ABSTRACT

Zebra Mussel Awareness in Central Texas

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Since the introduction of the zebra mussel, *Dreissena polymorpha*, into the United States, freshwater food webs have been drastically altered. This mussel filters phytoplankton, the basis for aquatic food chains, which causes secondary changes, such as the reduction of sportfish and waterfowl populations. Zebra mussels also cluster in water pipes costing cities up to $3 million to keep water treatment plants and power plants operational. Ultimately, the cheapest and most effective method for fighting zebra mussels is promoting zebra mussel awareness to stop these invasive species from ever entering a lake or stream. Surveys of boaters were conducted throughout the 2015 summer and based on the data gathered, certain water bodies with low boater awareness levels should be targeted in order for awareness promotion to have the greatest effect.

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ZEBRA MUSSEL AWARENESS IN CENTRAL TEXAS

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By

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ACKNOWLEDGEMENTS

Ever since I was a kid, I have loved aquatic animals and enjoyed studying the habitat they live in. However, only as a junior in college did I hear about zebra mussels when I read an article concerning that they had been introduced to Lake Waco. It was a problem that hit so close to home that it immediately had me interested. For a whole semester, I scoured the internet to learn what zebra mussels where and how the problems they posed to an ecosystem were being dealt with.

However, no amount of reading could have sufficiently prepared me to write this thesis, I had help from people in many different fields and areas of expertise. First, I would like to thank Professor Thomas Conry, Baylor University Environmental Science Department, my thesis advisor who kept me on track and pointed me in the right direction when I wasn't sure where to go or who to ask.

Secondly, I would like to thank everyone who helped me gain firsthand experience with zebra mussels. I was trained as a summer intern at Texas Parks and Wildlife Inland Fisheries by John Tibbs, Michael Baird, John Provine, and David Vicars. I was trained for zebra mussel awareness by the Waco U.S. Army Corps of Engineers and Nora Schell from the Waco Wetlands. While I collected data that is present in this thesis, I couldn't have possibly collected all the information I did without the help of my co-intern, Isaac Rodriguez, and the 8 Waco interns, DJ Achterhof, Lindsey King, Karen Kempenich, Luke Sanchez, Jessica Keller, Jeston Texeira, Stephanie Wetch, and Payton Pollard.

Thirdly, I would like to thank Brian Van Zee, Director of Region 1 for Texas Parks and Wildlife Fisheries Management, for allowing me to interview him and helping me understand what was going on in Lake Waco when I first started trying to learn more about the zebra mussel problem.

CHAPTER ONE

Zebra Mussels, What Are They and Where Did They Come From?

It has long been known humans live where water is available. Towns and cities develop along rivers, lakes, and beaches, as close as possible to an accessible water source. Civilizations flourish when there is ample water but can disappear during a drought. Despite water covering more than 70% of the earth's surface, only 1% or less of the global water is suitable for human consumption (Postel, 2015). Approximately two-thirds of Earth's freshwater are unavailable due to it being frozen in glaciers and icecaps. This leaves a very small portion of freshwater for the whole human population to use, much less the water required to maintain nature. With freshwater water being so important and limited, it is crucial to make sure that ecological balance is kept in an aquatic environment.

Pollutants, such as oil or sewage, damage aquatic environment in such a way to be often easily visible to a passerby. However, what isn't always so easily seen is how aquatic organisms can also cause very negative impacts on the environment. In Galveston Bay alone, there were over 84 invasive species in 2004 (Gosset, 2004). If 84 invasive species were in a single bay, it is hard to imagine how many more there might be in Texas, or the United States as a whole. Historically, species were often restrained to a certain area by natural boundaries, only occasionally ranging outside of their normal habitat. However, today species are often purposefully or accidentally transplanted by humans. Many times, these exotic species are unable to survive in their new environment.

Sometimes, though, the introduced species will adapt to the different habitat. When this occurs, the introduced species will often have no natural predators and will reproduce rapidly to the point they are classified as invasive. Frequently, invasive species will have the same prey as a native counterpart or even prey on the native species themselves, causing the original inhabitants to become endangered and disrupting the balance of the ecosystem.

One recent problem in the United States is the introduction of zebra mussels (*Dreissena polymorpha)*, a small freshwater mussel. For an organism that usually grows no more than 3.8 cm long, it has drastically changed many freshwater ecosystems. Zebra mussels are characterized by the brown and white stripes which mark their shells. They are native to the Black and Caspian Seas, but are now established in Great Britain, Ireland, Italy, Spain, and Sweden. Ballast water is a major transporter of aquatic species. Ship ballast is anything used to provide a ship with stability, although water tends to be the most common form. When a ship sets out, it takes in water at the bottom of the boat to give it more weight so it is not as easily rocked by waves. At the end of the journey, a ship will come into a port. A ship with ballast water sits too deep in the water to come into port without scraping the bottom, so the ballast water must be emptied, along with any organisms in the water. Zebra mussels are believed to have been brought to the United States in the ballast of a ship in the mid-1980's. Zebra mussels were first discovered in the Great Lakes, specifically in Lake St. Clair, and since then have spread throughout much of the United States.

Laboratory studies suggested the temperature range of *Dreissena polymorpha* (6-30°C) would prevent them from moving into the Southern United States. In 2009, zebra mussels reached the Texas-Oklahoma Border, ultimately proving this study to be unfounded. Currently, zebra mussels have been found in the following Texas Reservoirs: Belton, Bridgeport, Lavon, Lewisville, Ray Roberts, Texoma, and Waco. Brian Van Zee, the director for Region 1 of Texas Parks and Wildlife Fisheries Management, he explained that the mussels are capable of adapting to and surviving in warmer climates (VanZee, 2015). However, the increased temperature tolerance appears to have caused their metabolic rate to increase, resulting in a shorter lifespan. With the rapid increase in the distribution of zebra mussels, many changes can be seen in the rivers and lakes they occupy (see Ch.2).

The morphology and reproductive cycle of the zebra mussel gives it a competitive advantage over native mussels. All mussels have a larval form, but in zebra mussels this form is unique. Most native freshwater mussels begin life as glochidia. This larval form has hooks with which it will attach itself to a host fish for a period of time before falling off and developing into its juvenile form. Zebra mussel larvae don't have this parasitic stage, meaning when they disrupt ecosystem, they aren't kept in check by a host fish dying off. Unlike most freshwater bivalves, both the adult and juvenile forms are able to "attach to hard surfaces using a net of tough fibers called byssal threads" (Cohen, 2008). These fibers are made of collagen proteins and are secreted by a gland located in the organism's foot. This allows zebra mussels to stay securely attached to a substrate in fast

moving water or littoral areas which were previously uninhabitable by freshwater mussels. The few predators of zebra mussels, diving ducks, readear sunfish, and blue catfish, may feed on the invasive species, but often do not make a dent in established populations.

CHAPTER 2

Zebra Mussel Impacts

Not only are zebra mussels better equipped to withstand predators and natural threats, but they also negatively impact other mussels. Zebra mussels can attach to the shells of native bivalves, which "interferes with normal valve movements, deforms valve margins, and essentially suffocates and starves the native mussels by depleting the surrounding water of oxygen and food" (U.S. Fish and Wildlife Service). *Dreissena polymorpha* filters plankton out of the water and may promote toxic algal growth. They share the same food source as other mussels, which leads to competition for a limited resource.

Zebra mussels have caused the local extinction of freshwater mussels in the United States. For example, Higgins Eye (*Lampsilis higginsii*) can no longer be found in Wisconsin or Iowa (U.S. Fish and Wildlife Service). While *Dreissna polymorpha* has yet to cause the same results in Texas, they are threatening already endangered species. The Texas fatmucket (*Lampsilis bracteata*), the Texas pimpleback (*Lampsilis bracteata*), the Golden orb (*Quadrula aurea*), the Texas fawnsfoot (*Truncilla macrodon*), and the Smooth pimpleback (*Quadrula houston*) are all being considered as candidates for the endangered species list and conservation efforts have been made to help protect these populations. All of these mussels originally began decreasing due to "habitat loss and degradation" (U.S. Fish and Wildlife Service). Now they are more vulnerable to being wiped out by zebra mussels, who not only attach to them but filter "glochidia of native

mussels from the water column, thus reducing reproductive potential" (U.S. Fish and Wildlife Service).

An adult zebra mussel can filter up to a liter of water a day and when a lake has a heavy infestation, the water clarity can increase drastically. While it is good to have fairly clear water so light can penetrate, drastic changes can cause "planktonic food webs to wither and littoral food webs to flourish" (Strayer, 2015). What zebra mussels are filtering out of the water is phytoplankton, which is the basis for aquatic food webs. Phytoplankton is able to photosynthesize and provide energy to the animals that consume it. If the main source of a lake's energy is being removed, then the whole food web will be thrown out of balance. This is particularly important in lakes known for good fishing because the reduction in phytoplankton can cascade up the food web resulting in a reduction of prey fish abundance and ultimately reduce sportfish populations. Not only do zebra mussels filter phytoplankton, but they can selectively reject toxic foods such as blue-green algae. *Dreissna polymorpha* has the ability to intake many different types of phytoplankton and algae, but these mussels can then excrete toxic algae, undigested, back into the aquatic environment. The larger predation on phytoplankton and non-toxic algae can result in blue-green algae to "increase substantially as a percent of total biomass, especially in the nearshore zone" (Bierman, 2005). As this toxic algae accumulates it can cause botulism, "increases in botulism, which has killed large numbers of fish and birds" (Robbins, 2015).

Dreissena polymorpha not only affects other inhabitants of rivers and lakes, but human populations as well. These mussels have very sharp shells, which can cut through skin, making areas unsafe to swim in. They will colonize on many manmade structures, such as docks and boats. One of the main problems caused by zebra mussels is biofouling, an accumulation of organisms on a surface, such as in water pipes belonging to water treatment and power plants. At water treatment facilities where zebra mussels have proliferated, intake pipes have been reduced by as much as two-thirds their original diameter. In 2001, biofouling cost the United States "over $3.1 billion in damages over ten years to intake pipes, water filtration equipment and power plants" (Cataldo, 2015). More recently estimations said "invasive mussels cost the national economy at least $1 billion a year" (Robbins, 2015). In 2012, Zebra mussels made their way into Lake Ray Roberts, which supplies water to the surrounding areas. Not only have zebra mussels been found in intake pipes, but they have even "show[n] up in Denton's water treatment plant" (CBS DFW, 2014). In order to keep water flowing, the zebra mussels must be removed from the equipment and then controlled. However, these projects are "estimated to cost $3 million….[which] will probably result in a near 1% increase in area utility bills" (CBS DFW, 2014).

Despite the many efforts to eradicate zebra mussels, there is almost no way to completely eliminate them once they have taken root in a reservoir. Instead, it comes down to being able to control the mussels that are present and mitigating for their impacts. Depending on the location and number of zebra mussels present, different

methods are used to control the invasive species. In cases where there is an accumulation of zebra mussels on an object easily removed from the water or can be drained of water, manual removal if often used. This method consists of using a power washer to physically remove the mussels from their substrate and if the water is very hot, it can even kill the unwanted pests. Manual removal doesn't prevent the accumulation of more mussels in the future and leaves behind a debris of shells. In small areas with infrastructure, the most common method for dealing with zebra mussels in North America is by "chemical applications to water" (Sprecher, 2000). There are many different chemicals which can be used to kill zebra mussels, but the favored method is "chlorination, primarily via sodium hypochlorite…[because it] remains the least expensive" option (Sprecher, 2000). Chlorination of water is a method that has been used for over a hundred years to control biofouling of various species and is able to kill veliger larvae, the immature, mobile form of mussels, without harming most adult organisms. Applications of chemicals usually occur in the summer, around the time when zebra mussels spawn. A single female zebra mussel can produce anywhere from 100,000-500,000 eggs per year. Killing off the veligers, which are vulnerable without a shell, is an effective way to control zebra mussel populations. Despite the effectiveness of this method on unwanted pests, chemical applications are not species specific and can kill non-target organisms or make the water unfit for human consumption. Another method is tarping, which is good for recent invasions where the mussels are present in only one area of a lake or reservoir. A huge black tarp is placed over the invasion site and weighed down by sand bags. This tarp is left for several months and cuts off the mussels' access to

oxygen and nutrients in the water. However, if a population of zebra mussels is discovered too late, they will be too spread out for the tarping method to be feasible.

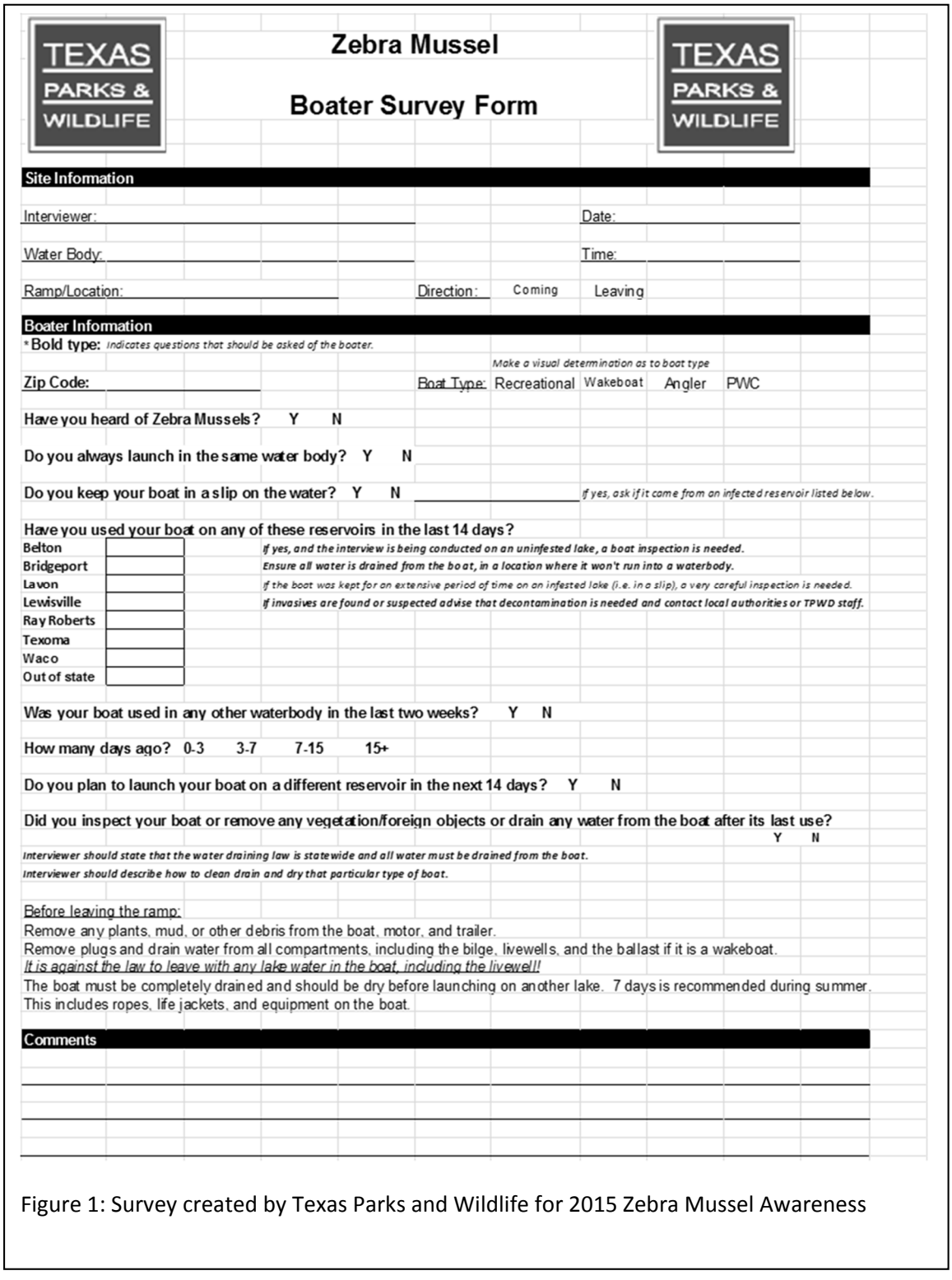
Although these treatments work, they have to be repeated and are often costly. The cheapest way by far to deal with zebra mussel is to prevent them from ever entering a lake or body of water in the first place. There are measures that can be taken to prevent their spread by humans. To keep lakes safe, any objects moved from one lake to another should be cleaned and inspected. In Texas, by law, watercraft must be drained of any water after being taken out of a lake. Afterwards, it is recommended they be rinsed and dried completely to ensure no veligers have settled or exist in water trapped on the vessels. It is best to power wash boats, as well as the trailers carrying them, with water 60°C or hotter. While veligers cannot survive out water for very long, adult zebra mussels can close their shells and live out of water for longer periods of time. In Texas, it is estimated that adult zebra mussels may be able to survive out of water for up to 15-20 days if weather conditions such as temperature and humidity are favorable (Tibbs, 2015). Veligers could still be present and viable in areas of boats retaining water, or in puddles, until said water evaporates unless they are drained and rinsed properly. It only takes one infested boat or bucket of contaminated water to potentially infect a whole lake. This means every boater, every person bringing potential water sources to the lake needs to be aware of the threat they pose. The best way to do this is through Zebra Mussel Awareness Programs to teach the public about the threat and how to prevent zebra mussels from spreading. Although there are costs in making informational brochures, signs, and hiring

people to lead awareness efforts, these costs are significantly lower than any amount spent to try to control zebra mussels once they are in a lake. In the few states so far not infected with zebra mussels but at high risk for infection, such as Montana, Wyoming, Washington, Oregon, and Idaho, more extreme awareness efforts have been put underway. There are inspection stations at the borders of some of the state lines to check boats. The same way dogs have been used to sniff out drugs, more recently there is "a group called Working Dogs for Conservation" who trains dogs to sniff out invasive zebra and quagga mussels (Robbins, 2015).

CHAPTER 3

Survey of Zebra Mussel Awareness in Central Texas

During the summer of 2015, I had an internship with Texas Parks and Wildlife (TPWD) Inland Fisheries in Waco. Part of my job was promoting Zebra Mussel Awareness on the weekends. TPWD trained me at the beginning of the summer on how to search for zebra mussels in boats and how to survey boaters to determine the threat that their boats posed to a lake. Every weekend and holiday, interns would be stationed at a boat ramp for a reservoir. Lake Belton and Lake Waco were the only places visited in which zebra mussels were already present, the other water bodies were at the time, zebra mussel free. As boaters came in or out, they would be stopped and asked the questions off a survey made by Texas Parks and Wildlife (refer to Figure 1). Only the owner of the boat would be surveyed and the answers recorded. The first question asked was if they had heard of zebra mussels and if they hadn't, they would informed of the threat the mollusks posed to the lake. Next, a series of questions to determine if their boat was likely to contain zebra mussels. Lastly, they would be asked what lakes their boat had recently been in, how long it has been out of the water, and if it was drained after the last use. If any of the answers to these questions gave a reason to believe the boat could possibly contain zebra mussels, the boat would then be inspected by looking along the side of the boat, the bottom of the boat, and at the engine to ensure safe entry into the water.



Zebra Mussel

Boater Survey Form

Site Information

Interviewer: _____ Date: _____

Water Body: _____ Time: _____

Ramp/Location: _____ Direction: Coming Leaving

Boater Information

*Bold type: *Indicates questions that should be asked of the boater.*

Make a visual determination as to boat type

Zip Code: _____ Boat Type: Recreational Wakeboat Angler PWC

Have you heard of Zebra Mussels? Y N

Do you always launch in the same water body? Y N

Do you keep your boat in a slip on the water? Y N _____ *If yes, ask if it came from an infected reservoir listed below.*

Have you used your boat on any of these reservoirs in the last 14 days?

Belton	
Bridgeport	
Lavon	
Lewisville	
Ray Roberts	
Texoma	
Waco	
Out of state	

If yes, and the interview is being conducted on an uninfested lake, a boat inspection is needed.
Ensure all water is drained from the boat, in a location where it won't run into a waterbody.
If the boat was kept for an extensive period of time on an infested lake (i.e. in a slip), a very careful inspection is needed.
If invasives are found or suspected advise that decontamination is needed and contact local authorities or TPWD staff.

Was your boat used in any other waterbody in the last two weeks? Y N

How many days ago? 0-3 3-7 7-15 15+

Do you plan to launch your boat on a different reservoir in the next 14 days? Y N

Did you inspect your boat or remove any vegetation/foreign objects or drain any water from the boat after its last use?
Y N

Interviewer should state that the water draining law is statewide and all water must be drained from the boat.
Interviewer should describe how to clean drain and dry that particular type of boat.

Before leaving the ramp:
Remove any plants, mud, or other debris from the boat, motor, and trailer.
Remove plugs and drain water from all compartments, including the bilge, livewells, and the ballast if it is a wakeboat.
It is against the law to leave with any lake water in the boat, including the livewell!
The boat must be completely drained and should be dry before launching on another lake. 7 days is recommended during summer.
This includes ropes, life jackets, and equipment on the boat.

Comments

Figure 1: Survey created by Texas Parks and Wildlife for 2015 Zebra Mussel Awareness

During the week, the answers to the surveys would be put into an Excel

spreadsheet with additional information, such as who conducted the survey and on which lake were they stationed. Over 2,000 surveys were taken throughout the summer at the nine different reservoirs. Some of the surveys were taken out due to not all the questions being answered. In the end, 2,434 surveys were used for this analysis of zebra mussel awareness levels in central Texas.

CHAPTER 4

DISCUSSION OF RESULTS AND FUTURE OBJECTIVES

A graph of the data was made showing each lake has a number in parenthesis after it, which indicates the number of days the lake was surveyed (refer to figure 2). The blue part of the bar chart represents the number of people who had heard of zebra mussels before coming to the lake, the red represents the people who had never heard of them. The City of Waco hired interns to survey Lake Waco for the summer, but the surveys were cut short due to reservoirs flooding. Once Lake Waco reopened, the Waco interns

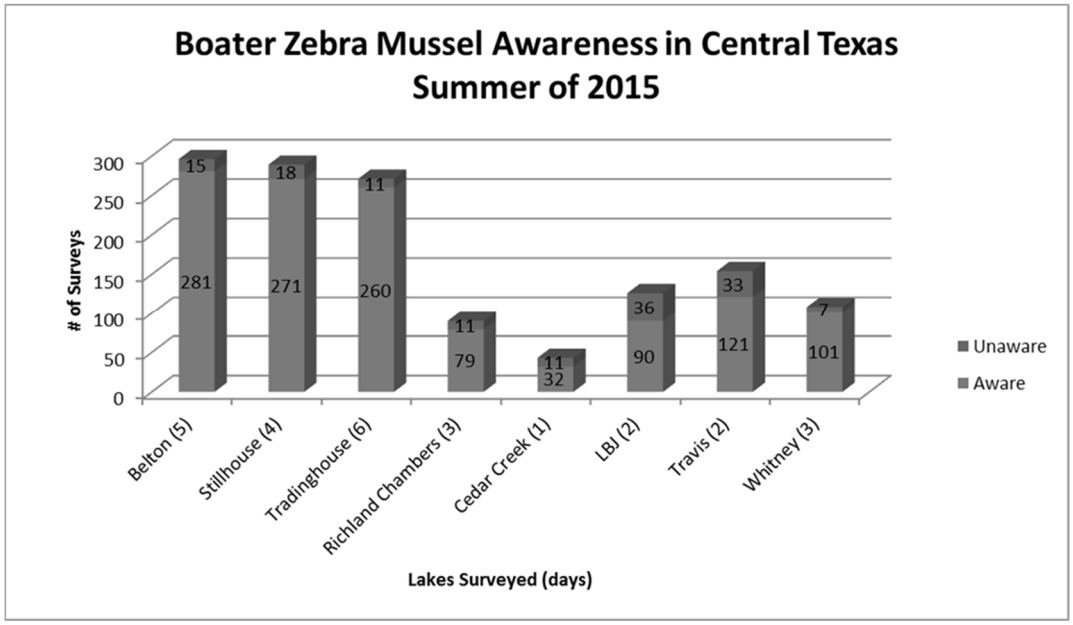


Figure 2: Graph of Lakes Surveyed

surveyed Lake Waco for many days and conducted a larger number of surveys than done at any of the other lakes, so it has not been included in the graph. For the whole summer, Lake Waco was surveyed twenty days and totaled 1,057 surveys. Only 24 boaters at Lake Waco were unaware of what zebra mussels were.

Using the data obtained that summer, I developed a map in Google Earth which shows the percentage of boaters unaware of zebra mussels at each lake (Figure 3). As a general trend, a higher percentage of unawareness occurred in the southern lakes more

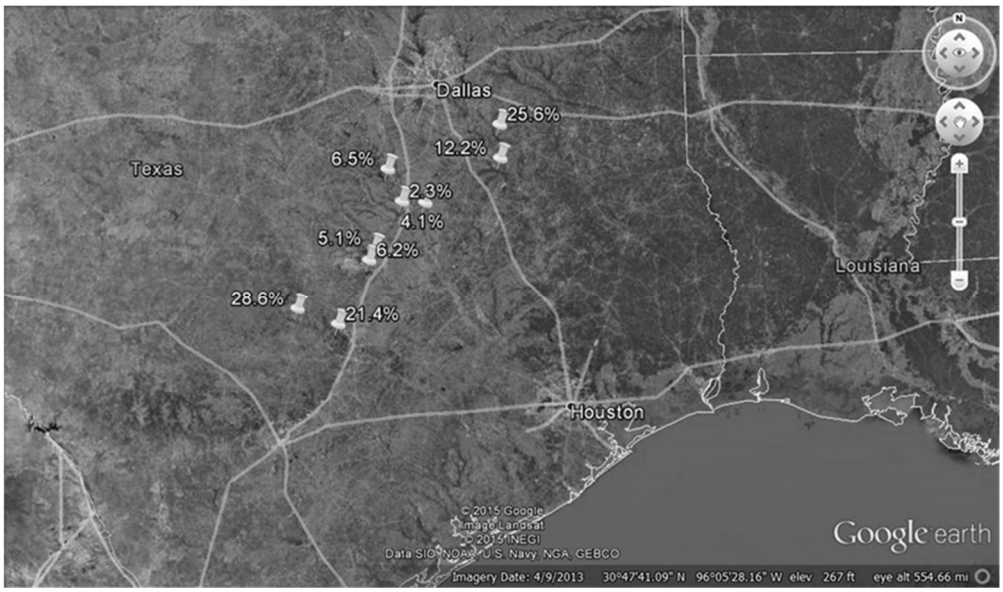


Figure 3: Map of Boaters unaware of zebra mussels in Waco = 2.3%, Belton = 5.1%, Tradinghouse = 4.1%, Richland Chambers = 12.2%, Cedar Creek = 25.6%, Lyndon B. Johnson = 28.6%, Travis = 21.4%, Whitney = 6.5%

so than the northern lakes. This is due to zebra mussels spreading southwardly from Texoma as they make their way through Texas, so people farther up north are more likely

to have heard of them before. Zebra mussel awareness efforts have mostly been concentrated in more northernly regions that are at high risk for invasion. Lake Belton, Lake Waco, and Tradinghouse Reservoir have been visited by zebra mussel awareness programs in the past, resulting in their high awareness rate. Lakes like Lyndon B. Johnson and Travis are in an area where there are few awareness programs, which is likely to have led to the low awareness levels.

However, there were a couple of outliers, like Cedar Creek (25.6%) and Richland Chambers (12.2%), where the percentage of unaware boaters was fairly high in a more northerly region. These values are most likely due to the small amount of time spent surveying there and the relatively few boaters surveyed, making it fairly easy for data to be inaccurate. Also throughout the surveying process, work was interrupted by flooding at the beginning of the summer and the closure of several lakes for an extended period. This may have changed boater's normal schedules and boating locations, causing differences in the data we collected. Although good weather cannot be ensured, in the future, it would be a good comparison to see how the data on these two lakes vary if there are clear surveying days as opposed to the days surveying was done there during 2015. When Cedar Creek and Richland Chambers were visited, there tended to be a low number of boaters showing up, making it harder to have data in comparison to lakes like Lake Belton or Lake Waco. Next time Cedar Creek and Richland Chambers are surveyed, it would be beneficial to visit them for more days despite the low visitation, in order to try and gain data more comparable to some of the more popular lakes.

Throughout the summer, few infested boats were found entering the lakes we visited, which was probably due to Belton and Waco (2 infested lakes) being closed for a good portion of the summer after intense flooding. The only ones found were entering either Lake Belton or Waco, so they were not a threat. However, near the end of the summer, a marina was closed down on Lake Belton and Texas Parks and Wildlife Inland Fisheries sent interns to each boat to attach information on how to clean boats with zebra mussels before putting them in another lake. Almost every boat in the water had zebra mussels all over the bottom of it and the sides of the marina were covered. If one was to pull anything out of the water which had spent a period of time there, such as old chain or a fishing line, it had zebra mussels clustered all over it. Many of these boats never leave Lake Belton so they were not a threat to other lakes, but with the marina closing, it was likely that they would have to be relocated. This was around the time we finished doing our surveys, but if we had continued, we may have found more infested boats as they were being transferred.

A problem encountered during the awareness effort was resurveying. Each weekend, the interns sent to a certain location changed. If two interns traveled to Lake Belton one weekend, two different interns may go back to the lake the following weekend. When the interns at a lake changed, there was no system for knowing which boaters had already been surveyed. There is a hesitation in asking boaters if they have already been surveyed, because due to the desire to get out on the lake or other motivators, they may not be truthful. One possible solution is using the TX tag number,

works like a license plate number. However, due to the attitudes of some of the boaters, who were suspicious of even being asked basic survey questions, asking for more information may make it harder to gain cooperation. Another possible solution is to handout stickers to be placed on inspected boats, but then the question of how long these stickers should be good for arises.

Since the arrival of *Dreissena polymorpha* almost two decades ago, they have spread to most of the United States and are still increasing their range despite the many efforts to contain them. They are costly and a nuisance to water enthusiasts and companies running water through their infrastructure. While awareness efforts may not completely prevent the spread of zebra mussels, it does slow the transfer. Awareness efforts are much cheaper than the methods used to control and lessen zebra mussels present in lakes and infrastructure. Therefore, it is worth the time and the money to put zebra mussel awareness efforts in place, even if they do not guarantee protection against the mussels. Also, the information gained from surveys, such as where boats have been most recently, could be valuable data used to figure out how a lake became infected if zebra mussels are discovered. Until a better option can be found, prevention methods need to be stepped up in high risk areas rather than waiting to handle the problem until zebra mussels have entered a reservoir.

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