

RECLAMATION

Managing Water in the West

Razorback Sucker Studies on Lake Mead, Nevada and Arizona 2008-2009 FINAL ANNUAL REPORT

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EXECUTIVE SUMMARY

In 1996 the Southern Nevada Water Authority (SNWA) and the Colorado River Commission of Nevada, in cooperation with the Nevada Department of Wildlife (NDOW), initiated a study to develop information about the Lake Mead razorback sucker (*Xyrauchen texanus*) population. BIO-WEST, Inc. (BIO-WEST), under contract with the SNWA, developed the study design and had primary responsibility for conducting the study. In 2005 the U.S. Bureau of Reclamation (Reclamation) became the principal funding agency, and the study became primarily a monitoring study in 2007. This report provides information and observations from the 13th (2008–2009) monitoring study.

During the 13th study year the habitat use and movements of 18 sonic-tagged fish were monitored and provided a total of 174 separate location points. Five of these fish remained from 2005–2006 tagging efforts. Twelve additional fish (four released at each spawning location) were from tagging efforts conducted in December 2008. By using the data gathered from sonic-tagged fish, in conjunction with trammel netting and larval sampling data, information regarding spawning locations was again obtained from the three primary study areas within Lake Mead. Along with spawning location information, sonic-tagged fish provided valuable data on movement patterns within and between Las Vegas Bay, the Muddy River/Virgin River inflow area, and Echo Bay. Sonic-tagged fish continue to provide invaluable data regarding the movement patterns and habitat use of razorback sucker in Lake Mead and have aided field crews in monitoring these locations. We expect that the sonic tags still active from the 2005–2006 tagging effort will expire in the near future (if they have not done so already). Therefore, it was important to tag additional fish this season to allow for continued, efficient monitoring of Lake Mead razorback sucker for the next several years.

Trammel netting for juvenile/subadult (“subadult” has been defined in our reports as razorback sucker greater than 300 mm in total length, yet sexually immature) and adult fish during the spawning period continued, and 80 razorback sucker—including 49 from Las Vegas Bay, 4 from Echo Bay, and 27 from the Muddy River/Virgin River inflow area—were captured. Interestingly, 35 of the razorback sucker collected (23 from Las Vegas Bay, 0 from Echo Bay, and 12 from the Muddy River/Virgin River inflow area) were subadult fish. Of the 80 total razorback sucker collected, 28 were recaptured fish.

In addition to the capture of 27 razorback sucker at the Muddy River/Virgin River inflow area and the elevated numbers of subadult fish captured in 2009, another highlight of the 13th field season was the capture of 207 larval razorback sucker at the Muddy River/Virgin River inflow area. This is the highest number of larval fish observed to date at that location and three times more larval fish than collected in 2008. The information obtained from trammel netting and larval sampling suggests that the Muddy River/Virgin River inflow area of Lake Mead is growing in importance for razorback sucker production and recruitment. Furthermore, based on data collected since 2004, it appears that the Echo Bay and Muddy River/Virgin River spawning aggregates are indeed one aggregate. Given that razorback sucker have been observed

intermixing regularly since 2004, these two groups of razorback sucker should be considered the same population for purposes of population estimates.

Average growth during this study year, as determined from seven recaptured fish, was 33.7 mm. Mean annual growth was 42.1 mm for Las Vegas Bay fish, while Echo Bay fish displayed limited growth at 1.6 mm. Mean growth rates from fish captured near the Muddy River/Virgin River inflow area were calculated for the first time this year, with the mean annual growth calculated at 32.9 mm. Growth rates of Lake Mead razorback sucker continue to be substantially higher overall than those recorded from other populations, suggesting that the Lake Mead razorback sucker populations are able to maintain a fairly strong cohort of young, fast-growing fish.

Fin-ray sections were removed from 53 razorback sucker for age determination during the 13th study year which, when combined with the 186 fish aged during previous study years, brings the total number of fish aged during the study to 239. Of particular interest is the continued documentation of recent (2000–2006) recruitment. Past collections and analyses identified recruitment through 1999; however, fin-ray material obtained during the last two field seasons indicates continued, recent recruitment in Lake Mead. Age-determination techniques continue to show that recruitment pulses in Lake Mead are associated with relatively high, stable lake elevations; however, based on data collected from 2007–2009 we have observed strong pulses in recruitment that coincide with low, declining lake elevations. Data collected to date indicate Lake Mead razorback sucker recruitment occurs nearly every year. This observation has prompted a need to review the overarching hypothesis concerning recruitment events on Lake Mead, which to date has tied recruitment to high lake elevations. This report reiterates the need to further our understanding of the conditions that promote the highly unique recruitment of razorback sucker in Lake Mead.

In addition to the efforts and findings reported above, BIO-WEST also worked collaboratively with biologists from NDOW and Reclamation in a continued effort to collect additional larval razorback sucker for Lake Mead repatriation efforts. These fish will allow for increased razorback sucker presence in Lake Mead, additional research opportunities to test our hypotheses concerning lake levels and cover, and increased understanding of recruitment patterns during future study years.

The 2008–2009 study year showed little movement of spawning locations compared with the previous year. However, unlike 2008, a definitive spawning area was located in Echo Bay primarily based on larval fish collections. An overall lack of adult captures and low larval abundance was also noted in Echo Bay. The overall lack of razorback sucker activity at this location is cause for concern, and this population will be monitored closely in 2010. Conversely, spawning near the Muddy River/Virgin River inflow area was successfully documented again in 2009, just south of the Virgin River inflow area. Our 2009 data indicate that this was the most productive sampling season to date at the Muddy River/Virgin River inflow area.

Given the potential decline in lake levels during 2009 and 2010, perhaps reaching the lowest levels observed during the study period, general research objectives for the 2009 study year include continuing to monitor razorback sucker at the three primary study areas, continuing to age individual razorback sucker from Lake Mead, and continuing to study razorback sucker use of the Overton Arm of Lake Mead. In addition to the general long-term data collection and monitoring efforts, we anticipate assisting in the creation of a Lake Mead razorback sucker management plan for species conservation.

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INTRODUCTION

The razorback sucker (*Xyrauchen texanus* [Abbott]) is an endemic fish species of the Colorado River Basin. It was historically widespread and common throughout the larger rivers of the Colorado River Basin (Minckley et al. 1991). The distribution and abundance of the razorback sucker are greatly reduced from historic levels, and it is one of four endemic, large-river fish species (i.e., Colorado pikeminnow [*Ptychocheilus lucius*], bonytail [*Gila elegans*], humpback chub [*Gila cypha*]) presently considered endangered by the U.S. Department of the Interior (USFWS 1991). One of the major factors causing the decline of razorback sucker and other large-river fishes has been 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). Competition and predation from nonnative fishes that are successfully established in the Colorado River and its reservoirs have also contributed to the decline of these endemic species (Minckley et al. 1991). Razorback sucker persisted in several of the reservoirs that were constructed in the lower Colorado River Basin; however, these populations were comprised primarily of adult fish that apparently recruited during the first few years of reservoir formation. The population of long-lived adults then disappeared 40–50 years following reservoir creation and the initial recruitment period (Minckley 1983). The largest reservoir population, estimated at 75,000 in the 1980s, occurred in Lake Mohave, Arizona and Nevada, but it had declined to less than 3,000 by 2001 (Marsh et al. 2003). Mueller (2005, 2006) reports the wild Lake Mohave razorback sucker population to be approaching 500 individuals, while the most recent 2009 estimate of Lake Mohave razorback sucker determined there are approximately 30 wild fish remaining (Pacey 2009).

Adult razorback sucker are most evident in Lake Mohave from January through April when they congregate in shallow shoreline areas to spawn, and larvae can be numerous soon after hatching. Today, the Lake Mohave population is largely supported by periodic stocking of captive-reared fish (Marsh et al. 2003, Marsh et al. 2005). Predation by bass (*Micropterus* spp.), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), sunfish (*Lepomis* spp.), and other nonnative species appears to be the primary reason for lack of razorback sucker recruitment (e.g., Minckley et al. 1991, Marsh et al. 2003, Carpenter and Mueller 2008, Schooley et al. 2008).

The Lake Mead population appeared to follow the trend of populations in other lower Colorado River Basin reservoirs. Lake Mead was formed in 1935 when Hoover Dam was closed and razorback sucker were relatively common lake-wide throughout the 1950s and 1960s, apparently from reproduction soon after the lake was formed. Their numbers became noticeably reduced in the 1970s, approximately 40 years after closure of the dam (Minckley 1973, McCall 1980, Minckley et al. 1991, Holden 1994, Sjoberg 1995). From 1980 through 1989, neither the Nevada Department of Wildlife (NDOW) nor the Arizona Game and Fish Department (AGFD) collected razorback sucker from Lake Mead (Sjoberg 1995). This trend may have been partially because of changes in the agencies' lake sampling programs; however, there was a considerable decline from the more than 30 razorback sucker collected during sportfish surveys in the 1970s.

These results are not surprising and fit well within the pattern of razorback sucker population declines approximately 40–50 years following reservoir development, as was seen in other lower Colorado River Basin reservoirs.

After receiving reports in 1990 from local anglers that razorback sucker were still found in Lake Mead in two areas (Las Vegas Bay and Echo Bay), NDOW initiated limited sampling. From 1990 through 1996, 61 razorback sucker were collected, 34 from the Blackbird Point area of Las Vegas Bay and 27 from Echo Bay in the Overton Arm (Holden et al. 1997). Two razorback sucker larvae were collected by an NDOW biologist in 1995 near Blackbird Point, confirming suspected spawning in this area. In addition to the captures of these wild fish, NDOW also stocked subadult (sexually immature) razorback sucker into Lake Mead. A total of 26 razorback sucker were stocked into Las Vegas Bay in 1994, and 14 were stocked into Echo Bay in 1995. All of these stocked fish were tagged with passive integrated transponder (PIT) tags, and all originated from the Dexter National Fish Hatchery 1984 year-class that was reared at Floyd Lamb State Park in Nevada. Collection of razorback sucker in the 1990s raised many questions about Lake Mead razorback sucker: How large is the population? Are the Las Vegas Bay and Echo Bay groups separate populations? Does razorback sucker recruitment occur in the lake? How old are the fish in Lake Mead, and are the two groups different in age structure? In 1996 the Southern Nevada Water Authority (SNWA), in cooperation with NDOW, initiated a study to attempt to answer some of these questions. 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 U.S. Bureau of Reclamation (Reclamation), which provided funding, storage facilities, and technical support; the U.S. National Park Service (NPS), which provided residence facilities in their campgrounds; the Colorado River Commission of Nevada; and the U.S. Fish and Wildlife Service (USFWS).

At the start of the project in October 1996, the primary objectives were to:

- determine the population size of razorback sucker in Lake Mead,
- determine habitat use and life history characteristics of the Lake Mead population, and
- determine use and habitat of known spawning locations.

In 1998 Reclamation agreed to contribute additional financial support to the project to facilitate fulfillment of Provision #10 of the Reasonable and Prudent Alternative generated by the USFWS's Final Biological and Conference Opinion on Lower Colorado River Operations and Maintenance-Lake Mead to Southerly International Boundary (USFWS 1997). In July 1998 a cooperative agreement between Reclamation and the SNWA was completed, specifying the areas to be studied and extending the study period into 2000.

Additional study objectives added to fulfill Reclamation's needs included the following:

- search for new razorback sucker population concentrations via larval light-trapping outside the two established study areas, and
- enhance the sampling efforts for juvenile razorback sucker at both established study sites.

If new populations were tentatively located by finding larval razorback sucker, trammel netting would be used to capture adults and sonic tagging would be used to determine the general range and habitat use of the newly discovered population. In 2002 Reclamation and SNWA completed another cooperative agreement to extend Reclamation funding into 2004. In 2005 a new objective of evaluating the lake for potential stocking options/locations was added to the project as a response to a growing number of larval fish that had been and were slated to eventually be repatriated to Lake Mead. Also in 2005 Reclamation became the primary funding agency and requested that a monitoring protocol be established to ensure the success and continuity of the long-term, growing database that is maintained by BIO-WEST and stems from Lake Mead collections made during its more than decade-long course of studies. In response BIO-WEST developed a monitoring protocol that helped raise efficiency levels of data collection efforts, while maintaining the amount of information that would be gained studying various life phases of razorback sucker during future monitoring and/or research efforts on Lake Mead. In 2007 the project became primarily a monitoring study. In 2008 Reclamation and SNWA completed another cooperative agreement, tentatively extending monitoring efforts and following monitoring protocols developed by Albrecht et al. (2006a).

This Annual Report presents the results of the 13th study year (February 2009 through early May 2009 monitoring data) and sonic-tagged razorback sucker data from July 2008 through June 2009, in accordance with the results reported by Albrecht et al. (2008a) and other past annual reports. Other information and data from previous years and reports are included as applicable.

SUMMARY OF EARLIER STUDY RESULTS, 1996–2008

Since the Lake Mead Razorback Sucker Study began in 1996, netting efforts have resulted in more than 750 total razorback sucker capture and/or stocking events, represented by nearly 500 unique individuals. The PIT tags proved valuable in assessing growth and movement patterns of the Lake Mead razorback sucker population. In 1997 four subadult razorback sucker were captured in Echo Bay, indicating that recent, natural recruitment had occurred within the Lake Mead population. Seventeen additional wild subadult razorback sucker were captured in the Blackbird Point area of Las Vegas Bay through 2005. From 2005–2008, an additional 39 subadult razorback sucker were captured in Lake Mead, indicating continued, natural recruitment. Beginning in 1999 small sections of fin rays were removed from wild razorback sucker for age-determination purposes, and through 2008 186 razorback sucker were aged. The adult fish collected have ranged in age from approximately 7–36 years, and subadult fish were between 2 and 6 years of age. We have hypothesized that lake-level fluctuations that promote

growth and then inundation of shoreline vegetation are largely responsible for the initiation of recruitment observed in Lake Mead's razorback sucker population. The inundated vegetation likely serves as protective cover that, along with turbidity, allows young razorback sucker to avoid predation by nonnative fishes. Recent nonnative introductions, such as quagga mussels (*Dreissena rostriformis bugensis*) and gizzard shad (*Dorosoma cepedianum*), could also affect the razorback sucker population in Lake Mead, but the nature and severity of these new potential stressors remains unknown at this time.

During the last several years, declining and low lake elevations have affected razorback sucker at spawning sites such as Echo Bay in Lake Mead. At Echo Bay from 1997–2001, aggregations of sonic-tagged adults, redd locations, and larval concentrations indicated that spawning was occurring at the back of Echo Bay along the south shore. Specifically, it appeared that adult razorback sucker were spawning at the base of a 50-foot (15.24-meter) cliff. At the end of the spawning season in May 2001, this site was dry. As lake levels declined during the last several years, the Echo Bay population continued to find new spawning sites in Echo Bay as sites from previous years dried, moving down the wash with the declining lake. At Las Vegas Bay during the first 9 years of this study, most razorback sucker larvae were captured along the western shore and tip of Blackbird Point. This suggests that the same portion of Blackbird Point was used for spawning every year, but the depth in this area changed dramatically as lake levels dropped and possible siltation occurred from Las Vegas Wash. In the late 1990s at a high lake elevation, the spawning location was thought to be near a depth of 80 feet (24.39 meters). By 2003 the spawning depth was closer to 20 feet (6.10 meters), and by the end of 2004 the area was completely desiccated. As a result spawning was not observed at the Blackbird Point spawning area during the 2003–2004 study year, and only four larval razorback sucker were captured during the entire season at Las Vegas Bay, a site that once harbored the largest razorback sucker population in Lake Mead. However, during the 2005 spawning period (January through April), Lake Mead elevations rose more than 20 feet (6.10 meters), allowing access to the Blackbird Point spawning site during the ninth study year. In 2006 and again in 2007, in response to lowered lake conditions, the spawning aggregate at Las Vegas Bay shifted spawning locations from Blackbird Point to the southwestern shoreline of Las Vegas Bay.

In 2000 and 2001 larval razorback sucker were captured in the Colorado River inflow region of Lake Mead. During the 2002 and 2003 spawning periods, no larval razorback sucker was captured in this area. This population either did not spawn, or spawning took place outside of our sampling area. Alteration of spawning sites resulting from lake elevation changes may be responsible for the apparent absence of spawning in the Colorado River inflow region. In 2003–2004 larval sampling was conducted at the Muddy River/Virgin River inflow areas and throughout the Overton Arm of Lake Mead. Despite having habitat characteristics similar to Echo and Las Vegas Bays (in terms of turbidity, vegetation, and gravel shorelines), no larval razorback sucker were captured in the Overton Arm north of Echo Bay on any of the sampling occasions. However, after following movements of a single, sonic-tagged fish in 2005, adult and larval sampling was reinitiated at the Muddy River/Virgin River inflow areas. The result of this effort was the documentation of spawning activities in this area of Lake Mead. In 2006, 2007,

and 2008, razorback sucker were again documented as spawning successfully near the Muddy River/Virgin River inflow area.

During the first 6 years of this study, 46 fish (42 wild and 4 hatchery reared) were equipped with internal or external sonic tags. Approximately half of these tags, implanted in 1997 and 1998, had a 12-month battery life, and the other half had a 48-month battery life. Sonic telemetry showed a seasonal habitat-use pattern within the lake. At Las Vegas Bay the fish concentrated in the Blackbird Point area during the spawning period but moved further out into the bay during the nonspawning period (June–November). Most of these fish were found using the north shore of Las Vegas Bay between Blackbird Point and Black Island. At Echo Bay a similar pattern was seen; fish left the Echo Bay spawning area and regularly used Rogers Bay and other points north of Echo Bay along the western shore of the Overton Arm. The four hatchery-reared fish implanted with sonic tags and stocked into the Colorado River inflow area early in the sixth study year (2002) were active in the Grand Wash area for several months after stocking. Two of the fish became stationary, and the remaining two fish were last contacted in the inflow area in April 2002. Despite numerous lake-wide searches, the missing fish were not relocated. In January 2003 (seventh study year) four razorback sucker (two in Echo Bay and two in Las Vegas Bay) were captured during standard trammel netting and implanted with 48-month sonic tags. One of the Las Vegas Bay fish was found stationary near Black Island in February 2003. The other Las Vegas Bay fish and one of the Echo Bay fish were last contacted in 2003 (the eighth study year). The remaining fish from the 2003 sonic-tagging effort was contacted several times during the early part of the 2004–2005 field season.

The drastic decline in larval fish abundance in 2004 spurred questions about whether or where the Las Vegas Bay population was spawning. Welker and Holden (2004) proposed tagging six razorback sucker from Floyd Lamb State Park as an experiment, hoping that these fish would integrate with the wild population in Las Vegas Bay and help identify new spawning areas. Hence, six fish from Floyd Lamb State Park were tagged during the 2004–2005 study year, and sonic surveillance of these individuals produced interesting results. All contact with the four fish introduced into the Las Vegas Bay area was lost within 1 month. It is most probable that the tags failed, as multiple and extensive searches of the lake for the missing fish were unsuccessful. However, two of the fish (experiencing the same surgery, handling, introduction, and monitoring protocols as the four Las Vegas Bay fish) were introduced at Echo Bay. In general, these fish appeared to integrate with the wild population and were followed throughout the 2004–2005 study year. One of these fish (code 344) spent the majority of the field season in the back of Echo Bay, while the other fish (code 222) displayed large movement patterns from Echo Bay and within the Overton Arm of Lake Mead. An additional 10 sonic-tagged fish were stocked in 2005, providing additional movement data following the expiration of tags from the 2004 sonic-tagging effort. One of these fish (code 447) displayed movement from Echo Bay, its original stocking location, through the Overton Arm, and between Echo Bay and Las Vegas Bay (Albrecht et al. 2006b, 2007, and 2008a). Approaching the longevity threshold of sonic tags from the 2005 tagging event, 12 additional sonic-tagged fish from Floyd Lamb State Park were released (four at each study area) in Lake Mead in December 2008. This report contains

movement information for only two of the tagged fish (code 365 and 376 from Echo Bay), which were contacted multiple times after their release and found actively moving between Echo Bay and the Overton Arm during a portion of the 2009 field season. In addition, this report also contains information from five residual hatchery-reared (Floyd Lamb State Park) razorback sucker that were tagged and released during the 2005–2006 field season and the other 10 sonic-tagged fish stocked in December 2008.

Overall, the sonic-telemetry data collected during this study have provided valuable information on razorback sucker spawning, movement patterns, and shifts in habitat use and spawning-site selection. Furthermore, it has been demonstrated that tracking even hatchery-reared, sonic-tagged razorback sucker can be highly effective in locating new spawning areas and monitoring known spawning locations used by wild razorback sucker populations. Hence, monitoring sonic-tagged fish can increase the efficiency of field efforts.

STUDY AREAS

All 2009 study activities occurred at the locations used for the 1996–2008 portions of the study (Holden et al. 1997, Holden et al. 1999, Holden et al. 2000a, Holden et al. 2000b, Holden et al. 2001, Abate et al. 2002, Welker and Holden 2003, Welker and Holden 2004, Albrecht and Holden 2005, Albrecht et al. 2006a, Albrecht et al. 2006b, Albrecht et al. 2007, Albrecht et al. 2008a, Albrecht et al. 2008b). The two most familiar areas sampled were Echo Bay and Las Vegas Bay (Figure 1). Razorback sucker activity was also studied at the Muddy River/Virgin River inflow area of Lake Mead, the part of Lake Mead near Fish Island in the northernmost portions of the Overton Arm (Figure 1).

Most areas of the lake, including the Overton Arm, Boulder Basin, and the Virgin Basin, were searched using telemetry equipment. Larval sampling and trammel netting were performed in Echo Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area.

Specific definitions for the various portions of the Las Vegas Wash/Bay in which the study was conducted were given in Holden et al. (2000b). The following definitions are still accurate for various portions of the wash:

- Las Vegas Wash is the portion of the channel with stream-like characteristics. In recent years this section has become a broad shallow area.
- Las Vegas Bay begins where the flooded portion of the channel widens and the velocity is reduced. Las Vegas Bay can have a flowing (lotic) and a nonflowing (lentic) portion. The flowing portion is typically short [200–400 yards (183–366 meters)] and transitory between Las Vegas Wash proper and Las Vegas Bay. Because lake elevation affects what is called the wash or bay, the above definitions are used to differentiate the various habitats at the time of sampling.

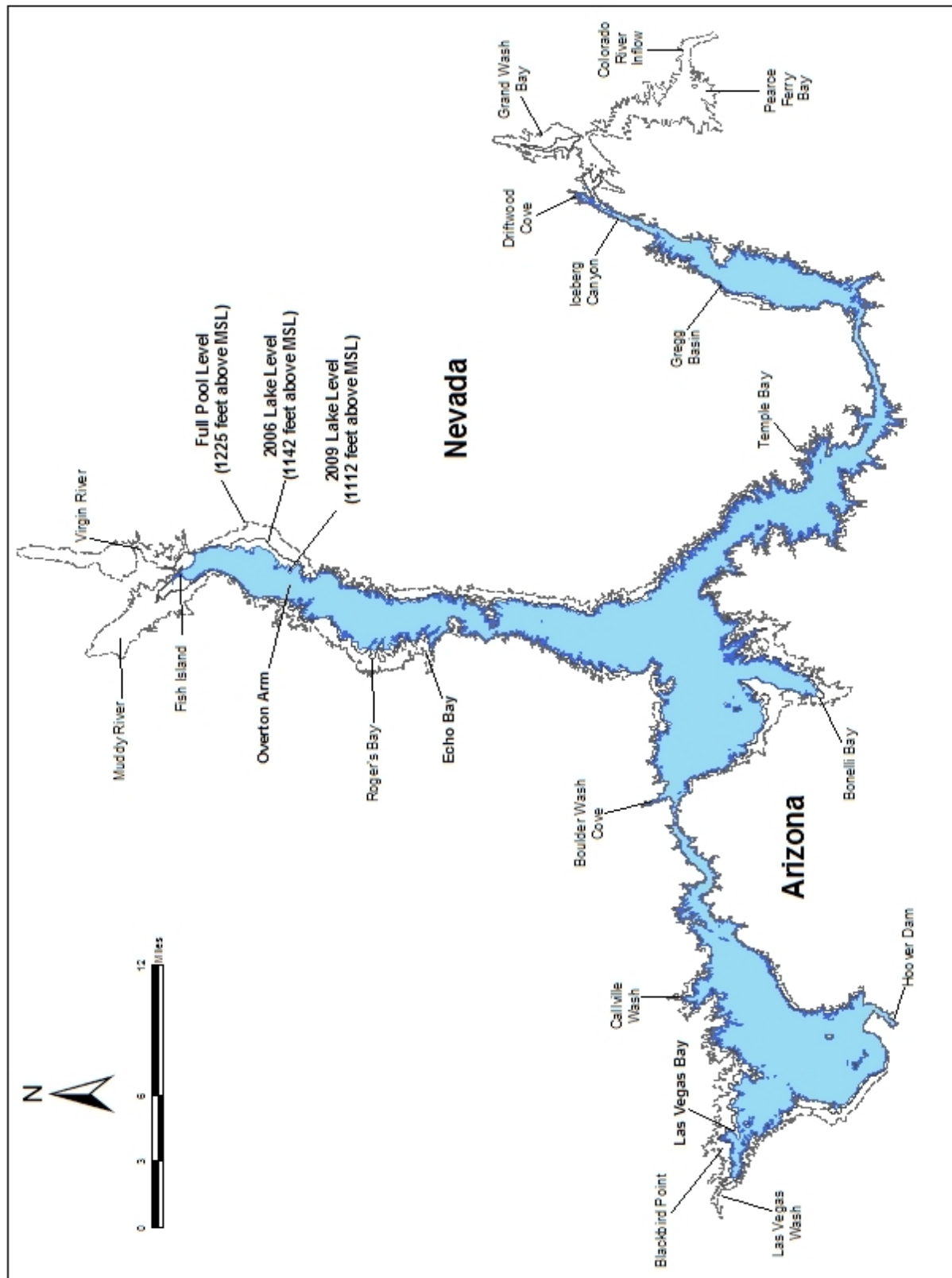


Figure 1. Lake Mead general study areas.

Throughout the text of this report, three portions of Las Vegas Bay may be referred to using the following terms:

- flowing portion (the area closest to, or within, Las Vegas Wash);
- nonflowing portion (usually has turbid water but very little, if any, current); and
- Las Vegas Bay (the majority of the bay that is not immediately influenced by Las Vegas Wash and is lentic in nature).

Additionally, the location of wild adult and larval razorback sucker in the northern portion of the Overton Arm necessitates a description of these areas. These location definitions follow those provided in Albrecht and Holden (2005):

- Muddy River/Virgin River inflow area (the lentic and littoral habitats located around the Muddy River confluence and the Virgin River confluence with Lake Mead at the upper end of the Overton Arm);
- Fish Island (located between the Muddy River and Virgin River inflows, bounded on the western side by the Muddy River inflow and on its eastern side by the Virgin River inflow. This area is no longer an actual island depending upon lake elevation); and
- Muddy River and Virgin River proper, the actual flowing, riverine portions that comprise the Muddy and Virgin rivers.

METHODS

Lake Elevation

Month-end lake elevations for the 2009 field season (July 1, 2008–June 30, 2009) were measured in feet above mean sea level (amsl) and obtained from Reclamation’s Lower Colorado Regional Office website (Reclamation 2009). The effect of fluctuating lake levels on razorback sucker habitat was documented by written observations and/or photographs during sampling trips to each of the study areas.

Adult Studies

The primary gear used to sample adult fish were trammel nets 300 feet long (274.4 meters) by 6 feet deep (1.8 meters) with an internal panel of 1-, 1.5-, or 2-inch mesh (2.54-, 3.81-, or 5.08-centimeter) and external panels of 12-inch mesh (30.48-centimeter). Nets were generally set with one end near shore in 10–30 feet (3.05–9.15 meters) 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). Sampling was generally conducted weekly within each

study area from February–April, following protocol developed by Albrecht et al. (2006a) with variable effort between months and locations. Netting locations for the three primary study areas were selected based on the locations used by sonic-tagged fish, the location of larval concentrations, and ancillary knowledge of historical spawning areas.

Fish were taken from nets, and live fish were held in large, 100-quart (94.6 L) coolers filled with lake water. Razorback sucker were isolated from other fish species and held in separate containers. All but the first five common carp were enumerated and returned to the lake, while other species (including five common carp) were identified, measured for total length, weighed, and released at the location of capture. Razorback sucker 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. Razorback sucker selected for age determination were anesthetized with MS-222 and then placed dorsal-side down on a padded surgical cradle for support while a segment of pectoral fin ray was collected.

BIO-WEST also worked cooperatively with the USFWS to collect milt samples from mature, ripe males at each of the sampling locations. Milt samples were collected in conjunction with the aforementioned work-up procedure. All samples were transferred to the USFWS for analysis. Results of this analysis are not included in this report. Results and details of this study should be available from the USFWS at a later date.

Larval Sampling

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 sucker to capture them. After sundown, two 12-volt “crappie” lights were connected to a battery, placed over each side of the boat, and submerged in 4–10 inches (10.2–25.4 centimeters) of water. Two “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 6–12 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.

As a result of fluctuating lake levels, larval sampling during spring 2009 could not be conducted at the same larval sites that were sampled in spring 2008. Larval sites were selected systematically to help locate spawning areas. When possible, the locations of active, sonic-tagged fish and the previous week’s adult netting results were also used to select larval sites over the course of the season. As a result, the larval sampling strategy was a much more responsive, fluid, and adaptable protocol than in the past. This strategy was useful in coping with fluctuating lake elevations during the 2009 spawning period and the movement of the spawning aggregate from the previous year.

In addition to standard larval sampling conducted this year, BIO-WEST also worked collaboratively with biologists from NDOW and Reclamation in an effort to collect additional larval razorback sucker for future repatriation efforts. The general collection protocol was essentially an extension of the larval sampling method BIO-WEST had developed (described above) with additional time spent collecting larval fish at specific sites where catch per unit effort (CPUE) was elevated during a particular night. BIO-WEST worked under the direct supervision of agency biologists, and larval razorback sucker were immediately turned over to NDOW and Reclamation biologists upon capture for transport and hatchery provisions. Larval fish capture results stemming from the collaborative sampling efforts discussed above are not included as part of this report; specimens and data-collection information are retained by and available from NDOW upon request.

Annual Spawning-Site Identification

We have found that multiple methods are needed to identify and pinpoint annual spawning sites. The basic, most effective spawning-site identification procedure has been to track sonic-tagged fish, keying in on the most heavily frequented areas. Once a location was identified as an area of heavy use by sonic-tagged fish, particularly during crepuscular hours, nets were set in an effort to capture adult razorback sucker. Captured fish were 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 adult trammel-net captures, larval sampling was 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.

Age Determination

Determination of Lake Mead razorback sucker age distribution was added to the project in 1998, when a subadult fish (381 mm TL) was collected and subsequently died (Holden et al. 1999). This initiated development of a nonlethal aging technique using fin ray sections beginning in 1999 (Holden et al. 2000a). As in past years, an emphasis of our 2009 efforts involved collecting fin-ray sections from razorback sucker for aging purposes.

During the 2009 spawning period, selected razorback sucker captured via trammel netting were anesthetized and a single, approximately 0.25-inch-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 about 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 developed by BIO-WEST. This surgical tool consists of a matched pair of finely sharpened chisels welded to a set of wide-mouth Vise-GripsTM 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 razorback sucker were immediately placed in a recovery bath of fresh lake water containing slime-coat protectant, allowed to recover, and released as soon as the fish 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, the readers viewed the structure together and 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), and other annual reports from past years.

Sonic Tagging

Sonotronics Model CT-05-48-I (48-month) tags were implanted in seven male and five female adult razorback sucker from Floyd Lamb State Park. Tagging events took place December 2–4, 2008, and tags were used to monitor razorback sucker movements and habitat selection during the 2008–2009 field season. The 48-month tags had an air weight of 29 g (14.5 g water weight) and measured 79 mm long by 16 mm in diameter. The tags used frequencies of 71, 72, 75, 76, 77, 78, 79, 80, and 81 kHz. Since each tag has a unique code, individual fish could be distinguished. 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. Surgical implants were performed on shore. Three people were involved in the surgery, a surgeon and two assistants. The assistants took data, captured pertinent photographs, and monitored fish respiration. A highly specialized surgeon, Dr. Chris Bunt of BIOTACTICS, Inc., was contracted to assist, demonstrate current surgical practices, and provide instruction on updated tagging methodologies (tagging surgeon from previous study year). Direct supervision by BIO-WEST staff occurred during all stages of the surgical procedure. In addition to Dr. Bunt, NDOW biologists, and the rest of the BIO-WEST team were responsible for attending to all aspects of the surgical procedure. Prior to surgery each fish was placed in live well containing fresh pond 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 pond 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 ETOH). After anaesthesia was induced (post-opercular movement cessation), total length, fork length, standard length, and weight 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 pond water with a maintenance concentration of 25 mL L⁻¹ clove oil/ETOH anaesthetic (Bunt et al. 1999). Following fish introduction to the maintenance anaesthetic, a 3–4 cm incision was made by the surgeon. The incision was positioned on the left side, posterior to the left pelvic fin. The sonic transmitter was inserted through the incision and pushed back to rest between the pelvic girdle and urogenital pore. The incision was closed with 2–3 sutures using 3-0 Maxon absorbable polygluconate monofilament suture with an attached PH 26 curved cutting needle. Surgery times typically ranged from 2–5 minutes per fish.

Fish were allowed to recover in a live well containing fresh pond water (until equilibrium was maintained), transferred to portable net pens within the pond, and monitored for approximately 2 hours. Fish were then held in aerated tanks provided by NDOW during transport from Floyd Lamb State Park to release points in Las Vegas Bay, Echo Bay, and the Muddy River/Virgin River inflow area. Upon arrival at the desired release points, fish were re-examined for signs of stress and then slowly acclimated to Lake Mead water temperatures prior to release. Tracking and movement monitoring ensued immediately after release and continued intensively for 48 hours, followed by detailed tracking in the days and weeks following (see Sonic Tracking section below).

Sonic Telemetry and Tracking

Unlike previous studies in which the focus of sonic telemetry was to determine habitat use and/or preference, telemetry data for the 13th study year was used primarily as a tool to locate and determine movement of spawning locations within the primary study areas. Four male and six female razorback sucker from Floyd Lamb State Park were sonic tagged during the 2005–2006 field season, and five fish from this tagging event were monitored this season. Twelve more sonic-tagged fish (seven male and five female) from a December 2008 tagging effort were also monitored in an effort to increase spawning site location effectiveness as previously stocked fishes' sonic tags expire. Fish were located on a weekly (or more frequently) basis, depending on the field schedule and weekly project goals. Fish searches were generally conducted along shorelines with listening points every 0.5 mile (0.8 kilometer) or less, 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). Once a signal was found, the directional capabilities of the hydrophone, volume of the transmitter, and triangulation techniques were used to pinpoint the actual location of the fish, which was then noted using a GPS unit.

Population Estimates

Capture data collected by BIO-WEST from 2007–2009 were used to calculate abundance estimates for razorback sucker populations in the Lake Mead. Two models from the program CAPTURE (Rexstad and Burnham 1992), as well as estimates from the model selection procedure, were used for this analysis. Stocked fish were not used in the population estimates

unless they had survived at least 1 year in Lake Mead. It was assumed that an adult stocked fish that had survived 1 year in the wild was able to reproduce and contribute progeny to the population (Albrecht and Holden 2005, Modde et al. 2005).

The two abundance estimators used were Chao's M_h (Chao 1989) and Model M_0 (Otis et al. 1978). The Model M_0 typically produces the most reliable estimates for endangered western fishes (R. Ryel 2001, pers. comm.), but it assumes equal catchability of individuals. Chao's M_h is a good estimator for sparse data, but unlike Model M_0 it assumes heterogeneity of capture probabilities. If the estimators gave very different numbers, then a reliable estimate was believed to lie somewhere between the two numbers. However, as shown in past reports, close agreement between the models indicated a fairly reliable estimate.

As indicated in Albrecht et al. (2006b), we had planned to forego reporting population estimates for Lake Mead razorback sucker because of the nature of the data collected and the violation of many of the assumptions that are key to closed-model population estimation techniques. However, population estimates are included simply from an informative and purely demonstrative standpoint to compare past results. Basing any management decisions solely on the population estimation information provided within this document is strongly discouraged due to the violations of many of the assumptions involved with closed-model population estimation techniques, which are more fully described by Albrecht et al. (2006b).

RESULTS

Lake Elevation

Similar to the 11th study year, lake elevations during the 13th study year diminished overall. From a starting elevation in January 2009 of approximately 1,112 feet (339 meters) amsl, lake levels dropped throughout the spawning period. Lake Mead elevation at the end of April 2009 was approximately 1,101 feet (335.7 meters) amsl. This translated to an overall loss of nearly 11 feet (3.35 meters) of depth during the spawning period (Figure 2). We observed the desiccation of vast expanses of wetted area within the Muddy River/Virgin River inflow between February and late April. Similar observations were made in Las Vegas Bay, especially at its confluence with Las Vegas Wash.

Adult Sampling

Trammel Netting

Table 1 shows the trammel netting effort, expressed as net nights, that occurred during 2009. One net night comprises a single net, set overnight. Trammel netting was conducted over 79 net nights during the 13th study year, with 25 net nights spent in the Las Vegas Bay/Boulder Basin area, 26 net nights spent in the Echo Bay area, and 28 net nights in the Muddy River/Virgin River inflow area. Trammel netting efforts were concentrated along the southwestern shoreline

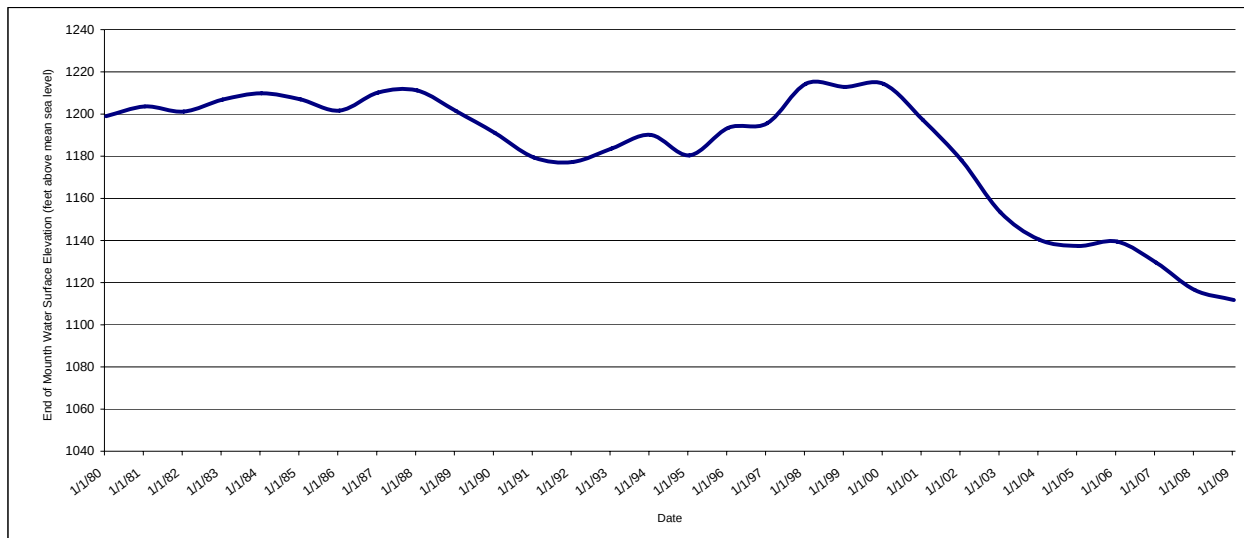


Figure 2. Lake Mead month-end elevations, January 1980–June 2009.

Table 1. Trammel netting effort (net nights) on Lake Mead during the 13th study year.

MONTH	LAS VEGAS BAY/ BOULDER BASIN	ECHO BAY	OVERTON ARM	TOTAL
February	15	12	15	42
March	6	11	9	26
April	4	3	4	11
Total	25	26	28	79

area in Las Vegas Bay, as well as within other Las Vegas Bay locations (Figure 3). Trammel netting was conducted primarily within the back of Echo Bay, with search efforts extending out into the main body of the lake (Figure 4). Net sets were dictated by the location of sonic-tagged fish in each of the sampling areas when possible.

Trammel netting efforts at the Muddy River/Virgin River inflow area were initially concentrated around the Fish Island shoreline, but efforts were designed to be flexible and were largely dictated by the habitat availability and the use and movements of sonic-tagged fish throughout the northern portions of Lake Mead (Figure 5). The bulk of our 2009 netting efforts near the Muddy River/Virgin River inflow area were conducted south of the confluence of the Virgin River with Lake Mead and along the eastern shoreline south of the Virgin River inflow. This was dictated by lowered lake conditions and the capture of multiple razorback sucker at these locations. Netting effort was expended from February through the end of April 2009 (Holden et al. 1997, 1999; Albrecht et al. 2006a, 2006b). No trammel netting effort specific to razorback sucker was expended at the Colorado River inflow area during the 13th study year.

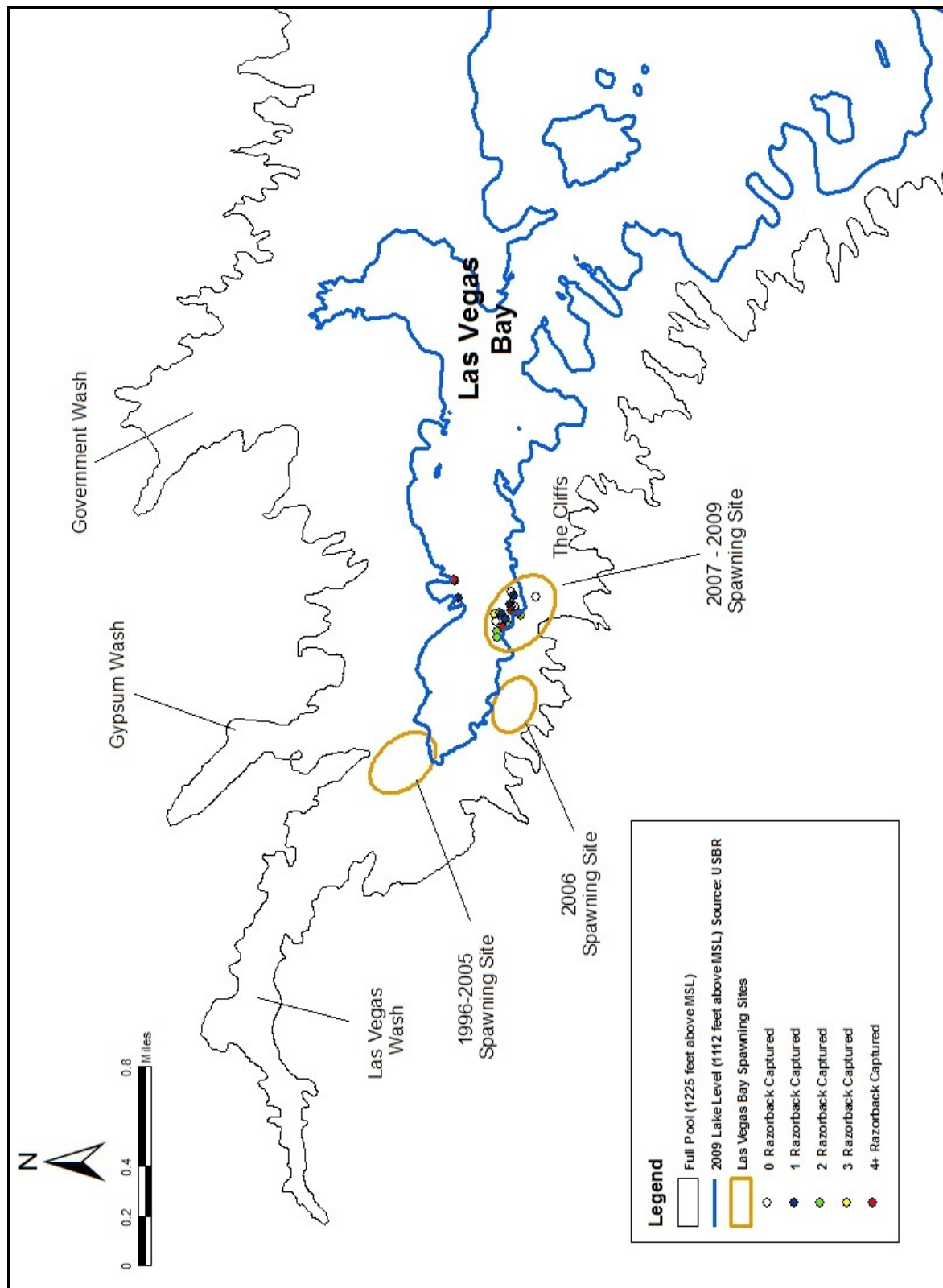


Figure 3. Las Vegas Bay study area showing locations of trammel netting and numbers of fish captured, July 2008–June 2009.

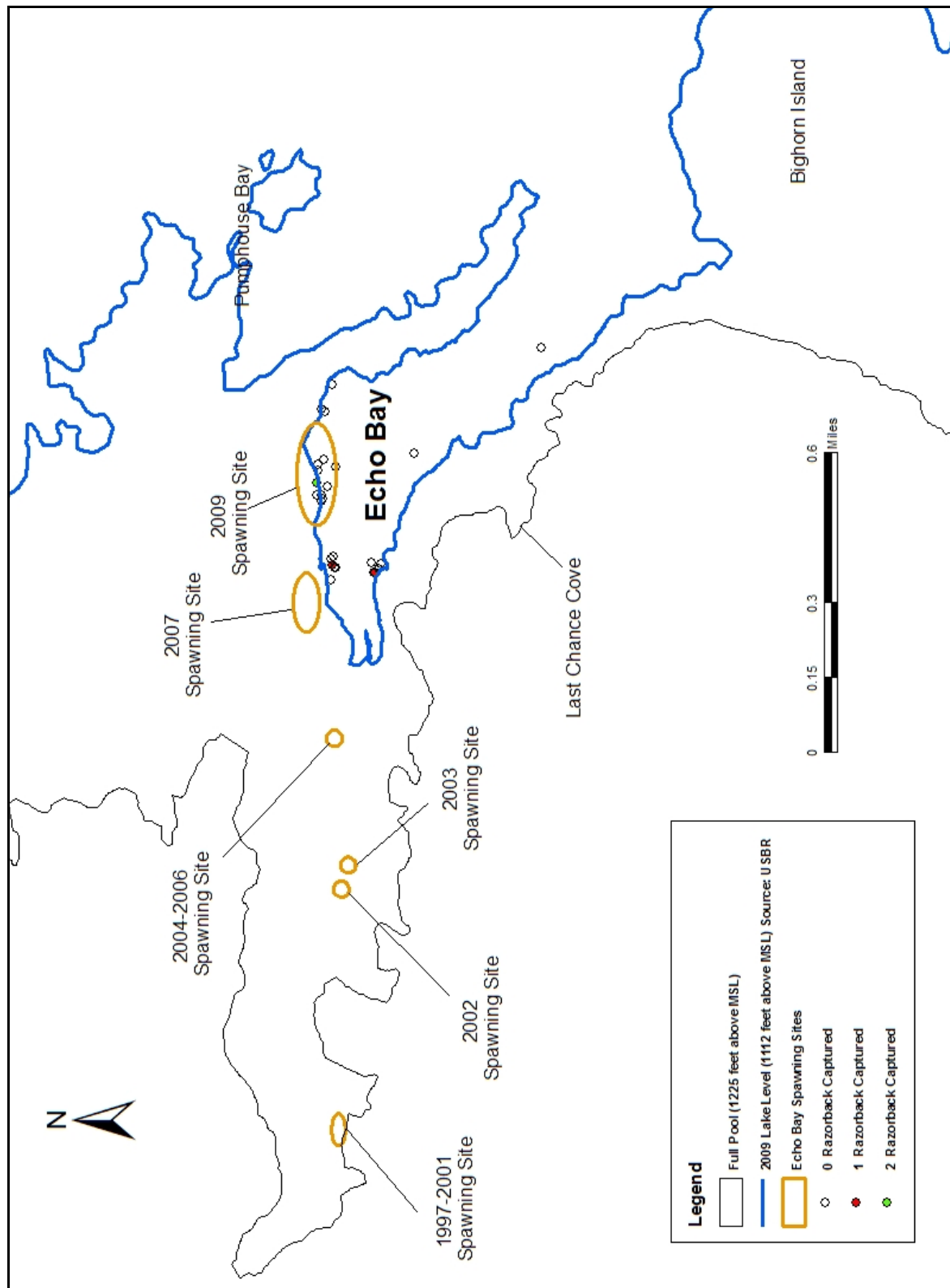


Figure 4. Echo Bay study area showing locations of trammel netting and numbers of fish captured, July 2008–June 2009.

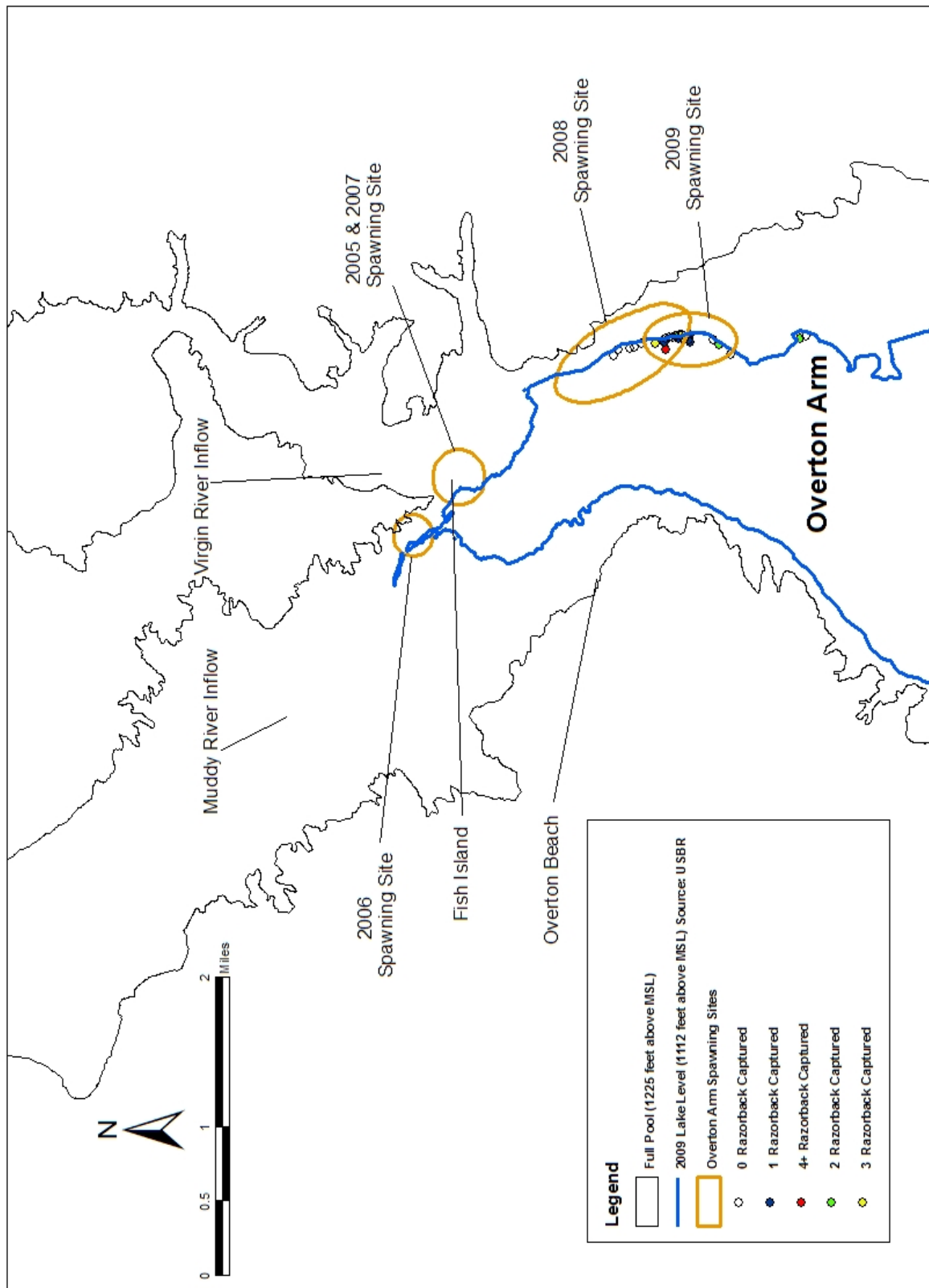


Figure 5. Muddy River/Virgin River inflow study area showing locations of trammel netting and numbers of fish captured, July 2008–June 2009.

Trammel netting efforts occurred from February through the latter portion of April 2009 in accordance with recommendations for long-term monitoring of Lake Mead razorback sucker as found in Albrecht et al. (2006a).

The first male razorback sucker expressing milt was captured on February 4, 2009, and the first female razorback sucker expressing eggs was captured February 20, 2009. The male fish was captured from the Muddy River/Virgin River inflow area and the female was captured in Echo Bay. Recapture rates varied between study areas in the 13th study year. At Las Vegas Bay 19 of the 49 razorback sucker caught were recaptures (38.8%), and 4 of those fish had been stocked by NDOW into Lake Mead. At Echo Bay three of the four razorback sucker caught were recaptures (75.0%), one of which was stocked by NDOW during a previous year. Finally, at the Muddy River/Virgin River inflow area, 6 of the 27 razorback sucker caught were recaptures (22.2%) all of which were wild fish.

Twenty-six adult and 23 subadult razorback sucker were captured at Las Vegas Bay (Table 2) during the 25 net nights expended during the 13th study year (Figure 3). Most fish were captured near the southwestern shoreline of Las Vegas Bay, providing continued evidence that the Las Vegas Bay razorback sucker population has the ability to shift spawning locations as habitat conditions dictate. In the past, most of the razorback sucker captured in Las Vegas Bay were netted at Blackbird Point (Holden et al. 1997, 1999, 2000a, 2000b, 2001; Abate et al. 2002; Welker and Holden 2003, 2004; Albrecht and Holden 2005). During the 2009 spawning period, the majority of razorback sucker were captured along a gravel/small-cobble section of shoreline off the southwestern side of Las Vegas Bay in net sets positioned perpendicular to the shoreline. Initially, efforts were increased along this particular shoreline because of the frequent presence of sonic-tagged fish. Since 2006 larval razorback sucker abundance confirmed this shoreline as the primary spawning area. The razorback sucker catch rate for trammel netting at the Las Vegas Bay area was 1.96 fish/net night for the 13th study year. This rate is higher than the previous year's rate (1.67 fish/net night) and is the highest catch rate observed during our studies at this location (0.10–1.67 fish/net night) (Figure 6). It should be noted that lengths and weights were not recorded for sonic-tagged fish 377. This fish was measured and weighed in December 2008 upon release. Therefore, to avoid inflicting unnecessary handling stress on this fish, no measurements of it were taken.

Table 2. Location, tagging, and size information for razorback sucker captured in Lake Mead during 2009.

DATE	CAPTURE LOCATION ^a	PIT TAG NUMBER	SONIC CODE	DATE STOCKED ^b	RECAPTURE	TL ^c (mm)	FL ^d (mm)	SL ^e (mm)	WT ^f (g)	SEX ^g
2/4/2009	OA	3D9.1C2C7F4AA7		2/4/2008	NO	496	461	421	1,620	F
2/4/2009	OA	3D9.1C2C8572E3		2/4/2008	NO	602	567	514	2,988	F
2/4/2009	OA	532568047C		2/22/2008	YES	542	502	468	1,742	M
2/4/2009	OA	53437D5852		4/1/2008	YES	547	507	463	1,890	M
2/5/2009	LB	45142C6506	377	12/4/2008	YES	NR ^h	NR ^h	NR ^h	NR ^h	M

Table 2. (Cont.)

DATE	CAPTURE LOCATION ^a	PIT TAG NUMBER	SONIC CODE	DATE STOCKED ^b	RECAPTURE	TL ^c (mm)	FL ^d (mm)	SL ^e (mm)	WT ^f (g)	SEX ^g
2/5/2009	LB	53255E1008		3/31/2006	YES	650	605	565	3,628	M
2/10/2009	EB	5326051F79		2/22/2007	YES	520	483	450	1,650	M
2/12/2009	OA	3D9.1C2C856E36		2/12/2009	NO	505	459	421	1,468	M
2/12/2009	OA	3D9.1C2C840833		2/12/2009	NO	553	508	470	2,108	M
2/13/2009	LB	3D9.1C2C83C3C9		2/13/2009	NO	395	364	335	688	I
2/13/2009	LB	3D9.1C2C8410E7		2/13/2009	NO	528	482	449	1,588	M
2/13/2009	LB	3D9.1C2C841383		2/13/2009	NO	630	574	551	3,390	M
2/17/2009	LB	3D9.1C2C8440B1		2/17/2009	NO	440	411	375	1,062	I
2/17/2009	LB	3D9.1C2C840C56		2/17/2009	NO	420	389	356	892	I
2/17/2009	LB	3D9.1C2C7F49A1		2/17/2009	NO	510	464	431	1,624	M
2/18/2009	LB	3D9.1C2C83BA92		2/18/2009	NO	411	383	351	858	I
2/18/2009	LB	3D9.1C2C8571F4		2/18/2009	NO	427	393	360	938	I
2/18/2009	LB	3D9.1C2C7F4C24		2/18/2009	NO	376	349	310	612	I
2/19/2009	OA	3D9.1C2C844813		2/19/2009	NO	464	429	442	1,398	M
2/20/2009	EB	3D9.1C2C8572E3		2/4/2009	YES	602	567	514	2,988	F
2/24/2009	LB	3D9.1C2C840767		2/24/2009	NO	403	388	355	908	I
2/24/2009	LB	3D9.1C2C84505D		2/24/2009	NO	446	416	NR ^h	1,078	I
2/24/2009	LB	3D9.1C2C83BE24		2/24/2009	NO	438	405	377	1,002	I
2/24/2009	LB	5325716B62		3/23/2006	YES	585	538	490	2,180	M
2/24/2009	LB	3D9.1C2C8410E7		2/13/2009	YES	528	482	449	1,588	M
2/25/2009	OA	3D9.1C2C8406B7		2/25/2009	NO	549	508	471	1,888	M
2/25/2009	OA	532576116B		4/1/2008	YES	530	490	450	1,798	F
2/25/2009	OA	5326016E52		4/1/2008	YES	475	440	411	980	M
2/26/2009	EB	3D9.1C2C83BA8C		2/26/2009	NO	662	620	580	3,618	F
2/26/2009	EB	7F7D2B2D5F		4/2/1993	YES	600	554	510	2,600	M
3/3/2009	LB	3D9.1C2C83C624		3/3/2009	NO	748	700	655	4,000	F
3/3/2009	LB	3D9.1C2C840769		3/3/2009	NO	521	484	450	1,828	F
3/3/2009	LB	3D9.1C2C7F48FC		3/3/2009	NO	565	530	492	2,280	F
3/3/2009	LB	3D9.1C2C8409EA		3/3/2009	NO	416	380	348	398	I
3/3/2009	LB	3D9.1C2C841AF7		3/3/2009	NO	340	315	281	498	I
3/3/2009	LB	3D9.1C2C840D21		3/3/2009	NO	431	399	365	952	I
3/3/2009	LB	3D9.1C2C83C157		3/3/2009	NO	419	386	351	828	I
3/3/2009	LB	3D9.1C2C83C69A		3/3/2009	NO	539	494	460	1,684	M
3/3/2009	LB	4514434A10	465	12/3/2008	YES	520	484	445	1,530	F

Table 2. (Cont.)

DATE	CAPTURE LOCATION ^a	PIT TAG NUMBER	SONIC CODE	DATE STOCKED ^b	RECAPTURE	TL ^c (mm)	FL ^d (mm)	SL ^e (mm)	WT ^f (g)	SEX ^g
3/3/2009	LB	3D9.1C2C840767		2/24/2009	YES	403	388	355	908	I
3/3/2009	LB	5324102B1D		2/12/2008	YES	535	498	460	1,528	M
3/3/2009	LB	3D9.1C2C7F49A1		2/17/2009	YES	510	464	431	1,624	M
3/11/2009	OA	3D9.1C2C7EF17C		3/11/2009	NO	585	544	503	1,960	F
3/11/2009	OA	3D9.1C2C840BE3		3/11/2009	NO	552	516	475	1,750	F
3/11/2009	OA	7F7E6A491A		3/26/2008	YES	665	611	570	3,682	F
3/11/2009	OA	532568047C		2/22/2007	YES	540	502	465	1,640	M
3/17/2009	LB	3D9.1C2C7EF14E		3/17/2009	NO	458	427	389	1,076	I
3/17/2009	LB	3D9.1C2C7F4BC3		3/17/2009	NO	421	397	360	824	I
3/17/2009	LB	3D9.1C2C840C27		3/17/2009	NO	440	400	365	962	I
3/17/2009	LB	3D9.1C2C7F4831		3/17/2009	NO	369	344	315	522	I
3/17/2009	LB	3D9.1C2C7F474B		3/17/2009	NO	377	355	325	620	I
3/17/2009	LB	3D9.1C2C83C3C6		3/17/2009	NO	546	501	465	2,042	M
3/17/2009	LB	3D9.1C2C840767		2/24/2009	YES	435	405	370	930	I
3/17/2009	LB	3D9.1C2C83BA92		2/18/2009	YES	420	385	355	826	I
3/17/2009	LB	3D9.1C2C8410E7		2/13/2009	YES	535	480	445	1,566	M
3/24/2009	OA	3D9.1C2C8417FA		3/24/2009	NO	366	335	306	514	I
3/24/2009	OA	3D9.1C2C840D17		3/24/2009	NO	572	531	494	2,130	M
4/6/2009	LB	3D9.1C2C83C3C6		3/17/2009	YES	546	561	465	2,042	M
4/6/2009	LB	53255E1008		3/31/2006	YES	650	605	565	3,628	M
4/6/2009	LB	3D9.1C2C841383		2/13/2009	YES	630	574	551	3,390	M
4/6/2009	LB	45142C6506	377	12/4/2008	YES	NR ^h	NR ^h	NR ^h	NR ^h	M
4/8/2009	OA	3D9.1C2C8416D1		4/8/2009	NO	291	265	239	280	I
4/8/2009	OA	3D9.1C2C836F25		4/8/2009	NO	348	320	292	480	I
4/13/2009	LB	3D9.1C2C844BBD		4/13/2009	NO	510	483	433	1,832	F
4/13/2009	LB	3D9.1C2C83BF75		4/13/2009	NO	451	419	370	1,068	I
4/13/2009	LB	3D9.1C2C84095B		4/13/2009	NO	536	502	447	1,688	M
4/13/2009	LB	3D9.1C2C83BDC4		4/13/2009	NO	578	558	499	2,668	M
4/13/2009	LB	5326000260	447	11/29/2005	YES	642	595	560	3,238	F
4/13/2009	LB	3D9.1C2C7F474B		3/17/2009	YES	377	355	325	620	I
4/13/2009	LB	53256B2638		2/20/2007	YES	570	525	485	1,956	M
4/13/2009	LB	45142C6506	377	12/4/2008	YES	NR ^h	NR ^h	NR ^h	NR ^h	M
4/15/2009	OA	3D9.1C2C83C686		4/15/2009	NO	374	344	306	594	I
4/15/2009	OA	3D9.1C2C844382		4/15/2009	NO	362	325	303	518	I

Table 2. (Cont.)

DATE	CAPTURE LOCATION ^a	PIT TAG NUMBER	SONIC CODE	DATE STOCKED ^b	RECAPTURE	TL ^c (mm)	FL ^d (mm)	SL ^e (mm)	WT ^f (g)	SEX ^g
4/15/2009	OA	3D9.1C2C83CA70		4/15/2009	NO	390	360	330	692	I
4/15/2009	OA	3D9.1C2C840638		4/15/2009	NO	365	335	305	602	I
4/15/2009	OA	3D9.1C2C83BB5F		4/15/2009	NO	386	355	327	674	I
4/15/2009	OA	3D9.1C2C841066		4/15/2009	NO	399	368	335	728	I
4/15/2009	OA	3D9.1C2C845019		4/15/2009	NO	390	360	325	750	I
4/15/2009	OA	3D9.1C2C83C68B		4/15/2009	NO	372	342	312	582	I
4/15/2009	OA	3D9.1C2C840A05		4/15/2009	NO	375	344	315	636	I

^a OA = Overton Arm (Muddy River/Virgin River inflow area), LB = Las Vegas Bay, EB = Echo Bay.

^b Date originally stocked or originally captured.

^c Total length.

^d Fork length.

^e Standard length.

^f Weight.

^g F = female, M = male, I = immature (sex not determined).

^h Not recorded, typically to avoid excessive handling stress.

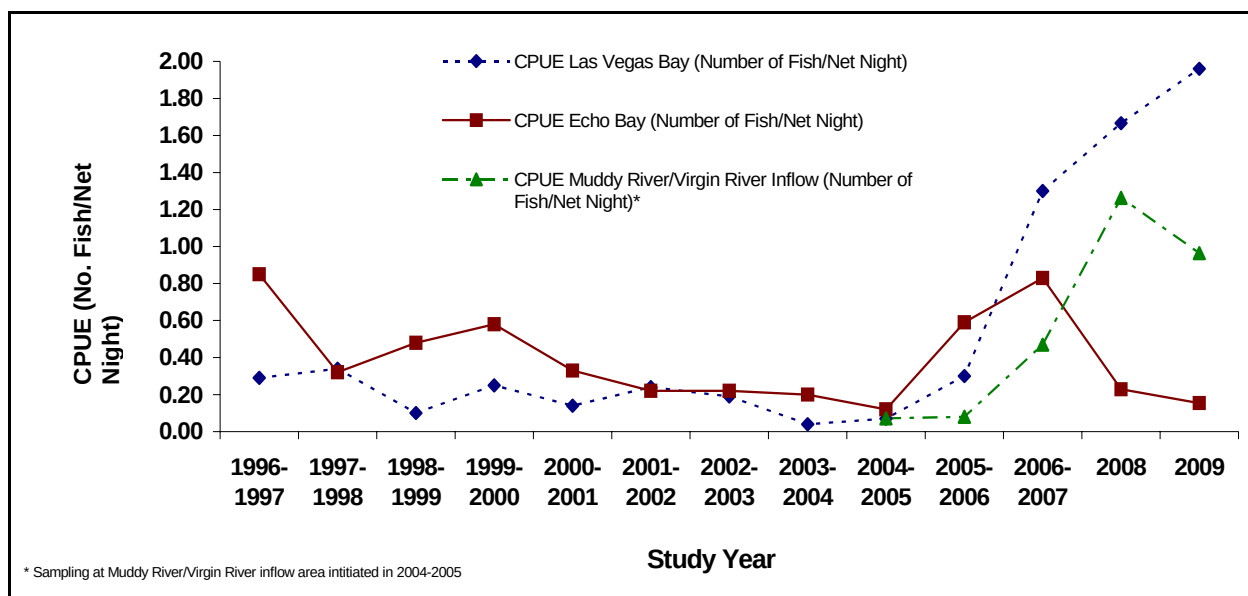


Figure 6. Trammel netting catch per unit effort (CPUE) during studies on Lake Mead razorback sucker, 1996–2009.

Throughout Echo Bay, nets were set with greater emphasis placed on the back portion of the bay in areas where contacts with sonic-tagged fish were concentrated, larval razorback sucker were found in the highest concentrations, and razorback sucker were previously captured (Figure 4). In all, only four adult razorback sucker were captured despite 26 net nights of effort (Table 2). No subadult fish were captured from Echo Bay during the 2009 spawning period. For comparative purposes, during the 2008 spawning period, eight adult razorback sucker were collected. The 2009 spawning season marks the second year in which no subadult razorback sucker was collected in Echo Bay. The 2009 razorback sucker catch rate for trammel netting at Echo Bay was 0.15 fish/net night, which is lower than the rate obtained during the previous study year (0.23 fish/net night) (Figure 6).

The 2009 spawning period was one of the more successful years for capturing razorback sucker at Muddy River/Virgin River inflow area to date (Figure 5). This is the fifth consecutive spawning season in which we have documented successful spawning in this area of Lake Mead. Trammel netting efforts resulted in the capture of 15 adult razorback sucker and 12 subadult fish. Most fish were captured over gravel and small cobble-sized substrates along the eastern shoreline immediately south of the Virgin River inflow/delta. The razorback sucker catch rate for trammel netting at the Muddy River/Virgin River inflow area was 0.96 fish/net night and, for the second consecutive season, catch rates were comparable with those typical of Las Vegas Bay or Echo Bay (2008 = 1.26 fish/net night; 2007 = 0.47 fish/net night; 2006 = 0.8 fish/net night; 2005 = 0.7 fish/net night) (Figure 6).

Some of the more interesting captures in 2009 involved fish that were originally captured within a particular study area and were recaptured this season in a different study area. This movement information further supports the idea that Lake Mead razorback sucker can and do move between spawning sites. As has been expressed in the past, the populations of razorback sucker in Lake Mead are considered small. As with any small population there is often concern for overall genetic health. Even though the populations within Lake Mead act largely as separate populations, this season's netting efforts and recapture information demonstrate that some limited level of population intermixing does occur. This year a wild fish that was originally captured and PIT tagged in the Muddy River/Virgin River inflow area in February 2007 and captured again in April 2008 near the same location was recaptured in Echo Bay in February 2009. As the current adult sampling protocol does not account for all movement of individuals within any given year and only represents a portion of the fishes within a population, we were also fortunate to record movement of a wild fish within a single month. This fish was originally captured in the Muddy River/Virgin River inflow area on February 4, 2009, and recaptured on February 20, 2009, in Echo Bay. These examples demonstrate that movement occurs between spawning locations annually, and that certain individuals can and do move between spawning locations within a single spawning season. As documented by Albrecht et al. (2007, 2008a), this behavior has been observed periodically throughout the course of this study. Furthermore, it is evident that movement occurs not only with stocked razorback sucker, but wild fish also move within and between spawning locations. Movement between Las Vegas Bay and the northern portions of Lake Mead is particularly impressive given the distance and lake bottom topography

that must be negotiated. Albrecht et al. (2007 and 2008a) document a similar trend; however, it should be noted that movement has been observed more readily between Echo Bay and the Muddy River/Virgin River inflow spawning area.

Another interesting find related to trammel netting in 2009 was the exceptionally high number of young, wild, subadult razorback sucker captured. Thirty-five immature individuals were captured from the three primary study areas, which marks the highest catch rates of wild subadult razorback sucker to date. This increased from 2008 in which 27 subadults were captured (Albrecht et al. 2008a). Similar to past findings (Albrecht et al. 2008a) many of these individuals were captured in the same net. Six immature individuals were captured in one net in Las Vegas Bay in March, while eight were captured in one net in the Muddy River/Virgin River inflow area. These capture events demonstrate the following:

- Subadult fish are present on/near spawning habitat during the spawning season and apparently can be found in aggregates or schools with conspecific fish.
- Our ability to capture and document wild subadult fish is rather stochastic and sporadic. Interestingly, an additional 17 subadult fish were captured at Las Vegas Bay during the remainder of the 2008 field season, and 4 more subadult fish were captured in the Muddy River/Virgin River inflow area. The likelihood of capturing young, wild razorback sucker in Lake Mead was also discussed by Albrecht et al. [2006a], who indicated potential difficulties in sampling for this younger portion of the Lake Mead razorback sucker population.).
- Natural recruitment of razorback sucker continues at Lake Mead, despite low and declining lake levels. As more research is conducted in Lake Mead, we are hopeful that components pertaining to continued razorback sucker recruitment events—despite diminished lake levels—will be clarified (a topic discussed in greater depth by Albrecht et al. [2008b] during their comprehensive review of Lake Mead razorback sucker research).

Continuing with the theme of interesting captures, there is an elevated catch rate of razorback sucker once again in Las Vegas Bay, marking the third year in a row for increased catch rates (Figure 6). Nearly 47% of the razorback sucker captured from this area were subadult fish. Similarly, just over 44% of the fish captured in the Muddy River/Virgin River inflow area were subadults, which improves insight into continued natural recruitment during low lake conditions. In all, the 2009 spawning season was a strong year for razorback sucker and unique in terms of overall numbers of subadult fish captured. This follows the trends reported by Albrecht et al. (2007, 2008a).

In summary, 145 unique individual razorback sucker from Echo Bay have been handled during the 13 years of this study, 79 of which were captured and PIT tagged by BIO-WEST personnel, 62 of which were PIT tagged by NDOW, and 4 of which were handled by the USFWS during collaborative efforts with BIO-WEST. At Las Vegas Bay, 258 unique razorback sucker have

been handled, including 134 individuals PIT tagged by BIO-WEST personnel, 117 PIT tagged by NDOW, and 7 PIT tagged by the USFWS. At the Muddy River/Virgin River inflow area, 57 unique razorback sucker have been captured, 56 of which were PIT tagged by BIO-WEST and one of which was PIT tagged by NDOW. Additionally two individuals were caught and tagged by NDOW in Alkali Bay in the Virgin Basin in 2008. Finally, 28 fish have been sonic tagged, PIT tagged, and stocked by BIO-WEST during collaborative research efforts with NDOW. BIO-WEST and NDOW also collaboratively stocked four individual fish into the Colorado River inflow area during the earlier years of this study. Thus, the lake-wide total of unique individual razorback sucker handled during this study is now 490 individuals.

Growth

In all, 28 razorback sucker were recaptured during the 2009 field season: 3 from the Echo Bay area, 19 from the Las Vegas Bay area, and 6 from the Muddy River/Virgin river inflow area. However, annual growth information analyses were only performed using data from seven of these individuals. Reasons for not including all 28 recaptures in this analysis were that some of the fish were captured more than once during the 2009 field season and, in other instances, a full year had not passed between the date of original capture or stocking event and the subsequent recapture. The difference in total length between capture periods was used to determine mean annual growth (Table 3). Interestingly and atypically (compared with past reports), all the recaptured fish for which growth calculations were performed were wild fish. Only two recaptured fish were stocked fish that were sonic tagged in December 2008 and, therefore, they were not included in the growth analysis. The combined, lake-wide, mean annual growth of razorback sucker recaptured from Lake Mead during the 13th study year was 33.7 mm. The combined mean annual growth of recaptured fish during the previous study year was 15.3 mm (Albrecht et al. 2008a). Mean annual growth could not be calculated for Echo Bay because only one fish was captured that could be included in the growth analysis. However, growth for this fish, calculated as mm/365 days, was 1.6 mm. Razorback sucker recaptured at Las Vegas Bay were all wild fish, had a mean annual growth of 42.1 mm, and ranged from 5.0–104.3 mm of growth per year. For the second time we are able to report overall growth of fish recaptured from the Muddy River/Virgin River inflow area. The mean annual growth of fish recaptured there was calculated to be 32.9 mm of growth per year from two wild individuals. This increased from 20.1 mm the previous season (Albrecht et al. 2008a).

In all, and as discussed in past annual reports (e.g., Albrecht et al. 2006b, Albrecht et al. 2007, Albrecht et al. 2008a, Albrecht et al. 2008b), growth rates for Lake Mead razorback sucker continue to be substantially higher than those of other razorback sucker populations, suggesting the overall youthfulness of Lake Mead razorback sucker populations (Modde et al. 1996, Pacey and Marsh 1998, Mueller 2006).

Table 3. Lake Mead recaptured razorback sucker growth histories for fish captured during the 2009 field season.

PIT TAG NUMBER	DATE STOCKED ^a	TL ^b (MM)	LAST DATE RECAPTURED	TL ^b (MM)	TOTAL GROWTH (MM)	DAYS BETWEEN MEASUREMENTS	GROWTH/ YEAR (MM/365 DAYS)
LAS VEGAS BAY							
<u>Wild Fish</u>							
5324102B1D	2/12/2008	425	3/3/2009	535	110	385	104.3
53255E1008	3/31/2006	635	4/6/2009	650	15	1102	5.0
53256B2638	2/20/2007	534	4/13/2009	570	36	783	16.8
5325716B62	3/23/2006	461	2/24/2009	585	124	1069	42.3
Mean annual growth							42.1
ECHO BAY							
<u>Wild Fish</u>							
7F7D2B2D5F	4/2/1993	574	2/26/2009	600	26	5809	1.6
Mean annual growth^c							N/A
OVERTON ARM (MUDDY/VIRGIN RIVER INFLOW AREA)							
<u>Wild Fish</u>							
5326051F79 ^d	2/22/2007	452	2/10/2009	520	68	719	34.5
532568047C	2/22/2007	476	3/11/2009	540	64	748	31.2
Mean annual growth							32.9
Mean annual growth of all Las Vegas Bay, Echo Bay and Overton Arm fish							33.7

^a The date fish were stocked into Lake Mead or, if wild, the date fish were originally captured.

^b Total length.

^c Could not be calculated for one fish.

^d Originally stocked into Echo Bay.

Sonic Telemetry

Including 12 new sonic-tagged fish released in 2008, 74 fish (38 wild and 36 hatchery reared) have been equipped with sonic tags throughout the 13 years of this study. Throughout the 2008–2009 Lake Mead field season, contact was made with 17 sonic-tagged fish. Five of these fish were from the 2005 event in which 10 fish were sonic tagged (Table 4). The other 12 individuals contacted this season were from the December 2008 tagging and stocking effort. As

the 48-month tags implanted in 2005 begin to reach the end of their battery life, it was important to have new sonic-tagged fish established in each of the three primary study areas to replace these individuals.

In all cases, when sonic-tagged fish moved into and used habitats within the riverine portions of Las Vegas Wash, the Muddy River, or the Virgin River, crews recorded the closest data point accessible by boat. As such, some of the figures below may not fully display the range of sonic-tagged fish movements into the shallow, flowing portions, or other habitat features that were not accessible by boat. It is also worth noting that as fish move to shallower habitat they become

Table 4. Tagging and stocking information, location, date of last contact, and current status of sonic-tagged fish in Lake Mead from July 2008–June 2009.

CAPTURE LOCATION ^a	DATE TAGGED	TAG CODE	TOTAL LENGTH (MM)	SEX ^b	STOCKING LOCATION ^a	LAST LOCATION ^a	DATE OF LAST LOCATION	CONTACTS MADE	CURRENT STATUS
Fish Tagged in 2005									
FDLB	11/30/05	445	545	M	LVB	LVB	2/23/09	7	Alive
FDLB	11/30/05	446	616	F	LVB	LVB	4/23/09	11	Alive
FDLB	11/29/05	447	647	F	EB	LVB	12/04/08	6	Alive
FDLB	11/30/05	448	515	M	LVB	LVB	2/17/09	7	Alive
FDLB	11/30/05	555	604	F	LVB	LVB	12/04/08	1	Alive
Fish Tagged in 2008									
FDLB	12/02/08	365	496	M	EB	MR/VR	3/24/09	12	Alive
FDLB	12/02/08	678	492	M	EB	EB	6/22/09	16	Alive
FDLB	12/02/08	3386	493	F	EB	MR/VR	2/03/09	7	Alive
FDLB	12/02/08	376	498	M	EB	MR/VR	4/20/09	11	Alive
FDLB	12/02/08	345	515	M	MR/VR	MR/VR	12/07/08	3	Alive
FDLB	12/02/08	366	479	M	MR/VR	MR/VR	3/10/09	5	Alive
FDLB	12/02/08	488	534	F	MR/VR	MR/VR	6/23/09	19	Alive
FDLB	12/02/08	3354	506	F	MR/VR	MR/VR	2/26/09	12	Alive
FDLB	12/03/08	3355	483	M	LVB	LVB	6/23/09	17	Alive
FDLB	12/03/08	377	479	M	LVB	LVB	6/23/09	17	Alive
FDLB	12/03/08	465	520	F	LVB	LVB	6/23/09	7	Alive
FDLB	12/03/08	677	529	F	LVB	LVB	6/23/09	16	Alive

^a Locations: FDLB = Floyd Lamb State Park, EB = Echo Bay, MR/VR = Muddy River/Virgin River inflow area, LVB = Las Vegas Bay.

^b Sex: F = female, M = male.

hard, if not impossible, to hear. This is perhaps one reason that many of these fish were not located often or have not been located recently. Throughout the year large expanses of very shallow habitat, specifically in Las Vegas Bay and the Muddy River/Virgin River inflow area, formed as the lake level declined. It is believed, based on sonic data described in detail later in this section, that these fish were utilizing this shallow environment and, therefore, limiting our contact ability.

The following dialog describes the history and habitat use of the remaining, active razorback sucker implanted with sonic tags during 2005–2006 field season, and the movements of fish implanted with sonic tags in December 2008. Refer to Table 4 for all origin, tagging, and current status information for sonic-tagged fish, and note that sonic data from July 2008 through June 2009 are presented below in an effort to remain consistent with data reporting procedures for this project.

Fish Sonic Tagged in 2005

Contact was made with the remaining fish sonic tagged in 2005 a total of 32 times during the 13th study year. Of these contacts nearly 69% were in 2008 prior to the spawning period. All remaining sonic-tagged fish from the 2005 tagging event were located in Las Vegas Bay (Table 4). Depths in which these fish were located ranged from 2–74 feet (0.6–22.6 meters) with an average depth of 26.3 feet (8.0 meters). Each of these five fish are still classified as alive and active and, in fact, sonic-tagged fish 446 was recently contacted on April 23, 2009.

Contrastingly, sonic-tagged fish 555 and 447 have not been contacted since December 2008. This could perhaps indicate that these tags have expired or are near expiration with signals too weak to pick up via the hydrophone. Future tracking trips will help determine the status of all the fish sonic tagged in 2005.

Movement of the fish sonic tagged in 2005 was limited to the Las Vegas Bay area during the 2008–2009 study season. Most of these fish showed movement within the bay near Las Vegas Wash (Figure 7). However, of particular interest was the location of sonic-tagged fish 446 on the east side of Sand Island toward Boulder Basin in July 2008. This fish then moved back into the bay near the spawning area. Sonic-tagged fish 445, 447, and 555 were all located at one time utilizing Government Wash. These fish, with the exception of fish 555, also used other areas of the bay including the 2009 spawning area. As mentioned previously, Government Wash was the only location in which fish 555 was located during the 13th study year. Although sonic-tagged fish 446 was located as recently as April 2009, sonic-tagged fish 445 and 448 were last contacted in February 2009.

Another noteworthy contact was made with sonic-tagged fish 448 in the Las Vegas Wash. The fish was located while hiking up the wash into shallow water not accessible by boat. This indicates that fish may be using these shallow waters, thereby limiting our ability to locate them by boat. As mentioned in Albrecht et al. (2007 and 2008a) sonic-tagged fish 447 has shown significant movement between spawning sites since stocking in Echo Bay in 2005. Fish 447

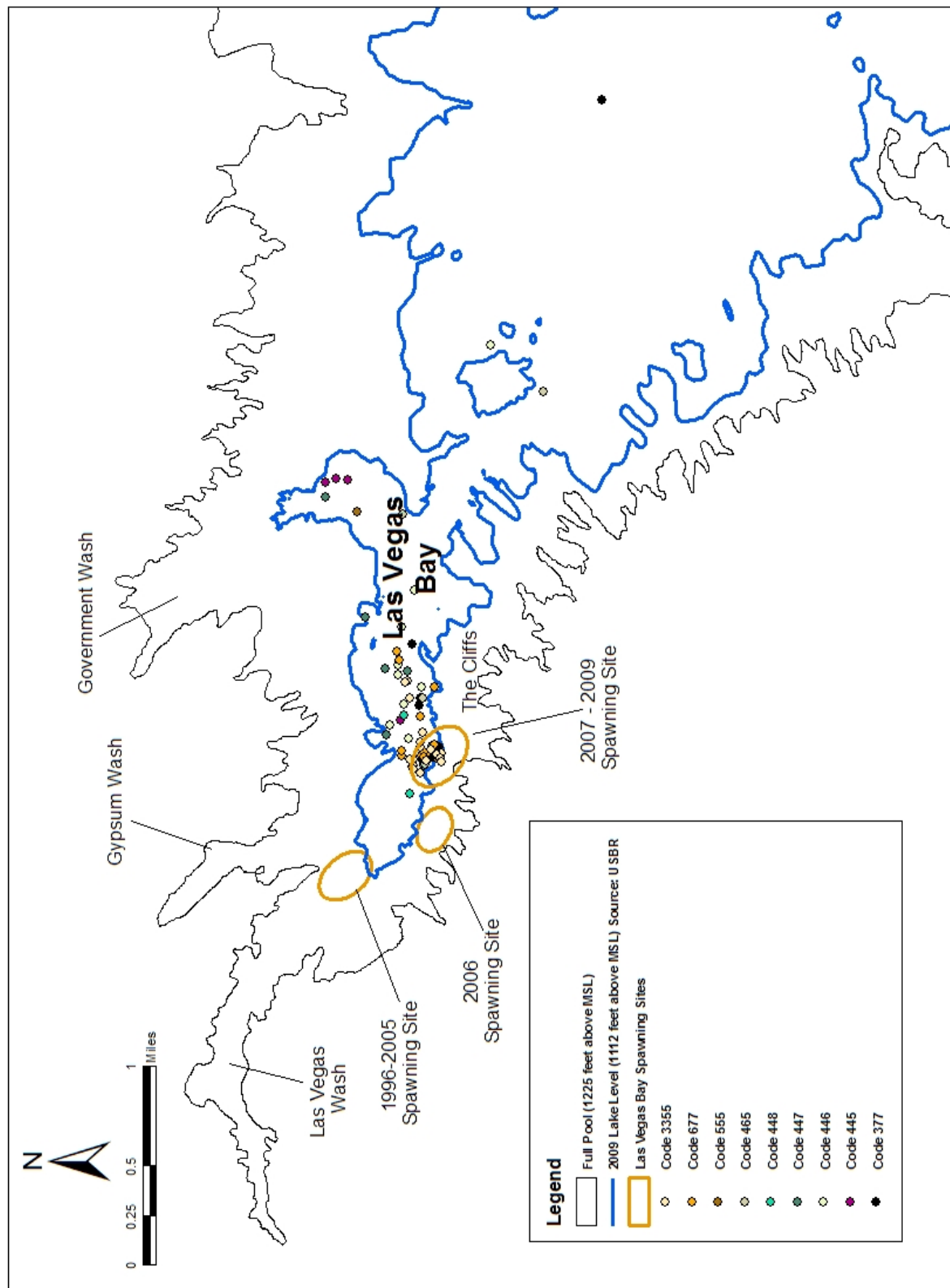


Figure 7. Distribution of sonic-tagged fish located in Las Vegas Bay during the 2008-2009 Lake Mead study season.

remained in Las Vegas Bay for the duration of the 2008–2009 study year; however, due to the relatively short duration of past movement and the frequency of the tracking efforts, it could be possible for fish to move without detection.

Fish Sonic Tagged in 2008

Twelve new sonic-tagged fish were stocked in Lake Mead in December 2008, four at each of the three primary spawning locations. In all, 142 contacts were made with these fish (Table 4). Roughly 33% of these contacts occurred in December 2008 during intensive efforts to track initial movement. These sonic-tagged fish utilized water ranging from 1–198 feet (0.3–60.4 meters) with an average depth of 23.2 feet (7.1 meters). All of these fish are considered alive and active although, like some of the fish tagged in 2005, some of these fish have not been contacted in several months (Table 4). For instance, sonic-tagged fish 345 has not been contacted since December 7, 2008 (5 days after stocking). Although it could be implied that the tag failed early, there are no data to suggest this as two other fish (3386 and 3354) have not been located since February 2009 and all of the fish stocked into Las Vegas Bay were contacted as recently as June 2009. It is more likely that fish 345, as well as others from the 2008 stocking effort, have moved into other areas of the lake, such as the Virgin Basin, that we have not been able to monitor under current study objectives. We are hopeful that these fish will return during the 2010 spawning season, if not sooner. Tracking efforts will continue for these individuals.

All of the fish sonic tagged and stocked in Las Vegas Bay (3355, 677, 465, 377) have remained in the bay during the 13th study year, based on tracking data gathered throughout the season and the recent contact made with all four fish in June 2009 (Table 4, Figure 7). These fish have become a valuable asset to spawning site location and utilization in Las Vegas Bay. Noteworthy contacts were those made with sonic-tagged fish 3355, 377, and 677 in Las Vegas Wash. These fish were at one time utilizing the shallow, flowing portions of the wash, and therefore making it difficult to pinpoint their exact locations.

Somewhat similar to Las Vegas Bay, there was no movement of sonic-tagged fish stocked in the Muddy River/Virgin River inflow area (345, 366, 488, 3354) to any of the other primary study areas in 2009 (Figure 8). All of these fish were stocked on December 2, 2008, and all contacts were made within the Overton Arm of Lake Mead. However, as discussed previously, fish 345 has not been located since shortly after stocking, fish 3354 has not been contacted since February 2009, and fish 366 was last contacted in March 2009. Fish 366 was last located in the Muddy River inflow (Figure 8). This area had to be accessed by jon boat from the Overton boat ramp, and the fish was found in a nonflowing portion where the Muddy River connects to Lake Mead via subsurface flow in less than 2 ft of water. This fish could not be heard from the navigable portions of the Overton Arm.

Unlike the other two study areas, three of the stocked, sonic-tagged fish moved from Echo Bay to the Muddy River/Virgin River inflow area (Table 4, Figure 9). Sonic-tagged fish 365 remained in Echo Bay until March 2009 after initial stocking on December 2, 2008. This same

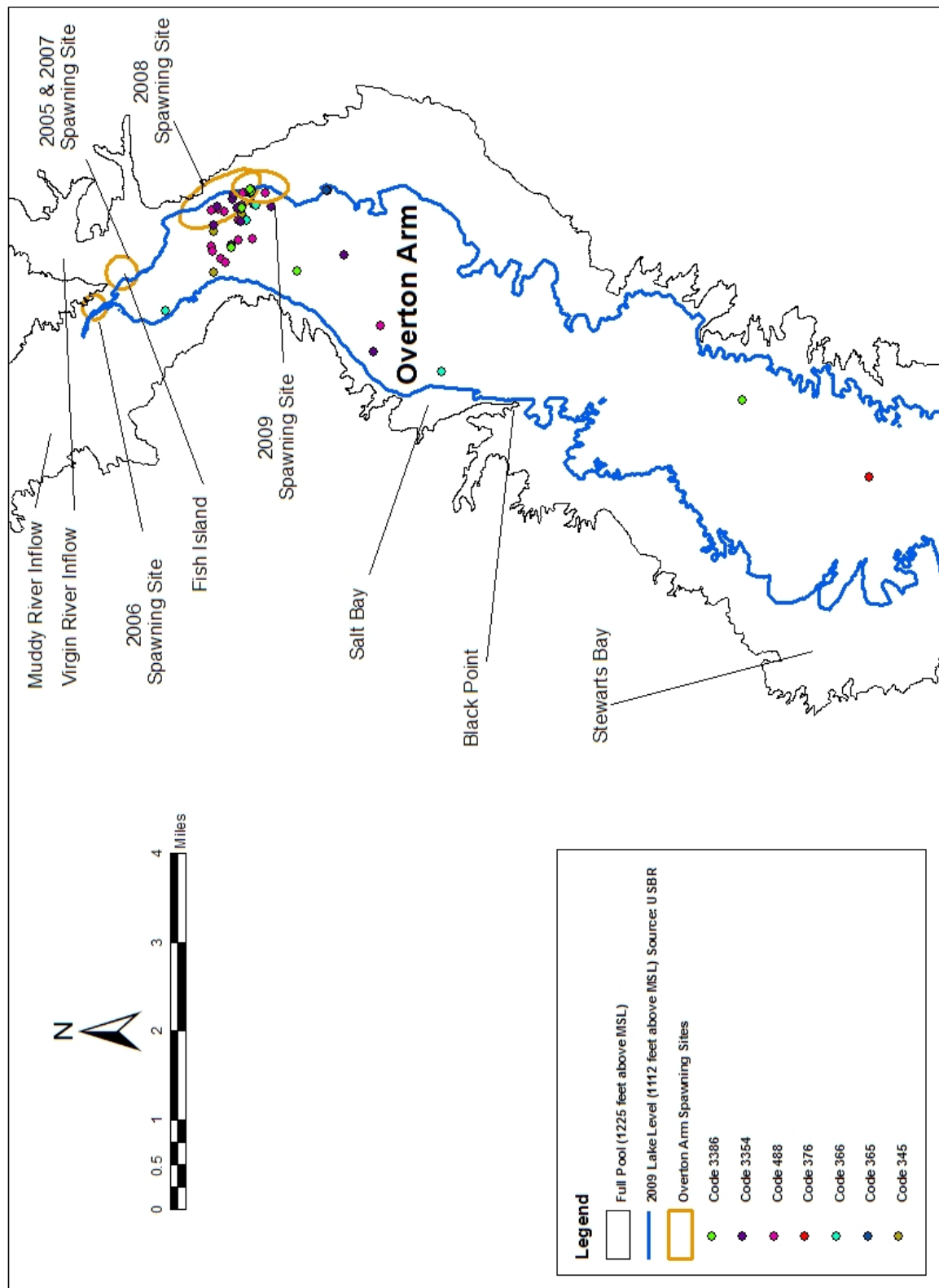


Figure 8. Distribution of sonic-tagged fish located in the Muddy River/Virgin River inflow area during the 2008–2009 Lake Mead study season.

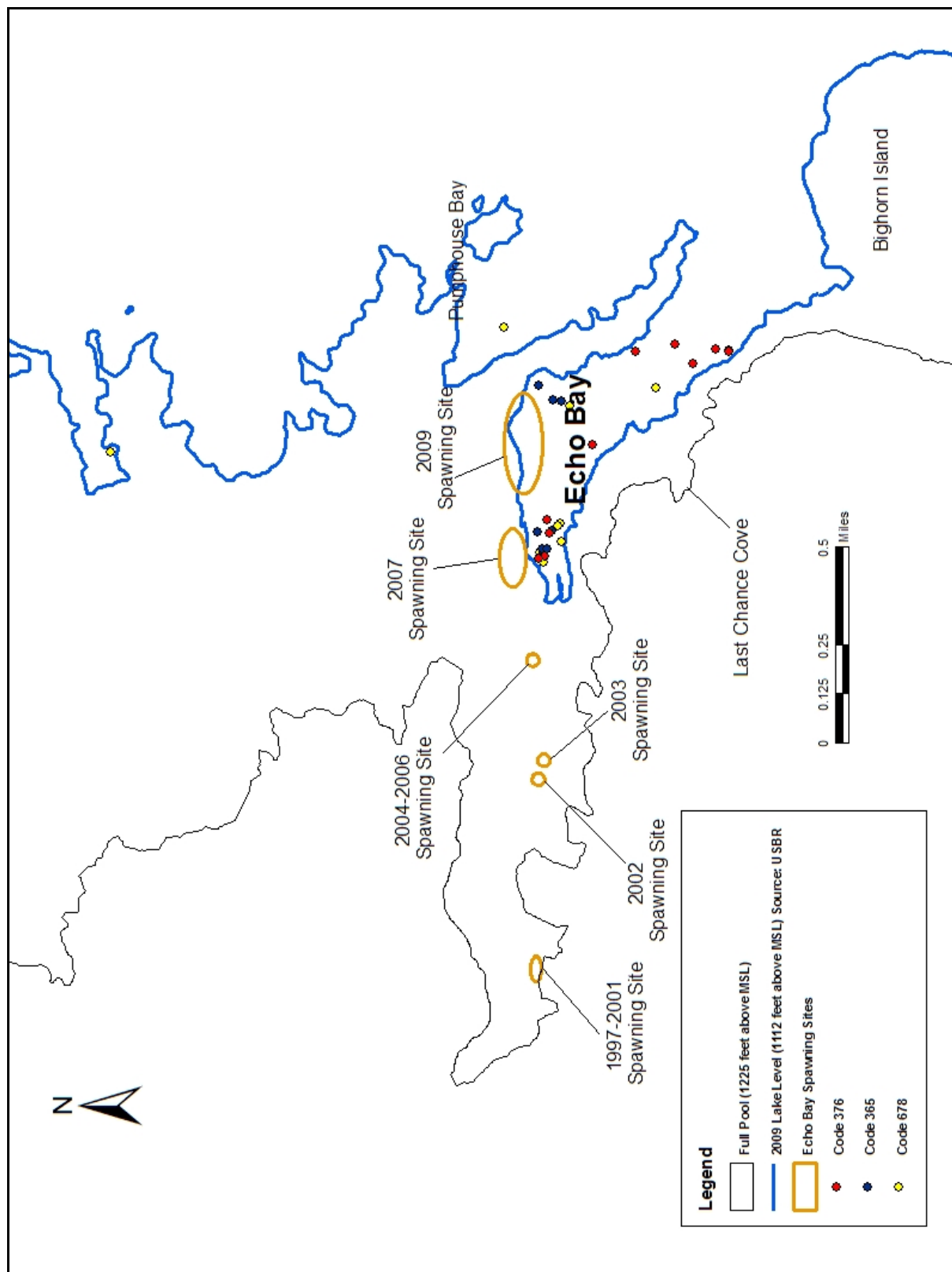


Figure 9. Distribution of sonic-tagged fish located in Echo Bay during the 2008–2009 Lake Mead study season.

fish was located in the Muddy River/Virgin River inflow area south of the 2009 spawning location later that same month, which was the last contact made with this fish (Figures 8 and 9). Sonic-tagged fish 3386 also moved to the Muddy River/Virgin River inflow within just 4 days of being released into Echo Bay. This fish was last contacted in the Muddy River/Virgin River inflow area on February 3, 2009 (Figures 8 and 9). Interesting movement data were collected for fish 376, which was stocked in Echo Bay on December 2, 2008. The fish quickly moved out into the Overton Arm just east of Stewart's Bay, where it was located on December 16, 2008 (Figure 8). This fish was not contacted again until March 19, 2009, in Echo Bay. It remained there until the last contact was made on April 20, 2009 (Figure 9).

Sonic telemetry data within Echo Bay did not coincide with larval and adult capture data for 2009 as denoted by the void of sonic-tagged fish utilizing the 2009 spawning area (Figure 9). Based on the telemetry data, the fish seemed to move around within the bay and out of the bay more than sonic-tagged fish in the other two study areas. In fact, fish 678 was most recently found in June 2009 near Pumphouse Bay just north of Echo Bay.

Larval Sampling

Sampling for razorback sucker larvae was initiated on February 2, 2009. Typically, four to eight monitoring sites at Las Vegas Bay, Echo Bay, and the Muddy River/Virgin River inflow area were sampled weekly (with few exceptions) during February, March, and April 2009. Larvae were first collected on February 4, 2009, at Las Vegas Bay over gravel/small-cobble substrates in a small cove on the southwestern shoreline of Las Vegas Bay. The majority of larvae were collected along this southwestern shoreline of Las Vegas Bay near the Las Vegas Wash inflow, the same area identified as a primary spawning location by Albrecht et al. (2008a). The 2009 data confirm continued use of this new spawning location (Figure 10). Las Vegas Bay yielded a total of 625 larval fish within 1,830 minutes of sampling, providing a catch per minute (CPM) value of 0.342 (Table 5). The trend of CPM of razorback sucker larvae at Las Vegas Bay in recent years is provided in Table 6.

At Echo Bay the first razorback sucker larvae were captured on April 1, 2009, with minimal and sporadic success throughout the rest of the season. Efforts in Echo Bay returned a total of 48 larval fish with a CPM of 0.021 in 2009 (Table 5). The larval fish were found on both the north and south shorelines, within and around the marina infrastructure (Figure 11). The 2009 Echo Bay larval capture rates are shown in relation to recent years in Table 6. Larval captures, although limited, did provide evidence of spawning activity in 2009 in Echo Bay, and a spawning site was identified along the northern shoreline (Figure 11).

At the Muddy River/Virgin River inflow areas, the first razorback sucker larvae for the season were captured on February 24, 2009, at a site approximately 400–500 m south of the Virgin River inflow along the eastern shoreline (Figure 12). No larvae were captured north of Fish Island at the historical spawning site as this area was dry in 2009. Larval captures followed multiple wild subadult and adult razorback sucker captures while trammel netting in the vicinity

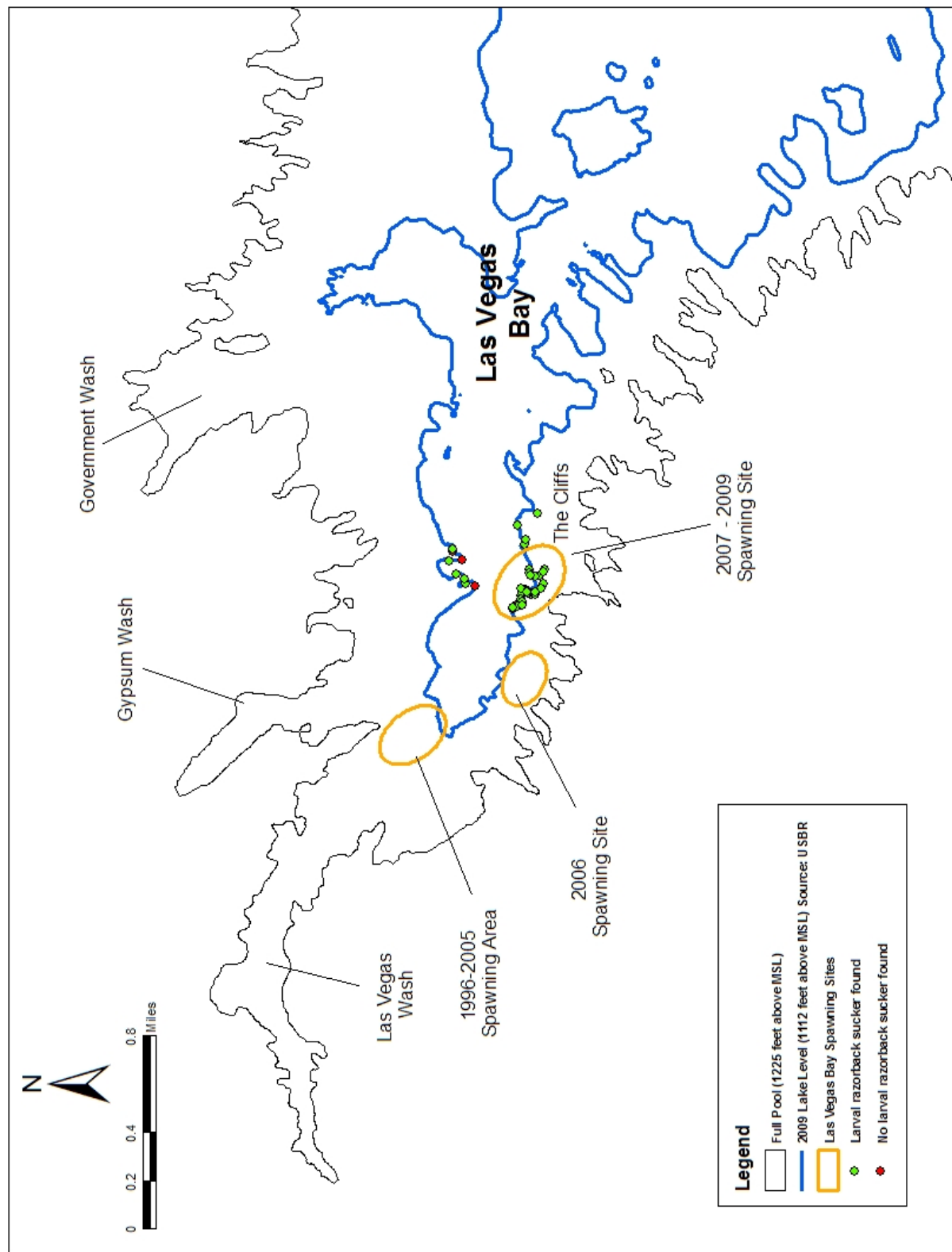


Figure 10. Las Vegas Bay study area showing larval razorback sucker sample and capture locations, 2009.

Table 5. Number of razorback sucker larvae collected at the Las Vegas Bay, Echo Bay, and Muddy River/Virgin River inflow areas of Lake Mead during 2009.

DATE	LAS VEGAS BAY SAMPLING SITES			ECHO BAY SAMPLING SITES			MUDDY RIVER/ VIRGIN RIVER INFLOW SAMPLING SITES		
	Minutes Sampled	Larvae Collected	CPM ^a	Minutes Sampled	Larvae Collected	CPM	Minutes Sampled	Larvae Collected	CPM
2/2/2009				90	0	0.000			
2/3/2009							150	0	0.000
2/4/2009	180	95	0.528						
2/9/2009				120	0	0.000			
2/10/09							180	0	0.000
2/11/09							150	0	0.000
2/12/09	210	46	0.219						
2/16/09	60	6	0.100						
2/17/09	180	67	0.372						
2/18/09							150	0	0.000
2/19/09				180	0	0.000			
2/23/09	180	79	0.439						
2/24/09							180	1	0.006
2/25/09				150	0	0.000			
3/2/09	180	87	0.483						
3/3/09				150	0	0.000			
3/4/09				210	0	0.000			
3/10/09							180	2	0.011
3/11/09				150	0	0.000			
3/12/09	60	1	0.170						
3/13/09	90	0	0.000						
3/17/09	180	138	0.767						
3/18/09							180	2	0.011
3/19/09				150	0	0.000			
3/24/09							180	148	0.822
3/25/09				180	0	0.000			
3/31/09	120	76	0.633						
4/1/09	120	0	0.000	150	27	0.180			
4/6/09	60	5	0.083						
4/7/09				90	0	0.000			
4/8/09				90	1	0.011	120	4	0.033
4/13/09	210	25	0.119						
4/15/09				240	15	0.063			
4/16/09							180	44	0.244
4/20/09							210	6	0.286
4/21/09				240	3	0.017			
4/22/09				120	2	0.017	75	0	0.000
Totals	1,830	625	0.342	2,310	48	0.021	1,935	207	0.107

^a CPM = Catch per minute.

Table 6. Larval razorback sucker catch-per-minute (CPM) comparisons by primary sampling location for 2006–2009.

PRIMARY SAMPLING LOCATION	2006	2007	2008	2009
Las Vegas Bay	0.012	0.390	0.430	0.342
Echo Bay	0.290	0.430	0.024	0.021
Muddy River/Virgin River inflow	0.003	0.001	0.116	0.107

(Table 5 and Figure 12). During the 13th study year, larval captures in the Muddy River/Virgin River inflow area were compared with the majority of previous years. Two hundred-seven larval fish were collected, generating a CPM of 0.107, one of the highest rates observed in this location to date (Tables 5 and 6).

Annual Spawning Site Identification and Observations

Decreasing lake levels during the last 9 years influenced habitat conditions in all areas where razorback sucker sampling activities have occurred during this 13-year study. As of June 1, 2009, the lake elevation was approximately 1,097 ft (334.5 m) amsl, compared with 1,107 ft (337.5 m) amsl recorded the previous year on this same date (Figure 13). As a result of decreasing lake levels, Lake Mead razorback sucker have shifted spawning site locations over the years to accommodate varying conditions.

During the 2005–2006 study year, we observed razorback sucker using a new spawning site in Las Vegas Bay for the first time during our studies (Albrecht et al. 2006b). This was the result of receding lake levels and the dessication of the historical spawning site (Blackbird Point [Albrecht et al. 2006b]). This report documents a continued shift in the primary spawning site of razorback sucker in the Las Vegas Bay/Las Vegas Wash portion of Lake Mead. The primary spawning site during the 2005–2006 field season was located 500 m south of the Las Vegas Wash inflow area, along the southwestern shoreline of Las Vegas Bay (Albrecht et al. 2006b). For the past 3 years the razorback suckers' primary spawning site was in the same general vicinity, shifting with receding water levels further southeast of the 2006 spawning site (Figure 10). Larval razorback sucker were captured in surrounding locations; however, the vast majority of larval captures (over 90%) occurred within the identified primary spawning site (Figure 10). As described in past annual reports (Welker et al. 2003, 2004; Albrecht et al. 2005; Albrecht et al. 2006b), receding lake levels resulted in frequent shifting of the primary Echo Bay spawning site in an eastward (down the bay) direction. Data for this season appear to be consistent with these findings (Figure 11). Although adult trammel net captures were limited, the presence of larval fish late in the spawning season on the north shore eludes to a preferred spawning site. Lower lake elevations have reduced the overall size of Echo Bay, and spawning sites are perceptibly forced to be located more proximal to the main body of Lake Mead. Logically, this serves to push spawning activities closer to the more unprotected portions of Echo Bay, similar to what we observed with the Las Vegas Bay spawning site in 2003, 2004, and 2005. As a

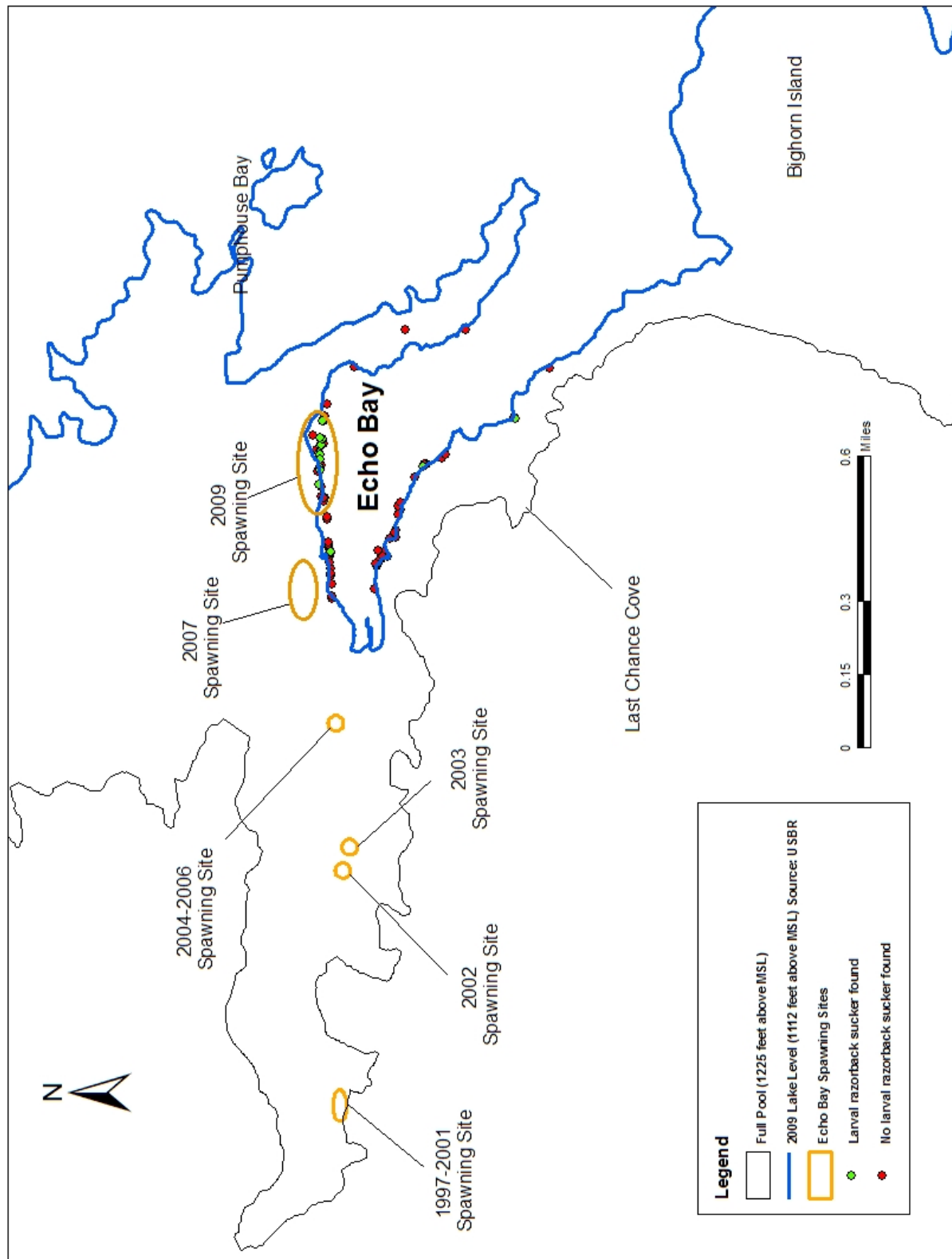


Figure 11. Echo Bay study area showing larval razorback sucker sample and capture locations, 2009.

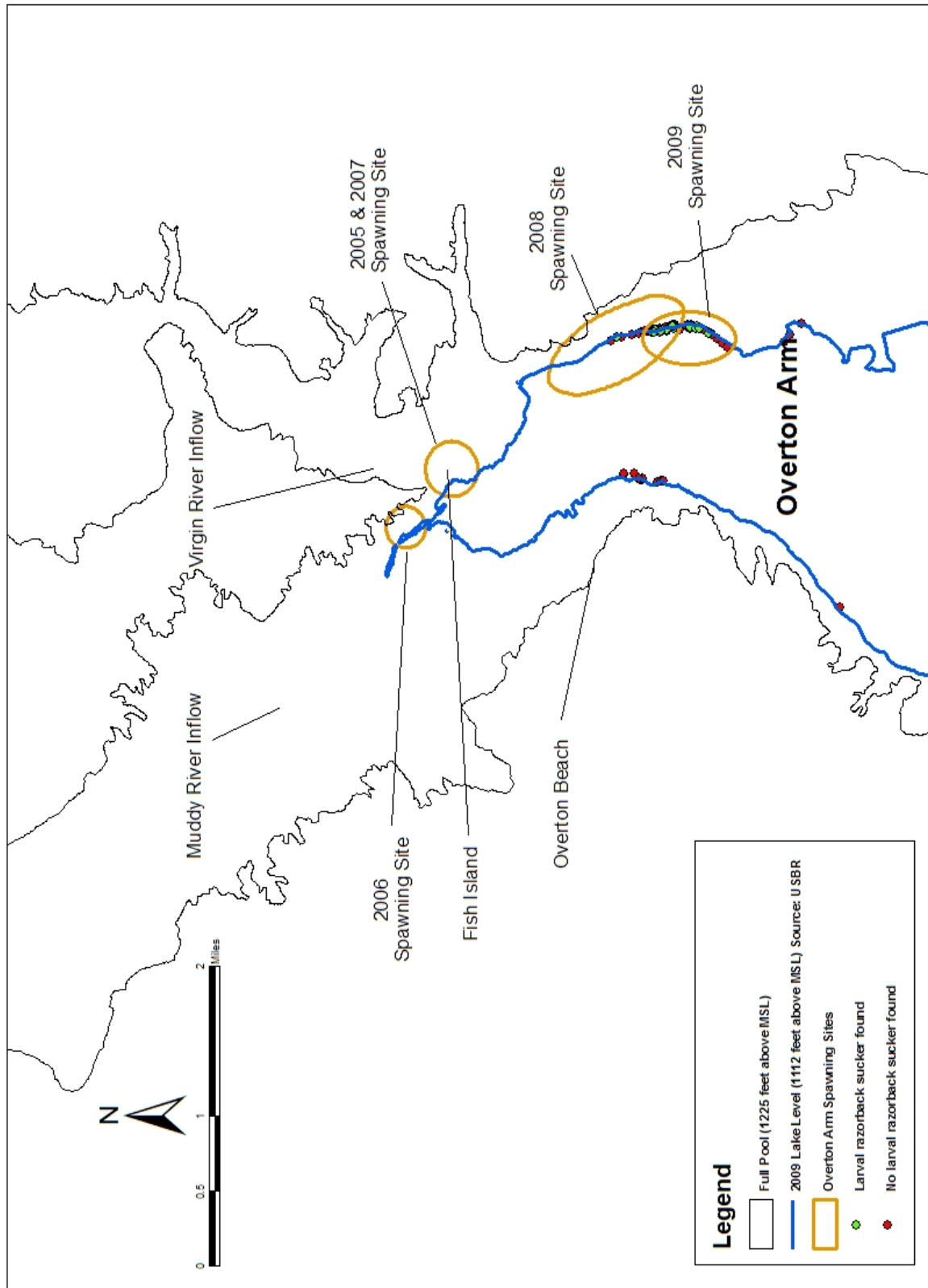


Figure 12. Muddy River/Virgin River inflow area showing larval razorback sucker sample and capture locations, 2009.

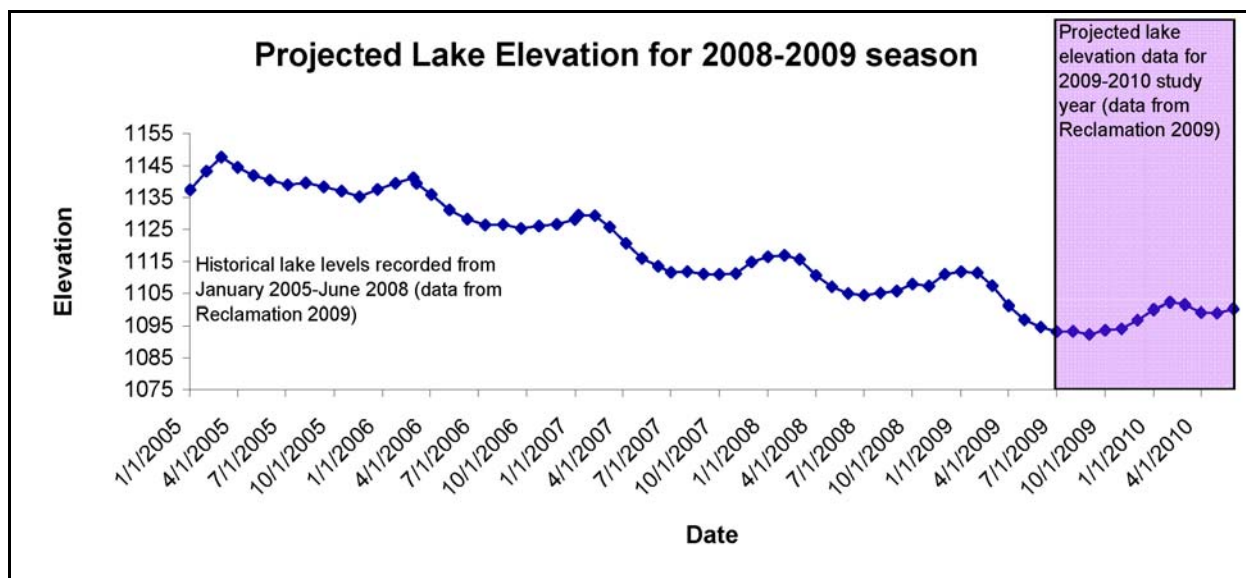


Figure 13. Lake Mead elevations using a combination of actual, recorded, and historical lake elevation data, as well as projected lake elevations for the 2009–2010 study period.

result, any successfully spawned larval razorback sucker are likely to be more exposed to wind and wave action, dispersal forces, and the impacts of nonnative fishes. Given all of the potential stressors to razorback sucker spawning at Echo Bay, we deem it highly important to continue monitoring efforts at this location.

In comparison with Echo Bay and Las Vegas Bay, still relatively little is known regarding the spawning aggregate utilizing the Muddy River/Virgin River inflow area of Lake Mead. Similar to the 2007 and 2008 field season, the collection of ripe adult razorback sucker signified that spawning was likely occurring in this portion of Lake Mead. Furthermore, the capture of 235 larval fish confirmed successful spawning in the northern area of the lake and signifies the highest number of larval fish caught to date in this location. The spawning site in the inflow region of the Muddy and Virgin rivers was approximately 500 m south of the Virgin River inflow on a gravel/cobble bar located along the eastern shoreline (Figure 12). This site was ascertained with a combination of sonic-fish tracking, adult/subadult razorback sucker captures, and the collection of larval fish. This differs considerably from the previous spawning sites established during the 2005, 2006 and 2007 study years, wherein the primary spawning sites were located near Fish Island. Future efforts in this area of Lake Mead are crucial to determine parameters such as changes in the size of the spawning aggregate, changes in spawning sites, and the degree to which successful spawning is occurring in the Muddy River/Virgin River inflow area. An important goal for future monitoring of this area will be to ultimately ascertain if and how recruitment is occurring at this location and to what degree this potential recruitment affects Lake Mead razorback sucker population dynamics.

Razorback Sucker Aging

Fifty-three of the razorback sucker collected by trammel netting on Lake Mead during 2009 sampling efforts had fin-ray sections surgically removed for age determination. A definitive age was obtained for all 53 fish (Appendix I and Figure 14). Thirty-seven of the 53 specimens (69.8%) were 7 years old or less, with the remainder between 8 and 17 years old. Fish from 3 to 8 years old were most common among the specimens obtained this season. The oldest fish determined this year (17 years) was a 655 mm TL male from Las Vegas Bay. The youngest fish aged in 2009 were 3 years old (2006 year class). Only in the last 3 study years have we aged fish that were spawned after 1999, which suggests a continued pattern of recruitment in Lake Mead despite relatively low lake elevations (Albrecht et al. 2006b, Albrecht et al. 2007, Albrecht et al. 2008a).

To date, all of the aged fish were spawned between 1973–2006, with the exception of one fish that was spawned around 1966 (Appendix I). Until the last few seasons, the majority of fish aged were spawned during high lake elevations between the 1978–1989 and 1997–1999 periods (Figure 14). However, our most recent data 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, 2000–2006 appears to be one of the better periods for recruitment, despite dropping lake levels (Figure 14a). In all, it appears that some level of recruitment is possible in Lake Mead regardless of lake level, with natural recruitment occurring nearly every year. This year's aging data validates natural, wild recruitment within the Lake Mead razorback sucker population as recently as 2006. As future monitoring continues, there is no reason to suspect that the trend in continued recruitment will cease, and we anticipate that fish spawned during the 2007–2009 spawning seasons will become susceptible to sampling gear within the next year or so.

Further analysis of recruitment by specific spawning locations revealed that the Las Vegas Bay recruitment pattern is similar to lake-wide recruitment (Figure 14b). This indicates that by the sheer numbers of individuals aged and their range of ages, Las Vegas Bay is largely driving the trends in recruitment indicated throughout the lake. Furthermore, as we look at more recent recruitment (2001–2006), the Muddy River/Virgin River inflow area has contributed substantially to recent recruitment success of Lake Mead razorback sucker (Figure 14c). In contrast, Echo Bay's contribution to overall recruitment is lower, perhaps because the majority of the fish aged from Echo Bay were from the 1980s and 1990s (Figure 14d).

When comparing lake levels to recruitment success by sampling location, both Las Vegas Bay and Echo Bay show signs of increased recruitment success during years of higher or rising lake levels (1982, 1993–1994, 1998) (Figure 14b, d). This also supports the hypothesis that recruitment success is, at least partially, related to the rising lake levels and increased littoral and spawning habitat. As shown by recruitment in the Muddy River/Virgin River inflow area and Las Vegas Bay in the early 2000s, razorback sucker are still recruiting despite declining lake levels (Figure 14b and 14c).

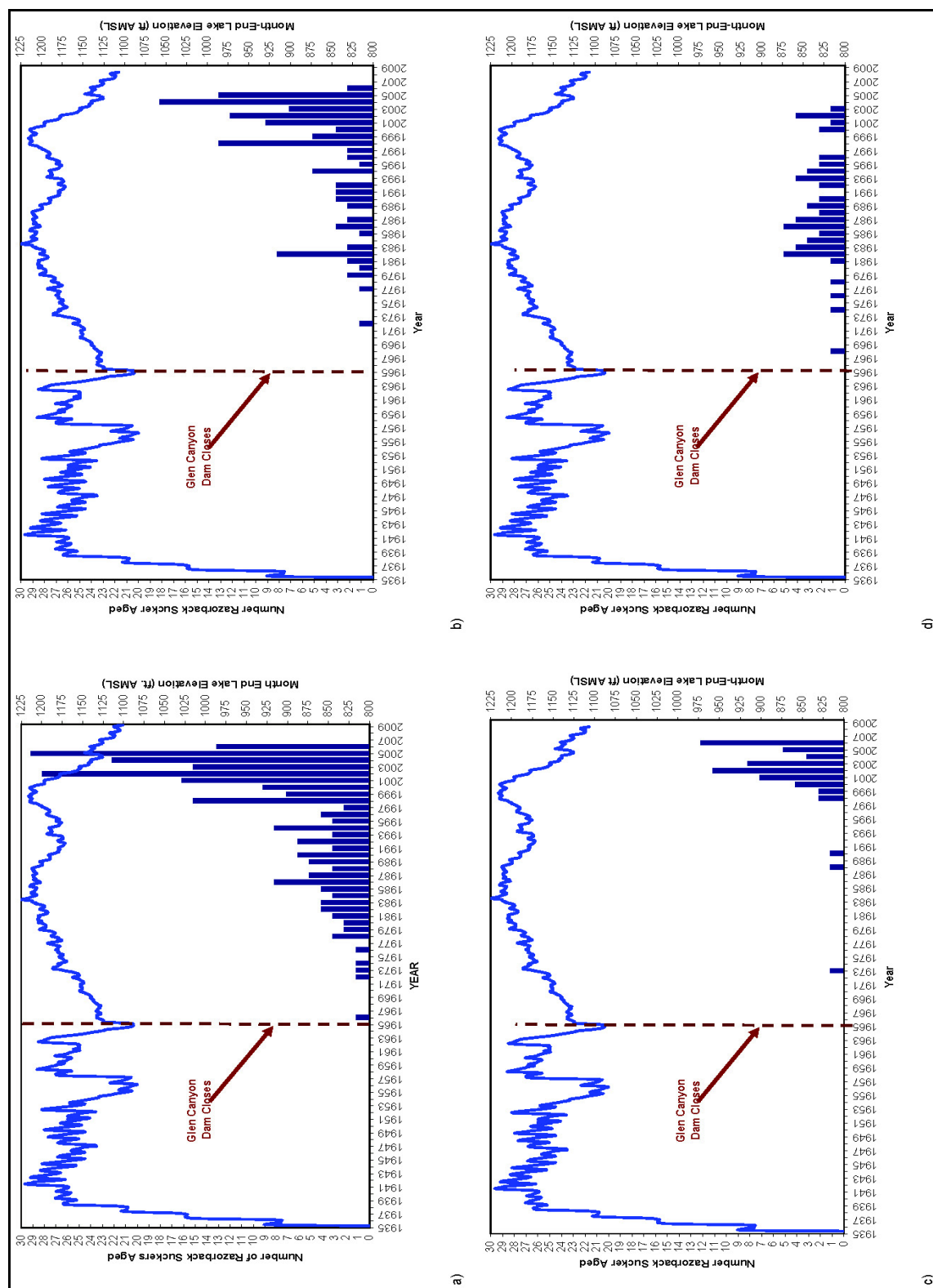


Figure 14. Lake Mead hydrograph from January 1935 to June 2009 with the number of aged razorback sucker that were spawned each year [a] lake wide, b) in Las Vegas Bay, c) in the Muddy River/Virgin River inflow area, d) in Echo Bay].

Population Estimate

Over the past several years there have been numerous occasions in which fish from Echo Bay have moved into the northernmost portions of Lake Mead and vice versa, as reported in Albrecht et al. (2007, 2008a, 2008b), as well as in this report. Hence, we can no longer categorize Echo Bay as a “closed” population, or as one separate from the Muddy River/Virgin River inflow area spawning aggregate. Thus, we provide a population estimate that includes data obtained from Echo Bay and the Muddy River/Virgin River inflow area as a combined estimate. Also, a lake-wide population estimate is given solely for comparative purposes. However, we caution using any of these estimates for management purposes based on the violations of assumptions for closed-model population estimates. Of additional interest, and as described previously in the trammel-netting section of this report, CPUE was elevated this year in Las Vegas Bay. Furthermore, many of the razorback sucker captured at Las Vegas Bay and at the Muddy River/Virgin River inflow area were new captures. This increase in CPUE and the number of newly captured individuals are mentioned here because they also reflect the overall increase in razorback sucker abundance, similar to the increase observed in the population estimates generated this year. Contrastingly, CPUE decreased in Echo Bay and at the Muddy River/Virgin River inflow area, and the number of newly captured individuals from Echo Bay declined compared with previous years. These factors could negatively affect population estimates lakewide and, more specifically, for the northern portion of Lake Mead (Table 7).

The Echo Bay and Muddy River/Virgin River inflow area combined razorback sucker estimates ranged from a low of 177 fish to a high of 538 fish during 2007–2009. The Las Vegas Bay population estimates were lower than those of the northern end of Lake Mead, ranging from a low of 82 to a high of 337 fish. Much like the previous year, there is an apparent increase in the estimates provided because of the relatively large number of young and unmarked fish captured during the 2009 spawning season. The lake-wide population, as predicted, is closely associated with combined estimates for the northern end of the lake and Las Vegas Bay. Estimates ranged from a low of 281 fish to a high of 743 fish.

Overall, population abundance remains highly variable at both study areas as well as lakewide, and patterns are therefore difficult to distinguish. However, given the wide variability of the population estimates provided over the years, perhaps an additional indication of relative population trends on Lake Mead can be gleaned from the annual trammel netting CPUE, which has been expressed as the number of fish collected per net night in our annual reports. Catch per unit effort information is also provided in this report.

DISCUSSION AND CONCLUSIONS

Information collected during the 2009 field season (13th study year) has expanded our knowledge of spawning behavior, habitat use, recruitment patterns, growth, and age of razorback sucker populations in Lake Mead. Additionally, information has been gained regarding age at sexual maturity, the nature of stocked and wild fish interactions, population abundance, and

Table 7. Population estimates using data from 2007–2009.

ESTIMATOR	2007–2009	95% CONFIDENCE INTERVAL
ECHO BAY AND MUDDY RIVER/VIRGIN RIVER INFLOW AREAS		
Model M_0	236	177–339
Chao M_h	315	204–538
<u>Model Selection Procedure</u>		
Jackknife	339	248–483
LAS VEGAS BAY		
Model M_0	104	82–147
Chao M_h	173	105–337
<u>Model Selection Procedure</u>		
Jackknife	189	129–298
LAKE WIDE		
Model M_0	332	281–408
Chao M_h	448	338–632
<u>Model Selection Procedure</u>		
Jackknife	546	417–743

razorback sucker response to declining lake elevations. Sonic telemetry, trammel netting, and larval collection reaffirms the importance of Echo Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area to spawning razorback sucker and subadult fish. Additional data on annual razorback sucker growth confirmed rates documented in previous years. Also, aging data from 53 new razorback sucker collected in 2009 were added to the 186 fish aged from 1998–2008, bringing the total number of aged fish to 239 during the course of our studies and demonstrating continued recruitment as late as the 2006 spawning period.

Sonic Telemetry

Sonic telemetry proved valuable during the 2008–2009 study year. We were able to maintain contact with the majority of sonic-tagged fish throughout the year, including five of the original 10 fish tagged during the 2005–2006 study year and 12 new fish from the December 2008 tagging effort. Considering the amount of time in which the 2005–2006 sonic tags have been implanted and the mobility of razorback sucker, the number of these fish relocated exceeded our original expectations. Along with habitat and movement data, sonic-tagged fish provided crucial information regarding the general location of the razorback sucker population, thus greatly enhancing our ability to catch adults, subadults, and larvae. Additionally, sonic telemetry allowed us to document movements among the spawning areas of Lake Mead (within and between Echo Bay and the Muddy River/Virgin River inflow area). As documented in previous reports (Albrecht et al. 2006b and 2008a), razorback sucker appear to move frequently between Echo Bay and the Muddy River/Virgin River inflow area of Lake Mead.

Throughout the 13th study year, several fish were found in the shallow, flowing portions of inflow areas such as Las Vegas Wash and the Muddy and Virgin Rivers. Understanding how

and when the razorback sucker use these areas will become more important as these inflow areas expand with declining lake levels. These could perhaps be refuge areas and important for razorback sucker survival and recruitment. This reinforces the importance of these inflow areas and further supports our hypothesis of increased turbidity and expanding inflow areas as refuges in the absence of inundated vegetation. Unfortunately, it is difficult to track sonic-tagged fish in these areas using the current sonic telemetry protocol. It is plausible that some of the sonic-tagged fish that have not been located recently could be in these shallow inflow areas and are, therefore, undetectable. Again, it will be important to continue to search for these individuals and it will be interesting to see if they return to their original stocking location and/or join the currently monitored spawning aggregates.

The data stemming from these sonic-tagged fish helped lead to the determination of 2009 spawning sites, new and interesting movement patterns, and valuable information regarding habitat use. In addition to habitat and movement data, sonic-tagged fish played an essential role in helping determine the placement of trammel nets for the successful capture of razorback sucker. As the lake recedes (Figure 13), sonic-tagged fish will continue to provide invaluable data in relation to changes in movement patterns, habitat use, and selected spawning sites.

Larval Sampling

Larval razorback sucker were captured at each of the previously documented spawning sites in Lake Mead (Las Vegas Bay, Echo Bay, and the Muddy River/Virgin River inflow area) during the 2009 spawning season. In terms of numbers of larvae captured, this study year exceeded past years. However, CPM was slightly lower than in 2008 for all study areas (Albrecht et al. 2008a). Larval sampling efforts in Echo Bay resulted in a relatively poor CPM (0.021 fish/min) for this area, which once consistently produced higher numbers of larval razorback sucker. Although catch rates were lower this season, a relatively late spawning event resulted in the capture of 48 larvae in Echo Bay. The Muddy River/Virgin River inflow area continues to be a successful spawning site with larval catch rates similar to those in 2008. This represents the second highest catch rate in this area since 2005.

The reasons for the rather diminished larval razorback sucker catch rates at Echo Bay (compared with previous years') remains unclear at this time. As reported in Albrecht (2008a), two interacting factors may have contributed to an apparent overall lack of habitat use by spawning razorback sucker at Echo Bay: (1) the diminishing lake level and/or (2) marina infrastructure construction and maintenance activities, which were conducted within Echo Bay during the 2008 spawning period. As described in past annual reports, Las Vegas Bay larval catch rates have been low in other years (Welker and Holden 2003, Welker and Holden 2004, Albrecht and Holden 2005). There had been speculation that the diminished larval catch rates at Las Vegas Bay were attributable to changes at the Blackbird Point spawning site. During high water years the Blackbird Point spawning site was relatively accessible yet protected from the open water of Las Vegas Bay and the rest of the lake. Now that lake elevations are lower, this spawning site is less accessible but more open and, therefore, subject to the effects of wind and wave action,

which are thought to disperse newly hatched razorback sucker. This could account for the decline in larval catch rates observed for several years at Las Vegas Bay. Ultimately, the Las Vegas Bay spawning aggregate shifted its primary spawning site to a more sheltered location on the southwestern shoreline, making it easier to catch and observe newly hatched razorback sucker larvae in recent years (Albrecht et al. 2007, Albrecht et al. 2008b). Perhaps a similar situation is occurring at Echo Bay as the lake diminishes and its more sheltered, calmer areas are desiccated. If this scenario is true, spawning is likely occurring closer to the main body of the lake each time the lake recedes, making the Echo Bay larval fish subject to the same wind and wave dispersal agents that were hypothesized to reduce larval catch rates at Las Vegas Bay during past study years. Additionally, it is plausible that Echo Bay marina parking and infrastructure activities disrupted spawning activities or perhaps introduced unsuitable spawning substrate types. Most probable is that the construction factors worked in concert with dropping lake levels to make Echo Bay a less desirable spawning site for razorback sucker in 2008. Monitoring effort this season produced similar results to the 2008 season with no data to suggest that this spawning population drastically shifted locations. One plausible hypothesis would be that fish in Echo Bay would move to the Muddy River/Virgin River inflow area to spawn. Although this has been documented many times in the past, fish stocked or PIT tagged in Echo Bay were not recaptured in the Muddy River/Virgin River inflow area this season.

Larval captures in Las Vegas Bay began earlier in 2009 than in 2008, with the first larval captures occurring in early February. Larval captures in the Muddy River/Virgin River inflow area occurred later in that same month, although the majority of larval fish were captured from late March through April. Although relatively few larval fish were found in Echo Bay, all were found in April. This may be attributed to localized, cooler water temperatures and the dynamics of lake-level fluctuation differences between these study areas. A similar trend was also noted in Albrecht et al. (2006b, 2007, 2008a). Larval catches at Las Vegas Bay appeared to peak during mid to late March, while the Muddy River/Virgin River inflow area catch rates peaked during late March. Echo Bay catch rates did not peak until early to mid April (Table 5). Similar to the past several field seasons, BIO-WEST teamed with biologists from NDOW and Reclamation to collect additional larval razorback sucker for future repatriation efforts. These larval fish are currently being held and reared by NDOW, and BIO-WEST continues to work with NDOW and Reclamation to design experimental stocking procedures and monitoring strategies.

Adult Sampling and Spawning-Related Observations

Perhaps the most interesting conclusion from our combined sampling efforts is that successful spawning and recruitment are still occurring despite continued declines in lake levels and associated habitat changes. In 2009 spawning sites, all primary spawning sites shifted minimally compared with previous years (Albrecht et al. 2006b, 2007, 2008a). We were able to identify a spawning location in Echo Bay, primarily based on larval fish collection data. Throughout recent years the spawning sites in Echo Bay have remained on the north side of the bay and

appeared to follow receding lake levels. Although a significant shift and/or change in location of the spawning site was anticipated in Echo Bay as lake levels receded and spawning habitat diminished, this was not the case in 2009.

Another noteworthy occurrence was the capture of both larval and adult fish on the north shore of Las Vegas Bay (Figures 3 and 10). Since 2006 spawning has primarily occurred at the interface of Las Vegas Wash on the southern shoreline. Although the general spawning site remained along the southwest shoreline in 2009, evidence suggests that spawning individuals are beginning to utilize other areas of the bay. This was evident by the capture of several adults and numerous larval fish along the northern shoreline near the Las Vegas Wash interface and numerous larval captures east of the current spawning site (Figures 3 and 10). As the lake recedes and the gradual slopes of the remaining southern shoreline become exposed, it is presumed that suitable habitat will diminish near the current spawning site. It will be interesting to see whether the razorback sucker will shift spawning sites and move further east or to the northern shore in the future.

Information obtained from past efforts in the northernmost portions of Lake Mead near the Muddy River/Virgin River inflow areas provides fairly sound evidence that this spawning aggregate is an extension of habitat use by what we have termed in past reports as the “Echo Bay spawning population.” Based on data collected since 2005, it appears that the northern Lake Mead razorback sucker population is much more diverse and broader in its use of spawning habitats than previously thought. Similarly, the size of the population in the northern end of Lake Mead appears to be larger than previously reported, and the number of new recruits displayed in this area of the lake is highly interesting and worthy of continued investigation. Data from 2009 concur with Albrecht et al. (2007), suggesting that the spawning aggregates in Echo Bay and the Muddy River/Virgin River inflow area be considered a single population because of the relatively common exchange of fish between these areas. Although there were only two fish in 2009 that were originally PIT tagged in the Muddy River/Virgin River inflow area and captured in Echo Bay, the interaction between these two sites still exists. Likewise, we propose that the broad use of spawning habitats throughout the northern portion of Lake Mead be considered highly important in terms of the overall status of razorback sucker in Lake Mead, suggesting that the total numbers of fish inhabiting the lake are likely higher than previously thought. The results provided herein suggest the highly interactive, dynamic nature of razorback sucker habitat use in the northern portions of Lake Mead. This idea is strengthened by the elevated numbers of fish captured in the northern portions of Lake Mead and at Las Vegas Bay from 2007–2009.

It is important to note that since the conclusion of the 2009 Lake Mead field season, the most recently identified spawning sites at the primary study areas have become desiccated. Continued monitoring of razorback sucker in all three portions of Lake Mead through sonic telemetry, adult netting, and larval sampling will be invaluable in describing future habitat use and determining spawning sites, as well as understanding recruitment patterns. It will be important to find other links to spawning-site preference and recruitment success such as water quality or littoral zone

predator abundance data. Physically, the three primary study areas have changed dramatically over the last 13 seasons. One of these changes is the presence of gizzard shad in Echo Bay and particularly at the Muddy River/Virgin River inflow area, which was documented this season. It will be important to track these physical, chemical, and biological changes over time to better understand and document razorback sucker success.

Lake Mead Recruitment Aspects

The observed increase in razorback sucker in all sampling locations—particularly the continued pulses of new, young, individuals—begs evaluation of the historical, overarching hypothesis describing why and how Lake Mead continues to support the only known, sustainable population of razorback sucker (Albrecht et al. 2006b). In the past, the rare and continued recruitment of Lake Mead razorback sucker has been attributed to a change in the management of Lake Mead, which was thought to be responsible for the apparent, sudden recruitment of razorback sucker. From the 1930s to 1963, Lake Mead was either filling (a time when initial recruitment likely occurred and created the original lake population of razorback sucker) or it was operated with a sizable annual fluctuation. The lake was drawn down approximately 100 feet (30.5 meters) in the mid 1960s as Lake Powell filled, and since that time it has been operated with relatively small annual fluctuations but relatively large multiple-year fluctuations. It has been suspected that the drawdown of Lake Mead (for filling of Lake Powell and a subsequent draw down in the 1990s) allowed terrestrial vegetation to become well established around the lake shoreline. The vegetation was then inundated as the lake rose, but (with small annual fluctuations) the vegetation remained intact for many years and provided cover in coves and other habitat that young razorback sucker may inhabit. Furthermore vegetation, coupled with turbidity (an additional form of cover), near the inflows has resulted in recruitment events. Before 1970 vegetation was unlikely to establish because of the relatively large, annual reservoir fluctuations. The presence of individual razorback sucker older than 30 years indicates that limited recruitment may have occurred during the 1966–1978 period, a time when lake elevations slowly rose to their highest levels (1978–1987) and the maximum amount of intact inundated vegetation probably existed in the lake.

To date much of our hypothesis regarding continued razorback sucker recruitment in Lake Mead has revolved around the presence/absence of vegetative cover. While turbidity was and is recognized as an important form of cover in Lake Mead, slightly less emphasis has been placed on its affect on recruitment. Data collected during recent spawning periods suggest that turbidity may be much more important for razorback sucker recruitment in Lake Mead than previously thought, at least under conditions imposed by low lake level conditions (Albrecht et al. 2008). Until recently, turbidity was deemed important and likely allowed for limited, sporadic recruitment of a few individuals during low-water years; however, in the last three study years, we have noticed a pulse of recruitment that coincides with low water/declining lake conditions. Figure 14 best exemplifies the pulses in recruitment in relation to lake elevation. As shown, 2002 and 2003 have now been identified as strong recruitment years with additional, and now substantial, recruitment continuing in 2004–2006. Given that all of these years were relatively

low, declining lake years, it appears as though turbidity may be much more important for razorback sucker recruitment than we thought. While both turbidity and vegetative cover are likely important, at low water levels, turbidity should be considered highly important; at minimum it is a logical parameter noteworthy of future investigation.

Albrecht et al. (2007, 2008a, 2008b) identified items to evaluate in terms of turbidity and its effects, with questions ranging from fairly simple to complex. For example, have turbidity levels increased in recent years (e.g., years since 1999 when the lake was at/near full pool)? Has there been a recent increase in the productivity of Lake Mead, especially near the known spawning locations? What impacts have lowered lake conditions had on the recruitment and status of littoral predatory fishes? Is it possible that lowered lake conditions have also impacted nonnative fish populations, (such as green sunfish [*Lepomis cyanellus*], bluegill [*Lepomis macrochirus*], and other littoral fishes), and are these data even available for evaluation? Is it possible that larger deltas near the inflows could in fact increase sediment loading and turbidity levels of the lake at lower reservoir elevations? Are there other water quality parameters that may have changed in Lake Mead recently, parameters that might impact early life stage fishes and particularly affect young razorback sucker survival?

One hypothesis explaining the recent pulse in recruitment in Lake Mead is that both low and high lake conditions are conducive to recruitment events. We have already described how recruitment is likely a possibility at high water levels because of the presence of inundated vegetation and turbidity. For example, consider Lake Mohave, where natural razorback sucker recruitment has not been documented. Golden and Holden (2003) have shown that cover, in terms of turbidity and vegetation, is more abundant in Echo Bay and Las Vegas Bay than in other Lake Mead or Lake Mohave coves. Furthermore, it has been accepted for years that turbidity plays a role in the susceptibility of young razorback sucker to predation (Johnson and Hines 1999). This information led to the hypothesis that low, annual fluctuations and large, multiyear lake elevation changes that promote the growth of vegetation around the lake, the inundation of that vegetation, and turbid conditions (compared with other lower Colorado River locations) are likely major reasons for razorback sucker recruitment in Lake Mead. Until now the majority of data collected using aging techniques demonstrated that most of the recruitment on Lake Mead seemed to coincide with high lake elevations, although a few limited, sporadic recruitment events occurred at low lake elevations. Thus the focus of our attention has been on recruitment events that happened to align with high lake levels. However, in light of the data collected in recent years, it is apparent that recruitment pulses can and do occur at lowered lake conditions, when vast expanses of vegetative cover may not be readily available. Given this, we hypothesize that turbidity may be an important driving factor allowing for recruitment under low lake level conditions on Lake Mead. It seems logical that the deltas associated with the various inflows in Lake Mead begin to expand during low water years, and riverine as well as wave action on the exposed sediment of the deltas could contribute to increased cover in the form of turbidity, either directly (by deposition of smaller suspended particles) or indirectly (through increased nutrient loading). In fact, we have observed this during the course of our studies. As the deltas expand because of the dropping lake levels, coupled with the hydrological forces of

flowing water at the inflows, more and more sediment could become subject to the effects of erosion. As stated previously, this may in turn increase the amount of sediment (turbidity) that enters Lake Mead at the inflows and effectively provides a form of cover for early life stages of razorback sucker. Hence cover in the form of turbidity increases, ultimately leading to increased recruitment. Since data obtained in 2007–2009 show that pulses in razorback sucker recruitment are possible at both low (e.g., 2002–2003) and high lake elevations (e.g., 1985–1978 or 1998–1999), cover in the form of turbidity and/or vegetation, similar to that found on Lake Mead, is a potential key to understanding and enabling the sustainability of the species basin wide. Therefore, we recommend that the interactions of these types of cover be explored in greater detail. Albrecht et al. (2008b) provides recommendations to this end.

Growth and Aging

Growth rates of recaptured Lake Mead razorback sucker continue to surpass those recorded for other wild razorback sucker populations. Mean annual growth for Lake Mead fish recaptured in 2009 was 33.7 mm, compared with very low growth (less than 2.0 mm per year) for razorback sucker in Lake Mohave (Pacey and Marsh 1998) and the Green River (McAda and Wydoski 1980, Tyus 1987). It should be noted that the calculated growth rate for Lake Mead razorback sucker in 2009 was based on wild fish recaptures as no stocked fish were recaptured for analysis. It is assumed that these growth rates would be greater than growth rates of stocked fish due to better foraging abilities. As indicated in Mueller (2006) and our past annual reports, these elevated growth rates indicate that Lake Mead razorback sucker populations are relatively young. As seen in 2009, of the fish aged, the 2005 and 2006 year classes (age 4 and 3 respectively) were the top two year classes in terms of numbers of individuals aged. These data are indicative of a healthy recruiting population, and the elevated numbers of young, quick-growing fish are likely driving the relatively high growth rates. As an increasing amount of young fish (< 7 years old) are captured and tagged, we remain hopeful that additional data will be provided that will enable us to understand and promote this relatively unknown life stage of razorback sucker in other locations.

Ages of the 53 fish evaluated during the 2009 study year and the 186 previously aged fish helped identify that recruitment occurred fairly regularly from 1974–2006. The greatest recruitment occurred during 2001–2006, with a total of 126 razorback sucker resulting from those spawning events alone. Nearly 70% of the fish aged from the most recent study year were less than 7 years old, indicating a strong recruitment trend in recent years. This strong pulse of young fish indicates that successful spawning and recruitment are indeed occurring at low lake levels, which has necessitated a reformation of our original hypothesis concerning factors that may result in successful recruitment of razorback sucker. This was discussed in Albrecht et al. (2008a, 2008b) in further detail. Despite unknown variables, the bottom line is that we are seeing sustained, if not increasing, recruitment of razorback sucker on Lake Mead.

Population Estimates

The population estimates for razorback sucker populations in Lake Mead generated from data collected during the 2007–2009 study years have increased in comparison with estimates from past study years. This same increase is also apparent in the recent trammel-netting CPM values in Las Vegas Bay. Again, we caution that direct management decisions and actions should not be solely based on these population estimates, which likely underestimate the Lake Mead razorback sucker population. Albrecht et al. (2008b) provide a more exhaustive discussion of the factors that potentially influence the annual population estimates of Lake Mead razorback sucker. Although these data may be somewhat subjective, the analysis allows for annual comparisons of the overall status of the razorback sucker in Lake Mead. Future study years will undoubtedly reveal more information regarding the population dynamics and trends of razorback sucker in Lake Mead, specifically in respect to the parameters that are currently driving the recent trends of increased recruitment.

As shown in Figure 6, CPM was again higher this season in Las Vegas Bay compared with past study years. Catch rates in the Muddy River/Virgin River inflow area were also higher than in most years with the exception of 2008. Coupled with the large number of new and young fish captured this season, it appears that Lake Mead razorback sucker are still undergoing, or have undergone, a pulse in recruitment, thereby increasing the number of razorback sucker in Lake Mead and in turn boosting our capture numbers. As discussed in Albrecht et al. (2008a), it is also possible that recent low lake elevations may have concentrated fish; hence we were able to more effectively sample and capture fish during the spawning season. This may not be the case in Echo Bay, where CPM was again much lower this season compared with previous years. Extraneous influences within Echo Bay as discussed in Albrecht et al. (2008a), such as construction and associated habitat alterations or the overall loss of habitat from lower lake levels, may have influenced the lower catch rate observed in 2008 and 2009.

Unfortunately, it is too soon to tell what has caused the increase in captured razorback sucker this year. Regardless of whether a recruitment pulse has occurred or our previous efforts to catch razorback sucker in Lake Mead were less effective during higher lake levels (e.g., inability to capture a substantial number of individuals comprising a given population), these results are a positive indication of the unique ability of Lake Mead razorback sucker to maintain what appears to be a sustainable, and perhaps growing, population despite pressures imposed by nonnative fishes and ever-changing lake conditions. Future monitoring and research efforts on Lake Mead should help us understand the increase in numbers of new and young fish captured in 2009.

Conclusion

After discovering the diminished catch rates and spawning activity in Echo Bay in 2008, it was unclear how this would effect the overall population of razorback sucker in Lake Mead. Although success was limited in Echo Bay this season, there was sufficient evidence for continued use of this area as a spawning site. As a result of strong catch rates and the capture of

an abundance of young fish at the other spawning sites, we remain optimistic about the status of the Lake Mead razorback sucker. When information on growth, age structure, and population estimates are considered in concert, the information suggests a generally young, growing, and self-sustaining population. This alone demonstrates the uniqueness of the Lake Mead razorback sucker population and provides one of the few positive stories for a rare species. As such, Lake Mead provides an unequalled opportunity to discover how to promote this unique trend in other locations throughout the Colorado River Basin; hence we reiterate the need for future research to understand how and why razorback sucker are able to maintain themselves naturally despite fluctuating habitat conditions. Finally, given the results and discussion of this year's efforts on Lake Mead, particularly the observation of continued pulses in razorback sucker recruitment in spite of lowered lake conditions, we reiterate and support any and all efforts to address the remaining recommendations posed by Albrecht et al. (2008b) during their comprehensive review of Lake Mead razorback sucker investigations.

2009–2010 RECOMMENDED WORK PLAN

Specific Objectives for the 14th Study Year

1. Continue historical data collection, including tracking efforts associated with the remaining active, sonic-tagged Floyd Lamb State Park razorback sucker in hopes of: (1) following spawning populations at the known spawning sites in order to evaluate whether any further shifts in spawning site selection occur; (2) further investigating the relatively new Muddy River/Virgin River inflow area spawning site to evaluate and understand habitat use in this area of Lake Mead; and (3) potentially identifying other, new spawning sites as dictated by tracking sonic-tagged fish. Continued monitoring efforts will also include larval sampling, adult trammel netting, and fin-ray collection and aging techniques, with particular emphasis on PIT-tagging and aging subadult and adult razorback sucker. Data stemming from continued monitoring will further assist with understanding the size and habitat use of the populations of razorback sucker in Lake Mead, help document the exchange of fish between the Muddy River/Virgin River inflow area spawning site and the Echo Bay spawning site, identify problems or habitat shifts associated with the known spawning aggregates (e.g., Echo Bay), and elucidate recruitment patterns in Lake Mead. Continued monitoring will also help determine whether the new spawning aggregate forming in the Muddy River/Virgin River inflow area is sustaining and whether this aggregate is largely comprised of Echo Bay fish next season. Methods will follow those outlined in Albrecht et al. (2006a), updated in Albrecht et al. (2007, 2008a), and reviewed by Albrecht et al. (2008b).
2. Lend support to organize and construct a formal, written, management plan for Lake Mead razorback sucker with the goal of developing this plan for the conservation of the species and contribute to the overall recovery of the species. The framework established for this management plan will be fleshed out to provide a written narrative of each of the tasks and facilities pertinent to Lake Mead razorback sucker and how each task/facility

interacts from a management perspective (i.e., Lake Mead Hatchery and Overton grow-out ponds). In the end, this document will provide guidance on how to manage Lake Mead razorback sucker in an efficient and effective manner, and will provide an active, driving document not only for the newly formed Lake Mead Interagency Working Group, but will allow for the ability to take the lessons learned on Lake Mead to other groups and locations within the Colorado River Basin. In short, this effort will also help the Lower Colorado River Multi-Species Conservation Program to more easily achieve their overall goals and objectives as related to razorback sucker.

3. Initiate efforts in the Colorado River inflow area of Lake Mead. Renewed efforts in the Colorado River inflow area may clearly answer the question of whether an additional spawning population exists within Lake Mead. We propose that this effort be initiated with a consolidated sonic-telemetry effort and larval sampling. This step will help determine whether trammel netting and aging techniques are warranted in that portion of Lake Mead. Such information could be exceptionally important in the future, particularly if repatriation efforts or future stocking events occur. In addition to the potential to provide a greater understanding of habitat use and movement patterns within Lake Mead, future sampling of a potential population at that location could provide additional information regarding the recruitment patterns of Lake Mead razorback sucker and would undoubtedly illuminate conditions that are conducive to these unique recruitment events. Furthermore, a Colorado River inflow-specific sonic-tagging effort would allow us to assess whether trammel netting is warranted, thereby capitalizing on the same suite of methodologies that allowed us to identify the Muddy River/Virgin River inflow area spawning aggregate. These efforts would enable and facilitate identifying whether an unknown, understudied population of razorback sucker exists in Lake Mead. Sonic-tagging efforts are a critical first step in determining whether additional monitoring and/or research actions would be beneficial at the Colorado River inflow. Identification of a “new” spawning population would be highly important for the Lake Mead Interagency Working Group to know at this juncture, particularly given the potential and additional age-related data that would help clarify and strengthen our abilities to determine the conditions involved in razorback sucker recruitment on Lake Mead. This would also help inform the group of a current or pre-existing razorback sucker spawning aggregate at the Colorado River inflow area prior to any stocking-related and/or research activities. Additionally, larval sampling of the Colorado River inflow area would add information on potential existing spawning aggregates, much as it did in 2000 and 2001.

We recommend releasing captive, pond-reared, sonic-tagged razorback sucker into the Colorado River inflow area and monitoring these fish by using a sampling protocol and suite of methodologies similar to those currently employed at Echo Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area. This proposed effort would involve surgically implanting razorback sucker with sonic tags, releasing tagged fish at the Colorado River inflow and tracking these fish using sonic-telemetry techniques. This effort would run simultaneously to and in conjunction with the currently funded

monitoring activities at known spawning sites and, therefore, would require an additional funding and/or agency cooperation to follow-up with the newly implanted, sonic-tagged fish. Larval sampling would follow up on locating sonic-tagged fish as verification of spawning activity. Once spawning sites are verified and located, trammel netting would occur, similar to the protocol established for the areas currently monitored on Lake Mead.

4. The need still exists to investigate what is currently available and what has already been accomplished pertaining to Lake Mead with regards to physical and limnological data collections (Albrecht et al. 2008b). To this end, a literature and data review with the objective of gathering and interpreting existing information is preferable to rashly designing a study to look at these factors. We believe that such a review has not been accomplished to date, with the exception of the work done by Golden and Holden (2001, 2002, and 2003), and particularly from a razorback sucker recruitment standpoint. Hence, to streamline and develop a study geared towards investing why and how Lake Mead razorback sucker are able to consistently recruit despite the presence of nonnative, predacious fish, a water-quality literature review is necessary. Ultimately, this review would enable us to develop a water-quality monitoring study design from a Lake Mead razorback sucker perspective that could be combined with current monitoring to determine potential causative factors that are driving this unique recruitment. We anticipate that the report generated from this effort would lay the cornerstone for developing and implementing a study design to help answer why Lake Mead razorback sucker are able to recruit given the state of their environment.

The U.S. Geological Survey and other agencies have monitored and continue to monitor water quality at several locations within Lake Mead; these data would likely be of aide in understanding the relationship between age-based recruitment data collected during the past decade and changes in historical Lake Mead water-quality parameters. However, it should be noted that current water-quality studies do not focus on specific locations of interest with regard to the existing razorback sucker spawning areas within Lake Mead. The continued collection of water-quality data by other groups could, however, potentially be used in conjunction with future spawning site-specific water-quality data to establish trends, place trends in context with past collections, and help establish potential links between future spawning site-specific water-quality data and data collected by other groups from different locations within Lake Mead. The SNWA has applied for a grant for this work and will seek additional funding with the Lake Mead Razorback Sucker Workgroup if the grant is not funded.

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