

Management in Practice

The 100th Meridian Initiative at the Lake Mead National Recreation Area, NV, USA: Differences between boater behaviors before and after a quagga mussel, *Dreissena rostriformis bugensis*, invasion

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Editor's note:

This paper was prepared by participants attending the workshop entitled “Quagga Mussels in the Western United States – Monitoring and Management” held in San Diego, California, USA on 1-5 March 2010. The workshop was organized within the framework of the National Shellfisheries Association, American Fisheries Society (Fish Culture Section) and World Aquaculture Society's Triennial Conference. The main objective of this workshop was to exchange and share information on invasive quagga mussels among agencies. The data presented in this special issue provide critical baseline information on quagga mussel monitoring and management at the early stages of introduction in the western United States.

Abstract

The 100th Meridian Initiative was developed to help prevent the spread of aquatic nuisance species (ANS) through boater education and research on boater movement patterns and behaviors. Surveys employing these elements were conducted at Lake Mead National Recreation Area (LMNRA) in 2002-2003 before the discovery of the quagga mussel (*Dreissena rostriformis bugensis* Andrusov 1897) and in 2007-2008 after an established population of quagga mussels was found in the Lake. Boaters were asked questions in a personal interview or a mail-in survey regarding what body of water they had previously launched their watercraft in, where they were planning to launch next, if they cleaned their watercraft between each launch, and if they were aware of quagga mussels or other ANS. Results from the personal interviews and mail-in surveys indicated a significant increase in mussel awareness between the pre- and post- mussel invasion groups. Cleaning habits between the study periods for both interviews and mail-in surveys did not differ significantly. Boat trailer states of registration were also documented in both study periods in the parking lots of LMNRA. In 2002-2003, 0.6% of the trailers documented were from states with known zebra or quagga mussel populations, whereas in 2007-2008, 98.2% of states documented had known zebra or quagga mussel populations. Increased boater awareness will help prevent the spread of aquatic invasive species and the 100th Meridian Initiative is a helpful way to educate boaters and collect relevant data on future mussel invasions. The preservation of natural waters is vital for the conservation of native species and the prevention of zebra and quagga mussel invasions will assist in this preservation. Further efforts should be directed toward educating boaters on effective cleaning methods.

Key words: Boater education, invasive mussels, Lake Mead, 100th Meridian Initiative

Introduction

Aquatic nuisance species (ANS), such as zebra and quagga mussels (*Dreissena polymorpha* Pallas, 1771 and *D. rostriformis bugensis* Andrusov, 1897, respectively) can attach to trailered boats and consequently, be introduced into new environments making boater education an imperative part of preventing the spread of

ANS. The United States Aquatic Nuisance Species Task Force began an initiative in 1997 to prevent the spread of zebra mussels and other ANS to waters west of the 100th meridian (100° west longitude) (Britton and McMahon 2005). The 100th meridian runs through Texas, Oklahoma, Kansas, Nebraska, South Dakota, and North Dakota. This project, referred to in this paper as "the 100th Meridian Initiative," was in

support of the United States National Invasive Species Act of 1996 (Public Law 101-636).

Six regional panels to advise the ANS task force were developed in different geographic regions of the USA. The Western Regional Panel took the lead on the 100th Meridian Initiative and began conducting three types of surveys (contact, mail-in, and trailer counts) in twelve states in 1998. Boater surveys can reveal boater travel patterns helpful in predicting the location of the next zebra/quagga invasion (Padilla et al. 1996; Johnson et al. 2001; Britton and McMahon 2005). Contact surveys were conducted with a standard form including questions that asked: 1) where boaters were from and where they had previously launched their boat; 2) where they were launching their boat next; 3) if they clean their boat between launchings; and 4) if they were aware of zebra or quagga mussels or other ANS. Mail-in surveys, consisting of the same questions as the contact survey, were placed on vehicle windshields. The last portion of the 100th Meridian Initiative survey project included trailer counts. The trailer count involved researchers counting and recording the state of registration of trailers at boat ramps and in marina parking lots. The goal of this research project was to conduct all three survey types at Lake Mead National Recreation Area (LMNRA) before and after quagga mussels were discovered in the lake. The surveys were conducted before the quagga mussel invasion due to lack of data on public awareness of ANS in the Lower Colorado River and to determine the risk of invasion of ANS to Lake Mead. Surveys after the invasions were conducted to determine the following: if boater awareness to ANS in Lake Mead changed since the first survey project, what states boaters were coming from, and which bodies of water Lake Mead boaters would be traveling to after launching in Lake Mead.

Methods

Contact surveys

As part of the nationwide initiative, the aforementioned surveys were conducted by employees of the University of Nevada Las Vegas from September 2002 to March 2003 at LMNRA. Surveys were conducted with a convenience sampling design before and after a boater launched into the lake, primarily on weekends at least two times each month. Survey

administrators stood on boat launch ramps in the park (n=6: Hemenway Harbor, Lake Mead Marina, Las Vegas Bay, Callville Bay, Echo Bay, and Overton Beach; Figure 1). When this initial study was conducted, there were no known populations of quagga mussels in Lake Mead. Post-invasion surveys were conducted at LMNRA from October 2007 to September 2008. Survey administrators went to launch ramps at LMNRA (n=4: Echo Bay, Callville Bay, Lake Mead Marina, and Hemenway Harbor) (Figure 1) to conduct the contact surveys. Boaters on the launch ramp either launching their boat or removing their boat from the water were approached by survey administrators and asked to participate in a short survey. Then the administrators would ask the boater the questions on the official 100th Meridian Initiative contact survey obtained from the 100th Meridian Initiative website at www.100thmeridian.org. If boaters were not aware of the threats of quagga mussels to the lake and to their boats, administrators would provide educational materials such as the Zap the Zebra brochure to the boater and discuss the topics with the boater. During the initial study, survey administrators only asked boaters about awareness of zebra mussels, not quagga mussels, and then were asked if they were aware of other types of invasive species. In the case of the 2007-2008 surveys, participants were specifically asked if they were aware of quagga mussels or other ANS.

Mail-in surveys

At the same launch ramps and marinas where contact surveys were conducted plus the Overton Beach launch ramp, and Las Vegas Bay in 2003, the official 100th Meridian Initiative mail-in surveys obtained from www.100thmeridian.org were placed on the windshield of vehicles with a boat trailer attached. If a boater chose to participate, they would fill in the survey then deposit it in the nearest mail box with prepaid postage to UNLV.

Trailer counts

In parking lots of the launch ramps and marinas, researchers documented the state of registration of boat or Personal Water Craft (PWC) trailers and recorded the counts on the 100th Meridian Initiative official sheet.

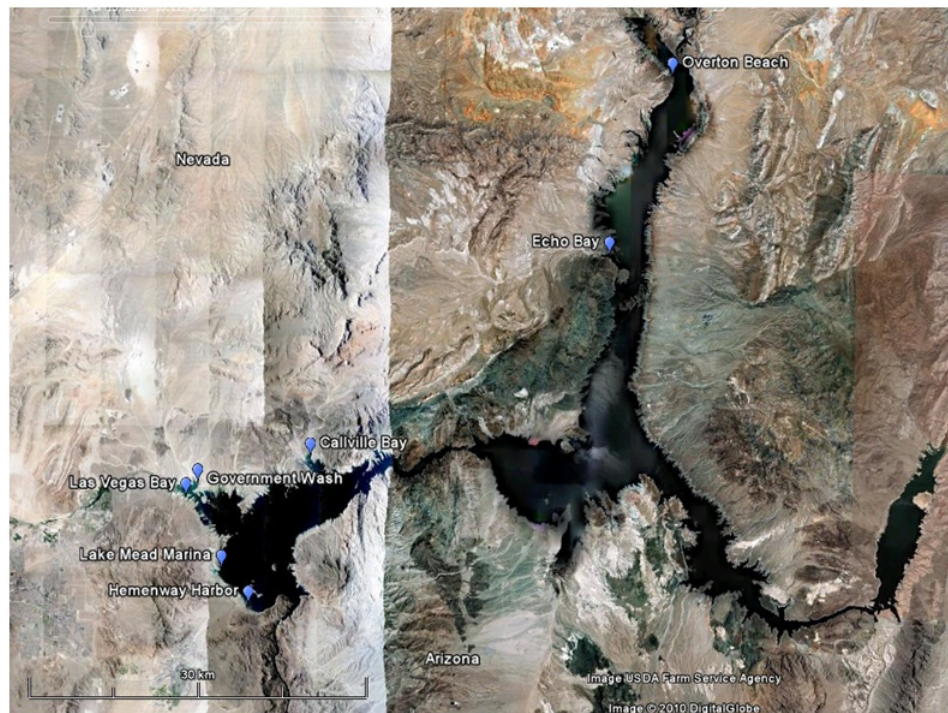


Figure 1. Locations of 100th Meridian Initiative surveys at LMNRA. Interview surveys, mail-in surveys, and trailer counts were conducted in 2002-2003 at Hemenway Harbor, Lake Mead Marina, Las Vegas Bay, Government Wash, Callville Bay, Echo Bay, and Overton Beach. Interview surveys, mail-in surveys, and trailer counts in 2007-2008 were conducted at all of the previous locations except Government Wash, Las Vegas Bay (due to decreasing water levels, these launch ramps were closed), and Overton Beach (only mail-in surveys and trailer counts).

Statistics

Contact survey data were used to create contingency tables to further understand the relationships between boater types and cleaning habits and boater types and quagga mussel awareness. Contingency tables were also created to compare expected and observed trends of awareness and cleaning habits in pre- vs. post-quagga mussel studies. When evaluating categorical data, few options are available. The chi-square comparison of proportions test is the most commonly used. Chi-square analyses were conducted on the contingency tables using SPSS version 16.0 to compare the observed and expected frequencies at the significance level $p \leq 0.05$. In the event of a cell in the contingency table containing an expected count less than 5, the likelihood ratio statistic (G^2) was reported; otherwise the chi-square statistic (χ^2) was reported.

Results

Contact surveys

During the 2002-2003 study period, researchers interviewed 242 boaters with the contact survey. Surveys were conducted at Echo Bay ($n=7$), Callville Bay ($n=82$), Lake Mead Marina ($n=24$), Hemenway Harbor ($n=55$), Overton Beach ($n=27$), and Las Vegas Bay ($n=48$). In this initial study, only 4 boaters interviewed came from states with a known and established dreissenid mussel population (USGS 2010). Most boaters interviewed in 2002-2003 owned pleasure boats (83%), whereas others had angling boats (12%), or personal water craft (PWCs) (6%; Table 1). Eighty-two percent of boaters cleaned their boats between launchings, and only 35% of boaters were aware of zebra mussels (Table 1) (Gerstenberger et al. 2003). Only 44% of boaters interviewed launched their boats exclusively in

Table 1. Summary of contact survey data from both studies.

Type of Craft	2002-2003	% of total	2007-2008	% of total
Angling	28	11	50	21
Jet Ski (PWC)	14	6	17	7
Pleasure	201	83	162	69
Other	0	0	7	3
Total	243		236	
Clean boat between launchings?	2002-2003	% of total	2007-2008	% of total
No	42	18	204	13
Yes	192	82†	32	86†
Total	234*		236	
Aware of zebra/quagga mussels?	2002-2003	% of total	2007-2008	% of total
No	158	65	43	18
Yes	85	35†	193	82†
Total	243		236	
Always launch in Lake Mead?	2002-2003	% of total	2007-2008	% of total
No	137	56	91	39
Yes	106	44	145	61
Total	243		236	

† Proportions were significantly different between 2002-03 and 2007-08; $p < 0.001$

* 9 boaters did not answer this question.

Lake Mead with no plans to launch in other bodies of water (Table 1).

In the 2007-2008 study, surveys were collected between 25 Oct 07 and 01 Sept 08 ($n=236$). Thirty-one people declined to participate. The surveys were conducted at Echo Bay ($n=23$), Callville Bay ($n=60$), Lake Mead Marina ($n=109$) and Hemenway Harbor ($n=44$). In contrast to the initial study, 11 boaters interviewed in 2007-2008 came from states without established zebra or quagga mussel populations (USGS 2010). Most boaters interviewed owned pleasure boats (69%), whereas others had angling boats (21%), PWCs (7%) and 3% owned a craft classified as "other" (Table 1). Craft classified as "other" included kayaks, houseboats, and sailboats. Most boaters (86%) stated they cleaned their boats between launchings and 18% of boaters had no awareness of quagga mussels or any other aquatic nuisance species. Sixty-one percent of boaters interviewed in 2007-2008 said they launch exclusively in Lake Mead, and had no plans to launch in any other body of water (Table 1).

The chi-square analysis determined that overall boater cleaning habits did not differ between the study years ($\chi^2=0.949$, $p=0.330$), however mussel awareness increased significantly overall from 2002-2003 to 2007-2008 ($\chi^2=106.5$, $p < 0.001$; Table 1). Significantly

more boaters interviewed in 2007-2008 always launched their boats in Lake Mead than boaters interviewed in 2002-2003 ($\chi^2=18.668$, $p < 0.001$; Table 1).

The cleaning habits of different types of boaters were not significantly different in 2002-2003 ($G^2=1.275$, $p=0.529$), but were statistically significant in 2007-2008 ($G^2=13.120$, $p=0.004$). Boaters with a craft classified as "other" cleaned at a lower than expected level than boaters with an angling boat, pleasure boat or PWC in the 2007-2008 data. When comparing mussel awareness among boater types, in 2002-2003, significantly more angling boaters were aware of zebra and quagga mussels than pleasure or PWC boaters ($G^2=7.226$, $p=0.027$), although no other boaters were observed in this period. However, there was not a statistical difference in awareness among the different types of boater interviewed in 2007-2008 ($G^2=1.028$, $p=0.794$).

Mail-in surveys

In 2002-2003, 3,005 mail-in surveys were placed on vehicle windshields. Of these, 132 (4%) were returned. Two people were from states with established dreissenid populations as of 2003 (USGS 2010). Seventy-six percent of boaters cleaned their boat between launchings; 63 of 130 participants answered that they had prior

Table 2. Summary of mail-in survey data from both study periods.

Type of Craft	2002-2003	% of total	2007-2008	% of total
Angling	30	21	19	32
Jet Ski (PWC)	12	8	3	5
Pleasure	98	68	32	53
Other	4	3	6	10
Total	144*		60	
Clean boat between launchings?	2002-2003	% of total	2007-2008	% of total
No	31	24	12	20
Yes	99	76	48	80
Total	130**		60	
Aware of zebra/quagga mussels?	2002-2003	% of total	2007-2008	% of total
No	67	52	2	3
Yes	63	48†	58	97†
Total	130**		60	
Always launch in Lake Mead?	2002-2003	% of total	2007-2008	% of total
No	66	50	26	43
Yes	66	50	34	57
Total	132		60	

*Some participants listed more than one type of boat owned.

**Two participants did not answer these questions.

† Proportions were significantly different between 2002-03 and 2007-08; $p < 0.001$

knowledge of zebra or quagga mussels; and 50% of boaters always launched their boats in Lake Mead (Table 2). Self-surveyed angling boat owners in 2002-2003 were significantly more aware of zebra mussels than other types of boaters ($G^2=19.506$, $p < 0.001$). There was not a significant difference between boater type and cleaning habits in 2002-2003 self-surveyed participants ($G^2=7.155$, $p=0.067$).

Mail-in surveys were placed on windshields of vehicles with trailers attached from 10 Nov 07 through 14 Feb 09 at five launch ramps throughout LMNRA (Figure 1). Of the 888 surveys distributed, 60 were returned for a 6.7% return rate. Nine participants were from states without an established dreissenid population (USGS 2010). Eighty-one percent of boaters cleaned their boat between launchings; only two participants had no prior knowledge of zebra or quagga mussels; and 56% only launched their boats in Lake Mead (Table 2). There were no significant differences between boat types and dreissenid mussel awareness or cleaning habits in the 2007-2008 self-surveyed boaters. When comparing the mail-in surveys from the two

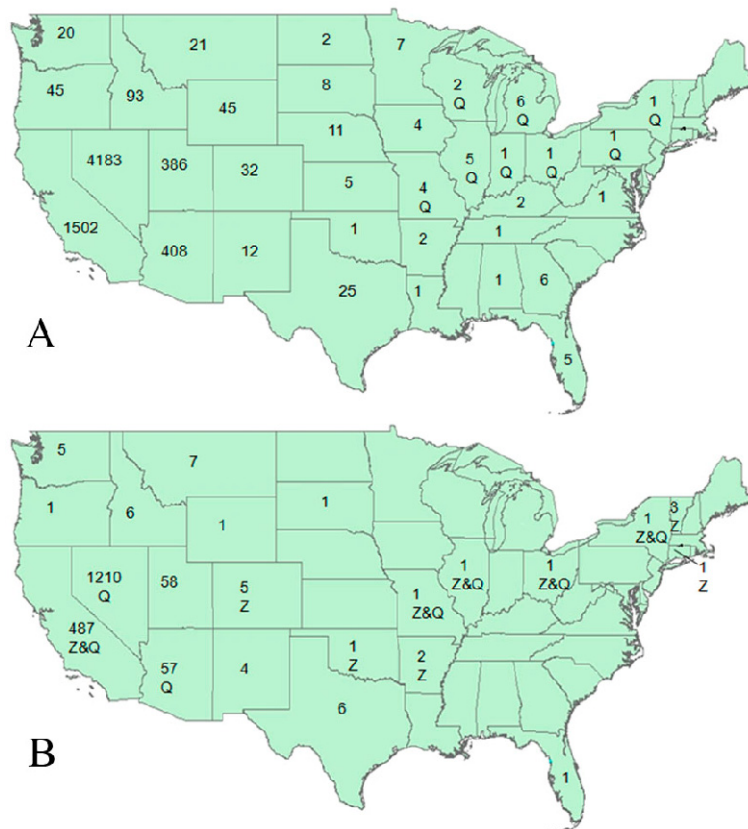
study periods, boaters were significantly more aware of zebra mussels in 2007-2008 than 2002-2003 ($\chi^2=37.387$, $p < 0.001$), but cleaning habits did not differ ($\chi^2=0.026$, $p=0.873$; Table 2).

Trailer counts

There were 6,799 trailer states documented in 2002-2003 (Figure 2A). Forty-five of the 6,799 trailers counted were from states with known zebra mussel populations (Gerstenberger et al. 2003; USGS 2010). A total of 1,864 trailer license plate state of registrations were recorded from 2007-2008. To contrast between the study years, only 90 of the 1,864 trailers documented in 2007-2008 came from states known to be without a known and established dreissenid infestation, indicating a trend in the opposite direction from 2002-2003 (USGS 2010). However, this is most likely due to an increase in the number of states with dreissenid populations since 2003. Figure 2B gives detailed geographic distributions of boaters found at Lake Mead in 2007-2008.

Figure 2. A. Trailer count distribution 2002-2003. At this time only eight states documented in the LMNRA were from states with established quagga mussel populations: IN, IL, MI, MO, NY, OH, PN, and WI marked by a "Q" in the map. This accounted for 21 of the total 6,799 or 0.3% trailers documented. The closest location to Lake Mead that harbored a known and established quagga mussel population at this time was near St. Louis, MO in the Mississippi River (USGS 2010). This location is 1,361 miles from LMNRA. The next closest location was Lake Michigan. Lake Michigan at its closest location is over 1,500 miles from LMNRA.

B. At the time of this study, ten of the states documented in the trailer counts did not have a quagga or zebra mussel infestation (FL, ID, MT, NM, OR, SD, TX, UT, WA, WY). States with a zebra or quagga mussel population in 2008 are documented with a "Z" or "Q," respectively. As of 2009, Texas has an established population of zebra mussels.



Discussion

Between the studies in 2002-2003 and 2007-2008, awareness of zebra and quagga mussels increased from 35% to 82%. The increase in boater awareness in this study from the one in 2002-2003 may be explained by an increase in press exposure about mussels. There are signs stating "Don't Move a Mussel: Clean, Drain and Dry Your Equipment" and "Stop Aquatic Hitchhikers" at each entrance and every launch ramp within LMNRA. Additionally, numerous newspaper articles and television interviews in Las Vegas have been conducted regarding the serious problems quagga mussels have on Lake Mead since the discovery of the quagga mussel in Lake Mead in January 2007. Although boater awareness of dreissenid mussels significantly increased from 2003-2008, boater cleaning habits did not.

Despite increased campaigning for boaters to clean their boats after each use, cleaning

frequencies stayed the same. Proper boat and trailer cleaning as well as public education are key factors to prevent the spread of aquatic invasive species. Unfortunately, every individual boater has a different definition of "clean." Attempts have been made to standardize cleaning methods, but more efforts need to be focused in this area. An additional question was added to the survey in 2007-2008 to gain an improved understanding of a boater's definition of "clean." If a boater answered that they cleaned their boat after each use, survey administrators then asked how they cleaned their boat. There were a wide variety of answers, but the most common answers were: wipe down or dry boat after use (25%), use soap and water (19%), use a vinegar and water solution to wash boat (16%), or use a pressure washer (15%). Other answers included: rinsing off boat with a hose, taking the boat to a carwash, using bleach, or spraying down boat with Pink Stuff® (an acid based concentrated liquid coil cleaner), Windex, or Simple Green.

According to www.ProtectYourWaters.net, an informative boater website ran by the USFWS under the federal "Stop Aquatic Hitchhikers" campaign, a boat should be cleaned using the following procedure: 1) remove all visible mud, plants, and fish or animals from the boat, trailer and all equipment; 2) eliminate water from all equipment; and 3) clean and dry anything that came into contact with the water with a 100% vinegar solution, a salt solution, or with water that is at least 40°C (USFWS 2009). In contrast, Morse (2009) found that spraying a watercraft with water less than 60°C for less than 10 seconds is not 100% effective in killing zebra and quagga mussels and recommended using water greater than 60°C for a period over 10 seconds at every point sprayed to fully sterilize a watercraft. However, 10 seconds may not be a long enough period if the spray was unable to reach certain areas directly, further recommending a longer spray period for hard to reach areas.

It is of the utmost importance for people to clean, drain, and dry their boats after each launch into a body of water due to the fact that mussels have been found to survive out of water for more than 10 days at less than 15°C and high humidity (McMahon et al. 1993; Britton and McMahon 2005). This may allow live, adult mussels to be transferred to non-infested bodies of water, where they could potentially dominate the aquatic system.

Increased boater awareness combined with proper watercraft cleaning can help prevent the spread of aquatic invasive species. The 100th Meridian Initiative allows for collection of relevant data regarding future mussel invasions through the use of surveys and boater education. Results from this study will assist lake managers and operators in deciding the best course of preventative action needed to prevent exotic species invasions. Due to the fact that 18% of people interviewed were unaware of zebra or quagga mussels, this education/research initiative should be continued to ensure the protection of other lakes from aquatic invasive species. The preservation of freshwater lakes, reservoirs, rivers and streams is vital for the conservation of native species and the prevention of zebra and quagga mussel invasions will assist in this preservation. Public awareness of ANS at Lake Mead may help prevent invasions in other water bodies and additional invasions in Lake

Mead. These surveys provided information to why Lake Mead was invaded with quagga mussels: lack of public awareness. Further use of boater surveys and increases in boater education in the Western United States, will be imperative to keep ANS out of uninfested waters. Where funding is not prohibitive, mandatory check stations will be the most effective tool in preventing invasive species

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