BioInvasions Records (2022) Volume 11, Issue 1: 136–148

Data Paper

Checklist of aquatic non-native and invasive species in lakes Mead and Mohave

Julianne Renner and Julie L. Day*

National Park Service, Lake Mead National Recreation Area, 601 Nevada Way, Boulder City, NV 89005, USA

Author e-mails: *Julianne_renner@nps.gov (JR), Julie.lynne.day@gmail.com (JD)*

**Corresponding author*

Citation: Renner J, Day JL (2022) Checklist of aquatic non-native and invasive species in lakes Mead and Mohave. *BioInvasions Records* 11(1): 136–148, https://doi.org/10.3391/bir.2022.11.1.14

Received: 18 November 2020

Accepted: 14 May 2021

Published: 12 November 2021

Handling editor: Russ Minton

Thematic editor: Kenneth Hayes

Abstract

More than half of National Parks in the United States report the presence of invasive animals. Here we report a checklist of non-native aquatic fauna at Lake Mead National Recreation Area, Nevada, with the earliest reported sighting in 1940. Seventy-two species of non-native aquatic fauna were found representing six taxonomic groups. 41 (57%) are established, 9 (13%) are either eradicated or failed, and the status of 19 species (26%) is unknown. This comprehensive species list represents a preliminary step in developing monitoring programs for invasive species currently found within Lakes Mead and Mohave. It will also help inform the development of early detection and rapid response activities and monitoring to safeguard the park from future invasions.

Key words: Lake Mead, Lake Mohave, aquatic invasive species, quagga mussels, species checklist

Introduction

Globalization motivates economic progress but also creates new challenges for environmental management issues, such as invasive species. Increasing travel and trade inevitably result in invasive species introductions across the globe (Meyerson and Mooney 2007; Resnick 2018). Environmental damages and economic losses attributed to non-native and invasive species cost $100–200 billion annually in the United States (US) alone (Pimentel et al. 2005). Forty-two percent of species listed as Threatened (likely to become endangered within the foreseeable future throughout part of its range) or Endangered (in danger of extinction throughout all or a significant portion of its range) under the U.S. Endangered Species Act (ESA 1973, as amended), are thought to be in decline at least in part as a result of exotic species introductions and resulting competition and predation (Pimentel et al. 2005). Invasive plants and animals represent an enduring threat to National Parks of the US (Dayer et al. 2019), over half of which report the presence of invasive animal species with only a small percentage of 1,400 reported populations considered to be under some sort of control (Resnick 2018). In addition to detrimentally affecting natural and culture resources, invasive species impact recreational opportunities available to park visitors (Dayer et al. 2019).

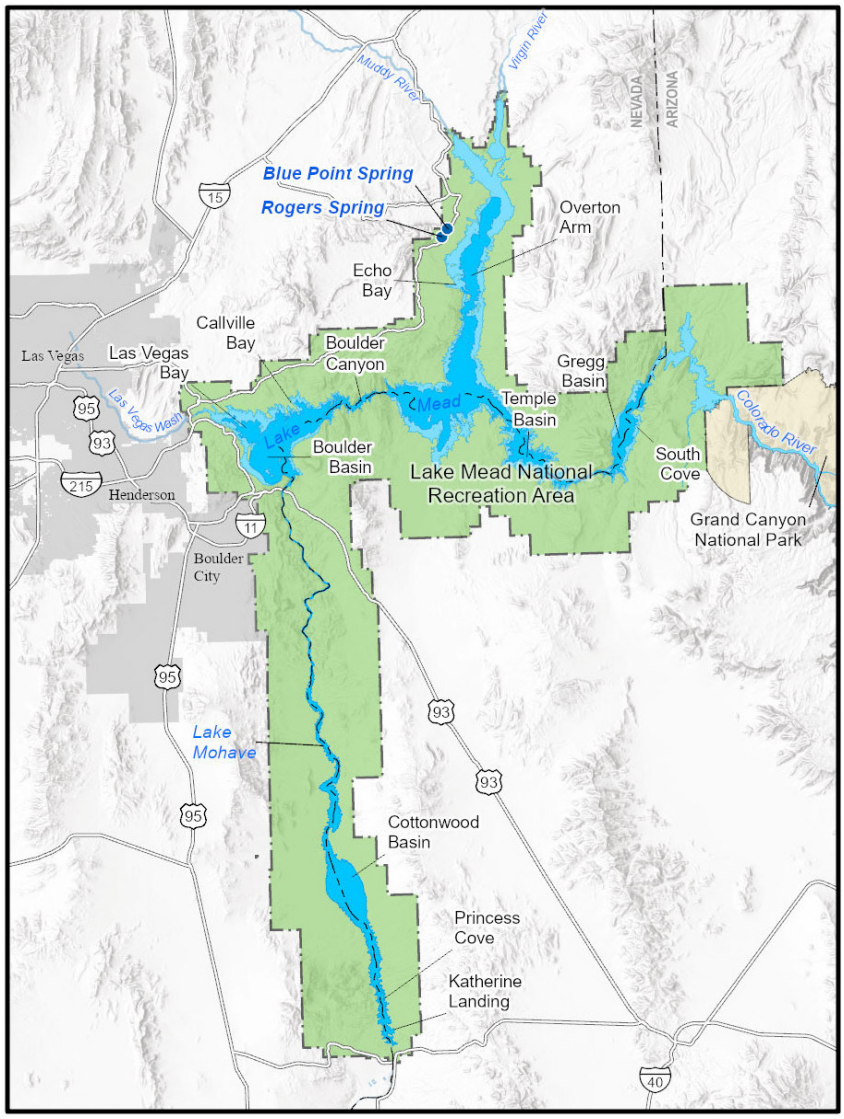

Figure 1. Map of Lakes Mead and Mohave within Lake Mead National Recreation Area on the Nevada-Arizona border.

Lake Mead National Recreation Area (LAKE) was established on October 8, 1964 as the National Park Service's first national recreation area and is situated along the state line between Nevada and Arizona (National Park Service 2016a, b). LAKE encompasses nearly 1.5 million acres including 225,000 acres of water, is the largest designated recreation area in the US, and hosts nearly eight million visitors each year (National Park Service 2016b). LAKE includes two large reservoirs; Lake Mead and Lake Mohave. Lake Mead was formed by the construction of the Hoover Dam in 1935 (National Park Service 2016c), and Lake Mohave was formed by the construction of Davis Dam in 1951 (Figure 1). With its centralized location, numerous urban and undeveloped access points, vast size, and high visitation, invasive species are a dynamic aspect of natural resource management at LAKE. LAKE maintains an active aquatic invasive species (AIS) decontamination program in partnership with the Nevada Department of Wildlife (NDOW) and Arizona Game and Fish Department (AZGFD)

aimed primarily at preventing the spread of quagga mussels (*Dreissena rostriformis bugensis* (Andrusov, 1897)). We reviewed available data and literature for all non-native and invasive species at LAKE to inform the development of a new early detection and rapid response program. Herein, we provide a checklist of non-native and invasive aquatic species at LAKE, summarize occurrence data for each species, and report details on population status for each species (established, eradicated, etc.).

Materials and methods

Species records were compiled from the Nonindigenous Aquatic Invasive Species database hosted by the US Geological Survey (USGS-NAS 2018), a federal repository of geo-referenced reported sightings of aquatic non-native species. We cross-referenced USGS-NAS database findings and searched for additional species records through Google Scholar. USGS-NAS database includes data from published scientific literature, personal communications from natural resource managers and biologists, as well as reports from citizen scientists. Records are verified by interviewing reporters or examining photos of specimens taken by reporters. Local experts were consulted to verify erroneous reports and contribute unpublished sightings. Thus, data may change daily as new reports are added. Here we present data queried on 15 November 2019.

The "search by drainage" tool was used to locate reports in the Lower Colorado and Lower Colorado-Lake Mead drainage areas, which together encompass the boundaries of LAKE. AIS reports in each drainage were then narrowed down to reports specifically located in LAKE using the point map associated with each species. A literature search for each species was then conducted using Google Scholar database to gather additional species information and cross-reference any additional records that may not have been reported to the USGS-NAS. We assigned one of the following population statuses:

- Established: Population shows evidence of successful reproduction (i.e. presence of multiple life stages or year classes) and overwinter survival.
- Eradicated: Population was eliminated by human intervention, e.g., treatment with Rotenone.
- Extirpated: Population was previously established but died out on its own, without human intervention, e.g., cold winter.
- Failed: Population did not successfully reproduce or have overwinter survival, e.g., died out without establishment.
- Stocked: Population is maintained through routine introductions by a natural resource management agency.
- Unknown: Insufficient information to determine status.

Results

72 non-native and invasive aquatic species were documented from LAKE waters, including 1 alga (1%), 3 aquatic plants (4%), 2 amphibians (3%), 4 reptiles (6%), 9 invertebrates (13%), and 53 (74%) fishes (Supplementary material Table S1). Over half of (n = 41; 57%) of species are established within LAKE. The status of 26% (n = 19) is unknown. Two species were eradicated (3%), two were extirpated (3%), and seven failed (10%). Comprehensive species list and summary data in Table S1 include scientific and common names, native range, year of first record at LAKE if known, location within LAKE (if reported or known), and population status designation. All species were found in the USGS-NAS database; literature searches did not reveal additional species. Here we highlight the most notable species found.

Discussion

Algae

Golden algae (*Prymnesium parvum* (Carter, 1937)) was first detected in the United States in 1985 in Texas (James and de la Cruz 1989) and was later recorded at Lake Mead in 2001 (Rosen et al. 2012). LaBounty and Burns (2005) also reported low densities of golden algae cells in the Boulder Basin of Lake Mead but did not specify *P. parvum* (Figure 1). Lake Las Vegas, a manmade reservoir located west of Lake Mead, was the first body of water in Nevada to report a toxic golden algal bloom in the winter of 2010 (Weber and Janik 2010). The effects of golden algal blooms depend on several different environmental factors but can found to cause extensive fish kills in certain conditions (VanLandeghem et al. 2013). *Prymnesium parvum* is an unconventional invasive species, as it is a microbe with worldwide origins (Edvardsen and Paasche 1998). The *P. parvum* microbes may be globally present, however certain environmental conditions are necessary for the microbes the present as a toxic algal bloom. Regardless, it is important to include golden algae on this list, as it is present at LAKE and could prove economically and ecologically harmful.

Aquatic Plants

Three species of aquatic invasive plant are documented at LAKE. Eurasian watermilfoil (*Myriophyllum spicatum* (Linnaeus, 1753)) was found below Davis Dam on Lake Mohave in 2014 (Figure 1; Center for Invasive Species and Ecosystem Health 2019). No other reports have been found in LAKE, however *M. spicatum* has been recorded at several locations south of Lake Mohave on the Colorado River (CCH1 2019). Eurasian watermilfoil has been found to negatively impact species diversity and water-based recreation values (Boylen et al. 1999), making it of concern to LAKE.

Both American tape grass (*Vallisneria americana* (Michaux, 1802)) and curly-leaved pondweed (*Potamogeton crispus* (Linnaeus, 1753)) have been found in Boulder Basin of LAKE in 1999, however no established populations have been identified (C. Norman *pers. comm*, Oct 2020; Figure 1). *Vallisneria americana* is native to Eastern North American but has been reported in some Western states (Korschgen and Green 1988) and is a common aquarium plant. *P. crispus* is native to Eurasia, Africa, Australia, and was first identified in North America in the late 1800's and spread across much of the U.S. (Catling and Dobson 1985; Stuckey1979). In water bodies where curly-leaf pondweed is established it can grow in large mats, restricting the growth of other aquatic organisms and impeding on recreation opportunities (Catling and Dobson 1985). There is little research on American tape grass as an invasive species in the West, and because there have been no other records of the plant since 1999, this species may be less of a concern for LAKE.

Amphibians

The American bullfrog (*Lithobates catesbeianus* (Shaw, 1802)) was first recorded at LAKE in 1966 and thought to have been introduced for food purposes (Stebbins 1966). *Lithobates catesbeianus* is a known competitor and predator of the relict leopard frog (*Rana once* (Cope, 1875)), whose only remaining native range is thought to encompass two separate populations within LAKE: within the Virgin River drainage near Hurricane, Utah extending to the Overton Arm of Lake Mead along the Muddy River of Nevada, and within Black Canyon springs below Hoover Dam (Harris 2006; Figure 1).

Sightings of the eastern tiger salamander (*Ambystoma tigrinum* (Green, 1825)) are not well documented. A comprehensive survey of amphibians in the eastern Mojave Desert by Bradford et al. (2005) reported collections at Willow Beach (1965) and Lake Mead (1966), and two larvae were collected at Blue Point Spring in 1963 (Figure 1). It is thought that *A. tigrinum* was introduced to LAKE as larvae for use as fishing bait (Bradford et al. 2005). *Ambystoma tigrinum* is capable of hybridizing which has resulted in the genetic extinction of native species in other systems (Johnson et al. 2011).

Reptiles

The spiny softshell turtle (*Apalone spinifera* (Le Sueur, 1827)) was reported as early as 1936, around the completion of Hoover Dam (Cowles and Bogert 1936). Their large native range spans most of the Eastern US but little is known about its impacts on native ecosystems as a non-native species (Averill-Murray 2007).

The earliest report of Texas spiny softshell turtle (*Apalone spinifera emoryi* (Agassiz, 1857)) in the NAS Database is in 1967, thought to be a released pet (Bradley and Deacon 1967). However, in his book *Snakes,*

Lizards, and Turtles of the Lake Mead Region, Russel K. Grater (1981) mentions records of this turtle at LAKE around the creation of Lake Mead in the 1930s. Though we did not find a formal report for red-eared slider (*Trachemys scripta elegans* (Wied-Neuwied, 1839)), many have been observed near boat ramps and marinas in Lakes Mead and Mohave as well as Rogers Spring in recent years, presumably released pets (J. Renner *unpublished data*; Figure 1).

Lastly, a juvenile caiman, presumably *Caiman latirostris* (Daudin, 1825) and thought to be a released or escaped pet was found inhabiting the Las Vegas Wash area at LAKE in 2005 (J. Sjöberg *pers. comm.*, Nov 2020; Figure 1).

Invertebrates

Asian clam (*Corbicula fluminea* (Müller, 1774)) was first reported at LAKE in 1948 (Ingram 1959). Due to its high fecundity and rapid growth, *C. fluminea* is one of the most prolific aquatic invasive species (McMahon 2002). Native to Asia, Africa, and Australia, *C. fluminea* first arrived in the US on the Pacific Coast in the 1920s and has since spread across the US and to other continents including South America and Europe (Colwell et al. 2017; Sousa et al. 2008). Impacts of *C. fluminea* include biofouling (Darrigran 2002) and consuming food sources for native bivalves (Strayer 1999).

We found three reports of New Zealand mudsnail (*Potamopyrgus antipodarum* (Gray, 1853)) at LAKE. The first sighting was in 2007, followed by 2 additional sightings in 2008, all north of Hoover Dam in the Boulder Basin and Overton Arm of Lake Mead (Illinois Natural History Survey 2011; Figure 1). Native to New Zealand, the first record of *P. antipodarum* in North America was in the Snake River system in Idaho in 1987, where it continued to spread to the Great Lakes and various western watersheds (Hickey 2010). *Potamopyrgus antipodarum* have been found in high-density groups of up to 800,000 individuals/m^2, competing with other native invertebrates for food and space (Kerans et al. 2005).

Quagga mussels were first reported at LAKE in 2007 (Hickey 2010). *Dreissena bugensis* is native to Eastern Europe and first discovered in the Great Lakes region of the US in 1991 (Mills et al. 1996; May and Marsden 1992). The most likely mode of transmission into the US was via ship ballast water, with continued spread via bilge waters of recreational boats transported over land (Wong and Gerstenberger 2011). The discovery of quagga mussels at LAKE was significant, as it was the first confirmed infestation of a large body of water in the West that did not first have zebra mussels (Wong and Gerstenberger 2011). This discovery extended the invasion 3,000 km farther across the US, from the Great Lakes to the desert Southwest (Wong and Gerstenberger 2011). The impacts of *D. bugensis* are lesser known, as the arrival of quagga mussels in North America was

preceded by their invasive counterpart the zebra mussel (*Dreissena polymorpha* (Pallas, 1771)). Because quagga mussels arrived after zebra mussels, the impacts of these dreissenids are difficult to distinguish (Nalepa et al. 2010). However, there are some notable differences between the two dreissenid species. Zebra mussels have been found to have stronger byssal threads with a higher production rate, making it easier for zebra mussels to attach to moving objects than quagga mussels (Karatayev et al. 2015). Unlike zebra mussels which are restricted to shallow lake waters, quagga mussels can be found throughout lakes, form larger populations than zebra mussels, and may filter greater volumes of water, thus contributing to larger system-wide changes (Karatayev et al. 2015). Dreissenid invasions have been found to impact native ecosystems in numerous ways, including removing suspended solids from the water, increasing water clarity, and decreasing phytoplankton and zooplankton numbers (Higgins and Vander Zanden 2010).

Fish

Fish comprise most non-native and invasive species; a total of 54 of the 72 species. Common carp (*Cyprinus carpio* (Linnaeus, 1758)) are a prevalent invasive fish found at LAKE; gizzard shad and carp combined comprise 75% of the fish community by biomass in Lake Mead (Rosen et al. 2012). Common carp have been introduced into ecosystems for over a century for aquaculture and angling purposes, as they are commonly used to help feed poor communities (Zambrano et al. 2001; Tapia and Zambrano 2003). Carp were first recorded in the park in 1962 (La Rivers 1962) and are thought to have been stocked for food. They are adept at uprooting and consuming vegetation, altering benthic and macrophyte communities, and increasing water turbidity (King and Hunt 1967; Zambrano and Hinojosa 1999; Tapia and Zambrano 2003).

Gizzard shad (*Dorosoma cepedianum* (Lesueur, 1818)) was first recorded at Lake Mead in 2007, however it was not recorded in Lake Mohave until 2012 (Webber and Jones 2007; Figure 1). *Dorosoma cepedianum* is known to become overpopulated and impact other species (Noble 1981). These fish are sediment feeders and affect the benthic environment, as well as impact zooplankton and phytoplankton communities (Schaus and Vanni 2000). However, a study of gizzard shad in LAKE by Beaver et al. (2018) has not found the species to have significant effects on zooplankton and phytoplankton communities. Redear sunfish (*Lepomis microlophus* (Güther, 1859)) are another notable invasive species, originating in the Southeast US and first recorded in Lake Mohave in 1976 (Deacon and Williams 1984; Figure 1). *Lepomis microlophus* are known to consume quagga mussels and have become the focus of several scientific studies of biocontrol solutions for invasive mussels.

Rogers Spring and Blue Point Spring are hot springs and popular sites for aquarium owners to release unwanted fish, which explains the wide variety of exotic fish in the springs at LAKE (Courtenay and Deacon 1983; Figure 1). Both springs have hosted Central American Convict cichlids (*Archocentrus nigrofasciatus* (Günther, 1867), Malabar danios (*Devario malabaricus* (Jerdon, 1849)), and numerous other species, many of which are thought to be aquarium releases (Schmitter-Soto 2007; Courtenay and Stauffer 1990). Some fishes, such as cichlids, are known predators of hydrobiid snails (Brown et al. 2008). Further investigation is needed in order to assess their potential contribution to native hydrobiid snail population declines at LAKE, particularly at Blue Point Spring (USFWS 2017; Wilcox and Jaeger 2020; Figure 1).

LAKE hosts a variety of desirable sportfish which support recreational opportunities in both lakes. No sportfish stocking occurs currently save for Rainbow trout (*Oncorhynchus mykiss* (Walbaum, 1792)) stocked in Lake Mohave by Willow Beach National Fish Hatchery. Historically, the Nevada Department of Wildlife (NDOW) stocked a variety of sportfish including: black bullhead (*Ameiurus melas* (Rafinesque, 1820)), black crappie (*Pomoxis nigromaculatus* (Lesueur, 1829)), bluegill (*Lepomis macrochirus* (Rafinesque, 1819)), channel catfish (*Ictalurus punctatus* (Rafinesque, 1818)), green sunfish (*Lepomis cyanellus* (Rafinesque, 1819)), largemouth bass (*Micropterus salmoides* (Lacepède, 1802)), rainbow trout (*Oncorhynchus mykiss*), smallmouth bass (*Micropterus dolomieu* (Lacepède, 1802)), striped bass (*Morone saxatilis* (Walbaum, 1792)), and white crappie (*Pomoxis annularis* (Rafinesque, 1818)).

This study represents the first comprehensive investigation and summary of aquatic non-native and invasive species found within the waters of Lake Mead National Recreation Area. As of 2020, 72 species of non-native and invasive aquatic flora and fauna have been documented from Lakes Mead and Mohave. This list is likely not comprehensive due to several constraints associated with data collection. Extensively surveying and monitoring vast, remote stretches of aquatic habitat makes it difficult to detect changes in population status and encounter new, potentially rare individuals. Additional species may have been reported via other mediums not found through our literature review, the NAS database, and local experts. Also, despite considerable effort to accurately identify and report species, the potential for misidentification remains present, particularly in early records. Timely, complete reporting through the NAS database and publication of new species records is critical for ensuring accuracy and completion of species checklists. Further, the high numbers of established and unknown population status designated species (41 and 19, respectively) supports the need for directed surveys.

Aquarium fishes appear to be restricted to warm springs, though more robust species such as goldfish and carp are widespread throughout LAKE. A wide variety of aquatic habitats are present throughout both Lakes Mead

and Mohave, including limnetic (lake-like), lotic (river-like), wetland, and natural spring habitats which support diverse assemblages of flora and fauna (Rosen et al. 2012). Notable variation in environmental conditions and riparian zones between lakes likely influences the establishment and distribution of non-native species. Vegetation is largely limited to tributary deltas in Lake Mead, while non-native tamarisk dominates Lake Mohave shorelines. A portion of the Las Vegas Wash, an urban river carrying treated wastewater and stormwater runoff, is located within LAKE, and flows into Lake Mead (Ryan et al. 2018). Water temperatures in Lake Mead are typical of a monomictic lake, characterized by thermal stratification for most of the year save for a single complete mixing event. However, every 1–2 years an incomplete mixing event occurs. Limnological conditions in Lake Mohave are more stable and typically fluctuate very little throughout the year, in part due to water release management from Hoover Dam, while Lake Mead fluctuates more frequently, losing 12 ft of surface elevation per year during average system conditions (Rosen et al. 2012).

Lake Mohave is considerably narrower and shallower, lacks protected coves that are common throughout Mead, and as such prey for fish species is less abundant. The Black Canyon, located immediately downstream of Hoover Dam and comprising the northern end of Lake Mohave, is heavily influenced by cool-water hypolimnetic inflows from Lake Mead (Figure 1). While it is tempting to draw conclusions about differences in non-native species distributions between Lakes Mead and Mohave based on habitat characteristics and environmental parameters, no directed monitoring for status and distribution of AIS other than quagga mussels currently occur in either lake and historic survey data are sparse. State and federal agencies and their partners conduct targeted monitoring for endangered species and sportfishes of interest, many of which are non-native, but non-target species are inconsistently reported. Habitat variation between lakes coupled with a lack of directed AIS survey data further demonstrate the need to develop effective monitoring approaches to increase our understanding of species distributions throughout LAKE. Environmental conditions in both lakes are conducive to year-round quagga mussel spawning, which may encourage the establishment of other species with similar life history traits.

Managing invasive species is a global challenge that continues to increase in magnitude and complexity and has become of importance in the western US since the discovery of quagga mussels at LAKE in 2007 (Hickey 2010; Larson et al. 2013). National Parks are particularly fragile and already host a considerable diversity of invasive plants and animals (Resnick 2018). A three-tiered approach to AIS mitigation is currently employed at LAKE and throughout much of the western US, including prevention, containment, and enforcement. Prevention efforts are aimed at protecting water bodies where AIS do not have a verifiable presence. Containment activities focus on preventing the spread of AIS from infected waterbodies. Enforcement

further prevents AIS spread through a variety of federal and state programs that include inspection stations, decontamination mandates, and a series of fees and penalties for negligent AIS transport. The extensive network of AIS inspection and decontamination stations at both containment and prevention stage water bodies minimizes AIS spread, with emphasis on quagga mussels and includes federal and state-run park systems with coverage across major highway transport routes. It is a critical landscape-level tool for ensuring that highly visited areas such as LAKE, which hosts an abundance of non-native and invasive species, do not become source populations for other water bodies, particularly those with important native species populations. This new species list provides a foundation for developing an inventory and monitoring strategy for current and potentially new AIS at LAKE and offers new insight on increasing the efficacy of containment operations at LAKE. It will also assist managers at other parks, recreation areas, and water bodies that host visitors arriving from LAKE develop and refine prevention and education programs that target these species.

Acknowledgements

Mark Sappington provided invaluable feedback on earlier drafts. Carrie Norman, Jef Jaeger, Giovanni Cappelli, Debra Herndon, Lisa Osborne, Jon Sjöberg, Todd Tietjen, and Tim Ricks served as local experts, for which we are grateful. Anna San prepared the map. Two anonymous reviewers provided excellent suggestions which improved this manuscript. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the US Government.

References

Averill-Murray R (2007) Spiny Softshell (*Apalone spinifera*). *Sonoran Herpetologist* 20(9): 94–95

Beaver JR, Kirsch JE, Tausz CE, Samples EE, Renicker TR, Scotese KC, McMaster HA, Blasius-West BJ, Zimba PV, Casamatta DA (2018) Long-term trends in seasonal plankton dynamics in Lake Mead (Nevada-Arizona, USA) and implications for climate change. *Hydrobiologia* 822: 85–109, https://doi.org/10.1007/s10750-018-3638-4

Boylen CW, Eichler LW, Madsen JD (1999) Loss of native aquatic plant species in a community dominated by Eurasian watermilfoil. *Hydrobiologia* 415: 207–211, https://doi.org/10.1023/A:1003804612998

Bradford DF, Jaeger JR, Shanahan SA (2005) Distributional changes and population status of amphibians in the Eastern Mojave Desert. *Western North American Naturalist* 65(4): 462–472

Bradley WG, Deacon JE (1967) The biotic communities of southern Nevada. *Nevada State Museum Anthropological Papers* 13: 201–273. http://www.nativefishlab.net/library/textpdf/12880.pdf

Brown KM, Lang B, Perez KE (2008) The conservation ecology of North American pleurocerid and hydrobiid gastropods. *Journal of the North American Benthological Society* 27: 484–495, https://doi.org/10.1899/07-062.1

Catling PM, Dobson I (1985) The Biology of Canadian Weeds: 69. *Potamogeton crispus* L. *Canadian Journal of Plant Science* 65: 655–668, https://doi.org/10.4141/cjps85-088

Center for Invasive Species and Ecosystem Health (2019) EDDMapS: Early detection and distribution mapping system [online database]. The University of Georgia, Tifton, Georgia, United States. https://www.eddmaps.org/tools/query/ (accessed 7 December 2019)

Colwell H, Ryder J, Nuzzo R, Reardon M, Holland R, Wong WH (2017) Invasive Asian clams (*Corbicula fluminea*) recorded from 2001 to 2016 in Massachusetts, USA. *Management of Biological Invasions* 8: 507–515, https://doi.org/10.3391/mbi.2017.8.4.05

CCH1 (2019) Consortium of California Herbaria [online database]. The University of California, California, United States. https://ucjeps.berkeley.edu/consortium (accessed 12 October 2020)

Courtenay WR, Deacon JE (1983) Fish Introduction in the American Southwest: A Case History of Rogers Spring, Nevada. *The Southwestern Naturalist* 28: 221–224, https://doi.org/10.2307/3671390

Courtenay WR, Stauffer JR Jr. (1990) The introduced fish problem and the aquarium fish industry. *World Aquaculture Society* 21: 145–159, https://doi.org/10.1111/j.1749-7345.1990.tb01017.x

Cowles RB, Bogert C (1936) The Herpetology of the Boulder Dam Region (Nev., Ariz., Utah). *Herpetologica* 1: 33–42, https://www.jstor.org/stable/3889460

Darrigran G (2002) Potential impact of filter-feeding invaders on temperate inland freshwater environments. *Biological Invasions* 4: 145–156, https://doi.org/10.1023/A:1020521811416

Dayer AA, Redford AA, Campbell KJ, Dickman CR, Epanchin-Niell RS, Grosholz ED, Hallac DE, Leslie EF, Richardson LA, Schwartz MW (2019) The unaddressed threat of invasive species in U.S. National Parks. *Biological Invasions* 22: 177–188, https://doi.org/10.1007/s10530-019-02128-0

Deacon JE, Williams JE (1984) Annotated list of the fishes of Nevada. *Proceedings of the Biological Society of Washington* 97(1): 103–118

Edvardsen B, Paasche E (1998) Bloom dynamics and physiology of *Prymnesium* and *Chrysochromulina*. In: Anderson DM, Cembella AD, Hallegraeff GM (eds), Ecology of Harmful Algal Blooms. Springer, Berlin, pp 193–208

ESA (1973) US Endangered Species Act of, as amended, Pub. L. No. 93-205, 87 Stat. 884 (Dec. 28, 1973). http://www.fws.gov/endangered/esa-library/pdf/ESAall.pdf

Grater RK (1981) Snakes, Lizards, and Turtles of the Lake Mead Region. Southwest Parks and Monuments Association, Globe, AZ, 55 pp

Harris SM (2006) Habitat selection by the relict leopard frog (*Rana onca*): Assessment of vegetation use at two scales. PhD Thesis, University of Nevada, Las Vegas, Las Vegas, NV, 51 pp, https://digitalscholarship.unlv.edu/rtds/2034

Hickey V (2010) The quagga mussel crisis at Lake Mead National Recreation Area, Nevada (USA). *Conservation Biology* 24: 716–731, https://doi.org/10.1111/j.1523-1739.2010.01490.x

Higgins SN, Vander Zanden MJ (2010) What a difference a species makes: a meta-analysis of dreissenid mussel impacts on freshwater ecosystems. *Ecological Monographs* 80: 179–196, https://doi.org/10.1890/09-1249.1

Illinois Natural History Survey (2011) Illinois Natural History Survey Collection Databases [online database]. Illinois Natural History Survey, Illinois, US. https://www.inhs.illinois.edu/collections (accessed 7 July 2020)

Ingram WM (1959) Asiatic clams as potential pests in California water supplies. *Journal of the American Water Works Association* 51: 363–370, https://doi.org/10.1002/j.1551-8833.1959.tb15750.x

James TL, de la Cruz (1989) *Pyrmnesium parvum* Carter (Chrysophyceae) as a suspect of mass mortalities of fish and shellfish communities in western Texas. *The Texas Journal of Science* 41: 429–430

Johnson JR, Thomson RC, Micheletti SJ, Shaffer HB (2011) The origin of tiger salamander (*Ambystoma tigrinum*) populations in California, Oregon, and Nevada: introductions or relicts? *Conservation Genetics* 12: 355–370, https://doi.org/10.1007/s10592-010-0144-2

Karatayev AY, Lyubov EB, Padilla DK (2015) Zebra versus quagga mussels: a review of their spread, population dynamics, and ecosystem impacts. *Hydrobiologia* 746: 97–112, https://doi.org/10.1007/s10750-014-1901-x

Kerans BL, Dybdahl MF, Gangloff MM, Jannot JE (2005) *Potamopyrgus antipodarum*: distribution, density, and effects on native macroinvertebrate assemblages in the Greater Yellowstone Ecosystem. *Journal of the North American Benthological Society* 24: 123–138, https://doi.org/10.1899/0887-3593(2005)024<0123:PADDAE>2.0.CO;2

King D, Hunt G (1967) Effect of carp on vegetation in a Lake Erie Marsh. *Journal of Wildlife Management* 31: 181–188, https://doi.org/10.2307/3798375

Korschgen CE, Green WL (1988) American Wildcelery (*Vallisneria americana*): Ecological Considerations for Restoration. U.S. Fish and Wildlife Service (USFWS). Fish and Wildlife Technical Report: 19, 24 pp

La Rivers I (1962) Fishes and fisheries of Nevada. Nevada State Print Office, Carson City, NV, 782 pp

LaBounty JF, Burns NM (2005) Characterization of Boulder Basin, Lake Mead, Nevada-Arizona, USA - based on analysis of 34 limnological parameters. *Lake and Reservoir Management* 21: 277–307, https://doi.org/10.1080/07438140509354435

Larson BMH, Kueffer C, Brock A, Edwards P, Gross M, Hall M, Higgs E, Jentsch A, Jeschke JM, Klein AM, Wynne B (2013) Managing invasive species amidst high uncertainty and novelty, *Trends in Ecology & Evolution* 28: 255–256, https://doi.org/10.1016/j.tree.2013.01.013

May B, Marsden JE (1992) Genetic identification and implications of another invasive species of Dreissenid mussel in the Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 49: 1501–1506, https://doi.org/10.1139/f92-166

McMahon RF (2002) Evolutionary and physiological adaptations of aquatic invasive animals: r selection versus resistance. *Canadian Journal of Fisheries and Aquatic Sciences* 59: 1235–1244, https://doi.org/10.1139/f02-105

Meyerson L, Mooney H (2007) Invasive alien species in an era of globalization. *Frontiers in Ecology and the Environment* 5: 199–208, https://doi.org/10.1890/1540-9295(2007)5[199:IASIAE]2.0.CO;2

Mills EL, Rosenberg G, Spidle AP, Ludyanskiy M, Pligin Y, May B (1996) A review of the biology and ecology of the quagga mussel (*Dreissena bugensis*), a second species of freshwater Dreissenid introduced to North America. *American Zoologist* 36: 271–286, https://doi.org/10.1093/icb/36.3.271

Nalepa TF, Fanslow DL, Pothoven SA (2010) Recent Changes in Density, Biomass, Recruitment, Size Structure, and Nutritional State of Dreissena Populations in Southern Lake Michigan. *Journal of Great Lakes Research* 36: 5–19, https://doi.org/10.1016/j.jglr.2010.03.013

National Park Service (2016a) Management - Lake Mead National Recreation Area. US National Park Service, http://www.nps.gov/lake/learn/management/index.htm (accessed 7 November 2020)

National Park Service (2016b) Foundation Document Overview: Lake Mead National Recreation Area. Arizona and Nevada: U.S. Department of the Interior, 15 pp

National Park Service (2016c) History & Culture - Lake Mead National Recreation Area. US National Park Service, http://www.nps.gov/lake/learn/historyculture/index.htm (accessed 7 November 2020)

Noble RL (1981) Management of forage fishes in impoundments of the southern United States. *Transactions of the American Fisheries Society* 110: 738–750, https://doi.org/10.1577/1548-8659(1981)110<738:MOFFII>2.0.CO;2

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273–288, https://doi.org/10.1016/j.ecolecon.2004.10.002

Resnick JR (2018) Biodiversity under siege, invasive animals and the National Park Service: A state of knowledge report. Natural resource report National Park Service, Natural Resource Stewardship and Science Directorate-Biological Resources Management Division-2018/1679. National Park Service, Fort Collins, CO, https://irma.nps.gov/DataStore/Reference/Profile/2253966 (accessed 7 July 2020)

Rosen MR, Turner K, Goodbred SL, Miller JM (eds) (2012) A Synthesis of Aquatic Science for Management of Lakes Mead and Mohave: US Geological Survey Circular 1381, 162 pp, https://doi.org/10.3133/cir1381

Ryan KLN, Wittmann ME, Chandra S, Turner K, Sappington M, Thom T (2018) Lake Mead National Recreation Area Limnological and Riparian Resource Condition Assessment. National Park Service, Natural Resource Report, 415 pp, https://irma.nps.gov/DataStore/Reference/Profile/2265898

Schaus MH, Vanni MJ (2000) Effects of gizzard shad on phytoplankton and nutrient dynamics: role of sediment feeding and fish size. *Ecology* 81: 1701–1719, https://doi.org/10.1890/0012-9658(2000)081[1701:EOGSOP]2.0.CO;2

Schmitter-Soto JJ (2007) A systematic revision of the genus *Archocentrus* (Perciformes: Cichlidae), with the description of two new genera and six new species. *Zootaxa* 1603: 1–78, https://doi.org/10.11646/zootaxa.1603.1.1

Sousa R, Antunes C, Guilhermino L (2008) Ecology of the invasive Asian clam *Corbicula fluminea* (Müller, 1774) in aquatic ecosystems: an overview. *International Journal of Limnology* 44: 85–94, https://doi.org/10.1051/limn:2008017

Stebbins RC (1966) A Field Guide to Western Reptiles and Amphibians. Houghton Mifflin Company, Boston, MA, 279 pp

Strayer DL (1999) Effects of Alien Species on Freshwater Mollusks in North America. *Journal of the North American Benthological Society* 18: 74–98, https://doi.org/10.2307/1468010

Stuckey RL (1979) Distributional History of *Potamogeton crispus* (Curly Pondweed) in North America. *Bartonia* 46: 22–42, https://www.jstor.org/stable/41610371

Tapia M, Zambrano L (2003) From aquaculture goals to real social and ecological impacts: carp introduction in rural central Mexico. *AMBIO A Journal of the Human Environment* 32: 252–257, https://doi.org/10.1579/0044-7447-32.4.252

USFWS (2017) US Fish and Wildlife Service. Species Status Assessment Report for 14 Springsnails in Nevada and Utah (June 22, 2017 version). US Fish and Wildlife Service, Pacific Southwest Region, Sacramento, California, United States, 309 pp

USGS-NAS (2018) US Geological Survey. Nonindigenous Aquatic Species database [online database]. US Geological Survey, Gainesville, Florida, https://nas.er.usgs.gov/ (accessed 15 September 2019)

VanLandeghem MM, Farooqi M, Farquhar B, Patino R (2013) Impacts of golden alga *Prymnesium parvum* on fish populations in reservoirs of the Upper Colorado River and Brazos River Basins, Texas. *Transactions of the American Fisheries Society* 142: 581–595, https://doi.org/10.1080/00028487.2012.754786

Webber PA, Jones MT (2013) Continued gizzard shad (*Dorosoma cepedianum*) range expansion in the Colorado River Basin. *Western North American Naturalist* 73: 110–112, https://doi.org/10.3398/064.073.0112

Weber S, Janik J (2010) *Prymnesium parvum* bloom in a Nevada reservoir. *LakeLine* 30: 27–31, https://www.nalms.org/wp-content/uploads/2018/09/30-2-7.pdf (accessed 7 July 2020)

Wilcox C, Jaeger JR (2020) The Blue Point *Pyrgulopsis*: population density, distribution, and sensitivity to exotic fishes. University of Nevada, Las Vegas, Las Vegas, Nevada, United States, 30 pp

Wong WH, Gerstenberger SL (2011) Quagga mussels in the Western United States: monitoring and management. *Aquatic Invasions* 6: 125–129, https://doi.org/10.3391/ai.2011.6.2.01

Zambrano L, Hinojosa D (1999) Direct and indirect effects of carp (*Cyprinus carpio* L.) on macrophyte and benthic communities in experimental shallow ponds in central Mexico. *Hydrobiologia* 408: 131–138, https://doi.org/10.1023/A:1017085129620

Zambrano L, Scheffer M, Martínez-Ramos M (2001) Catastrophic response of lakes to benthivorous fish introduction. *Oikos* 94: 344–350, https://doi.org/10.1034/j.1600-0706.2001.940215.x

Supplementary material

The following supplementary material is available for this article:

Table S1. Checklist of aquatic non-native and invasive species in Lakes Mead and Mohave.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2022/Supplements/BIR_2022_Renner_Day_SupplementaryMaterial.xlsx