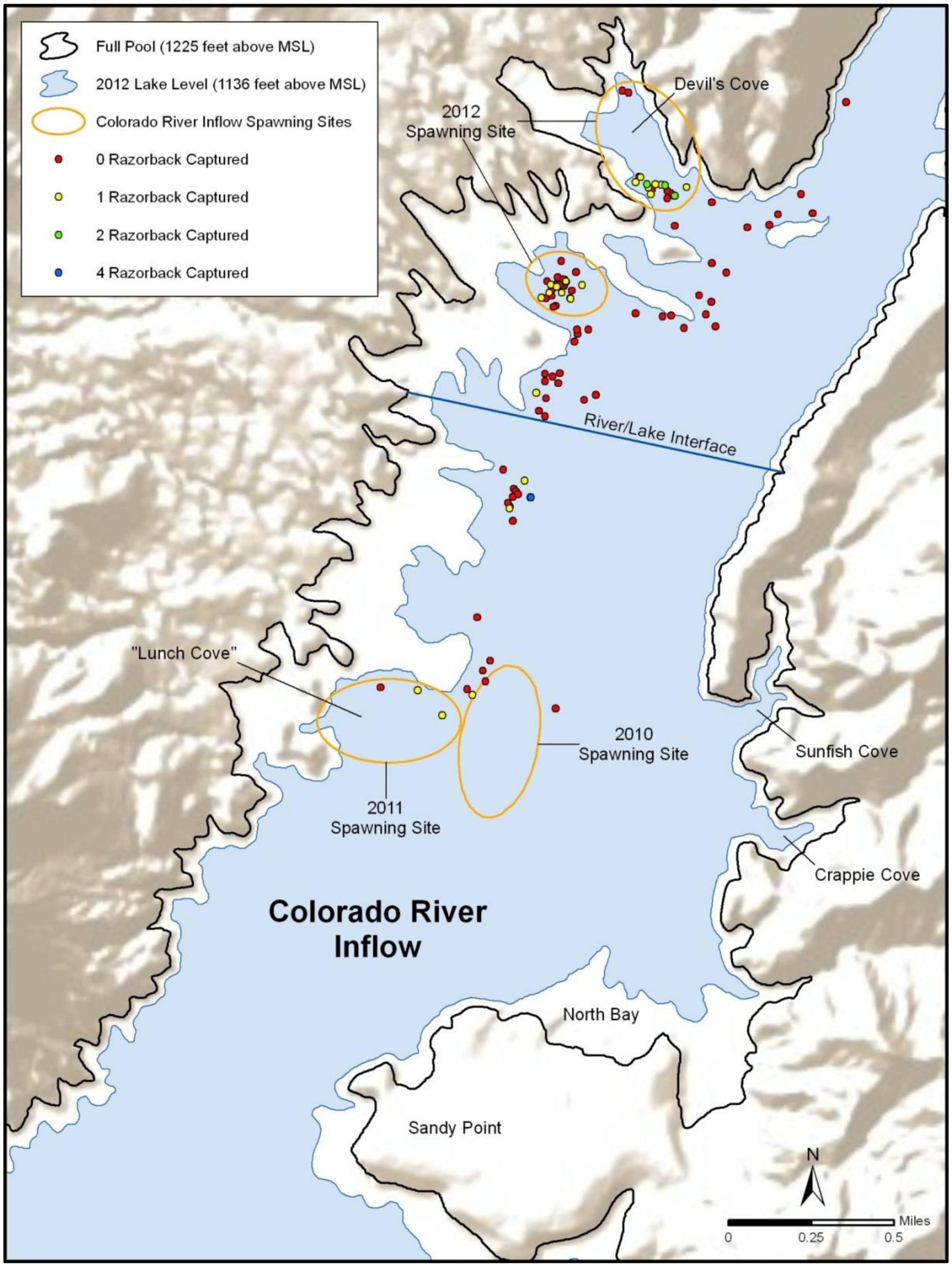

Figure 6.—Trammel netting locations and numbers of fish captured at the CRI, January – May 2012.

Table 3.—Date, PIT tag, size, and status information for razorback suckers and razorback sucker x flannelmouth sucker hybrids stocked or captured at the CRI during 2012

Date	Species[a]	PIT tag number	Sonic code	Date[b]	Recapture (status)	TL (mm)	FL (mm)	SL (mm)	Wt[c] (g)	Sex[d]
1/25/2012	RS	3D9.257C60EB6A	227	2/23/2010	YES (STOCKED 2010)	542	495	455	2042	M
1/26/2012	RS	384.1B796EE5D5		1/26/2012	NO	602	557	516	2680	F
2/21/2012	RS	384.1B796EE08B		2/21/2012	NO	604	551	519	2415	F
2/21/2012	RS	3D9.1C2C8572E3		2/4/2009	YES	635	589	552	2745	F
2/29/2012	RS	384.1B796EE629	6678	1/5/2011	YES (STOCKED 2011)	562	518	481	2605	M
3/1/2012	RS	384.1B796EE08B		2/22/2012	YES	NA[e]	NA[e]	NA[e]	NA[e]	F
3/1/2012	RS	384.1B796EE5D5		1/26/2012	YES	NA[e]	NA[e]	NA[e]	NA[e]	F
3/1/2012	RS	384.1B796EF01F		3/1/2012	NO	559	512	484	1755	M
3/1/2012	RS	384.1B796EEEEE		3/1/2012	NO	546	508	480	1930	M
3/1/2012	RS	3D9.1C2C8572E3		2/4/2009	YES	NA[e]	NA[e]	NA[e]	NA[e]	F
3/6/2012	RS	384.1B796EE89F		3/6/2012	NO	573	529	482	1830	F
3/6/2012	RS	384.1B796EE0FF	447	1/5/2011	YES (STOCKED 2011)	535	488	446	1965	M
3/6/2012	RS	384.1B796EF482		3/6/2012	NO	572	540	500	2155	F
3/6/2012	RS	3D9.1C2C8572E3		2/4/2009	YES	NA[e]	NA[e]	NA[e]	NA[e]	F
3/8/2012	RS	384.1B796EE7EF		3/8/2012	NO	557	513	483	1885	M
3/14/2012	RS	384.1B796EE629	6678	1/5/2011	YES (STOCKED 2011)	NA[e]	NA[e]	NA[e]	NA[e]	M
3/20/2012	RS	384.1B796EE31C		3/20/2012	NO	548	497	453	1905	M
3/20/2012	RS	384.1B796EE9AA		3/20/2012	NO	630	583	540	2530	M
3/20/2012	RS	5341793221		1/5/2011	YES (STOCKED 2011)	494	457	427	1495	M
3/20/2012	RS	384.1B796EE5D5		1/26/2012	YES	NA[e]	NA[e]	NA[e]	NA[e]	F
3/21/2012	RS	384.1B796EEEEE		3/1/2012	YES	NA[e]	NA[e]	NA[e]	NA[e]	M
3/21/2012	RS	384.1B796EE5D5		1/26/2012	YES	NA[e]	NA[e]	NA[e]	NA[e]	F
3/21/2012	RS	3D9.1C2D265F36		3/21/2012	NO	571	522	484	1965	M
3/27/2012	RS	384.1B796EF01F		3/1/2012	YES	NA[e]	NA[e]	NA[e]	NA[e]	M
3/28/2012	RS	384.1B796EE6C7		3/28/2012	NO	572	531	490	1945	M
4/3/2012	RS	3D9.1C2D265F36		3/21/2012	YES	NA[e]	NA[e]	NA[e]	NA[e]	M
4/3/2012	RS	384.1B796EEEB3		4/3/2012	NO	602	572	531	2245	F
4/5/2012	RS	3D9.1C2D2683FE		2/8/2011	YES	600	565	525	2485	F
4/17/2012	RS	3D9.1C2D265F36		3/21/2012	YES	NA[e]	NA[e]	NA[e]	NA[e]	M
4/24/2012	RS	384.1B796EE0FF	447	1/5/2011	YES (STOCKED 2011)	NA[h]	NA[e]	NA[e]	NA[e]	M
4/24/2012	RS	MORTALITY		4/24/2012	NO	555	515	475	1855	M
4/24/2012	RS	384.1B796EE6C7		3/28/2012	YES	NA[e]	NA[e]	NA[e]	NA[e]	M
4/24/2012	RS	384.1B796EE629	6678	1/5/2011	YES (STOCKED 2011)	NA[e]	NA[e]	NA[e]	NA[e]	M
1/12/2012	H	3D9.1C2D266590		1/12/2012	NO	480	440	405	1158	M
4/10/2012	H	384.1B796EE764		4/10/2012	NO	565	531	493	1860	F

[a] Species: RS = razorback sucker, and H = hybrid.
[b] Date originally stocked or originally captured.
[c] Wt = weight in grams.
[d] Sex: M = male, and F = female
[e] Not recorded, typically to avoid excessive handling stress.

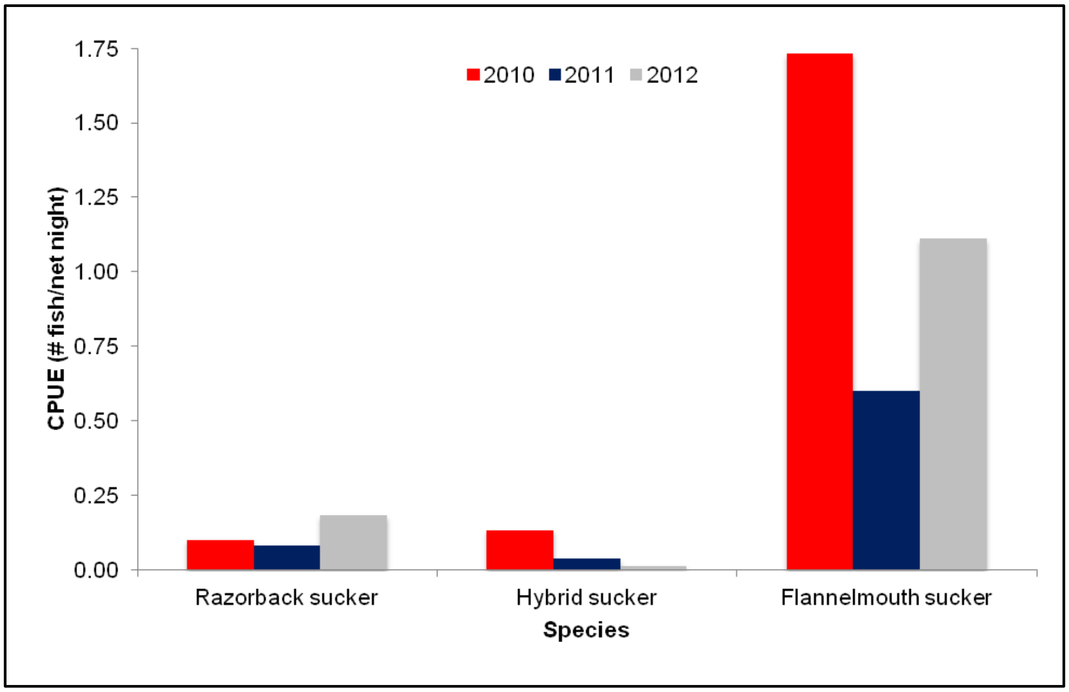

Figure 7.—Trammel netting CPUE values from the CRI, 2010–12.

equal to the CPUE at the Muddy River/Virgin River inflow area in 2005 and 2006, when that spawning aggregate was first identified and adult sampling was initiated (Shattuck et al. 2011). Razorback sucker CPUE at the CRI was also higher than the CPUE in Las Vegas Bay in 2012 (Albrecht et al. 2013).

The first wild razorback sucker captured in 2012 was a female with a TL of 602 mm (24 in). This fish showed slight spawning coloration but was not expressing eggs on January 26, 2012. The first wild, female razorback sucker expressing eggs was captured on February 21, 2012, and the first wild, male razorback sucker expressing milt was captured on March 1, 2012 (see table 3). The sex ratio of wild razorback suckers captured at the CRI in 2012 was 1:1 (males to females). Two razorback sucker x flannelmouth sucker hybrids were captured at the CRI in 2012, resulting in an overall CPUE of 0.01 hybrid fish per net-night (see table 3 and figure 7). One individual was a new, wild male, identified based on appearance, which was expressing milt on January 12, 2012. The other was a new, wild female, verified as a hybrid from a genetic sample (T. Dowling 2012, personal communication), which was displaying spawning color on April 10, 2012 (see table 3). Since 2010, 13 hybrids have been captured at the CRI. The sex ratio for hybrids was 1:2.3 (males:females), with both sexes typically expressing gametes or other signs of sexual maturity at the time of capture.

Additionally, 201 flannelmouth suckers were captured (36 were recaptured fish, and 165 were new, wild fish), resulting in an overall CPUE of 1.10 flannelmouth suckers per net-night for the 2012 field season (figure 7 and attachment 1). Since 2010, 365 flannelmouth suckers have been captured at the CRI. Catch rates have varied by year but have remained higher than catch rates of razorback or hybrid suckers. Many of these fish were immature, or sex was not readily identifiable at the time of capture; thus, sex ratios are not included.

Length and Growth Information

Although 20 razorback suckers were recaptured at the CRI in 2012, annual growth rate analyses were performed using data from 6 individuals (tables 3 and 4) because many of the razorback sucker captures during the 2012 field season were the result of a single individual being captured more than once during the study year. Differences in TL between capture periods were used to determine mean daily growth rate values, which were extrapolated to produce mean annual growth rates for appropriate, recaptured individuals. All stocked fish included in growth analyses were reared in Floyd Lamb State Park and stocked during the 2010 or 2011 sonic tagging events at the CRI. The estimated mean annual growth, as determined from all recaptured razorback suckers from the CRI in 2012, was 15.8 mm (0.59 in) per year (table 4). For comparison, the mean annual growth of all razorback suckers captured from other locations in Lake Mead during 2012 was 16.8 mm (0.66 in) per year (Albrecht et al. 2013). The mean annual growth of recaptured CRI-stocked fish was 19.7 mm (0.78 in) per year, while the mean annual growth of recaptured CRI-wild fish was 8.0 mm (0.31 in) per year. This value includes growth data from one wild individual originally captured in the Overton Arm and subsequently recaptured in Echo Bay during long-term monitoring efforts in 2009. This same fish was most recently recaptured at the CRI in 2012 (tables 3 and 4).

Razorback suckers captured at the CRI in 2012 ranged in TL from 494 to 635 mm (19.4–25.0 in). The hybrid suckers (razorback x flannelmouth) captured at the CRI in 2012 were 480 mm (18.9 in) and 565 mm (22.2 in) TL (see table 3). Finally, the more numerous flannelmouth suckers captured in 2012 at the CRI ranged in size from 204 to 565 mm (8.0–22.2 in) TL (figure 8).

Larval Sampling

Sampling for razorback sucker larvae was initiated at the CRI on January 25, 2012 (table 5). Razorback sucker larvae were first collected on April 3, 2012, when a single larval fish was captured in the northwest corner of Devil's Cove via a larval light trap. This area of the cove contained relatively thick, inundated

Table 4.—Growth histories for razorback suckers recaptured at the CRI during the 2012 field season

PIT tag number	Date stocked[a]	TL (mm)	Last date recaptured	TL (mm)	Total growth[b] (mm)	Days between measurement	Growth/ year[c]
Colorado River wild fish							
3D9.1C2C8572E3[d]	2/4/2009	602	2/21/2012	635	33	1,112	10.8
3D9.1C2D2683FE	2/8/2011	594	4/5/2012	600	6	422	5.2
						Mean annual growth	**8.0**
Colorado River stocked fish							
5341793221	1/5/2011	462	3/20/2012	494	32	440	26.5
384.1B796EE0FF	1/5/2011	505	3/6/2012	535	30	426	25.7
384.1B796EE629	1/5/2011	565	2/29/2012	562	-3	420	-2.6
3D9.257C60EB6A	2/23/2010	486	1/25/2012	542	56	701	29.2
						Mean annual growth	**19.7 ±7.5**
						Mean annual growth of all fish combined	**15.8 ±5.4**

[a] The date a fish was stocked into Lake Mead or the date a wild fish was originally captured.
[b] Negative values are thought to be attributable to measurement error.
[c] Growth/year = mm/365 days.
[d] Fish captured originally in the Overton Arm, then in Echo Bay (both in 2009), and most recently captured at the CRI.

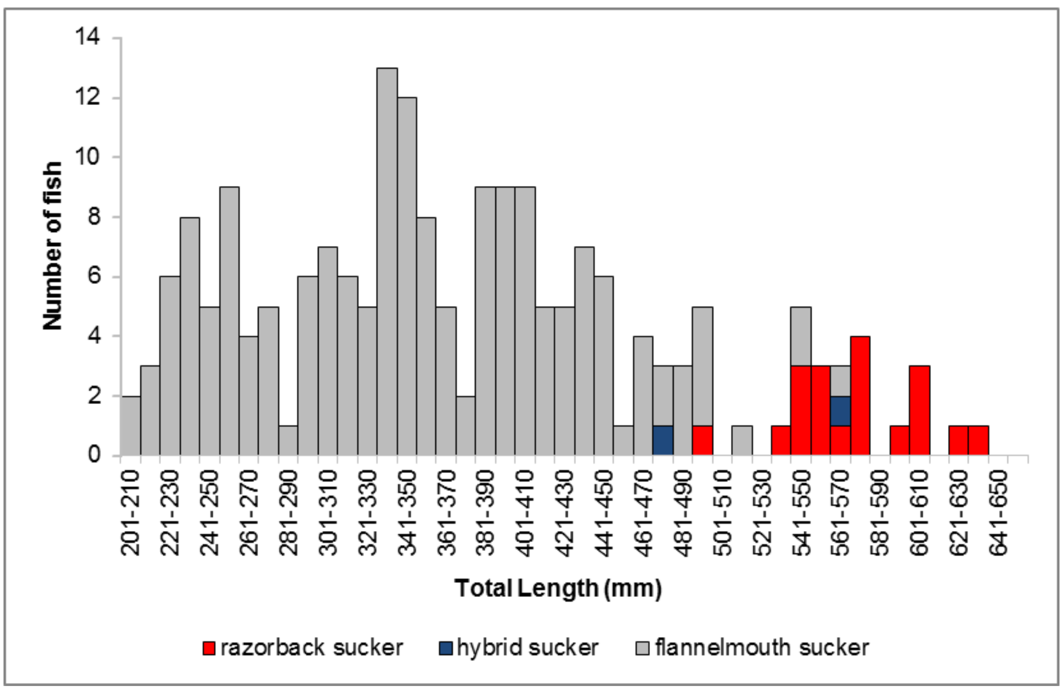

Figure 8.—Length-frequency distributions for native suckers captured at the CRI, 2012.

Table 5.—Number of razorback sucker larvae collected at the CRI during 2012

Date	CRI sampling sites		
	Minutes sampled	**Razorback sucker larvae collected**	**Catch per minute**
01/25/12	90	0	0.0000
01/31/12	90	0	0.0000
02/01/12	120	0	0.0000
02/06/12	120	0	0.0000
02/07/12	120	0	0.0000
02/08/12	120	0	0.0000
02/14/12	240	0	0.0000
02/16/12	240	0	0.0000
02/21/12	180	0	0.0000
02/22/12	180	0	0.0000
02/28/12	90	0	0.0000
03/05/12	120	0	0.0000
03/07/12	90	0	0.0000
03/14/12	195	0	0.0000
03/15/12	150	0	0.0000
03/19/12	150	0	0.0000
03/20/12	150	0	0.0000
03/21/12	150	0	0.0000
03/22/12	120	0	0.0000
03/26/12	300	0	0.0000
03/27/12	150	0	0.0000
03/29/12	120	0	0.0000
04/02/12	120	0	0.0000
04/03/12	405	0	0.0000
04/09/12	210	0	0.0000
04/16/12	375	0	0.0000
04/17/12	270	0	0.0000
04/18/12	300	0	0.0000
04/23/12	150	0	0.0000
04/24/12	240	2	0.0083
04/25/12	150	0	0.0000
04/30/12	180	3	0.0167
05/02/12	270	0	0.0000
05/07/12	180	0	0.0000
05/08/12	240	0	0.0000
05/09/12	180	0	0.0000
05/14/12	300	0	0.0000
05/16/12	150	5	0.0333
05/21/12	120	0	0.0000
Totals	**7,125**	**10**	**0.0014**

vegetation (predominately willows), making it difficult to sample using our traditional sampling methodology. Razorback sucker larvae were not collected using the crappie light method until April 24, 2012, when two were captured along a cobble and gravel shoreline with inundated vegetation in the cove south of Devil's Cove. In 2010 and 2011, this area (just south of Iceberg Canyon and upstream of the 2010 spawning area) contained many small, disconnected backwaters. As water levels rose in 2011, they were reconnected during the 2012 spawning period and were routinely frequented by razorback suckers (figure 9).

In total, 12 razorback sucker larvae were captured from April 3 to May 16, 2012, along the west shoreline of the CRI just below Iceberg Canyon (table 4 and figure 9). Ten of these larvae were collected by our standard crappie light method used in the Lake Mead razorback sucker studies for the past 16 years. Our exploratory method (utilizing larval light traps to cover more area and increase the time fished) resulted in the capture of two additional larvae. Only the data from the standard method are reported in table 5 for consistent CPUE comparisons among sampling years. However, the fact that larval fish can be captured at the CRI using larval light traps is a promising result. All razorback sucker larvae were captured within a 6-week period, when water temperatures ranged from 17.0 degrees Celsius (°C) (62.6 degrees Fahrenheit [°F]) to 22.0 °C (71.6 °F). A total time of 7,125 light-minutes was spent sampling using crappie lights, for a CPUE of 0.0014 razorback sucker larvae per minute (see table 5). Larval light traps were deployed for a total of 37,102 light-minutes, for a CPUE of 0.0001 razorback sucker larvae per minute, or 0.05 fish per trap set. In comparison, the catch per minute value of razorback sucker larvae collected at the CRI in 2012 is higher than that observed at the Muddy River/Virgin River inflow area in 2007 (0.001), shortly after that spawning aggregate was first identified and larval sampling was initiated (table 6). Although statistically insignificant (ANOVA, $p = 0.0728$), the 2012 larval razorback sucker catch rate was lower than both the 2010 and 2011 catch rates (see table 6). The capture of razorback sucker larvae and sexually mature, ripe adults again confirmed the CRI as a spawning location for razorback suckers in 2012.

Although other larval sucker species (flannelmouth and razorback x flannelmouth suckers) were collected in 2010 and 2011, razorback sucker larvae were the only catostomid larvae collected in 2012. The collection of other catostomid larvae, along with sonic telemetry and trammel netting data, help confirm that the CRI provides spawning habitat not only for razorback suckers, but also for flannelmouth suckers, and the potential hybridization between the two species.

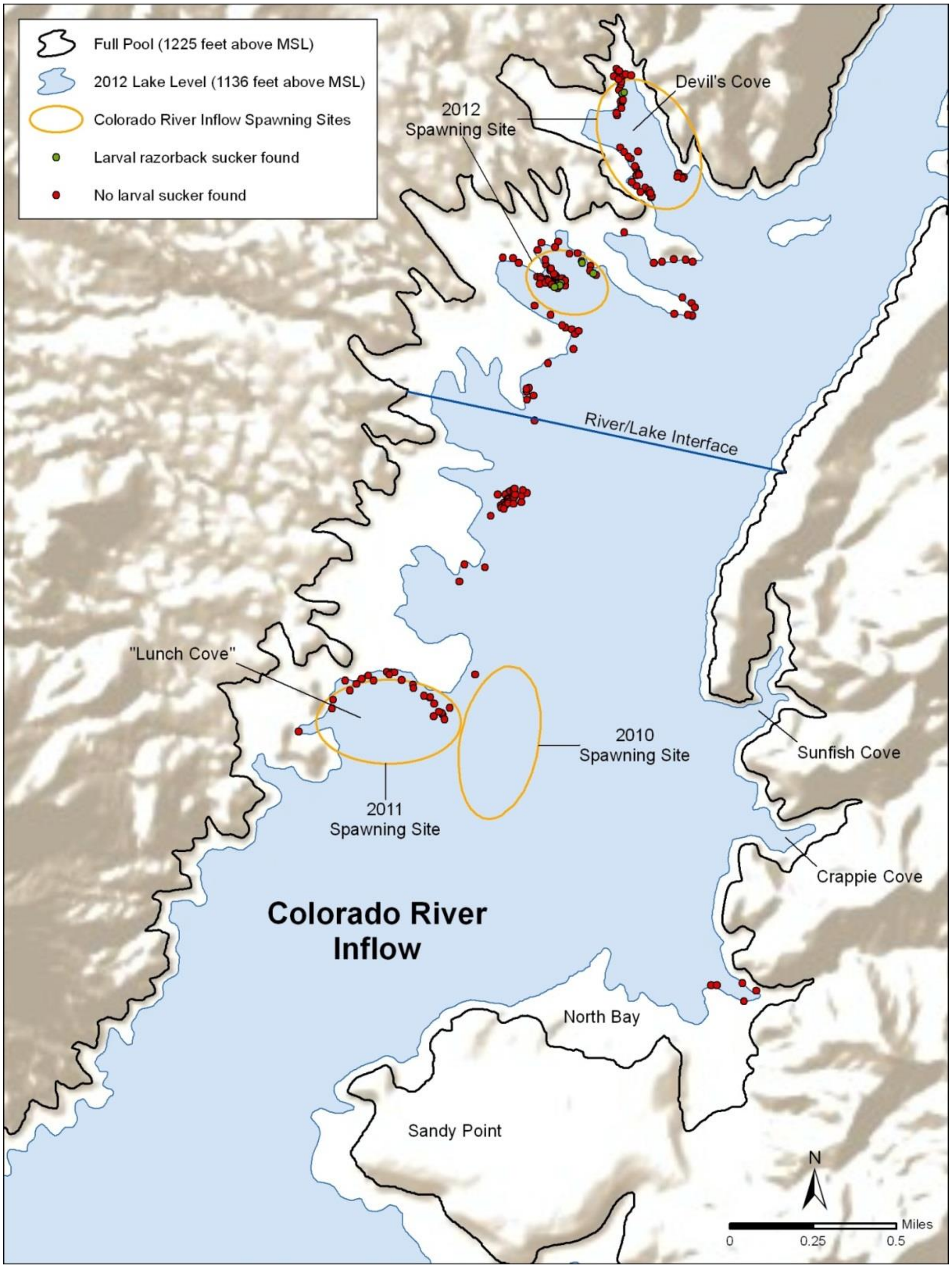

Figure 9.—Larval razorback sucker sample and capture locations at the CRI, 2012.

Table 6.—Larval razorback sucker catch-per-minute comparisons by primary sampling location on Lake Mead for 2007–12 (modified from Albrecht et al. 2013)

Primary sampling location	2007	2008	2009	2010	2011	2012
CRI	–	–	–	0.002[a]	0.007[a]	0.0014[a]
Las Vegas Bay	0.39	0.43	0.342	0.093	0.282	0.1791
Echo Bay	0.43	0.024	0.021	0.269	1.482	0.2197
Muddy River/Virgin River inflow	0.001	0.116	0.107	0.011	0.013	0.0036

[a] Razorback sucker larvae data only.

Spawning Site Identification and Observations

In 2012, the primary CRI spawning sites were determined to be along the western shoreline of Lake Mead, below the mouth of Iceberg Canyon (see figure 9), or, more specifically, Devil's Cove, and the second cove to the south and west of Devil's Cove. The shoreline substrates of these coves consisted mostly of cobble, gravel, and sand. Ripe fish signified that spawning was likely occurring in these areas. Subsequent capture of larval fish confirmed successful spawning in both coves. Furthermore, sonic/radio-tagged fish frequented these areas. Similar to other spawning areas throughout Lake Mead, spawning adults seemed to shift their habitat use from year to year in response to changing lake levels. In 2012, the majority of the spawning fish moved upstream from the previous year into habitats that would have been considered isolated backwaters during the previous year. Fluctuating lake levels over the last 10 years (the majority in decline) have influenced habitat conditions in all areas where razorback sucker sampling activities have occurred during studies on Lake Mead (Albrecht et al. 2010c). Typical habitat shifts at the previously known razorback sucker spawning areas are characterized by fish following shoreline configurations as needed, apparently to accommodate fluctuating lake levels and changing conditions (Albrecht et al. 2010c). As of July 1, 2012, the lake elevation was approximately 339.9 m (1,115 ft) asl, compared with 362.6 m (1,106 ft) asl recorded the previous year on this same date (figure 10).

Razorback Sucker Aging

At the CRI in 2012, all 13 of the new, wild razorback suckers, and the 1 recaptured, stocked, adult razorback sucker, had fin ray sections surgically removed for age determination. A definitive age was obtained for each fish (attachment 2 and figure 11). Ages for the new, wild fish ranged from 6 to 10 years, meaning these individuals were spawned from 2002 to 2006. The recaptured fish was originally stocked from Floyd Lamb State Park for telemetry purposes in 2011 and was aged at 11 years.

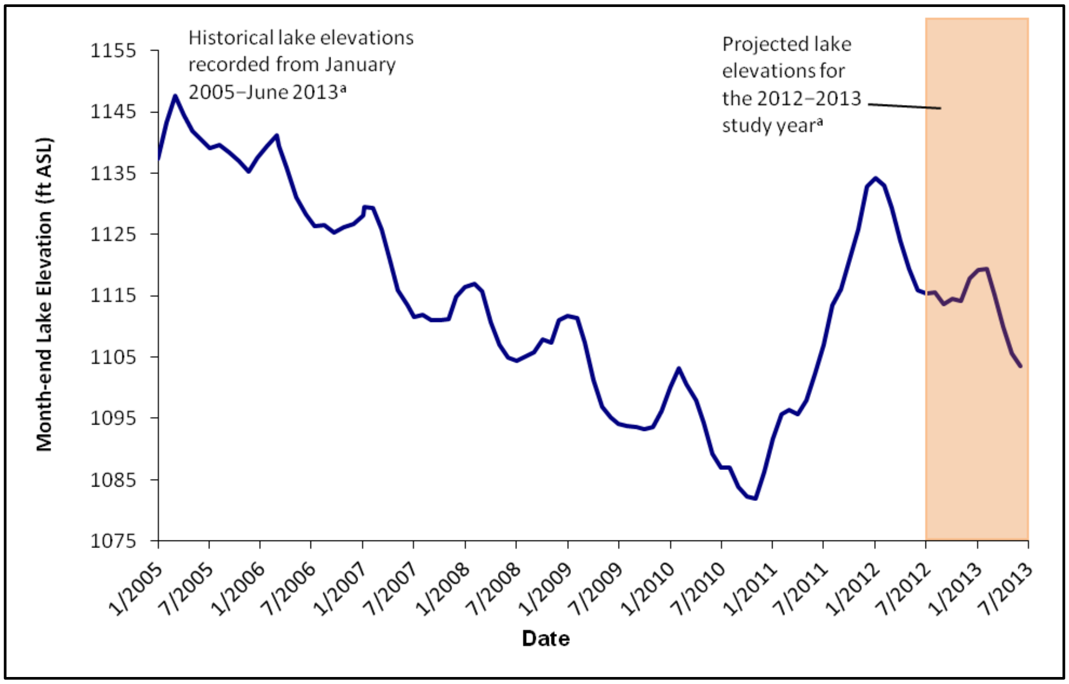

Figure 10.—Lake Mead elevations using a combination of actual, recorded, and historical lake elevation data as well as projected lake elevations for the remainder of the 2012–13 study period (Reclamation 2012).

In addition to presenting information on the razorback suckers captured and aged at the CRI in 2012, figure 11 presents cumulative Lake Mead razorback sucker recruitment data as reported by Albrecht et al. (2013). The rationale for presenting the larger aging and recruitment dataset from Lake Mead with the CRI aging data is to continue putting razorback sucker recruitment events into a more holistic dataset. It is not our intent to put the CRI 2012 data into the larger context of lake-wide Lake Mead razorback sucker recruitment. It is our hope that continued efforts in all study areas will add to the body of knowledge pertaining to the unique razorback sucker recruitment occurring within Lake Mead.

To date, all of the aged fish were spawned between 1972 and 2008, with the exception of one fish, which was spawned around 1966 (attachment 2). Until the last few seasons, the majority of fish aged were spawned during high lake elevations between 1978–89 and 1997–99 (figure 11). However, recent data, now including aging data from CRI specimens, show Lake Mead razorback sucker recruitment occurring beyond 1999, which coincides with the steady decline in lake levels through 2010. With the inclusion of this year's data, 2001–06 still appears to be one of the better periods for Lake Mead razorback sucker recruitment despite dropping lake levels (figure 11). When combined with the long-term data, fish aged from the CRI coincide with strong cohorts observed from other areas of the lake (Albrecht et al. 2013).

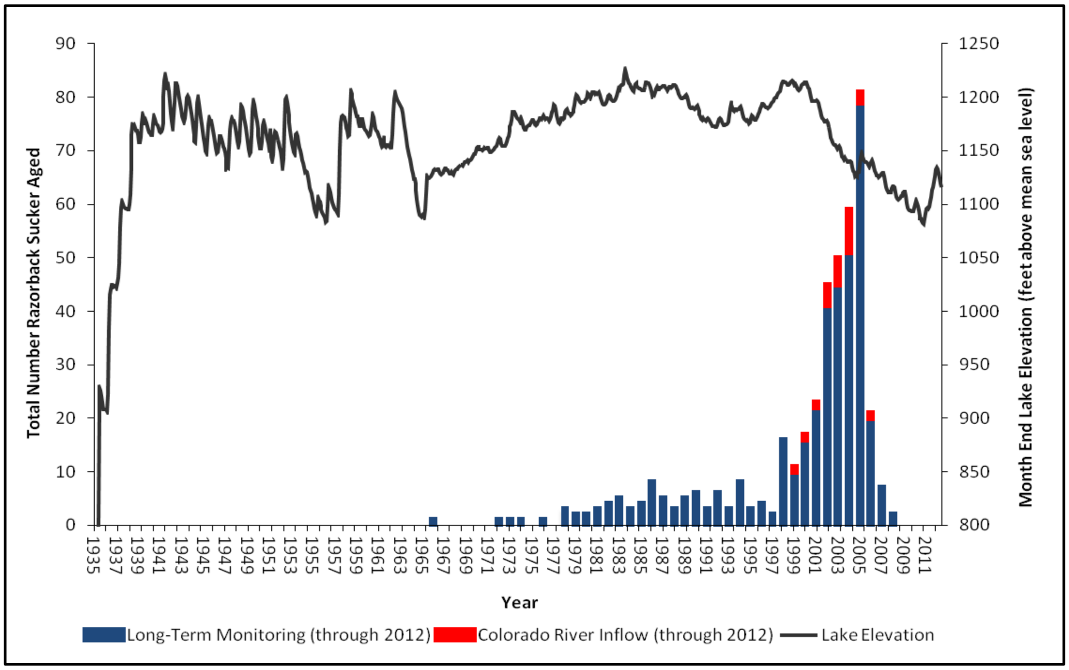

Figure 11.—Lake Mead hydrograph from January 1935 to June 2012, with the number of aged razorback suckers spawned each year.
Red bars denote the number of razorback suckers captured at the CRI through 2012, and blue bars denote recruitment and aging data from the cumulative long-term monitoring and aging efforts (modified from Albrecht et al. 2013).

Fin ray specimens from both flannelmouth suckers and hybrid suckers were obtained using the methodologies described for razorback suckers. Specific ages obtained for 1 hybrid and 14 flannelmouth suckers are given in attachment 3. Depending on the project scope and overall interest, recruitment patterns of flannelmouth suckers and hybrid suckers could also be investigated as more data are collected on these native species during future efforts at the CRI.

Population and Survival Rate Estimation Results

Population Estimation

Using data from 2010–12, the CRI population was estimated at 41 individuals and bounded with a 95% confidence interval (CI) of 33 and 61 individuals (table 7). Although it is feasible to estimate the population of razorback suckers at the CRI as a standalone population, movement data suggest that wild and stocked individuals do move and occupy other spawning locations. Thus, estimates were calculated for the northern portion of the lake (CRI, Echo Bay, Muddy River/Virgin River inflow) and lake-wide (including Las Vegas Bay). The CRI, Echo Bay, and Muddy River/Virgin River inflow estimate was calculated at 529 individuals (CI = 408–715), while the lake-wide estimate was calculated at

Table 7.—Population estimates for razorback suckers in Lake Mead using mark-recapture data from 2010–12 from the program MARK

Population estimate	95% CI	Capture histories	Capture probability
CRI			
41	33–61	41	0.0282
CRI, Echo Bay, and Muddy River/Virgin River inflow area			
529	408–715	35	0.0114
Lake-wide			
596	468–786	41	0.0116

596 individuals (CI = 468–786) (Albrecht et al. 2013) (table 7). Model ranking according to AICc weights and model likelihoods for estimates produced in the program MARK can be found in attachment 4.

Survival Rate Estimation

The model ranking in the program MARK found the best fit CJS model carried 100.0% of the AICc weight, and the best fit Pradel model carried greater than 99.9% of the AICc weight. The CJS survival model calculated an estimated apparent survival rate of 0.92 (CI = 0.87–0.95), and the Pradel model calculated an estimated apparent survival rate of 0.87 (CI = 0.83–0.91) (table 8).

Table 8.—Lake-wide apparent survival rate estimates for razorback suckers in Lake Mead using mark-recapture data from 2010–12

Model	Apparent survival rate estimate	95% CI (lower)	95% CI (upper)	Capture histories	Capture probability
CJS	0.92	0.87	0.95	41	0.0249
Pradel	0.87	0.83	0.91	41	0.0368

DISCUSSION AND CONCLUSIONS

The information collected since 2010 at the CRI has helped expand our knowledge of spawning behavior, habitat use, growth, and age of razorback sucker populations in Lake Mead. Combined evidence from sonic telemetry, trammel netting, and larval collection data confirm that razorback suckers occupied CRI habitats and successfully spawned there in 2010, 2011, and 2012. It is still unclear how consistently razorback sucker spawning occurs, or to what degree razorback sucker recruitment occurs, within this area. Although we documented sonic-tagged fish moving upstream of the Pearce Ferry Rapid as far as Quartermaster Canyon in 2012, it is still a bit unclear (based on the data collected in the last three field seasons) if, when, and why wild razorback suckers utilize the Colorado River proper. Tracking fish movement upstream was a substantial link to razorback sucker habitat use of the lower Grand Canyon. In fact, in October 2012, Arizona Game and Fish Department personnel captured an unmarked adult razorback sucker near Spencer Creek (RM 246) (A. Bunch 2012, personal communication). This finding, combined with sonic-tagged fish moving into the lower Grand Canyon, is significant considering razorback suckers have not been collected in the Grand Canyon in approximately two decades (Valdez et al. 2012a). There is much to be learned regarding razorback suckers and what functions the Lower Grand Canyon may serve in wild recruitment. These recent findings identify linkages between Lake Mead and the lower Grand Canyon and support the need for additional studies to fully understand razorback sucker use of the Lower Grand Canyon (Valdez et al. 2012b).

Sonic Telemetry

Sonic telemetry proved to be a valuable tool during the 2012 field season. We were able to maintain contact with fish from the January 2011 and February 2010 stocking and tagging efforts as well as with one fish tagged during the 2008 long-term studies. Considering the size of the CRI, its dynamic nature, and the previously unknown status of razorback suckers using its habitats (before this study), the success of using pond-reared fish to locate new, wild individuals exceeded expectations for the first 3 years of this study. Along with habitat and movement data, sonic-tagged fish provided crucial information regarding the general location of the razorback sucker population, greatly enhancing the ability to capture new, wild razorback suckers at the CRI.

These observations from the CRI reinforce the importance of inflow areas to razorback suckers. Large inflow areas have been documented to contain increased fish species diversity and reproduction and to allow for recruitment in a variety of systems (Kaemingk et al. 2007; Albrecht et al. 2010a; Schreck 2010). It was important to further investigate razorback sucker use of shallow, riverine areas within the Colorado River proper in 2012 because annual patterns and variations in movement seemed to be dictated by differing water levels and changes in habitat. For example, in early 2012, water elevations were high enough that the Pearce Ferry Rapid was easily navigable by boat throughout the razorback sucker spawning season. It is unknown whether this rapid is a barrier to upstream fish movement during lower water elevations, but perhaps higher lake levels allowed for upstream movement above the rapid. Likewise, it will be important to continue searching for sonic-tagged fish to see whether they return to previously utilized spawning areas during similar water years or shift spawning locations based on water levels as was documented in 2012.

Data stemming from the CRI sonic-tagged fish helped identify the 2012 spawning sites, illustrated movement patterns, and provided valuable information regarding razorback sucker habitat use within Lake Mead and the Colorado River. In addition, sonic-tagged fish helped determine the placement of trammel nets for the successful capture of wild razorback suckers. As water levels fluctuate, sonic-tagged fish will continue to provide valuable data on changes in razorback sucker movement patterns, habitat use, and spawning site selection regardless of whether or not study efforts occur within the lake, the interface, or the river proper in future years.

In August 2011, one Las Vegas Bay sonic-tagged fish (3355) from a 2008 stocking was located at the CRI during a single tracking event. In 2010 and 2011, we were able to document one Muddy River/Virgin River inflow area sonic-tagged fish and one Las Vegas Bay sonic-tagged fish (codes 3354 and 465, respectively, both from the 2008 stocking event) using the CRI. While fish 3355 was not contacted or captured again to verify its location, both fish apparently integrated or, at a minimum, joined the CRI aggregate to spawn (Albrecht et al. 2010c; Shattuck et al. 2011). This integration suggests that stocked razorback suckers in Lake Mead navigate throughout the lake and can leave their original stocking location to integrate into other, potentially unknown spawning aggregates. This finding also suggests we should refrain from citing tag failure or surgical complications when sonic-tagged fish are not immediately located during standard telemetry or monitoring efforts.

This conclusion is further supported by contacts made during the 2011 season with sonic-tagged fish 267, which was originally thought to have experienced tag battery failure in 2010 (Kegerries and Albrecht 2011).

Finding fish that had been stocked in other parts of the lake at the CRI raises the question of whether wild fish from populations at the long-term monitoring locations display similar large-scale movements. Such evidence was discovered this year when a wild, female razorback sucker originally captured at the Muddy River/Virgin River inflow area in 2009 was recaptured at the CRI near the confirmed spawning areas. In fact, this same fish was also recaptured in Echo Bay in 2009, shortly after being captured at the Muddy River/Virgin River inflow area. The question of wild fish movement and utilization of multiple spawning locations could also be answered by sonic tagging wild, Lake Mead razorback suckers of various size classes, similar to efforts conducted during the earlier years of this study (e.g., Holden et al. 1997). Other questions posed in this report could also be addressed by sonic tagging wild razorback suckers, such as, do wild fish utilize the flowing portions of the Colorado River proper as we saw in 2012 with stocked fish? What are the behaviors and habitat use of juvenile, wild razorback suckers in Lake Mead, and do they hold the key to understanding recruitment success? A pilot study to help address this question was initiated in 2012 (Albrecht et al. 2013).

Of particular interest is our use of sonic-tagged fish from the 2010 and 2011 stocking events in the Nevada portions of the Colorado River. Anticipating that sonic-tagged fish stocked into the Colorado River would remain in the river, combination sonic/radio-tagged fish were stocked there in 2011. Although these fish did not provide data on upstream movement throughout the river proper, many tagged individuals used riverine habitats closer to the lake interface. For example, in 2011, we found aggregates of sonic-tagged fish periodically occupied slower-moving slackwaters and eddies in this dynamic portion of the river. In 2012, this same pattern of riverine movement and habitat use was observed just downstream from the Pearce Ferry Rapid. Because water levels were higher and the rapid did not appear to be a barrier for upstream movement (based on visual observations only), efforts to track sonic-tagged fish above the rapid into the lower Grand Canyon were conducted. Based on SUR data, it was determined that sonic-tagged fish did travel up and down the river proper above Pearce Ferry Rapid. It was interesting that the majority of the sonic-tagged fish located at the CRI in 2012 occupied flowing portions of the river at some point. Two of these fish even traveled more than 48 km (30 mi) upstream. Although these are stocked fish, it is important to remember that they are likely functioning similarly to wild fish, as suggested by their use for years to successfully find wild, spawning populations. It is hypothesized that wild fish would exhibit similar behavior, and utilizing wild fish to test this hypothesis is recommended. These riverine movements over the past two field seasons led field crews to develop methods to try to capture other wild razorback suckers behaving similarly. Although unsuccessful, methods to capture razorback suckers inhabiting the river since 2010 have included trammel netting, seining, drift netting, electrofishing, and setting fyke nets. Perhaps modified methods of hoop netting or even block seining could provide better results. These results are not surprising given the dynamic nature of the inflow area and the Colorado River proper, along with the relatively short period that the sonic-tagged fish occupied slackwater and eddy habitats, which made it difficult to devote much field time to those areas.

Although sonic-tagged fish were detected utilizing flowing portions of the river proper both in 2011 and 2012, the scale in which movement occurred was starkly different. In fact, even the two fish stocked into the river proper in 2011 quickly made their way downstream into the lake. The reason for this movement is unclear, especially since one of those same fish was detected above the Pearce Ferry Rapid in 2012, and it remained there for approximately 5 weeks. Similar to 2011, all of the sonic-tagged fish detected above Pearce Ferry Rapid in 2012 returned to the lake by late July. Perhaps the use of the river is related to habitat preference or availability and/or ease of passage depending on lake and river conditions. These stocked fish could also be in search of wild razorback suckers but are unable to maintain themselves in flowing water systems because they have not been conditioned to do so; thus, they move into the lake. This gap in our understanding underscores the importance of tagging wild razorback suckers to determine if they use river habitats differently than stocked fish. Regardless of our lack of understanding at this time, the amount of time that stocked, sonic-tagged fish spend in the flowing portion of the Colorado River, and their frequent movement in and out of the area, suggests the habitat offered by the combination of the lake and the river may be critical for wild razorback suckers. As we continue to study this location, it will be important to maintain the ability to track fish and sample in areas they frequent to answer questions regarding how they use the lower Colorado River and CRI.

Although maintaining contact with fish moving in and out of the flowing portions of the Colorado River is critical, this environment poses many difficulties and can reduce tracking effectiveness using standard methods. This observation led to an investigation into the most effective and efficient methods of tracking under these less than desirable conditions. It was found that it is feasible to effectively track sonic-tagged razorback suckers employing a combination of passive and active telemetry using a variety of settings in order to capitalize on listening time while drifting downstream.

Passive telemetry proved to be a valuable method for tracking sonic-tagged fish at the CRI. Because of limited knowledge of razorback sucker existence at the CRI, it remained important to track the movement of sonic-tagged fish to locate spawning aggregates. The SURs were placed strategically to try to capture any large-scale movements into or out of Gregg Basin and the Colorado River. This technology aided in tracking fish 357 as it made its way out of the CRI and into Las Vegas Bay. Fish not contacted for long periods via manual or passive methods may have been in areas of the river proper or the lake that are not conducive to active sonic telemetry detection. They may also have been at depths, distances, or in areas of underwater cover that did not allow for detection by the SUR. Although the SURs collected valuable data, maintaining them in the lake and deploying them in the river is an ongoing task, with challenges similar to those of any other new and developing methodologies. Issues with tampering and theft, as well as changing water levels and river conditions, mean the SURs demand fairly regular attention and monitoring. Despite these potential problems, the SURs collected data without field crews present, which increased the efficiency and effectiveness of the study.

The usefulness of stationary SUR technology can be limited by geographic placement. To obtain effective movement data, several SURs must be located within a given basin. Combining active and passive tracking methods allowed field crews to more efficiently and effectively locate spawning razorback suckers. SUR data are also validated by manual tracking data. The SURs were valuable tools in the active search for sonic-tagged fish—we were able to narrow the search area based on the most recently logged data. SUR data also provided insight into when razorback suckers move and how far they can potentially travel in a given period of time. As more data are collected on interbasin fish movements within Lake Mead, SURs may help determine whether Lake Mead razorback suckers should be managed as one population or as multiple, independent, and largely separate populations.

Adult Sampling- and Spawning-Related Observations

Perhaps the most interesting conclusion presented in this report is that razorback suckers successfully spawned at the CRI in 2012, confirming consistent annual spawning since investigations began in 2010. While maintaining increased effort similar to 2011, captures of razorback suckers more than doubled from the previous season. The capture of razorback sucker x flannelmouth sucker hybrids and flannelmouth suckers has also been a fairly common occurrence at the CRI since 2010 (Albrecht et al. 2010b; Kegerries and Albrecht 2011). Although hybridization between flannelmouth suckers and razorback suckers is extensively documented and summarized by Bestgen (1990), the reasons for hybridization between these species at the CRI are not clearly understood. Hubbs and Miller (1953) hypothesized that chance mixing of eggs and sperm in flowing water may be the main cause when both species are present in the same habitats. Habitat alterations could also potentially reduce reproductive isolation, thereby increasing the likelihood of hybridization (Muhlfeld et al. 2009), which may be more likely the case at the CRI. Hybridization between these two species has also been documented on the San Juan River, where razorback suckers are stocked on top of large flannelmouth sucker populations (Ryden 2006). It is unclear whether hybridization will have a negative impact on the wild razorback sucker population at the CRI or whether the hybrids will contribute to reproduction and recruitment of razorback suckers. It appears the hybrids do produce viable gametes, which allows for backcrossing to either species (T. Dowling 2012, personal communication). Flannelmouth suckers and razorback suckers are both Lower Colorado River Multi-Species Conservation Program species of concern, highlighting the importance of the CRI for the sustainability and conservation of both species. With the presence of flannelmouth, razorback, hybrid, and bluehead suckers (Kegerries and Albrecht 2011), the CRI appears to provide key habitat for native suckers within the Colorado River system.

Compared to Echo Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area, very little is known regarding habitat use of spawning razorback suckers at the CRI. Similar to the original documentation of the Muddy River/Virgin River inflow area as a spawning site for razorback suckers in 2006, sonic-tagged fish movement patterns within specific CRI habitats that appeared to be potential spawning areas lead to the collection of ripe, wild, adult razorback suckers. Important goals for future investigations of the CRI will be to ascertain whether recruitment is occurring there, and if so, how that recruitment is occurring and to what degree the recruitment impacts Lake Mead razorback sucker population dynamics as a whole. Perhaps, like the Muddy River/Virgin River inflow area in 2005, our investigations at the CRI coincide with its early establishment as a spawning area. The data showing an increase in numbers of wild, adult razorback suckers, the expansion of the areas used to spawn, and the lack of juvenile razorback suckers seems to support the hypothesis that, at this point, the CRI is a fairly new spawning area. We suspect that successful recruitment will occur at the CRI and that those young individuals will appear in subsequent sampling efforts either by direct capture or through aging techniques.

Lake levels are projected to fluctuate on Lake Mead over the next several years (see figure 10). If this occurs, razorback suckers at the CRI are likely to change spawning site locations to adapt to the highly variable conditions imposed by these fluctuations and Colorado River dynamics as they have done in preceding years. Given the relatively large inflow area and delta formed by the Colorado River proper, as well as the magnitude of change that has occurred at the CRI (kilometers of change rather than meters of change typical at the other, more thoroughly researched study areas), we hypothesize that shifts in spawning site location will continue to occur at the CRI during future field seasons. These changes necessitate continued and careful monitoring of this relatively understudied razorback sucker spawning aggregate. How the potentially dramatic habitat changes will affect razorback sucker spawning success, and ultimately recruitment at the CRI are unknown and must be tracked over time.

In summary, the rather intensive level of trammel netting conducted at the CRI in 2012 yielded several interesting results.

1. Razorback suckers are present at the CRI and can be found in spawning condition on and near appropriate habitat during the spawning period. Successful spawning has been documented and confirmed for the past three field seasons. The number of razorback suckers at this location is rather nebulous, and the timing of spawning appears to be more variable than at other known spawning areas in Lake Mead (Albrecht et al. 2010b, 2010c; Kegerries and Albrecht 2011; Shattuck et al. 2011). Factors for this disparity may include annual river and lake conditions, inter- and intra-annual water level fluctuations (and the resulting gains or losses of littoral habitat types at the CRI), temperature differences and variability between the lake and river proper, and the interaction of these factors. A more holistic understanding of the importance of this unique location to razorback suckers may be attained through continued efforts at the CRI and the Colorado River proper.

2. Wild, ripe razorback suckers were captured at different locations for three consecutive field seasons at the CRI, demonstrating the possibility of unknown aggregates of razorback suckers at other locations in Lake Mead or the Colorado River proper to exist. Sampling unexplored areas of the lake or within flowing portions of the river with suitable razorback sucker habitat may lead to documentation of new, unknown spawning aggregates. Such sampling would require increased field efforts; however, our current methodologies for finding new aggregates would ensure that field efforts would be efficient and effective.

3. The sonic telemetry techniques described in this report, as well as in other Lake Mead razorback sucker reports, can be used as an effective tool for trammel net placement to help document razorback sucker habitat use in understudied and unexplored areas of Lake Mead. Telemetry has also proved important for determining the extent of razorback sucker interaction within the lower Grand Canyon. Therefore, these techniques should be continued and improved though future efforts.

4. Razorback and flannelmouth sucker (likely even bluehead sucker) habitat use overlaps at the CRI, as throughout the upper basin. Hybridization of these native sucker species has been documented through direct capture of razorback sucker x flannelmouth sucker hybrids. Trammel netting, sonic telemetry, and larval sampling data from the CRI suggest that all sucker species and hybrids are using the more lentic portions of the CRI for spawning activities. Perhaps these species are also spawning upstream in the unsampled portion of the river.

As more research is conducted in Lake Mead, we anticipate that our understanding of conditions important for razorback sucker recruitment—despite lake level changes—will be clarified though the findings of this study and the long-term monitoring efforts described most recently by Albrecht et al. (2008b, 2010c, 2013) and Shattuck et al. (2011) during their comprehensive review of Lake Mead razorback sucker research. It remains key to monitor razorback suckers not only at the CRI but also at the long-term monitoring sites and the Colorado River proper in an integrated and comparable manner.

Larval Sampling

Although in relatively low numbers, larval razorback suckers were captured again at the CRI during the 2012 spawning period, confirming successful spawning of the species. The numbers and catch rates of larval razorback suckers at the CRI from 2010–12 have been similar to those during the first two field seasons of larval sampling in the Muddy River/Virgin River inflow area. Capture rates of larvae, juveniles, and adults in the Muddy River/Virgin River inflow area have increased over time (Albrecht et al. 2010c, 2013; Shattuck et al. 2011), and it will be interesting to evaluate whether similar trends occur at the CRI.

The majority of larval razorback sucker captures at the CRI in 2012 occurred over the course of 3 weeks (April 24 – May 16). These dates, as well as the dates larvae were collected in 2010 (Albrecht et al. 2010b) and 2011 (Kegerries and Albrecht 2011), are similar to larval capture dates reported by Albrecht et al. (2008b) during their comprehensive review of Lake Mead razorback sucker investigations. They report that larval fish were captured at the CRI on April 29, 2000, and April 29, 2001. This information should be considered important for field crews working within the CRI in the future.

For the CRI in particular, river currents, high spring winds, and increased wave action could decrease the number of larvae captured as they drift into Lake Mead from a spawning area in the Colorado River. If in fact native suckers are spawning upstream in the river proper, it is possible that a portion of the larvae collected at the CRI is a result of downstream larval drift. However, all larvae that were collected were within or near a confirmed spawning area, and lentic conditions extended well beyond Iceberg Canyon during our sampling. Without current documentation of spawning occurring within the Colorado River upstream of Lake Mead, we can only assume natal origin is Lake Mead, and we submit that additional effort in this regard is warranted.

Growth and Aging

Based on data collected from razorback suckers at the CRI to date, it appears that growth rates for razorback suckers captured in this area are similar to the relatively high growth rates observed in razorback suckers collected at the Las Vegas Bay, Echo Bay, and Muddy River/Virgin River study areas (Modde et al. 1996; Pacey and Marsh 1998; Albrecht et al. 2008a, 2010c). This finding makes sense considering the fairly young ages of razorback suckers (less than 10 years) recently reported in Lake Mead (Albrecht et al. 2010b, 2013; Shattuck et al. 2011). Future growth rate findings for razorback suckers captured at the CRI will allow for a more robust comparison to the overall size and age structure of all spawning aggregates across study areas. Similarly, it will be interesting to see whether future efforts result in the capture of smaller, juvenile razorback suckers, which would confirm recruitment at the CRI.

Determining the ages of 13 wild CRI razorback suckers during the 2012 field season, and incorporating the ages of 383 wild fish from previous studies, helps verify that razorback sucker recruitment has occurred regularly in Lake Mead from 1973 to 2008, with the exception of 1 fish that was spawned around 1966 (Shattuck et al. 2011; Albrecht et al. 2013) (attachment 2). Based on lake-wide data collected to date, some of the most pronounced recruitment occurred from 2001 to 2006, with a total of 273 razorback sucker captures resulting from those spawning events alone. Data suggest a strong recruitment trend in recent years. This pulse of young fish indicates that successful spawning and recruitment are occurring at low and fluctuating lake levels. Lake-wide aging data confirm natural, wild recruitment within the Lake Mead razorback sucker population as recently as 2008 (Shattuck et al. 2011; Albrecht et al. 2013). Fish spawned as recently as the 2011 season should become susceptible to sampling gear within the next year or two. This assumes that recruitment is occurring and will continue for these age classes, for which we have no reason to suggest otherwise. Finally, as more specimens are obtained from all areas of Lake Mead, including the CRI, we hope to identify conditions that promote recruitment, and we remain optimistic that capturing additional razorback suckers at the CRI will help clarify results from study efforts throughout Lake Mead.

To date, we have collected and identified fish from eight year-classes (1999–2006) at the CRI. Aging results from the 2012 field season alone identified one additional year-class (2006). Interestingly, all eight year-classes found at the CRI correlate with relatively strong year-classes across Lake Mead (see figure 11). It will be interesting to capture and age additional razorback suckers from the CRI to ascertain whether years of strong recruitment at the CRI correlate with years of strong recruitment across the rest of Lake Mead.

Population and Survival Rate Estimation

Population Estimation

The 2012 field season marks the first year in which population estimates could be calculated for the CRI using consistent methods reported for the long-term razorback sucker studies (Albrecht et al. 2013). There are particular assumptions in a closed-population model (Albrecht et al. 2008a) that may not have been fully met. However, the assumption of natality and mortality are thought to have been somewhat mitigated by using 3 years of data for all estimates. Razorback suckers are a long-lived, slow-growing species, and turnover in the adult population likely occurs at a slow rate, which increases the probability of survival between sampling occasions (Minckley 1983). Additionally, by combining sites that have demonstrated connectivity, or by constructing a lake-wide model, immigration and emigration is accounted for, and those assumptions are somewhat mitigated. For example, the areas of Echo Bay and the Muddy River/Virgin River inflow have been combined with the CRI because the movement of a wild individual between those sites was observed. Furthermore, the lake-wide population estimate includes data from our efforts at all four razorback sucker monitoring locations again because of observed movement of fish (both wild and stocked) between the Colorado River inflow and long-term monitoring sites. Though we include the CRI standalone population estimate, current data support the inclusion of other spawning locations, as wild fish movement has been observed along with stocked fish movement within the lake proper and even up into the Colorado River (as reported herein).

Interestingly, the population estimates produced from the period of 2010–12 and those from the period of 2006–11 (Albrecht et al. 2008a; Shattuck et al. 2011), suggest the population abundance of razorback suckers is increasing based on empirical field data. Linear regression indicated a relatively high level of goodness of fit (Albrecht et al. 2013). For a more detailed explanation and comprehensive review of Lake Mead razorback sucker population estimation, refer to Albrecht et al. (2013). Continued monitoring may provide a greater understanding of the population dynamics and drivers of the Lake Mead razorback sucker population, and additional data will help improve our ability to detect significant correlations between population estimates through time.

Survival Rate Estimation

Apparent survival rate estimates for razorback suckers in Lake Mead were included in this report in order to provide an additional understanding of this relatively young population of razorback suckers. Other studies from locations with prominent razorback sucker populations within the Colorado River basin have included apparent survival estimates (e.g., Zelasko and White 2011; Kesner et al. 2012). However, this aspect of the Lake Mead razorback sucker population had not been previously analyzed, and these new estimates further the ability to make relative comparisons within the Colorado River basin. The Lake Mead Pradel and CJS survival estimates demonstrate high apparent survival among Lake Mead razorback suckers with relatively narrow CI bounds (i.e., Pradel CI = 0.83–0.91, and CJS CI = 0.87–0.95) (see table 8) (Albrecht et al. 2013).

Sampling on Lake Mead focuses on the spawning adult population, although juvenile fish are captured periodically during trammel netting efforts. In comparison, the post-stocking apparent survival for Lake Mohave razorback suckers ranged from 0.70 to 0.80 for large (greater than 500 mm TL), adult repatriated fish for data from 1992–2010 (Kesner et al. 2012). Furthermore, results from the Green River and upper Colorado River subbasins show that the apparent survival ranged from 0.67 to 0.97 for stocked, adult razorback suckers over 500 mm TL (Zelasko and White 2011). Although apparent survival appears to be similar between Lake Mead and the Green River and upper Colorado River subbasins, apparent survival at Lake Mead includes razorback suckers less than 500 mm TL, with survival, in general, typically increasing with fish length (Miller et al. 1988). The 2010–12 dataset used for this analysis includes Lake Mead razorback suckers ranging in TL from 234 to 706 mm, with 59 individuals being less than 500 mm TL. This disparity in size between Lake Mead razorback suckers and razorback suckers of other areas of the Colorado River basin may suggest that a factor other than TL may be driving the higher apparent survival rate estimate and subsequent recruitment (Albrecht et al. 2013).

It is hypothesized that general survival in Lake Mead may be a function of habitat or ecological conditions in terms of cover as discussed by Golden and Holden (2003). Future efforts in monitoring the apparent survival rate for Lake Mead razorback suckers could provide further insights pertaining to higher apparent survival under given lake conditions. Until recently, adult sampling has been the primary focus of efforts on Lake Mead. To date, juvenile fish apparent survival rates at Lake Mead remain unknown. Future studies focusing on the smaller cohorts may provide more information about the survival and recruitment of younger, wild razorback suckers (Albrecht et al. 2013).

Conclusions and Future Considerations

In 2012, BIO-WEST documented razorback suckers at the CRI by capturing several wild, unmarked, adult fish in spawning condition. Larval razorback suckers were also captured, providing evidence that the species spawned successfully in or near the CRI in 2012. Stocked, sonic-tagged razorback suckers demonstrated upstream movement in excess of 48 km (30 mi), in some cases into the Colorado River proper. BIO-WEST also captured a number of flannelmouth suckers and two flannelmouth sucker x razorback sucker hybrids at the CRI in 2012.

After 3 years of sampling, we have answered many questions, including whether a spawning razorback sucker population exists at the CRI. Additionally, we have determined that spawning activities appear to occur every year and that spawning locations may shift depending on changes to habitat. This is very similar to what occurs at other spawning areas throughout Lake Mead. Many questions have also resulted from our sampling over the last 3 years. For example, what role is the river playing in wild razorback sucker recruitment? What, if any, is the long-term use of the lower portions of the Colorado River proper during both the spawning and nonspawning periods of the year? Does the Pearce Ferry Rapid create a natural barrier to upstream movement of razorback suckers at specific water elevations? These questions may have never been asked had we not tracked razorback suckers into the flowing portions of the Colorado River. Hybridization with flannelmouth suckers is something that was undocumented in Lake Mead; however, based on our recent studies, hybridization is now known to occur. As such, the question becomes, what does this hybridization potential mean for razorback sucker recruitment and recovery? We have also discovered flannelmouth suckers to be common at the CRI, concluding that the habitat at the CRI is suitable for native suckers in general and is perhaps very important for flannelmouth suckers. However, several questions remain that extend beyond the scope of our initial study efforts – questions that continued research and monitoring could help answer. For example, will this area be a consistent spawning area beyond our initial 3-year study? Does this area of Lake Mead produce larval fish every year? Do juvenile razorback suckers inhabit the CRI (which would provide direct evidence of natural, wild recruitment) as has been documented at other locations in Lake Mead? These are questions that could be answered with subsequent sampling. We have identified a fairly young population of razorback suckers at the CRI (less than 12 years old), but could enough fin ray specimens be collected to better understand the age structure of the fish currently using the CRI, or could enough fin ray specimens be collected to extrapolate and predict the age structure of fish using the area in the future? With more sampling and a longer-term dataset, comparisons could be made regarding recruitment patterns with other Lake Mead locations used by razorback suckers. The last 3 years have demonstrated similarities in habitat characteristics utilized by razorback suckers when compared to other Lake Mead spawning locations, but perhaps there are differences that have not been identified that could be critical for wild recruitment. The most important questions is, can we learn from the apparent natural recruitment success of Lake Mead razorback sucker and apply the information to other areas throughout the Colorado River basin that are presently or were historically occupied by the species? This study at the CRI, combined with the long-term monitoring on Lake Mead, has brought us a lot closer to understanding, identifying, and perhaps establishing wild recruitment throughout the historic range of razorback suckers. At a minimum, these efforts have spurred research in other, similar areas (e.g., Lake Powell). At this time, it is important to consider where the razorback sucker population at the CRI (and Lake Mead in general) fits into recovery plans for both the Lower Colorado River Basin and the Grand Canyon. Decisions will need to be made by the Lake Mead Work Group (and others) to determine the importance of, and potential strategies for, monitoring this population. Determinations on the level and scope of continued research for razorback suckers, and perhaps flannelmouth suckers, will also need to be made at that time.

The information presented in this report, along with findings from the long-term monitoring areas (e.g., Albrecht et al. 2013), suggests the Lake Mead razorback sucker population is generally young, growing, and self-sustaining. This demonstrates the uniqueness of the Lake Mead razorback sucker population and provides one of the few positive stories for this endangered species.

2012–13 COLORADO RIVER INFLOW RECOMMENDATIONS FOR STUDY

Given the findings from the CRI to date, maintaining sampling efforts comparable to the 2010–12 efforts at the CRI should be continued for this population of razorback suckers during the next and future calendar years. These efforts should include year-round sonic telemetry, trammel netting from February to May, sampling for larvae from February to May, and aging adult and juvenile razorback suckers and razorback sucker x flannelmouth sucker hybrids that are captured. Wild razorback suckers from Lake Mead should be sonic tagged as needed when contact is lost with the majority of the currently tagged fish. These efforts will help us to: (1) identify the 2013 (and future) CRI spawning location(s); (2) better understand razorback sucker habitat use within the Colorado River proper; (3) potentially identify other, new spawning sites as dictated by tracking sonic-tagged fish; and (4) identify seasonal riverine habitat use patterns if they exist. Data stemming from sampling efforts can be used to assist in understanding the size and habitat use of razorback suckers at the CRI, help document the movement of tagged fish between sites, identify potential limitations or habitat shifts associated with the CRI spawning aggregates, identify lake-wide recruitment patterns, and help characterize the habitat use and relationship that Lake Mead razorback suckers have with the Colorado River proper.

Lastly, we recommend taking a comprehensive approach to synthesizing the data collected on Lake Mead razorback suckers over the past 16 years. It is apparent that the CRI population should not be viewed or managed independently from the other razorback sucker populations in Lake Mead. This is also true for any razorback suckers that may be present in the lower Grand Canyon. A holistic look at wild razorback sucker recruitment as it relates to Lake Mead, and the lower Grand Canyon as a whole and as a continuum, may help to better characterize the conditions needed to establish and maintain a recruiting population not only in Lake Mead but also in other locations historically occupied by this species. Continued efforts may also help to address questions and objectives outlined in future recovery goals and plans.

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ATTACHMENT 1

Date, Passive Integrated Transponder (PIT) Tag, and Size Information for Flannelmouth Suckers Captured at the Colorado River Inflow Area during 2012

Table 1-1.—Date, PIT tag, and size data for flannelmouth suckers captured at the Colorado River inflow area in 2012

Date	Species	Pit tag number	Sonic code	Date stocked[a]	Recapture	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	Wt[e] (g)	Sex[f]
1/12/2012	Flannelmouth sucker	3D9.1C2D261548	NA	1/12/2012	NO	295	275	250	215	I
1/12/2012	Flannelmouth sucker	3D9.1C2D268828	NA	1/12/2012	NO	343	320	290	365	I
1/12/2012	Flannelmouth sucker	3D9.1C2D268A05	NA	1/12/2012	NO	440	420	385	750	I
1/12/2012	Flannelmouth sucker	3D9.1C2D268237	NA	1/12/2012	NO	430	400	365	678	I
1/12/2012	Flannelmouth sucker	3D9.1C2D2628F3	NA	1/12/2012	NO	385	360	326	480	I
1/12/2012	Flannelmouth sucker	3D9.1C2D263058	NA	1/12/2012	NO	397	380	346	635	I
1/12/2012	Flannelmouth sucker	3D9.1C2D2680C3	NA	1/12/2012	NO	340	318	285	378	I
1/12/2012	Flannelmouth sucker	3D9.1C2D2685C7	NA	1/12/2012	NO	434	407	370	717	I
1/12/2012	Flannelmouth sucker	3D9.1C2D2662E2	NA	1/12/2012	NO	403	382	345	610	I
1/12/2012	Flannelmouth sucker	3D9.1C2D26A318	NA	1/12/2012	NO	400	374	340	599	I
1/12/2012	Flannelmouth sucker	3D9.1C2D26795D	NA	1/12/2012	NO	420	395	360	720	I
1/12/2012	Flannelmouth sucker	3D9.1C2D267CAB	NA	1/12/2012	NO	339	320	290	360	I
1/12/2012	Flannelmouth sucker	3D9.1C2D2611CF	NA	1/12/2012	NO	325	303	275	297	I
1/12/2012	Flannelmouth sucker	3D9.1C2D261BE9	NA	1/12/2012	NO	432	410	375	701	I
1/12/2012	Flannelmouth sucker	3D9.1C2D260DE0	NA	1/12/2012	NO	232	214	192	115	I
1/18/2012	Flannelmouth sucker	384.1B796EE271	NA	1/18/2012	NO	226	210	185	100	I
1/25/2012	Flannelmouth sucker	3D9.1C2D2633BE	NA	1/25/2012	NO	473	440	400	930	U
1/25/2012	Flannelmouth sucker	3D9.1C2D266918	NA	1/25/2012	NO	442	412	380	751	U
1/25/2012	Flannelmouth sucker	3D9.1C2D25F94E	NA	1/25/2012	NO	235	220	200	120	I
1/25/2012	Flannelmouth sucker	3D9.1C2D2675F8	NA	1/25/2012	NO	470	445	400	930	U
1/25/2012	Flannelmouth sucker	3D9.1C2D268284	NA	1/25/2012	NO	357	338	305	374	I
1/25/2012	Flannelmouth sucker	3D9.1C2D2689DE	NA	1/25/2012	NO	370	345	313	411	I
1/25/2012	Flannelmouth sucker	3D9.1C2D2682F7	NA	1/25/2012	NO	435	402	365	729	U
1/25/2012	Flannelmouth sucker	384.1B796EEA52	NA	3/3/2011	YES	493	472	425	1050	F
1/25/2012	Flannelmouth sucker	3D9.1C2D2636A1	NA	1/25/2012	NO	381	355	310	469	I
1/25/2012	Flannelmouth sucker	3D9.1C2D2662E5	NA	1/25/2012	NO	305	286	252	224	I
1/26/2012	Flannelmouth sucker	384.1B796EE1B5	NA	1/26/2012	NO	394	366	335	530	I
2/1/2012	Flannelmouth sucker	384.1B796EEE11	NA	2/1/2012	NO	305	290	255	220	I
2/2/2012	Flannelmouth sucker	384.1B796EEB68	NA	2/2/2012	NO	390	363	332	460	I
2/2/2012	Flannelmouth sucker	384.1B796EEC9F	NA	2/2/2012	NO	300	285	260	246	I
2/2/2012	Flannelmouth sucker	384.1B796EE223	NA	2/2/2012	NO	325	308	279	310	I
2/2/2012	Flannelmouth sucker	3D9.1C2D267CAB	NA	1/12/2012	YES	344	324	298	340	I
2/2/2012	Flannelmouth sucker	384.1B796EF928	NA	2/2/2012	NO	414	394	356	650	U
2/2/2012	Flannelmouth sucker	384.1B796EFBD7	NA	2/2/2012	NO	340	316	288	350	I
2/2/2012	Flannelmouth sucker	3D9.1C2D278BF7	NA	2/2/2012	NO	221	207	187	95	I
2/2/2012	Flannelmouth sucker	3D9.1C2D26A318	NA	1/12/2012	YES	400	370	336	550	I
2/7/2012	Flannelmouth sucker	3D9.1C2D2675F8	NA	1/25/2012	YES	NA	NA	NA	NA	U
2/7/2012	Flannelmouth sucker	384.1B796ED708	NA	2/7/2012	NO	440	415	379	780	U
2/7/2012	Flannelmouth sucker	384.1B796EDF50	NA	2/7/2012	NO	473	449	416	880	U
2/7/2012	Flannelmouth sucker	384.1B796ED70F	NA	2/7/2012	NO	365	341	315	445	I
2/7/2012	Flannelmouth sucker	384.1B796EE207	NA	2/7/2012	NO	404	380	346	560	I
2/7/2012	Flannelmouth sucker	384.1B796EE203	NA	2/7/2012	NO	312	294	262	235	I
2/7/2012	Flannelmouth sucker	384.1B796ED6A9	NA	2/7/2012	NO	420	397	364	600	U
2/8/2012	Flannelmouth sucker	384.1B796EE3B4	NA	2/8/2012	NO	405	385	355	625	U

Table 1-1.—Date, PIT tag, and size data for flannelmouth suckers captured at the Colorado River inflow area in 2012

Date	Species	Pit tag number	Sonic code	Date stocked[a]	Recapture	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	Wt[e] (g)	Sex[f]
2/8/2012	Flannelmouth sucker	384.1B796EE6CD	NA	2/8/2012	NO	385	360	330	435	I
2/8/2012	Flannelmouth sucker	384.1B796EE875	NA	2/8/2012	NO	360	345	315	470	I
2/8/2012	Flannelmouth sucker	384.1B796EE3B4	NA	2/8/2012	NO	230	215	195	105	I
2/8/2012	Flannelmouth sucker	384.1B796EF469	NA	2/8/2012	NO	345	321	290	300	I
2/8/2012	Flannelmouth sucker	384.1B796EE3FF	NA	2/8/2012	NO	286	266	243	195	I
2/8/2012	Flannelmouth sucker	384.1B796EDE9D	NA	2/8/2012	NO	235	224	198	130	I
2/8/2012	Flannelmouth sucker	3D9.1C2D267BED	NA	2/8/2012	NO	334	314	285	360	I
2/8/2012	Flannelmouth sucker	384.1B796EDB04	NA	2/8/2012	NO	256	240	217	160	I
2/8/2012	Flannelmouth sucker	384.1B796EE90C	NA	2/8/2012	NO	258	232	210	110	I
2/8/2012	Flannelmouth sucker	3D9.1C2D27950A	NA	2/8/2012	NO	313	296	270	265	I
2/8/2012	Flannelmouth sucker	384.1B79ED659	NA	2/8/2012	NO	500	480	445	995	U
2/8/2012	Flannelmouth sucker	384.1B796EE3F7	NA	2/8/2012	NO	240	230	210	120	I
2/8/2012	Flannelmouth sucker	384.1B796EE7EB	NA	2/8/2012	NO	400	375	345	525	U
2/16/2012	Flannelmouth sucker	384.1B796EE1B5	NA	1/26/2012	YES	NA	NA	NA	NA	I
2/16/2012	Flannelmouth sucker	384.1B796EEB28	NA	2/16/2012	NO	378	358	326	465	I
2/16/2012	Flannelmouth sucker	384.1B796EDEFD	NA	2/16/2012	NO	465	433	398	1030	U
2/16/2012	Flannelmouth sucker	384.1B796EEA52	NA	1/25/2012	YES	NA	NA	NA	NA	F
2/16/2012	Flannelmouth sucker	384.1B796ED6C8	NA	2/16/2012	NO	348	329	299	360	I
2/16/2012	Flannelmouth sucker	3D9.1BF1D890F5	NA	7/12/2005	YES	547	520	480	1705	F
2/15/2012	Flannelmouth sucker	384.1B796EEA79	NA	2/15/2012	NO	291	273	252	240	I
2/15/2012	Flannelmouth sucker	384.1B796A8756	NA	2/15/2012	NO	241	222	204	115	I
2/15/2012	Flannelmouth sucker	384.1B796EDDFE	NA	2/15/2012	NO	300	281	269	255	I
2/15/2012	Flannelmouth sucker	384.1B796EDFDA	NA	2/15/2012	NO	291	270	246	249	I
2/15/2012	Flannelmouth sucker	384.1B796EEF42	NA	2/15/2012	NO	280	263	239	184	I
2/15/2012	Flannelmouth sucker	3D9.1C2D265DC1	NA	2/15/2012	NO	415	390	353	625	U
2/15/2012	Flannelmouth sucker	384.1B796EDA6B	NA	2/15/2012	NO	430	405	380	742	U
2/15/2012	Flannelmouth sucker	384.1B796ED6EF	NA	2/15/2012	NO	410	380	350	641	U
2/15/2012	Flannelmouth sucker	3D9.1C2D268641	NA	2/15/2012	NO	391	365	335	509	U
2/15/2012	Flannelmouth sucker	384.1B796EDAEC	NA	2/15/2012	NO	235	220	197	145	I
2/15/2012	Flannelmouth sucker	384.1B796EEEF3	NA	2/15/2012	NO	465	432	370	920	F
2/15/2012	Flannelmouth sucker	384.1B796EF0A8	NA	2/15/2012	NO	390	365	320	550	F
2/15/2012	Flannelmouth sucker	384.1B796EDE37	NA	2/15/2012	NO	445	420	370	820	F
2/15/2012	Flannelmouth sucker	384.1B796EF025	NA	2/15/2012	NO	355	332	290	395	I
2/15/2012	Flannelmouth sucker	384.1B796EE631	NA	2/15/2012	NO	336	316	275	325	I
2/15/2012	Flannelmouth sucker	384.1B796EDE67	NA	2/15/2012	NO	210	190	162	85	I
2/15/2012	Flannelmouth sucker	384.1B796EE3F4	NA	2/15/2012	NO	351	335	305	380	I
2/15/2012	Flannelmouth sucker	384.1B796EEE5F	NA	2/15/2012	NO	260	244	220	160	I
2/21/2012	Flannelmouth sucker	384.1B796EEC97	NA	2/21/2012	NO	348	328	295	370	I
2/21/2012	Flannelmouth sucker	3D9.1C2D2633BE	NA	1/25/2012	YES	NA	NA	NA	NA	U
2/21/2012	Flannelmouth sucker	384.1B796EE5F6	NA	2/21/2012	NO	214	201	179	90	I
2/21/2012	Flannelmouth sucker	3D9.1BF1D890F5	NA	7/12/2005	YES	542	516	478	1640	F
2/21/2012	Flannelmouth sucker	384.1B796EE933	NA	2/21/2012	NO	428	403	365	770	F
2/21/2012	Flannelmouth sucker	384.1B796EE4EE	NA	2/21/2012	NO	410	385	350	685	U

Table 1-1.—Date, PIT tag, and size data for flannelmouth suckers captured at the Colorado River inflow area in 2012

Date	Species	Pit tag number	Sonic code	Date stocked[a]	Recapture	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	Wt[e] (g)	Sex[f]
2/21/2012	Flannelmouth sucker	384.1B796EE3BC	NA	2/21/2012	NO	241	224	200	120	I
3/1/2012	Flannelmouth sucker	384.1B796EE43D	NA	3/1/2012	NO	423	396	363	650	U
2/29/2012	Flannelmouth sucker	384.1B796EEC9E	NA	2/29/2012	NO	514	490	461	1215	U
2/29/2012	Flannelmouth sucker	384.1B796EDAAC	NA	2/29/2012	NO	431	410	383	740	U
2/29/2012	Flannelmouth sucker	384.1B796EDC41	NA	2/29/2012	NO	444	415	380	340	U
3/8/2012	Flannelmouth sucker	384.1B796ED985	NA	3/6/2012	YES	NA[g]	NA	NA	NA	I
3/8/2012	Flannelmouth sucker	384.1B796EE180	NA	3/6/2012	YES	230	215	197	115	I
3/8/2012	Flannelmouth sucker	384.1B796EE270	NA	3/8/2012	NO	315	295	266	300	I
3/8/2012	Flannelmouth sucker	384.1B796EE1B5	NA	1/26/2012	YES	NA	NA	NA	NA	I
3/8/2012	Flannelmouth sucker	384.1B796EE527	NA	3/8/2012	NO	313	292	268	275	I
3/8/2012	Flannelmouth sucker	384.1B796EE4EE	NA	2/21/2012	YES	NA	NA	NA	NA	I
3/8/2012	Flannelmouth sucker	384.1B796EE06E	NA	3/8/2012	NO	249	233	212	125	I
3/8/2012	Flannelmouth sucker	384.1B796EEAD6	NA	3/8/2012	NO	484	456	416	1055	U
3/6/2012	Flannelmouth sucker	384.1B796EF03F	NA	3/6/2012	NO	453	425	390	790	U
3/6/2012	Flannelmouth sucker	384.1B796EE10F	NA	3/6/2012	NO	383	362	328	510	U
3/6/2012	Flannelmouth sucker	384.1B796EEA52	NA	3/3/2011	YES	NA	NA	NA	NA	F
3/6/2012	Flannelmouth sucker	384.1B796EE55B	NA	3/6/2012	NO	389	368	334	500	I
3/6/2012	Flannelmouth sucker	384.1B796EE045	NA	3/6/2012	NO	335	322	295	440	I
3/6/2012	Flannelmouth sucker	384.1B796EE8D7	NA	3/6/2012	NO	338	315	295	375	I
3/6/2012	Flannelmouth sucker	384.1B796EE180	NA	3/6/2012	NO	227	212	195	130	I
3/6/2012	Flannelmouth sucker	384.1B796EE723	NA	3/6/2012	NO	483	475	440	1215	F
3/5/2012	Flannelmouth sucker	384.1B796EDF0E	NA	3/5/2012	NO	310	289	260	265	I
3/5/2012	Flannelmouth sucker	384.1B796EF109	NA	3/5/2012	NO	495	462	428	1155	F
3/5/2012	Flannelmouth sucker	384.1B796ED985	NA	3/5/2012	NO	344	322	295	375	I
3/5/2012	Flannelmouth sucker	384.1B796EEEC0	NA	3/5/2012	NO	218	205	184	100	I
3/6/2012	Flannelmouth sucker	384.1B796EEC9E	NA	2/29/2012	YES	NA	NA	NA	NA	U
3/6/2012	Flannelmouth sucker	384.1B796EE099	NA	3/6/2012	NO	229	210	187	110	I
3/14/2012	Flannelmouth sucker	384.1B796EE140	NA	3/14/2012	NO	450	420	386	815	F
3/14/2012	Flannelmouth sucker	384.1B796EDE6C	NA	3/14/2012	NO	395	379	342	670	I
3/13/2012	Flannelmouth sucker	384.1B796EE723	NA	3/6/2012	YES	490	465	429	1140	F
3/13/2012	Flannelmouth sucker	384.1B796EE527	NA	3/8/2012	YES	NA	NA	NA	NA	I
3/13/2012	Flannelmouth sucker	384.1B796EDD15	NA	3/13/2012	NO	255	233	208	120	I
3/13/2012	Flannelmouth sucker	384.1B796EE146	NA	3/13/2012	NO	256	236	215	140	I
3/15/2012	Flannelmouth sucker	384.1B796EF506	NA	3/15/2012	NO	307	289	264	280	I
3/15/2012	Flannelmouth sucker	384.1B796EE201	NA	3/15/2012	NO	429	403	370	735	F
3/20/2012	Flannelmouth sucker	384.1B796EF03F	NA	3/6/2012	YES	NA	NA	NA	NA	F
3/20/2012	Flannelmouth sucker	384.1B796EDF50	NA	2/7/2012	YES	NA	NA	NA	NA	F
3/20/2012	Flannelmouth sucker	384.1B796EEDFD	NA	3/20/2012	NO	340	315	284	385	I
3/20/2012	Flannelmouth sucker	384.1B796EE470	NA	3/20/2012	NO	278	258	234	185	I
3/21/2012	Flannelmouth sucker	3D9.1C2D26947B	NA	3/21/2012	NO	330	306	281	420	I
3/21/2012	Flannelmouth sucker	3D9.1C2D2680E6	NA	3/21/2012	NO	495	465	425	1285	F
3/21/2012	Flannelmouth sucker	384.1B796EDE6C	NA	3/14/2012	YES	NA	NA	NA	NA	I
3/21/2012	Flannelmouth sucker	3D9.1C2D262724	NA	3/21/2012	NO	204	187	171	75	I

Table 1-1.—Date, PIT tag, and size data for flannelmouth suckers captured at the Colorado River inflow area in 2012

Date	Species	Pit tag number	Sonic code	Date stocked[a]	Recapture	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	Wt[e] (g)	Sex[f]
3/21/2012	Flannelmouth sucker	3D9.1C2D262724	NA	3/21/2012	YES	NA	NA	NA	NA	I
3/21/2012	Flannelmouth sucker	3D9.1C2D267753	NA	3/21/2012	NO	347	326	297	415	U
3/21/2012	Flannelmouth sucker	3D9.1C2D2659F0	NA	3/21/2012	NO	393	371	340	575	U
3/21/2012	Flannelmouth sucker	3D9.1C2D26176C	NA	3/21/2012	NO	348	330	300	400	U
3/22/2012	Flannelmouth sucker	3D9.1C2D2680E6	NA	3/21/2012	YES	NA	NA	NA	NA	F
3/22/2012	Flannelmouth sucker	3D9.1C2D267B37	NA	3/22/2012	NO	276	258	234	205	I
3/22/2012	Flannelmouth sucker	3D9.1C2D26303E	NA	3/22/2012	NO	275	254	234	175	I
3/22/2012	Flannelmouth sucker	3D9.1C2D2636A1	NA	1/25/2012	YES	NA	NA	NA	NA	I
3/27/2012	Flannelmouth sucker	3D9.1C2D267CAB	NA	1/12/2012	YES	NA	NA	NA	NA	I
3/27/2012	Flannelmouth sucker	3D9.1C2D263215	NA	3/27/2012	NO	331	310	282	350	I
4/3/2012	Flannelmouth sucker	384.1B796EDA6B	NA	2/15/2012	YES	NA	NA	NA	NA	U
4/3/2012	Flannelmouth sucker	3D9.1C2D269BB6	NA	4/3/2012	NO	345	323	296	410	I
4/3/2012	Flannelmouth sucker	3D9.1C2D267579	NA	4/3/2012	NO	357	334	306	445	I
4/3/2012	Flannelmouth sucker	3D9.1C2D2613E8	NA	4/3/2012	NO	382	362	331	515	I
4/3/2012	Flannelmouth sucker	3D9.1C2D266245	NA	4/3/2012	NO	351	332	305	375	I
4/4/2012	Flannelmouth sucker	384.36F2B25F7B	NA	4/4/2012	NO	240	224	197	145	I
4/5/2012	Flannelmouth sucker	384.36F2B25F7B	NA	4/4/2012	YES	NA	NA	NA	NA	I
4/5/2012	Flannelmouth sucker	3D9.1C2D267583	NA	4/5/2012	NO	321	297	272	265	I
4/5/2012	Flannelmouth sucker	384.1B796EE55B	NA	3/6/2012	YES	382	361	336	440	U
4/5/2012	Flannelmouth sucker	384.1B796EE203	NA	2/17/2012	YES	NA	NA	NA	NA	I
4/5/2012	Flannelmouth sucker	3D9.1C2D261A95	NA	4/5/2012	NO	335	315	289	345	U
4/5/2012	Flannelmouth sucker	384.1B796EF579	NA	4/5/2012	NO	252	235	216	165	U
4/5/2012	Flannelmouth sucker	384.1B796A90C9	NA	4/5/2012	NO	363	344	316	465	U
4/5/2012	Flannelmouth sucker	384.1B796EF579	NA	4/5/2012	YES	NA	NA	NA	NA	U
4/5/2012	Flannelmouth sucker	3D9.1C2D279302	NA	4/5/2012	NO	306	286	263	255	I
4/12/2012	Flannelmouth sucker	384.1B796EDD02	NA	4/12/2012	NO	275	259	231	200	I
4/12/2012	Flannelmouth sucker	384.1B796EDF99	NA	4/12/2012	NO	309	291	263	240	I
4/12/2012	Flannelmouth sucker	384.1B796EF0F1	NA	4/12/2012	NO	266	249	233	195	I
4/12/2012	Flannelmouth sucker	384.1B796EF5EA	NA	4/12/2012	NO	399	372	343	591	I
4/12/2012	Flannelmouth sucker	384.1B796EF878	NA	4/12/2012	NO	371	353	323	495	I
4/12/2012	Flannelmouth sucker	384.1B796EE059	NA	4/12/2012	NO	346	332	304	385	I
4/12/2012	Flannelmouth sucker	384.1B796EE8D7	NA	3/6/2012	YES	335	NA	286	360	I
4/12/2012	Flannelmouth sucker	384.1B796EE663	NA	4/12/2012	NO	341	324	285	340	I
4/12/2012	Flannelmouth sucker	381.1B796EDB52	NA	4/12/2012	NO	314	297	271	310	I
4/10/2012	Flannelmouth sucker	384.1B796EE764	NA	4/10/2012	NO	565	531	493	1860	F
4/10/2012	Flannelmouth sucker	384.1B796EE13E	NA	4/10/2012	NO	269	252	231	370	I
4/10/2012	Flannelmouth sucker	384.1B796EE720	NA	4/10/2012	NO	470	438	403	997	F
4/10/2012	Flannelmouth sucker	384.1B796EDAAC	NA	2/29/2012	YES	435	415	382	845	F
4/10/2012	Flannelmouth sucker	384.1B796EDD9B	NA	4/10/2012	NO	302	285	259	265	I
4/17/2012	Flannelmouth sucker	3D9.1C2D268860	NA	4/17/2012	NO	351	331	304	420	U
4/17/2012	Flannelmouth sucker	3D9.1C2D26880A	NA	4/17/2012	NO	267	251	226	165	I
4/17/2012	Flannelmouth sucker	3D9.1C2D268107	NA	4/17/2012	NO	330	308	283	350	I
4/17/2012	Flannelmouth sucker	3D9.1C2D267D21	NA	4/17/2012	NO	405	371	334	465	I

Table 1-1.—Date, PIT tag, and size data for flannelmouth suckers captured at the Colorado River inflow area in 2012

Date	Species	Pit tag number	Sonic code	Date stocked[a]	Recapture	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	Wt[e] (g)	Sex[f]
4/17/2012	Flannelmouth sucker	3D9.1C2D266121	NA	4/17/2012	NO	444	418	382	815	F
4/17/2012	Flannelmouth sucker	3D9.1C2D26317C	NA	4/17/2012	NO	266	250	228	150	I
4/17/2012	Flannelmouth sucker	384.1B796EEF42	NA	2/15/2012	YES	NA	NA	NA	NA	I
4/17/2012	Flannelmouth sucker	3D9.1C2D279321	NA	4/17/2012	NO	413	387	355	645	I
4/17/2012	Flannelmouth sucker	3D9.1C2D25E9B9	NA	4/17/2012	NO	407	384	349	605	I
4/17/2012	Flannelmouth sucker	3D9.1C2D26A36C	NA	4/17/2012	NO	345	232	297	380	I
4/17/2012	Flannelmouth sucker	3D9.1C2D26A2F9	NA	4/17/2012	NO	298	279	255	295	I
4/17/2012	Flannelmouth sucker	3D9.1C2D267924	NA	4/17/2012	NO	405	377	350	670	I
4/17/2012	Flannelmouth sucker	384.1B796EE9A2	NA	4/17/2012	NO	235	219	197	115	I
4/17/2012	Flannelmouth sucker	384.1B796EEE56	NA	4/17/2012	NO	245	232	213	145	I
4/17/2012	Flannelmouth sucker	384.1B796EE382	NA	4/17/2012	NO	331	307	278	325	I
4/17/2012	Flannelmouth sucker	384.1B796EDFB4	NA	4/17/2012	NO	248	230	208	130	I
4/17/2012	Flannelmouth sucker	384.1B796EEDBD	NA	4/17/2012	NO	219	204	186	100	I
4/17/2012	Flannelmouth sucker	384.1B796EDC97	NA	4/17/2012	NO	442	419	390	810	F
4/18/2012	Flannelmouth sucker	384.1B796EE10F	NA	3/6/2012	YES	NA	NA	NA	NA	U
4/18/2012	Flannelmouth sucker	384.1B796EE9C3	NA	4/18/2012	NO	365	342	315	445	I
4/18/2012	Flannelmouth sucker	384.1B796EE846	NA	4/18/2012	NO	360	345	309	455	I
4/18/2012	Flannelmouth sucker	384.1B796EE24C	NA	4/18/2012	NO	253	234	213	155	I
4/19/2012	Flannelmouth sucker	384.1B796EE5CB	NA	4/19/2012	NO	367	345	313	490	I
4/19/2012	Flannelmouth sucker	384.1B796EDF6B	NA	4/19/2012	NO	315	296	270	295	I
4/19/2012	Flannelmouth sucker	384.1B796ED708	NA	2/16/2012	YES	NA	NA	NA	NA	U
4/19/2012	Flannelmouth sucker	384.1B796EE9C3	NA	4/18/2012	YES	NA	NA	NA	NA	I
4/19/2012	Flannelmouth sucker	384.1B796ED738	NA	4/19/2012	NO	260	233	219	155	I
4/19/2012	Flannelmouth sucker	384.1B796EE49D	NA	4/19/2012	NO	407	379	348	635	F
4/19/2012	Flannelmouth sucker	384.1B796EE37F	NA	4/19/2012	NO	254	239	216	135	I
4/24/2012	Flannelmouth sucker	384.1B796EEA4B	NA	4/24/2012	NO	340	320	290	370	I
4/24/2012	Flannelmouth sucker	384.1B796EEA7F	NA	4/24/2012	NO	234	218	196	120	I
4/24/2012	Flannelmouth sucker	384.1B796ED985	NA	3/6/2012	YES	NA	NA	NA	NA	I

[a] Date originally stocked or originally captured.
[b] Total length in millimeters.
[c] Fork length in millimeters.
[d] Standard length in millimeters.
[e] Weight in grams.
[f] I =immature, U = unidentified (sex not determined), and F = female.
[g] Not recorded, typically to avoid excessive handling stress.

ATTACHMENT 2

Ages Determined from Razorback Sucker Pectoral Fin Ray Sections Collected from Lake Mead

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
Las Vegas Bay			
5/10/1998	588	10[b]	1987
12/14/1999	539	13	1986
12/14/1999	606	17+	1979 – 1982
12/14/1999	705	19+	1977 – 1980
1/8/2000	650	18+	1978 – 1981
2/27/2000	628	17+	1979 – 1982
1/9/2001	378	6	1994
2/7/2001	543	11	1989
2/22/2001	585	13	1987
12/1/2001	576	8 – 10	1991 – 1993
12/1/2001	694	22	1979
12/1/2001	553	10	1991
2/2/2002	639	16	1985
3/25/2002	650	22	1979
3/25/2002	578	10 – 11	1990 – 1991
3/25/2002	583	22 – 24	1977 – 1979
3/25/2002	545	20[b]	1982
3/25/2002	576	20	1982
5/7/2002	641	15	1986
6/7/2002	407	6	1995
6/7/2002	619	20[b]	1982
6/7/2002	642	20[b]	1982
12/3/2002	354	4	1998
12/6/2002	400	4	1998
12/6/2002	376	4	1998
12/19/2002	395	4	1998
1/7/2003	665	16	1986
1/22/2003	494	4	1998
2/5/2003	385	4	1998
2/18/2003	443	5	1997
3/4/2003	635	19	1983
3/20/2003	420	4	1998
4/8/2003	638	21[b]	1982
4/17/2003	618	10	1992
4/22/2003	650	20 – 22	1980 – 1982
5/4/2003	415	3+[c]	1999

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
3/3/2004	370	5	1998
2/22/2005	529	6	1998
2/22/2005	546	6	1998
3/29/2005	656	16	1989
1/26/2006	740	15	1991
2/21/2006	621	23	1983
3/23/2006	461	5	2001
3/23/2006	718	16	1990
3/31/2006	635	7	1999
3/31/2006	605	6	2000
4/4/2006	629	6	2000
4/25/2006	452	4	2002
4/25/2006	463	4	2002
1/30/2007	514	5	2002
2/6/2007	519	5	2002
2/6/2007	574	8	1999
2/13/2007	526	5	2002
2/16/2007	530	5	2002
2/20/2007	534	6	2001
2/21/2007	358	3	2004
2/21/2007	511	5	2002
2/27/2007	645	13	1994
2/27/2007	586	15	1992
2/27/2007	603	13	1994
2/27/2007	650	17	1990
3/6/2007	515	4	2003
3/6/2007	611	13	1994
3/6/2007	565	6	2001
3/13/2007	586	7	2000
3/13/2007	636	25	1982
3/13/2007	524	5	2002
4/2/2007	704	9	1998
4/9/2007	644	11	1996
2/12/2008	425	5	2003
2/12/2008	390	3	2005
2/12/2008	490	3	2005
2/12/2008	430	4	2004

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
2/12/2008	379	4	2004
2/12/2008	399	4	2004
2/12/2008	430	4	2004
2/12/2008	413	4	2004
2/12/2008	554	9	1999
2/12/2008	426	9	1999
2/18/2008	385	3	2005
2/25/2008	605	6	2002
2/25/2008	655	36	1972
4/3/2008	468	4	2004
4/3/2008	619	7	2001
4/3/2008	640	10	1998
4/3/2008	560	11	1997
4/8/2008	423	3	2005
4/8/2008	535	6	2002
4/10/2008	422	3	2005
4/10/2008	375	3	2005
4/10/2008	452	4	2004
4/10/2008	472	4	2004
4/10/2008	467	4	2004
4/10/2008	429	5	2003
4/23/2008	430	4	2004
2/13/2009	395	5	2004
2/13/2009	528	11	1998
2/13/2009	630	15	1994
2/17/2009	510	8	2001
2/17/2009	440	5	2004
2/17/2009	420	5	2004
2/18/2009	376	4	2005
2/18/2009	411	4	2005
2/18/2009	427	4	2005
2/24/2009	438	5	2004
2/24/2009	403	6	2003
2/24/2009	446	6	2003
3/3/2009	416	4	2005
3/3/2009	565	8	2001
3/3/2009	431	5	2004

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
3/3/2009	340	5	2004
3/3/2009	539	8	2001
3/3/2009	521	8	2001
3/3/2009	419	6	2003
3/3/2009	535	6	2003
3/3/2009	748	17	1992
3/17/2009	377	3	2006
3/17/2009	458	4	2005
3/17/2009	421	4	2005
3/17/2009	369	3	2006
3/17/2009	440	5	2004
4/6/2009	546	8	2001
4/13/2009	536	7	2002
4/13/2009	510	7	2002
4/13/2009	451	4	2005
4/13/2009	578	13	1996
2/2/2010	531	5	2005
2/2/2010	391	5	2005
2/2/2010	342	5	2005
2/11/2010	351	3	2007
3/3/2010	485	5	2005
3/3/2010	553	6	2004
3/3/2010	621	9	2001
3/23/2010	395	3	2007
3/23/2010	500	5	2005
3/23/2010	514	6	2004
4/20/2010	560	7	2003
2/8/2011	587	8	2003
2/10/2011	574	12[d]	1999
3/3/2011	364	7	2004
3/3/2011	434	4	2007
3/24/2011	411	4	2007
3/24/2011	390	3	2008
3/29/2011	379	6	2005
3/29/2011	346	4	2007
3/29/2011	376	3	2008

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
Echo Bay			
1/22/1998	381	5	1993
1/9/2000	527	13	1987
1/9/2000	550	13	1987
1/9/2000	553	13	1987
1/9/2000	599	12 – 14	1986 – 1988
1/27/2000	557	13	1986
1/27/2000	710	19+	1979 – 1981
2/9/2001	641	13	1988
2/24/2001	577	18+	1980 – 1982
2/24/2001	570	8	1992
2/24/2001	576	15	1986
2/24/2001	553	18	1983
12/18/2001	672	13	1988
2/27/2002	610	18 – 20	1982 – 1984
3/26/2002	623	16	1986
4/2/2002	617	35+	1966 – 1968
4/17/2002	583	20[b]	1982
5/2/2002	568	18 – 19	1983 – 1984
11/18/2002	551	13	1989
12/4/2002	705	26	1976
1/21/2003	591	16	1986
2/3/2003	655	27 – 29	1974
2/3/2003	580	13	1989
4/2/2003	639	19 – 20	1982
4/2/2003	580	23 – 25	1978
4/23/2003	584	10	1992
5/6/2003	507	9+	1993
5/6/2003	594	20	1982
12/18/2003	522	20	1982
1/14/2004	683	14	1989
2/18/2004	613	10	1993
3/17/2004	616	19	1983
3/17/2004	666	17	1985
3/17/2004	618	9	1994
4/6/2004	755	17	1985
3/2/2005	608	15	1990

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
3/2/2005	624	8	1996
1/10/2006	630	12	1994
2/1/2006	705	16	1990
2/16/2006	601	22	1984
1/11/2007	535	5	2002
1/11/2007	493	5	2002
2/1/2007	637	7	2000
2/8/2007	609	12	1995
2/14/2007	501	4	2003
3/2/2007	590	11	1996
3/9/2007	660	12	1995
3/16/2007	691	21	1986
3/28/2007	564	13	1994
2/28/2008	640	25	1983
2/29/2008	635	8	2000
3/5/2008	653	24	1984
3/19/2008	532	6	2002
3/19/2008	510	7	2001
2/20/2009	602	7	2002
2/26/2009	662	16	1993
2/18/2010	520	7	2003
2/25/2010	465	5	2005
3/10/2010	535	7	2003
3/10/2010	530	9[e]	2001
3/24/2010	451	4	2006
3/24/2010	465	5	2005
3/24/2010	466	5	2005
4/8/2010	470	5	2005
4/8/2010	540	8	2002
4/22/2010	538	7	2003
4/22/2010	489	8	2002
4/22/2010	460	9	2001
2/9/2011	529	7	2004
2/9/2011	524	7	2004
2/24/2011	555	7	2004
3/2/2011	513	6	2005
4/7/2011	533	7	2004

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
4/7/2011	522	7	2004
4/19/2011	537	6	2005
4/19/2011	540	7	2004
4/19/2011	515	6	2005
2/9/2012	619	10	2002
2/9/2012	644	29	1983
2/16/2012	559	9	2003
2/16/2012	565	12	2000
2/22/2012	589	10	2002
2/22/2012	548	12	2000
3/1/2012	585	7	2005
3/7/2012	663	12	2000
3/29/2012	571	12	2000
3/29/2012	595	13	1999
4/12/2012	610	13	1999
4/12/2012	571	14	1998
Muddy River/Virgin River inflow area			
2/23/2005	608	6	1998
2/22/2006	687	33[f]	1973
2/22/2007	452	4	2003
2/22/2007	542	5	2002
2/22/2007	476	5	2002
2/22/2007	459	4	2003
2/22/2007	494	5	2002
3/1/2007	477	5	2002
3/1/2007	512	4	2003
3/8/2007	463	5	2002
3/8/2007	455	4	2003
3/15/2007	516	4	2003
4/3/2007	508	4	2003
4/11/2007	498	7	2000
2/27/2008	465	4	2004
2/27/2008	670	20	1988
3/25/2008	530	6	2002
3/25/2008	271	2[g]	2006
3/26/2008	345	3	2005
3/26/2008	541	7	2001

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
3/26/2008	521	7	2001
3/26/2008	665	18	1990
4/1/2008	229	2	2006
4/1/2008	370	3	2005
4/1/2008	360	3	2005
4/1/2008	385	4	2004
4/1/2008	514	5	2003
4/1/2008	536	5	2003
4/1/2008	514	6	2002
4/1/2008	548	6	2002
4/1/2008	518	7	2001
4/1/2008	530	7	2001
4/1/2008	494	8	2000
4/1/2008	535	9	1999
4/1/2008	559	10	1998
4/22/2008	533	6	2002
4/22/2008	504	6	2002
2/4/2009	496	9	2000
2/12/2009	553	10	1999
2/12/2009	505	8	2001
2/19/2009	464	5	2004
2/25/2009	549	7	2002
3/11/2009	585	8	2001
3/11/2009	552	8	2001
3/24/2009	366	3	2006
3/24/2009	572	9	2000
4/8/2009	348	3	2006
4/8/2009	291	3	2006
4/15/2009	374	3	2006
4/15/2009	372	3	2006
4/15/2009	390	3	2006
4/15/2009	365	3	2006
4/15/2009	375	3	2006
4/15/2009	399	3	2006
4/15/2009	362	3	2006
4/15/2009	386	4	2005
4/15/2009	390	4	2005

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
2/3/2010	455	3	2007
2/3/2010	475	5	2005
2/3/2010	441	5	2005
2/3/2010	495	7	2003
2/3/2010	532	8	2002
2/9/2010	491	5	2005
2/9/2010	444	5	2005
2/9/2010	500	5	2005
2/9/2010	464	6	2004
2/9/2010	471	6	2004
2/17/2010	494	6	2004
2/17/2010	470	7	2003
2/17/2010	479	7	2003
2/17/2010	425	7	2003
2/17/2010	483	7	2003
2/24/2010	234	4	2006
3/17/2010	477	4	2006
3/17/2010	465	5	2005
3/17/2010	485	5	2005
3/17/2010	499	6	2004
3/17/2010	491	6	2004
3/17/2010	600	9	2001
3/18/2010	452	5	2005
3/18/2010	473	5	2005
3/24/2010	485	5	2005
2/1/2011	601	7	2004
2/1/2011	571	6	2005
2/1/2011	556	7	2004
2/1/2011	586	6	2005
2/1/2011	506	8	2003
2/1/2011	572	8	2003
2/1/2011	500	6	2005
2/22/2011	501	7	2004
2/22/2011	534	6	2005
2/22/2011	506	6	2005
2/22/2011	508	6	2005
2/22/2011	524	7	2004

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
2/22/2011	517	8	2003
2/22/2011	580	5	2006
2/22/2011	509	8	2003
2/22/2011	586	6	2005
2/22/2011	512	7	2004
2/22/2011	585	6	2005
2/23/2011	545	6	2005
2/23/2011	500	6	2005
2/23/2011	527	7	2004
2/23/2011	552	5	2006
3/1/2011	510	10	2001
3/1/2011	573	9	2002
3/1/2011	518	8	2003
3/1/2011	538	6	2005
3/1/2011	532	9	2002
3/1/2011	553	6	2005
3/1/2011	595	6	2005
3/1/2011	563	6	2005
3/1/2011	555	6	2005
3/1/2011	483	7	2004
3/1/2011	599	9	2002
3/1/2011	560	5	2006
3/9/2011	556	7	2004
3/9/2011	534	6	2005
3/9/2011	549	7	2004
3/9/2011	494	4	2007
3/9/2011	505	6	2005
3/15/2011	575	8	2003
3/15/2011	551	8	2003
3/15/2011	515	7	2004
3/15/2011	558	8	2003
3/15/2011	576	8	2003
3/15/2011	587	8	2003
3/15/2011	572	7	2004
3/15/2011	575	10	2001
3/15/2011	551	7	2004
3/15/2011	561	7	2004

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
3/15/2011	566	9	2002
3/15/2011	542	6	2005
3/15/2011	577	8	2003
4/5/2011	521	7	2004
4/5/2011	495	6	2005
4/12/2011	572	8	2003
1/31/2012	604	7	2005
1/31/2012	570	7	2005
2/1/2012	525	12	2000
2/7/2012	525	9	2003
2/8/2012	536	7	2005
2/8/2012	501	9	2003
2/8/2012	623	12	2000
2/21/2012	566	10	2002
2/21/2012	590	10	2002
3/13/2012	555	9	2003
3/13/2012	521	9	2003
3/13/2012	618	9	2003
3/13/2012	610	12	2000
3/14/2012	539	7	2005
3/14/2012	530	9	2003
3/15/2012	546	7	2005
3/15/2012	576	10	2002
3/15/2012	574	10	2002
3/21/2012	559	7	2005
3/28/2012	575	8	2004
4/4/2012	551	6	2006
4/4/2012	575	7	2005
4/11/2012	535	9	2003
Colorado River inflow area			
4/20/2010	563	6	2004
4/20/2010	508	6	2004
4/20/2010	568	11	1999
2/8/2011	594	8	2003
3/10/2011	659	11	2000
3/24/2011	584	9	2002
3/24/2011	530	7	2004

Table 2-1.—Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead

Date collected	Total length[a] (mm)	Age	Presumptive year spawned
3/24/2011	545	6	2005
4/19/2011	636	9	2002
4/20/2011	570	10	2001
1/26/2012	602	8	2004
2/21/2012	604	10	2002
3/1/2012	546	8	2004
3/1/2012	559	9	2003
3/6/2012	535[g]	11	2001
3/6/2012	573	6	2006
3/6/2012	572	7	2005
3/8/2012	557	8	2004
3/20/2012	630	10	2002
3/20/2012	548	8	2004
3/21/2012	571	9	2003
3/28/2012	572	8	2004
4/3/2012	602	9	2003
4/24/2012	555[e]	9	2003

[a] Total length in millimeters.
[b] Fish stocked from Echo Bay larval fish captured in 1999 and raised at the Nevada Department of Wildlife Lake Mead Fish Hatchery.
[c] Fish stocked from Floyd Lamb Park ponds (1982 Dexter National Fish Hatchery cohort placed in Floyd Lamb Park ponds in 1984).
[d] Fish stocked from Floyd Lamb Park ponds, sonic tagged.
[e] Fish stocked from Floyd Lamb Park ponds (from an unknown 2001–03 cohort stocking event).
[f] Fish was aged at 33 years of age, ± 2 years.
[g] Fish was a mortality; found dead in net.

ATTACHMENT 3

Ages Determined from Flannelmouth and Hybrid Sucker Pectoral Fin Ray Sections Collected from the Colorado River Inflow Area of Lake Mead

Table 3-1.—Ages determined from hybrid sucker pectoral fin ray sections collected from the Colorado River Inflow Area of Lake Mead

Date collected	Species	Total length[a] (mm)	Age[b]	Presumptive year spawned
Colorado River inflow area				
4/8/2010	Flannelmouth sucker	418	13	1997
4/8/2010	Flannelmouth sucker	477	11	1999
4/8/2010	Flannelmouth sucker	460	14	1996
4/8/2010	Flannelmouth sucker	470	10	2000
4/8/2010	Flannelmouth sucker	485	9	2001
4/8/2010	Flannelmouth sucker	352	5	2005
2/2/2011	Flannelmouth sucker		4	2007
2/8/2011	Flannelmouth sucker	465	7	2004
2/10/2011	Flannelmouth sucker	410	7	2004
3/23/2011	Flannelmouth sucker	470	6	2005
3/29/2011	Flannelmouth sucker	420	4	2007
3/29/2011	Flannelmouth sucker	417	5	2006
3/29/2011	Flannelmouth sucker	420	7	2004
3/30/2011	Flannelmouth sucker	484	6	2005
3/31/2011	Flannelmouth sucker	378	3	2008
3/31/2011	Flannelmouth sucker	462	4	2007
3/31/2011	Flannelmouth sucker	458	4	2007
3/31/2011	Flannelmouth sucker	395	5	2006
3/31/2011	Flannelmouth sucker	453	6	2005
4/5/2011	Flannelmouth sucker	355	4	2007
4/5/2011	Flannelmouth sucker	422	4	2007
4/5/2011	Flannelmouth sucker	501	6	2005
4/5/2011	Flannelmouth sucker	421	7	2004
4/5/2011	Flannelmouth sucker	458	7	2004
4/5/2011	Flannelmouth sucker	503	8	2003
4/5/2011	Flannelmouth sucker		9	2002
4/6/2011	Flannelmouth sucker	462	5	2006
4/19/2011	Flannelmouth sucker	405	4	2007
4/19/2011	Flannelmouth sucker	509	6	2005
1/12/2012	Flannelmouth sucker	232	2	2010

Table 3-1.—Ages determined from hybrid sucker pectoral fin ray sections collected from the Colorado River Inflow Area of Lake Mead

Date collected	Species	Total length[a] (mm)	Age[b]	Presumptive year spawned
1/12/2012	Flannelmouth sucker	403	3	2009
1/12/2012	Flannelmouth sucker	325	3	2009
1/12/2012	Flannelmouth sucker	343	4	2008
1/12/2012	Flannelmouth sucker	440	4	2008
1/12/2012	Flannelmouth sucker	430	4	2008
1/12/2012	Flannelmouth sucker	385	4	2008
1/12/2012	Flannelmouth sucker	340	4	2008
1/12/2012	Flannelmouth sucker	434	4	2008
1/12/2012	Flannelmouth sucker	400	4	2008
1/12/2012	Flannelmouth sucker	420	4	2008
1/12/2012	Flannelmouth sucker	339	4	2008
1/12/2012	Flannelmouth sucker	432	4	2008
1/12/2012	Flannelmouth sucker	397	5	2007
4/7/2010	Hybrid sucker	555	9	2001
4/7/2010	Hybrid sucker	510	6	2004
4/20/2010	Hybrid sucker	510	6	2004
2/16/2011	Hybrid sucker	519	8	2003
3/23/2011	Hybrid sucker	478	8	2003
3/23/2011	Hybrid sucker	556	8	2003
3/31/2011	Hybrid sucker	476	8	2003
4/13/2011	Hybrid sucker	562	7	2004
5/11/2011	Hybrid sucker	540	10	2001
1/12/2012	Hybrid sucker	480	6	2006

[a] Total length in millimeters.
[b] Note: Not all flannelmouth and hybrid suckers captured were aged.

ATTACHMENT 4

Model Selection Summary Information for Closed-Capture Population and Survival Estimates for Razorback Suckers in Lake Mead Using Mark-Recapture Data from 2010–12 and Generated in the Program MARK

Table 4-1.—Model selection summary information for closed-capture population and survival estimates for razorback suckers in Lake Mead using mark-recapture data from 2010–12 and generated in the program MARK

Model[a]	AICc[b]	Delta AICc[c]	AICc weight[d]	Model likelihood[e]	Number of parameters[f]	Deviance[g]
Colorado River inflow (population estimate)						
π(.)ρ(.)N(.)	251.8973	0.0000	0.1715	1.0000	2	220.4183
π(.)ρ(.)N(t)	251.8973	0.0000	0.1715	1.0000	2	220.4183
π(t)ρ(.)N(.)	251.8973	0.0000	0.1715	1.0000	2	220.4183
π(t)ρ(.)N(t)	251.8973	0.0000	0.1715	1.0000	2	220.4183
π(.)ρ(t)N(.)	253.9074	2.0101	0.0628	0.3660	3	220.4183
π(.)ρ(t)N(t)	253.9074	2.0101	0.0628	0.3660	3	220.4183
π(t)ρ(t)N(.)	253.9074	2.0101	0.0628	0.3660	3	220.4183
π(t)ρ(t)N(t)	253.9074	2.0101	0.0628	0.3660	3	220.4183
Colorado River inflow, Echo Bay, and Muddy River/Virgin River inflow (population estimate)						
π(.)ρ(.)N(.)	182.1729	0.0000	0.1828	1.0000	2	352.8216
π(.)ρ(.)N(t)	182.1729	0.0000	0.1828	1.0000	2	352.8216
π(t)ρ(.)N(.)	182.1729	0.0000	0.1828	1.0000	2	352.8216
π(t)ρ(.)N(t)	182.1729	0.0000	0.1828	1.0000	2	352.8216
π(.)ρ(t)N(.)	184.1749	2.0020	0.0672	0.3675	3	352.8216
π(.)ρ(t)N(t)	184.1749	2.0020	0.0672	0.3675	3	352.8216
π(t)ρ(t)N(.)	184.1749	2.0020	0.0672	0.3675	3	352.8216
π(t)ρ(t)N(t)	184.1749	2.0020	0.0672	0.3675	3	352.8216
Lake-wide (population estimate)						
π(.)ρ(.)N(.)	161.9069	0.0000	0.1828	1.0000	2	367.4369
π(.)ρ(.)N(t)	161.9069	0.0000	0.1828	1.0000	2	367.4369
π(t)ρ(.)N(.)	161.9069	0.0000	0.1828	1.0000	2	367.4369
π(t)ρ(.)N(t)	161.9069	0.0000	0.1828	1.0000	2	367.4369
π(.)ρ(t)N(.)	163.9086	2.0017	0.0672	0.3675	3	367.4369
π(.)ρ(t)N(t)	163.9086	2.0017	0.0672	0.3675	3	367.4369
π(t)ρ(t)N(.)	163.9086	2.0017	0.0672	0.3675	3	367.4369
π(t)ρ(t)N(t)	163.9086	2.0017	0.0672	0.3675	3	367.4369
Lake-wide (Cormack-Jolly-Seber survival estimate)						
ϕ(.) p(.)	449.4744	0.0000	1.0000	1.0000	2	259.5116
ϕ(.) p(t)	486.8902	37.4158	0.0000	0.0000	35	218.5033
ϕ(t) p(.)	511.3466	61.8722	0.0000	0.0000	35	242.9596
ϕ(t) p(t)	579.2661	129.7917	0.0000	0.0000	67	205.7544
Lake-wide (Pradel survival estimate)						
ϕ(.) p(.) f(t)	1838.0300	0.0000	0.9999	1.0000	11	297.9495
ϕ(.) p(t) f(t)	1856.9200	18.8905	0.0001	0.0001	40	243.6694
ϕ(.) p(t) f(.)	1857.1020	19.0723	0.0001	0.0001	37	252.3853
ϕ(.) p(.) f(.)	1868.5850	30.5555	0.0000	0.0000	3	345.5520
ϕ(t) p(.) f(t)	1900.6880	62.6583	0.0000	0.0000	45	272.6332
ϕ(t) p(.) f(.)	1911.6320	73.6019	0.0000	0.0000	36	309.7041
ϕ(t) p(t) f(t)	1947.4970	109.4671	0.0000	0.0000	71	228.4232
ϕ(t) p(t) f(.)	1952.9400	114.9102	0.0000	0.0000	70	237.8788

[a] π = probability that the individual occurs in the mixture, (.) = parameter consistent through time, ρ = capture probability, N = abundance estimate, (t) = parameter variable through time, ϕ = apparent survival, and f = recruitment.

[b] Adjusted Akaike's information criterion (AICc) adjusted for small sample size bias.

[c] AICc minus the minimum AICc.

[d] Ratio of delta AICc relative to entire set of candidate models.

[e] Ratio of AICc weight relative to AICc weight of best model.

[f] Number of parameters.

[g] Log-likelihood of model minus log-likelihood of the saturated model (Zelasko and White 2011).