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The 100th Meridian Initiative in Nevada: Assessing the westward movement of the Zebra mussel to the Lake Mead National Recreation Area

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The 100th Meridian Initiative in Nevada: Assessing the Westward Movement of the Zebra Mussel to the Lake Mead National Recreation Area

by

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Abstract

Zebra mussels, *Dreissena polymorpha*, are a concern for all bodies of water in North America. East of the 100th Meridian, zebra mussels have infested the waters and dramatically changed the natural ecosystems. The US Fish and Wildlife Services set up the 100th Meridian Initiative project to monitor the boat traffic to and from infested and non-infested waters of the United States and Canada. Surveys were conducted from October 19, 2002 through March 31, 2003, focusing specifically on the Lake Mead National Recreation Area (LMNRA) for the scope of this thesis. This study addresses the movement of trailers, boats, and other watercraft that enter the LMNRA. Specifically, we addressed three items 1) the origin of trailers that come to the LMNRA, 2) the three previous boat launch sites (ex. Michigan, Idaho, and California) of boats launching at the LMNRA, and 3) the boat cleaning strategies of anglers, pleasure, jet skis, canoes, and other boaters. A total of 4739 trailers were surveyed with a total of 4152 (at 88%) from Nevada, California, and Arizona with a total of 587 (at 12%) from other recorded states; while a total of 177 contact interviews were performed. Descriptive statistics and Chi Square analysis were completed to test the differences from our expected results. A vast majority of the boats surveyed at LMNRA came from local states and non-infested waters; and pleasure boaters were identified as the subgroup of boaters who clean their boats more regularly. Based on the launch locations records of infested states, personal interviews, and cleaning practices the risk of zebra mussel transport to the LMNRA is low.

Introduction

The purpose of the study was to asses the potential movement of the zebra mussel, *Dreissena polymorpha*, west of the 100th meridian, to educate people about the risk that the zebra mussels have on ecosystems, and to collect data about the boats and trailers entering the Lake Mead National Recreation Area (LMNRA). Data collection on the zebra mussel provides information to the US Fish and Wildlife Service so appropriate preventative and extermination steps can be taken in the western half of the United States.

In 1988, the US Fish and Wildlife Services (USFWS) initiated the 100th Meridian Initiative Project to track, document, and prevent the introduction of invasive species, specifically the zebra mussel to western waters. The 100th meridian runs through Manitoba Providence, Canada, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. The U.S. Fish and Wildlife Service have identified the 100th Meridian as a guideline for where the zebra mussels' westward movement has stopped. In states west of the 100th meridian, there is a potential hazard for mussel's migration, but the nation wide study will specifically determine whether zebra mussels have been introduced into these waters.

The 100th Meridian Initiative falls under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA). The University of Nevada Las Vegas' involvement with the 100th Meridian focuses on the possible introduction of the zebra mussel into the waters of Lake Mead, Lake Mojave, and Lake Powell. Zebra mussels travel from one body of water to another by attaching themselves to boat hulls, trailers, live wells, and bilge water. Personal interviews and surveys were used to track boaters that entered the Lake Mead National Recreation Area. When the USFWS knows where the boaters are coming from, the tracking of zebra mussels on boats or in contact with infested water, will aid in controlling the spread of the mussels.

The USFWS and the 100th Meridian Initiative have studied the westward attachment of the zebra mussel, but the majority of this work has been done in the Great Lakes Region and the St. Lawrence River Way, where the problem is so prominent. Stoeckman (1997)

constructed an energy budget for the zebra mussels from the western basin of Lake Erie. The study was done during the mussels' main growing periods, May through October. Stoeckman's study measured the metabolic costs, body mass change, and feces production weekly during the study months determining if the size of the zebra mussel had a factor to the rate of growth in the size-based population. During the study the mussels were marked to determine the shell growth that had occurred. The researchers factored into their calculations the mussel size distribution, coming to the conclusion that the greatest proportion of population consumption was from the most abundant size class (Stoeckman 1997). Stoeckman's study proves that the size of a zebra mussel can contribute to the population growth. The exponential growth of the zebra mussel happens shortly after the population is introduced. After the introduction of the zebra mussel into a body of water, the potential spread to another area is even higher, especially the probability of spread westward where mussels are not present. Many other studies of the Great Lakes have been done, but the goals of the 100th Meridian Initiative are to get the same types of information about the waters west of the 100th Meridian. The USFWS believes that the mussels are not in the states west of the 100th meridian.

The spread of the zebra mussel is a national concern, one that can be extended to the Lake Mead National Recreation Area. This means that there are smaller questions that arise from the overall question posed by the 100th Meridian Initiative. These sub questions include: 1) Are boaters coming to western lakes such as Lake Powell, Lake Mojave, and Lake Mead from water that are infested with zebra mussels, and are the boaters aware of the problem? 2) Are zebra mussels a potential threat to the Lake Mead National Recreation Area? 3) Do boats launched in infested waters cross over the 100th meridian and into waters like the Lake Mead National Recreation Area, that are not infested?

Through the research the evaluation of the potential movement of zebra mussels from infested waters to the Lake Mead National Recreation Area, by attachment and travel on boats and trailers across the 100th Meridian. The potential transport of zebra mussels to the Lake

Mead National Recreation Area will be addressed by tracking the states that boaters are registered.

Studies, e.g. Shrader-Frechette 2001 and Lauer 2001, have shown that the zebra mussels are causing hazards; (changes in ecosystems, clogging pipes, and attaching to personal watercraft) in the waters that are already infested. These studies help to support the argument of the zebra mussel as a risk to the environment, the native organisms, the economic industry, and other bodies of water that come into contact with the organisms.

The overall objective of the 100th Meridian Initiative is to determine whether there is a possibility that the zebra mussel could be transported to, and introduced into, the Lake Mead National Recreation Area. Specifically three hypotheses related to the overall objective have been developed.

1. Boat trailers surveyed in the Lake Mead National Recreation Area will be mainly from the states without known zebra mussel contamination, specifically 80% of the trailers will be from Nevada, California, and Arizona. Data will be acquired from the Trailer Counts at Launch Survey.
2. Based on the last three recorded boat launch sites (ex. Michigan, Idaho, and California), boats launching at the Lake Mead National Recreation Area will not come from zebra mussel infested waters. Data will be acquired from the Interview Form for the Trailered Boat Survey.
3. Boaters do not take any precautionary measures between launches to eliminate zebra mussel transportation, specifically there will be no difference between anglers, pleasure, jet skis, canoes, or other boaters. Data will be acquired from the Interview Form for the Trailered Boat Survey.

Impacts of the Zebra Mussel

Zebra mussels pose a problem to the natural ecosystems. Colonies have emerged in to the millions throughout the Great Lakes Region, including the states of Michigan, Wisconsin, Illinois, Indiana, Ohio, and New York. Zebra mussel colonies can grow to sizes of 700,000 individuals per square meter (Frost 2001). Studies have been done in the Great Lakes that have shown zebra mussels grow so rapidly that their growth is an impairment or degradation to that which it is growing on (Lauer 2001). A zebra mussel is a biofouler, an organism that impairs or degrades something, like a pipe, ship haul, or an ecosystem, as a result of the growth or activity of the organism.

Zebra mussels have the ability to withstand a wide variety of living conditions and are extremely adaptable to various environments. The ability to adapt is why this organism causes such a negative impact or concern to many different habitats, industry, and boaters. Water treatment facilities, industry, and utility plants "have experienced clogged or blocked intakes and distribution piping throughout the facilities, an increase in the corrosion of iron or steel piping and riveting, build up of methane gasses from decaying mussel tissue, as well as the fouling of pumps, forbays, holding tanks, trash racks, and condenser units" (US Army Corps of Engineers: Updated March 14, 2002).

Boaters and recreational facilities also experience negative impacts from zebra mussel infestation such as: the fouling of boat hulls and engines, heavy fouling of navigational buoys making them useless, the accumulation of windrows of mussel shells along beaches and shorelines, and the excessive accumulation on docks with colonizing mussels (Frost 2001). The negative effects that the mussels have on the ecosystems are shown annually through the millions of dollars spent to treat the pipes in municipal and industrial raw water systems (Shrader-Frechette 2001).

The biological characteristics of the zebra mussel directly relate to the reasons that the organism so easily attaches itself to a facility, boat, or body of water. Major problems for man-

made systems result from mussel attachment to a structure with byssal threads, the mussel's high fecundity under suitable environmental conditions, its ability to translocate to more suitable areas, the mussel's high tolerance for a wide range of conditions, and its microscopic, free-swimming veliger stage (US Army Corps of Engineers: Updated March 14, 2002). A member of the U.S. Army Engineer Waterways Experiment Station said the following in 1995 about the impact that the zebra mussel can have on a system:

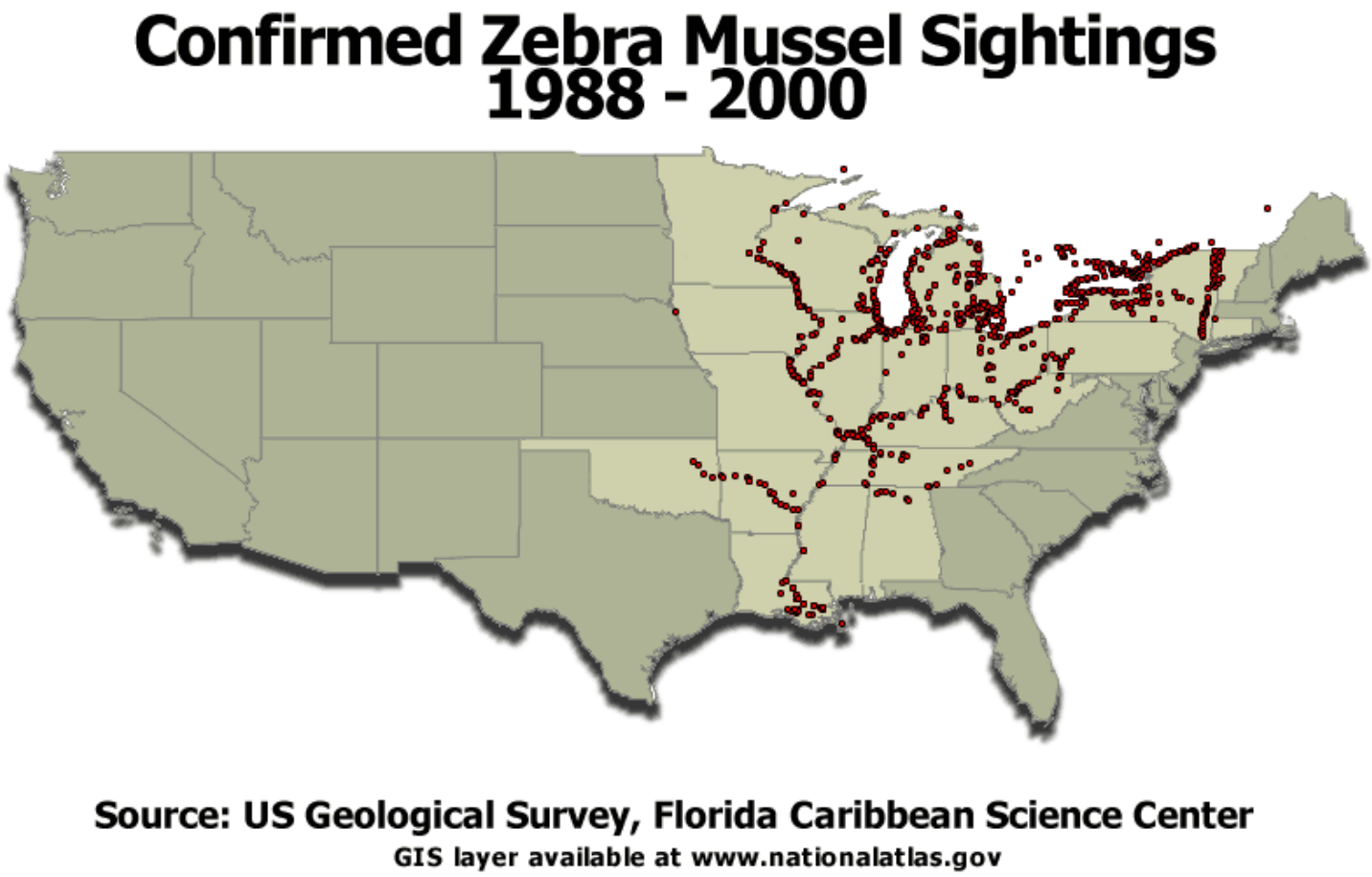
> "Zebra mussels could render inoperable miter gates on locks, fire prevention systems..., reservoir release structures, navigation dams, pumping stations, water-intake structures, dredges, and commercial and recreational vessels. Materials and equipment, such as small-diameter pipes, seals, valves, gears, air vents, weep holes, screens, trash racks, chains, pulleys, and wire ropes are vulnerable." (US Army Corps of Engineers: Updated March 14, 2002, "Impacts").

Brief History and Life Cycle of the Zebra Mussel

-History-

The zebra mussel was "originally described by the famous Russian scientist and explorer Pyotr Simon Pallas from a population in a tributary of the Ural River in the Caspian Sea Basin" (US Army Corps of Engineers: Updated March 14, 2002, "Life History"). Because of the expansion of canals and commercial boat traffic, the spread of the mussels west from Russia into Europe occurred during the 19th century (US Army Corps of Engineers: Updated March 14, 2002, "Life History"). Sometime between the 19th century and 1988 Zebra mussels found their way into North America. First found in 1988 in Lake St. Clair, a water body connecting Lake Huron and Lake Erie, see Figure 1, zebra mussels began their infiltration of the Great Lakes Area.

Figure 1: Map of Area of Confirmed Zebra Mussel Sightings from 1988-2000



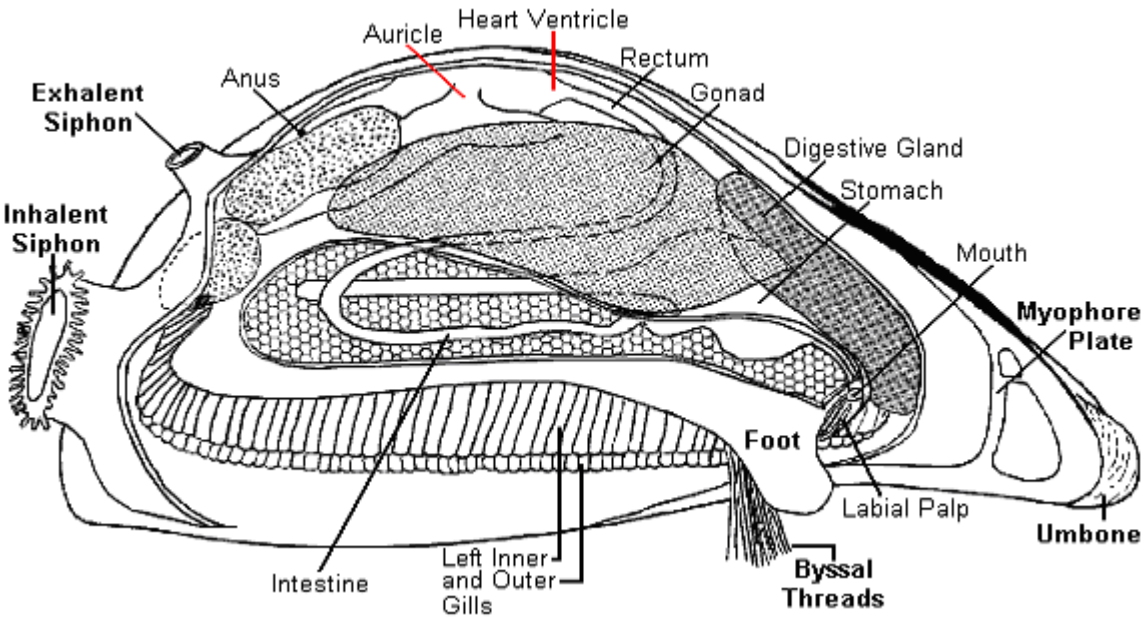
-Anatomy and Physiology of the Zebra Mussel-

The zebra mussel obtained its common name from the prominent zebra stripes present on the shell. The stripe pattern on the shells of zebra mussels can vary from one mussel to the next, ranging from mostly cream to almost black. Adult mussels range from approximately 6 to 45 mm and generally live to be 2-3 years old in temperate climates (US Army Corps of Engineers: Updated March 14, 2002, “Reproduction”). Mussels are considered adults when they become sexually mature.

There are distinct male and female zebra mussels in a population, equal in numbers, but hermaphrodism is encountered rarely. Reproduction can occur within 12 months of life, mostly

beginning in early May. Gonad (sexual organ) development ends in the winter (Martel 2001), and then accelerates as temperatures increase in the spring, leading to mature gametes within 2 months. In the summer spawning occurs between 15-17 °C (US Army Corps of Engineers: Updated March 14, 2002, "Reproduction). The amount of time required for a fertilized gamete to develop into a fully developed juvenile is longer at colder water temperatures and thus can range from 8 to 240 days (Selegean 2001). Fertilization of the zebra mussel occurs externally in the water column and the release of eggs and sperm must be timed perfectly. A female releases more than a million eggs, visible as tiny white dots, into the water column via the exhalant siphon (Figure 2). A male can release up to 10 billion sperm during reproduction.

Figure 2: The Internal Organs of the Zebra Mussel



(US Army Corps of Engineers: Updated March 14, 2002, "Reproduction")

Once adult mussels (sexually mature) are attached to a substrate by their byssal threads, they generally remain there for life; this is particularly true for larger mussels.

The three main periods in a zebra mussel life cycle are 1) the larva stage 2) the juvenile stage and 3) the adult stage. The planktonic larva, a free-floating form in a water way also have three stages: the trochcphore, straight-hinged veliger, and umbonal veliger (Sprung 1988) all of which can be rapidly transported in water. Eventually the larva settles in the substrate, grows, and then begins to crawl. A zebra mussels life cycle is defined by the morphology and behavior of the organism, but may somewhat overlap.

Studies examining areas with a zebra mussel problem have shown that they also cause problems for indigenous mussels, a mussel that occurs naturally in an environment, including reproduction and growth (Frost 2001). Zebra mussels feed more than other organisms in the area, thus starving them by eating both organic and inorganic particles. They filter micro-algae, micro-invertebrates, bacteria, detritus, and other organic material (Sprung 1988). Sprung and Rose reported in 1988 that the zebra mussel can filter out and ingest bacteria that are <1 μm. They also stated that the maximum retention of the zebra mussel particles were in the 5 to 35 μm in diameter range. One example of the zebra mussels' impact is demonstrated by the habitat takeover in the lake trout stocked in the Great Lakes that spawn on the shallow reefs. The zebra mussel has inhabited this area to the extent that the shallow water substrates are being rapidly colonized, and thus the result is a degradation of the spawning substrate (Marsden 2001).

Funding and Client Information

The funding for the research of the study was due to the involvement and interest of the USFWS about the spread of the zebra mussel. In supporting and providing aid to the efforts of the USFWS project and the 100th Meridian Initiative, the study completed three surveys designed to track boats and trailers that come into Lake Mead National Recreation Area, addressing the question of zebra mussel movement.

The USFWS was the client for the research funding and overall project. The information gathered will be compiled with the data from other researchers and aid in the knowledge of the movement and spread of the zebra mussels across the United States. Because of the project, boaters and anglers will become more aware of the actions that they can take to prevent the western dispersal of the zebra mussel. Education and information of boaters is a large part of the USFWS goals of the 100th Meridian Initiative.

Dr. Gerstenberger, of the University of Nevada Las Vegas (UNLV) and the Environmental Studies Department, submitted the proposal for the funding of the project. The original funding that was asked for $12,572.00 from the USFWS. The funding given was for a grant period of September 1, 2002 through February 28, 2003. Dr. Gerstenberger was the principal investigator for the project.

Approach

The research for the 100th Meridian Initiative was done through a series of surveys provided by the USFWS. These surveys were administered throughout the country and were previously written for the use of the investigators. Alreck (1985) stated that there are three reasons that sponsors request a survey to be done. They want to 1) influence or persuade an audience, 2) create or modify a product or service for a particular public, and 3) focus directly on understanding or predicting a behavior or condition. When a survey is written Alreck said that two roles of the survey must be taken into account: 1) those that sponsor the survey and seek the information, and 2) those that are to design and conduct the research. The people that received the survey and gave the wanted data were also a consideration for the design of the surveys. The four surveys are pretested and given to anyone who is part of the 100th Meridian Project.

Through the 100th Meridian Initiative there are three main surveys that were distributed and reported including 1) Trailered Boat Traffic Summary Report, 2) Interview Form for the

Trailered Boat and 3) the Self Survey. The three surveys completed at major boat launches including Overton, Las Vegas Bay, Callville Bay, etc, were part of the study and were used to acquire data regarding the westward movement of the zebra mussel. From the information that was collected, we aim to find out if there are boaters traveling from infested waters east of the 100th meridian and identify if boaters are coming to Lake Mead National Recreation Area.

Where are the boaters using Lake Mead, Lake Mojave, and Lake Powell coming from? This question is the main interest of the USFWS and can be answered through the surveys. Collecting the data over the study period provided a large sample group of people, about 2000 total trailers counted and multiple interviews of boaters that come to the Lake Mead National Recreation Area. Information about the extent of the westernization of these mussels will also help in knowing if and when zebra mussels could come to the three lakes of the Colorado River system. Boater registration helps to track the places that the boaters come from, as well as where they have been.

The “Trailer Counts for Launch Areas Survey” from the 100th Meridian Project collects the state identification information from all boats and trailers that are coming to Lake Mead National Recreation Area and possibly launching. Each state has the possibility of representation in this part of the study and provides an opportunity for zebra mussel movement in the Lake Mead National Recreation Area.

Through the trailer survey the distribution between states that use these waters was seen. The surveys were taken at the boat launch areas by a visual inspection of the license plate on the trailer. If there was not a plate on the trailer, then the registration state of the boat was recorded.

The second way that the information will be gathered was through the Trailered Boat Traffic Summary Report. The survey determined the types of boats that are used at the Lake Mead National Recreation Area and the potential risk that was associated with the different boat

types. Data on jet skis, bass boats, pleasure boats, canoes, and other water craft was separated for the survey for the more detailed information that was needed.

The third survey was through the Self Survey that was left on the windows of the Cars that had trailers attached to them. Cars that did not have trailers attached did not get the surveys. Through the self mail-in survey, information of the boaters' habits was gathered even without the interviewer talking to the boaters.

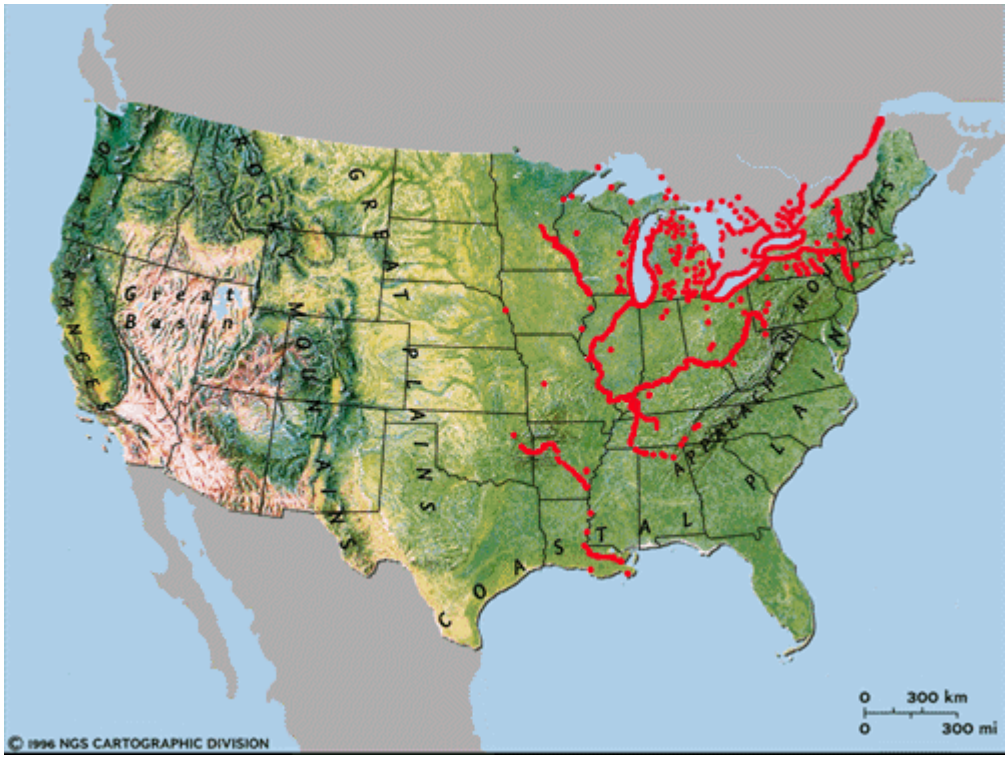
Methods/Procedures

The study through the University of Nevada Las Vegas began on September 1, 2002 and ended on February 28, 2003, while the data collection for the study occurred between October 10, 2002 and March 31, 2003. At the Lake Mead National Recreation Area there are six sites that the surveys was administered, these included the launch sites at Hemenway Launch Site, Lake Mead Marina, Las Vegas Bay, Callville Bay, Echo Bay, and Overton Beach (see appendix A). The surveys administered included the Trailer Counts at Launch Survey (see appendix B), the Interview Form for the Trailered Boat Survey (see Appendix C), and the Self Survey, which was returned by mail to UNLV (see Appendix D).

From these three surveys, information was extracted that answered the three main hypotheses of the thesis. The different states boaters come from, their projected destinations, and a projection of where their next stop provided valuable pieces of information in tracking the potential zebra mussel movement. The origin of boats from infested and non-infested states is an important set of data that was extracted from the surveys. Infested waters are defined as waters that have known zebra mussel colonies present, these states include: Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Louisiana, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Vermont, West Virginia, Wisconsin (see Figure 3). Any other state is considered a non-infested state and is not currently thought to be a risk to the Lake Mead National Recreation Area. The determination of

infested states comes from the 100th Meridian Initiative and was used to classify trailers that come to Lake Mead National Recreation Area.

Figure 3: 1999 United States Map of the Zebra Mussel Infestation



The first step in the study was to become familiar with the 100th Meridian Initiative web site at www.100thmeridian.org. This web site gives any information needed to complete the surveys. Each survey gives different information to the researcher, thus using the appropriate survey for the data that is important.

Obtaining the Surveys:

1. Go to the 100th meridian web site at www.100thmeridian.org
2. Click on the documents tab on the left side of the page.
3. Scroll down to 2002 Current Survey and Interview Forms (PDF files)
4. Download the following:
    a. 2002 Trailer Counts for Launch Areas and Related Facilities and Instructions

b. 2002 Interview Form for Trailered Boat Survey and Instructions

c. Make appropriate copies of each form

d. Begin surveys with instructions from download

e. Do not use the procedures that are for one survey for a different survey

Surveyors must check with the sponsoring university to comply with any Human Subjects protocol in place.

Hypothesis 1 states that boat trailers surveyed in the Lake Mead National Recreation Area are from the states without known zebra mussel contamination, specifically 80% of these trailers will be from Nevada, California, and Arizona. To investigate this hypothesis the steps that will be taken are as followed.

Procedures for the Trailer Counts at Launch Survey (Appendix B):

1. Copy appropriate sheets needed for the number of launch areas
2. Map out the launch sites that will be attended that day
3. Fill in information at top of collection sheet
4. Go to specified launch area
5. Track states that every trailer is from in the lot and at the launch area, beginning with your home state
6. Tally results from each state
7. Fill in information at the bottom of the sheet
8. Copy of each page of data
9. Turn in the results to Dr. Gerstenberger and 100th Meridian Representative

During the study period over 4000 trailers were counted at the different launch sites. With the data that was colleted, tables, graphs, and charts was made in Excel to illustrate trends in the data. These determinations of state characteristics are made through the data from the 100th Meridian Initiative questioner directions found on the web site.

Hypothesis 2 states that based on the last three boat launch sites (ex. Michigan, Idaho, and California) boats launching at the Lake Mead National Recreation Area will not come from zebra mussel infested waters. The information from the Interviewed Form for the Trailered Boat Survey was administered as follows:

Procedures for the Interview Form for the Trailered Boat (Appendix C):

1. Copy appropriate sheets needed for the number of launch areas
2. Map out the launch sites that will be attended that day
3. Fill in information at top of collection sheet
4. Go to specified launch area
5. At a launch site find a willing subject to interview
6. Explain the reason for the study
7. Have participant fill out the informed consent form*
8. Administer the survey
9. Thank participant
10. Give "Zap the Zebra" handout
11. Copy data and informed consent sheets for each interview given
12. Turn in the results to Dr. Gerstenberger and 100th Meridian Representative

*Be aware that in Wentland's article (1993), she states that there is a potential for untruthful answers from people could be any of the following: misinterpretation of the question, faulty memory, or distorted recall

177 personal interviews were administered during the survey at the specified launch sites. Once the survey data was collected, the information that is needed for the graphs and charts is located under the "Where else have you launched recently?" section of the questionnaire. These states are split into two categories: infested states and non-infested states. From this information, a Chi-square analysis and contingency tables were made to analyze the data.

Hypothesis 3 states that boaters do not take any precautionary measures between launches to eliminate zebra mussel transportation, specifically no differences between anglers, pleasure boaters, jet skiers, canoers, or other boaters will be noted. From the Interview Form for the Trailered Survey the type of boat that the participant owned was recorded. The information from the Interview Form shows the relationship to the type of boat and if precautionary measures were taken between launches by the boater. A 4x2 contingency table was used to analyze the data and determine if there are any significant differences between the watercraft types with respect to boat cleaning.

The proposal for the Lake Mead Area was through the USFWS Region 2. Dr. Gerstenberger proposed the project to be completed from September 1, 2002 to February 28, 2002. The required paperwork includes the Cooperative Agreement with the USFWS and UNLV Department of Environmental Studies, the National Park Service forms, and the Research Involving Human Subjects with UNLV were all completed. Informed consent from each person being interviewed was within regulation with UNLV. A study by Thomas, in his book Designing Surveys that Work, states that the informed consent of a participant is voluntary and the person can stop at any time during the survey. In the *Ethics of Research* it states that informed consent must be used if: minors are being asked to participate, surveyor has power over the interviewer (ex. Teacher or employer), and the topic is sensitive (Thomas 1999). After the required paperwork is turned in then the survey process can begin.

Results/Data Analysis

Survey data collected at the Lake Mead National Recreation Area was analyzed to address my three hypotheses as well as the overall objective of the 100th Meridian Initiative. With the knowledge of the boaters' habits, the westward spread of the zebra mussel can more accurately be assessed. Table 1 shows the daily totals for trailer counts beginning October 19,

2002 and ending March 31, 2003. During the entire study period, 46 separate days of data were collected. Analysis of the sampling times was not addressed in this thesis.

Table 1: Dates and overall numbers of trailers counted at Lake Mead

Date	Totals per Day
10/19/2002	506
10/20/2002	179
11/1/2002	98
11/7/2002	6
11/22/2002	73
11/23/2002	182
11/24/2002	113
12/1/2002	39
12/5/2002	33
12/6/2002	14
12/7/2002	131
12/8/2002	95
12/14/2002	28
12/16/2002	36
12/17/2002	37
12/26/2002	36
12/27/2002	79
12/28/2002	90
12/29/2002	39
1/3/2003	46
1/6/2003	7
1/7/2003	43
1/8/2003	22
1/20/2003	51

Date	Total Per Day
1/24/2003	70
1/25/2003	160
2/1/2003	109
2/8/2003	65
2/12/2003	6
2/24/2003	9
3/1/2003	67
3/5/2003	112
3/6/2003	119
3/14/2003	40
3/15/2003	46
3/17/2003	16
3/18/2003	24
3/19/2003	23
3/20/2003	80
3/22/2003	308
3/23/2003	294
3/24/2003	87
3/26/2003	102
3/28/2003	197
3/29/2003	357
3/30/2003	465
Total	**4739**

Hypothesis 1: Results from the Trailered Counts Survey

The Trailered Counts Survey provided specific data about trailers that enter the Lake Mead National Recreation Area, specifically; the state that trailers are originally from. Each survey provided information as to the awareness of boaters and potential transportation of zebra mussels to the Lake Mead National Recreation Area. Table 2 shows which states had trailered boats visit the Lake Mead National Recreation Area during the study period. The total trailers counted per state, the percentage each state represented, and if the state contains zebra mussel infested waters based on the 100th Meridian Initiative List of Infested Waters

(www.100thmeridian.org). Over the study period from October 19, 2002 to March 31, 2003, 4739 trailers surveyed.

Table 2: Total Number of Trailers, Percentages, and their Respective State of Origin for Trailer Counts at the LMNRA

State	Total	Overall Percent	Zebra Mussel Infested States (Y/N)
Nevada	2942	62.08	N
California	885	18.67	N
Arizona	325	6.86	N
Utah	254	5.36	N
Idaho	99	2.09	N
Oregon	47	0.99	N
Wyoming	42	0.89	N
Montana	21	0.44	N
Colorado	20	0.42	N
Texas	19	0.4	N
New Mexico	12	0.25	N
Washington	11	0.23	N
South Dakota	8	0.17	N
Nebraska	7	0.15	N
Georgia	6	0.13	N
Michigan	5	0.11	Y
Kansas	5	0.11	N
Minnesota	5	0.11	Y
Illinois	4	0.08	Y
Florida	4	0.08	N
Kentucky	2	0.04	Y
Missouri	2	0.04	Y
Arkansas	2	0.04	Y
Iowa	2	0.04	Y
North Dakota	2	0.04	N
Pennsylvania	1	0.02	Y
Louisiana	1	0.02	Y
Wisconsin	1	0.02	Y
New York	1	0.02	Y
Indiana	1	0.02	Y
Virginia	1	0.02	N
Alaska	1	0.02	N
Tennessee	1	0.02	Y
Totals	**4739**	**99.98**	

Hypothesis 1 states that boat trailers surveyed in the Lake Mead National Recreation Area will be mainly from the states without known zebra mussel contamination, specifically 80% of the trailers will be from Nevada, California, and Arizona. The trailers from Nevada, California, and Arizona, combined, accounted for 4152 (at 88%) of the total trailers, while all other states accounted for 587 (at 12%) for the entire study period. Table 3, shows the potentially infested states (states which contain zebra mussel infested waters, which could be possibly transferred to the LMNRA) that came to Lake Mead and the rank order that they were represented, from greatest to the least number of trailers.

Table 3: Ranking of Trailers Arriving at Lake Mead from Potentially Infested Zebra Mussel States

State	Total	Overall Percent	From zebra mussel infested waters (Y/N)
Michigan	5	0.11	Y
Minnesota	5	0.11	Y
Illinois	4	0.08	Y
Kentucky	2	0.04	Y
Missouri	2	0.04	Y
Arkansas	2	0.04	Y
Iowa	2	0.04	Y
Pennsylvania	1	0.02	Y
Louisiana	1	0.02	Y
Wisconsin	1	0.02	Y
New York	1	0.02	Y
Indiana	1	0.02	Y
Tennessee	1	0.02	Y
Total	**28/4739**	**0.58**	13

A Chi square test was performed to observe the possibility of a significant difference in the expected value of 80% to the observed value of 88% of boaters being from Nevada, California, and Arizona. The total observed trailers from the three states was 4152 and the expected was 3321. From the remaining 47 states the observed number of trailers surveyed was 587 and the expected amount of trailers was 469. Hypothesis 1 states that the trailers from Nevada, California, and Arizona will be 80% of the total trailers surveyed in the study. Table 4

shows the direct relationship of the observed and expected values for the overall trailers surveyed at the Lake Mead National Recreation Area.

Table 4: Chi Square of the Trailers Counted at the LMNRA

	Not Infested	**Infested**		
Observed	4711	28	D.F.=1	X^2=1.0004
Expected	3792	947	0.50<P>0.25	

With a p value between 0.50 and 0.25, this shows that the expected value of 80% of the trailers being from Nevada, California, and Arizona was within the scope of the observed data, showing that there was no significant difference.

Hypothesis 2: Results from the Interview Form Survey

Using the Interview Form for the Trailered Survey data, the amount of visitors that have previously launched in other states was determined. The movement across state lines into Nevada was determined to assess the possible transport of zebra mussels to Nevada. The last three launch locations of boaters and trailers were recorded. With the knowledge of the last three launch locations, a better assessment of the likelihood of zebra mussels being transported to the Lake Mead National Recreation Area was conducted.

Hypothesis 2 states that based on the last three-recorded boat launch sites (ex. Michigan, Idaho, and California), boats launching at the Lake Mead National Recreation Area will not come from zebra mussel infested waters. A total of 177 interviews were conducted during the study period between October 19, 2003 through March 30, 2003.

Table 5 shows the Chi square and the exact number of boaters that came from non-infested states and infested states had no significant difference between what was observed and what was expected. With a total of 177 interviews, the null hypothesis was that at least 80% of the interviewees would be from non-infested states and that 20% would be from infested

states. The alternative hypothesis was that there was less than 80% of the boaters would be from non-infested states and more than 20% from infested waters.

Table 5: Chi Square for Home State of Interviewed Boaters

	Not Infested	**Infested**		
Observed	172	5	D.F.=1	X^2=0.779
Expected	142	35	P>0.25	

80% of the total 177 would have been 142 surveyed from 177 surveys, but during the study period we surveyed 172 trailers from non-infested waters. Similar to the trailer counts from non-infested waters, the observed launch locations was lower that the expected. The p value of the Chi-square test was less than 0.25; the degrees of freedom were calculated at 1 with an X^2 value of 0.779. There was no difference in what was expected and what was found and thus the null hypothesis was accepted.

Boaters' history for past launches was also tracked in the Interview Form for the Trailered Survey. The null hypothesis states that the boaters will be coming from states that are not infested 75% of the time and from states that are infested 25% of the time. The alternative hypothesis states that the boaters will be coming from states that are infested more than 25% of the time. Table 6 shows the observed and expected calculations for the Interview Form.

Table 6: Chi Square of Water Bodies Launched in Previously

	Not Infested	**Infested**		
Observed	104	2	D.F.=1	X^2= 0.942
Expected	80	26	P>0.25	

The chi square value was calculated at 0.942 with a 1-degree of freedom, and a p value of less than 0.25. This data shows that the expected values were relatively close to the data observed.

Hypothesis 3: Results from the Interview Form Survey (Boater Types)

Each survey also determined the type of boater that was completing the questionnaires, giving the data for hypothesis #3. We used a Chi-square to determine if there were differences in boat types that visited Lake Mead, and if these boaters clean their boats between launches. Hypothesis 3 states that boaters do not take any precautionary measures between launches to eliminate zebra mussel transportation, specifically there will be no difference between anglers, pleasure, jet skis, canoes, or other boaters. The null hypothesis was that there was no difference in the type of boater and cleaning the boat between launches. The alternative hypothesis states that the different types of boaters will have different cleaning habits between launches. Table 7 shows the contingency table for the angler, pleasure, jet ski, and other boats that were surveyed in the Lake Mead National Recreation Area.

Table 7: Contingency Table for the Boater Types and Cleaning Habits

	Angler	**Pleasure**	**Jet Ski**	**Other (speed ski)**	
No	4 (8.5)	20 (65)	1 (2.5)	10 (5)	D.F.=3 X^2=261.134
Yes	13 (8.5)	110 (65)	4 (2.5)	0 (5)	P<0.0005

The total number of surveys taken during the study period show that the people that wash their boats at the highest rate is the pleasure boaters, with 110 boater responses saying that they do clean their boats. The degrees of freedom were 3 and the Chi square value calculated at 261.134. The difference between the expected and observed values showed what was actually seen and what was expected to be seen before the study. This shows that the expectation of no difference between boater types of cleaning between lands was not supported. The actual results indicate that the boaters not all clean their boats equally. The statistic that accounts for the greatest change in the data comes form the pleasure boaters. The data indicates that 110 pleasure boaters clean their boat where 20 did not. This is not close to the 50-50 ratios that were expected at the beginning of the study, and in fact account for greater

than 90% of the overall Chi square calculations. These survey results do show that the boaters in the pleasure area are cleaning their boats more often and thus are preventing the spread of the zebra mussels.

Data Interpretation/Discussion

Over the course of the study boaters were surveyed to determine the likelihood of the westward movement of zebra mussels. With the data tabulated in the results section, conclusions were made as to the likelihood of zebra mussels moving across the 100th meridian into Lake Mead National Recreation Area. The risks of the zebra mussels entering Lake Mead are minimal because the amount of boaters that come to the lake are, for the majority, from non-infested states. Boat traffic is the most possible source of the movement and also, if properly educated, the preventative measure to prevent the westward spread of the zebra mussels.

In total, 4739 trailers were surveyed at the Lake Mead National Recreation Area. With this large sample size of boaters surveyed, the low number of boats from the infested states supports the minimal risk of the mussels being transported to Lake Mead. The 4152 boats from California, Arizona, and Nevada constituted more that 88% of the total boats visiting the Lake Mead National Recreation Area. The percentage of boats from non-infested states was 99% with the remaining 1% percent from states containing infested waters. The percentage of boaters from Nevada, California, and Arizona was weighted against the number of boaters from all other states. The difference in boaters from these three states and the remaining states seen at Lake Mead over the study period supported my hypothesis of primarily local boat traffic.

Due to the low percentage of boaters that come from infested states to the Lake Mead National Recreation Area, it can be assumed that the level of potential exposure is low. In addition, the distance from infested lakes to Lake Mead is extensive, thus zebra mussels are very unlikely to survive the travel out of water when the boat moves from one lake to another. Studies done by researchers in the Great Lakes Area (Patchakayayla 2000) describe the

characteristics of the zebra mussels. Zebra mussels can live in optimal water temperatures of a few degrees less than 25°C and for short periods of time, but not in temperatures that exceed 30°C, with the limits of temperatures being 0°C (US Army Corps of Engineers: Updated March 14, 2002, "Water Temperature"). The average temperature of Lake Mead in May is about 22°C, thus making Lake Mead a suitable temperature for zebra mussels to inhabit. Due to these optimal temperature conditions Lake Mead can be viewed as an optimal habitat for zebra mussels, but for two reasons it is listed as a non-infested lake. The first is that zebra mussel larva need vegetation in the water to grab onto when the sperm and egg are meeting. Lake Mead is in the Mojave Desert is primarily an oligotrophic lake, and thus has very little vegetation throughout the perimeter of the lake. The second is the distance to infested lakes is extensive. Table 8 shows the approximate distances and travel times to Lake Mead from the closest know zebra mussel infested waters.

Table 8: Estimated distances and travel times to the Lake Mead National Recreation Area from the closest zebra mussel infested waters

State	Miles from Lake Mead	Drive Time
Des Moines, IA	1436 miles	23 hr, 19 min
Tulsa, OK	1208 miles	20 hr, 27 min
St Paul, MN	1680 miles	27 hr, 15 min
Baton Rouge, LA	1748 miles	29 hr, 13 min

This distance from infested lakes makes zebra mussels transport unlikely, especially when one considers temperatures that can exceed over 32°C in many of these states in the summer months when the majority of the travel will occur.

When looking at the number of states outside California, Nevada, and Arizona, the numbers of boaters that have launched in infested waters and traveled across the country was determined. This was done through the analysis of data collected with the Interview Form for

the Trailered Boat Survey. Hypothesis 2 stated that the last three recorded boat launches would be from states that are not infested with zebra mussels. The states that are on the infested waters list were compared to the states that are not infested using a Chi Square test. These results indicated that 104 of the responses were coming from non-infested states and 2 responses were from infested waters, with a total of 106 boaters surveyed. These findings were consistent with the expected values at the beginning of the study, thus we accepted the null hypothesis of 80% or more boaters traveling from non-infested waters.

Hypothesis 3 addressed the types of boaters that were launching at the Lake Mead National Recreation Area, and the habits of these different boaters when cleaning their boats between launches. The type of boater that cleans their boat most often was the pleasure boater with an overwhelming amount of 110 responses out of 130 surveyed. The Chi square analysis was used to determine if there were differences in the type of boater, and their boat cleaning habits. Pleasure boaters do clean their boats more often than the other types of boaters. In addition, the majority of these boaters launch each time they come to the lake, as well as store their boats in dry storage, not in the water. The boaters indicated that they cleaned their boats at the end of the season very well, but in the middle of the season only part of the time. This meant that they spray the hull of the boat with water and dry it off.

The algae bloom that occurred in Lake Mead in the last few years has also caused local boaters to clean their boat hulls more often because when the algae dries on the outside of the boat it becomes hard to remove and does not come off the boat without harsh scrubbing. This may have contributed to additional cleaning by pleasure boaters, thus altering our results. The knowledge of the boaters' habits can be used for future education of the boaters that do not clean their boats as frequently. These boaters included anglers, jet skiers, and other boaters (mostly speed skiers). Studies on why the other types of boaters clean their boats less frequently should be further examined.

Even though the data indicate that the possibility of zebra mussel transport to the Lake Mead National Recreation Area is low, zebra mussels move like a disease. They begin in one area, like the Great Lakes, and slowly move to the surrounding lakes. Because of this movement, over time, the possibility of the mussels reaching the lakes in the West increases. Slowly, boaters will travel from infested lakes to non-infested and over time and additional lakes will be infested. These newly infested lakes will act as an intermediate stepping stone, starting a chain reaction and shortening the distance between infested and non-infested lakes. With the protection, inspection, and education of boaters, we can prevent the species from infesting the lakes West of the 100th Meridian. Zebra mussels at this time are highly unlikely to populate Lake Mead, because of the distance that the mussel populations are from the lake, and the origin of boats launching and the lake.

In a final analysis, the most represented state that comes to Lake Mead is Nevada, consistently over 2900 (62%) of the trailers. California and Arizona had the second and third highest counts of trailers at the lake, most likely due to their close proximity to the Lake Mead National Recreation Area. Boater movement in the southwest is primarily localized. Unlike the Midwest, where the numbers of lakes in a 100-mile radius are more numerous, lakes of the southwest are few and far between. Boaters that come to Lake Mead and other southwest lakes go to one lake specifically and do not lake hop. Lake hopping, going to more than one lake in a day, is a very easy way to transport the zebra mussel. With the distance between lakes in the southwest, it would be difficult for the mussels to travel across state lines and the 100th Meridian, practically the Lake Mead National Recreation Area.

Conclusion

From the data collected as part of the 100th Meridian Project, the conclusion can be made that boaters are coming mainly from states on the perimeter of Nevada. Thus the waters and boats are not infested with zebra mussels because they are west of the 100th Meridian. It

can also be stated that the potential of the zebra mussels coming to Lake Mead is low, limited numbers of boats, high temperatures and great distance between lakes minimize transport. The assessment of boaters' habits indicates that some do take preventative measures with their boats, washing them between launches and storing them on land, but these are mostly pleasure boaters, not all watercraft users. Although unlikely, a boater can bring a colonization of zebra mussels to the lake. Education, inspection, and treatment are the strongest form of prevention and must continue.

In conclusion, the zebra mussel movement and infestation of lakes, depends on the proximity of the infested lakes to non-infested lakes. Zebra mussels, and other invasive species, can travel west of the 100th Meridian and states that are closer to this line are at a higher risk than Lake Mead. High-risk states include Manitoba Providence, Canada, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas, the states that are on, or near, the 100th Meridian. Lake Mead National Recreation Area does have a high volume of boaters, primarily in the warmer months, thus the lake still needs to be monitored for boater traffic and education of invasive species and zebra mussels, but at this time the risk of zebra mussel introduction is thought to be low.

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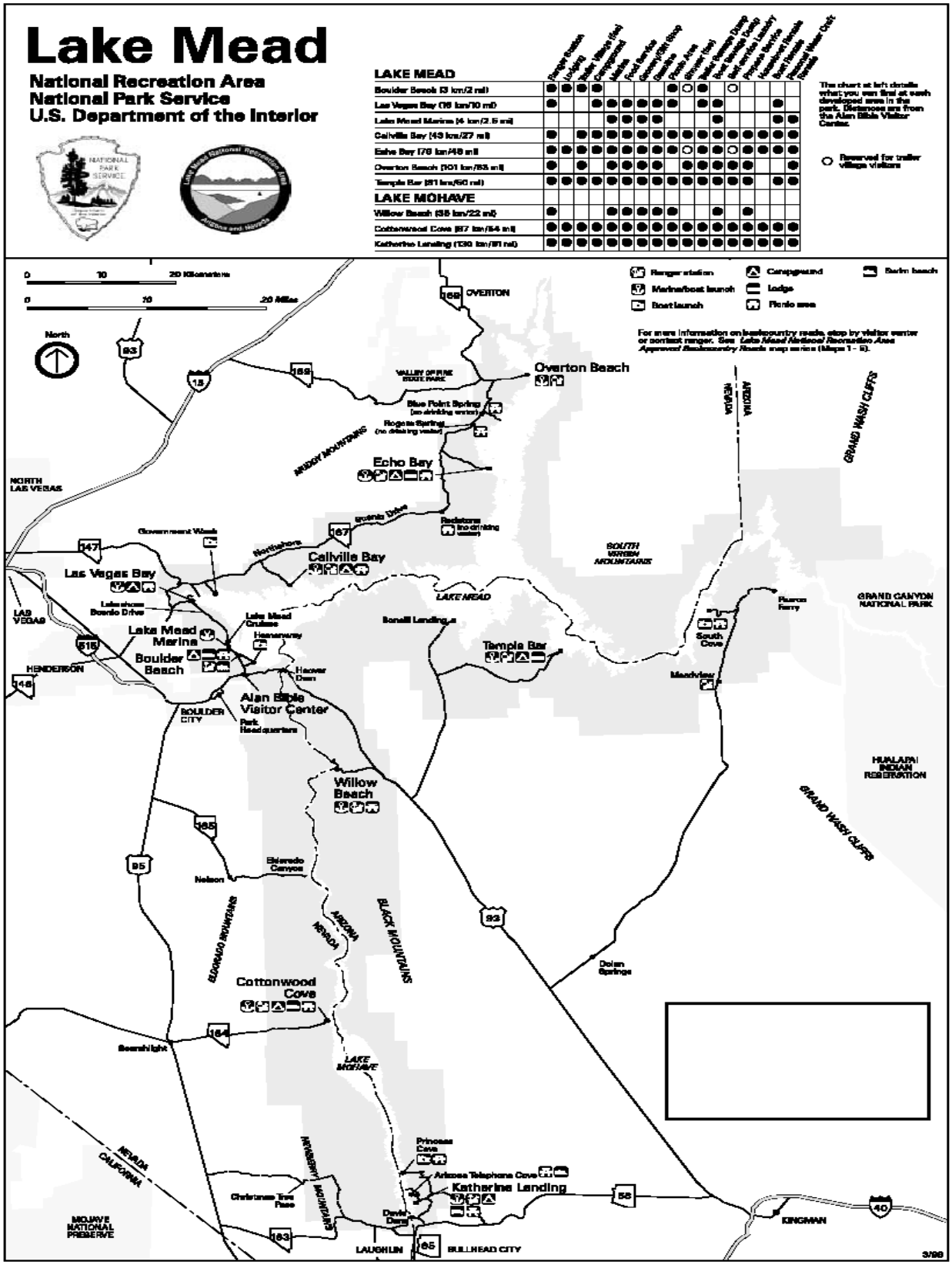
Appendix A


Lake Mead
National Recreation Area
National Park Service
U.S. Department of the Interior
LAKE MEAD
Boulder Beach (3 km/2 mi)
Las Vegas Bay (16 km/10 mi)
Lake Mead Marina (4 km/2.5 mi)
Callville Bay (43 km/27 mi)
Echo Bay (76 km/48 mi)
Overton Beach (101 km/63 mi)
Temple Bar (91 km/60 mi)
LAKE MOHAVE
Willow Beach (35 km/22 mi)
Cottonwood Cove (87 km/54 mi)
Katherine Landing (139 km/91 mi)
Ranger station
Marina/boat launch
Boat launch
Campground
Lodge
Picnic area
Swim beach
Overton Beach
Echo Bay
Callville Bay
Las Vegas Bay
Lake Mead Marina
Boulder Beach
Alan Bible Visitor Center
Willow Beach
Cottonwood Cove
Temple Bar
Katherine Landing
OVERTON
NORTH LAS VEGAS
LAS VEGAS
HENDERSON
BOULDER CITY
Hoover Dam
Bonelli Landing
South Cove
Meadview
Pierce Ferry
Dolan Springs
Nelson
Searchlight
Princess Cove
Arizona Telephone Cove
Christmas Tree Pass
Davis Dam
LAUGHLIN
BULLHEAD CITY
KINGMAN
MOJAVE NATIONAL PRESERVE
NEVADA
CALIFORNIA
ARIZONA
LAKE MEAD
LAKE MOHAVE
VIRGIN MOUNTAINS
MUDDY MOUNTAINS
EldoradoMOUNTAINS
BLACK MOUNTAINS
GRAND WASH CLIFFS
HUALAPAI INDIAN RESERVATION
GRAND CANYON NATIONAL PARK
3/99

Appendix B

Zebra Mussel

THE 100TH MERIDIAN INITIATIVE TO PREVENT THE WESTWARD SPREAD OF ZEBRA MUSSEL

TRAILER COUNTS FOR LAUNCH AREAS & RELATED FACILITIES FROM 2002

Surveyor: last first	Date:	Time:	am / pm
Location:	State:		

LIST STATES AND NUMBERS OF TRAILERS COUNTED

	(Your State)	States and Numbers of Trailers								
SITE										
TOTALS (by state):										

TOTAL (All):		Your State	TOTAL (from your state)
TOTAL (Out of State):		Percent Out of State:	
Self-Interview Forms Distributed:			

Organisms:

Nothing Found: □

Zebra Mussels: □ States of Origin: _____

Vegetation: □ States of Origin: _____

Other: □ States of Origin: _____

If other is checked indicate types of organisms found:_____

_____

Appendix C

100TH MERIDIAN INITIATIVE TO PREVENT THE WESTWARD EXPANSION OF ZEBRA MUSSELS
Interview Form for Trailered Boat Survey 2002

Interviewer: Last name	First name		
Date:	Time: AM / PM	Survey Type:	☐ Contact ☐ Observation
Water Body:	State:		
Launch Site:			

Where are you from?

Home State:	Zip Code:	Personal ☐ **Type of Transport** Commercial ☐ ↵ Other ☐ explain
How many times have you launched in the last year?		
Do you always launch in the same water body? Yes ☐		

Type of Boat: ☐ Angling ☐ Pleasure ☐ Jet Ski ☐ Canoe ☐ Other explain

Where else have you launched recently?

Water Body:	State:	County:	Date:
1.			
2.			
3.			

Where will you launch next?

Water Body:	State:	County:	Date:
1.			
2.			

Do you clean your boat and trailer between launchings?	☐ Yes ☐ No
Is you boat kept on land or in water when not in use?	☐ On Land ☐ In Water
If in water, where is it kept? Water body:	State:

Information Exchange: ☐ Viewed? ☐ Read? ☐ Both? ☐ Boater asked questions
Boater already aware of threats of… ☐ Zebra Mussels ☐ Any ANS

Boat Inspection Results: Inspection ☐ Rejected
Nothing Found: ☐ Undertaken by: ☐ Party ☐ Interviewer ☐ Both

	Zebra Mussels	Still Alive	Vege-tation	Other Exotics	Describe Other	Action Taken
Boat Deck	☐	☐	☐	☐		
Boat Hull	☐	☐	☐	☐		
Bilge & Bait Wells	☐	☐	☐	☐		
Motor	☐	☐	☐	☐		
Trailer	☐	☐	☐	☐		
Fishing Equipment	☐	☐	☐	☐		
Other	☐	☐	☐	☐		

Comments:

Appendix D

LOCATION _____ STATE _____ DATE _____

The Zebra Mussel

100TH MERIDIAN INITIATIVE TO PREVENT THE WESTWARD EXPANSION OF ZEBRA MUSSELS
2002 BOATER SELF-SURVEY

The 100th Meridian Initiative is a multi-agency partnership effort to prevent the westward spread of zebra mussels and other aquatic nuisance species to western North American waters. The U.S. Fish & Wildlife Service is sponsoring and coordinating education outreach and voluntary trailered boat surveys with other agencies in the states on the 100th meridian. Surveys similar to this are being conducted in Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota and the Canadian Province of Manitoba. This survey is now being extended to the Colorado River. You as a boater are being asked to voluntarily inspect your trailer, boat and related equipment for any transported aquatic species, such as the **zebra mussel**, which may be carried accidentally to new locations. Your assistance and participation is appreciated in completing this survey and returning it in the provided, stamped envelope to the agency that is conducting this survey for the U.S. Fish and Wildlife Service. Please review the enclosed information on introduced aquatic species and boat and trailer inspections. Be sure to clean your boat, trailer and equipment after hauling-out the boat and before leaving the ramp area. Thanks for your help!

The following instructions will help you complete the survey.

Part One – Where are you from? (Any information provided is voluntary and anonymous.)
Please state the purpose of your visit, and fill in the boxes relating to your boat and home state. Your most recent launches are very important information, so please be as complete as possible.

Part Two – Where are you going?
Please indicate where you will be launching next **after you leave this lake**. Do not list further launchings at this lake. Again, please be as complete as possible in filling out this section.

Part Three – Returning the survey.
That's all there is to it! All you need to do is place this page in the provided, stamped, return envelope, seal it, and drop it in the mail.

SURVEY INFORMATION (Please Print)

PART ONE: Where are you from?	Home State:	Zip Code:
Type of Boat: ☐ Angling ☐ Pleasure ☐ Jet Ski ☐ Canoe ☐ Other		explain

How many times have you launched in the last year?			
Do you always launch in the same water body? ☐ Yes ☐ No If no, please list below where else you have launched recently.			
Water Body:	State:	County:	Date:
1.			
2.			
3.			

PART TWO: Where are you going? Please list below where you plan to launch next.

Water Body:	State:	County:	Date:
1.			
2.			

Are you already aware of threats of zebra mussels? ☐ Yes ☐ No Or any other aquatic nuisance species? ☐ Yes ☐ No
Do you clean your boat and trailer between launchings? ☐ Yes ☐ No
Is you boat kept on land or in water when not in use? ☐ On Land ☐ In Water
If in water, where is it kept? Water body: State:
Any Comments: