RECLAMATION

Managing Water in the West

Razorback Sucker Studies on Lake Mead, Nevada and Arizona 2007-2008 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 Southern Nevada Water Authority (SNWA), developed the study design and had primary responsibility for conducting the study. The NDOW provided equipment, technical support, and field support for the project. Other agencies that joined as cooperators at the beginning of the study include: the Bureau of Reclamation (Reclamation), which provided funding for equipment, storage facilities, and technical support; the National Park Service, which provided residence facilities in their campgrounds; and the U.S. Fish and Wildlife Service, which assisted with permitting issues. This report provides information and observations from the 12th (2007–2008) monitoring season.

During the 12th study year the habitat use and movements of seven sonic-tagged fish were monitored and provided a total of 63 separate location points. One of the fish was a residual tagged fish (code 222) from the 2004–2005 tagging event, while the remaining six fish were the result of the 2005–2006 tagging efforts. 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 at the primary study areas within Lake Mead. Along with spawning location information, sonic-tagged fish provided valuable data on movement patterns within Las Vegas Bay and Echo Bay. Sonic-tagged fish continue to provide invaluable data regarding the movement patterns and habitat use of razorback sucker in Lake Mead. We expect that the active sonic tags will expire in the next few months, so it will be important to implant and release a new cohort of sonic-tagged razorback sucker prior to the 2009 spawning period. This will allow for continued, efficient monitoring of Lake Mead razorback suckers for the next several years.

Trammel netting for juvenile/subadult and adult fish during the spawning period continued, and 72 razorback sucker—including 40 from Las Vegas Bay, 8 from Echo Bay, and 24 from the Muddy River/Virgin River inflow area—were captured. Interestingly, 27 of the razorback sucker collected (20 from Las Vegas Bay, 0 from Echo Bay, and 7 from the Muddy River/Virgin River inflow area) were subadult fish ("subadult" has been defined in our reports as razorback sucker greater than 300 mm in total length, yet sexually immature). Two juvenile fish from the Muddy River/Virgin River inflow area were less than 300 mm total length and represent the smallest specimens captured to date. Of the 72 total razorback sucker collected, 21 were recaptures; this recapture rate is slightly lower than the ranges reported for previous years.

In addition to the capture of 24 razorback sucker at the Muddy River/Virgin River inflow area, and the elevated numbers of subadult fish captured in 2008, another highlight of the 12th field season was the capture of 63 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. The information

obtained from trammel netting and larval sampling suggests that the Muddy River/Virgin River inflow area of Lake Mead continues to be an important area 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 15 recaptured fish, was 15.3 mm. Mean annual growth was 20.6 mm for Las Vegas Bay fish, while Echo Bay fish displayed near zero growth. Growth rates from fish captured near the Muddy River/Virgin River inflow were calculated for the first time this year, with the mean annual growth calculated at 20.1 mm per year. 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 fish.

Fin ray sections were removed from 54 razorback sucker for age determination during the 12th study year which, when combined with the 132 fish aged during previous study years, brings the total number of fish aged during the study to 186. Of particular interest is the 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 in 2007 and 2008 we have observed strong pulses in recruitment that coincided 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. We recommend initiating an investigation of the factors enabling recent pulses in recruitment, despite lowered lake elevations.

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 2007–2008 study year marks the third consecutive documentation of the Las Vegas Bay population spawning at a location other than its historical Blackbird Point spawning site. Spawning again occurred along the southwestern shoreline of Las Vegas Bay, as indicated by large numbers of juvenile/subadult and adult captures, relatively abundant larval densities, and heavy utilization of these habitats by residual sonic-tagged fish along this particular shoreline. It

appears that the Las Vegas Bay razorback sucker population is able to shift spawning locations as needed to cope with reservoir elevation fluctuations, similar to observations of the spawning plasticity displayed by the Echo Bay population during the majority of past study years. How this shift in spawning habitat use at Las Vegas Bay relates to future year-class recruitment remains to be seen, particularly given ever-changing habitat conditions, introductions of new nonnative species (e.g., quagga mussels, gizzard shad), and other biotic and abiotic stressors to the Lake Mead Razorback sucker population.

Similarly, during the last four spawning periods (2002–2005) at Echo Bay, the spawning site used the previous year was dry because of declining lake levels; however, each year this population found other suitable spawning sites in other portions of Echo Bay. We were unable to pinpoint a primary spawning location at Echo Bay during the 2008 spawning period for the first time since the onset of our efforts in 1996. An overall lack of adult captures and larval abundance was also noted. The overall lack of razorback sucker activity at Echo Bay is cause for concern, and this population will be monitored closely in 2009. Conversely, spawning near the Muddy River/Virgin River inflow area was successfully documented again in 2008, just south of the Virgin River inflow. Our 2008 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 2008 and 2009, perhaps achieving the lowest levels observed during the study period, general research objectives for the 2009 study year include continuing to monitor at the three primary study locations, 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 also recommend that efforts be made to surgically implant additional Floyd Lamb State Park razorback sucker in order to continue with seamless monitoring data collection efforts over the course of the next several years.

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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 fishes that apparently recruited during the first few years of reservoir formation. The population of long-lived adults then disappeared 40 to 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 2008 estimate of Lake Mohave razorback sucker determined there are approximately 47 wild fish remaining (Marsh 2008).

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 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 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 decade-long course of studies. In response, BIO-WEST developed a monitoring protocol that helped to raise efficiency levels of data collection efforts, while maintaining the amount of information gained from studying various life phases of razorback sucker during future monitoring and/or research efforts on Lake Mead. In 2008 Reclamation and SNWA recently completed another cooperative agreement, tentatively extending monitoring efforts and following monitoring protocols developed by Albrecht et al. (2006).

This Annual Report presents the results of the 12th study year (February 2008 through early May 2008 monitoring data). This annual report also presents sonic-tagged razorback sucker data from July 2007 through June 2008. This is to keep in accordance to the results reported by Albrecht et al. (2007) and other past annual reports. Other information and data from previous years and reports are included when and where applicable.

SUMMARY OF EARLIER STUDY RESULTS, 1996–2007

Since the Lake Mead Razorback Sucker Study began in 1996, netting efforts have resulted in more than 700 total razorback sucker capture and/or stocking events, represented by nearly 450 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 to 2007, an additional 10 subadult (sexually immature) 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 2007 132 razorback sucker were aged. The adult fish collected have ranged in age from approximately 7 to 36 years, and subadult fish were between 3 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 pattern 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 have implications to 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 spawning sites at Echo Bay and the Colorado River inflow area of 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-high cliff. At the end of the spawning season in May 2001, this site was dry. As the lake level continued to decline 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 ft. By 2003 the spawning depth was closer to 20 ft, 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 ft, 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 were 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 comparatively understudied area of

Lake Mead. In 2006 and in 2007 razorback sucker were again documented 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 had a 12-month battery life (implanted in 1997 and 1998), 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 at Echo Bay and two at 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 fish and one of the Echo Bay fish were last contacted in 2003 (the eighth study year). The last fish from the 2003 telemetry implantation effort to be contacted was one of the Echo Bay fish, which 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 6 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 to identify new spawning areas. As a result, 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. This report contains movement information for only one of the 2004–2005 tagged fish (code 222 from Echo Bay), which was contacted multiple times after its release and active during a portion of the 2008 field season. In addition, this report also contains information from six residual hatchery-reared (Floyd Lamb State Park) razorback sucker that were tagged and released during the 2005–2006 field season.

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, using sonic-tagged fish can increase the efficiency of field efforts.

STUDY AREAS

All 2008 study year activities occurred at the locations used in the 1996–2007 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. 2008). 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, Virgin Basin, and portions of Colorado River inflow areas, were searched using telemetry equipment. Larval sampling was performed in Echo Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area. Trammel netting was conducted at Las Vegas Bay, Echo Bay, and at the Muddy River/Virgin River inflow area (Figure 1).

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. This section is usually relatively narrow with obvious banks.

- 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 non-flowing (lentic) portion. The flowing portion is typically short (200–400 yards) 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.

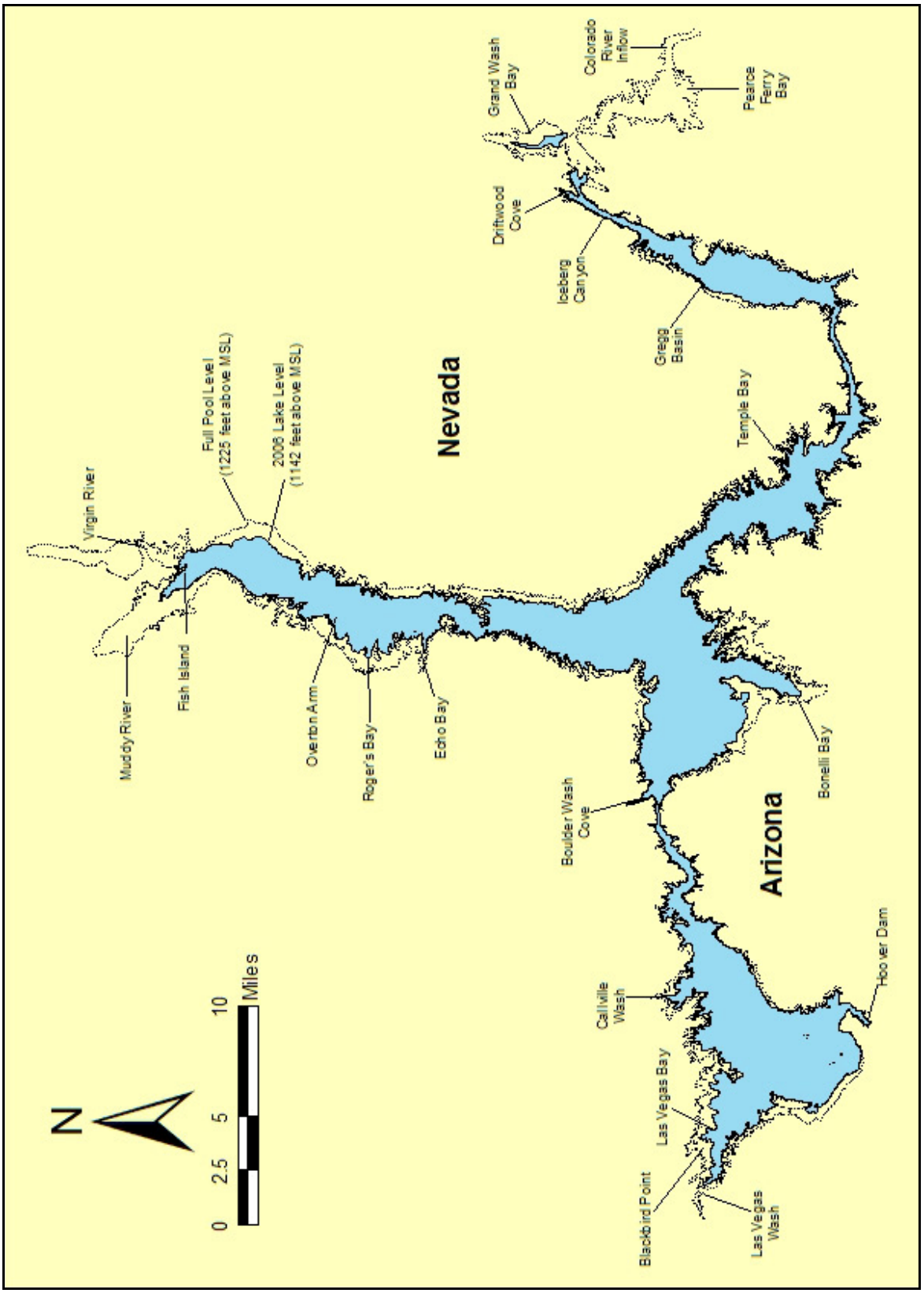

Figure 1. Map of Lake Mead showing general study locations.

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);
- non-flowing 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 between the Muddy River confluence and the Virgin River confluence with Lake Mead);
- 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 may or may not be 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 2008 field season (July 1–June 30) were measured in feet above mean sea level (amsl) and obtained from Reclamation's Lower Colorado Regional Office website (Reclamation 2008). 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

Trammel nets (300-ft-long by 6-ft-deep with an internal panel of 1-, 1.5-, or 2-inch mesh and external panels of 12-inch mesh) were the primary gear used to sample adult fish. Nets were generally set with one end near shore in 10–30 ft of water, with the net stretched out into deeper areas. All trammel nets were set in the late afternoon (just before sundown) and pulled the next morning (shortly after sunrise). Sampling was generally conducted weekly within each study area from February to April, following protocol developed by Albrecht et al. (2006b) with

variable effort between months and locations. Netting locations for the three primary study sites 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 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 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 by collecting a segment of the pectoral fin ray were anesthetized with MS-222 and then placed dorsal side down on a padded surgical cradle for support during processing.

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 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 2008 could not be conducted at the same 12 Echo Bay and Las Vegas Bay standard larval sites that were sampled in spring 1999, 2000, and 2001 (Holden et al. 2000a, 2000b, 2001). During 2002–2008 only some of the original sites were used, and others were assigned based on initial sampling. Additional larval sites were selected at random 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. At Echo Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area, larval sampling sites changed during the course of the season because of the ever-changing desiccation and inundation of sites throughout the study year. 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 2008 spawning period.

In addition to the 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 effort (time, boats, number of lights, etc.) 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 as well as data collection information is 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 2008 efforts involved collecting fin ray sections from razorback sucker for aging purposes.

During the 2008 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. The surgical tool used to remove fin rays and developed by BIO-WEST consists of a matched pair of finely sharpened chisels welded to a set of wide-mouth Vise-Grips™ 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 of the fish 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. Oil immersion techniques were also used on occasion to increase clarity and aide in proper specimen age identification. 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. (2006a), and other annual reports from past years.

Sonic Tagging

No sonic tagging occurred, or was necessary during the 2008 study year because there were sufficient numbers of sonic-tagged fish from the 2005–2006 tagging event. Those interested in the sonic-tag implantation methods used during Lake Mead razorback sucker studies, please refer to Albrecht et al. (2006a) or other past annual reports.

Sonic Tracking

Sonic telemetry was used to assess adult habitat use and movement within and between spawning areas during the 2008 study year. Four male and six female razorback sucker from Floyd Lamb State Park were sonic tagged during the 2005–2006 field season, and in 2006–2007 we continued to follow a single, residual fish from the 2004–2005 tagging event. In 2008, six fish from the 2005-2006 tagging event were monitored, as well as one fish from the 2004–2005 tagging event (Albrecht and Holden 2005, Albrecht et al. 2006a). 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 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 2006–2008 were used to calculate abundance estimates for razorback sucker populations at Echo Bay and Las Vegas Bay. 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). Estimates for populations were derived from the most recent 3-year data collection period (2006–2008) of this study.

Two abundance estimators were used, Chao's M_h (Chao 1989) and Model M_o (Otis et al. 1978). The Model M_o 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_o 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.

Spawning Site Water Quality Monitoring

Collection of basic water quality information at the known spawning locations was initiated in the 12th study season. The long-term objective for collecting water quality data on Lake Mead is to determine, or better isolate, conditions that may be enabling continued recruitment of razorback sucker in Lake Mead (Albrecht et al. 2008). Water quality information, combined with sonic tracking, trammel netting, and larval collection techniques, have the potential to facilitate the prediction of future spawning locations. After locating larval fish within the three primary sampling locations (Las Vegas Bay, Echo Bay, and Muddy River/Virgin River inflow area) two vertical profiles were obtained on a near weekly interval with a Hydrolab Quanta water quality probe. The "inshore" profile was defined as a site where larval fish were present in less than 3 m of water. The "offshore" profile location was determined to be close to the inshore profile with depths of greater than 3 m and no greater than 9 m. Water quality data was collected in half-meter intervals from the surface to the bottom between 10 a.m. and 2 p.m. local standard time. Once each site was established, these same locations were used for all weekly profiles collected during the course of the spawning season. Water quality parameters collected included temperature measured in degrees Celsius, specific conductivity measured in mS/cm^2, dissolved oxygen measured in mg/L, dissolved oxygen percent saturation, pH, total dissolved solids measured in g/L, and turbidity measured in nephelometric turbidity units (NTU). Other data included time, date, weather conditions, and a global position system (GPS) location point. This newly established protocol will continue in the 13th study year and into the future until a more detailed, razorback-specific water quality data collection study design replaces these efforts. Further revisions to this protocol may be made if necessary to improve data collection methods.

RESULTS

Lake Elevation

Similar to the eleventh study year, lake elevations during the 12th study year diminished overall. From a starting elevation in January 2008 of approximately 1,116 ft amsl, lake levels dropped

throughout the spawning period. Lake Mead elevation at the end of April 2008 was approximately 1,111 ft amsl. This translated to an overall loss of nearly 5 ft of depth during the spawning period (Figure 2). We visually observed that the littoral shoreline habitat at Fish Island, near the Muddy River/Virgin River inflows, diminished 10–20 m between February and late March. Similar observations were made at Echo Bay and Las Vegas Bay.

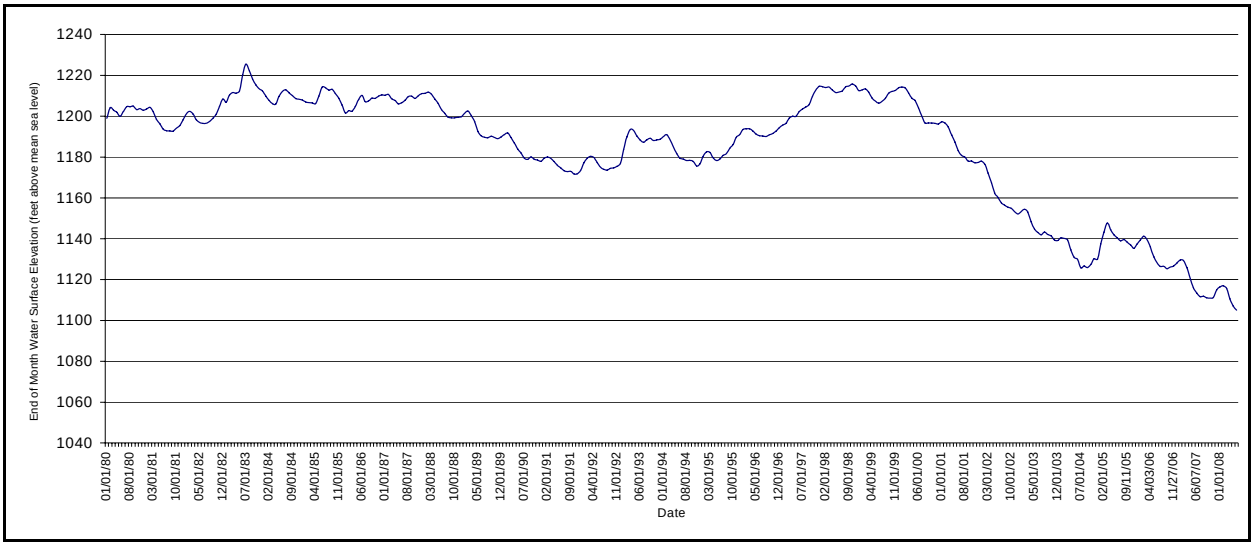

Figure 2. Lake Mead month-end elevations, January 1980–June 2008.

Adult Sampling

Trammel Netting

Table 1 shows the trammel netting effort, expressed as net nights, that occurred during 2008. One net night comprises a single net, set overnight. Trammel netting was conducted over 78 net nights during the 12th study year, with 24 net nights spent in the Las Vegas Bay/Boulder Basin area, 35 net nights spent in the Echo Bay area, and 19 net nights in the Muddy River/Virgin River inflow area. Trammel netting efforts were concentrated along the southwestern shoreline area in Las Vegas Bay, as well as within other Las Vegas Bay locations (Figure 3). Trammel netting was conducted primarily near the back of Echo Bay, with search efforts extending out into the main body of the lake (Figure 4). In all cases, net sets were largely 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 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 2008 netting efforts near the Muddy River/Virgin River inflow were conducted near the confluence of the Virgin River with

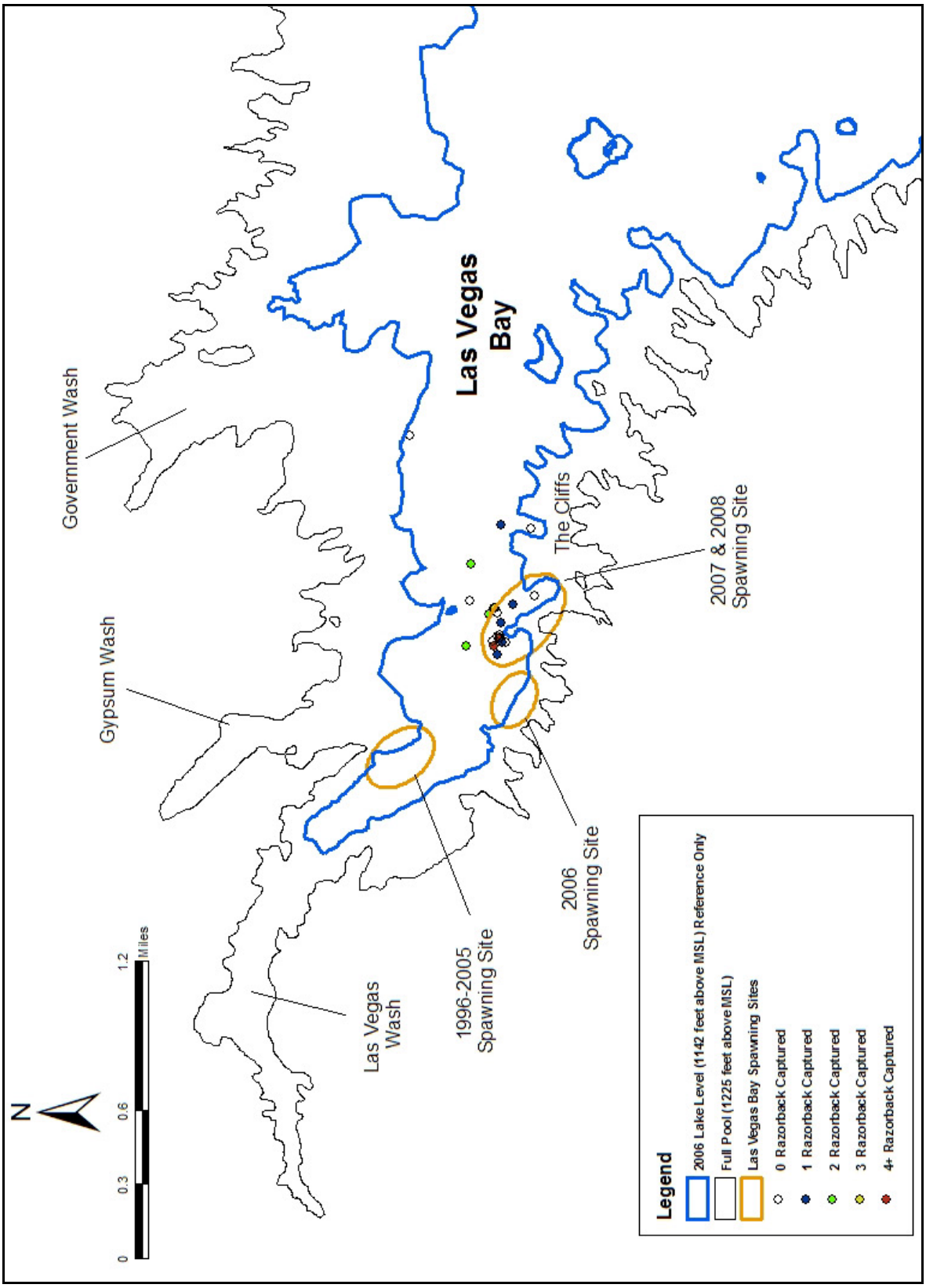

Figure 3. Las Vegas Bay study area showing locations of trammel netting and numbers of fish captured, July 2007–June 2008.

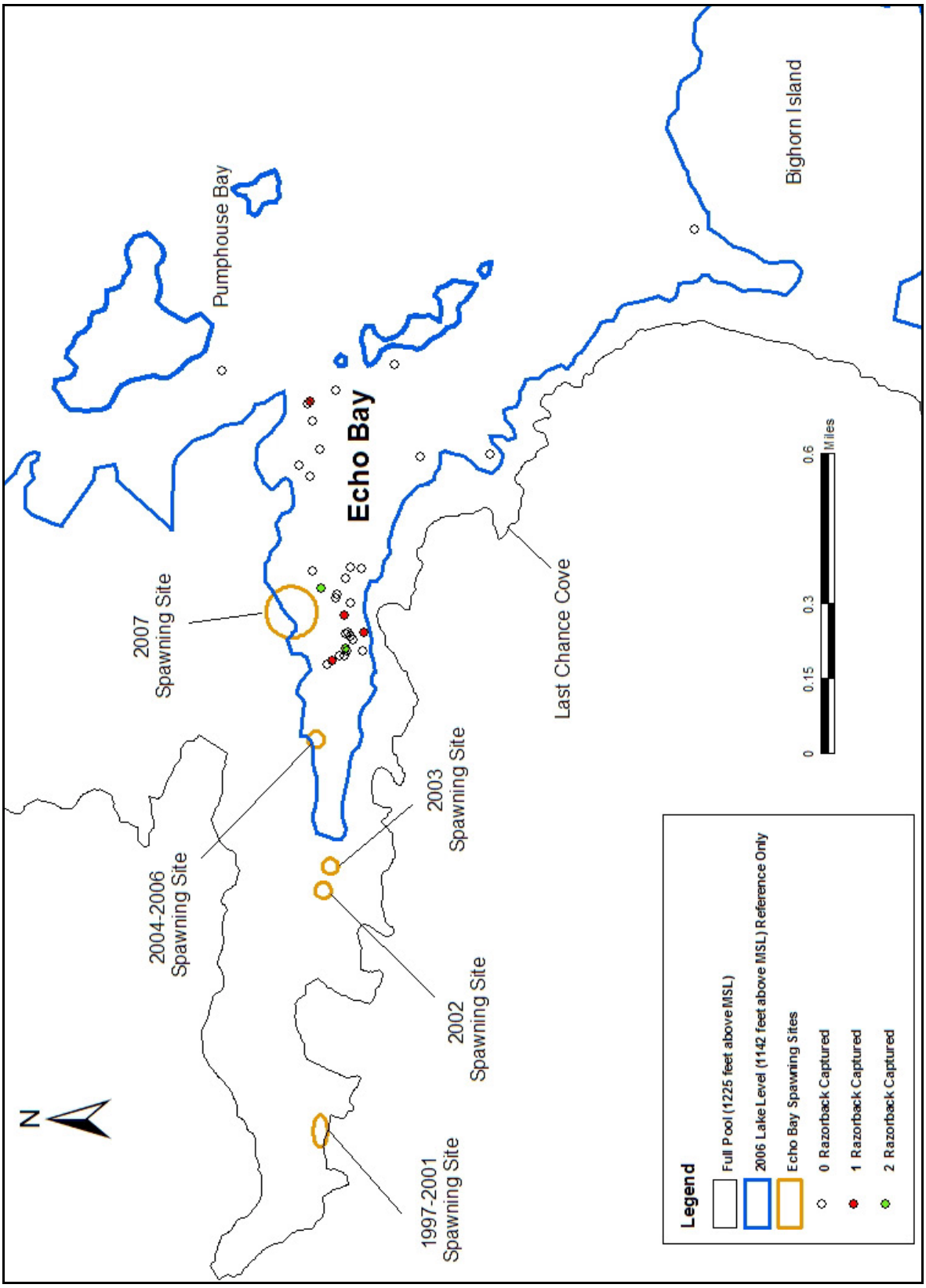

Figure 4. Echo Bay study area showing locations of trammel netting and numbers of fish captured, July 2007–June 2008.

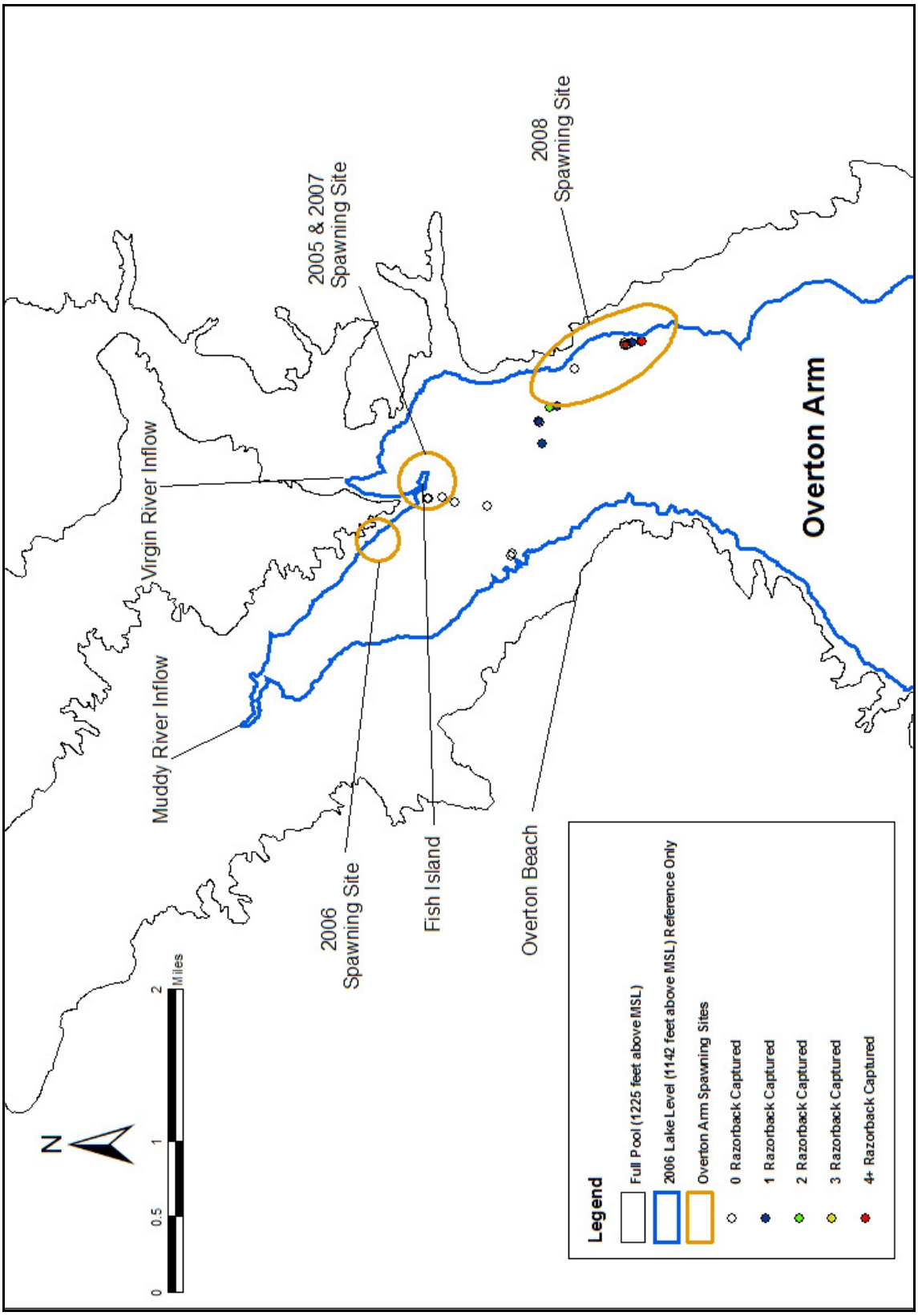

Figure 5. Muddy River/Virgin River inflow study area showing locations of trammel netting and numbers of fish captured, July 2007–June 2008.

Table 1. Trammel netting effort (net nights) on Lake Mead during the 12th study year.

MONTH	LAS VEGAS BAY/ BOULDER BASIN	ECHO BAY	OVERTON ARM	TOTAL
February	11	14	5	30
March	3	10	9	22
April	10	11	5	26
Total	**24**	**35**	**19**	**78**

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 2008 (Holden et al. 1997, 1999; Albrecht et al. 2006a, 2006b). During the 2008 field season, near the Virgin River inflow area, adult razorback sucker were captured at depths ranging from 4–11 ft, with a mean capture depth of 7.5 ft (averaged across all netting and razorback sucker capture locations). No trammel netting effort specific to razorback sucker was expended at the Colorado River inflow area during the 12th study year.

In accordance with previous study years (Holden et al. 2000a, 2000b, 2001; Abate et al. 2002; Welker and Holden 2003, 2004; Albrecht and Holden 2005, Albrecht et al. 2006a, Albrecht et al. 2007), the timing of trammel netting for the 12th study year was coordinated with seasonal differences in water temperature, air temperature, and the spawning season. Netting during the first two study years revealed that warmer air and water temperatures encountered during summer netting efforts appeared to stress razorback sucker that were brought to the surface. Hence trammel netting was not conducted from June to October 2008. One change implemented during the 2001–2002 field season that was not a part of netting protocol during the previous three field seasons was netting during the razorback sucker spawning season (January–May). This practice was again employed during the 12th study year, following monitoring recommendations posed by Albrecht et al. (2006b). Prior to the sixth study year, it was believed that netting during the spawning season was stressful to spawning razorback sucker, and that this activity might disrupt spawning or influence adult survival. However, return rates for razorback sucker sampled by the USFWS in 2000 and 2001, during the spawning period, were similar to return rates for fish captured outside of the spawning period. Furthermore, many of the fish captured by the USFWS were new individuals, indicating that BIO-WEST was not sampling the portion of the populations in both Las Vegas Bay and Echo Bay that moved into these areas late to spawn. Therefore, trammel netting was conducted during the 2008 spawning season to effectively sample the adult Lake Mead razorback sucker population.

In addition, most trammel netting effort occurred from February through the latter portion of April 2008. This change was implemented to follow recommendations for long-term monitoring of Lake Mead razorback sucker as found in Albrecht et al. (2006b).

The first male razorback sucker expressing milt was captured on February 12, 2008, and the first female razorback sucker expressing eggs was also captured February 12, 2008. Both fish were captured at Las Vegas Bay. Please note that in the 12th study year, sampling efforts were not initiated until February, following monitoring recommendations outlined in Albrecht et al. (2006b). Recapture rates varied between study locations in the 12th study year. At Las Vegas Bay, 16 of the 40 razorback sucker caught were recaptures (40.0%), and 4 of those fish had been stocked by NDOW into Lake Mead. At Echo Bay four of the eight razorback sucker caught were recaptures (50.0%), one of which was stocked by NDOW during previous years. Finally, at the Muddy River/Virgin River inflow area, one of the 24 razorback sucker caught was a recapture (or 4.0%). Overall, these return rates demonstrate that stocked fish are able to find and incorporate themselves into wild populations, a phenomenon also observed by Modde et al. (2005) in the Green River and similarly described in Albrecht and Holden (2005) and Albrecht et al. (2006a).

Twenty adult and 20 subadult razorback sucker were captured at Las Vegas Bay (Table 2) during the 24 net nights expended during the 12th study year (Figure 3). As described in Albrecht et al. (2006a) and Albrecht et al. (2007), most fish were captured near the southwestern shoreline of Las Vegas Bay, providing continued evidence 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 2006 through 2008 spawning periods, the majority of razorback sucker were captured in fairly shallow water 12–22 ft deep along a gravel 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 introduced into Las Vegas Bay during the 2005–2006 field season, many of which were still active in 2008. Since 2006, larval razorback sucker abundance confirmed this location as the primary spawning area. The razorback sucker catch rate for trammel netting at the Las Vegas Bay area was 1.67 fish/net night for the 12th study year. This rate is higher than the previous year's rate (1.30 fish/net night) and is the highest catch rate observed during our studies at this location (0.10–1.30 fish/net night) (Figure 6).

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). Razorback sucker were collected from depths ranging from 8–19 ft. In all, only 8 adult razorback sucker were captured despite 35 net nights of effort (Table 2). No subadult fish were captured from Echo Bay during the 2008 spawning period. For comparative purposes, during the 2007 spawning period, 5 subadult razorback sucker were collected, as were 28 adult razorbacks. The 2008 razorback sucker catch rate for trammel netting at Echo Bay was 0.23 fish/net night, which is lower than the rate obtained during the previous study year (0.83 fish/net night) (Figure 6). It is worth noting that modifications to shoreline habitat occurred at Echo Bay during the 2008 spawning season. These modifications were the result of diminished lake levels

Table 2. Location, tagging, and size information for razorback sucker collected in Lake Mead during 2008.

DATE	CAPTURE LOCATION[a]	PIT TAG NUMBER	SONIC CODE	DATE[b] STOCKED	RECAPTURE	TL [c] (mm)	FL [d] (mm)	SL [e] (mm)	WT [f] (g)	SEX[g]
2/12/08	LVB	53256D591C	-	2/12/08	NO	430	394	360	866	U
2/12/08	LVB	4324102B1D	-	2/12/08	NO	425	388	353	870	U
2/12/08	LVB	53340B060F	-	2/12/08	NO	554	505	472	1,782	M
2/12/08	LVB	5340605729	-	2/12/08	NO	379	355	322	622	U
2/12/08	LVB	45081E467E	-	2/12/08	NO	399	374	340	644	U
2/12/08	LVB	53412B3546	-	2/12/08	NO	430	400	365	886	U
2/12/08	LVB	5344543D0A	-	2/12/08	NO	413	385	350	840	U
2/12/08	LVB	1F4A40391E	-	5/7/98	YES	605	550	500	3,130	M
2/12/08	LVB	53256B2638	-	2/20/07	YES	555	510	405	2,098	M
2/12/08	LVB	532557480A	-	2/12/08	YES	540	501	462	2,048	M
2/12/08	LVB	5324495232	-	2/21/07	YES	530	478	453	1,689	M
2/12/08	LVB	5325773752	-	2/6/07	YES	608	560	521	2,280	F
2/12/08	LVB	447E191829	-	2/12/08	NO	390	365	327	734	U
2/12/08	LVB	5335283565	-	2/12/08	NO	490	388	360	946	U
2/12/08	LVB	5332553E2E	-	2/12/08	NO	426	395	355	808	U
2/18/08	LVB	53240F2008	-	2/18/08	NO	385	365	324	710	U
2/19/08	LVB	5325716B62	-	3/23/06	YES	577	536	493	2,280	M
2/19/08	LVB	532F43475C	-	3/13/07	YES	630	590	536	2,985	F
2/25/08	LVB	5334071B55	-	2/25/08	NO	605	565	520	2,990	F
2/25/08	LVB	201D5B2345	-	11/19/98	YES	655	595	568	3,660	M
2/27/08	OA	1F500E4043	-	1/22/02	YES	670	610	560	3,750	F
2/27/08	OA	5325537E55	-	2/27/08	NO	465	437	398	1,080	M
2/28/08	EB	5326000260	-	11/29/05	YES	640	594	555	3,890	F
2/29/08	EB	532F161F08	-	2/29/08	NO	635	585	545	3,448	F
3/5/08	EB	1F4A0B0E7E	-	12/2/03	YES	653	608	563	3,300	F
3/5/08	OA	53254B0C5E	-	3/5/08	NO	530	493	452	1,725	U
3/18/08	LVB	5325661D5B	445	11/30/05	YES	545	500	464	2,260	M
3/19/08	EB	53456A002B	-	3/19/08	NO	515	480	443	1,905	F
3/19/08	EB	53313C1A11	-	3/19/08	NO	532	491	452	1,695	M
3/19/08	EB	533F0C2F0F	-	3/19/08	NO	510	481	438	1,670	F
3/25/08	OA	MORTALITY[h]	-	3/25/08	NO	271	255	232	160	U
3/26/08	OA	447D085C21	-	3/26/08	NO	345	322	295	510	U
3/26/08	OA	7F7E6A491A	-	3/26/08	NO	665	616	578	3,465	F
3/26/08	OA	533F077370	-	3/26/08	NO	541	510	475	1,930	F
3/26/08	OA	534148541A	-	3/26/08	NO	521	488	450	1,675	F
4/1/08	OA	533F077370	-	3/26/08	YES	NA[i]	NA	NA	NA	F
4/1/08	OA	532576116B	-	4/1/08	NO	518	479	440	1,590	F
4/1/08	OA	7F7D307D5F	-	4/1/08	NO	559	517	480	1,945	F
4/1/08	OA	533342342B	-	4/1/08	NO	514	476	440	1,320	M
4/1/08	OA	53437D5852	-	4/1/08	NO	535	476	460	1,605	M
4/1/08	OA	53341D334C	-	4/1/08	NO	536	501	460	1,968	F

Table 2. (Cont.)

DATE	CAPTURE LOCATION[a]	PIT TAG NUMBER	SONIC CODE	DATE[b] STOCKED	RECAPTURE	TL [c] (mm)	FL [d] (mm)	SL [e] (mm)	WT [f] (g)	SEX
4/1/08	OA	5332411E4D	-	4/1/08	NO	514	482	442	1,480	F
4/1/08	OA	533171627D	-	4/1/08	NO	548	513	476	1,735	F
4/1/08	OA	5334564400	-	4/1/08	NO	530	494	462	1,825	F
4/1/08	OA	5326051F79	-	2/22/07	YES	494	455	422	1,345	M
4/1/08	OA	53417E0F5C	-	4/1/08	NO	370	340	302	600	U
4/1/08	OA	5342774F75	-	4/1/08	NO	360	337	304	550	U
4/1/08	OA	5326016E52	-	4/1/08	NO	385	353	322	610	U
4/1/08	OA	7F7D782849	-	4/1/08	NO	229	209	181	115	U
4/2/08	EB	53257C0232	-	4/2/03	YES	578	529	495	2,955	M
4/2/08	EB	5325615E4A	-	4/5/04	YES	732	695	644	5,225	F
4/3/08	LVB	534013292C	-	4/3/08	NO	640	595	546	2,795	F
4/3/08	LVB	5344304E63	-	3/6/07	YES	619	586	538	2,325	F
4/3/08	LVB	5325716B62	-	3/23/06	YES	568	526	482	1,650	M
4/3/08	LVB	5326000260	447	11/29/05	YES	647	606	562	3,540	F
4/3/08	LVB	533F432623	-	4/3/08	NO	560	516	477	2,135	M
4/3/08	LVB	533E0E4730	-	4/3/08	NO	468	427	394	1,275	U
4/8/08	LVB	5334475A6E	-	3/13/07	YES	544	532	473	1,925	M
4/8/08	LVB	45143E6E5C	-	4/8/08	NO	535	493	444	1,605	U
4/8/08	LVB	5341350345	-	4/8/08	NO	423	394	356	925	U
4/10/08	LVB	53456A002B	-	4/10/08	YES	512	482	441	1,885	F
4/10/08	LVB	5325563A2E	-	4/10/08	NO	452	419	380	980	U
4/10/08	LVB	4515364D7B	-	4/10/08	NO	472	435	394	1,265	U
4/10/08	LVB	53240E6C39	-	4/10/08	NO	467	441	399	1,305	U
4/10/08	LVB	4515441369	-	4/10/08	NO	429	397	399	935	U
4/10/08	LVB	534303627B	-	4/10/08	NO	422	385	349	795	U
4/10/08	LVB	53260B4E61	-	4/10/08	NO	375	344	309	455	U
4/23/08	LVB	1F4A1C4A31	-	9/30/02	YES	560	515	470	1,565	M
4/23/08	LVB	533F694D2F	-	4/23/08	NO	430	402	368	925	U
4/24/08	LVB	5334071B55	-	2/25/08	YES	NA	NA	NA	NA	F
4/22/08	OA	5325733449	-	4/22/08	NO	533	496	463	1,885	F
4/22/08	OA	5334451F49	-	4/22/08	NO	504	470	435	1,350	M

[a] Locations: EB = Echo Bay, LVB = Las Vegas Bay, OA = Overton Arm (Muddy River/Virgin River inflow area).
[b] Date originally stocked or originally captured.
[c] TL = Total length.
[d] FL = Fork length.
[e] SL = Standard length.
[f] WT = Weight.
[g] F = female, M = male, U = sex not determined.
[h] This fish was found dead upon retrieval of net. Evidence of predator-inflicted wounds was observed.
[i] NA = not applicable.

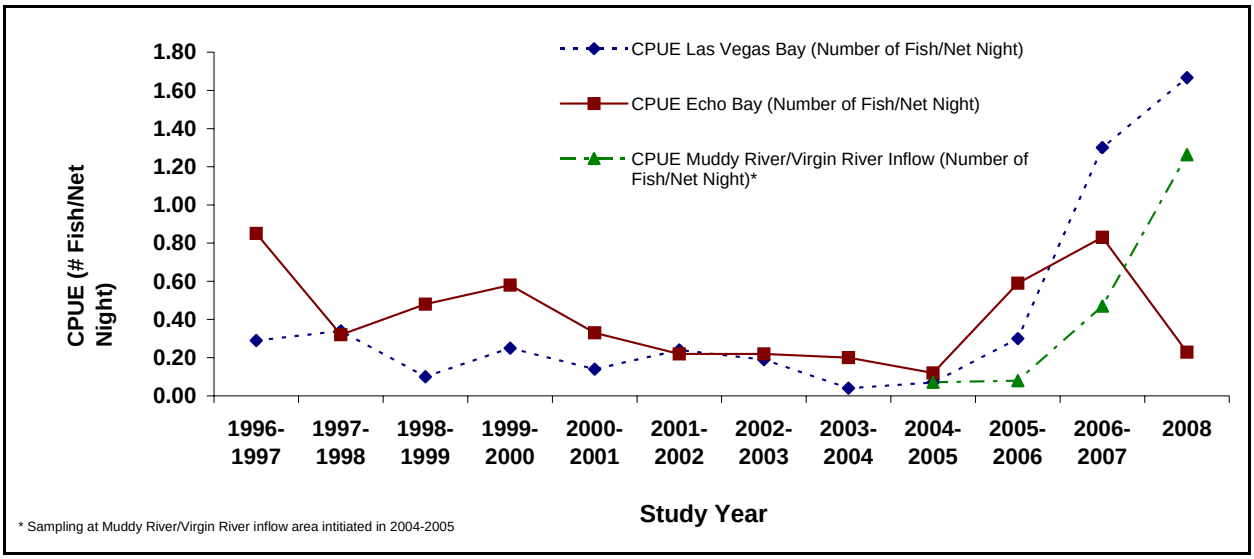

Figure 6. Trammel netting catch per unit effort (CPUE) during studies on Lake Mead razorback sucker, 1996–2008.

and the associated need to modify the configuration of the Echo Bay marina and its associated infrastructure. Along the north shoreline, there was evidence of dredging and earth moving activity to create a parking area and relocate some of the docks around the marina. Furthermore, the overall reduction in the size, depth, and topography of Echo Bay during 2008 served to push net sets further out into the main body of Lake Mead, away from the more confined habitats associated with the back of Echo Bay, and this may have contributed to an overall reduction in netting efficiency. Albrecht et al. (2007) indicated that the condition of Echo Bay during the 2007 spawning period allowed them to almost barricade the back portions of Echo Bay, effectively blocking off fish located in the back portions of Echo Bay. Which factor or combination of factors lead to lower catch rates is speculative; however it is evident that Echo Bay catch rates declined during 2008.

The 2008 spawning period marks the highest number of razorback sucker captured at the Muddy River/Virgin River inflow area (Figure 5). This is the fourth consecutive spawning season in which we have documented successful spawning in this area of Lake Mead. Trammel netting efforts resulted in the capture of 17 adult razorback sucker. We also captured seven subadult fish during the 2008 spawning period while trammel netting at the Muddy River/Virgin River inflow area. Capture depths ranged from 4 to 11 ft, and most fish were captured over gravel substrates along the eastern shoreline just south of the Virgin River inflow/delta. The razorback sucker catch rate for trammel netting at the Muddy River/Virgin River inflow area was 1.26 fish/net night, substantially higher than any of the past study year's CPUE values and comparable for the first time to catch rates at Las Vegas Bay or Echo Bay (2006–2007 = 0.47 fish/net night; 2005–2005 = 0.8 fish/net night; 2004–2005 = 0.7 fish/net night) (Figure 6).

Albrecht and Holden (2005), as well as Albrecht et al. (2006a), discussed possible interactions and the potential for intermixing of the Muddy River/Virgin River spawning aggregate with fish known to use Echo Bay as a spawning location. Albrecht et al. (2007) suggested that the Echo Bay and Muddy River/Virgin River populations should be considered the same population because of the additional evidence of intermixing stemming from 2007 spawning period capture data. Through the 2006 spawning period, we found that a hatchery-reared, repatriated fish stocked by NDOW in 2002 at Echo Bay were using habitats near the Muddy and Virgin River inflows. We also observed one of the sonic-tagged fish, which had been stocked into Echo Bay, using habitats at the northern end of Lake Mead. However, prior to 2007, we had never observed a wild Lake Mead razorback sucker moving between locations. During the 2008 field season, sonic-tagged fish continued to move between Echo Bay and the Muddy River/Virgin River inflows (Albrecht et al. 2007, 2008). We captured another hatchery-reared razorback sucker (stocked at Echo Bay by NDOW) that had been using habitats near the Virgin River inflow. This supports the suggestion to combine Echo Bay and Muddy River/Virgin River capture data for population estimation techniques. As such, this report will provide population estimates (see below) for the Las Vegas Bay population as well as for the population comprising Echo Bay and Muddy River/Virgin River razorback suckers (following Albrecht et al. 2007).

Some of the more interesting captures in 2008 involved fish that were originally captured within one of the study locations, and were recaptured this season in different study locations. This movement information further supports the idea that Lake Mead razorback sucker can and do move between spawning site locations. As has been expressed in the past, the populations of razorback sucker in Lake Mead are considered to be small populations. As with any small population there is often concern for overall genetic health. Even though the populations at Las Vegas Bay and those in the northern portion of Lake Mead appear to 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 we observed a fish, originally stocked in to Las Vegas Bay in November 2005 from Floyd Lamb, that was captured at Echo Bay in February 2008 and then recaptured at Las Vegas Bay in early April 2008. Another fish, a wild individual originally captured in Echo Bay, was captured in Echo Bay in March 2008 and recaptured less than a month later at the Las Vegas Bay spawning location. 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. This behavior has been observed periodically (four wild fish) throughout the course of this study. Furthermore, it is evident that movement occurs not only with stocked razorback sucker, but that wild fish can display movements 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) also document a similar trend; however, it should be noted that movement has been observed more readily between Echo Bay and the Virgin River/Muddy River inflow spawning area. This movement pattern was observed again this season, with a fish that was originally stocked into Echo Bay being recaptured near the Virgin River inflow.

Another interesting find related to trammel netting in 2008 was the exceptionally high number of young, wild, subadult razorback sucker captured from a single netting occasion at Las Vegas Bay. In early February, two nets set near the 2007 spawning area at Las Vegas Bay resulted in the capture of 17 fish. Eleven of the captured fish were subadult fish (this was sufficient enough numbers that two of the fish had to be released without being processed due to concerns about the welfare and health of the young fish). This is the highest number of young razorbacks captured in a single occasion since the onset of our studies in 1996. This unique capture event demonstrates at least three things. First, subadult fish are present on/near spawning habitat during the spawning season and apparently can be found in aggregates, or in schools with their conspecifics. Secondly, this interesting capture event demonstrates the rather stochastic and sporadic nature in the ability to actually capture and document wild subadult fish. Interestingly, an additional 11 subadult fish were captured at Las Vegas Bay during the remainder of the 2008 field season. The likelihood of capturing young, wild razorback sucker in Lake Mead was also discussed by Albrecht et al. (2006b), who indicated potential difficulties in sampling for this younger portion of the Lake Mead razorback sucker population. Lastly, and perhaps most importantly, the capture of this large group of subadult fish demonstrates that natural recruitment of razorback sucker continues at Lake Mead, despite low and declining lake elevations. As more research is conducted in Lake Mead we are hopeful that questions pertaining to continued razorback sucker recruitment events despite diminished lake conditions will become more clear (a topic discussed in greater depth by Albrecht et al. [2008] during their comprehensive review of Lake Mead razorback sucker research).

Continuing with the theme of interesting captures, there is the elevated catch rate of razorback sucker near the Virgin River inflow in 2008. The razorback sucker catch rate for trammel netting at the Muddy River/Virgin River inflow area was 1.26 fish/net night, substantially higher than any of the past study year's CPUE values in this area of Lake Mead (Figure 6). Again, 41% of the razorbacks collected from this area were subadult fish, which improves insight into continued natural recruitment during low lake conditions. Conversely, catch rates at Echo Bay were lower than those of the previous year. Potential reasons for this are described above. Lower catch rates at Echo Bay may be one of the factors that explain the increase in razorback sucker captures at Las Vegas Bay and the Muddy River/Virgin River inflow area (assuming intermixing). As shown above, movement of Echo Bay fish has been observed to occur from Echo Bay to Las Vegas Bay and from Echo Bay to the Muddy River/Virgin River inflow area. Compared to earlier study years, these movement patterns seem to have expanded in recent years. It remains to be seen if this is an artifact of declining spawning habitat conditions at the back of Echo Bay. Future monitoring should help to clarify potential trends and changes in the use of Echo Bay as a preferred spawning location.

In all, the 2008 spawning season was unique in terms of large fish movement patterns and the overall numbers of adult and subadult fish captured. This follows the trends reported by Albrecht et al. (2007). The potential trend of declining CPUE in Echo Bay and increasing CPUE in the Muddy River/Virgin River inflow is perhaps best exemplified in Figure 6. Assuming the trend continues, this could indicate the onset of a new, growing spawning aggregate.

In summary, 144 unique individual razorback sucker from Echo Bay have been handled during the 12 study years, 78 of which were captured and PIT tagged by BIO-WEST personnel, 62 of which were PIT tagged by NDOW, and 4 handled by the USFWS during collaborative efforts with BIO-WEST. At Las Vegas Bay 240 unique razorback sucker have been handled, including 116 individuals PIT tagged by BIO-WEST personnel, 117 PIT tagged by NDOW, and 7 razorback sucker tagged at Las Vegas Bay by the USFWS. At the Muddy River/Virgin River inflow area, 36 unique razorback sucker have been captured, 35 of which were PIT tagged by BIO-WEST and one of which was PIT tagged by NDOW. Finally, 16 fish have been sonic tagged, PIT tagged, and stocked by NDOW, during collaborative research efforts with BIO-WEST. 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 440 individuals.

Growth

In all, 23 razorback sucker were recaptured during the 2008 field season, 4 from the Echo Bay area, 16 from the Las Vegas Bay area, and three from the Muddy River/Virgin river inflow area. However, annual growth information analyses were only performed using data from 15 of these fish. Reasons for not including all 23 recaptures in this analysis were that some of the fish were captured more than once during the 2008 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 date. The difference in total length between capture periods was used to determine mean annual growth (Table 3). The combined, lake-wide, mean annual growth of razorback sucker recaptured from Lake Mead during the 12th study year was 15.3 mm. The combined mean annual growth of recaptured fish during the previous study year was 8.1 mm (Albrecht et al. 2007). Mean annual growth of fish recaptured at Echo Bay was -0.3 mm (5.4 mm for stocked fish and -3.2 for wild fish) and ranged from -6.0 mm to 5.4 mm of growth per year. Razorback sucker recaptured at Las Vegas Bay had a mean annual growth of 20.6 mm (16.9 mm for stocked fish and 23.1 mm for wild fish) and ranged from 1.1 mm to 52.6 mm of growth per year. For the first time we are able to report overall growth of fish recaptured from the Overton Arm. The mean annual growth of fish recaptured from the Overton Arm was calculated to be 20.1 mm of growth per year.

Negative growth values are thought to reflect measurement error between values recorded during the initial capture occasion and those values observed during the recapture date and may be a function of very old and/or slow-growing individuals. Alternatively, this observed change could be reflective of netting-related stress, stress associated with sonic tagging, or other unknown, naturally induced stressors (Holden et al. 2000b). In all, and as alluded to in past annual reports (e.g., Albrecht et al. 2006, Albrecht et al. 2007, Albrecht et al. 2008), 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 2008 field season.

PIT TAG NUMBER	CAPTURE DATE [a]	TOTAL LENGTH (mm) [b]	RECAPTURE DATE	TOTAL LENGTH (mm)	TOTAL GROWTH (mm)	DAYS BETWEEN MEASUREMENTS	GROWTH PER YEAR (mm/ 365 days)
LAS VEGAS BAY							
Stocked Fish							
1F4A40391E	5/01/1997	576	2/12/2008	605	29	3,939	2.7
5325661D5B	11/30/2005	528	3/18/2008	545	17	839	7.4
5326000260 [c]	11/29/2005	635	4/03/2008	647	12	856	5.1
1F4A1C4A31	9/30/2002	269	4/23/2008	560	291	2,032	52.3
Mean annual growth of Las Vegas Bay stocked fish							**16.9**
Wild Fish							
532557480A	1/30/2007	514	2/12/2008	540	26	378	25.1
5325773752	2/06/2007	574	2/12/2008	608	34	371	33.5
201D5B2345	11/19/1998	645	2/25/2008	655	10	3,385	1.1
5325716B62	3/23/2006	461	4/03/2008	568	107	742	52.6
5344304E63	3/06/2007	611	4/03/2008	619	8	394	7.4
5334475A6E	3/13/2007	524	4/08/2008	544	20	392	18.6
Mean annual growth of Las Vegas Bay wild fish							23.1
Mean annual growth calculated from Las Vegas Bay stocked and wild fish combined							20.6
ECHO BAY							
Stocked Fish							
1F4A0B0E7E	12/02/2003	630	3/05/2008	653	23	1,555	5.4
Mean annual growth of Echo Bay stocked fish							N/A
Wild Fish							
5325615E4A	4/05/2004	756	4/02/2008	732	-24	1,458	-6.0
53257C0232	4/02/2003	580	4/02/2008	578	-2	1,827	-0.4
Mean annual growth of Echo Bay wild fish							**-3.2**
Mean annual growth of Echo Bay stocked and wild fish							**-0.3**
OVERTON ARM (MUDDY RIVER/VIRGIN RIVER INFLOW AREA)							
Stocked Fish							
1F500E4043 [c]	1/22/2002	656	2/27/2008	670	14	2,227	2.3
Mean annual growth of Overton Arm stocked fish							**N/A**
Wild Fish							
5326051F79	2/22/2007	452	4/01/2008	494	42	404	37.9
Mean annual growth of Overton Arm wild fish							**N/A**
Mean annual growth of Overton Arm stocked and wild fish combined							**20.1**
Mean annual growth of all Echo Bay, Las Vegas Bay, and Overton Arm stocked fish combined							**12.5**
Mean annual growth of all Echo Bay, Las Vegas Bay, and Overton Arm wild fish combined							**18.9**
Mean annual growth of all recaptured fish during course of 2008 study year							**15.3**

[a] The date a fish was stocked into Lake Mead, or the date a fish was originally captured if wild.
[b] Total length in millimeters.
[c] Fish stocked originally into Echo Bay.

Sonic Telemetry

During the first 11 years of the study, 62 fish (38 wild and 24 hatchery reared) were equipped with sonic tags. Throughout the 2007–2008 Lake Mead field season, contact was made with seven of these sonic-tagged fish. One of these tagged fish (code 222) was the lone remaining individual from the 2004 tagging event, while the remaining six tagged fish were tagged in 2005 (Table 4). Four of the original 10 fish (codes 554, 556, 557, and 558) implanted with transmitters in 2005 were not located throughout the 2007–2008 Lake Mead field season; tag 554 was deemed a mortality near the end of the 2005–2006 season, while 556 became inactive immediately following the tagging procedure (Albrecht et al. 2006a). Sonic fish 557 was last contacted near Fish Island on 28 February, 2007, and the status of this fish is unknown. Similarly, sonic fish 558 was not located during the 2007–2008 season. Fish 558 was found the previous season on 20 March, 2007. This fish migrated from the Fish Island area to the mouth of Echo Bay where it was last contacted. Based on our past experiences with sonic-tagged fish in Lake Mead, it is thought that sonic tags 557 and 558 may have expired early. Capturing these fish during future trammel netting events would confirm this hypothesis.

Table 4. Tagging and stocking information, location, and date of last contact, and current status of telemetered fish in Lake Mead from July 2007–June 2008.

CAPTURE LOCATION[a]	DATE TAGGED	TAG CODE	TOTAL LENGTH (MM)	SEX[b]	STOCKING LOCATION[a]	LAST LOCATION[a]	DATE OF LAST LOCATION	CURRENT STATUS
FDLB	12/01/04	222	524	M	EB	BPB	7/20/07	Unknown
FDLB	11/29/05	444	610	F	OA/FI	OA/FI	2/13/08	Mortality
FDLB	11/30/05	445	545	M	LVB	LVB	4/11/08	Alive
FDLB	11/30/05	446	616	F	LVB	LVB	6/23/08	Alive
FDLB	11/29/05	447	647	F	EB	LVB	6/23/08	Alive
FDLB	11/30/05	448	515	M	LVB	LVB	4/11/08	Alive
FDLB	11/30/05	555	604	F	LVB	LVB	6/23/08	Alive

[a] Locations: BPB = Blue Point Bay, FDLB = Floyd Lamb State Park, EB = Echo Bay, OA/FI = Overton Arm/Fish Island (Muddy River/Virgin River inflow area), LVB = Las Vegas Bay.
[b] Sex: F = female, M = male.

In all cases, when sonic-tagged fish moved into and used habitats within the riverine portions of Las Vegas Wash, 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 of Las Vegas Wash, or other habitat features that were not accessible by boat.

The following dialog describes the history and habitat use of the remaining, active razorback suckers implanted during 2005–2006 field season, and the movements of the single, residual fish (code 222) tagged in 2004–2005. Refer to Table 4 for all origin, tagging, and current status

information for sonic-tagged fish, and note that sonic data from July 2007 through June 2008 is presented below in an effort to remain consistent with data reporting procedures for this project.

Las Vegas Bay

Fish 445

Contact was established with fish 445 on 12 occasions during the 2007–2008 Lake Mead field season (Figure 7). As observed during the previous study year (Albrecht et al. 2007), all recorded locations were within the Las Vegas Bay vicinity. The sonic locations of fish 445 and other telemetered fish in Las Vegas Bay, in conjunction with netting and larval efforts, documented a shift in spawning location in this area of Lake Mead. The average depth at which fish 445 was located at was 22.9 ft, with depths ranging from 5 to 42 ft. The majority of contacts with fish 445 were in Las Vegas Bay near the identified 2007–2008 spawning site; however, the earliest recorded locations (20 October, 2007, and 14 November, 2007) were in Government Wash on the north shore (Table 4). Fish 445 is currently classified as active, and we anticipate that tracking this fish will continue to provide valuable data.

Fish 446

Contact was established with fish 446 on 13 different occasions within Las Vegas Bay during the 2007–2008 Lake Mead field season (Figure 7). The average depth that fish 446 used was 35.5 ft, with depths ranging from 11 to 48 ft. Although Fish 446 spent time between the north and south shorelines and throughout Las Vegas Bay, it was found numerous times close to the 2007–2008 identified spawning site and close to other sonic-tagged fish. The most recent telemetry contact with fish 446 was on 23 June, 2008, just east of the 2008 Las Vegas Bay spawning site. This fish is classified as active, and it is anticipated to provide valuable data about spawning locations and habitat use in the future (Table 4).

Fish 447

Contact was established with fish 447 on 16 occasions during the 2007–2008 Lake Mead sampling season (Figures 7, 8, 9). Fish 447 was located within both the Las Vegas Bay and Echo Bay primary study areas. In previous years (Albrecht et al. 2006a) fish 447 was documented using Echo Bay and its immediate vicinity and in Albrecht et al. (2007) fish 447 was documented in all three primary study areas. The first sonic contact during the 2007–2008 field season was on 20 July, 2007, and the last on 23 June, 2008, near the north shore of Las Vegas Bay across from the 2007–2008 spawning site. However, fish 447 spent much of the winter near Echo Bay (18 December, 2007, through 28 February, 2008). Based on 2008 data, its movement from Las Vegas Bay to Echo Bay occurred within 33 days. Similarly, fish 447's movement back to Las Vegas bay occurred within 29 days. Fish 447 was located throughout Las Vegas Bay and Echo Bay without discernable patterns or apparent location preferences. Interestingly, on 28 February, 2008, fish 447 was located just off Bighorn Island near the mouth of Echo Bay, then captured the next morning toward the back (i.e., the westernmost end) of Echo Bay. As a mobile fish, tag 447 occupied depths ranging from 8 to 74 ft. Fish 447 has demonstrated similar behavior in previous years, adding valuable data regarding the mobility of the razorback sucker within Lake Mead.

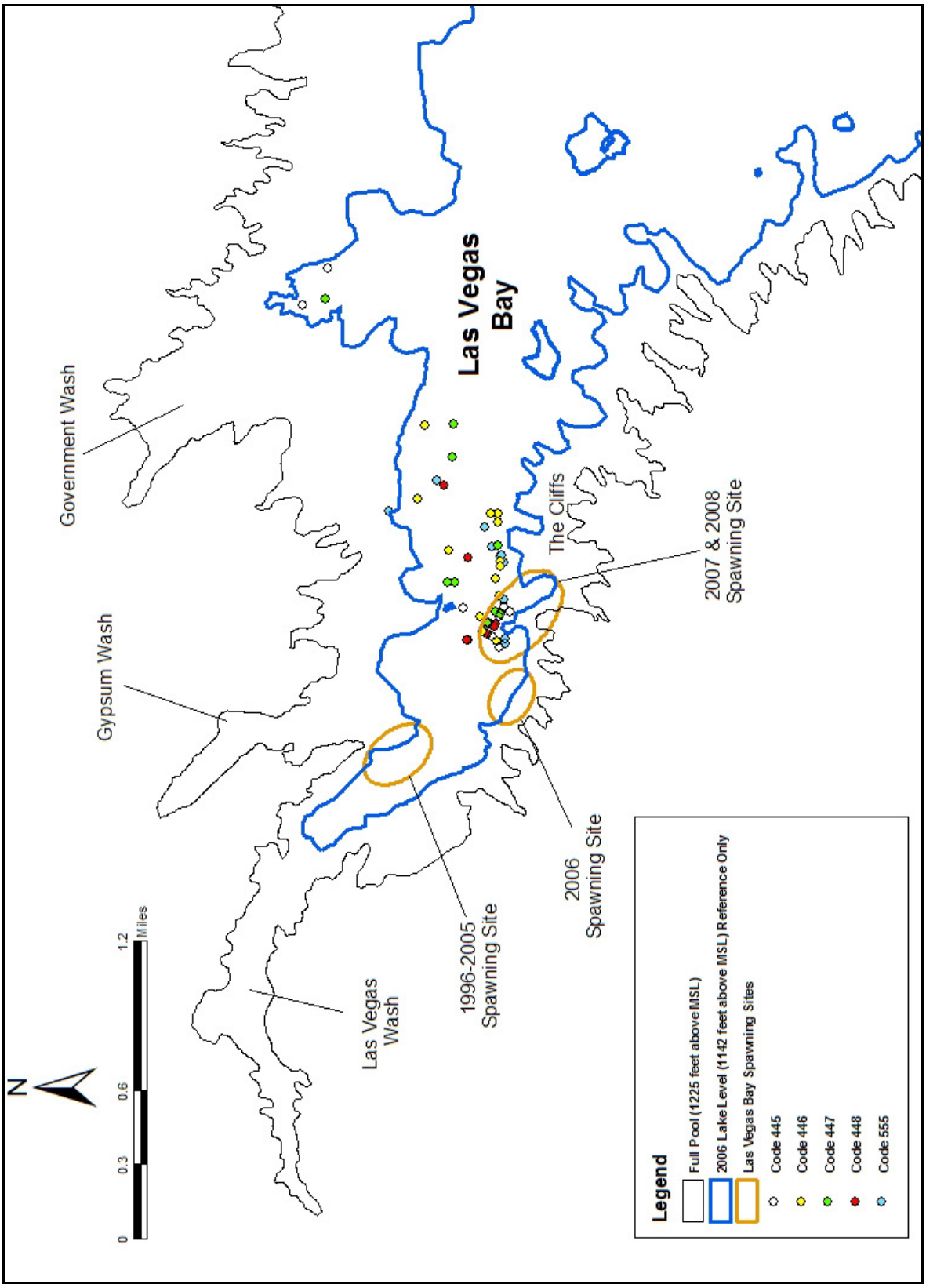

Figure 7. Distribution of sonic-tagged fish numbers 445, 446, 447, 448, and 555 in Las Vegas Bay during the 2007–2008 Lake Mead study season.

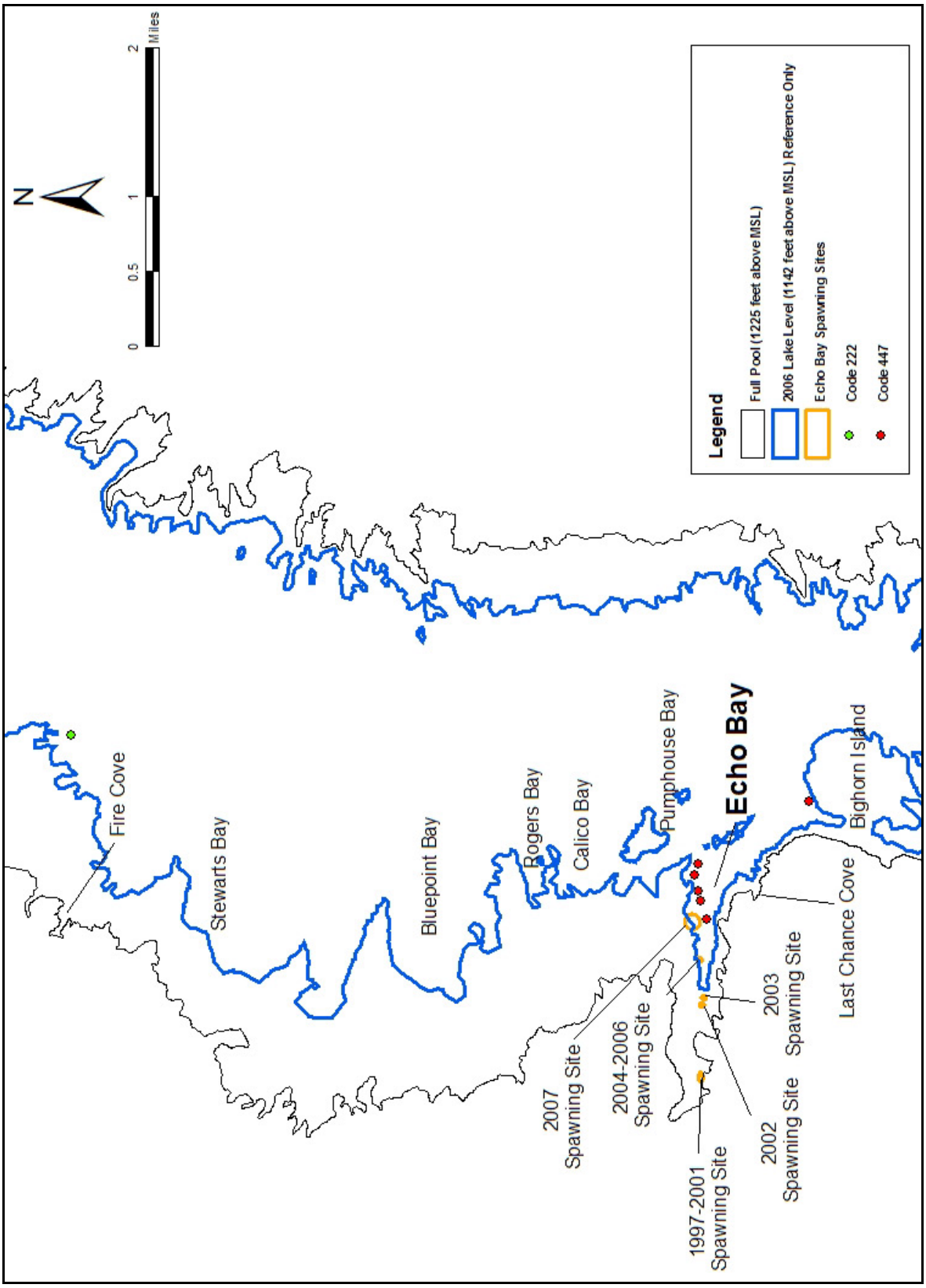

Figure 8. Distribution of sonic-tagged fish numbers 222 and 447 in Echo Bay during the 2007–2008 Lake Mead study season.

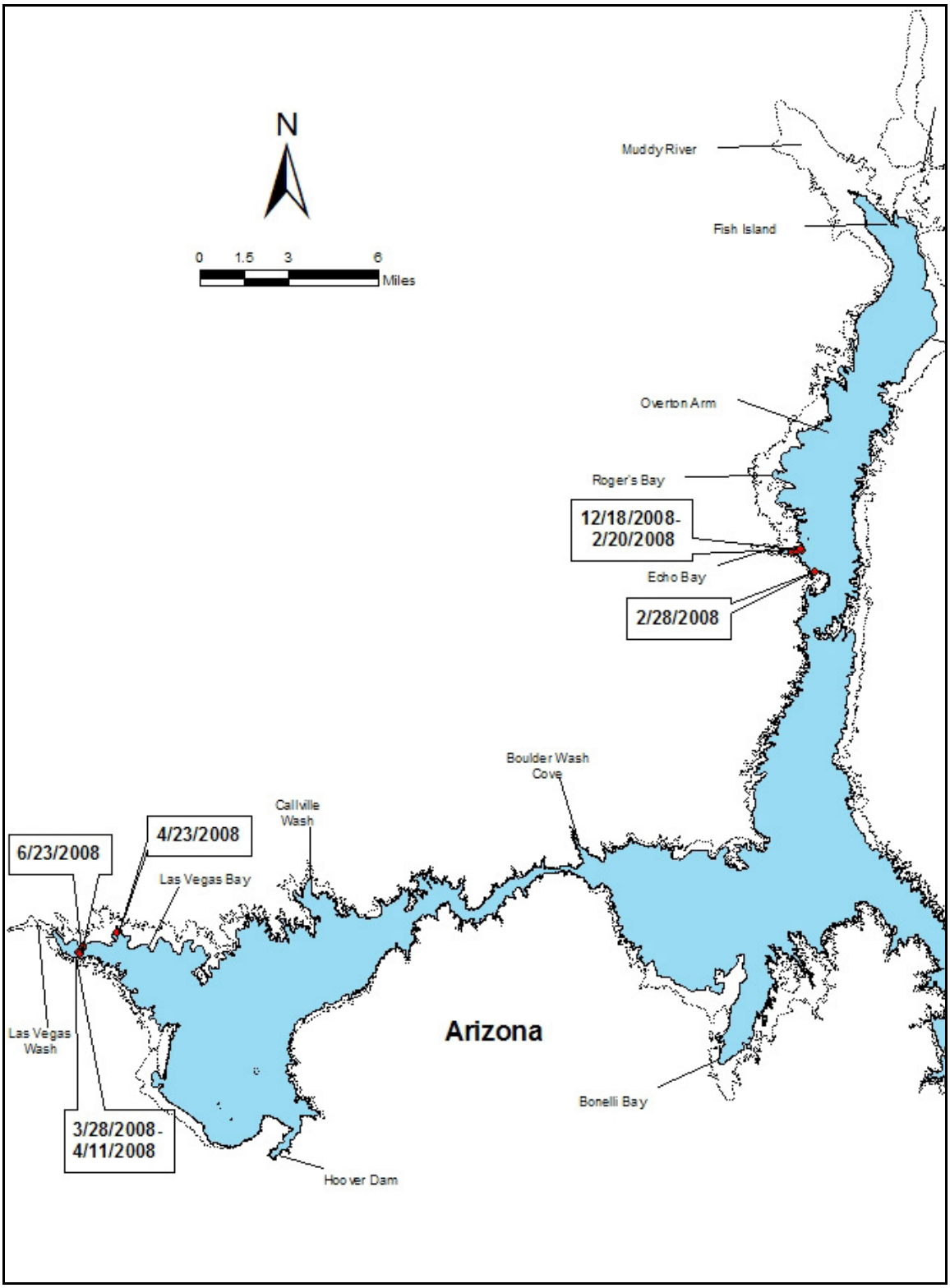

Figure 9. Distribution of sonic-tagged fish number 447 throughout Lake Mead and corresponding dates wherein this fish was located.

Fish 448

Sonic fish 448 was located via sonic telemetry on six occasions (Figure 7), primarily in the vicinity of the 2007–2008 Las Vegas Bay spawning site. The average depth at which fish 448 was located was 27.2 ft. This fish was commonly found close to sonic fish 555. Fish 448 is classified as active, and we are hopeful that it will continue providing habitat and movement data during the 2008–2009 field season.

Fish 555

Throughout the 2007–2008 field season on Lake Mead, fish 555 was located 14 times (Figure 7). All contacts were in Las Vegas Bay in the vicinity of the 2007–2008 spawning site. Average depth at contact was 34.3 ft. Sonic fish 555 is often found close to fish 448. These two individuals consistently provided locations where razorback sucker were likely concentrated, which lead to increased netting success and larval fish captures. Fish 555 is currently classified as active, and continues to provide valuable data.

Echo Bay Area

Other than sonic fish 447, whose movements were reported in detail in the previous section, only one other sonic fish was located in the vicinity of Echo Bay. Sonic fish 222 was located once during the 2007–2008 field season, north of Echo Bay near Blue Point Bay in the Overton Arm on 20 July, 2007 (Figure 8). The fish was located in approximately 36 ft of water. Because this fish has not been located since, its current status is unknown. However, we believe it is likely that the sonic tag has expired. Albrecht et al. (2006a) indicated that sonic fish 222 was the only remaining sonic-tagged fish from the 2004 implantations. There is no reason to believe that the fish is a mortality, based on the findings in Albrecht et al. (2007), in which seven previously sonic-tagged fish were captured in trammel nets. Two of these individuals had inactive tags from surgical events occurring in 2003 and 2004. Although both tags were inactive, the fish appeared healthy and were apparently participating in spawning activities at time of capture (Albrecht et al. 2007).

Muddy River/Virgin River Inflow Area

Fish 444

Contact was established with fish 444 on one occasion during the 2007–2008 field season (Figure 10). The fish was located in approximately 7 ft of water in the same location it was found the previous field season. Based on results reported by Albrecht et al. (2007), coupled with the data point collected in 2008, fish 444 has not moved from this current location since 7 March, 2007. Contact this season further supports the thought that this fish is either a mortality or has shed its sonic tag. At this time it is thought that the fish and/or sonic tag may now be on dry land because of the last known location of the tag and the shallow water conditions near the Muddy River inflow area. Contact has not been established since 13 February, 2008.

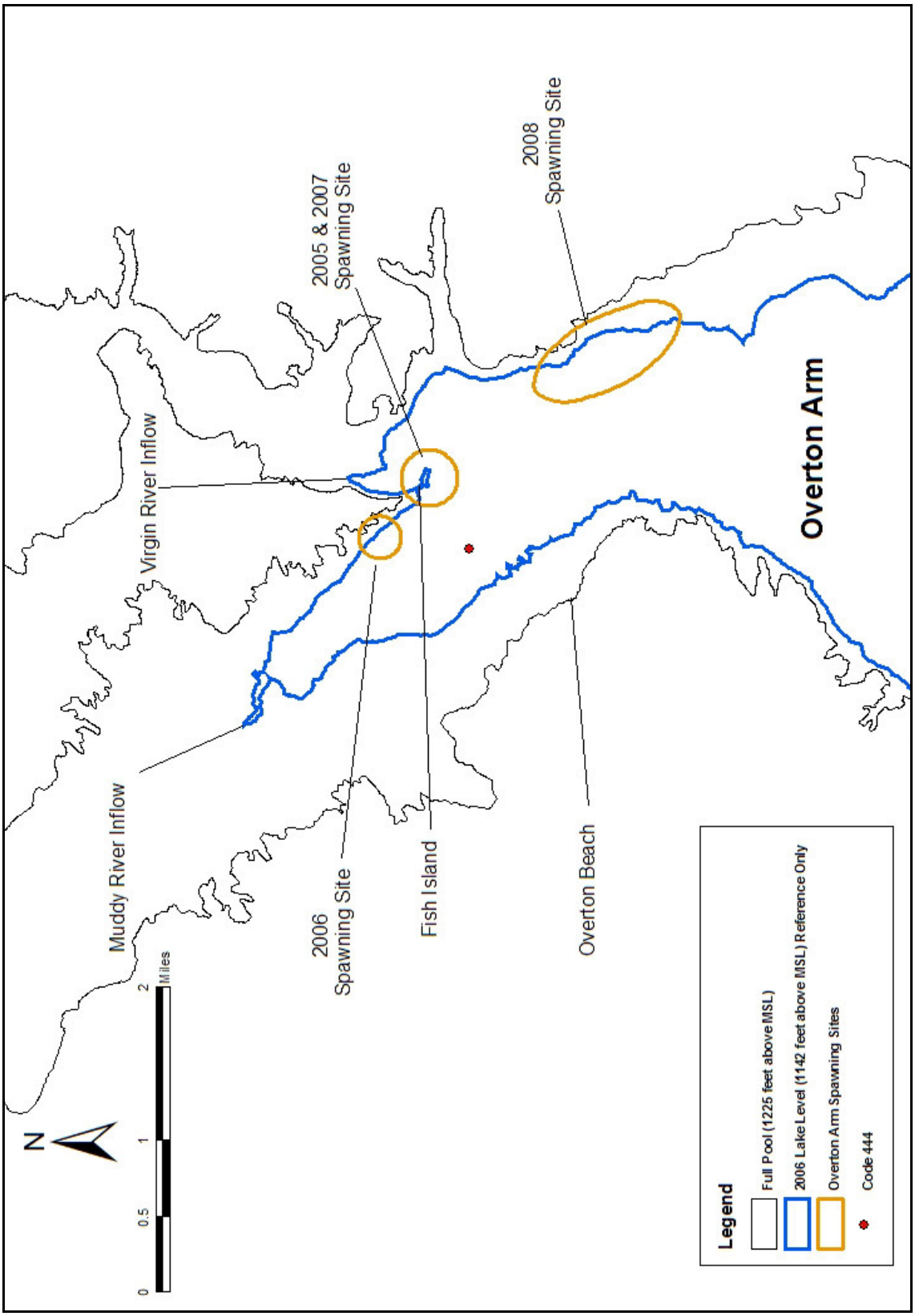

Figure 10. Distribution of sonic-tagged fish number 444 in the Muddy River/Virgin River inflow during the 2007–2008 Lake Mead study season.

Telemetry Summary

During the 12th study year, the habitat use and movements of seven sonic-tagged fish were monitored, which provided a total of 63 separate location points. One of the sonic-tagged fish was a residual fish (code 222) from the 2004–2005 tagging event, while the remaining six fish were the result of the 2005–2006 tagging efforts. 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 at the primary study areas of Lake Mead (Figures 7 and 10). Along with spawning location information, sonic-tagged fish provided valuable data on movement patterns within Las Vegas Bay and Echo Bay. As described in detail above, one sonic-tagged fish was documented moving between Echo Bay and Las Vegas Bay. In fact, this individual (fish 447) was observed making this migration twice during the 2007–2008 sampling year (Figure 9).

The average depth at which tagged fish were located throughout all portions of Lake Mead was 30.5 ft, with minimum and maximum depths of 1 and 74 ft. A comparison of depths used by tagged fish amongst Las Vegas Bay, Echo Bay, and the Muddy River/Virgin River inflow area showed no significant differences (Figure 11). Conversely, and as shown in previous reports, (Albrecht et al. 2006a and Albrecht et al. 2007), Echo Bay fish have been known to inhabit deeper water compared with fish in Las Vegas Bay and the Muddy River/Virgin River inflow area (ANOVA, $p<0.01$; Tukey post hoc test, $p<0.05$) (Albrecht et al. 2006a, Albrecht et al. 2007). Albrecht et al. (2006a, 2007) explained that the differences observed with the Echo Bay sonic-tagged fish were likely related to the Echo Bay sonic-tagged fishes' propensity to demonstrate diel migration behavior, with movement patterns typically observed between the profundal areas surrounding Echo Bay and the relatively shallower bay itself (Albrecht et al. 2006a). However, during the 2007-2008 sampling season this was not the case. At all three locations (Las Vegas Bay, Echo Bay, and Muddy River/Virgin River inflow area) sonic fish were found to be at similar depths. Admittedly, this may be a function of small sample size for Echo Bay and the Muddy River/Virgin River inflow areas.

As noted previously, many of the 48-month sonic tags have failed or expired early, leaving relatively few sonic-tagged fish available for tracking purposes. Fish tagged in 2005 will expire in 2009 assuming the tags last the full 48 months. The only consistent sonic tag results are those from Las Vegas Bay. The interaction once found between fish in the upper portion of the lake can no longer be documented because the tags have expired in those fish. Without sonic-tagged fish, locating spawning sites is very difficult. Without this tool locating spawning sites are based on previous year's findings, but this can be especially difficult considering many of the spawning sites from the previous year dry up as lake levels drop. Tracking the movement of fish and the integration of stocked fish into wild fish populations is important to understand the factors that may be critical for the growth, reproduction, and recruitment of the razorback sucker in Lake Mead. As spawning sites change and populations migrate, it will be important to locate these aggregates to efficiently and effectively document the success of the population in years to come.

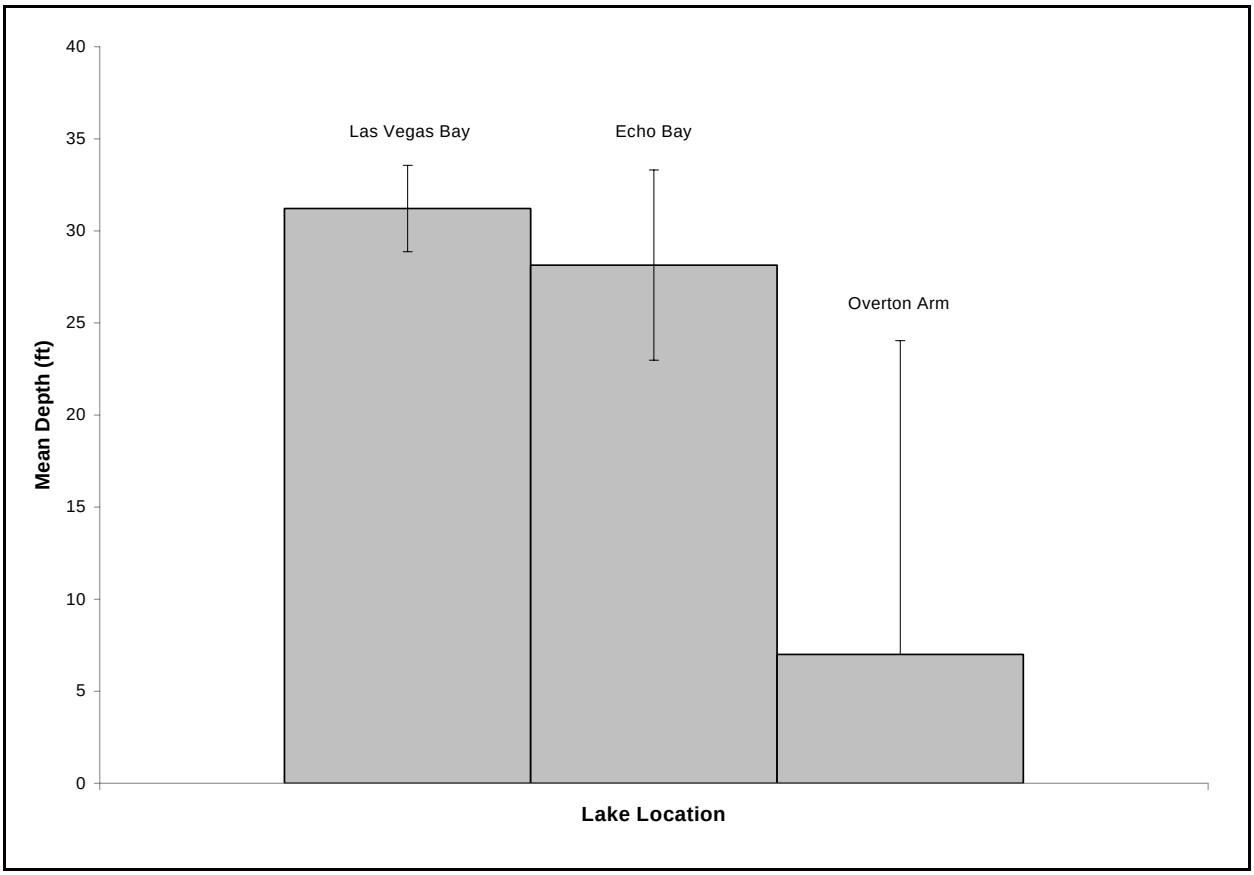

Figure 11. Average depths at which sonic-tagged fish were located during the 2007–2008 Lake Mead study season. Note: error bars indicate one standard error and that A and B refer to Tukey post hoc significance groupings.

Larval Sampling

Sampling for razorback sucker larvae was initiated on February 11, 2008. Typically, 8 to 12 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 2008. Larvae were first collected on February 25, 2008, at Las Vegas Bay over gravel/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 location identified as a primary spawning location by Albrecht et al. (2007). The 2008 data confirms continued use of that relatively new spawning location (Figure 12). Las Vegas Bay yielded a total of 405 larval fish, within 942 minutes of sampling, providing a catch per minute (CPM) value of 0.430 (Table 5). Overall, the CPM of razorback sucker larvae at Las Vegas Bay, was higher in 2008 than in 2007 or 2006 (Table 6).

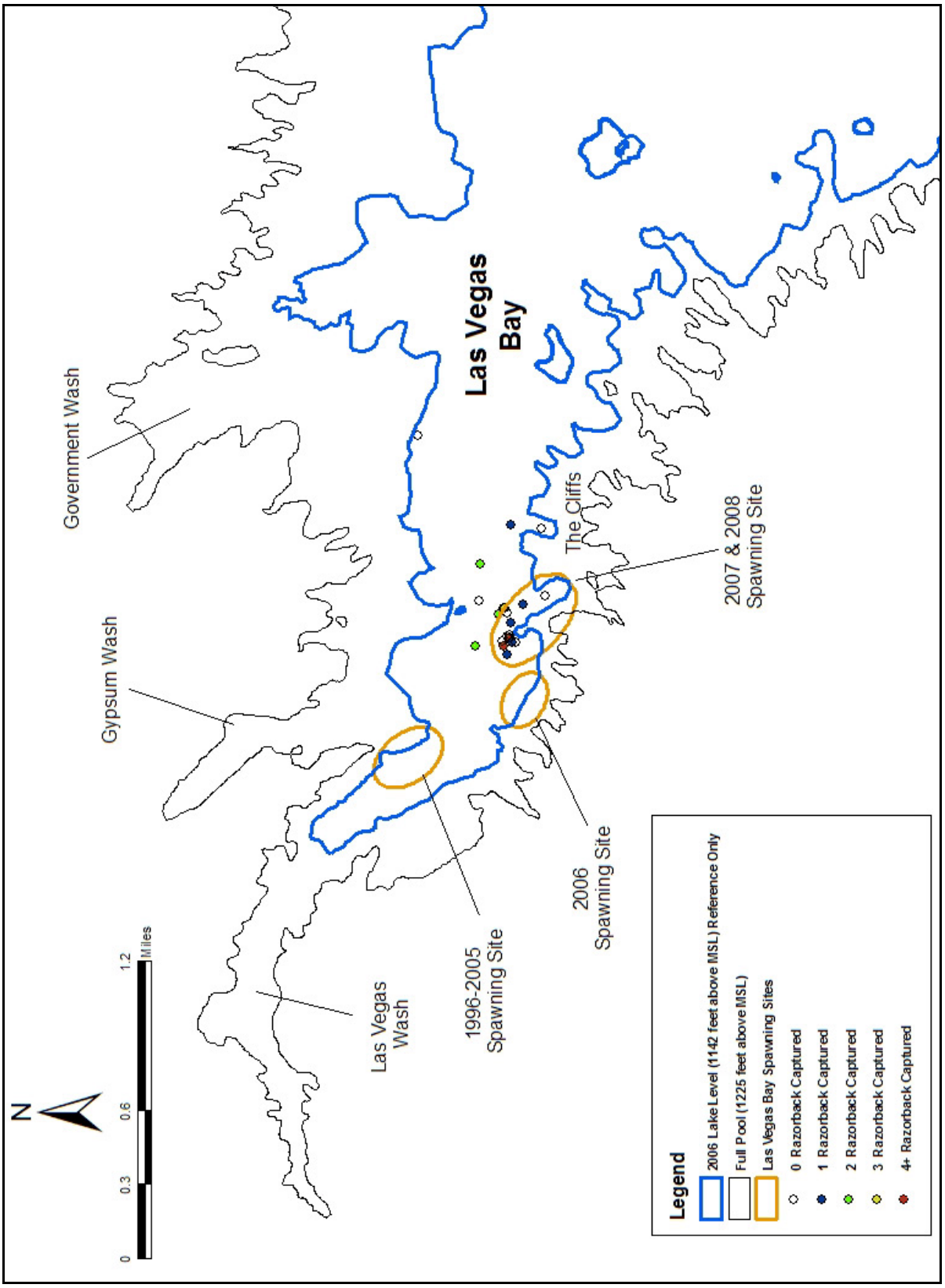

Figure 12. Las Vegas Bay study area showing larval razorback sucker sample and capture locations, 2008.

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 2008.

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
2/11/08	42	0	0.000						
2/12/08							30	0	0.000
2/14/08				90	0	0.000			
2/18/08	105	0	0.000						
2/19/08	90	0	0.000						
2/21/08				75	0	0.000			
2/25/08	90	1	0.011						
2/26/08							90	0	0.000
2/27/08				90	0	0.000			
2/28/08				90	0	0.000			
3/4/08							75	0	0.000
3/6/08	90	130	1.444						
3/17/08	90	83	0.922						
3/18/08				90	0	0.000			
3/19/08				75	12	0.160			
3/24/08							90	3	0.033
3/25/08							90	4	0.044
3/26/08				95	0	0.000			
3/31/08							75	48	0.640
4/1/08				105	8	0.076			
4/2/08	90	70	0.778						
4/3/08	90	47	0.522						
4/7/08	90	43	0.478						
4/9/08	90	26	0.289						
4/10/08				90	1	0.011			
4/14/08				75	1	0.013			
4/21/08							95	8	0.084
4/22/08				90	1	0.011			
4/23/08	75	5	0.067						
Totals	942	405	0.430	965	23	0.024	545	63	0.116

[a] CPM = Catch per minute.

Table 6. Larval razorback sucker catch-per-minute (CPM) comparisons by primary sampling location for 2006–2008.

PRIMARY SAMPLING LOCATION	2006	2007	2008
Las Vegas Bay	0.012	0.39	0.43
Echo Bay	0.29	0.43	0.024
Muddy River/Virgin River inflow	0.003	0.001	0.116

At Echo Bay the first razorback sucker larvae were captured on March 19, 2008, with minimal and sporadic success throughout the rest of the season. Efforts in Echo Bay returned a total of 23 larval fish with a CPM of 0.024 in 2008 (Table 5). The larval fish were found on both the north and south shorelines, within and around the marina infrastructure (Figure 13). The 2008 Echo Bay larval captures showed a decline from the 2007 and 2006 seasons (Table 6). Furthermore, larval captures in 2008 account for the lowest CPM values ever recorded at Echo Bay since the onset of our studies in 1996. Because there was an overall lack of consistent larval captures at Echo Bay, coupled with limited trammel netting captures of adult razorback sucker and the lack of sonic-tagged fish in this area, we were unable to identify a primary spawning location for the 2008 spawning period.

At the Muddy River/Virgin River inflow areas, the first razorback sucker larvae for the season were captured on March 24, 2008, across the bay from Fish Island north of the old Overton marina. However, throughout the rest of the season the majority of larval fish in the Overton Arm site came from a cobble bar approximately 400 m south of the Virgin River inflow (Figure 14). Interestingly, larval fish were not limited to the cobble/gravel area, but were also common within the sandy and silted areas immediately south of the Virgin River inflow. In 2008 most larvae were collected along the east shore of the Overton Arm, just south of the Virgin River inflow, with only six individuals captured on the west shore near the old marina. No larvae were captured north of Fish Island, the historical spawning site at this location. Larval captures followed multiple wild sub-adult and adult razorback sucker captures while trammel netting in the vicinity (Table 5 and Figure 14). During the 12th study year, the Overton Arm experienced elevated larval fish captures compared to previous years. A total of 63 larval fish were collected generating a CPM of 0.116, the highest rate observed in this location to date (Tables 5 and 6).

Annual Spawning Site Identification and Observations

Decreasing lake levels during the last 8 years influenced habitat conditions in all areas where razorback sucker sampling activities have occurred during this 12-year study. As of June 1, 2008, the lake elevation was at 1,107 ft amsl, compared with 1,113 ft amsl recorded the previous year on this same date (Figure 15). As a result of decreasing lake levels, Lake Mead razorback sucker shifted spawning site locations to accommodate varying conditions.

During the 2005–2006 study year, razorback sucker were found to use a new spawning location in Las Vegas Bay for the first time during our studies (Albrecht et al. 2006a). This was the result of receding lake levels and the dessication of the historical spawning site (Blackbird Point [Albrecht et al. 2006a]). This report documents another and/or continued shift in the primary spawning location of razorback sucker in the Las Vegas Bay/Las Vegas Wash portion of Lake Mead. The primary spawning location during the 2005–2006 field season was located 500 m south of the wash inflow area, along the southwestern shoreline of the bay (Albrecht et al. 2006a). For the past 2 years the razorback's primary spawning site was in the same general vicinity, approximately 150 m further southeast, of the 2006 spawning location (Figure 12). Figure 12 shows that larval razorback sucker were captured in surrounding locations; however,

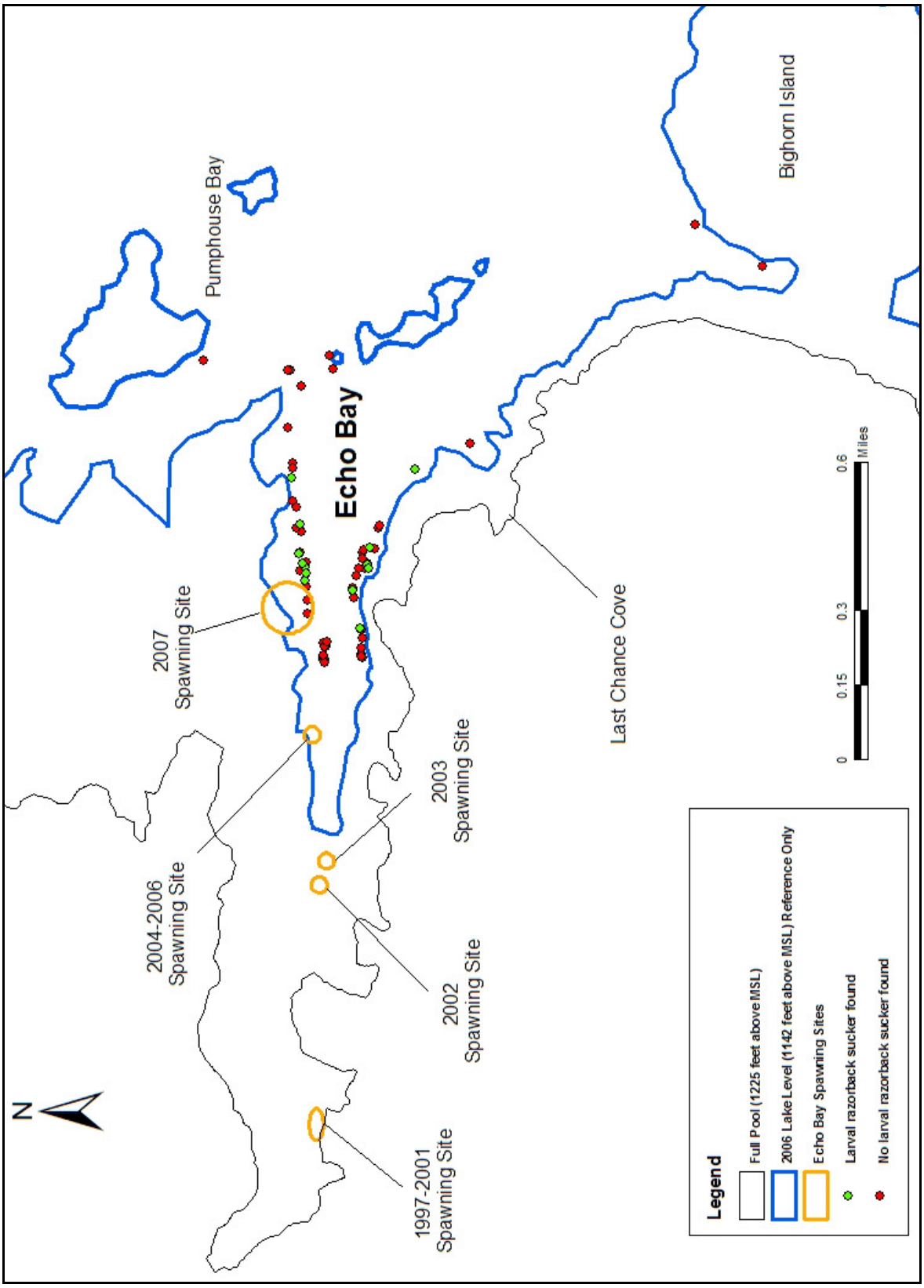

Figure 13. Echo Bay study area showing larval razorback sucker sample and capture locations, 2008.

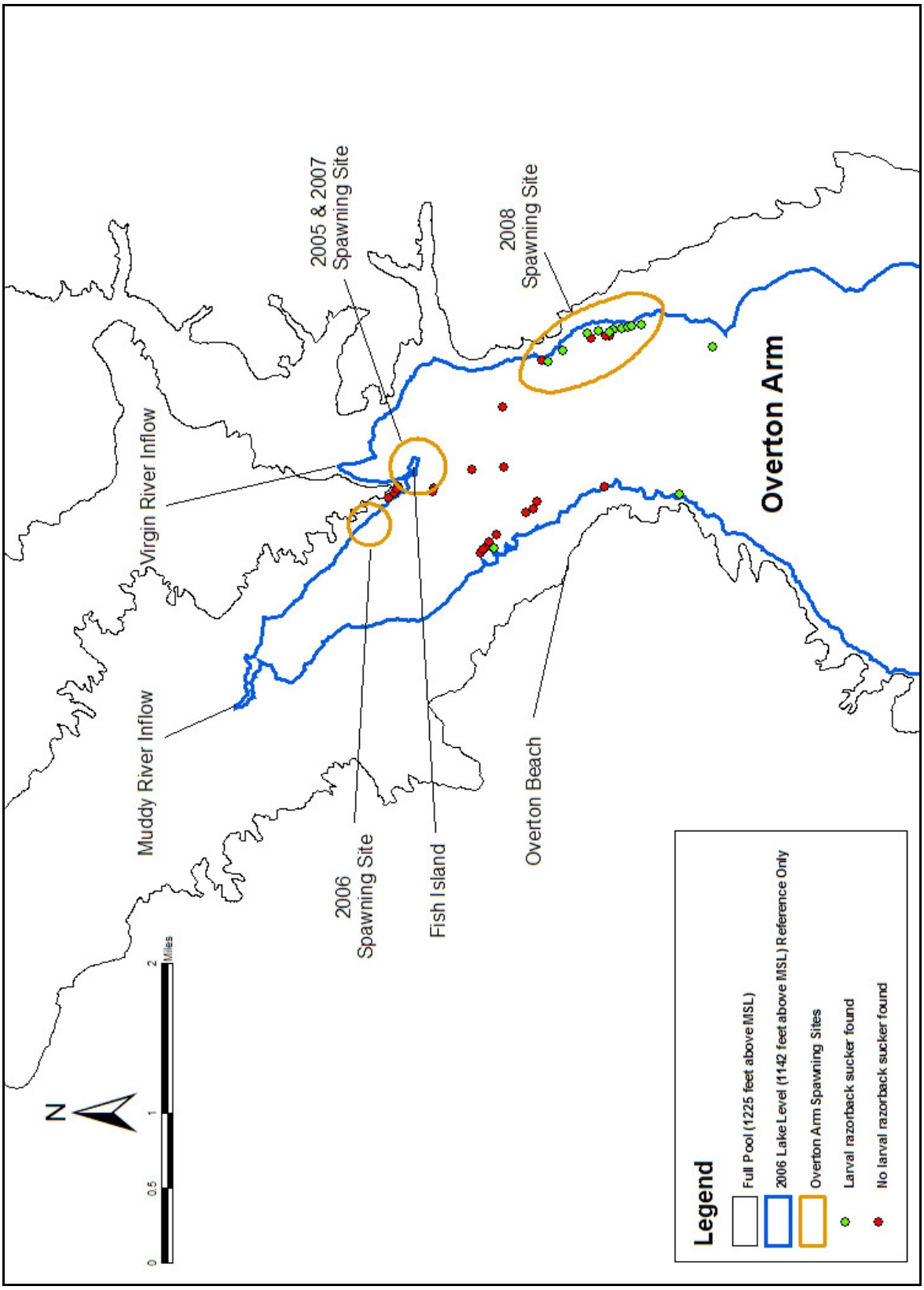

Figure 14. Muddy River/Virgin River inflow area showing larval razorback sucker sample and capture locations, 2008.

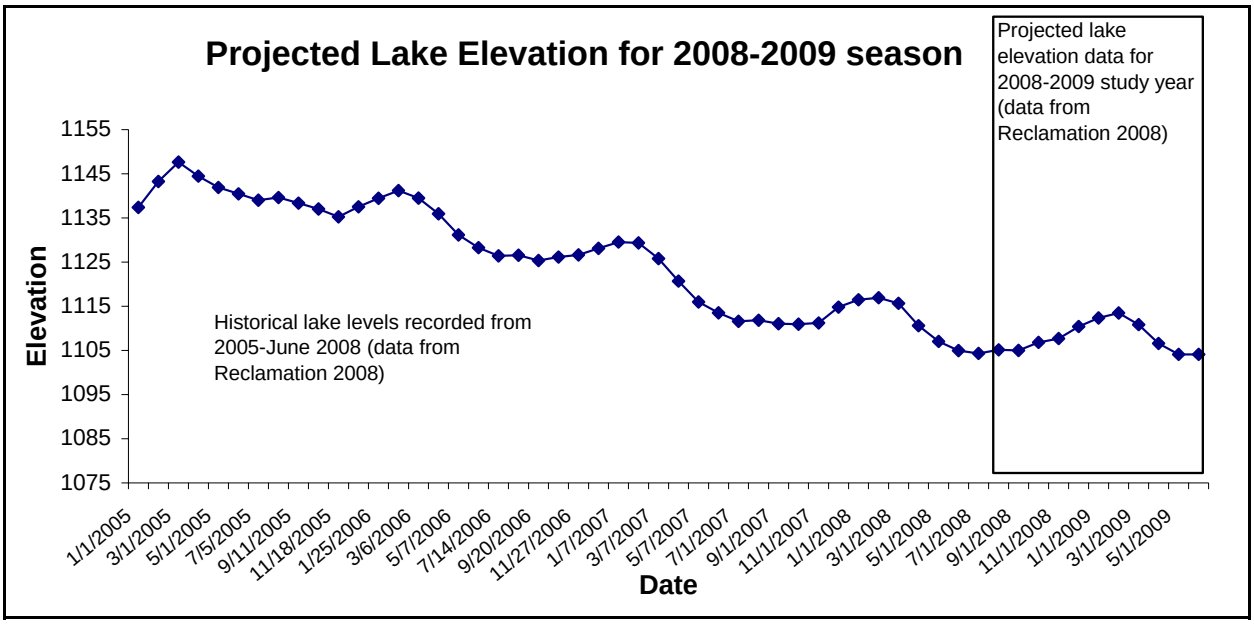

Figure 15. Lake Mead elevations using a combination of actual, recorded and historical lake elevation data, as well as projected lake elevation for the 2008–2009 study period.

the vast majority of larval captures (95%) occurred within the identified primary spawning location.

As described in past annual reports (Welker et al. 2003, 2004; Albrecht et al. 2005; Albrecht et al. 2006a), receding lake levels have resulted in frequent shifting of the primary Echo Bay spawning site in an eastward (down the bay) direction. Based on data from this spawning season a defined spawning site could not be established (Figure 13). Because of the lack of sonic locations, captured adults, and larval fish observations, spawning success of razorback sucker in Echo Bay during the 2008 season can only be assumed. The distribution of larval fish captures included a broad area of Echo Bay. Densities and total number of larval razorback sucker (23) were low and distributed evenly among the north and south shorelines, precluding us from pinpointing a primary spawning area in 2008. During the 2008 spawning season, an effort by the Echo Bay concessionaire was initiated to move the marina and create more proximal parking to the marina services. The associated disturbance of the northern shoreline may have contributed to a lack of adult and larval captures in Echo Bay. Furthermore, we observed that a layer of fine silt was deposited in the water, apparently from the construction along the northern shoreline of Echo Bay. As indicated above, the overall size and complexity of the habitats at Echo Bay appears to be declining as lake elevations decline over time. Lower lake elevations have reduced the overall size of Echo Bay and spawning locations 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 happening with the Las Vegas Bay spawning site in 2003, 2004, and 2005. As a 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 and we remain hopeful to document a primary spawning site in 2009.

In comparison to Echo Bay and Las Vegas Bay, relatively little is known regarding the spawning aggregate utilizing the Muddy River/Virgin River inflow area of Lake Mead. Similar to the 2006–2007 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 63 larval fish confirmed successful spawning in the northern area of the lake. The spawning location in the inflow region of the Muddy and Virgin rivers was approximately 400 m south of the Virgin River inflow on a gravel/cobble bar located along the eastern shoreline (Figure 14). This location was ascertained with a combination of adult/subadult razorback sucker captures and the collection of larval fish. This differs considerably from the previous spawning sites established for the 2005, 2006 and 2007 study years, wherein the primary spawning areas 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 locations, and the degree to which successful spawning is occurring in the Muddy River/Virgin River inflow. 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 the overall Lake Mead razorback sucker population dynamics.

Razorback Sucker Aging

Fifty-four of the razorback sucker collected by trammel netting on Lake Mead during the 2008 sampling period had fin ray sections surgically removed for age determination. A definitive age was obtained for all 54 fish (Table 7 and Figure 16). Forty of the 54 specimens (74%) were aged at 7 years or less, with the remainder aging between 8 and 36 years. Fish aged at 3 and 4 years old were most common among the specimens obtained this season. The oldest fish aged this year (36 years old) came from Las Vegas Bay, a 655 mm TL male fish. The youngest fish aged in 2008 were two immature razorback sucker captured near the Muddy River/Virgin River inflow area. Both fish were found to be 2 years of age (2006 year class). These two individuals are the youngest (and smallest) fish that have been captured on Lake Mead during the course of our studies. The lengths of these fish were 271 mm TL and 229 mm TL, respectively. As indicated in Table 2 and elsewhere, the 271 mm TL fish was a mortality. This fish was found dead upon retrieval of our net set and the carcass displayed obvious evidence of predator-induced injuries. This is the first direct mortality related to trammel netting efforts on Lake Mead since the onset of our study in 1996. However, in a more positive light, we were able to obtain an otolith from this specimen for age validation purposes. Both the otolith and fin ray were aged from this specimen. Both structures were evaluated independently and blindly by three readers with both specimens unanimously being determined to be 2 years of age, which confirms the effectiveness of using fin rays as a method for aging Lake Mead razorback sucker.

Table 7. Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead.

DATE COLLECTED	TOTAL LENGTH (mm[a])	AGE	PRESUMPTIVE YEAR SPAWNED
		LAS VEGAS BAY	
05/10/1998	588	10[b]	1987
12/14/1999	539	13	1986
12/14/1999	606	17+	1979–1982
12/14/1999	705	19+	1977–1980
01/08/2000	650	18+	1978–1981
02/27/2000	628	17+	1979–1982
01/09/2001	378	6	1994
02/07/2001	543	11	1989
02/22/2001	585	13	1987
12/01/2001	576	8–10	1991–1993
12/01/2001	694	22	1979
12/01/2001	553	10	1991
02/02/2002	639	16	1985
03/25/2002	650	22	1979
03/25/2002	578	10–11	1990–1991
03/25/2002	583	22–24	1977–1979
03/25/2002	545	20[b]	1982
03/25/2002	576	20	1982
05/07/2002	641	15	1986
06/07/2002	407	6	1995
06/07/2002	619	20[b]	1982
06/07/2002	642	20[b]	1982
12/03/2002	354	4	1998
12/06/2002	400	4	1998
12/06/2002	376	4	1998
12/19/2002	395	4	1998
01/07/2003	665	16	1986
01/22/2003	494	4	1998
02/05/2003	385	4	1998
02/18/2003	443	5	1997
03/04/2003	635	19	1983
03/20/2003	420	4	1998
04/08/2003	638	21[b]	1982
04/17/2003	618	10	1992
04/22/2003	650	20–22	1980–1982
05/04/2003	415	3+[c]	1999
03/03/2004	370	5	1998
02/22/2005	529	6	1998
02/22/2005	546	6	1998
03/29/2005	656	16	1989
01/26/2006	740	15	1991
02/21/2006	621	23	1983
03/23/2006	461	5	2001
03/23/2006	718	16	1990
03/31/2006	635	7	1999
03/31/2006	605	6	2000
04/04/2006	629	6	2000

Table 7. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm[a])	AGE	PRESUMPTIVE YEAR SPAWNED
		LAS VEGAS BAY (Cont.)	
04/25/2006	452	4	2002
04/25/2006	463	4	2002
01/30/2007	514	5	2002
02/06/2007	519	5	2002
02/06/2007	574	8	1999
02/13/2007	526	5	2002
02/16/2007	530	5	2002
02/20/2007	534	6	2001
02/21/2007	358	3	2004
02/21/2007	511	5	2002
02/27/2007	645	13	1994
02/27/2007	586	15	1992
02/27/2007	603	13	1994
02/27/2007	650	17	1990
03/06/2007	515	4	2003
03/06/2007	611	13	1994
03/06/2007	565	6	2001
03/13/2007	586	7	2000
03/13/2007	636	25	1982
03/13/2007	524	5	2002
04/02/2007	704	9	1998
04/09/2007	644	11	1996
02/12/2008	425	3	2005
02/12/2008	390	3	2005
02/12/2008	490	3	2005
02/12/2008	430	4	2004
02/12/2008	379	4	2004
02/12/2008	399	4	2004
02/12/2008	430	4	2004
02/12/2008	413	4	2004
02/12/2008	554	9	1999
02/12/2008	426	9	1999
02/18/2008	385	3	2005
02/25/2008	605	6	2002
02/25/2008	655	36	1972
04/03/2008	468	4	2004
04/03/2008	619	7	2001
04/03/2008	640	10	1998
04/03/2008	560	11	1997
04/08/2008	423	3	2005
04/08/2008	535	6	2002
04/10/2008	422	3	2005
04/10/2008	375	3	2005
04/10/2008	452	4	2004
04/10/2008	472	4	2004
04/10/2008	467	4	2004
04/10/2008	429	5	2003
04/23/2008	430	4	2004

Table 7. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm[a])	AGE	PRESUMPTIVE YEAR SPAWNED
		ECHO BAY	
01/22/1998	381	5	1993
01/09/2000	527	13	1987
01/09/2000	550	13	1987
01/09/2000	553	13	1987
01/09/2000	599	12–14	1986–1988
01/27/2000	557	13	1986
01/27/2000	710	19+	1979–1981
02/09/2001	641	13	1988
02/24/2001	577	18+	1980–1982
02/24/2001	570	8	1992
02/24/2001	576	15	1986
02/24/2001	553	18	1983
12/18/2001	672	13	1988
02/27/2002	610	18–20	1982–1984
03/26/2002	623	16	1986
04/02/2002	617	35+	1966–1968
04/17/2002	583	20[b]	1982
05/02/2002	568	18–19	1983–1984
11/18/2002	551	13	1989
12/04/2002	705	26	1976
01/21/2003	591	16	1986
02/03/2003	655	27–29	1974
02/03/2003	580	13	1989
04/02/2003	639	19–20	1982
04/02/2003	580	23–25	1978
04/23/2003	584	10	1992
05/06/2003	507	9+	1993
05/06/2003	594	20	1982
12/18/2003	522	20	1982
01/14/2004	683	14	1989
02/18/2004	613	10	1993
03/17/2004	616	19	1983
03/17/2004	666	17	1985
03/17/2004	618	9	1994
04/06/2004	755	17	1985
03/02/2005	608	15	1990
03/02/2005	624	8	1996
01/10/2006	630	12	1994
02/01/2006	705	16	1990
02/16/2006	601	22	1984
01/11/2007	535	5	2002
01/11/2007	493	5	2002
02/01/2007	637	7	2000
02/08/2007	609	12	1995
02/14/2007	501	4	2003
03/02/2007	590	11	1996
03/09/2007	660	12	1995

Table 7. (Cont.)

DATE COLLECTED	TOTAL LENGTH (mm[a])	AGE	PRESUMPTIVE YEAR SPAWNED
		ECHO BAY (Cont.)	
03/16/2007	691	21	1986
03/28/2007	564	13	1994
02/28/2008	640	25	1983
02/29/2008	635	8	2000
03/05/2008	653	24	1984
03/19/2008	532	6	2002
03/19/2008	510	7	2001
		MUDDY RIVER/VIRGIN RIVER INFLOW AREA	
02/23/2005	608	6	1998
02/22/2006	687	33[d]	1973
02/22/2007	452	4	2003
02/22/2007	542	5	2002
02/22/2007	476	5	2002
02/22/2007	459	4	2003
02/22/2007	494	5	2002
03/01/2007	477	5	2002
03/01/2007	512	4	2003
03/08/2007	463	5	2002
03/08/2007	455	4	2003
03/15/2007	516	4	2003
04/03/2007	508	4	2003
04/11/2007	498	7	2000
02/27/2008	465	4	2004
02/27/2008	670	20	1988
03/205/2008	530	6	2002
03/25/2008	271	2[e]	2006
03/26/2008	345	3	2005
03/26/2008	541	7	2001
03/26/2008	521	7	2001
03/26/2008	665	18	1990
04/01/2008	229	2	2006
04/01/2008	370	3	2005
04/01/2008	360	3	2005
04/01/2008	385	4	2004
04/01/2008	514	5	2003
04/01/2008	536	5	2003
04/01/2008	514	6	2002
04/01/2008	548	6	2002
04/01/2008	518	7	2001
04/01/2008	530	7	2001
04/01/2008	494	8	2000
04/01/2008	535	9	1999
04/01/2008	559	10	1998
04/22/2008	533	6	2002
04/22/2008	504	6	2002

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

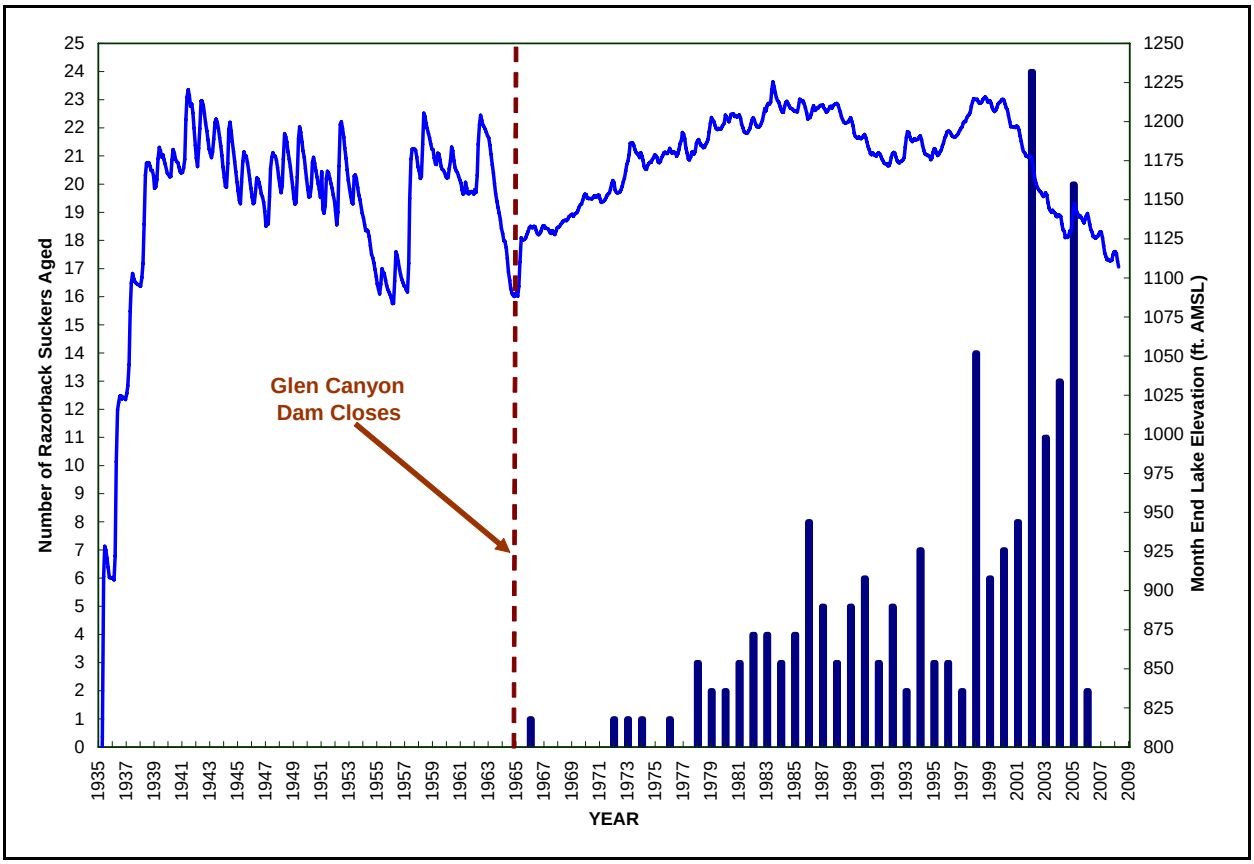

Figure 16. Lake Mead hydrograph from January 1935 to June 2008 with the number of aged razorback sucker that were spawned each year.

Only in the last 2 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. 2006a, Albrecht et al. 2007, Albrecht et al. 2008). This year (2008) marks the first time that we have captured and aged a razorback sucker from Lake Mead that was back-calculated to have been spawned as recently as 2006, another low-water year.

Table 6 shows the ages of 132 fish previously aged and the additional 54 fish aged in 2008. Figure 16 shows the number of razorback sucker recruits per year plotted against Lake Mead elevations from January 1935 to May 2008. All of the fish aged were spawned between 1973–2006, with the exception of one fish that was spawned around 1966. Until the last few seasons, the majority of fish aged were spawned during high-lake elevations between the 1978–1989 and 1997–1999 periods. However, our most recent data show recruitment occurring beyond 1999, which coincides with the steady decline in lake levels during recent years. Based on data obtained this season, 2002–2005 appears to be one of the better series of years for recruitment, despite dropping lake levels. 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 monitoring data documents natural, wild recruitment within the Lake Mead razorback sucker population as recently as 2006. As future monitoring continues there is no reason to suspect this trend in continued recruitment will cease, and we anticipate that fish spawned during the 2007 and 2008 spawning seasons will become susceptible to sampling gear within the next few years.

Population Estimate

As indicated in Albrecht et al. (2006a) we initially 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, we have included population estimation information this season simply from an informative and purely demonstrative standpoint. We strongly caution basing any management decisions solely on the population estimation information provided below because of the violations of many of the assumptions involved with closed-model population estimation techniques, which are more fully described by Albrecht et al. (2006a).

With regard to the 2008 Lake Mead razorback sucker population estimates, note that we can no longer categorize Echo Bay as a closed population, or as one separate from the Muddy River/Virgin River spawning aggregate, because there are 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, 2008) as well as this report. Hence 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, as an addition, a lake-wide population estimate is reported for comparative purposes. With the movement of fish from Las Vegas Bay to Echo Bay and the connection with populations from Echo Bay and the Muddy River/Virgin River Inflow area this could be a feasible method for estimating the razorback sucker population. Additional data on fish movement will be needed to support lake-wide estimations alone. Of additional interest, and as described previously in the trammel netting section of this report, CPUE was elevated this year in Las Vegas Bay and the Muddy River/Virgin River inflow area. This increase in CPUE was evident for both the Las Vegas Bay and Muddy River/Virgin River primary sampling sites but was vastly elevated at the Muddy River/Virgin River inflow area. Furthermore, many of the razorbacks 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 is mentioned here again because it also reflects 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 the number of newly captured individuals drastically declined compared to previous years, all of which affect population estimates lake-wide and more specifically for the northern portion of Lake Mead.

Table 8 shows the results of the 2008 Lake Mead population estimation using two models from the program CAPTURE (Rexstad and Burnham 1992), as well as estimates from the model selection procedure. The Echo Bay and Muddy River/Virgin River inflow combined razorback

Table 8. Population estimates using data from 2006–2008.

ESTIMATOR	2006–2008	95% CONFIDENCE INTERVAL
ECHO BAY AND MUDDY RIVER/VIRGIN RIVER INFLOW AREAS		
Model M_o	165	131-223
Chao M_h	215	149-350
Model Selection Procedure		
Jackknife	228	171-323
LAS VEGAS BAY		
Model M_o	123	97-170
Chao M_h	166	112-285
Model Selection Procedure		
Jackknife	175	128-257
LAKE WIDE		
Model M_o	278	234-343
Chao M_h	367	267-523
Model Selection Procedure		
Jackknife	430	331-584

sucker estimates ranged from a low of 131 fish to a high of 350 fish during 2006–2008. The Las Vegas Bay population estimates were lower than those of the northern end of Lake Mead, ranging from a low of 97 to a high of 285 fish. In both locations there is an apparent increase in the estimates provided (compared with past annual reports) because of the relatively large number of young and unmarked fish captured during the 2008 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 234 fish to a high of 584 fish.

Overall, population abundance remains highly variable at both study areas as well as lake-wide, 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. As shown in Figure 6, CPUE was dramatically higher this season in Las Vegas Bay and the Muddy River/Virgin River inflow area compared with past study years. Coupled with the large number of new and young fish captured this season, it appears that Lake Mead razorback sucker are 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. Likewise (and equally plausible), it is also possible that recent lower lake elevations may have concentrated fish; hence we were able to more effectively sample and capture fish during the 2008 spawning season. This may not be the case in Echo Bay; CPUE was much lower this season compared to the previous season. Extraneous influences within Echo Bay, such as construction and associated habitat alterations, or the overall loss of habitat from lower lake levels, may be influential to the lower catch rate observed at Echo Bay in 2008.

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 catch the majority 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 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 2008.

Spawning Site Water Quality Monitoring

As previously mentioned, water quality monitoring was initiated this season to establish a protocol for collecting baseline data to compare water quality among spawning sites in each of the three primary spawning areas. The long-term objective is to establish correlations to spawning site preferences and strong year classes. This data, combined with lake level fluctuations, may provide a better understanding as to recruitment success or why fish decide to move from one area of the lake to another. The ranges of all the parameters at the water's surface are reported in the vertical profiles described in the Methods section (Table 9). The water quality data will become more valuable as conditions can be related back to wild recruitment of razorback suckers at our sample sites. Comparisons to other water quality data throughout other stations within the lake would also prove beneficial. A complete data set can be made available upon request; this is only a portion of the data collected.

Table 9. Water quality results showing ranges of surface values for each primary spawning location both inshore and offshore.

LOCATION	DATE	TEMP[a]	CONDUCTIVITY[b]	DO[c]	PH	TDS[d]	DO%[e]	TURBIDITY[f]
Echo Bay Inshore	3/19/08-4/23/08	12.6-17.7	1.17-1.21	8.92-11.33	8.53-8.83	0.8	86.4-104.6	2.6-40.7
Echo Bay Offshore	3/19/08-4/23/08	12.5-17.3	1.17-1.21	9.00-10.37	8.51-9.04	0.8	88.4-95.1	0.4-10.1
Las Vegas Bay Inshore	3/18/08-4/24/08	15.7-22.4	2.03-2.78	7.32-10.55	8.25-8.71	1.3-1.8	80.5-111.2	17.2-82
Las Vegas Bay Offshore	3/18/08-4/24/08	18.5-22.1	1.75-2.82	7.99-9.42	8.47-8.74	1.1-1.8	86.4-105.3	12.2-224
Muddy River/Virgin River Inflow Inshore	3/26/08-4/22/08	15.3-19.1	1.33-1.59	8.32-10.29	8.50-8.70	0.9-1.0	90.4-103.0	5.3-40.5
Muddy River/Virgin River Inflow Offshore	3/26/08-4/22/08	15.2-17.3	1.27-1.76	8.89-9.99	8.59-8.67	0.8-0.9	93.2-100.0	4.5-25.9

[a] Temperature measured in degrees Celsius.
[b] Measured in microsiemens per centimeter (µS/cm).
[c] Dissolved oxygen measured in milligrams per liter (mg/L).
[d] Total dissolved solids measured in grams per liter (g/L).
[e] Dissolved oxygen percentage.
[f] Measured in nephelometric turbidity units (NTU).

DISCUSSION AND CONCLUSIONS

Information collected during the 2008 field season (12th study year) on Lake Mead 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 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 and provided insight to the growth rates at the Muddy River/Virgin River inflow for the first time. Also, aging data from 54 new razorback sucker collected in 2008 were added to the 132 fish aged from 1998–2007, bringing the total number of aged fish to 186 during the course of our studies and demonstrating continued recruitment as late as the 2006 spawning period.

Sonic Telemetry

Sonic telemetry proved very valuable during the 2007–2008 study year. We were able to maintain contact with most of the fish throughout the year, including 6 of the original 10 fish tagged during the 2005–2006 study year and one fish tagged from 2004–2005. Considering the amount of time in which sonic tags have been implanted and the mobility of razorback sucker, the proportions of 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 Las Vegas Bay and the northern spawning locations). As documented in previous reports (Albrecht et al. 2006a), razorback sucker appear to move frequently between Echo Bay and the Muddy River/Virgin River inflow region of Lake Mead. We were also able to document movement of sonic-tagged fish between the Overton Arm and Las Vegas Bay. Mueller et al. (2000) documented similar long-range movements in Lake Mohave. It should be noted that this degree of wide-ranging movement is somewhat new to Lake Mead (Albrecht et al. 2007), as the bulk of sonic-tagged fish observed during the course of our studies have remained relatively close to their stocking/tagging locations.

Sonic-tagged fish provided invaluable data about the movement patterns and habitat use of razorback sucker in Lake Mead. The data stemming from these fish helped lead to the determination of 2008 spawning locations, 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 12), 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 locations of Lake Mead (Las Vegas Bay, Echo Bay, and the Muddy River/Virgin River inflow area) during the 2008 spawning season. In terms of numbers of larvae captured and CPUE, this most recent study year was comparable with or exceeded past study seasons (except at Echo Bay). In Las Vegas Bay, the CPUE (0.430 fish/min) exceeded those documented in past years (Albrecht et al. 2006a). Conversely and somewhat concernedly, larval sampling efforts in Echo Bay resulted in a relatively poor CPUE (0.024 fish/min) for this area, which once consistently produced higher numbers of larval razorback sucker. However, larval catch rates at the Muddy River/Virgin River inflow area, far surpassed rates recorded during past study years. The 2008 larval CPUE value of 0.116 fish/min is one to two orders of magnitude higher than any of the other larval catch rates observed at the Muddy River/Virgin River inflow area since the inception of efforts at this location in 2005.

The reasons for the rather diminished larval razorback sucker catch rates at Echo Bay (compared to the previous year) remain unclear at this time. However, two interacting factors that may have contributed to what appears to be an overall lack of habitat use by spawning razorback sucker at Echo Bay include the diminishing lake level and/or marina infrastructure construction and maintenance activities, which were conducted within Echo Bay during the 2008 spawning period. As has long been speculated internally and described in past annual reports, Las Vegas Bay larval catch rates have been low in past years (Welker and Holden 2003, Welker and Holden 2004, Albrecht and Holden 2005). There has been speculation that the diminished larval catch rates at Las Vegas Bay are attributable to changes at the Blackbird Point spawning area. During high water years the Blackbird Point spawning area 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 location is less accessible but more open, and therefore subject to the effects of wind and wave action, which is thought to disperse newly hatched razorback sucker. This could account for the decline in larval catch rates. Ultimately, the Las Vegas Bay spawning aggregate shifted its primary spawning site location 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. 2008). Perhaps there is a similar situation at Echo Bay as the lake diminishes and effectively desiccates its more sheltered and calm areas. 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 the maintenance and construction activities associated with the Echo Bay marina parking and infrastructure disrupted spawning activities, or perhaps introduced unsuitable substrate types. Most probable is that the construction factors worked in concert with dropping lake levels to make Echo Bay a less desirable spawning location for razorback sucker in 2008. It will be important to ascertain what happens with the Echo Bay spawning aggregate over the next few years.

Compared with Las Vegas Bay, larval captures in Echo Bay and the Muddy River/Virgin River inflow area were delayed by approximately 1 month. This may be attributable 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. (2006a, 2007). Larval catches at Echo Bay and the Muddy River inflow/Virgin River appeared to peak during the end of March, while catch rates at Las Vegas Bay appeared to peak toward the first part of March (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 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 is still occurring despite a continued decline in lake levels and the associated habitat changes. In 2006, 2007, and 2008, as a result of the dessication and sedimentation of Blackbird Point (Albrecht et al. 2006a, Albrecht et al. 2007) and our increased ability to locate adult razorback sucker habitat by following sonic-tagged fish, we have documented a successful (i.e., larval fish were produced) shift in spawning site selection of the Las Vegas Bay razorback sucker population using multiple methodologies. During 2006, 2007, and 2008, the Las Vegas Bay razorback sucker population spawned along the southwestern shoreline, near the inflow of Las Vegas Wash. Although differential selection of spawning habitats has consistently been the norm at Echo Bay, this is a recent observation at Las Vegas Bay (2006-2008 spawning periods). While we have speculated internally that the Las Vegas Bay population would make the shift when/if required, shifts in spawning habitat use have now been documented over the past three spawning seasons. Evaluating the ramifications of these shifts, particularly in terms of recruitment, and identifying how spawning at this new location will add individuals to the spawning population will be important in future study years. Furthermore, because the lake level has the potential to decline through 2009, it will be a monitoring priority to follow the Las Vegas Bay population's spawning habitat selection to identify further shifts in spawning habitat use.

As mentioned previously, we are most concerned with the Echo Bay spawning aggregate because we were not able to pinpoint a primary spawning area in 2008 and larval captures appear to be undergoing a downward trend in abundance. Typically, the spawning movement pattern of Echo Bay razorback sucker relative to lake levels has been to adjust spawning site selection in a downward fashion and towards the mouth of Echo Bay as dictated by the declining lake. Each year, as the lake has declined, we have found a primary spawning location positioned further and further out towards the main body of Lake Mead and away from the more sheltered portions of the back of Echo Bay. Furthermore, Echo Bay has long been a top-producing location of larval razorback sucker (Albrecht et al. 2008). This phenomenon indicates that Echo Bay razorback sucker have the ability to exhibit spawning site fidelity, but possess enough plasticity in their spawning behavior to use alternate locations when the preferred site is inaccessible. This behavior has also been observed in razorback sucker inhabiting the Green River, Utah (Tyus

1987, Bowen et al. 2001), where different spawning sites were used at different river elevations. During all years of the study, the spawning site selection at Echo Bay has varied from less than 10 ft to more than 20 ft depending on lake level. Perhaps finally we are arriving at the extent of plasticity that the Echo Bay spawning aggregate can display in terms of their use of Echo Bay as a primary spawning location. It will be interesting to evaluate if recruitment occurred at Echo Bay during 2008. We remain hopeful that the Echo Bay spawning aggregate will resume full and normal use of Echo Bay in 2009, and we will continue data collection efforts to ascertain habitat use and selection in this area of Lake Mead.

Combined information obtained from efforts in the northernmost portions of Lake Mead near the Muddy River/Virgin River inflow areas provide fairly sound evidence that the Muddy River/Virgin River 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. Based on the most recent data, we concur with Albrecht et al. (2007) and continue to recommend that the spawning aggregate in Echo Bay and the Muddy River/Virgin River inflow area be considered one and the same because of the relatively common exchange of fish between Echo Bay and the Muddy River/Virgin River inflow area. 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 notion is further strengthened by the elevated numbers of fish captured in the northern portions of Lake Mead and at Las Vegas Bay during 2007 and 2008. Whether the increased capture rates in 2007 and 2008 are attributable to low lake levels and a subsequent increase in sampling and capture efficiency, or if the populations have undergone a recent pulse of recruitment, the result is the same: there appears to be a greater number of razorback sucker in Lake Mead than previously thought.

It is important to note that since the conclusion of the 2008 Lake Mead field season, the most recently identified spawning sites at the primary study locations have become desiccated by decreasing lake levels (again, we were unable to identify a primary spawning location at Echo Bay in 2008). 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 spawning locations, as well as understanding recruitment patterns of Lake Mead razorback suckers. It is important to continue collecting water quality data in hopes of finding other links to spawning site preference and recruitment success. Physically, the three primary study areas have changed dramatically over the last 12 seasons. It will be important to track these physical and/or chemical changes over time to better understand and document razorback sucker success.

Aspects of Lake Mead Recruitment

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. 2006a). 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 ft 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 drawdown 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 have 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 suggests 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 16 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 and 2005. In 2008 we also captured two very small razorback suckers that were positively aged to be 2 years old (2006 year class). This demonstrates recruitment occurring as recently as 2006, another low-water year on Lake Mead. Given that all of these years were relatively low and declining lake years, it appears as though turbidity may be much more important for razorback sucker recruitment than we have typically given it credit. 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, 2008) 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 litoral 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. 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, multi-year lake elevation changes that promote the growth of vegetation around the lake, the inundation of that vegetation, and turbid conditions (compared to 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 provide a form of cover for early life stage razorback sucker. Hence cover in the form of turbidity increases, ultimately leading to increased recruitment. Since data obtained in 2007 and 2008 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. (2008) 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 2008 was 15.3 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). As indicated in Mueller (2006) and in our past annual reports, these elevated growth rates indicate that Lake Mead razorback sucker populations are relatively young. 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.

Fin-ray extraction and aging efforts continued during the 12th study year, resulting in the definitive age determination of 54 adult/subadult razorback sucker. Calculated ages ranged from 2- to 36-years old. Ages of the 54 fish evaluated during the 2008 study year and the 132 previously aged fish helped identify that recruitment occurred fairly regularly from 1974–2003. The greatest recruitment occurred during 2002–2005, with a total of 68 razorback sucker resulting from those spawning events alone. Seventy-four percent of the fish aged from the most recent study year were less than 7 years old, indicating a strong recruitment trend in recent years. As stated previously, this strong pulse of young fish indicates that successful spawning and recruitment are indeed occurring at diminished lake levels, which has necessitated a reformation of our original hypothesis concerning factors that may result in successful recruitment of razorback sucker.

Population Estimates

The population estimates for razorback sucker populations in Lake Mead generated from data collected during the 2006-2008 study years have increased in comparison with estimates from past study years. This same increase is also apparent in the recent trammel netting CPUE values. However, we caution that direct management decisions and actions should not be solely based on these population estimates, and that these estimates likely underestimate the Lake Mead razorback sucker population. Albrecht et al. (2008) provide a more exhaustive discussion of the factors that potentially influence the annual population estimates of the Lake Mead razorback sucker. 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.

Conclusion

Despite our concerns regarding the Echo Bay spawning aggregate, we remain optimistic about the status of razorback sucker in Lake Mead. 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 rare species. As such, Lake Mead provides an unequaled opportunity to discover how to promote this unique trend in other locations throughout the Colorado River Basin, and we reiterate the need for future research to understand how and why razorback suckers are able to maintain themselves naturally despite fluctuating habitat conditions. Finally, provided 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 recommendations posed by Albrecht et al. (2008) during their comprehensive review of Lake Mead razorback sucker investigations.

2008-2009 RECOMMENDED WORK PLAN

Specific Objectives for the 13th Study Year

1. Continue historical data collection, including the continuation of 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 areas in order to evaluate whether any further shifts in spawning site selection occurs; (2) further investigating the relatively new Muddy River/Virgin River spawning site to evaluate habitat use and help further understand habitat use in this area of Lake Mead; and (3) potentially identifying other, new spawning areas 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 in 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 spawning site and the Echo Bay spawning area, 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 if a new spawning aggregate is forming in the Muddy River/Virgin River inflow, and if this aggregate is largely comprised of Echo Bay fish next season. Methods will follow those outlined in Albrecht et al. (2006b), updated in Albrecht et al. (2007), and reviewed by Albrecht et al. (2008).

2. Implant an additional twelve Floyd Lamb State Park razorback sucker with sonic tags and release them within the three primary study locations. The rational for this study objective is the same as described above: to facilitate seamless data collection and to assist field crews in accomplishing monitoring objectives over the course of the next several spawning seasons.

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REFERENCES

Abate, P.D., T.L. Welker, and P.B. Holden. 2002. Razorback sucker studies on Lake Mead, Nevada. 2001–2002 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-578-6.

Albrecht, B. and P.B. Holden. 2005. Razorback sucker studies on Lake Mead, Nevada. 2004–2005 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-960-1.

Albrecht, B., P.B. Holden, and M. Golden. 2006a. Razorback sucker studies on Lake Mead, Nevada. 2005–2006 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-977-1.

Albrecht, B., P.B. Holden, and M. Golden. 2006b. Lake Mead razorback sucker monitoring recommendations. 2005–2006 Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-977-1.

Albrecht, B., T. Sanderson, and P.B. Holden. 2007. Razorback sucker studies on Lake Mead, Nevada. 2006–2007 Annual Report. Prepared for the U.S. Bureau of Reclamation and the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-1093-1.

Albrecht, B., T. Sanderson, and P.B. Holden. 2008. Razorback sucker studies on Lake Mead, Nevada and Arizona. 1996–2007 Comprehensive Report. Prepared for the U.S. Bureau of Reclamation and the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-1093-2.

Burke, T. 1995. Rearing wild razorback sucker larvae in lake-side backwaters, Lake Mohave, Arizona/Nevada. Proceeding of the Desert Fishes Council 26:35 (abstract only).

Bowen, Z.H., K.D. Bovee, T.J. Waddle, T. Modde, and C. Kitcheyan. 2001. Habitat measurement and modeling in the Green and Yampa Rivers. Project Report, Natural Resources Preservation Program, U.S. Geological Survey, Midcontinent Ecological Science Center, Fort Collins, CO.

Carpenter, J. and G.A. Mueller. 2008. Small nonnative fishes as predators of larval razorback suckers. Southwestern Naturalist 53(2):236-242.

Chao, A. 1989. Estimating population size for sparse data in capture-recapture experiments. Biometrics 45:427-438.

Golden, M.E., and P.B. Holden. 2003. Determining conditions that promote razorback sucker recruitment in Lake Mead: a summary of the 2000–2002 pilot study. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-784-2.

Holden, P.B., and C.B. Stalnaker. 1975. Distribution of fishes in the Dolores and Yampa River systems of the upper Colorado Basin. Southwestern Naturalist 19:403-412.

Holden, P.B. 1994. Razorback sucker investigations in Lake Mead, 1994. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. Final Report, PR-470-1.

Holden, P.B., P.D. Abate, and J.B. Ruppert. 1997. Razorback sucker studies on Lake Mead, Nevada. 1996–1997 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-578-1.

Holden, P.B., P.D. Abate, and J.B. Ruppert. 1999. Razorback sucker studies on Lake Mead, Nevada. 1997–1998 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-578-2.

Holden, P.B., P.D. Abate, and J.B. Ruppert. 2000a. Razorback sucker studies on Lake Mead, Nevada. 1998–1999 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-578-3.

Holden, P.B., P.D. Abate, and J.B. Ruppert. 2000b. Razorback sucker studies on Lake Mead, Nevada. 1999–2000 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-578-4.

Holden, P.B., P.D. Abate, and T.L. Welker. 2001. Razorback sucker studies on Lake Mead, Nevada. 2000–2001 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-578-5.

Johnson, J.E., and R.T. Hines. 1999. Effect of suspended sediment on vulnerability of young razorback suckers to predation. Transactions of the American Fisheries Society 128:648-655.

Joseph, T.W., J.A. Sinning, R.J. Behnke, and P.B. Holden. 1977. An evaluation of the status, life history, and habitat requirements of endangered and threatened fishes of the upper Colorado River system. U.S. Fish and Wildlife Service, Office of Biological Services, Fort Collins, CO. FWS/OBS Rep. 24, part 2. 183 p.

Marsh, P.C. 2008. Update regarding the March 2008 Lake Mohave razorback sucker round-up to the Native Fish Workgroup via email on 4/20/2007. Native Fish Lab, Arizona State University, Tempe, AZ.

Marsh, P.C., B.R. Kesner, and C.A. Pacey. 2005. Repatriation as a management strategy to conserve a critically imperiled fish species. North American Journal of Fisheries Management 25:547-556.

Marsh, P.C., C.A. Pacey, and B.R. Kesner. 2003. Decline of razorback sucker in Lake Mohave, Colorado River, Arizona and Nevada. Transactions of the American Fisheries Society 132:1251-1256.

McAda, C.W. and R.S. Wydoski. 1980. The razorback sucker, *Xyrauchen texanus*, in the upper Colorado River basin. U.S. Fish and Wildlife Service Technical Paper 99:1-15.

McCall, T. (Arizona Game and Fish Department). 1980. Fishery investigation of Lake Mead, Arizona-Nevada, from Separation Rapids to Boulder Canyon, 1978–79. Water and Power Resources Service, Boulder City, NV. Final Report. Contract Number 8-07-30-X0025. 197 p.

Minckley, W.L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix, AZ.

Minckley, W.L. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the Lower Colorado River Basin. Southwestern Naturalist 28:165-187.

Minckley, W.L., P.C. Marsh, J.E. Brooks, J.E. Johnson, and B.L. Jensen. 1991. Management toward recovery of razorback sucker. *In:* W.L. Minckley and J.E. Deacon, editors. Battle against extinction: native fish management in the American West. Tucson: University of Arizona Press. pp. 303-357.

Modde, T., K.P. Burnham, and E.J. Wick. 1996. Population status of the razorback sucker in the middle Green River (U.S.A.). Conservation Biology 10(1):110-119.

Modde, T., Z.H. Bowen, and D.C. Kitcheyan. 2005. Spatial and temporal use of a spawning site in the middle Green River by wild and hatchery-reared razorback suckers. Transactions of the American Fisheries Society 134:937-944.

Mueller, G., P.C. Marsh, G. Knowles, and T. Wolters. 2000. Distribution, movements, and habitat use of razorback sucker (*Xyrauchen texanus*) in a lower Colorado River reservoir, Arizona-Nevada. Western North American Naturalist 60:180-187.

Mueller, G.A. 2005. Predatory fish removal and native fish recovery in the Colorado River mainstem: what have we learned? Fisheries 30(9):10-19.

Mueller, G.A. 2006. Ecology of bonytail and razorback sucker and the role of off-channel habitats to their recovery. Scientific Investigations Report 2006–5065. U.S. Department of the Interior, U.S. Geological Survey. 64 p.

Otis, D.L., K.P. Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62:1-135.

Pacey, C.A. and P.C. Marsh. 1998. Growth of wild adult razorback sucker in Lake Mohave, Arizona-Nevada. Presented at 30th Annual Meeting, Desert Fishes Council, Page, AZ. November 14, 1998.

[Reclamation] Bureau of Reclamation. 2008. Historical Lake Mead reservoir levels. Location: http://www.lc.usbr.gov/. Numerous links utilized.

Rexstad, E. and K. Burnham. 1992. User's guide for interactive program CAPTURE. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, CO.

Ryel, R. 2001. Consultant, personal communication with Tim L. Welker of BIO-WEST, Inc., Logan, Utah, regarding population abundance estimates. 09/14/2001.

Schooley, J.D., A.P. Karam, B.R. Kesner, P.C. Marsh, C.A. Pacey, and D.J. Thornbrugh. 2008. Detection of larval remains after consumption by fishes. Transactions of the American Fisheries Society 137:1044-1049.

Sjoberg, J.C. 1995. Historic distribution and current status of the razorback sucker in Lake Mead, Nevada-Arizona. Proceedings of the Desert Fishes Council 26:24-27.

Tyus, H.M. 1987. Distribution, reproduction, and habitat use of the razorback sucker in the Green River, Utah, 1979–1986. Transactions of the American Fisheries Society 116:111-116.

U.S. Fish and Wildlife Service (USFWS). 1991. Endangered and threatened wildlife and plants; the razorback sucker (*Xyrauchen texanus*) determined to be an endangered species; Final rule. Federal Register 56 (23 October 1991): 54957-54967.

U.S. Fish and Wildlife Service (USFWS). 1997. Final biological and conference opinion on Lower Colorado River operations and maintenance-Lake Mead to southerly international boundary. U.S. Fish and Wildlife Service, Phoenix, AZ.

Welker, T.L. and P.B. Holden. 2003. Razorback sucker studies on Lake Mead, Nevada. 2002–2003 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-578-7.

Welker, T.L. and P.B. Holden. 2004. Razorback sucker studies on Lake Mead, Nevada. 2002–2003 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority, by BIO-WEST, Inc., Logan, UT. PR-578-8.

Wick, E.J., C.W. McAda, and R.V. Bulkley. 1982. Life history and prospects for recovery of the razorback sucker. *In:* W.H. Miller, H.M. Tyus, and C.A. Carlson, editors. Fishes of the upper Colorado River System: present and future. American Fisheries Society, Western Division, Bethesda, MD. pp. 120-126.