Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Razorback Sucker Investigations at the Colorado River Inflow Area Lake Mead, Nevada and Arizona 2011 FINAL ANNUAL REPORT

U.S. DEPARTMENT OF THE INTERIOR
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Lower Colorado River
Multi-Species Conservation Program

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EXECUTIVE SUMMARY

In 2010 the Bureau of Reclamation (Reclamation) and the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) 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. 2008b). Several of the recommendations from this report were highlighted by the Lake Mead Work Group for inclusion into 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 second year of efforts to determine the status of razorback sucker in the CRI.

Based on research during long-term Lake Mead razorback sucker investigations, our efforts involved tagging and releasing pond-reared razorback suckers into the CRI for the second consecutive year and tracking these fish using sonic-telemetry techniques. In 2011 eight sonic- and/or radio-tagged razorback suckers were released into the CRI and followed via manual tracking (similar to long-term razorback sucker monitoring methods) and passive tracking (using submersible ultrasonic receiver technology). Of the eight sonic-tagged fish released, seven remain active and have been detected 171 times manually and 9,498 times passively. Along with fish stocked in 2011, seven of the eight fish tagged and stocked in 2010 were continually tracked throughout the CRI. Additionally, one fish sonic tagged in December 2008 (and stocked into the Muddy River/Virgin River inflow area of Lake Mead) was located near the CRI. At the end of the 2011 monitoring period, this fish was again active in the Muddy River/Virgin River inflow area.

Using the sonic-tagged fish to locate potential spawning sites, we sampled for larvae on 39 nights during the 2011 spawning period. Larval sampling resulted in the capture of 65 larval razorback suckers and 11 larval flannelmouth suckers (*Catostomus latipinnis*). With a 350% increase in catch per unit effort from 2010, the identification of larval razorback sucker in the CRI helped confirm the presence of spawning adult razorback sucker and documented successful spawning in 2011.

Trammel netting was used to capture adults where concentrations of razorback sucker were suspected, and fin ray specimens were obtained from appropriate adult razorback suckers for aging purposes. From 187 net-nights, 9 wild razorback suckers, 7 razorback x flannelmouth sucker hybrids, and 112 flannelmouth suckers were captured. Of these fish, 2 razorback suckers, 1 hybrid, and 39 flannelmouth suckers were recaptures from 2010. Three of the wild razorback suckers were males expressing milt; the other six were females showing signs of spawning, which helped confirm spawning activities. To our knowledge these are the first female razorback suckers collected from within the CRI. Ages from the seven new wild razorback suckers ranged from 6–11 years.

The goal to determine the presence or absence of razorback sucker in the CRI, while more than doubling the sampling effort from 2010, was met during 2011. This was accomplished by using sonic-tagged razorback suckers to locate wild razorback suckers, marking captured razorback suckers, sampling for larval fish, determining razorback sucker habitat use, and employing aging techniques to begin characterizing the age structure of the razorback sucker population in the CRI. Many questions still need to be addressed, and the study could be improved through building a larger data set over subsequent years. Future goals for the study include continuing to study the razorback sucker population in the CRI using increased sonic tracking, larval sampling, and netting effort. This increased effort will allow for better characterization of razorback sucker habitat in the CRI and improve our ability to locate additional groups of fish or spawning areas in the vicinity. 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, is also of interest.

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INTRODUCTION AND BACKGROUND

The razorback sucker (*Xyrauchen texanus* [Abbott]) is one of four endemic, large-river fish species (Colorado pikeminnow [*Ptychocheilus lucius*], bonytail chub [*Gila elegans*], and humpback chub [*Gila cypha*]) of the Colorado River Basin presently considered endangered by the U.S. Department of the Interior (USFWS 1991). The razorback sucker was historically widespread and common throughout the larger rivers of the Colorado River Basin (Minckley et al. 1991). The current distribution and abundance of razorback sucker are greatly reduced from historic levels, mainly due to the construction of mainstem 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 sucker persisted in several reservoirs constructed in the lower Colorado River Basin; however, these populations were composed primarily of adult fish that apparently recruited during the first few years of reservoir formation. The populations of long-lived adults then disappeared 40–50 years following reservoir creation and the initial recruitment period (Minckley 1983) due to a lack of recruitment. Riverine populations in the Upper Colorado River Basin also have declined as recruitment has not occurred at significant levels since the construction of these mainstem 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 same trends of razorback sucker decline were occurring in Lake Mead. Razorback sucker numbers, initially high in Lake Mead, noticeably decreased in the 1970s, and no razorback suckers were collected during the 1980s. However, in the early 1990s the Nevada Department of Wildlife (NDOW) was 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 NDOW soon confirmed the presence of remnant populations of razorback sucker in Lake Mead. In 1996 the Southern Nevada Water Authority (SNWA), in cooperation with 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 SNWA and NDOW. Other cooperating agencies included the Bureau of Reclamation (Reclamation), National Park Service (Park Service), Colorado River Commission of Nevada, and U.S. Fish and Wildlife Service (USFWS). This work eventually led to the discovery of several groups of spawning and recruiting wild fish in the reservoir, and it currently represents the only known recruiting and naturally expanding population within the entire Colorado River Basin (Albrecht et al. 2008b, 2010b, Kegerries et al. 2009).

Larval razorback suckers were found in the CRI during 2000 and 2001, but despite opportunistic netting efforts no adult razorback suckers were captured at that time (Albrecht et al. 2008b). In 2008 the Arizona Game and Fish Department (AGFD) 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 program.

More recently a comprehensive review evaluating the entire Lake Mead razorback sucker data set obtained from 1996–2007 was finalized (Albrecht et al. 2008b). This report provided a summary of the lessons learned, methods used, and cumulative findings regarding Lake Mead razorback sucker 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) and is used and updated by the Lake Mead Work Group, which is comprised of the various agencies involved with the Lake Mead razorback sucker.

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 Colorado River Inflow area of Lake Mead (CRI) was the most reasonable 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 USFWS, if appropriate" (USFWS 2007). Thus, the Lake Mead Work Group decided to begin investigative efforts in 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 that has been implemented to date and is the first step in meeting the conservation measure from the USFWS in their 2007 Biological Opinion (USFWS 2007, Albrecht et al. 2009).

Based on previous success of locating razorback sucker in the Muddy River/Virgin River inflow area, it was determined that use of sonic telemetry was appropriate for locating "new" spawning aggregates (Albrecht and Holden 2005). Thus, we proposed initiating telemetry and limited sampling efforts in the CRI in 2010. This allowed us to better assess potential spawning habitat and resulted in the confirmation of a new Lake Mead spawning aggregate (Albrecht et al. 2010a). Combining stocking and tracking sonic-tagged razorback suckers, trammel netting, and larval sampling increased the potential of finding a new spawning population of razorback sucker at the CRI. As recent as 2009 there was an apparent surge in recruitment as the overall numbers of young, subadult fish increased at known spawning areas (Albrecht et al. 2008b, Kegerries et al. 2009); therefore, it was determined that the potential to successfully document razorback sucker at the CRI would likely be very good at this time. Given the recent successes of monitoring fish implanted with improved sonic tags, we concluded that renewing efforts in the CRI would help clarify whether an additional spawning population existed within Lake Mead (Albrecht et al. 2008b, Kegerries et al. 2009). In addition to providing 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 sucker, which will undoubtedly help identify the conditions that are conducive to these unique recruitment events.

We also felt that the CRI held potential information regarding the impacts, scale, and magnitude of lake-level and habitat changes in relation to razorback sucker recruitment. For example, the habitat at Echo and Las Vegas Bays has changed during our long-term studies, especially during the last decade. As a result of receding lake levels, razorback sucker spawning habitat locations and spawning habitat use have also changed. Habitat in the CRI has also changed during the past decade, but at a much larger spatial scale. During 2001–2003, 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, kilometers 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 unique (kilometers of habitat change compared with meters 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. It 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 within the CRI. This goal was met in 2010 by accomplishing the following objectives:

- Use sonic-tagged razorback suckers to locate and capture various life stages of wild razorback suckers 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 in the CRI.

The overall objectives remained the same for 2011. However, Reclamation decided that effort and manpower should be doubled 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 time could be spent in the Colorado River proper trying to understand the relationship between the riverine environment and habitat utilization of razorback sucker during the spawning season. In addition to sonic-telemetry methods, combination sonic and radio tags were also used to determine the feasibility of this technology in such a study.

This report presents the findings of the second study year at the CRI and covers the intensive field efforts conducted from January–May 2011; it also presents sonic telemetry data obtained from July 2010–June 2011 in accordance with the results reported by Albrecht et al. (2008a), Kegerries et al. (2009), Albrecht et al. (2010a), and other annual Lake Mead razorback sucker reports. Other information and data from previous studies are included, as applicable. This report not only presents efforts and findings from investigations conducted at the CRI in 2011, it also serves as a companion report to the 2011 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 2011. Readers interested in the results of long-term Lake Mead razorback sucker monitoring efforts are encouraged to obtain and read the companion report (Shattuck et al. 2011).

STUDY AREAS

The 2011 CRI study activities occurred within Gregg Basin of Lake Mead and the Colorado River below the Pearce Ferry Rapid (Figure 1).

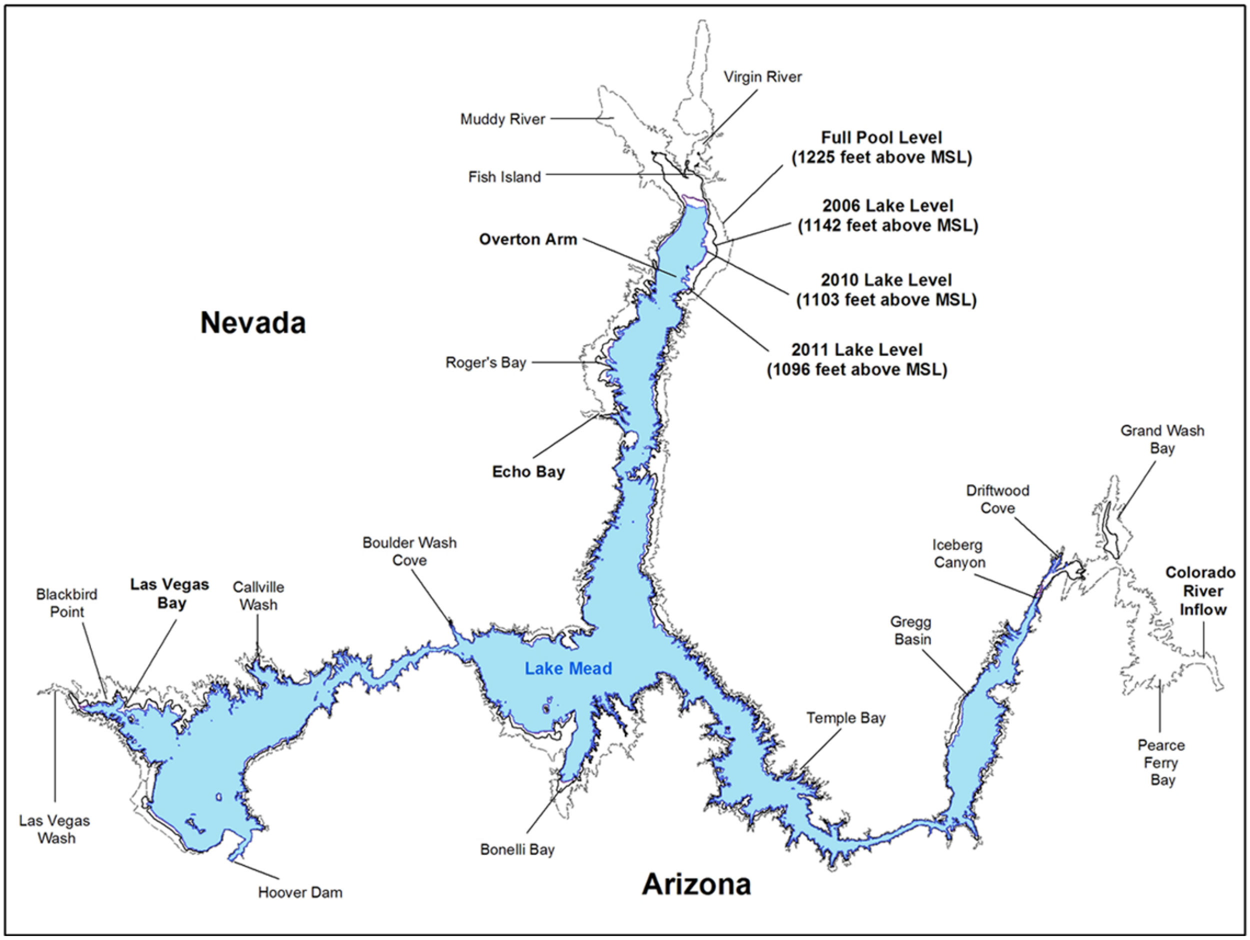

Figure 1. Lake Mead general study areas.

Definitions for various portions of the CRI (Figure 2) in which the study was conducted may be referred to using the following terms:

- Lake Mead proper begins where the flooded portion of the river channel widens and velocity is reduced.
- Colorado River proper is simply the flowing river. Depending on conditions, this area may or may not be accessible by large boat.

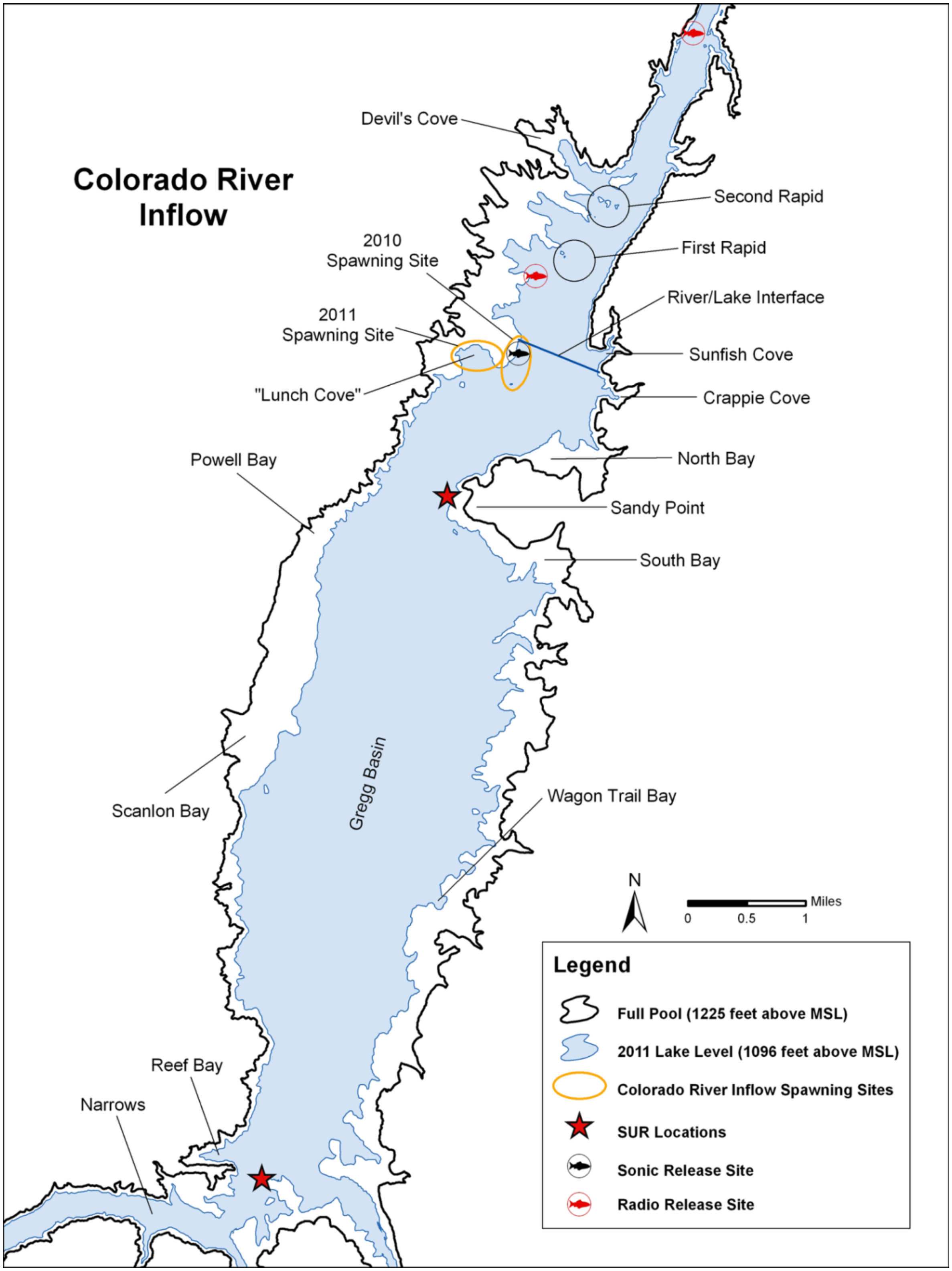

Figure 2. **Colorado River Inflow area of Lake Mead (CRI) overview, locations of initial sonic-tagged fish stocking sites, locations of submersible ultrasonic receiver (SUR) deployment, and the primary razorback sucker spawning site identified within the CRI in 2011.**

- 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 in nature.

- “Lunch Cove” is the name given by BIO-WEST for the relatively large cove just west of the river/lake interface where substantial field efforts were spent in 2011.

METHODS

Lake Elevation

Month-end lake elevations for the 2011 field season (July 1, 2010–June 30, 2011) were measured in ft above sea level (asl) and obtained from Reclamation’s Lower Colorado Regional Office website (Reclamation 2011). 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

Ten razorback suckers reared in ponds at Floyd Lamb State Park were captured using trammel nets on the morning of January 4, 2011. The NDOW provided hauling equipment to transport the razorback suckers from Floyd Lamb State Park to the South Cove boat ramp on Lake Mead. The fish were held overnight in the lake in floating net pens, and the next morning four males were implanted with Sonotronics Model CT-05-48-I (48-month) tags. The 48-month tags used in 2011 had a water weight of 12 g and measured 79 mm long by 15.6 mm in diameter. The tags used frequencies of 73, 74, 75, and 76 kHz. Because each tag had a unique code, individual fish could be readily distinguished.

One female and three male razorback suckers were implanted with Sonotronics combination acoustic and radio-transmitter (model ART-01) tags with a battery life of 1 year. These tags can transmit acoustic and radio signals, allowing for tracking both above and below water. The combination tags had a water weight of 12 g and measured 105 mm long by 18 mm in diameter. The tags used radio frequencies (RF) of 148.020, 148.350, 148.550, and 148.660 kHz with acoustic frequencies of 70–73 kHz. The remaining two razorback suckers were captured and retained as backup in the unlikely event that any fish died during transport or surgery. These fish were not used and as such were tagged with PIT tags and released into the CRI.

The following surgical protocol was established from procedures developed by Valdez and Nilson (1982), Kaeding et al. (1990), and Valdez and Trinca (1995) for humpback chub; Tyus (1982) for Colorado squawfish (pikeminnow); and Valdez and Masslich (1989) for Colorado squawfish (pikeminnow) and razorback sucker. A transmitter air weight to fish weight of 2% (Bidgood 1980, Marty and Summerfelt 1990) was used as a guideline to ensure that the tags were not too large for the fish being tagged. Surgery was performed on shore and involved one surgeon and two assistants. The assistants recorded data, captured pertinent photographs, and monitored fish respiration. Dr. Chris Bunt of BIOTACTIC, Inc., assisted with the surgeries, demonstrated current surgical practices, and provided instruction on updated tagging methodologies to the field biologists. Prior to surgery each fish was placed in a live well containing fresh lake water. All surgical instruments were cold sterilized with iodine and 90%

isopropyl alcohol and allowed to air dry on a disposable sterile cloth. Razorback sucker were initially anaesthetized in 30 L of lake water with a 50 mL/L^{-1} clove oil/ethanol mixture (0.5 mL clove oil [Anderson et al. 1997] emulsified in 4.5 mL ethanol) (Bunt et al. 1999). After anesthesia was induced, total length, fork length, standard length, and weight of each fish were recorded. Fish were then placed dorsal-side down on a padded surgical cradle for support during surgery. Head and gills were submerged in 20 L of fresh lake water with a maintenance concentration of 25 mL/L^{-1} clove oil/ethanol anesthetic (Bunt et al. 1999). Following fish introduction to the maintenance anesthetic, the surgeon made a 2–3 cm incision on the left side, posterior to the left pelvic girdle. A PIT tag was placed into the incision followed by the transmitter, which was pushed between the pelvic girdle and urogenital pore. The incision was closed with 2–4 sutures using 3-0 Maxon absorbable poliglecaprone 25 monofilament suture with an attached PS-1 reverse-cutting, curved needle. Surgery times typically ranged from 2–5 minutes per fish.

After surgical procedures were completed, fish were allowed to recover in a floating net pen in the lake and closely monitored until equilibrium was maintained. Once fully recovered, tagged fish were taken by boat to predetermined release points within the CRI. All four sonic-tagged fish were released in a small cove near the lake interface close to the 2010 spawning area, while the four radio-tagged fish were taken up the Colorado River and released at two locations. Two of the radio-tagged fish were released just upstream from the lake interface, about 200 m below the first river rapid in a small slackwater area. The remaining two radio-tagged fish were transported approximately 1.2 mi (2.0 km) upstream from the lake interface and released in a larger slackwater area. Upon arrival all fish were reexamined for signs of stress and released. Tracking ensued immediately after release and continued intensively for 48 hours; detailed tracking continued intensively for weeks following surgery.

Active Sonic Telemetry and Tracking

During the intensive field season associated with the spawning period (January–May), sonic-tagged fish were located weekly (or sometimes daily), depending on the field schedule and weekly project goals. During the remainder of the year, sonic-tagged fish were typically located monthly. Fish searches were largely conducted along shorelines with listening points of approximately 0.5 mi (0.8 km) 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, the effectiveness of a sonic-telemetry signal is often reduced in shallow, turbid environments.) Active tracking consisted of listening underwater for coded sonic tags using a Sonotronics USR-08 or earlier model of ultrasonic receiver 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 fish’s tag number, GPS location, and depth information were then recorded. Radio-tagged fish were tracked using similar methods with a Lotek SRX 400a receiver and Yagi antenna.

Passive Sonic Telemetry and Submersible Ultrasonic Receiver Data-Collection Efforts

Along with the active tracking methods, submersible ultrasonic receivers (SUR) were deployed in various locations throughout the CRI. The advantage to using SURs is their ability to record continuous telemetry data without field crews being present. With an approximate 9-month battery life and the ability to detect manual-tracking transmitters, SURs save valuable field time while collecting additional telemetry data.

Two SURs were deployed in the CRI at different times during the 2011 field season. To track fish moving in and out of Gregg Basin, the first SUR was deployed on the upstream end of the Narrows on January 5, 2011 (Figure 2). The other SUR was deployed on January 18, 2011, just downstream of the CRI on the north end of Sandy Point (Figure 2).

Both SURs were programmed to detect implanted, active sonic-tag frequencies using Sonotronic's SURsoft software. The semibuoyant SURs were then suspended from an anchor (rock, anchor, block) using approximately 18 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. The SURs were downloaded 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 two millisecond interval units.

Adult Studies

The primary gear used to sample adult fish were 300 ft (274.4 m) long by 6 ft (1.8 m) deep trammel nets with an internal panel of 1 in (2.54 cm) mesh and external panels of 12 in (30.48 cm) mesh. On occasion, shorter 150 ft long (45.72 m) trammel nets 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 5–30 ft (3.05–9.15 m) 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, 100-quart (94.6-L) coolers filled with lake water. Razorback suckers and/or flannelmouth suckers 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, weighed, and released at the capture location. Razorback suckers, flannelmouth suckers, or suspected razorback sucker x flannelmouth sucker hybrids were scanned for PIT tags, PIT tagged if they were not recaptured fish, measured (including standard length and fork length), weighed, and released at the point of capture. Native sucker species selected for age determination were anesthetized with 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. Due to the presence of suspected hybrid suckers at the CRI, genetic material was also removed from many of the native suckers (including suspected hybrids); a small bit of material was obtained from the caudle fin and preserved in 95% ethanol in case of future need.

It should be noted that other alternative capture methods were also experimented with during the 2011 efforts at the CRI. These methods included setting 150 ft (45.72 m) trammel nets in slackwater areas within the river proper, using these small trammel nets to seine in slackwater or backwater areas, drifting the trammel nets in the flowing portion of the river, and setting them in eddy lines below river rapids. Trap or Fyke nets were also set in slackwater areas. Deep, turbid conditions, coupled with debris-laden habitats and high velocities, resulted in no razorback sucker captures and very few captures of any fish species overall. However, these efforts did result in the capture of a single flannelmouth sucker, the data from which were lumped with flannelmouth sucker data obtained from trammel netting efforts for this report. Similar to last year's trial electrofishing efforts, these relatively minimal and largely unproductive experimental efforts will not be further analyzed.

Larval Sampling

Our larval sampling methods followed those 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 4–10 in (10.2–25.4 cm) of water. Two to four netters equipped with long-handled aquarium dip nets were stationed to observe the area around the lights. Larval razorback sucker 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 each location, and 4–12 sites were customarily sampled 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 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 et al. (2004). Razorback sucker larvae were originally identified in the field and later verified by BIO-WEST under laboratory conditions using the Catostomid key (Snyder et al. 2004). It should be noted that not all sucker larvae were preserved for identification. Only those that were difficult to identify in the field were preserved for verification.

Spawning-Site Identification

We have found that multiple methods are needed to identify and pinpoint annual spawning sites in Lake Mead. 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 being 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 indicative of spawning. After the initial identification of a possible spawning site through sonic-tagged razorback sucker habitat use and other, untagged subadult 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 and 2011.

Age Determination

For age determinations, we used a nonlethal technique employing fin ray sections developed in 1999 on Lake Mead razorback sucker (Holden et al. 2000). As in past years, an emphasis of our 2011 CRI efforts involved collecting fin ray sections from razorback suckers for aging purposes. Specimens were also obtained from flannelmouth suckers and suspected hybrid suckers for age determination.

During the 2011 spawning period, selected suckers captured via trammel netting were anesthetized and a single, approximately 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, NaCl, and slime-coat protectant to reduce surgery-related stresses, speed recovery, and avoid accidental injury to fish that may thrash during surgical procedures. During the surgery standard processing was conducted (weighing, measuring, PIT-tagging), and a sample was surgically collected using custom-made bone snips originally developed by BIO-WEST. This surgical tool consists of a matched pair of finely sharpened chisels welded to a set of wire-stripping pliers. The connecting membrane between 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 slime-coat protectant and NaCl, 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 the readers in instances where 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. For further information regarding the evolution of our fin ray aging technique, please refer to Albrecht and Holden (2005), Albrecht et al. (2006b), Albrecht et al. (2008a), and other annual Lake Mead razorback sucker reports.

RESULTS

Lake Elevation

From a starting record-low lake elevation in January 2011 of approximately 1,092 ft (332.8 m) asl, lake levels increased in February 2011 to 1,096 ft (334.1 m) asl. Lake levels then remained rather consistent through April 2011, fluctuating near 1,096 ft (334.1 m) asl. Lake levels continued to climb in May 2011, reaching a peak of nearly 1,098 ft (334.7 m) asl, which coincided with our intensive studies during the 2011 spawning period. This increase translated to an overall gain of nearly 6 ft (1.8 m) of lake depth during the 2011 spawning period (Figure 3). The result was an overall increase of wetted, littoral habitats, including increased amounts of inundated vegetation within the CRI between February and late May 2011. The effects of water level increases and the dynamic addition 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 sucker spawned in 2011 (Shattuck et al. 2011).

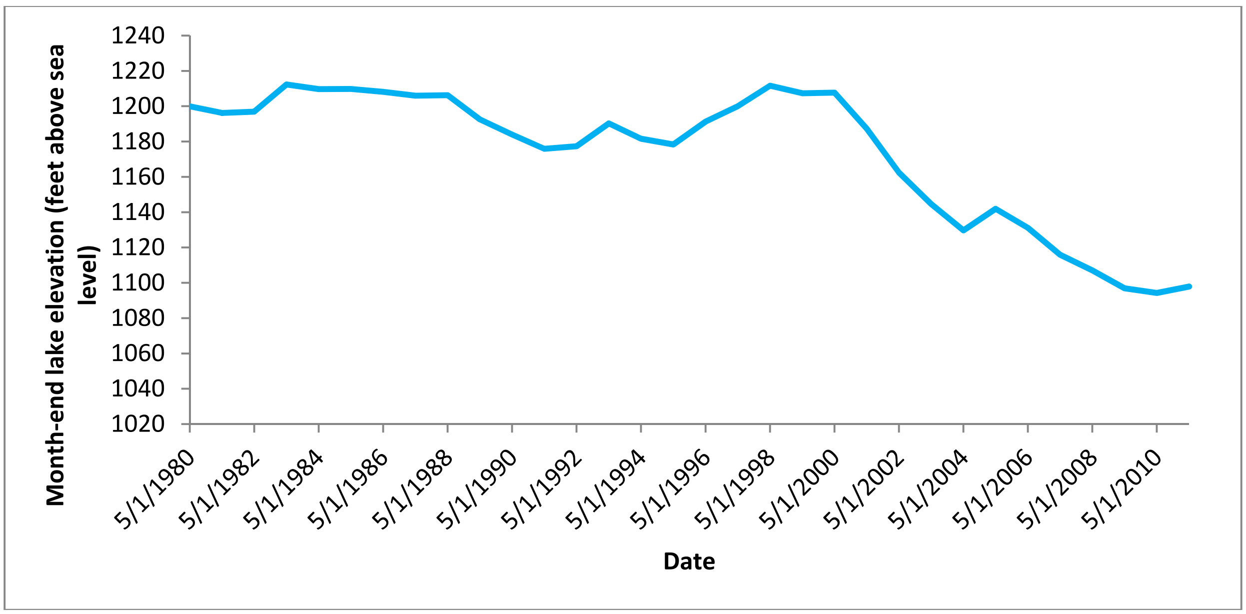

Figure 3. Lake Mead month-end elevations, May 1980–May 2011.

Acoustic and Radio Telemetry and Tracking

A total of 16 sonic- and/or radio-tagged fish have been released into the CRI since 2010, including four newly implanted sonic-tagged and four newly implanted radio-tagged razorback suckers released at three locations within the CRI on January 5, 2011 (Table 1, Figure 4). The four 2011 sonic-tagged fish were released near a known 2010 spawning area within the lake proper and close to the inflow area. The four radio-tagged fish were released in the river proper to help determine the effectiveness and feasibility of using this technology in flowing habitats with the intent of increasing our listening capability (Figure 4). During the 2010 field season we

Table 1. Tagging and stocking information, location, date of last contact, and current status of sonic-tagged fish released into the Colorado River Inflow area of Lake Mead (CRI) in 2011, as well as information pertaining to fish from the 2010 and 2008 tagging events that were found using CRI habitats in 2011.

CAPTURE LOCATION [a]	DATE TAGGED	TAG CODE	TOTAL LENGTH (mm)	SEX [b]	STOCKING LOCATION [a]	LAST LOCATION [a]	DATE OF LAST LOCATION	CONTACTS MADE 2010–2011	CURRENT TAG STATUS
Fish Tagged in 2011									
FDLB	1/5/2011	447	505	M	CRI	CRI	6/19/2011	1,161 total 31 active 1,130 passive	Alive
FDLB	1/5/2011	3546	496	M	CRI	CRI	6/16/2011	1,862 total 30 active 1,832 passive	Alive
FDLB	1/5/2011	3666	504	M	CRI	CRI	3/15/2011	31 total 12 active 19 passive	Stationary
FDLB	1/5/2011	3774	509	M	CRI	CRI	5/29/2011	605 total 24 active 581 passive	Alive
FDLB	1/5/2011	5578	487	M	CRI/River	CRI	6/29/2011	3,860 total 29 active 3,831 passive	Alive
FDLB	1/5/2011	5767	515	M	CRI/River	CRI	5/13/2011	742 total 11 active 731 passive	Alive
FDLB	1/5/2011	5768	530	F	CRI/River	CRI	5/24/2011	457 total 23 active 434 passive	Alive
FDLB	1/5/2011	6678	565	M	CRI/River	CRI	6/16/2011	982 total 23 active 959 passive	Alive
Fish Tagged in 2010									
FDLB	2/23/2010	227	486	M	GB	CRI	6/23/2011	3,510 total 10 active 3,500 passive	Alive
FDLB	2/23/2010	249	511	M	CRI	CRI	6/29/2011	8,617 total 19 active 8,598 passive	Alive
FDLB	2/23/2010	258	502	M	CRI	CRI	6/12/2011	8,304 total 19 active 8,285 passive	Alive

Table 1. (Cont.)

CAPTURE LOCATION [a]	DATE TAGGED	TAG CODE	TOTAL LENGTH (mm)	SEX [b]	STOCKING LOCATION [a]	LAST LOCATION [a]	DATE OF LAST LOCATION	CONTACTS MADE 2010–2011	CURRENT TAG STATUS
FDLB	2/23/2010	267	534	F	GB	CRI	6/30/2011	1,200 total 12 active 1,188 passive	Alive
FDLB	2/23/2010	339	501	M	CRI	CRI	6/21/2011	2,029 total 30 active 1,999 passive	Alive
FDLB	2/23/2010	348	516	M	GB	CRI	3/17/2011	1 total 1 active 0 passive	Stationary
FDLB	2/23/2010	357	490	M	GB	CRI	6/28/2011	1,214 total 12 active 1,202 passive	Alive
FDLB	2/23/2010	485	517	M	CRI	CRI	6/30/2011	4,448 total 14 active 4,434 passive	Alive
Fish Tagged in 2008									
FDLB	12/2/2008	3354	506	F	MR/VR	MR/VR	4/26/2011	3,305 total 2 active 3,303 passive	Alive

[a] Locations: FDLB = Floyd Lamb State Park, CRI = Colorado River inflow area, River = Colorado River proper, GB = Gregg Basin near Scanlon Bay, MR/VR = Muddy River/Virgin River inflow area.
[b] Sex: M = male, F = female.
[c] Number of contacts are presented using active sonic-telemetry techniques, passive sonic-telemetry techniques (i.e., submersible ultrasonic receivers), and in total (the number of active and passive contacts combined). Please refer to the active and passive sonic-tracking methodologies in this report for details.

learned that sonic-tagged fish had an affinity for the river proper, but we were unable to effectively track these individuals using the acoustic technology due to the noise created from the flowing river water. We thought if radio-tagged fish moved upstream we would be able to track their movement throughout the river using the radio signal. After completing a few quick field trials, we determined that the radio signal would be difficult to pinpoint for any fish deeper than approximately 7 ft (2.29 m) of water. However, radio-tagged fish were detected in the flowing portions of the river throughout the year and by airplane shortly after stocking. Although functional and feasible, the radio technology was not used during most of the field season or subsequent tracking trips because the radio-tagged fish moved from the river proper to the lake interface within a few weeks of stocking in the river. The four radio-tagged fish were detected by acoustic sonic-tracking methods (both manual and passive) more than 6,000 times from January–June. Overall, movement patterns of these fish were very similar to other fish sonic tagged and stocked in the lake proper, and relatively few contacts were made using the RF technology alone (Figure 5).

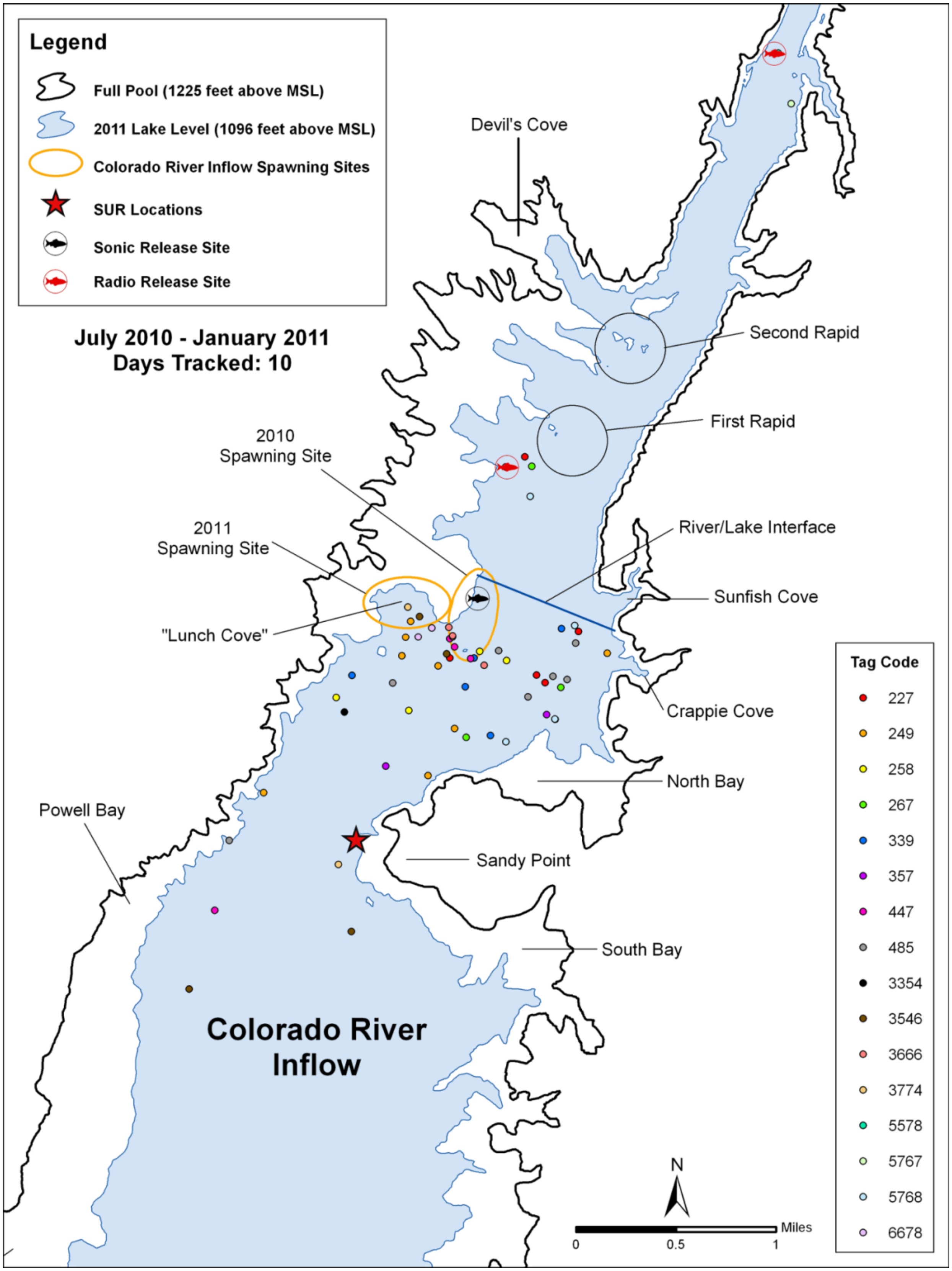

Figure 4. Distribution of sonic-tagged fish in the Colorado River Inflow area of Lake Mead during the nonspawning months of July 2010–January 2011.

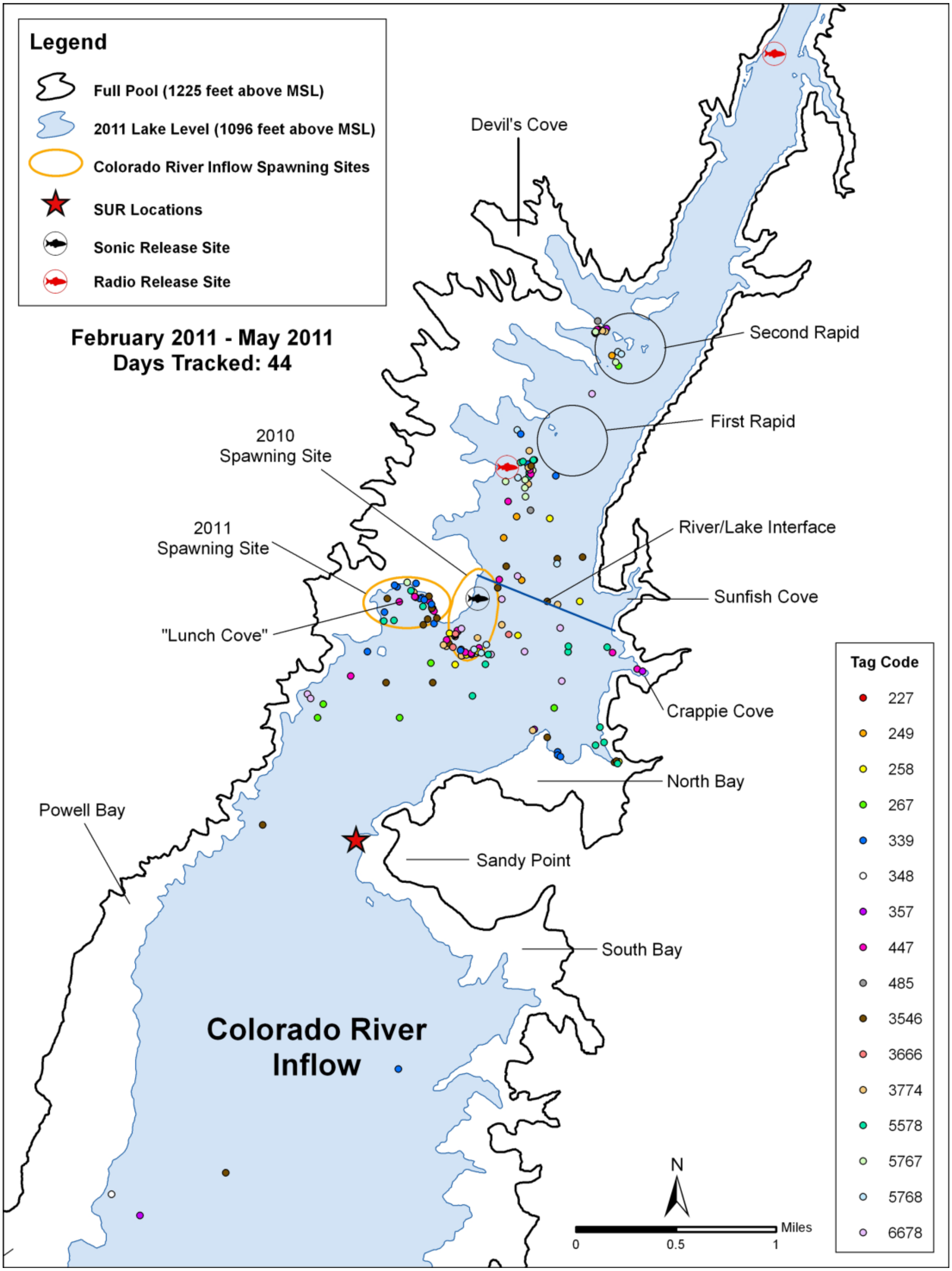

Figure 5. **Distribution of sonic-tagged fish in the Colorado River Inflow area of Lake Mead during the spawning months of February 2011–May 2011.**

In total, 17 sonic-tagged fish were contacted more than 42,000 times (302 manual, 42,026 SUR) from July 2010–June 2011 at the CRI. Of these 17 fish, eight were newly stocked in 2011, eight were stocked in 2010, and one was from a 2008 stocking at the Muddy River/Virgin River inflow area of Lake Mead. With a few exceptions to be discussed later, all of these fish remained in the vicinity of the CRI throughout the year, and there was no indication that they traveled upstream beyond our ability to detect them for any extended period. Most of the tagged fish using the river proper spent several days in riverine habitat and later returned to the lentic portions of Lake Mead. Particularly heavy use was observed at or near the interface of the Colorado River and Lake Mead. Passive telemetry using two SUR units resulted in 42,026 sonic-tag detections during the 2011 field season. It should be noted that detections were recorded by SURs at the south end of Gregg Basin and near the CRI (Figures 4 and 5). Sixteen uniquely coded sonic-tagged fish were detected via this method from July 2010–June 2011.

Manual tracking efforts from July 2010 through the end of January 2011 (nonspawning months) consisted of 10 days of tracking for a total of 54 contacts (Figure 4). 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 deeper open water and showed little to no preference for any particular habitat. Due to the limited number of tracking events within the river proper during these months, relatively few fish were documented in the riverine habitat. Figure 4 also depicts tracking and movement data for the four radio-tagged fish released in the river proper in early January. These fish joined other sonic-tagged fish within the lake proper shortly after release. Sonic-tagged fish released in the CRI tended to remain relatively close to their original release site and the previous year's spawning location.

During the spawning period (February–May), sonic-tagged fish continued to occupy habitats close to the river/lake interface (Figure 5). We spent 44 days manually tracking the tagged fish during this period for a total of 221 contacts. In the course of our efforts, it became evident that sonic-tagged fish were utilizing shallower littoral habitats. Many of the contacts occurred within the Lunch Cove area and the area near the 2010 spawning location. Both of these areas are just downstream of the river/lake interface and sheltered from the intense turbidity and flow coming from the river proper. Movement of sonic-tagged fish into the flowing portions of the river was also common (Figure 5). Several sonic-tagged fish spent days to weeks occupying slackwater or eddy habitats upstream of the inflow area, immediately below the first and second rapids. No sonic-tagged fish were tracked above the second rapid after February 2011. The number of contacts with sonic-tagged fish in Lunch Cove, combined with larval and netting data (reported later in this document), helped identify the area most likely to be the primary spawning area for razorback sucker in 2011 (Figure 5).

Netting close to sonic-tagged fish locations aided in the capture of several wild and stocked adult razorback suckers. During one sampling event in early February, five sonic-tagged fish were found along the shore of a small island (at the time of sampling) located just south of the river/lake interface along the western shoreline of the lake proper. Trammel netting, guided by the presence of sonic-tagged fish, resulted in the capture of three adult razorback suckers, one of which was a new wild fish. The two other fish were fish stocked during the 2010 sonic tagging event. 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. Two sonic-tagged fish and two stocked PIT-tagged fish from the 2010 stocking event were also captured in 2011 while we attempted to capture other wild adults. All recaptured fish appeared to be in good health and were tracked moving throughout the CRI after being captured and released. The use of the North Bay area by sonic-tagged fish (Figure 5) also aided in the capture of larval and adult razorback suckers, again demonstrating the importance of sonic-tagged fish in locating additional spawning areas. These findings confirm the importance of using sonic-tagged fish to locate wild razorback sucker spawning areas, understand razorback sucker habitat use, and, perhaps most importantly, increase the effectiveness and efficiency of sampling efforts, particularly within unknown or understudied locations.

Noteworthy Contacts

Contact was made with sonic-tagged fish 3354, which was stocked into the Muddy River/Virgin River inflow in 2008 (Table 1, Figure 4). This fish was contacted throughout the spawning season in 2010 at the CRI and reported in Albrecht et al. (2010a). It remained in the CRI until it was last contacted on October 29, 2010, via SUR in the Narrows (south end of Gregg Basin). This fish then moved into Echo Bay, where it was contacted in November 2010. It later moved up to the Muddy River/Virgin River inflow area by December 2010, where it remained and was last contacted in April 2011 (Shattuck et al. 2011).

Sonic-tagged fish 267 was reported in Albrecht et al. (2010a) to have had battery failure shortly after it was stocked in February 2010. Although this was a likely scenario considering the weak signal it was transmitting and the fact that this fish was not detected by either SUR or manual tracking efforts, the battery had not failed. Fish 267 was again contacted in December 2010 and continually contacted throughout the 2011 field season through the end of June. It is unlikely the fish left the CRI undetected for 10 months, but it is plausible the fish avoided contact by the Gregg Basin SUR and resided in an area of the lake field crews were not tracking during that time. The sonic tag could have also malfunctioned for 10 months, but currently there is no evidence to suggest that occurred.

There are two sonic-tagged fish currently transmitting a stationary signal within the CRI—fish 348 and fish 3666. Fish 348 has been stationary on the west shoreline of Gregg Basin for over a year, and the tag is transmitting in approximately 12 ft (3.66 m) of water. Stationary tags generally result from fish that died, and the tag fell out as the fish deteriorated, or the fish remained alive and expelled the tag. It is not known what may have caused the apparent mortality because this fish was active for several weeks after surgery and release in February 2010.

Fish 3666 moved only slightly after being released from its original location in January 2011. The surgery and release of this fish were successful; however, no movement has been recorded since that time. Although the sutures appeared to be secure, it is possible that the tag was shed from the body cavity through the incision. Most likely the fish died from unknown complications with surgery.

Adult Sampling

Trammel Netting

Trammel netting was conducted for a total of 187 net-nights at the CRI during 2011(Table 2). In general, trammel netting was concentrated near the CRI because the area was frequented by sonic-tagged fish and because of previous successes capturing razorback suckers there during the 2010 and 2011 field seasons. More specifically, a large portion of this effort was expended in Lunch Cove (Figure 6). Toward the latter portion of the field season, efforts were also expended along the eastern shoreline of the CRI at and around the North Beach area because sonic-tagged fish were found frequenting coves in that general location (e.g., North Bay and Crappie Cove).

Table 2. Trammel-netting effort (net-nights) in the Colorado River Inflow area of Lake Mead during 2011.

MONTH	COLORADO RIVER INFLOW NET NIGHTS
February	38
March	60
April	68
May	21
Total	**187**

Trammel netting occurred from January through late May 2011. One of the goals for the 2011 field season was to increase our trammel-netting effort in hopes of catching more razorback suckers from the CRI. We accomplished this goal, increasing our trammel-netting effort by more than 600%, as compared to 2010. As a result trammel netting provided for the capture of 15 razorback suckers, 9 of which were wild individuals (Table 3). Seven of the nine wild captures were new, wild, unmarked fish (46.7% of all captures were new, wild, unmarked fish). Overall, this equates to more than a five-fold increase in total razorback sucker captures at the CRI this season, as compared to 2010 (Albrecht et al. 2010a). For the 2011 field season, razorback sucker catch per unit effort (CPUE) based on 15 total captures was 0.08 fish/net-night (Figure 7) compared to 0.10 fish/net-night in 2010. Although the CPUE decreased slightly in 2011, it is not significantly different than the 2010 CPUE (ANOVA, p = 0.7311). The CPUE for new, wild razorback suckers was 0.04 fish/net-night. Trammel netting provided perhaps the most striking evidence of razorback sucker spawning activity in the CRI in 2011. In comparison, the CPUE for razorback suckers captured at the CRI in 2011 is the same as the CPUE at the Muddy River/Virgin River inflow area in 2006 one year after that spawning aggregate was first identified and adult sampling was initiated (Shattuck et al. 2011).

The first of the nine wild razorback suckers captured in 2011 was a male with a total length (TL) of 594 mm; this fish was not in spawning condition on February 8, 2011. The first wild male razorback sucker expressing milt was captured on March 9, 2011, and the first wild female razorback sucker expressing eggs was captured on March 10, 2011 (Table 3). The 2011 field season marks the first year during our 15 years of Lake Mead razorback sucker studies in which

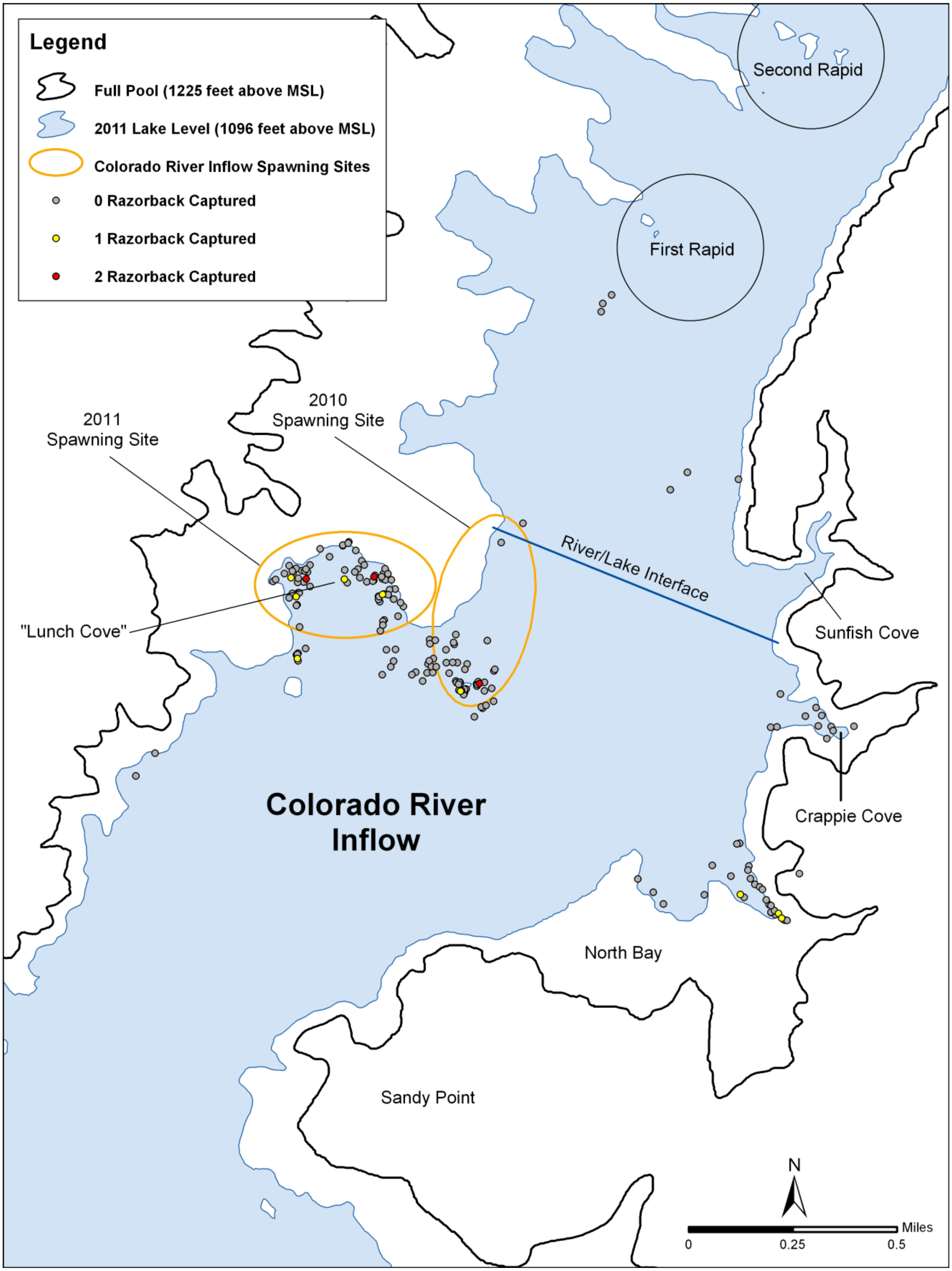

Figure 6. Trammel-netting locations and numbers of fish captured in the Colorado River Inflow area of Lake Mead, February 2011–May 2011.

Table 3. Date, PIT-tag, size, and status information for razorback suckers and suspected razorback sucker x flannelmouth sucker hybrids stocked or captured in the Colorado River Inflow area of Lake Mead during 2011.

DATE	SPECIES	PIT-TAG NUMBER	SONIC CODE	DATE [a]	RECAPTURE/ STATUS	TL [b] (mm)	FL [c] (mm)	SL [d] (mm)	WT [e] (g)	SEX [f]
1/5/2011	Razorback Sucker	384.1B796EE0FF	447	1/5/2011	NO/STOCKED IN 2011 [g]	505	471	438	1670	M
1/5/2011	Razorback Sucker	384.1B796EE390	5767	1/5/2011	NO/STOCKED IN 2011 [g]	515	481	446	1780	M
1/5/2011	Razorback Sucker	384.1B796EE629	6678	1/5/2011	NO/STOCKED IN 2011 [g]	565	418	475	2530	M
1/5/2011	Razorback Sucker	384.1B796EE7D5	3666	1/5/2011	NO/STOCKED IN 2011 [g]	504	465	425	1580	M
1/5/2011	Razorback Sucker	384.1B796EECB1	5768	1/5/2011	NO/STOCKED IN 2011[g]	530	495	458	1760	F
1/5/2011	Razorback Sucker	384.1B796EF023	3546	1/5/2011	NO/STOCKED IN 2011 [g]	496	458	423	1480	M
1/5/2011	Razorback Sucker	384.1B796EFA81	5578	1/5/2011	NO/STOCKED IN 2011 [g]	487	451	414	1280	M
1/5/2011	Razorback Sucker	3D9.1C2D642832		1/5/2011	NO/STOCKED IN 2011 [g]	449	421	382	1080	M
1/5/2011	Razorback Sucker	3D9.1C2D6964A6	3774	1/5/2011	NO/STOCKED IN 2011 [g]	509	473	440	1700	M
1/5/2011	Razorback Sucker	5341793221		1/5/2011	NO/STOCKED IN 2011 [g]	462	430	396	1180	U
2/8/2011	Razorback Sucker	3D9.1C2D2683FE		2/8/2011	NO/NEW WILD FISH IN 2011	594	554	505	2255	F
2/8/2011	Razorback Sucker	3D9.1C2D694DBC	258	2/23/2010	YES/STOCKED FISH FROM 2010 [g]	551	510	465	2165	M
2/8/2011	Razorback Sucker	3D9.1C2D695D3A		2/23/2010	YES/STOCKED FISH FROM 2010 [g]	527	480	431	1530	M
3/8/2011	Razorback Sucker	3D9.257C60DFD0	339	2/23/2010	YES/STOCKED FISH FROM 2010 [g]	528	495	470	1695	M
3/9/2011	Razorback Sucker	3D9.1C2D260A5A		4/20/2010	YES/WILD FISH FROM 2010	574	535	492	2305	M
3/10/2011	Razorback Sucker	384.1B796EDB73		3/10/2011	NO/NEW WILD FISH IN 2011	659	619	555	3652	F
3/23/2011	Razorback Sucker	3D9.257C60DFD0	339	2/23/2010	YES/STOCKED FISH FROM 2010 [g]	N/A [i]	N/A	N/A	N/A	M
3/24/2011	Razorback Sucker	384.1B796EDD6D		3/24/2011	NO/NEW WILD FISH IN 2011	584	538	507	1235	F

Table 3. (Cont.)

DATE	SPECIES	PIT-TAG NUMBER	SONIC CODE	DATE [a]	RECAPTURE/ STATUS	TL [b] (mm)	FL [c] (mm)	SL [d] (mm)	WT [e] (g)	SEX [f]
3/24/2011	Razorback Sucker	384.1B796EDD6D		3/24/2011	NO/NEW WILD FISH IN 2011	584	538	507	1235	F
3/24/2011	Razorback Sucker	384.1B796EF2E8		3/24/2011	NO/NEW WILD FISH IN 2011	530	490	454	1634	M
3/24/2011	Razorback Sucker	384.1B796EF47F		3/24/2011	NO/NEW WILD FISH IN 2011	545	500	471	1813	M
3/24/2011	Razorback Sucker	3D9.1C2D694DBC	258	2/23/2010	YES/STOCKED FISH FROM 2010 [g]	N/A	N/A	N/A	N/A	M
3/30/2011	Razorback Sucker	3D9.257C60DFD0	339	2/23/2010	YES/STOCKED FISH FROM 2010 [g]	N/A	N/A	N/A	N/A	M
4/19/2011	Razorback Sucker	384.1B796EE475		4/19/2011	NO/NEW WILD FISH IN 2011	636	597	547	2615	F
4/20/2011	Razorback Sucker	384.1B796EEA0D		4/20/2011	NO/NEW WILD FISH IN 2011	570	532	498	2475	F
4/21/2011	Razorback Sucker	3D9.1C2D2683FE		2/8/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
2/16/2011	Hybrid [h]	3D9.1C2D26254C		2/16/2011	NO/NEW WILD FISH IN 2011	519	489	448	1410	M
3/23/2011	Hybrid [h]	384.1B796EDFBD		3/23/2011	NO/NEW WILD FISH IN 2011	478	444	415	1001	M
3/23/2011	Hybrid [h]	384.1B796EE49B		3/23/2011	NO/NEW WILD FISH IN 2011	556	521	483	1598	F
3/23/2011	Hybrid [h]	3D9.1C2D269A92		4/7/2010	YES/STOCKED FISH FROM 2010 [g]	531	504	468	1574	F
3/31/2011	Hybrid [h]	384.1B796EE9C7		3/31/2011	NO/NEW WILD FISH IN 2011	476	436	398	1098	F
4/13/2011	Hybrid [h]	3D9.1C2D2608F0		4/13/2011	NO/NEW WILD FISH IN 2011	562	530	496	1768	F
5/11/2011	Hybrid [h]	384.1B796EE0E6		5/11/2011	NO/NEW WILD FISH IN 2011	540	504	479	1763	F

[a] Date originally stocked or originally captured. [b] Total length. [c] Fork length. [d] Standard length. [e] Weight. [f] F = female, M = male, I = immature, U = unidentified (sex not determined). [g] Razorback sucker from Floyd Lamb State Park stocked as part of the 2010 or 2011 sonic-tagging events (i.e., not a wild Colorado River Inflow capture). [h] Suspected razorback sucker x flannelmouth sucker hybrid. [i] Not recorded, typically to avoid excessive handling stress.

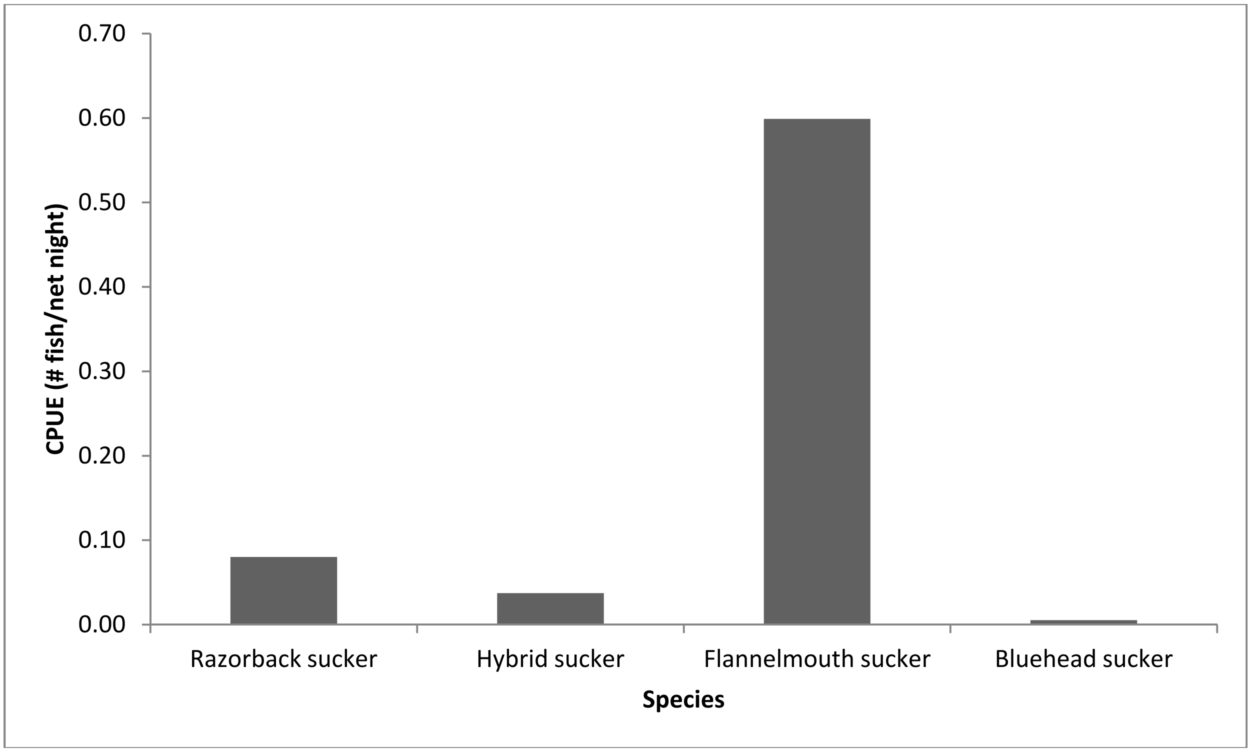

Figure 7. Trammel-netting catch per unit effort values from the Colorado River Inflow area of Lake Mead, 2010.

new, wild females were collected at the CRI (Albrecht et al. 2010a). The sex ratio of the nine, wild razorback suckers captured at the CRI in 2011 was 3:6 (males to females).

Similar to the 2010 sonic-tagging event, 10 razorback suckers from Floyd Lamb State Park were stocked into the CRI in 2011. Four of these fish were implanted with standard sonic tags, four were implanted with dual-function sonic/radio telemetry tags, and two were implanted with PIT tags. Most of these fish were new to the system and ripe at time of stocking; therefore, they were not included in the various totals and metrics provided in the previous paragraphs.

Seven razorback sucker x flannelmouth sucker hybrids were captured at the CRI in 2011, resulting in an overall CPUE of 0.04 hybrid fish/net-night. One of these hybrids was a recaptured individual from the 2010 field season (Table 3). Interestingly, the sex ratio for hybrids was 2:5 (males to females), with both sexes typically expressing gametes or otherwise showing signs of sexual maturity at time of capture. Additionally, 112 flannelmouth suckers were captured (39 were recaptured fish from 2010, and 73 were new, wild fish from 2011), resulting in an overall CPUE of 0.60 flannelmouth suckers/net-night for the 2011 field season. We do not include sex ratios for flannelmouth sucker because many fish were immature or not readily identifiable at time of capture.

Finally, a single bluehead sucker (*Catostomus discobolus*) that was 282 mm TL and of undetermined sex was captured during the 2011 field season (CPUE = 0.005). This marks the first time that bluehead sucker have been collected during our razorback sucker research and monitoring efforts on Lake Mead. To our knowledge, it is also the first record of bluehead sucker captured on Lake Mead. Similarly, 2011 marks only the second season in which flannelmouth sucker have been captured from Lake Mead during our studies (Albrecht et al. 2010a) (Appendix A).

Length and Growth Information

Although eight razorback suckers were recaptured in the CRI in 2011, annual growth rate analyses were performed using data from only the initial capture of the four unique individuals (Table 3). All eight recaptures were not included in this analysis because three of these unique fish were captured more than once during the 2011 field season. The difference in TL between capture periods was used to determine mean daily growth rate values, which were then 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 sonic-tagging events. Estimated mean annual growth, as determined from all recaptured razorback suckers from the CRI in 2011, was 33.4 mm/year. For comparison, mean annual growth of all razorback suckers captured from other locations in Lake Mead during 2011 was 24.7 mm/year (Shattuck et al. 2011). Mean annual growth of recaptured CRI-stocked fish only was 40.3 mm/year, while mean annual growth of the sole wild CRI-recaptured fish was 12.4 mm/year.

Razorback suckers captured at the CRI in 2011 ranged from 527–659 mm TL. Hybrid suckers captured at the CRI in 2011 ranged from 476–562 mm TL. Finally, the more numerous flannelmouth suckers captured in 2011 at the CRI ranged from 230–510 mm TL (Figure 8).

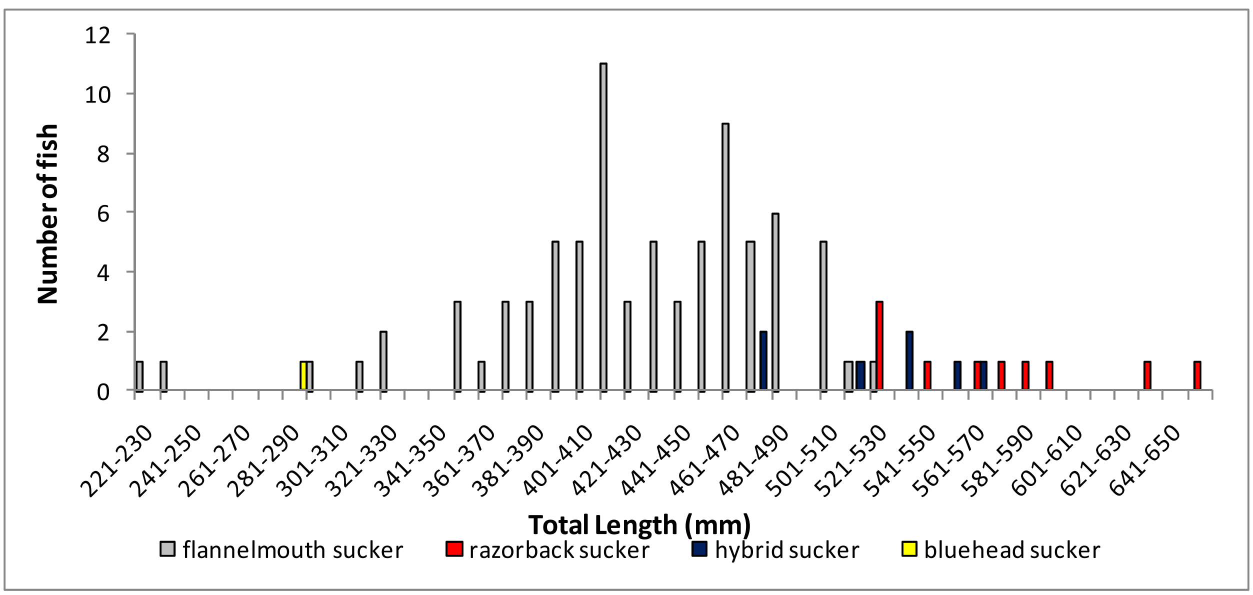

Figure 8. Length-frequency distributions for native suckers captured at the Colorado River Inflow area of Lake Mead in 2011.

Larval Sampling

Sampling for razorback sucker larvae was initiated at the CRI on January 31, 2011 (Table 4). Razorback sucker larvae were first collected on February 14, 2011, when a single larval fish was captured along a cobble and gravel shoreline with inundated vegetation. This area, just north and west of the 2010 razorback spawning location, was formally a small cove on the west side of the CRI (Figure 9). At the time this individual was captured, the north end of the cove was

Table 4. Number of razorback sucker larvae collected at the Colorado River Inflow area of Lake Mead during 2011.

DATE	CRI SAMPLING SITES						
	Minutes Sampled	Razorback Sucker Larvae Collected	CPM [a]	Flannelmouth Sucker Larvae Collected	CPM [a]	Flannelmouth or Hybrid Sucker Larvae Collected	CPM [a]
01/31/11	120	0	0.0000	0	0.0000	0	0.0000
02/02/11	90	0	0.0000	0	0.0000	0	0.0000
02/07/11	135	0	0.0000	0	0.0000	0	0.0000
02/09/11	240	0	0.0000	0	0.0000	0	0.0000
02/14/11	300	1	0.0067	0	0.0000	0	0.0000
02/15/11	240	0	0.0000	0	0.0000	0	0.0000
02/21/11	240	0	0.0000	0	0.0000	0	0.0000
02/22/11	240	0	0.0000	0	0.0000	0	0.0000
02/23/11	240	0	0.0000	0	0.0000	0	0.0000
02/28/11	180	0	0.0000	0	0.0000	0	0.0000
03/01/11	120	0	0.0000	0	0.0000	0	0.0000
03/02/11	180	0	0.0000	0	0.0000	0	0.0000
03/08/11	240	0	0.0000	0	0.0000	0	0.0000
03/09/11	240	0	0.0000	0	0.0000	0	0.0000
03/10/11	240	0	0.0000	0	0.0000	0	0.0000
03/14/11	180	0	0.0000	0	0.0000	0	0.0000
03/15/11	225	0	0.0000	0	0.0000	0	0.0000
03/17/11	270	0	0.0000	0	0.0000	0	0.0000
03/22/11	360	0	0.0000	0	0.0000	0	0.0000
03/23/11	180	0	0.0000	0	0.0000	0	0.0000
03/24/11	180	0	0.0000	0	0.0000	0	0.0000
03/28/11	270	0	0.0000	2	0.0222	0	0.0000
03/29/11	180	0	0.0000	0	0.0000	0	0.0000
03/30/11	180	0	0.0000	0	0.0000	0	0.0000
03/31/11	180	0	0.0000	1	0.0167	0	0.0000
04/04/11	390	0	0.0000	0	0.0000	0	0.0000
04/11/11	330	0	0.0000	0	0.0000	0	0.0000
04/14/11	540	37	0.2741	0	0.0000	0	0.0000

Table 4. (Cont.)

DATE	CRI SAMPLING SITES						
	Minutes Sampled	Razorback Sucker Larvae Collected	CPM [a]	Flannelmouth Sucker Larvae Collected	CPM [a]	Flannelmouth or Hybrid Sucker Larvae Collected	CPM [a]
04/18/11	90	5	0.1111	0	0.0000	0	0.0000
04/19/11	300	15	0.1000	1	0.0067	0	0.0000
04/25/11	150	3	0.0400	0	0.0000	0	0.0000
04/26/11	150	2	0.0267	5	0.0667	0	0.0000
04/27/11	180	1	0.0111	1	0.0111	0	0.0000
05/02/11	150	0	0.0000	1	0.0133	0	0.0000
05/04/11	150	1	0.0133	0	0.0000	0	0.0000
05/10/11	360	0	0.0000	0	0.0000	0	0.0000
05/11/11	300	0	0.0000	0	0.0000	0	0.0000
05/12/11	300	0	0.0000	0	0.0000	0	0.0000
05/16/11	120	0	0.0000	0	0.0000	0	0.0000
Totals	**8760**	**65**	**0.0074**	**11**	**0.0013**	**0**	**0.0000**

[a] CPM = Catch per minute.

inundated again, reconnecting it to the river/lake. The timing and presence of this single individual was interesting because razorback sucker larvae were collected in mid-April in 2010. Continued efforts to locate more razorback sucker larvae were unsuccessful until April 14, 2011, when 37 larvae were collected in Lunch Cove (Table 4, Figure 9). Larval razorback sucker captures continued throughout April and into early May (Table 4). Ninety-five percent of the razorback sucker larvae were captured from April 14–26, 2010. Water temperatures during this time ranged from 13–19°C. Larval sampling in the CRI yielded a total catch of 65 larval razorback suckers in 8,760 minutes of sampling, resulting in a catch per minute (CPM) value for razorback sucker larvae of 0.0074 (Table 4). In comparison, the CPM value of razorback sucker larvae collected at the CRI in 2011 is higher than the CPM value 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 5). Although statistically insignificant (ANOVA, $p = 0.1800$), the 2011 larval razorback sucker catch rate increased by 350% compared with 2010 (Table 5). The capture of razorback sucker larvae and sexually mature, ripe adults again confirmed the CRI as a spawning location for razorback sucker in 2011.

In addition to positively identified larval razorback suckers, several other Catastomid larvae were collected and identified at the CRI in 2011 (Figure 9), which corresponds with the 2011 CRI trammel-netting captures and observations of flannelmouth suckers and flannelmouth sucker x razorback sucker hybrids. A total of 11 flannelmouth sucker larvae were collected and identified in 2011 (taxonomic verifications were conducted by BIO-WEST while in the field and by BIO-WEST under laboratory conditions) (Table 4). These findings, along with sonic-telemetry and trammel-netting data, help confirm that the CRI provides spawning habitat not only for razorback sucker but also for flannelmouth sucker.

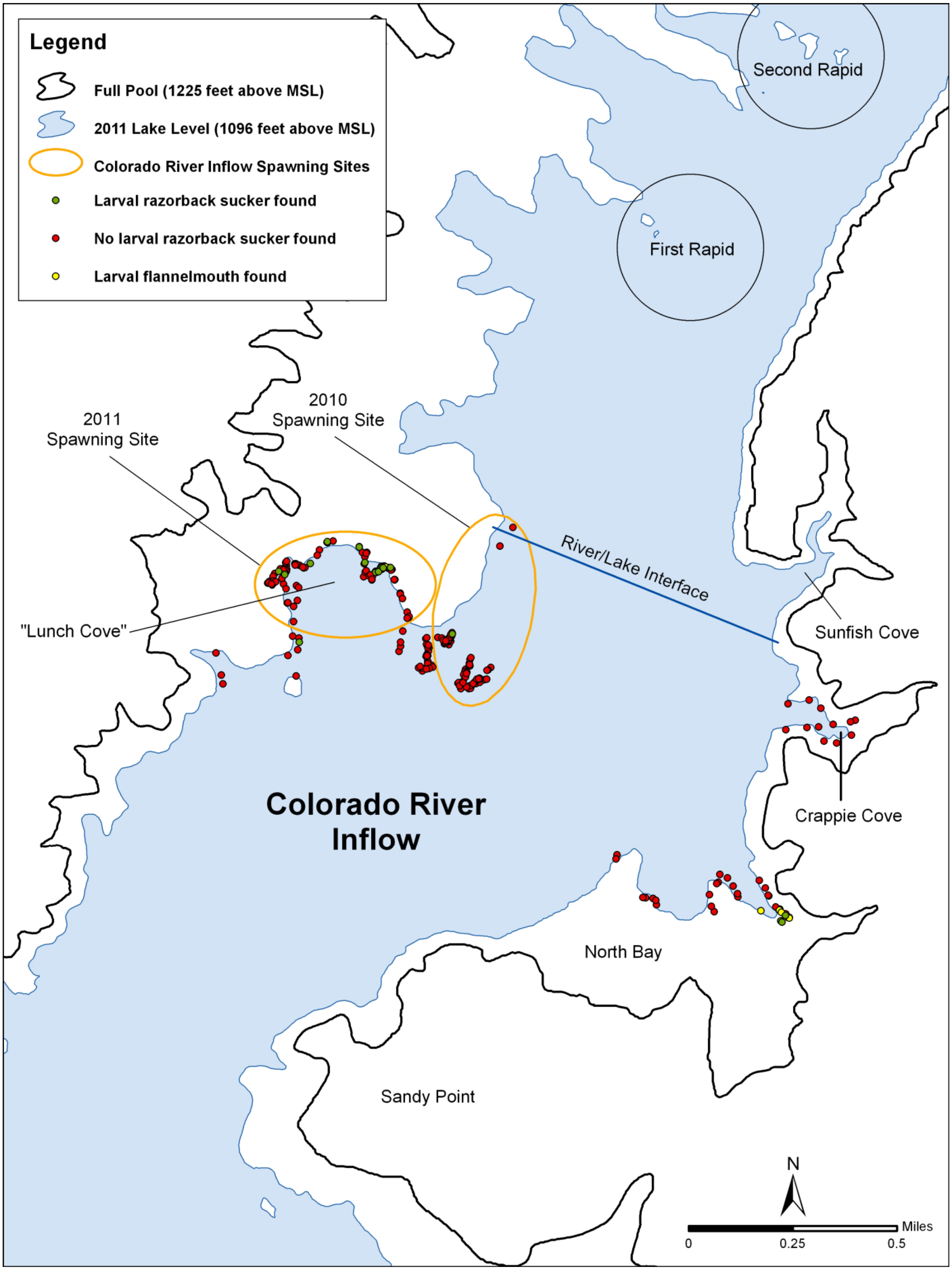

Figure 9. Larval razorback sucker sample and capture locations in the Colorado River Inflow area of Lake Mead, 2011.

Table 5. Larval razorback sucker catch-per-minute comparisons by primary sampling location on Lake Mead for 2007–2011 (modified from Albrecht et al. 2010b).

PRIMARY SAMPLING LOCATION	2007	2008	2009	2010	2011
Colorado River Inflow	--	--	--	0.002 [a]	0.007 [a]
Las Vegas Bay	0.39	0.43	0.342	0.093	0.282
Echo Bay	0.43	0.024	0.021	0.269	1.482
Muddy River/Virgin River Inflow	0.001	0.116	0.107	0.011	0.013

[a] Razorback sucker larvae data only.

Spawning-Site Identification and Observations

The primary 2011 CRI spawning site was determined to be the Lunch Cove area (Figure 9). Just west of the river/lake interface, the cove's shoreline consists mostly of cobble, gravel, and sand substrates. Ripe, milting fish signified that spawning was likely occurring in this area. Subsequent capture of larval fish confirmed successful spawning in the cove. Futhermore, sonic/radio-tagged fish frequented the area. Similar to other spawning areas throughout Lake Mead, spawning adults seemed to shift their habitat use. In other areas of the lake the shift is generally linear or downstream (Albrecht et al. 2010b), whereas spawning adults at the CRI shifted perpendicular to the river interface. Decreasing lake levels over the last 10 years have influenced habitat conditions in all areas where razorback sucker sampling activities have occurred during our Lake Mead study (Albrecht et al. 2010b). Typical habitat shifts at the previously known razorback spawning areas are characterized by fish following shoreline configurations as needed, apparently to accommodate fluctuating lake levels and changing conditions (Albrecht et al. 2010b). As of July 1, 2011, the lake elevation was approximately 1,106 ft (362.6 m) asl, compared with 1,087 ft (331.3 m) asl recorded the previous year on this same date (Figure 10).

Razorback Sucker Aging

At the CRI in 2011, all seven of the new, wild, adult razorback suckers and two recaptured razorback suckers from the 2010 stocking event had fin ray sections surgically removed for age determination. A definitive age was obtained for each fish (Appendix B and Figure 11). Ages for the new, wild fish ranged from 6–11 years, meaning these individuals were spawned from 2000–2005. The two recaptured fish were aged at 8 and 9 years, which corresponds with stocking records for Floyd Lamb State Park, further verifying the accuracy of the aging technique.

In addition to presenting information on the seven new, wild razorback sucker captured and aged at the CRI in 2011, Figure 11 presents cumulative Lake Mead razorback sucker recruitment data as reported by Shattuck et al. (2011). The rational for presenting the larger aging and recruitment data set from Lake Mead with the CRI aging data is to continue putting razorback sucker recruitment events into a more holistic data set. It is not our intent to imply that fish captured in the CRI stemmed from successful spawning and recruitment that may have occurred at the CRI;

rather, our intent is to highlight the data obtained from the CRI in 2011 and put it 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 our knowledge pertaining to the unique razorback sucker recruitment occurring within Lake Mead.

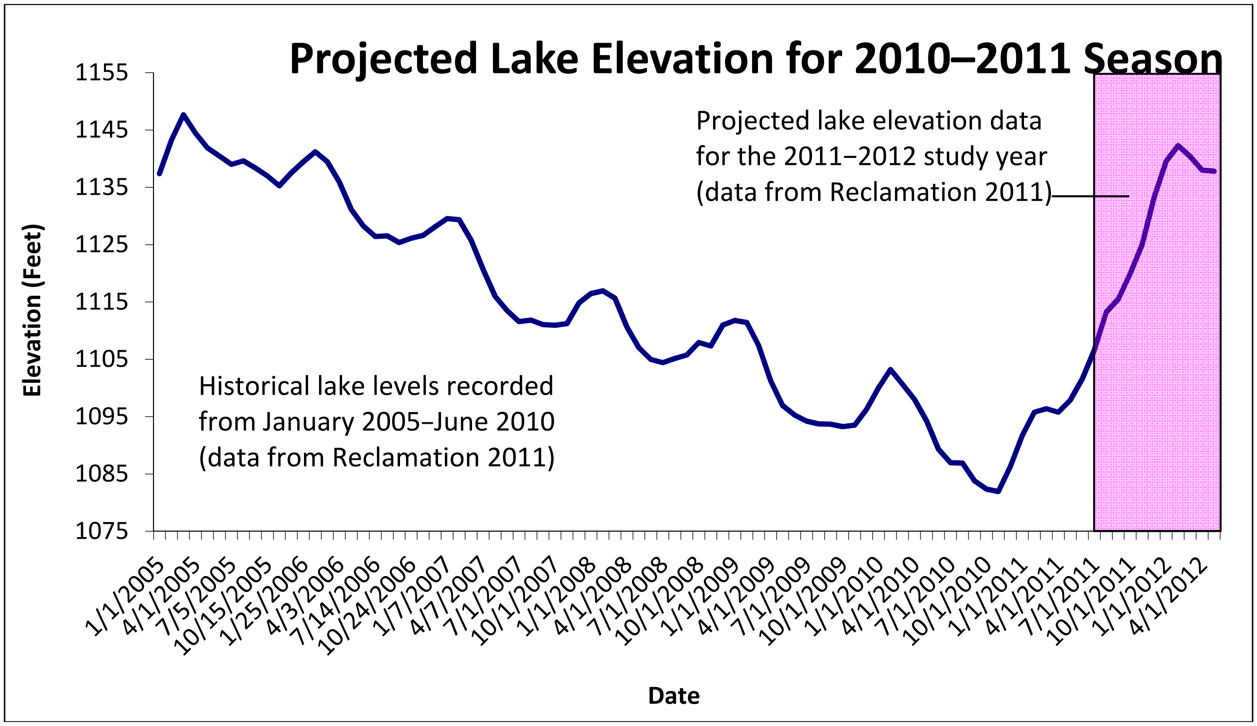

Figure 10. Lake Mead elevations using a combination of actual, recorded, and historical lake elevation data, as well as projected lake elevations for the remainder of the 2011–2012 study period.

To date, all of the aged fish were spawned between 1973 and 2008, with the exception of one fish that was spawned around 1966 (Appendix A). Until the last few seasons, the majority of fish aged were spawned during high lake elevations between 1978–1989 and 1997–1999 (Figure 11). However, our most 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 during recent years. Based on data obtained this season, 2001–2006 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.

Fin ray specimens from both flannelmouth suckers and hybrid suckers were obtained using the methodologies described for razorback suckers. Specific ages obtained for the six hybrid suckers are given in Appendix C. Ages obtained for 23 CRI flannelmouth suckers are presented in Appendix D. Depending on the project scope and overall interest, recruitment patterns of flannelmouth sucker and hybrid sucker could also be investigated as more data are collected on these native species during future efforts at the CRI.

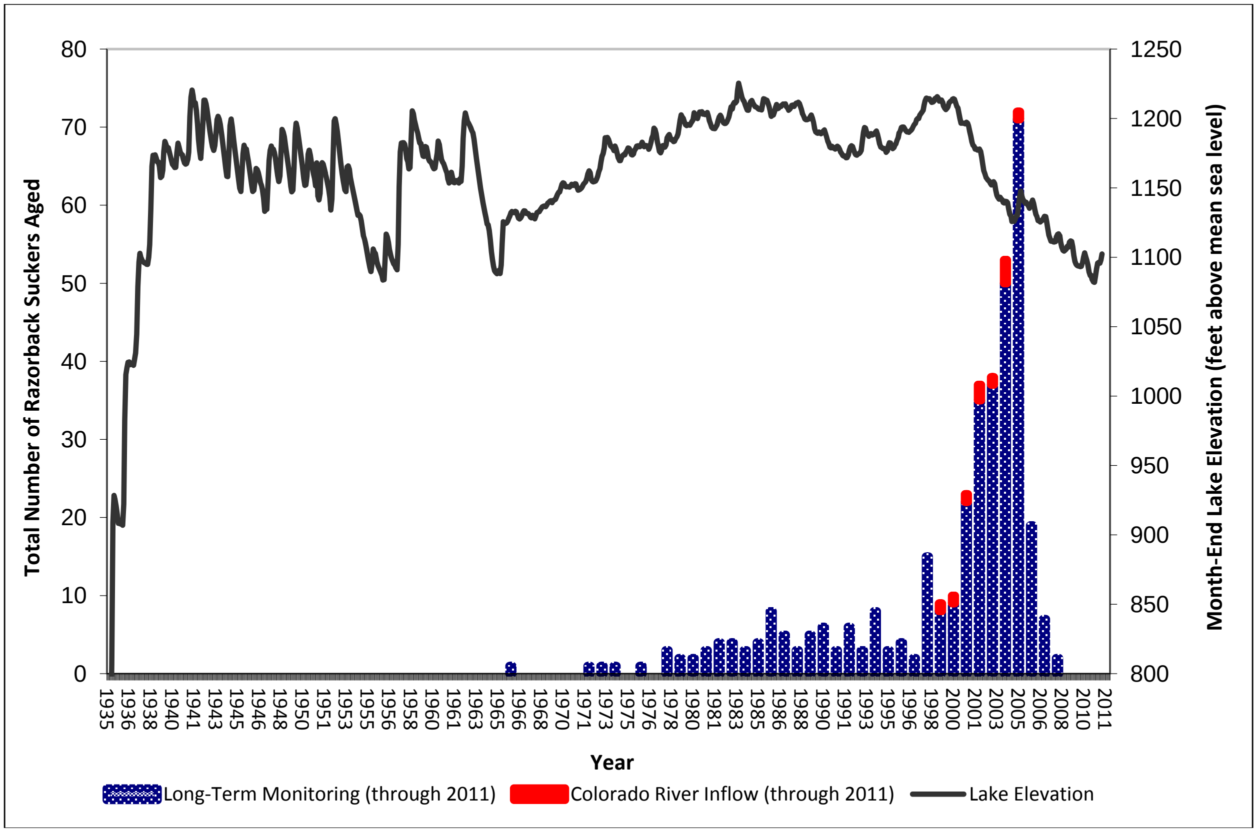

Figure 11. Lake Mead hydrograph from January 1935 to June 2011, with the number of aged razorback suckers spawned each year. Red bars denote the number of razorback suckers captured at the Colorado River Inflow area through 2011, while textured bars denote recruitment and aging data from the cumulative long-term monitoring and aging efforts (modified from Shattuck et al. 2011).

DISCUSSION AND CONCLUSIONS

Information collected during the 2010 and 2011 field seasons at the CRI has expanded 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 occur at the CRI and that they successfully spawned there in 2010 and 2011. It is still unknown how large the razorback sucker population is at the CRI, or to what degree razorback sucker recruitment occurs within this area.

Sonic Telemetry

Sonic telemetry proved valuable during the 2011 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 unknown status of razorback sucker using its habitats, the success of using pond-reared fish to locate new, wild individuals exceeded our expectations for the first 2 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 our ability to capture razorback suckers at the CRI.

These observations reinforce the importance of inflow areas to razorback sucker. It will be important to further investigate razorback sucker use of shallow riverine areas within the Colorado River proper in 2012 to determine annual patterns and variations among differing water years. Likewise, it will be important to continue searching for sonic-tagged fish to see whether they return to their 2011 spawning area or provide evidence for spawning-habitat shifts as we documented this past season.

Data stemming from the CRI sonic-tagged fish helped identify the 2011 spawning site, illustrated movement patterns, and provided valuable information regarding razorback sucker habitat within Lake Mead proper and the Colorado River proper. 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.

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. Both fish apparently integrated into the newly identified CRI spawning aggregate (Albrecht et al. 2010b, Shattuck et al. 2011), suggesting 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, a conclusion supported by contacts made this season on sonic-tagged fish 267, which was originally thought to have had battery failure in 2010.

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 a question could 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 what are the behaviors and habitat use of juvenile/subadult wild razorback suckers in Lake Mead, and do they hold the key to understanding recruitment success? A sonic-telemetry study could become a paired study if similar numbers of wild, Lake Mead razorback suckers and pond-reared razorback suckers are implanted with sonic tags. If sufficient numbers of wild juvenile/subadult fish were captured and tagged, valuable insights could be gained into the recruitment successes of Lake Mead razorback suckers. This would test the hypothesis that smaller, wild-spawned juvenile/subadult fish are able to escape predation in Lake Mead by using an unknown feature or area of the lake. Until such a study is implemented, we will continue to monitor sonic-tagged fish at the CRI and search throughout Lake Mead for other sonic-tagged fish with an “unknown” tag status.

Of particular interest is our use of sonic-tagged fish from the 2010 and 2011 stocking events on 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 river habitats closer to the lake interface. Aggregates of sonic-tagged fish periodically occupied slower-moving slackwaters and eddies in this dynamic portion of the river, leading field crews to develop methods to try to capture other wild razorbacks behaving similarly. Methods to capture these individuals included trammel netting, seining, drift netting, and setting fyke nets. These methods were unsuccessful, which raises the question of what methods can be used to successfully capture these and other wild razorback suckers. Perhaps modified methods of hoop netting or even block seining could provide better results. The dynamic nature of the inflow area, and the relatively short period that the sonic-tagged fish occupied the slackwater and eddy habitats, made it difficult to devote much time to those areas. It was interesting that none of the sonic-tagged fish ventured past the second major rapid upstream from the lake proper. In fact, even the two fish stocked above these rapids quickly made their way downstream into the lake. The reason for this is unclear. Perhaps it is related to habitat preference or habitat availability. These stocked fish could also be in search of wild razorback suckers and are unable to maintain themselves in flowing water systems because they have not been conditioned to do so. 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 they spend in the flowing portion of the Colorado River—and their frequent movement in and out of the area—suggests the habitat may be critical for CRI razorback suckers. As we continue to study this population 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.

As briefly discussed in Results, the trial use of combination sonic/radio tags in the CRI provided valuable data on the feasibility and effectiveness of this technology in Lake Mead razorback sucker studies. Although the tags were functional and the ability to use the radio technology was a nice addition to river tracking, the application became irrelevant because all four radio-tagged fish began using lake habitats more conducive to sonic tracking. Because the ability to hear fish in the river using sonic-tracking methods is quite difficult, the combination tags would have been more valid had the fish remained in the river. Advantages of the combination sonic/radio technology include the ability to track fish fairly easily from the air or by land without interference from the turbulence and noise of the flowing river. The redundancy of both technologies also provided a means of verifying our location data when both tracking methods were feasible. Limitations to the technology include reduced battery life relative to tag size (1 year for sonic/radio tags vs. 4 years for sonic tags), high conductivities of the river reducing signal strength, and limited radio-tracking capability in water deeper than approximately 7 ft. There are applications where the combination tag could be very beneficial. One particular application would be to implant it in wild fish in hopes of ascertaining if they travel upriver to a greater extent than the pond-reared/stocked razorback suckers have traveled to date. However, until there is data suggesting razorback suckers will in fact travel long distances upriver, the disadvantages of this technology seem to outweigh the advantages.

Passive telemetry proved to be a valuable method for tracking sonic-tagged fish in the CRI. Because of our limited knowledge of razorback sucker existence in the CRI, it was important to track the movement of released 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 3354 as it made its way out of the CRI and into Echo Bay. Fish not contacted for long periods via manual or passive methods may have been in areas of the river proper or Gregg Basin that are not conducive to active sonic-telemetry detection; they may also have been at a depth, distance, or in an area of underwater cover that did not allow for detection by the SUR. These scenarios indicate limitations in our current sonic-telemetry methodologies that could be tested and perhaps resolved through additional feasibility studies using submerged test tags at various depths and distances from the SUR. Although the SURs collected valuable data, maintaining them in the lake and deploying them in the river is an ongoing task, similar to the challenges of using other new, 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 concerns, the SURs collected data without field crews, which increased the efficiency and effectiveness of the study and validated their use.

Stationary SUR technology can be limited by geographic placement. To obtain effective movement data, several SURs need to be located within a given basin. Although not the intent of this study, combining active and passive tracking methods allowed field crews to more efficiently and effectively locate spawning razorback suckers. The SUR data also helped validate active-tracking data. The SURs were valuable tools in the active search for sonic-tagged fish, as we were able to narrow the search area based on the most recently logged data. The SUR data also provided insight into when razorback suckers move and how far they can potentially travel in 24 hours. As more data are collected on interbasin fish movements within Lake Mead, SURs may help determine whether Lake Mead razorback sucker should be managed as one population or independent, 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 2011. By more than doubling our monitoring efforts at the CRI, adult razorback sucker captures increased by 500% compared to 2010. This increased effort also resulted in the capture of more razorback sucker x flannelmouth sucker hybrid adults and a single bluehead sucker. Although hybridization between flannelmouth sucker and razorback sucker is extensively documented and summarized in 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 is 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 sucker. It appears the hybrids do produce gametes, although their viability is unknown. Flannelmouth sucker and razorback sucker are 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 sucker, 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 sucker in the CRI. Similar to the original documentation of the Muddy River/Virgin River inflow area as a spawning site for razorback sucker 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; if so, how that recruitment is occurring; and to what degree the recruitment impacts Lake Mead razorback sucker population dynamics as a whole.

Lake levels are projected to fluctuate on Lake Mead over the next several years (Figure 10). If this occurs, razorback suckers at the CRI are likely to change spawning site locations to accommodate the highly variable conditions imposed by these fluctuations and Colorado River dynamics. 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 since the years of higher lake elevations (kilometers of change rather than meters of change typical at the other, more thoroughly researched study areas), we hypothesize that dramatic shifts in spawning site location could 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.

In summary, the rather intensive level of trammel netting conducted at the CRI in 2011 provided several interesting results. The following four results need to be explored in greater detail through future research:

1. Razorback suckers are present in 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 two field seasons. The number of razorback suckers at this location is undetermined, and the timing of spawning appears to be more variable than at other known spawning areas in Lake Mead (Albrecht et al. 2010a, 2010b). The reasons for this disparity are unknown, but important factors may include annual river and lake conditions, inter- and intra- annual water-level fluctuations and the resulting gain or loss of littoral habitat types at the CRI, temperature differences and variability between the lake and river proper, and the interaction of these factors. Continued efforts at the CRI will facilitate our understanding of the importance of this unique location to Lake Mead razorback sucker.

2. Wild, ripe razorback suckers were captured at different locations for two consecutive field seasons in the CRI, demonstrating the potential for unknown aggregates of razorback suckers to exist at other locations in Lake Mead. Sampling unexplored areas of the lake

with suitable razorback sucker habitat may help us find new spawning aggregates. Such sampling would require increased field efforts; however, our current methodologies for finding new aggregates would ensure that the field efforts were 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. Therefore, the techniques should be continued.

4. Razorback sucker 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 flannelmouth and bluehead sucker are also spawning upstream in the unsampled portion of the river. Researching the potential effects of this hybridization to the razorback sucker population could help broaden our understanding of the sustainability or longevity of the Lake Mead CRI population.

As more research is conducted in Lake Mead, we anticipate that 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. (2010b), Shattuck et al. (2011), and Albrecht et al. (2008b) during their comprehensive review of Lake Mead razorback sucker research.

Larval Sampling

Larval razorback suckers were captured again at the CRI during the 2011 spawning period, confirming successful spawning of the species. The numbers and catch rates of larval razorback suckers in the CRI were intriguingly similar to those during the first two field seasons of larval sampling in the Muddy River/Virgin River inflow area. Capture rates of larvae, subadults, and adults in the Muddy River/Virgin River inflow area have increased over time (Albrecht et al. 2010, Shattuck et al. 2011), and it will be interesting to evaluate whether similar trends occur in the CRI. In just 1 year of studying the CRI larval razorback sucker, catch rates increased by 350%.

The majority of larval razorback sucker captures in the CRI in 2011 occurred during a relatively compressed 2-week period (April 14–27) within a single cove. These dates, as well as the two days larvae were collected in 2010 (Albrecht et al. 2010a), are similar to larval capture dates reported by Albrecht et al. (2008b) during their comprehensive review of Lake Mead razorback sucker investigations. Albrecht et al. (2008b) 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 2012.

In addition, larval flannelmouth suckers were captured at the CRI in 2011. Along with trammel-netting results, these findings suggest the importance of the CRI as a spawning area for razorback sucker and flannelmouth sucker. As previously discussed, the discovery of suspected larval hybrid suckers in 2010 and the capture of adult hybrid suckers in both 2010 and 2011 confirms species hybridization at the CRI; hence, hybridization issues should be considered prior to any stocking and augmentation efforts there.

Larval sampling near any large-river inflow may affect capture efficiency. For the CRI in particular, river currents and high spring winds could decrease the number of larvae captured as they drift into Lake Mead from a spawning area in the Colorado River. We hypothesize that the relatively early capture of a single razorback sucker larvae in a cove on February 14, 2011, may have been the result of larval drift from the river proper. Perhaps additional sampling was hindered by the somewhat untimely inundation of the cove by the river proper. Changing from a lentic cove environment to a lotic environment may have contributed to larval dispersal and difficult sampling conditions at that location. If in fact other native suckers are spawning upstream in the river proper it is possible that a portion of larvae collected at the CRI are a result of downstream larval drift.

Growth and Aging

Based on fairly limited data collected from razorback suckers in the CRI to date, it appears that growth rates for razorback suckers captured in this area follow 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. 2008b, 2010b). This finding appears to make sense considering the fairly young ages reported within this document. Future growth-rate findings for razorback suckers captured at the CRI will allow us to more fully compare 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, subadult razorback suckers, directly confirming recruitment in the CRI.

Determining the ages of seven CRI fish during the 2011 field season, as well as incorporating the ages of 363 fish from previous studies, helps verify that razorback sucker recruitment has occurred regularly in Lake Mead from 1973–2008, with the exception of one fish that was spawned around 1966 (Shattuck et al. 2011) (Appendix B). Based on lake-wide data collected to date, some of the most pronounced recruitment occurred from 2001–2006, with a total of 244 razorback suckers resulting from those spawning events alone. These data suggest a strong recruitment trend in recent years. This pulse of young fish indicates that successful spawning and recruitment are occurring at low lake levels. This year's aging data confirm natural, wild recruitment within the Lake Mead razorback sucker population as recently as 2008 (Shattuck et al. 2011). Fish spawned during the 2009–2011 field seasons should become susceptible to sampling gear within the next year or so (assuming that recruitment will continue and is occurring for these age classes). Finally, as more specimens are obtained from all areas of Lake Mead, including the CRI, we hope to identify conditions promoting recruitment and 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 seven year classes (1999–2005) at the CRI. Aging results from the 2011 field season alone identified an additional four year classes. Interestingly, all seven year classes found at the CRI correlate with strong year classes across Lake Mead (Shattuck et al. 2011). 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.

Conclusions and Future Considerations

In 2011 BIO-WEST documented razorback sucker in 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 the CRI in 2011. BIO-WEST also captured a number of flannelmouth suckers and flannelmouth sucker x razorback sucker hybrids in the CRI in 2011.

After 2 years of sampling, several questions remain that extend beyond the scope of our study. For example, how many razorback suckers use the CRI, and what is the spawning population's size? Do razorback suckers continually use the CRI, and can they be found there annually? 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? Can enough fin ray specimens be collected to begin understanding the age structure of the fish currently using the CRI? Can enough fin ray specimens be collected to predict the age structure of fish using the area in the future? How does the CRI relate to the other Lake Mead locations used by razorback suckers, and are the recruitment patterns in the areas similar or distinct? Can sufficient numbers of razorback suckers be captured, marked, and recaptured to perform population estimates at the CRI? Do razorback suckers use different habitats at the CRI area compared to fish in other, known populations in Lake Mead? 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? How does the recent discovery of razorback suckers in the CRI affect the overall Lake Mead razorback sucker population estimate? How important is the CRI to the flannelmouth sucker life cycle? What is the extent of hybridization between flannelmouth sucker and razorback sucker at the CRI? 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 presently and historically occupied by the species?

It is difficult to make any inferences into these questions based on data from two years. However, data gathered over the next several years at the CRI could begin to provide insight into these important topics. After the 2012 field season, it will be important to consider where the razorback sucker population at the CRI 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 Workgroup to determine the importance of and potential strategies for monitoring this population. Determinations on the level and scope of continued research for razorback sucker, and perhaps flannelmouth sucker, 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., Shattuck et al. 2011), 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.

2011–2012 COLORADO RIVER INFLOW WORK PLAN

Maintain increased sampling efforts comparable to the 2011 efforts at the CRI, including sonic tracking, trammel netting, sampling for larvae, and aging adult and juvenile razorback suckers and razorback sucker x flannelmouth sucker hybrids. Razorback suckers from Floyd Lamb State Park or, better yet, wild-caught razorback suckers from Lake Mead will be sonic-tagged as needed should we lose contact with the majority of the currently tagged fish. These efforts will help us (1) identify the 2012 CRI spawning location(s); (2) better understand razorback sucker habitat use within the Colorado River proper; and (3) potentially identify other, new spawning sites as dictated by tracking sonic-tagged fish. We will use data stemming from sampling efforts to assist with understanding the size and habitat use of razorback suckers at the CRI, help document the movement of tagged fish between sites, identify problems or habitat shifts associated with the CRI spawning aggregates, identify lake-wide recruitment patterns, and help characterize the habitat use and relationship that razorback suckers have with the Colorado River proper.

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APPENDIX A. DATE, PIT-TAG, AND SIZE INFORMATION FOR FLANNELMOUTH AND BLUEHEAD SUCKERS CAPTURED AT THE COLORADO RIVER INFLOW AREA DURING 2011

Table A. Date, PIT-tag, and size data for flannelmouth and bluehead suckers captured at the Colorado River inflow area in 2011.

DATE	SPECIES	PIT-TAG NUMBER	SONIC CODE	DATE [a]	RECAPTURE/ STATUS	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	WT [e] (g)	SEX [f]
2/2/2011	Flannelmouth sucker	3D9.1C2D267591	N/A	2/2/2011	NO/NEW WILD FISH	N/A[g]	N/A	N/A	N/A	U
2/8/2011	Flannelmouth sucker	3D9.1C2D2607A7	N/A	2/8/2011	NO/NEW WILD FISH	414	395	357	645	M
2/8/2011	Flannelmouth sucker	3D9.1C2D2617BE	N/A	2/8/2011	NO/NEW WILD FISH	473	450	412	850	U
2/8/2011	Flannelmouth sucker	3D9.1C2D2675C9	N/A	2/8/2011	NO/NEW WILD FISH	465	433	380	825	M
2/8/2011	Flannelmouth sucker	3D9.1C2D267733	N/A	2/8/2011	NO/NEW WILD FISH	473	454	416	880	F
2/8/2011	Flannelmouth sucker	3D9.1C2D267A2A	N/A	2/8/2011	NO/NEW WILD FISH	429	409	365	675	F
2/8/2011	Flannelmouth sucker	3D9.1C2D267DA1	N/A	2/8/2011	NO/NEW WILD FISH	451	425	387	730	M
2/8/2011	Flannelmouth sucker	3D9.1C2D268496	N/A	2/8/2011	NO/NEW WILD FISH	489	459	418	890	F
2/8/2011	Flannelmouth sucker	3D9.1C2D269180	N/A	2/8/2011	NO/NEW WILD FISH	421	404	375	765	M
2/9/2011	Flannelmouth sucker	3D9.1C2D26657A	N/A	2/9/2011	NO/NEW WILD FISH	368	344	310	405	F
2/9/2011	Flannelmouth sucker	3D9.1C2D267A2A	N/A	2/8/2011	YES/WILD FISH FROM 2011	435	408	372	670	F
2/10/2011	Flannelmouth sucker	3D9.1C2D261B89	N/A	2/10/2011	NO/NEW WILD FISH	445	420	385	765	U
2/10/2011	Flannelmouth sucker	3D9.1C2D26629C	N/A	2/10/2011	NO/NEW WILD FISH	410	385	352	735	F
2/10/2011	Flannelmouth sucker	3D9.1C2D26676F	N/A	2/10/2011	NO/NEW WILD FISH	510	485	445	1170	F
2/10/2011	Flannelmouth sucker	3D9.1C2D267CA9	N/A	2/10/2011	NO/NEW WILD FISH	431	409	372	730	F
2/15/2011	Flannelmouth sucker	3D9.1C2D267CAA	N/A	2/15/2011	NO/NEW WILD FISH	466	449	411	930	M
2/16/2011	Flannelmouth sucker	3D9.1C2D2617BE	N/A	2/8/2011	YES/WILD FISH FROM 2011	470	444	408	810	U
2/16/2011	Flannelmouth sucker	3D9.1C2D2675C9	N/A	2/8/2011	YES/WILD FISH FROM 2011	466	435	395	825	M
2/16/2011	Flannelmouth sucker	3D9.1C2D268078	N/A	2/16/2011	NO/NEW WILD FISH	453	425	387	800	U
2/22/2011	Flannelmouth sucker	3D9.1C2D266A32	N/A	2/22/2011	NO/NEW WILD FISH	431	415	380	770	F
2/22/2011	Flannelmouth sucker	3D9.1C2D2699FB	N/A	2/22/2011	NO/NEW WILD FISH	439	420	N/A	770	F
2/23/2011	Flannelmouth sucker	3D9.1C2D265D60	N/A	2/23/2011	NO/NEW WILD FISH	398	373	327	534	F
2/23/2011	Flannelmouth sucker	3D9.1C2D26676F	N/A	2/10/2011	YES/WILD FISH FROM 2011	506	481	442	1119	F
2/23/2011	Flannelmouth sucker	3D9.1C2D26744B	N/A	2/23/2011	NO/NEW WILD FISH	485	429	373	1099	F

Table A. (Cont.)

DATE	SPECIES	PIT-TAG NUMBER	SONIC CODE	DATE [a]	RECAPTURE/ STATUS	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	WT [e] (g)	SEX [f]
2/23/2011	Flannelmouth sucker	3D9.1C2D26749B	N/A	2/15/2011	NO/NEW WILD FISH	355	335	298	377	U
2/23/2011	Flannelmouth sucker	3D9.1C2D267CAA	N/A	2/14/2011	YES/WILD FISH FROM 2011	478	445	391	914	M
2/24/2011	Flannelmouth sucker	384.1B796EEB66	N/A	2/24/2011	NO/NEW WILD FISH	485	461	426	1010	F
2/24/2011	Flannelmouth sucker	384.1B796EF67F	N/A	2/24/2011	NO/NEW WILD FISH	440	414	372	655	F
2/24/2011	Flannelmouth sucker	3D9.1C2D2672AA	N/A	2/24/2011	NO/NEW WILD FISH	315	294	260	222	U
3/1/2011	Flannelmouth sucker	384.1B796EDE16	N/A	3/1/2011	NO/NEW WILD FISH	419	398	359	646	F
3/1/2011	Flannelmouth sucker	384.1B796EDF4B	N/A	3/1/2011	NO/NEW WILD FISH	355	343	312	395	F
3/1/2011	Flannelmouth sucker	384.1B796EE693	N/A	3/1/2011	NO/NEW WILD FISH	512	486	429	1221	F
3/1/2011	Flannelmouth sucker	384.1B796EEEDB	N/A	3/1/2011	NO/NEW WILD FISH	419	400	361	629	F
3/2/2011	Flannelmouth sucker	384.1B796EDF4B	N/A	3/1/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
3/2/2011	Flannelmouth sucker	384.1B796EE693	N/A	3/1/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
3/3/2011	Flannelmouth sucker	384.1B796EEA52	N/A	3/3/2011	NO/NEW WILD FISH	473	443	413	990	F
3/8/2011	Flannelmouth sucker	384.1B796EE0A9	N/A	3/8/2011	NO/NEW WILD FISH	417	384	355	236	U
3/8/2011	Flannelmouth sucker	3D9.1C2D26629C	N/A	2/10/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
3/9/2011	Flannelmouth sucker	3D9.1C2D26676F	N/A	2/10/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
3/10/2011	Flannelmouth sucker	3D9.1B796EDF4B	N/A	3/1/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	U
3/15/2011	Flannelmouth sucker	3D9.1C2D26676F	N/A	2/10/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
3/16/2011	Flannelmouth sucker	384.1B796EE546	N/A	3/16/2011	NO/NEW WILD FISH	397	372	343	536	U
3/16/2011	Flannelmouth sucker	384.1B796EE9D3	N/A	3/16/2011	NO/NEW WILD FISH	416	394	362	601	F
3/16/2011	Flannelmouth sucker	3D9.1C2D278698	N/A	4/14/2010	YES/WILD FISH FROM 2010	467	449	409	838	M
3/23/2011	Flannelmouth sucker	384.1B796EDFE5	N/A	3/23/2011	NO/NEW WILD FISH	373	348	318	440	I
3/23/2011	Flannelmouth sucker	384.1B796EE168	N/A	3/23/2011	NO/NEW WILD FISH	470	444	412	925	U
3/23/2011	Flannelmouth sucker	384.1B796EE26F	N/A	3/23/2011	NO/NEW WILD FISH	420	393	362	607	I
3/23/2011	Flannelmouth sucker	384.1B796EE962	N/A	3/23/2011	NO/NEW WILD FISH	451	428	397	830	F
3/24/2011	Flannelmouth sucker	384.1B796EDFDB	N/A	3/24/2011	NO/NEW WILD FISH	445	422	384	883	U

Table A. (Cont.)

DATE	SPECIES	PIT-TAG NUMBER	SONIC CODE	DATE [a]	RECAPTURE/ STATUS	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	WT [e] (g)	SEX [f]
3/24/2011	Flannelmouth sucker	384.1B796EE7D1	N/A	3/24/2011	NO/NEW WILD FISH	484	465	434	1043	U
3/24/2011	Flannelmouth sucker	384.1B796EEDA9	N/A	2/8/2011	NO/NEW WILD FISH	441	414	380	707	U
3/24/2011	Flannelmouth sucker	3D9.1C2D26629C	N/A	2/10/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	N/A
3/29/2011	Flannelmouth sucker	384.1B796EE0A9	N/A	3/8/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	U
3/29/2011	Flannelmouth sucker	384.1B796EE26F	N/A	3/23/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	M
3/29/2011	Flannelmouth sucker	384.1B796EE4AB	N/A	3/29/2011	NO/NEW WILD FISH	420	398	357	669	F
3/30/2011	Flannelmouth sucker	384.1B796EE7D1	N/A	3/24/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
3/31/2011	Flannelmouth sucker	384.1B796EE008	N/A	3/31/2011	NO/NEW WILD FISH	395	366	334	575	I
3/31/2011	Flannelmouth sucker	384.1B796EE05F	N/A	3/31/2011	NO/NEW WILD FISH	378	357	234	432	I
3/31/2011	Flannelmouth sucker	384.1B796EE0A9	N/A	3/8/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	U
3/31/2011	Flannelmouth sucker	384.1B796EE5D4	N/A	3/31/2011	NO/NEW WILD FISH	462	435	397	813	F
3/31/2011	Flannelmouth sucker	384.1B796EFAA8	N/A	3/31/2011	NO/NEW WILD FISH	458	430	402	831	F
3/31/2011	Flannelmouth sucker	3D9.1C2D268078	N/A	2/16/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
4/4/2011	Flannelmouth sucker	384.1B796EE168	N/A	3/23/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	U
4/5/2011	Flannelmouth sucker	384.1B796EE65A	N/A	4/5/2011	NO/NEW WILD FISH	503	471	433	1059	F
4/5/2011	Flannelmouth sucker	384.1B796EEFD9	N/A	4/5/2011	NO/NEW WILD FISH	N/A	N/A	N/A	N/A	U
4/5/2011	Flannelmouth sucker	3D9.1C2D26749B	N/A	2/23/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	U
4/5/2011	Flannelmouth sucker	3D9.1C2D267775	N/A	5/26/2010	YES/WILD FISH FROM 2010	501	466	429	1178	U
4/5/2011	Flannelmouth sucker	3D9.1C2D269180	N/A	2/8/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	U
4/5/2011	Flannelmouth sucker	3D9.1C2D279311	N/A	4/5/2011	NO/NEW WILD FISH	422	397	366	670	U
4/5/2011	Flannelmouth sucker	3D9.1C2D63A981	N/A	4/5/2011	NO/NEW WILD FISH	458	424	396	865	U
4/6/2011	Flannelmouth sucker	384.1B796EE5D4	N/A	3/31/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	U
4/6/2011	Flannelmouth sucker	384.1B796EEF0D	N/A	4/6/2011	NO/NEW WILD FISH	330	306	279	231	I
4/12/2011	Flannelmouth sucker	3D9.1C2D260EA0	N/A	4/12/2011	NO/NEW WILD FISH	466	444	405	909	U
4/12/2011	Flannelmouth sucker	3D9.1C2D26577F	N/A	4/12/2011	NO/NEW WILD FISH	521	495	460	1409	F

Table A. (Cont.)

DATE	SPECIES	PIT-TAG NUMBER	SONIC CODE	DATE [a]	RECAPTURE/ STATUS	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	WT [e] (g)	SEX [f]
4/12/2011	Flannelmouth sucker	3D9.1C2D2673E8	N/A	4/12/2011	NO/NEW WILD FISH	414	390	356	638	I
4/12/2011	Flannelmouth sucker	3D9.1C2D26790A	N/A	4/12/2011	NO/NEW WILD FISH	401	384	345	510	I
4/13/2011	Flannelmouth sucker	3D9.1C2D260EA0	N/A	4/12/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	U
4/13/2011	Flannelmouth sucker	3D9.1C2D26577F	N/A	4/12/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
4/13/2011	Flannelmouth sucker	3D9.1C2D267432	N/A	4/13/2011	NO/NEW WILD FISH	411	384	346	680	I
4/13/2011	Flannelmouth sucker	3D9.1C2D2694AA	N/A	4/13/2011	NO/NEW WILD FISH	383	361	322	920	I
4/14/2011	Flannelmouth sucker	384.1B796EDE16	N/A	3/1/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	U
4/14/2011	Flannelmouth sucker	3D9.1C2D263011	N/A	4/14/2011	NO/NEW WILD FISH	410	382	355	625	M
4/14/2011	Flannelmouth sucker	3D9.1C2D2691B6	N/A	4/14/2011	NO/NEW WILD FISH	475	446	416	925	M
4/14/2011	Flannelmouth sucker	3D9.1C2D2720A7	N/A	4/14/2011	NO/NEW WILD FISH	391	373	342	517	F
4/19/2011	Flannelmouth sucker	384.1B796EE101	N/A	4/19/2011	NO/NEW WILD FISH	399	372	336	550	U
4/19/2011	Flannelmouth sucker	384.1B796EE801	N/A	4/19/2011	NO/NEW WILD FISH	469	436	404	820	M
4/19/2011	Flannelmouth sucker	384.1B796EEDE3	N/A	4/19/2011	NO/NEW WILD FISH	509	486	454	1034	F
4/19/2011	Flannelmouth sucker	3D9.1C2D2619E5	N/A	4/19/2011	NO/NEW WILD FISH	405	374	343	579	I
4/19/2011	Flannelmouth sucker	3D9.1C2D267591	N/A	2/3/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	I
4/19/2011	Flannelmouth sucker	3D9.1C2D268496	N/A	2/8/2011	YES/WILD FISH FROM 2011	481	451	414	925	U
4/20/2011	Flannelmouth sucker	384.1B796EE801	N/A	4/19/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	N/A
4/20/2011	Flannelmouth sucker	384.1B796EEB66	N/A	2/24/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	N/A
4/21/2011	Flannelmouth sucker	384.1B796EE3E7	N/A	4/21/2011	NO/NEW WILD FISH	402	375	346	623	I
4/27/2011	Flannelmouth sucker	384.1B796EE05F	N/A	3/31/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	N/A
4/27/2011	Flannelmouth sucker	384.1B796EE4BF	N/A	4/27/2011	NO/NEW WILD FISH	380	359	325	473	F
4/27/2011	Flannelmouth sucker	384.1B796EE709	N/A	4/27/2011	NO/NEW WILD FISH	235	217	195	114	I
4/27/2011	Flannelmouth sucker	384.1B796EEFA2	N/A	4/27/2011	NO/NEW WILD FISH	322	298	279	319	I
4/27/2011	Flannelmouth sucker	3D9.1C2D267733	N/A	2/8/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
4/28/2011	Flannelmouth sucker	384.1B796EDE4A	N/A	4/28/2011	NO/NEW WILD FISH	357	332	302	302	I

Table A. (Cont.)

DATE	SPECIES	PIT-TAG NUMBER	SONIC CODE	DATE [a]	RECAPTURE/ STATUS	TL[b] (mm)	FL[c] (mm)	SL[d] (mm)	WT [e] (g)	SEX [f]
4/28/2011	Flannelmouth sucker	384.1B796EDF15	N/A	4/28/2011	NO/NEW WILD FISH	412	390	350	675	F
4/28/2011	Flannelmouth sucker	384.1B796EE029	N/A	4/28/2011	NO/NEW WILD FISH	295	274	246	249	I
4/28/2011	Flannelmouth sucker	384.1B796EE42F	N/A	4/28/2011	NO/NEW WILD FISH	483	449	412	1105	F
4/28/2011	Flannelmouth sucker	384.1B796EE4D3	N/A	4/28/2011	NO/NEW WILD FISH	230	212	193	105	I
4/28/2011	Flannelmouth sucker	384.1B796EE962	N/A	3/23/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
4/28/2011	Flannelmouth sucker	384.1B796EF1F6	N/A	4/28/2011	NO/NEW WILD FISH	386	365	334	605	F
4/28/2011	Flannelmouth sucker	3D9.1C2D262C75	N/A	5/5/2010	YES/WILD FISH FROM 2010	415	400	363	685	M
4/28/2011	Flannelmouth sucker	3D9.1C2D26744B	N/A	2/23/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	F
5/3/2011	Flannelmouth sucker	384.1B796EDF15	N/A	4/28/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	N/A
5/3/2011	Flannelmouth sucker	384.1B796EF085	N/A	5/3/2011	NO/NEW WILD FISH	382	362	312	503	I
5/3/2011	Flannelmouth sucker	3D9.1C2D2607A7	N/A	5/3/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	M
5/3/2011	Flannelmouth sucker	3D9.1C2D262C75	N/A	4/28/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	N/A
5/5/2011	Flannelmouth sucker	384.1B7963EE427	N/A	4/28/2011	YES/WILD FISH FROM 2011	N/A	N/A	N/A	N/A	N/A
4/26/2011	Bluehead sucker	384.1B796EED13	N/A	4/26/2011	NO/NEW WILD FISH	282	263	241	222	U

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

APPENDIX B. AGES DETERMINED FROM WILD RAZORBACK SUCKER PECTORAL FIN RAY SECTIONS COLLECTED FROM LAKE MEAD (ALL SITES)

Table B. Ages determined from wild razorback sucker pectoral fin ray sections collected from Lake Mead (all sites).

DATE COLLECTED	TOTAL LENGTH (mm) [a]	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
3/3/2004	370	5	1998

Table B. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
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
2/12/2008	379	4	2004
2/12/2008	399	4	2004
2/12/2008	430	4	2004
2/12/2008	413	4	2004

Table B. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
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
2/12/2009	536	7	2002
2/12/2009	510	7	2002
2/20/2009	377	3	2006
2/24/2009	458	4	2005
2/24/2009	421	4	2005
2/26/2009	369	3	2006
3/3/2009	376	4	2005
3/3/2009	411	4	2005
3/3/2009	438	5	2004
3/3/2009	451	4	2005
3/3/2009	395	5	2004
3/3/2009	416	4	2005
3/13/2009	427	4	2005
3/11/2009	565	8	2001
3/11/2009	510	8	2001
3/17/2009	440	5	2004
3/17/2009	420	5	2004
3/17/2009	431	5	2004
3/17/2009	340	5	2004
3/17/2009	44	5	2004
3/24/2009	546	8	2001
3/24/2009	539	8	2001

Table B. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
4/8/2009	521	8	2001
4/13/2009	419	6	2003
4/13/2009	403	6	2003
4/13/2009	446	6	2003
4/13/2009	535	6	2003
4/15/2009	578	13	1996
4/15/2009	748	17	1992
4/15/2009	528	11	1998
4/15/2009	630	15	1994
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
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
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

Table B. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
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
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

Table B. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
3/5/2008	653	24	1984
3/19/2008	532	6	2002
3/19/2008	510	7	2001
2/19/2009	602	7	2002
4/15/2009	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 [f]	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
4/7/2011	522	7	2004
4/19/2011	537	6	2005
4/19/2011	540	7	2004
4/19/2011	515	6	2005
MUDDY RIVER/VIRGIN RIVER INFLOW AREA			
2/23/2005	608	6	1998
2/22/2006	687	33 [d]	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

Table B. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
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 [e]	2006
3/26/2008	345	3	2005
3/26/2008	541	7	2001
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	549	7	2002
2/13/2009	348	3	2006
2/13/2009	374	3	2006
2/13/2009	372	3	2006
2/17/2009	390	3	2006
2/17/2009	365	3	2006
2/17/2009	375	3	2006
2/18/2009	399	3	2006
2/18/2009	291	3	2006
2/18/2009	366	3	2006
2/24/2009	362	3	2006
2/25/2009	585	8	2001
3/3/2009	386	4	2005
3/3/2009	390	4	2005
4/6/2009	464	5	2004
4/8/2009	552	8	2001

Table B. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
4/15/2009	496	9	2000
4/15/2009	553	10	1999
4/15/2009	572	9	2000
4/15/2009	505	8	2001
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

Table B. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
2/22/2011	524	7	2004
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
3/15/2011	566	9	2002
3/15/2011	542	6	2005

Table B. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
3/15/2011	577	8	2003
4/5/2011	521	7	2004
4/5/2011	495	6	2005
4/12/2011	572	8	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
3/24/2011	545	6	2005
4/19/2011	636	9	2002
4/20/2011	570	10	2001

[a] mm = millimeters.
[b] Fish stocked from Echo Bay; larval fish captured in 1999 and raised at Nevada Department of Wildlife Lake Mead Fish Hatchery.
[c] Fish stocked from Floyd Lamb State Park ponds (1982 Dexter National Fish Hatchery cohort placed in Floyd Lamb State Park ponds in 1984).
[d] Fish was aged at 33 years of age, ± 2 years.
[e] Fish was a mortality. Found dead in net, obvious net predation/wounds. Fin ray aging results validated using otoliths.
[f] Fish stocked from Floyd Lamb State Park ponds (from an unknown 2001–2003 cohort stocking event).

APPENDIX C. AGES DETERMINED FROM HYBRID SUCKER PECTORAL FIN RAY SECTIONS COLLECTED FROM THE COLORADO RIVER INFLOW AREA OF LAKE MEAD

Table C. Ages determined from hybrid sucker pectoral fin ray sections collected from the Colorado River Inflow area of Lake Mead.

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE	PRESUMPTIVE YEAR SPAWNED
COLORADO RIVER INFLOW AREA			
4/7/2010	555	9	2001
4/7/2010	510	6	2004
4/20/2010	510	6	2004
2/16/2011	519	8	2003
3/23/2011	478	8	2003
3/23/2011	556	8	2003
3/31/2011	476	8	2003
4/13/2011	562	7	2004
5/11/2011	540	10	2001

[a] mm = millimeters.

APPENDIX D. AGES DETERMINED FROM FLANNELMOUTH SUCKER PECTORAL FIN RAY SECTIONS COLLECTED FROM THE COLORADO RIVER INFLOW AREA OF LAKE MEAD

Table D. Ages determined from flannelmouth sucker pectoral fin ray sections collected from the Colorado River Inflow area of Lake Mead.

DATE COLLECTED	TOTAL LENGTH (mm) [a]	AGE [b]	PRESUMPTIVE YEAR SPAWNED
COLORADO RIVER INFLOW AREA			
4/8/2010	418	13	1997
4/8/2010	477	11	1999
4/8/2010	460	14	1996
4/8/2010	470	10	2000
4/8/2010	485	9	2001
4/8/2010	352	5	2005
2/2/2011		4	2007
2/8/2011	465	7	2004
2/10/2011	410	7	2004
3/23/2011	470	6	2005
3/29/2011	420	4	2007
3/29/2011	417	5	2006
3/29/2011	420	7	2004
3/30/2011	484	6	2005
3/31/2011	378	3	2008
3/31/2011	462	4	2007
3/31/2011	458	4	2007
3/31/2011	395	5	2006
3/31/2011	453	6	2005
4/5/2011	355	4	2007
4/5/2011	422	4	2007
4/5/2011	501	6	2005
4/5/2011	421	7	2004
4/5/2011	458	7	2004
4/5/2011	503	8	2003
4/5/2011		9	2002
4/6/2011	462	5	2006
4/19/2011	405	4	2007
4/19/2011	509	6	2005

[a] mm = millimeters.
[b] Please note that not allflannelmouth suckers captured 2010 or 2011 were aged.