STOPPING THE SPREAD:

EXAMINING THE EFFECTIVENESS OF POLICIES IN THE MISSISSIPPI RIVER BASIN AIMED AT PREVENTING THE SPREAD OF ZEBRA MUSSELS

By

JULIE CAREY

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Thesis Approved:

Dr. Dale Lightfoot

Thesis Adviser

Dr. Jon Comer

Dr. Jacqueline Vadjunec

Dr. A. Gordon Emslie

Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Zebra mussels (*Dreissena polymorpha*) are a mollusk indigenous to the Aral, Caspian, and Black Seas in Eastern Europe (Pacific States Marine Fisheries Commission 2008). However, starting in 1775 with the construction of a canal between Dnieper and Zapadnyi Bug rivers and the Black Sea, they have been making their way west, having invaded the United Kingdom as early as 1850 and France by 1950 (See Figure 1) (Minchin and Gollasch 2002). The possibility of zebra mussels reaching North America was realized as early as 1921, when, after reading a description of the spread in the British Isles by Dr. James Ritchie, C.W. Johnson (1921) commented,

> "The possibility of…the zebra mussel being introduced [to the United States] is very great. There is entirely too much reckless dumping of aquaria into our ponds and streams. A number of foreign freshwater shells, etc., have been recklessly introduced this way. Why not the mussel?" (64).

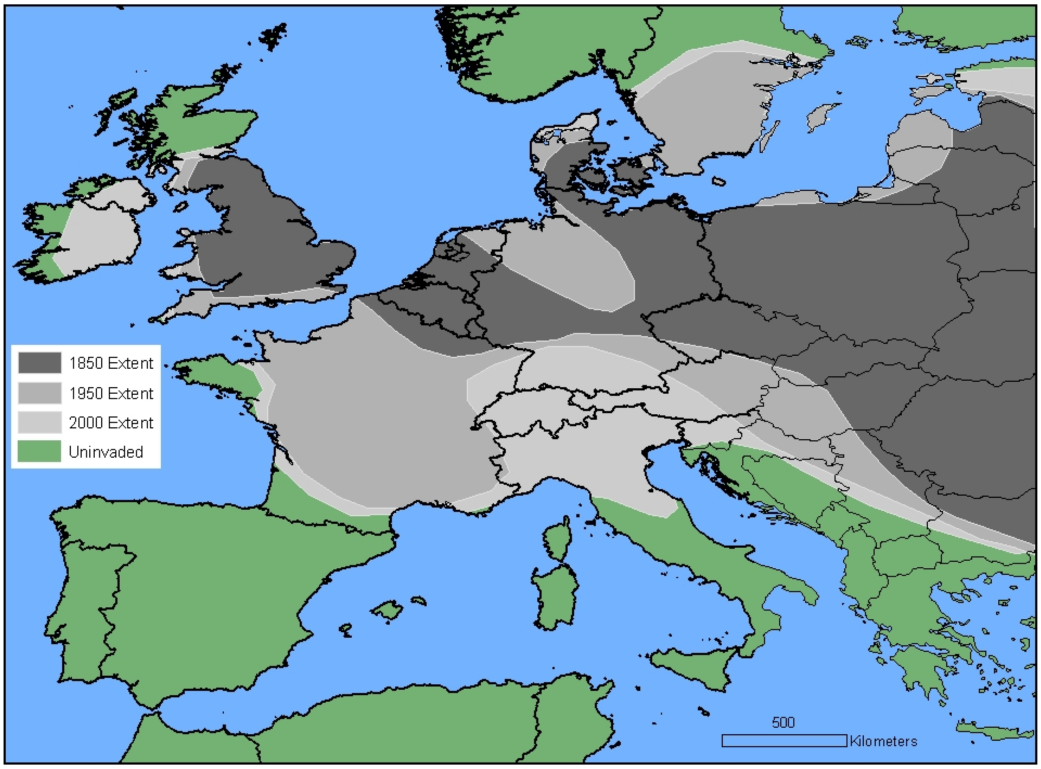

Figure 1: Zebra Mussel Extent in Europe
(Adapted from Minchin and Gollasch., 2002, Figure 1, Pg. 137)

It was about 67 years after this observation when zebra mussels were first discovered in Lake St. Clair (Johnson and Carlton 1996). As C.W. Johnson (1921) noted, it is not the first invasive species to be introduced; in the Great Lakes alone, there have been approximately 162 aquatic nuisance species introduced in the past 200 years, many of these after the completion of the St. Lawrence canal system, mimicking the pattern seen in Europe (Vasarhelyi and Thomas 2003, Carlton 1993). In addition to canals, zebra mussels spread quickly through other interconnected waterbodies with the assistance of water flow, as well as unconnected waterbodies via recreational boating (Figure 2) (Johnson *et al.* 2001). By 1993, zebra mussels had reached as far west as the McClelland-

Kerr Navigation System in Oklahoma, and as far south as the Mississippi delta (Benson 2008).

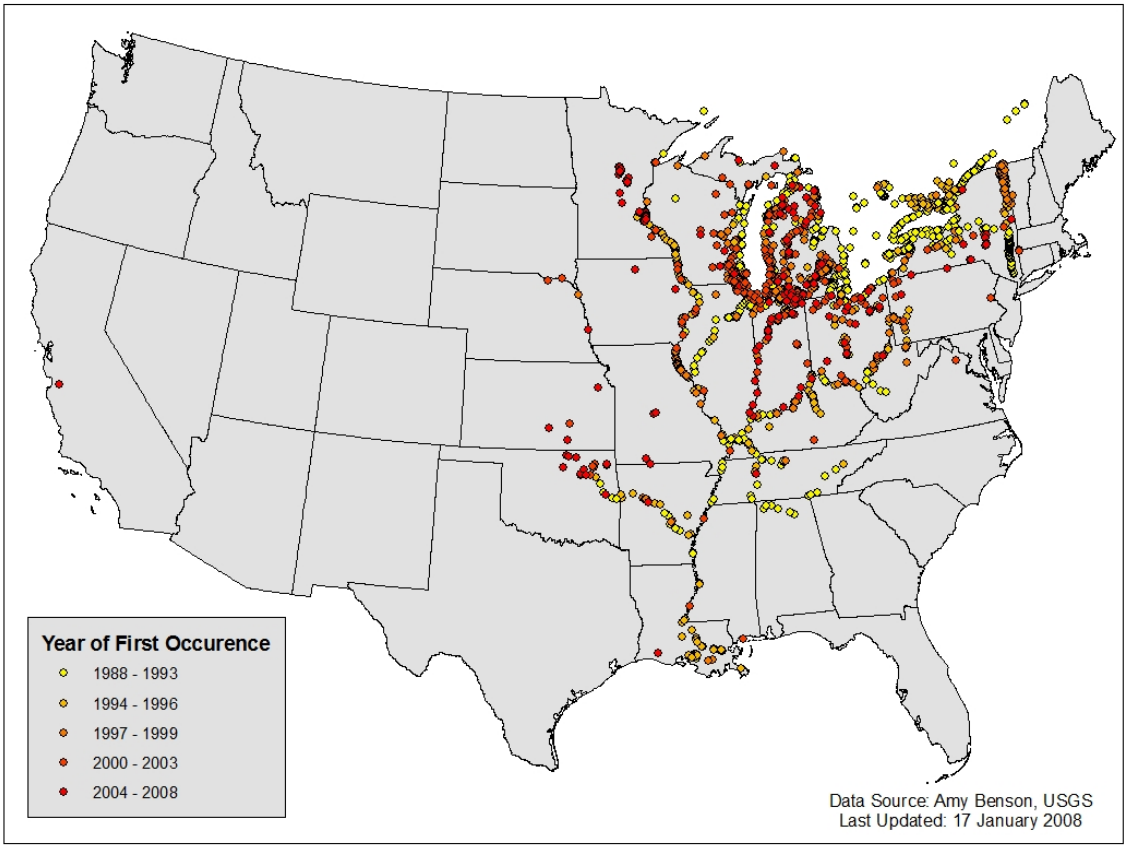

Figure 2: Map showing the spread of zebra mussels in the U.S. (Adapted from Benson 2008)

The zebra mussel has some unique characteristics that make it especially amenable to overland diffusion. The first of these are the byssel threads which the mussel uses to attach to hard substances (see Figure 3) (Kew 1893). The second characteristic is its prolific reproduction capability, as a single female can release more than 1 million eggs during her life, or more than 40,000 eggs per cycle (Kew 1893, Bobeldyke *et al.* 2005, Benson *et al.* 2004). Lastly, the zebra mussel can adapt to environments that are quite different from its native habitat, both chemically and physically (Kew 1893, Padilla *et al.*

1996). For example, in Europe, zebra mussels have been found in brackish water that reaches a salinity of 12 parts per trillion, while in the U.S. they are usually found in waters with a salinity of five parts per trillion. In addition, the temperature of the water they can be found in ranges from 14 degrees Celsius to 32 degrees Celsius with 14 to 16 degrees being the optimum temperature for spawning, 17 – 25 degrees for the mussel to grow and 32 degrees being lethal to the mussel (Benson *et al.* 2004).

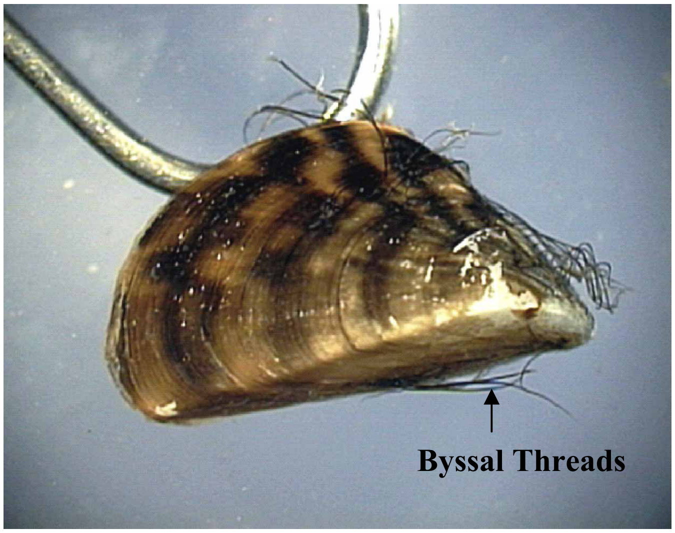

Figure 3: Zebra mussel attached to an object.
(Adapted from GMRP 2002, Pg. 19)

STATEMENT OF THE PROBLEM

The presence of zebra mussels in and of itself is not necessarily a problem, it is the environmental and economic damage caused by their presence. Even if just a fraction of the eggs produced by each female mussel survive, that still leads to large populations, which reduce the amount of food and oxygen that is available for native organisms. They also attach to native organisms (see Figure 4), completely covering them and inhibiting their ability to feed and escape predators (Pimentel *et al.* 1999, Benson *et al.* 2004). Each mussel can filter up to a liter of water a day with 90% efficiency, increasing water clarity and allowing greater sunlight penetration resulting in algal blooms (Pacific States Marine Fisheries Commission 2008, Benson *et al.* 2004).

Figure 4: Mussels on a Crayfish (Mittermaier 1996)

In addition to attaching themselves to other organisms, zebra mussels also use their byssal threads to attach to each other, leading to densities reaching 700,000 mussels per square meter (Pimentel *et al.* 1999). Mussels have been able to attach to water intake pipes and hydropower turbines, with the pipe being subsequently clogged (Figure 5) (Padilla *et al.* 1996). The estimated cost of the damage this has caused has varied from four million dollars in 1994 in Wisconsin, to a national annual cost of five billion dollars in 1999. (Padilla *et al.* 1996, Pimentel *et al.* 1999). Unfortunately, eradication without harming the native organisms is expensive, and all but impossible once a population becomes established. A study at the University of Florida found that for Lake Okeechobee there is a benefit-cost ratio of 1.2:1 for late eradication, increasing to 4.4:1 with early eradication, and jumping to 70:1 for prevention (Lee *et al.* 2007).

Figure 5: Mussels Clogging a Pipe (Jentes 2001)

Because of this, it is in a state's best interest to prevent the introduction of zebra mussels into waterbodies over which they have jurisdiction. However, there are some holes in existing policies that states have implemented. For example, guidelines state that vessels should be sterilized with a chlorine solution, washed with hot water, or left out of the water for long periods, which would kill any zebra mussels present. However, boater compliance has been low, and in public education efforts, minimal attention has been given to educating boaters about how zebra mussels can be attached to the plant life that can be present on their boats or boat trailers and the hazards of dumping live bait into the waterbody (Johnson *et al.* 2001).

PURPOSE OF STUDY

This study evaluates how effective states have been at preventing the introduction of zebra mussels and examines the policies they have employed and the knowledge and attitudes of recreational boaters. This will help identify areas where states can improve their policies and target their public education efforts. This will be a three part process, as outlined in the objectives below.

OBJECTIVES

Table 1: Research Objectives and Methods

Objective	Method
1. What is the relative effectiveness of states' zebra mussel prevention policies?	Rank the states using distance/time, number infested waterbodies, and upstream infestation level factors.
2. What policies do the most effective, moderately effective, and least effective states employ?	Evaluate states' Aquatic Nuisance Species Management Plans and talk to state officials.
3. How does the knowledge and attitudes of states' recreational boaters affect the state's effectiveness?	Interview recreational boaters and evaluate responses for differences.

CHAPTER II

REVIEW OF LITERATURE

WATER AS A COMMON POOL RESOURCE

Common-pool resources, or often simply "commons" are "goods that can be kept from potential users only at a great cost or with difficulty but that are subtractable in consumption and can thus disappear" (McKean 2000, 28). One example is that of water resources. Human bodies being made up mostly of water, it is one of the few resources that everyone requires on a regular basis. However; it is not always used simply for drinking and food production. It can be used for electricity generation, sanitation, or even for recreation. Because of these many uses, most water supplies are not under the custodianship of a private entity, but rather a government which permits users to utilize water in these many fashions, often without limits.

Another aspect of water resources that makes it difficult to manage is that it is a resource which flows across politically constructed boundaries, but yet cannot itself be divided (McKean 2000, 37-38). Because of this, multiple appropriators are using the same resources, and it is economically unfeasibly to attempt to exclude others from any improvements or degredation that occurs in one portion of the resource or another (Ostrom 1990, 31-32). Lake Texoma in southern Oklahoma-northern Texas is one such example. If a foreign substance, for instance zebra mussels, is introduced on the Texas side of the lake, there is nothing to keep the mussels from spreading to the Oklahoma side as they do not recognize the political boundary and there is no physical boundary separating the two portions of the waterbody. There are some instances where authorities have attempted to construct barriers, but this is applicable under very specific circumstances.

THEORIES OF THE COMMONS

In Garret Hardin's commons theory, resource degradation occurs when each user increases his or her use of a shared resource beyond acceptable limits in an effort to increase profit. Because it is shared land, the additional stress is shared amongst all users while the person with the extra share reaps the full benefit (Hardin 1968). Since the publication of Hardin's initial article, many researchers have built upon this idea and created their own theories, some of which are not in full agreement with his analysis, not-with-standing the success a commons system had in Medieval England (Feeny *et al.* 1990).

In order to understand these many theories surrounding the use of common resources, it is helpful to review the ideas behind resource ownership. According to Feeny and colleagues (1990), there are four types of ownership: open access, private property, communal property, and finally state property. Open access is where there is an absence of well-defined property rights and anyone is free to utilize the resource. Private property is the opposite; an individual retains the right to use the resource and controls the rights of others to utilize it as well. This works best when the resource is isolated, the use of it does not affect a third party, and the owner can reap a benefit from allowing others to utilize it (Bish 1977). Communal property is very similar. This property type is owned by a group which may legally exclude others from using this property or its resources. The final type is state property, where the rights to control use and access is vested in the government who may use coercive techniques to force compliance (Feeney *et al.* 1990).

It is not always clear which category of ownership common pool resources fall under. Baden (1977) considers public goods to fall under the category of open access, and argues that because exclusion is impossible users have no incentive to protect it, aside from any social pressure from others. For example, if one boater were to see another start to launch his boat with weeds hanging off the trailer, then the first could pressure the second into checking his boat and removing any foreign debris. Feeny and colleagues (1990) feel that in analyzing Hardin's tragedy many confuse communal property with open access. They believe it is this open-access scenario that is presented by Hardin, who believes that the only systems under which exclusion can operate are that of private property and state property. By introducing the concept of communal property, another scenario is presented which would allow for exclusion and regulation (Feeny *et al* 1990.)

The engine behind resource use, overuse and control is economics. Ostrom (1990) presents this as the "Prisoner Game." In this model, the players do not have the opportunity communicate and therefore, do not know what the other person is going to do. Each player has two choices: to use the resource normally, or to use it to maximize his or her profit. If each user chooses to stay within the limits of the resource, then they will both receive 10 units of profit. If they both overuse ("defect"), then they will receive no units of profit. However, if one player defects, he or she will earn 11 units of profit while the other loses one unit. When one is penalized for following the rules (the loss of one unit of profit), little incentive is provided for doing so when others are getting ahead by breaking the rules (the gain of 11 units). If all resource users communicate, then there exists an increase potential for profit for all users as opposed to just those who choose to do the wrong thing. However, this game assumes that users know what the right thing to do is. In the case of zebra mussels, this may not always be the case as a user may not be familiar with this particular kind of resource degradation. However, if water users share the information with each other, and those that do know the proper steps to take set a good example, then the other users would be more likely to follow suit.

This system of being rewarded for misusing a resource does not lend itself to environmentally friendly activities as people forget that everything in the environment is connected to everything else (otherwise known as the first law of ecology) (Young 1981). Lee (1982) sees the problem as the lack of private property as people are unable to be honest and make a fair exchange – they are only willing to work for the common good if everyone else is. This idea is played out through the modified prisoner game, in which players are rewarded for cooperating and the defector is the one who is penalized by an external observer (Ostrom 1990). In many cases, this third party looking out for the common good is the government, which can suspend the rule of willing consent when action to do what is right will not be taken voluntarily (Young 1981, Baden 1977). The levels of government involvement can vary depending on how the resource is seen. If natural resources are seen as social capital, then the government should only be involved in correcting or supplementing market transactions (Young 1981). The alternative view is the ecological view. According to Young (1981), "In effect, the ecological perspective suggests that man should adopt an attitude of stewardship in dealing with the natural environment and that the role of steward must be assumed primarily by governmental agencies" (4). Ostrom (1990) agrees that central government control can help avoid the tragedy depicted by Hardin, although Bish (1977) points out that in England, surface rights to reservoirs are granted to an organization, which then controls access and use.

In general, the preferable action for government to take is to regulate an industry as opposed to nationalizing it, especially in a capitalist system. Regulation is a popular tool to use when either private property rights greatly overlap or it is impossible to restrict competition and is aimed at protecting resources when the actions of individuals will not obtain the desired results (Young 1981). The process of policymaking can be likened to a game where one player makes a move, and then another has the option of accepting the situation or changing it. Ostrom (2005) uses the example of a light bulb with two switches; the person at one switch can turn the light bulb on, and then the person at the other switch has to decide whether to accept the situation, or alter it by turning the light off. In the case of zebra mussel prevention policy, this would be the equivalent to user groups either just accepting the policies developed by the state, effective or not, or taking it upon themselves to educate their fellow resource users or lobbying the state to take more aggressive actions. These are simple examples in which an action either occurs or does not occur. Ostrom chooses not to address the issues of externalities, such as light coming through a window. However, in policy making it is important as there will always be situations beyond government control, such flooding which may cause an infested waterbody to mix with a previously uninfested one.

Not everyone agrees that government control of resources is a good thing. Lee (1982) believes that government activities are intended to benefit only a select group, at the expense of many (many often being the taxpayers). One of the justifications for regulation is often the cost of environmental degradation; however, agencies often exert their own costs. “It is naïve in the extreme to imagine that those with political influence will not employ this power for their own narrow purposes.” (Lee 1982, 202). In this case, privatization by splitting the commons and not allowing intermingling would be the only way of protecting the integrity of the commons. While this would be easy to do in the case of land; it would be costly in the case of resources such as water and air as the methods of privatization would have to include limits on allowable amount, time, or access to equipment (Ostrom 1990).

Much of this literature has focused on the over-use of resources. However, resource pollution is also a concern. Lee (1982) makes a point that many of us dump our waste, be it trash, sewage or engine exhaust, into the environment without giving it as much thought as we do many of our other resource decisions. One example presented was that of gasoline. We may think about how much money is spent on gas because it’s tradable on the open market. However, the cost of emissions is borne by everyone in terms of the lack of clean air, which has no market value. The main solution that has been presented is to create a pollution-rights system where the polluter pays, possibly by the metric ton, for the right to pollute, much like what has been done with CO_2 allowances (Lee 1982). As Hardin (1968) points out, to avoid excessive pollution, the coercive means must make it cheaper to avoid pollution than to bear the fraction of the cost of pollution.

FACTORS INFLUENCING SUCCESSFUL RESOURCE MANAGEMENT

For successful resource management, there are three main considerations that the governing bodies need to keep in mind: the rights of the users, how the resource is to be managed, and under whose authority (McKean 2000). Under the category of users, the main considerations are that the users of the resource have the right to form groups. These groups can have their own criteria for membership, which does not have to be inclusive of all users of the resource. This category overlaps the management category in that representatives from these groups have the right to modify their use rules within the limits of environmental responsibility, as long as they are clear, fair, and easily enforceable with graduated penalties for infractions. (McKean 2000, 43-50) By allowing the punishments to be graduated, flexibility is introduced to allow for scenarios where the breaking of the rule could not be avoided or is continually breached (Ostrom 1990). With multiple user groups using the same resources, these rules are likely to be disputable so there should be an effective, inexpensive system for resolving minor conflicts. Finally, it needs to be determined who has the final decision making authority. This ensures that the overall management goal is not lost as well coordinating between the different user groups, between which communication may be sparse due to distance or other causes (McKean 2000).

Finally, once the regulations are put into place, the governing body needs to be able to ensure compliance by finding a method of altering behavior. Enforcement is one method of coercing compliance, but when a new regulation has been put into place, there is no previous knowledge as to how the enforcement efforts will influence compliance as it is a combination of factors such as attitudes, incentives, and policies of relevant agencies. It is also difficult to force compliance when there is more incentive to ignore the regulations (Young 1981). For example, states can set up decontamination stations near waterbodies with a requirement that boaters utilize these stations prior to launching their boat. To use the decontamination stations would cost the boaters time and money, such that it is better economically to degrade the resource, especially if the boater is not a local who has a stake in the quality of the waterbody. Because of this, agencies find outreach or incentive programs worthwhile. As Hardin (1968) points out, "Education can counteract the natural tendency to do the wrong thing…"

POLICY ANALYSIS

One recommendation for evaluating the strength of a state's policies is by comparing existing statutes with a set of ideals to determine the strength of the state's programs. The justification for this approach is the idea that "…the first step to building a state's arsenal of invasive species control tools is to ensure that adequate statues are on the books and that the relevant authorities exist to give those statutes sufficient force" (Filby *et al.* 2002, 95). The authors recognize that just because a tool is in the books does not mean that it is implemented to its fullest potential and effectiveness. Filby and colleagues also developed three standards that states can achieve: a bronze, silver, and gold. Intuitively, the bronze is the standard that would have the fewest requirements and be the easiest to achieve. Unfortunately, using information provided about state policies in the document (summarized in Tables 11-13 in Appendix 1), none of the states in my study area would achieve this minimum standard (see Table 1). Minnesota and South Carolina were the closest, lacking only the funding and emergency powers requirements respectively. However, Minnesota has zebra mussels and South Carolina does not, indicating that there are more factors that what is being accounted for. In their summaries of the tools available to states, they highlight the current policies of existing states, but fail to include any rationale as to whether the policy was effective in reality as opposed to purely theoretically.

Table 2: Number of Polices Toward Bronze Standard (adapted from Filby *et al.* 2002)

State	Bronze Standard Score	Zebra Mussels Present?
Alabama	0	Y
Arkansas	0	Y
Georgia	0	Y
Indiana	0	Y
Iowa	0	Y
Kansas	0	Y
Missouri	0	Y
Nebraska	0	Y
North Carolina	0	N
North Dakota	0	N
Pennsylvania	0	Y
South Dakota	0	Y
Wyoming	0	N
Colorado	1	N
Illinois	1	Y
Kentucky	1	Y
Michigan	1	Y
Mississippi	1	Y
New York	1	Y
Ohio	1	Y
Oklahoma	1	Y
Tennessee	1	Y
Virginia	1	Y
West Virginia	1	Y
Louisiana	2	Y
Maryland	2	Y
Montana	2	N
Texas	2	N
Wisconsin	2	Y
Minnesota	3	Y
South Carolina	3	N

Note: Bronze Standard Score values indicate number of policies employed by the state towards achieving the Bronze Standard.

According to Susskind and colleagues (2001), "the techniques of policy analysis emphasize a structured and systematic approach… [that] (1) define a problem and develop evaluative criteria, (2) generate policy options, forecast future requirements… and (3) evaluate and rank alternative policy options" (91). One approach to policy analysis mentioned is "systems analysis." The basic form of systems analysis is operational research, which uses mathematical models to determine and compare several different possible outcomes of a particular decision. These models compare and rank the alternatives, using indicators such as an index value, figure of merit, or objective function. Because of its use of models, a systems approach is known as an analytical approach to policy analysis. The authors warn that while it may seem as if an analytical approach is the most objective way of conducting a policy analysis, its effectiveness is still limited by values and assumptions that go into the examined variables.

Stock (1989) suggests that most, if not all, policy analysis occurs prior to implementation, "A common econometric problem is predicting the average effect of a proposed policy on some dependent variable, where the variable typically is either directly or indirectly related to individual welfare" (567). He proposes that a model can be constructed which combines features of parametric and nonparametric models by finding the parametric function and adding to it a factor that accounts for location-specific variation. In doing this, he assumes that this model does not vary once the policy is enacted.

SUCCESSFUL INVASIVE SPECIES POLICY

In an Ecological Society of America (ESA) Report published in 2006 by Lodge and colleagues, the authors take a stance that the most effective policies focus on the pathways of invasion. This can include government oversight of known sources of introduction (such as with the ballast water program) and monitor other pathways to evaluate the risk that they present. One specific recommendation that they made under this category is to “install in canals [barriers] that connect major watersheds” to prevent the movement of non-indigenous species (Lodge *et al.* 2006, 2041). A second recommendation is to conduct a risk analysis of all organisms that companies are proposing to import into the U.S. For example, a company that wants to import a new kind of goldfish for use in ponds would need to write a report outlining the risk of their species to the environment should it escape. The ESA report admits that some of these policies are already in place; however, it maintains that the current evaluation techniques are not rigorous enough and that a species is often added to the injurious species list maintained by the U.S. Fish and Wildlife Service only after its introduction into the wild. The final recommendation the ESO had was to “Expand existing authority of the National Invasive Species Council (NISC)… to better coordinate policies among government agencies and with other countries” (Lodge *et al.* 2006, 2048). Invasive Species policy and authority is currently handled by 20 different agencies depending on species, taxa, pathway of invasion, or stage of invasion. This reduces the interdependency awareness, affecting the overall cost effectiveness of prevention and mitigation efforts (Lodge *et al.* 2006) .

According to Carlton (1993), “Containment or control measures to slow or prevent the dispersal of Dreissena by human activities must take into account the full range of mechanisms available.” (678). Carlton contends that workboats and barges are overlooked in many policies, as well as bilge water and catamaran pontoons. Johnson and colleagues (2001) sees that the key is to target boats with an abundance of plant life, and to incorporate this information into boater education and boat cleaning activities that are currently in place.

An example of a successful boater education is that in Ireland. Ireland discovered zebra mussels in its navigation systems by 1996. Due to the concern of transmission into trout ponds, a public information campaign was started in 1997 to make anglers aware of the problem and what they can do to make sure they do not transport this organism. This program has shown success; as of 2000, no new lakes had become infested and despite an increase in overland vessel traffic, the biomass of zebra mussels on these vessels has decreased. Unfortunately, according to the Minchin and Gollasch (2002), it seems inevitable that future lakes in Ireland will be colonized as public interest in the hazard will likely wane without continued infestations to keep it in the public eye.

PATHWAYS OF INVASION

Another problem with creating effective policies has been the lack of understanding as to the nature and rate of the dispersal of zebra mussels. This has led environmental managers to utilize a variety of techniques, relying mostly on intuition. Within these, the camp was divided as to whether policies should focus on natural or anthropogenic causes (Johnson and Carlton, 1996).

Aquaculture accounts for about 25% of all introduced aquatic species, whether species escape during a flood event or from aquarists dumping their unwanted fish into a local lake or stream (Vasarhelyi and Thomas 2003, Carlton 1993). Zebra mussels, on the other hand, were introduced unintentionally via ballast from ships originating from the Baltic. It is believed that the mussels were either in their planktonic stage or adults attached to plant life or sludge that was pushed out with the dumping of ballast water. In a 1990 survey, 10 percent of commercial ships contained some form of bivalve mollusk larvae, four of which were from Europe (Carlton 1993). Once in North America, mussels spread more quickly through connected waterways and less quickly to isolated waterbodies (Padilla *et al.* 1996).

Johnson and Carlton (1996) identify three types of spread: diffusive, advective, and saltatory. The diffusive spread is demonstrated by the spread of an invasive species within a waterbody. Once a body of water has become infested, it is then more likely that its outflowing stream and subsequent lakes will then become infected, which is advective spread (Bobeldyke *et al.* 2005, Johnson and Carlton 1996). According to Carlton (1993), the spread of mussels through connected waterways usually happens while the mussel is in its larval stage, where it stays suspended in the plankton for up to thirty days. Once they attach to a substance, they can become free floating either via releasing their hold or by being knocked loose (Carlton 1993). However, in Bobeldyke and colleagues' (2005) study, the further the waterbody is from a source, the less likely it is that it will be affected by the upstream source, with a limit of approximately 20 kilometers.

Finally, saltatory spread occurs between watersheds, for example the Ohio River watershed to the Upper Mississippi River watershed (Johnson and Carlton 1996). Johnson and colleagues (2001) observed, "Dispersal between hydrographically isolated waters requires specific adaptations for overland transport and survival in inhospitable terrestrial environments or further assistance from human vectors" (1789). Unlike other aquatic species, which can spend only minimal time out of water, zebra mussels can last several days. One study showed that 73.3 percent of adult zebra mussels could survive

10 days out of water in air temperature of 10 degree Celsius and 95 percent relative humidity, allowing them to travel long distances (Ricciardi *et al.* 1995). Overland pathways can include waterfowl, wet fur on mammals, reptiles, and of course, humans (Padilla *et al.* 1996, Carlton 1993)

Animals are another potential vector for the spread of zebra mussels, however this potential is limited. Birds and aquatic mammals such as otters that may pick up a mussel, take it to another part of the waterbody or watershed, and leave it unconsumed. One study cited by Johnson and Carlton (1996) demonstrated that mussels consumed by a duck and passed through its digestive track did not survive. Of the mussels that were instead attached to a duck's body, half survived over short distances. However, these ducks were exposed to zebra mussels at a very high density, which is believed to contribute to an overestimation as to the rate of dispersal. Human mechanisms are not nearly as limited, with commercial shipping playing a large role early on, with the majority of occupied waters being major shipping lanes (Johnson and Carlton 1996). Outside of commercial shipping, zebra mussels can be found in several places on a recreation vessel: the motor, anchors, propellers, centerboard, and even the trailer if it becomes entangled in plant matter (which Johnson *et al.* 2001 referred to as "piggyback dispersal"). The overland movement of trailerable boats has lead to dispersal to isolated waterbodies and is likely what helped the spread to some lakes in Europe (Carlton 1993). In addition to these external portions of the vessels, closed places where water can accumulate and remain for long periods, such as the live wells, bilges, and cooling systems, are also a concern (Johnson *et al.* 2001). In a study conducted by Johnson and Carlton in 1996 of boaters at

Lake St. Claire, larvae were found in 43 of 52 livewells[1]. A final concern for boaters is the equipment that may be used, such as SCUBA gear and waterskis. However, the human threat is not limited to boaters; sport fishermen who may fish from the shore pose a threat as well as bait buckets, and fish holding tanks. Tackle and nets can also contain mussels, especially if plant life is involved (Carlton 1993).

In a report by Buch and McMahon (2001), it was suggested that the dispersal of aquatic nuisance species is random, based on a survey of non-local boaters in the states straddling the 100th Meridian (significance to be explained later) taken in 1998 and 1999. The conclusion may have been accurate in that the occupied waterbodies did not follow a seemingly logical diffusion pattern on a large-scale. However, these surveys, while touching briefly on the knowledge and attitude of the vessel operator, failed to take into consideration the ANS policies of either the home locality or the receiving waterbody. Johnson and Carlton (2006) used lakes in Michigan that were considered high-risk "due to large size, high degree of public access, and proximity to established populations of zebra mussels in the Great Lakes" when determining which lakes are high-risk for the purpose of seeking out mussels (1688). Padilla and colleagues (1996) would add to this that the pattern of lake use and what waterbodies people usually visit also play a large role, observing that the lakes with zebra mussels are in the top 80% of most-used lakes. They used this to explain the relatively low occurrence of mussels in Wisconsin in 1996, as there were few boats that were used in both the Great Lakes as well as inland waters. In determining lake usage, both of these studies used information obtained from surveying trailered boat, as they represent more of a potential for spread than resident

[1] Livewells are the area of a boat which contains water in which to keep fish alive until the fisherman returns to shore.

boats[2], which only create a concern either when they are sold and moved, or the owners change residences (Padilla *et al.* 1996, Johnson *et al.* 2001). Johnson and colleagues (2001) conducted their surveys in person on weekends and holidays, talking to boaters either as they entered or exited the waterbody at access points while Padilla and colleagues (1996) stated that their surveys were mailed to registered boat owners in Wisconsin.

Johnson and colleagues (2006) emphasized that distance from the Great Lakes is a relatively minor factor in zebra mussel dispersion, and instead it is the proximity to a source that matters more. This study in Indiana noted that the state has a high proportion of infested lakes while the majority of state waterbodies are relatively remote from the Great Lakes. A third of Indiana's infested lakes occur in a single county, leading to the conclusion that there was likely a single long-distance (primary) dispersal event with several short-distance (secondary) dispersals. Ohio, which is immediately adjacent to the Great Lakes, was also examined. However, a relatively low percentage of its lakes were infested, with one possible cause being that the state's lakes are relatively more dispersed.

POST-INVASION MANAGEMENT AND MITIGATION

Even after a species is introduced, all hope need not be abandoned. With early detection, possible through the use of developing technologies and surveillance techniques, it may be possible to eradicate small populations of invasive species; the larger the populations, the harder it will be to control further growth of the species. In

[2] Resident boats are those boats which are permanently docked or moored at a marina or private dock.

order to assist in the response to a report of an invasion, emergency funds and legal authority to proceed with all due haste need to be available. In Australia, the eradication of Mytilopsis (a marine mussel) was made possible through the ability to quarantine. Currently, the United States lacks a framework for the cooperation of federal, state, and local authorities to accomplish the same goal outside of the National Aquatic Nuisance Species Panel. One example provided by the ESA report is the lack of regulations on noxious weeds residing on private or unoccupied lands. The bureaucracy of obtaining needed permits for some eradication methods also slows the process down, permitting the growth of the population. By eliminating this, responders would be able to proceed more quickly. There also should be incentives provided to the state and tribal government for controlling the spread of nuisance species on private or public lands, in an effort to "slow-the-spread" (Lodge *et al.* 2006, 2048).

According to Philip Hulme (2003), one of the problems with managing invasive species is that though our current methods of assessing and mapping invasions in and of themselves are top of the line, they do little to help provide solutions to the problem. He takes the stance that "until these [limitations] are adequately addressed progress towards arresting biological invasion will be limited" (179). The first problem he addresses is with maps. Currently, there is no standard in mapping invasions. Enumeration units, type of data, extent, and resolution should all be standardized in order to aid in comparison. It would also assist in discovering a spatial pattern of invasion, hotspots, and predicting rates of spread. At too large of an enumeration unit, maps can be deceiving on the extent of the problem, or even the true, non-politically bounded, distribution. By using a smaller enumeration unit, such as the county-size used in Europe, not only can hotspots be more accurately pinpointed, but data such as climate, soil, and vegetation can be included. A second problem is the use of climatic variables in determining potential distributions.

Several techniques have been tested in an attempt to control or eradicate zebra mussels. The first is to use ammonia. It was found that at two milligrams per liter, the mussels showed signs of stress and at three milligrams per liter the mussels experience 90-100 percent mortality (Nichols 1993). The next technique was temperature control. Nichols (2003) found that temperatures above 24 degrees Celsius caused a die off, or for populations that adapted to higher temperatures, an increase of four degrees caused a mortality of less than 0.04% per week. Jenner and Janssen-Mommen (1993) recognized that the heat necessary to kill the mussels varied with where the mussel was found. Leach (1993) noted that the mussels appeared to be adapting quickly as the temperatures veligers[3] were found in decreased to 7.5 – 14.5 degrees Celsius from 18.1 – 21.7 degrees in 1988. A final method involves increasing water velocity to 1.5m/sec in order to prevent new settlement; however, this would do nothing for established populations (Jenner and Janssen-Mommen 1993).

These methods are not without risk, however. Europeans have experimented with using chlorine, but the amounts that were effective surpass the U.S Environmental Protection Agencies guidelines. The Dutch are also concerned that chlorine would affect the hormones of native species of all kinds. If low levels are used, it would take about 2-4 weeks at temperatures of greater than 15 degrees Celsius and would have to correspond with the end of a reproductive cycle (Jenner and Janssen-Mommen 1993).

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[3] A veliger is a zebra mussel in its larval stage.

AUTHORITY-GRANTING LEGISLATION

While legislation to help prevent or control invasive species has existed in the U.S. since 1912, aquatic nuisance species were not addressed until the National Environmental Policy Act of 1970. However, this legislation was aimed only at the intentional introduction of these species by requiring organizations and agencies wishing to import these species to complete an environmental impact report (National Invasive Species Center 2008).

The first comprehensive policy aimed at preventing the unintentional introduction of aquatic nuisance species was in 1990 with the Non-indigenous Aquatic Nuisance Prevention and Control Act. This act did several things; it created the Aquatic Nuisance Species Task force to determine the threat to the ecology and economy of areas outside the Great Lakes, directed the United States Coast Guard to initiate a ballast water program, and instructed the Corps of Engineers to develop plans regarding the protection of public works in infested waterways. (National Invasive Species Center 2008). The ballast water program was in part based off Captain Thomas E. Thompson's testimony to the House of Representatives Committee on Merchant Marine and Fisheries. Captain Thompson testified as to the current ballast water policies of Canada and Australia. Canada instituted a voluntary program in 1989 which requested that the masters of international ships provide information on their ballast water, and to perform a ballast water exchange in the St. Lawrence Seaway if one was not done at sea (U.S. Congress 1990). Australia, on the other hand, had instituted a mandatory program where masters of the ship had three choices – they could provide certification that their ballast water contained no harmful organisms, reballast at sea, or certify that there would be no release of water while in port. One concern that Captain Thompson had was that these programs could be only partially effective as it is impossible to remove all water and sediment from the ballast tanks. Another concern, addressed by Reeves (1999) was that the construction of a ship's ballast was such that for older, poorly maintained ships ballasting in open sea could cause the ship to break in half.

This act was amended further in 1996 and retitled the Nonindegenous Species Act (NISA) to mandate that vessels use practices that limit the amount of ballast water, but as of 2003 no specific guidelines had been developed due to the stalling of the Great Lakes Ecology Protection Act of 2003 and NAISA of 2002 in Congress (P.L. 104-332 1996, Vasarhelyi and Thomas 2003) . NISA also indicated that funding should be provided for research. The last piece of legislation that included the zebra mussel was an amendment to the Lacy Act in 1998, which prohibited the transportation of injurious species between U.S. states and territories (National Invasive Species Center 2008). The original version of this act, enacted in 1900 in order to protect states' game wildlife, focused on the transportation of flora and fauna that was illegally obtained. It was amended several times in the following 98 years, but this amendment was the first time that alien species were included in the prohibition (Importation or shipment of injurious mammals, birds, fish (including mollusks and crustacea), amphibia, and reptiles; permits, specimens for museums; regulations 2006, Fisher and Sandra 2000).

In 1999, President Clinton signed Executive Order 13112, which required federal agencies to monitor, participate in research, and create outreach programs to prevent the spread of aquatic nuisance species. In effect, this executive order upgraded the Aquatic

Nuisance Species Task Force into a council, which created a national management plan in 2001 (Vasarhelyi and Thomas 2003).

NATIONAL AND REGIONAL ORGANIZATIONS

100th Meridian Initiative

The 100th-Meridian Initiative was first conceptualized in 1996 in response to amendments to the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990. One of the primary goals of this initiative is to prevent aquatic nuisance species introduced in the east from spreading westward of 100th meridian, with an emphasis on zebra mussels (Mangin 2001). However, it was not until 1998 that the first draft of an action plan was released.

Key players in this initiative include representatives from federal, state and tribal governments, as well as private and commercial entities. The two organizations that bear most of the responsibility for the activities of the 100th Meridian Initiative are the Fish and Wildlife Service and the National Oceanic and Atmospheric Administration (Mangin 2001). Other affiliated organizations include subgroups of the U.S. Coast Guard and Coast Guard Auxiliary, the U.S. Corps of Engineers, the National Park Service, and the University of Texas – Arlington, as well as representatives of Canadian provincial governments (100th Meridian Initiative 2008).

The main pathway of invasion that the Initiative focuses on is boats that are hauled overland on trailers. There are seven components to accomplishing this goal: 1) Informing the public as to the biological and economical impacts of zebra mussels and what can be done to prevent the spread, 2) Asking boaters to participate in voluntary inspections and surveys to determine where they've been and how aware they are of the problem, 3) Inspecting boats used for commercial purposes or fishing tournaments, 4) Monitoring for the presence of zebra mussels, 5) Taking immediate action to contain or eradicate zebra mussels when found, 6) Evaluating other pathways and develop an action plan to address them, and finally 7) Evaluating the effectiveness of the 100th-Meridian Initiative (Mangin 2001).

Regional Panels

In 1955, the Great Lakes Fishery Commission was formed by the Convention on Great Lakes Fisheries Between the United States and Canada to explore ways to eradicate the sea lamprey from the Great Lakes and its tributaries. The commission was given the authority to develop research programs, recommend procedures, implement a program to eradicate the sea lamprey, and to publish research. The U.S. states that make up the commission include Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin (Smith *et al.* 1955)

The commission, under the National Aquatic Nuisance Prevention and Control Act, created the Great Lakes Panel on Aquatic Nuisance Species in 1991. In 1996, the Panel created a guide for states to use when developing their own (Showalter 2003). Some of the suggested components include background on the invasive species of concern, background of policy, management actions, implementation schedule, and a plan for evaluating their program (Glassner-Schwayder 1996)

The Western Regional Panel held its first meeting in July 1996 after its formation was mandated by the National Invasive Species Act of 1996. There are 42 members, representing states that are west of the 100th Meridian, including Guam, Hawaii, and

Alaska. Also part of this panel are industries, academia and conservation organizations. This panel is different from the Great Lakes Panel in that there was no existing structure. Instead, their funding and administrative support must come from members of the Executive Committee. This type of organization has greatly hindered the progress of the panel, which has only produced one document, which was a model for a management plan. The main focus of this panel is ballast water, despite the large number of states that are land-locked. A second focus is public education and outreach (Showalter 2003).

Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont make up the Northeast Aquatic Nuisance Species Panel, along with three Canadian provinces. The panel has three committees working in education and outreach, policy and legislation, and science and technology. Since its inception, the panel has helped Maine and Massachusetts get their plans approved by the national panel (Showalter 2003).

The Gulf of Mexico Regional Panel started out under the administration of the Gulf of Mexico Program operated by the U.S. Environmental Protection Agency. In 2002, it was officially transferred to the Gulf States Marine Commission, although it reports directly to the National Aquatic Nuisance Species Task Force. (Gulf of Mexico Regional Panel 2002) At their first meeting, the Gulf of Mexico Regional Panel established seven workgroups: 1) Pathways and Prevention, 2) Eradication, Control and Restoration, 3) Vessel-mediated Transport, 4) Research and Development, 5) Education and Outreach, 6) Early Detection and Rapid Response, and 7) Information Management (Gulf of Mexico Regional Panel 2003).

The Gulf of Mexico Regional Panel is made up of Florida, Alabama, Mississippi, Louisiana and Texas, which contains seven of the 10 busiest ports in the U.S. Its activities include creating a document entitled "Initial Survey of Aquatic Invasive Species Issues in the Gulf of Mexico region," hosting workshops focusing on ballast water, and developing state plans, one state at a time (Showalter 2003).

Through this review of literature, it is evident that there are many ideas that are being brought into the problem. First, it is necessary to recognize that water is a common pool resource – it is a resource in which it is difficult and financially infeasible to prevent access. As such, there are many considerations that must resource managers need to consider. First, the role of the resource users needs to be recognized. They should have a say in the rules that are outline, whether it relates to the angler, recreational boater or water utility user. Next, these rules need to be communicated and enforced. If no one knows that they are required to inspect their boats prior to launch, then the policy will not accomplish its objectives and if they it is not enforced, there is no incentive for users to comply. Some of these considerations are evident in current policy, for example the educational campaign in Ireland. This study aims to examine how effective states in the Mississippi River Basin have been at preventing the spread of zebra mussels and how they relate to commonly accepted commons practices.

CHAPTER III

METHODOLOGY

First, in order to determine the relative effectiveness of states' policies, a series of ranks utilizing location quotients, distance and time from the original sighting and from the nearest previous sighting, and previous upstream occurrences was used. Once the ranks were determined, the best, average, and worst three states were selected for further review. The policies of these states were evaluated to try to ascertain what policies are employed by the most effective states that differ from the least affective. Finally, it needed to be determined how knowledge of zebra mussels and attitudes surrounding the problem is related to how affective states have been at preventing zebra mussels. This was accomplished by surveying of boat owners either in person or via mail.

To accomplish these objectives, a number of steps were taken in GIS and Excel to process the data needed for my analysis. Those steps are summarized in the following sections; for more detailed information, please see Appendix 2.

DATA

One of my integral datasets is a shapefile provided to me by Amy Benson of the U.S. Geological Survey in January of 2008. This dataset contains information on all sightings of zebra mussels, whether one or many, that have been confirmed and reported by local officials, and includes information as to locality, latitude-longitude, how the location was derived (estimated, map, or GPS) and the year the sighting occurred.

Because this dataset illustrates the location of each sighting that has been confirmed, it was useful in determining which waterbodies are infested and distances between sightings (Benson 2008). This dataset is not readily available and was obtained through special request, and as a result will not be updated; therefore, my analysis will be limited to sightings that occurred prior to January of 2008. Pre-processing of this dataset included reprojecting it from Geographic Coordinate System North American Datum 1983 to Projected Coordinate System North American Albers Equal Area Conic in order to have distances in meters as opposed to decimal degrees. The main problem with this dataset is that the data that is provided is not uniform. Not all sightings have the full date of discovery, and the method of determining the latitude and longitude of the points varied, which would result in different levels of accuracy. A second problem is that the data does not indicate whether a specific sighting is a new sighting, a persistent sighting, or the result of natural diffusion.

The second dataset that will be utilized is the streams and waterbodies dataset developed by NationalAtlas.gov. The National Atlas is a project authorized by Congress to provide geospatial information and data to the American public. The streams and waterbodies dataset reflects waterbodies and streams present from the time period of 1995 through 2002 and was digitized using a variety of existing digital and paper sources, mostly in the form of topographic maps (National Atlas 2007). This is a static dataset, and is not currently scheduled for an update. Pre- processing of this dataset included extracting the lakes, reservoirs and streams for my study area from the original dataset. Dry and intermittent waterbodies, as well as salt-waterbodies were not being included as it is unlikely that zebra mussels would be able to inhabit these areas. It was also reprojected into the Projected Coordinate System North America Albers Equal Area Conic to match the zebra mussel dataset.

OBJECTIVE 1

In order to rank the effectiveness of zebra mussel prevention policies in each state, three factors were used: 1) Location quotient of infested waterbodies, as this gives an indication as to whether the state has a below or above average level of infestation. States that are below average would be considered more effective, and states that are above average less effective. 2) A speed of dispersal ratio, referred to as distance-time. A slow rate of dispersal from the nearest source compared to the Great Lakes indicates that it is likely that the infestation resulted from a primary dispersal event. A fast rate of dispersal would indicate that the infestations occur through a secondary dispersal event. In many cases, the nearest source would occur within the same state, giving them more control over possible degrees of knowledge, and therefore those states with a slow speed of dispersal relative to the Great Lakes would be ranked higher. Finally, 3) a waterbody connectivity factor. This will allow for state ranks to be adjusted in order to account for spread that occurs through the natural flow of water as opposed to saltatory dispersal. Because of this, the more upstream occurrences a state has, the higher the ranking they will receive.

These factors are limited to events since 1998, which was the year the Lacey Act was amended to make it illegal to transport injurious species across state lines. Prior to the passage of this act, the emphasis on research and the creation of policies would not have been less than after the passage when federal money and assistance became available.

To determine the location quotient, each waterbody that corresponded with zebra mussel sightings was assigned a value of one such that when exported into Excel, a subtotal for each state could be calculated. Using the count function, other totals that were calculated include the total number of waterbodies for each state, the number of infested waterbodies in my study area, and the total number of waterbodies in my study area. These values were inserted into Equation 1, which gives the location quotient.

$$LQ = \frac{S_I/S_T}{M_I/M_T} \qquad (1)$$

where S_I is the number of infested waterbodies in a state, S_T is the total waterbodies in the state, M_I is the total number of infested waterbodies in my study area, and $M_T$is the total number of waterbodies in my study area. Location quotient calculations yield a numerical result that has zero as a lower limit, and infinity as an upper limit. A value of zero would indicate no infested waterbodies, and therefore the ranking would start with the state having the lowest value receiving a rank of one. The states continued to be ranked sequentially as the value of the location quotient increased. After the results from this were mapped, there seemed to be a strong relationship between the location quotients for this factor and the distance from the Great Lakes. In order to verify this, a Pearson's Correlation test was completed for the location quotient against distance to the great lakes as the higher this value is the more influence distance has on how effective state policies have been.

The speed of dispersal factor is a ratio that compares the speed of dispersal between a sighting and its nearest neighbor that is within the Mississippi River Basin, and the speed of dispersal between a sighting and the Great Lakes, using 1988 as the beginning year. By doing this, the figure compares the speed of diffusion for each sighting to a theoretical ideal based off the notion that near places should be infested before far places. From the data that were available, it is impossible to know what the actual source was for any given new occurrence as it did not contain any genetic population data. As a proxy, the nearest source was used as literature indicated that it is more likely that the majority of lakes are infested as a result of a secondary dispersal event as opposed to directly from the point of origin. Because the data were divided by year, the nearest source observation had to be from a previous year. While it is possible that the actual source could have been from the same year-group, it is unlikely as it would take time for the new population to reach a point where it has been noticed, making this restriction acceptable.

The first step was to find the distance of each new zebra mussel sighting to that of the nearest possible source. To do this, two sets of shapefiles were created. The first set will be a cumulative year-by-year collection of sightings, starting with 1998. For example, a point shapefile labeled 1998 will have the sightings from 1988 through 1998; the 2000 file contains the sightings from 1988 to 2000. These files are referred to as the "source points." The second set contains just the sightings for an individual year, from 1998-2007 and are referred to as the "new sightings". Then, a model was created in ArcGIS that created a Euclidean distance raster layer starting from the specified source points and converted this information into a format that allows for further analysis (see Figure 6).

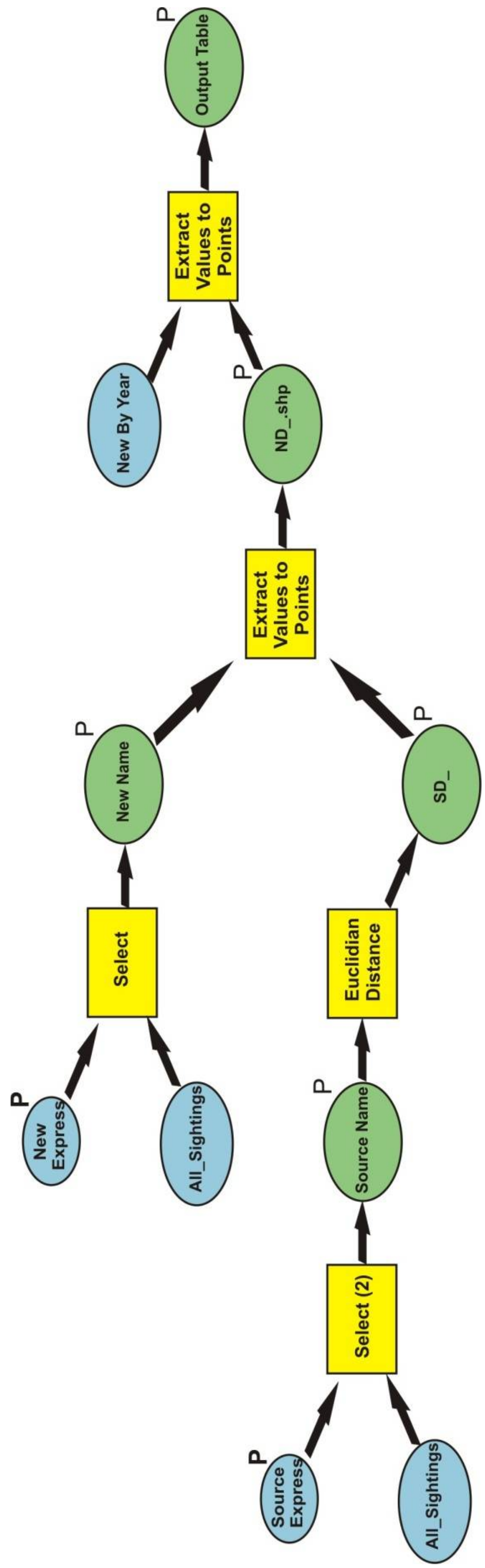

Figure 6: Model for Determining Distance to Nearest Source

Secondly, the number of years that it has taken that waterbody to be invaded from the initial introduction into the U.S. was determined. The temporal resolution of this variable was down to the month level, and the numerical value for the month was converted into its decimal equivalent (for example, if the confirmation was June, with a value of six, of 2006, $2006 + \frac{6}{12} = 2006.5$). 1988.5 (the earliest known confirmation is June of 1988) was then subtracted from the year the waterbody was first found to be infested to give the time for dispersion. In order to determine the time it took for zebra mussels to spread from the nearest source, it had to first be determined which existing observation was the closest. To do that, Thiessen polygons were created around the existing observations, and then the date value extrapolated to the table of the corresponding new sighting (Figure 7). To find the time, the date of the nearest sighting was subtracted from the date of the new sighting. For both the time from the Great Lakes and the time to the nearest sighting, the mathematical operation can be summarized with equation 2.

$$Time = Date_2 - Date_1 \qquad (2)$$

Where $Date_2$ is the new occurrence and $Date_1$ is either the nearest sighting or 1988.55 to represent the middle of the year when the month is not known.

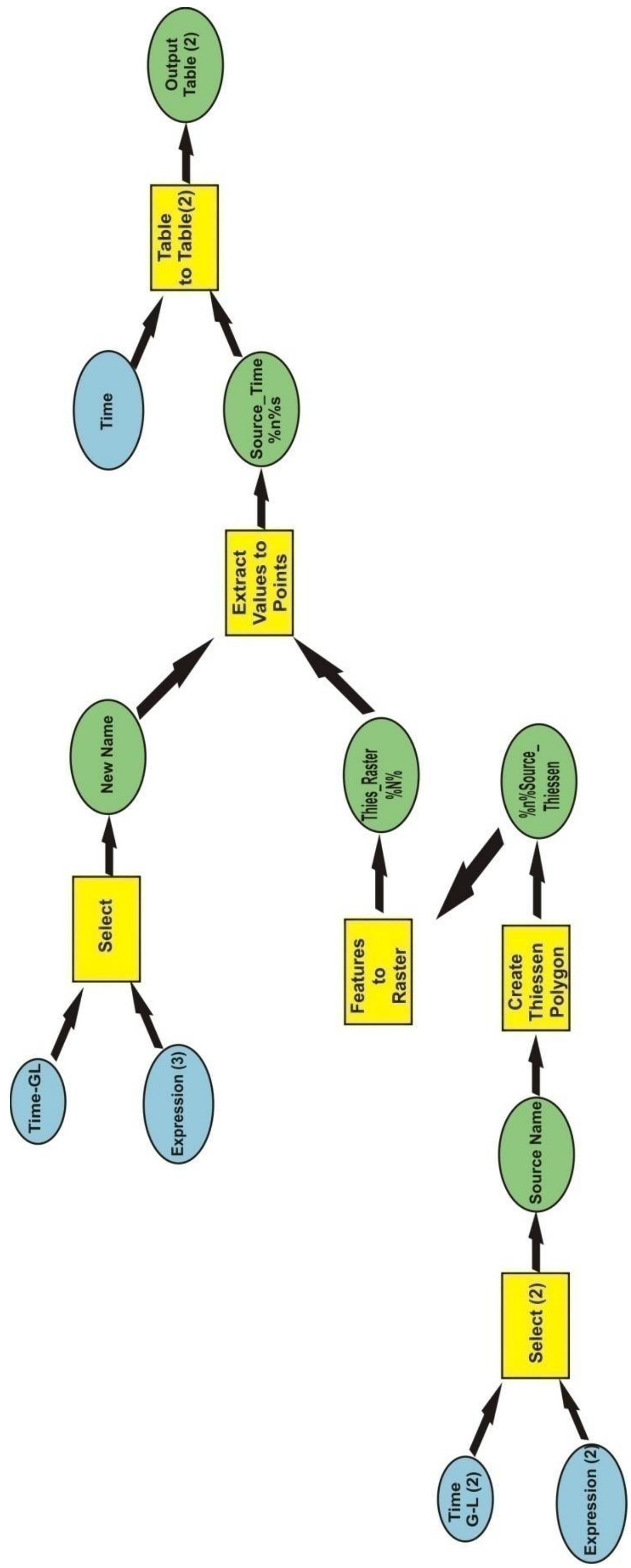

Figure 7: Model for Determining Time to Nearest Source

Next, the distance and time factors for each observation were combined as ratio in order to compare the speed of local spread to the speed of overall spread (equation 3).

$$\frac{D}{T_i} = \frac{Distance_{NS}/Time_{NS}}{Distance_{GL}/Time_{GL}} \qquad (3)$$

Where NS refers to the nearest source, and GL refers to the Great Lakes.

The mean Distance/Time ratio was then calculated for each state following equation 4.

$$\frac{D}{T} = \frac{\sum_1^n D/T}{n} \qquad (4)$$

Where *n* is the total number of zebra mussel sightings for the state. The ideal value from the equation is zero, which would indicate that the rate of the spread of zebra mussels within the state is much slower than that of what the rate would be if the source were the Great Lakes and therefore indicates a greater level of efficiency than if the rate of spread from the nearest source were greater than that from the Great Lakes. Accordingly, the ranking would start with a rank of one being awarded to the lowest values, and the rest of the states ranked sequentially as the value increases.

The last factor is that of natural diffusion. As many sources pointed out, zebra mussels spread faster through connected waterbodies due to outflow, so this was taken into consideration as a form of correction factor in recognition of forces that are beyond states' control. To account for this, a stream network geodatabase was obtained from the Center for Research in Water Resources at the University of Texas, Austin. Utilizing the Network Analyst feature in ArcGIS, it was determined for how many years prior to the sighting of the observation of interest there had been observations of zebra mussels upstream. For example, for an observation that occurred in 2000, if there were observations in 1996, 1994, 1992, and 1988, it would be given a value of four. Details of these steps are provided in Appendix 4. The average of these upstream sightings for each state was then used to rank the states, with the highest value receiving the rank of one, and the lowest value the worse ranking.

To obtain the final rankings, equation 5 was used using the state ranks for each variable.

$$Rank\ Score = 0.5 \cdot Upstream + 0.3 \cdot \frac{D}{T} + 0.2 \cdot LQ \tag{5}$$

The upstream factor was counted the highest because of the heavy influence that had on zebra mussel dispersion. The D/T was weighted next highest, recognizing that there may be some inevitability to the overland transport as it relies heavily on public cooperation and there is never going to be the 100% compliance. Therefore, it seems as if the delay of the spread is a better indicator of effectiveness than the outright prevention of the introduction.

After the overall rank was determined, the best three states, average three states, and worst three states were chosen for a closer examination of the policies they have put into place. The best three states would be the states ranked one (Alabama), two (Georgia), and three (New Mexico), and the worst three states ranked 26 (Indiana), 27 (Pennsylvania), and 29 (Ohio). For the average grouping of states, the median state was determined and the states on either side included. The results in the average grouping having the ranks of 14 (Tennessee), 15 (Arkansas) and 16 (Missouri).

OBJECTIVE 2

The second objective is to determine what policies have been effective and which have not. To do this, the states' aquatic invasive species plans were obtained and the policies compared to look for similarities and differences. Additionally, the states' invasive species coordinators were also contacted and asked questions about the prevention activities their states are participating in, with an emphasis on sign postings and vessel examinations. When a coordinator was not available, one or two other experts were contacted as a proxy. Most of these interviews were conducted via email, at the request of my contacts. The exception to this was Pennsylvania, in which phone calls were made to ask the questions. A sample list of questions can be found in Appendix 4.

One component of each state's management plan was to summarize current activities, often divided by agency. To aid in comparing the policies and activities, a chart was created and the number of times an activity was mentioned in either the management plan or by the experts was inserted. These data do not include Arkansas as the contacted experts did not return the interview questions.

OBJECTIVE 3

The third objective was to determine how boaters' knowledge and attitudes about zebra mussels affect the effectiveness of states' policies. This was determined by asking boaters in each state to answer a short questionnaire. For Pennsylvania, Ohio, Indiana, Missouri and New Mexico, the surveys were completed in person. Figure 8 shows the general locations of where these surveys were conducted.

Tennessee, Georgia and Alabama were completed by members of the U.S. Power Squadron and U.S. Coast Guard Auxiliary, administered by a contact person who was given an instruction and FAQ sheet (the survey packet can be found in Appendix 3). Unfortunately, Arkansas was once again excluded due to an ice storm the week before surveys were to be completed. For the best group, a total of 24 surveys were collected, the average group completed 18 surveys, and finally the worst group completed 26 surveys.

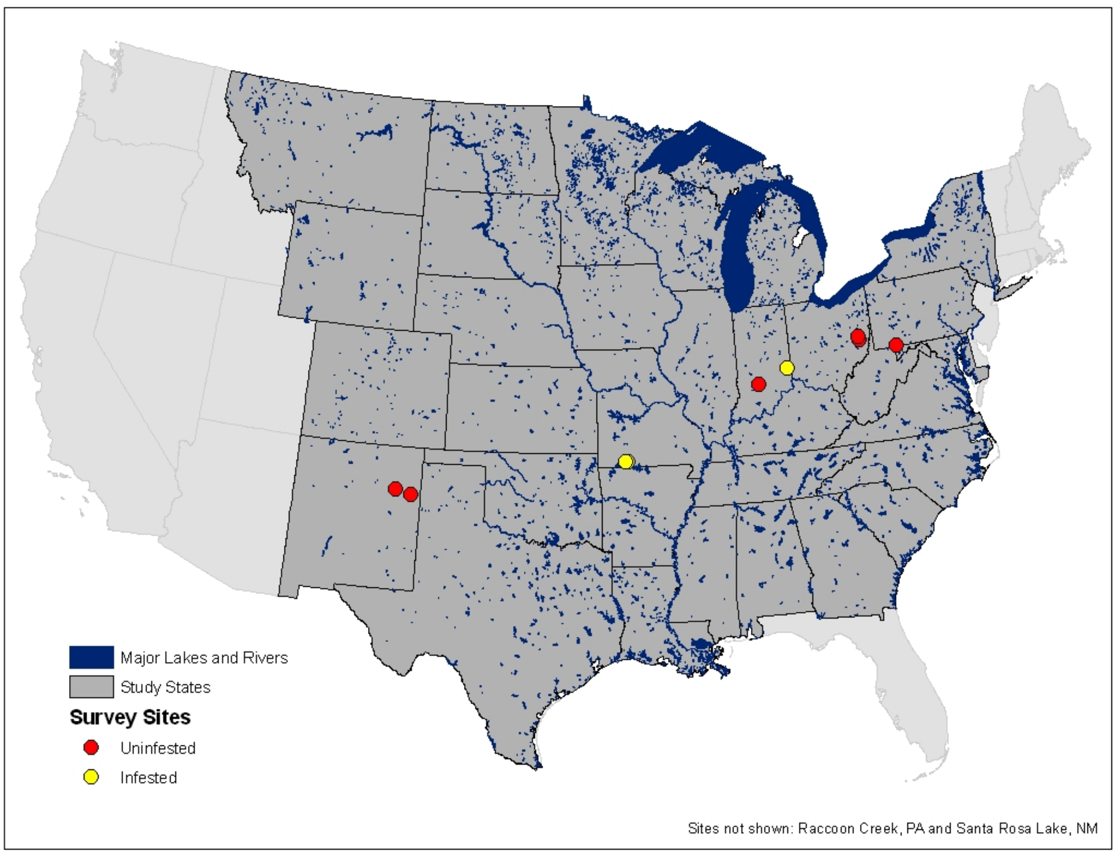

Figure 8: Locations of in-person surveys

Chi-Square tests were completed to determine if there was any significant difference in the response of boaters from the three groups of states for each question, as well as for the overall accuracy in the general preventative knowledge portion of the survey. The Chi-Square Test is a statistical test for nominal data that returns a value that indicates if the difference between groups is significant. For example, for many of the questions on the survey respondents answered on a scale of 1 to 5. The Chi-Square test looks at how many people responded each of the possible values for each of group A, B, and C, and then if the difference in the total occurrence of each value is significantly different across the three groups by comparing the observed occurrences with the expected occurrences (see Table 2, Observed). The null hypothesis is that there is no difference between the three groups, that each group would have an equal proportion of respondents answering the same way, which is determined by dividing the row sum by the total number of respondents and multiplying by the column sum (Table 2, Expected). The further away the observed values are from these expected values the more significant the difference becomes, which is indicated by the p-value. If the p-value is less than 0.10 the null hypothesis of no difference is rejected.

Table 3: Example of Chi-Square Analysis

Observed

	A	B	C	Sum of Row
1	0	1	5	6
2	1	4	7	12
3	8	4	3	15
4	7	6	4	17
5	8	3	7	18
Sum of Columns	24	18	26	68

Expected

	A	B	C
1	2.12	1.59	2.29
2	4.24	3.18	4.59
3	5.29	3.97	5.74
4	6	4.5	6.5
5	6.35	4.76	6.89

(O-E)^2/E

	A	B	C
1	2.12	0.22	3.19
2	2.47	0.21	1.27
3	1.38	0.0002	1.30
4	0.17	0.5	0.96
5	0.43	0.65	0.002

Chi-Square	14.88
DoF	8
P-Value	0.062

.

STUDY AREA

The Mississippi River Basin covers all or part of 29 states (Figure 9). Because of its proximity to the Great Lakes, the states in the basin are considered the front lines to preventing the westward spread of zebra mussels. Of the 31 states, nine are either partially or completely west of the 100th-Meridian (Rasmussen 2009). Only one of the states located entirely west of the meridian has discovered mussels in its waters, although they have been found on trailered vessels preparing to launch elsewhere. (U.S. Geological Survey 2008).

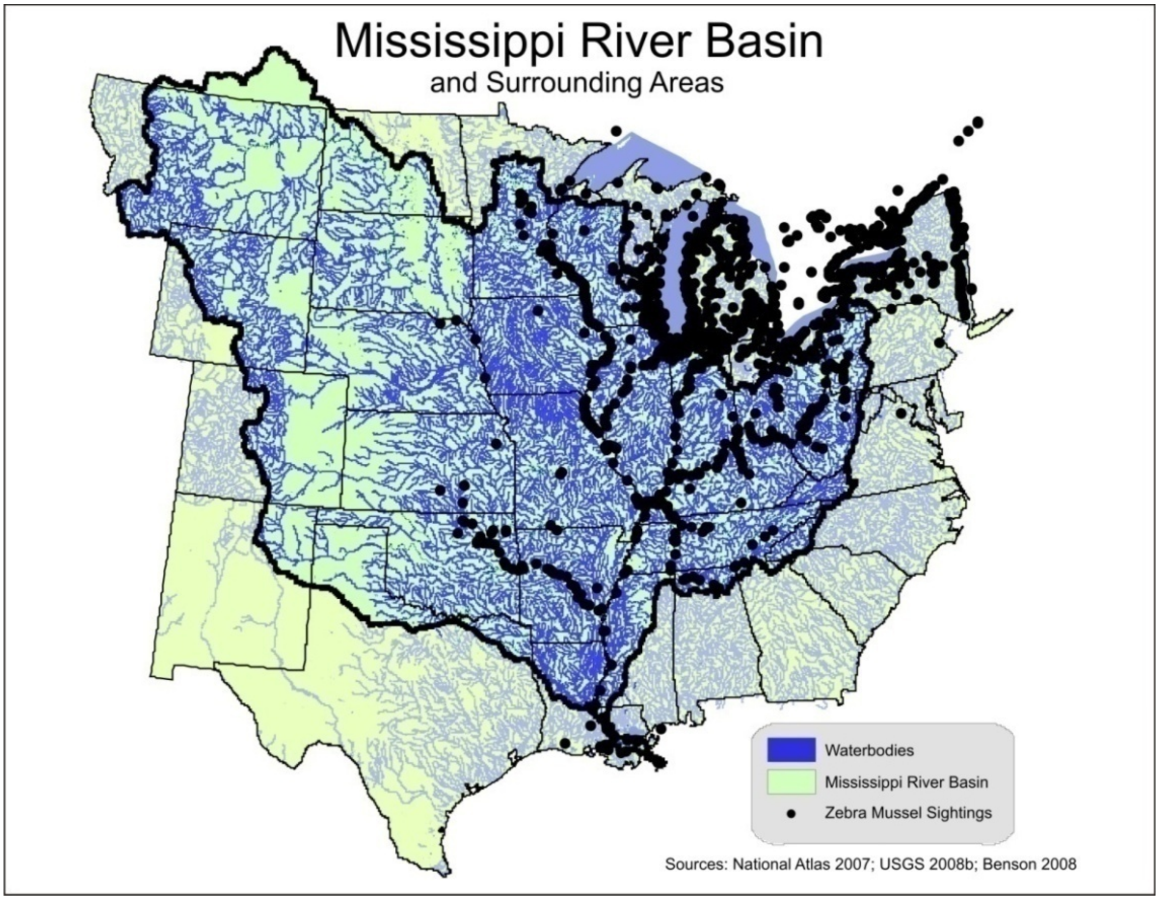

Figure 9: Map of the Mississippi River Basin

CHAPTER IV

FINDINGS

Zebra mussels are a species of freshwater mussel that, once introduced, cause a large amount of economic damage to the users of the waterbody and ecological damage to the waterbody itself. Because of this, it is important to determine what policies have been effective at preventing the introduction of zebra mussels. To accomplish this goal, the states of the Mississippi River Basin have been ranked according to three factors: location quotient, distance-time ratio, and upstream occurrences. From there, the best, average, and worse ranking states were chosen for a closer examination of their policies as well as the attitudes and knowledge of the states' boat owners.

OBJECTIVE 1

The first objective was to determine state effectiveness according to a location quotient factor, a distance time factor, and an upstream occurrence factor.

The location quotient compares the level of infestation for a state to the level of infestation for the entire study area, the calculations for which is summarized in Table 2. A location quotient near zero indicates that the state's level of infestation is less than that for the study area as a whole. A value of one would indicate the level of infestation is the same as the study area as a whole. A high location quotient, with no upper limit, means that the level of infestation is higher than that for the study area.

Table 4: Location Quotient Values
Rank assigned where 1 is best

State	No. Waterbody Records	Number Infested	LQ	Rank
Alabama	62	0	0	4.5
Colorado	205	0	0	4.5
Georgia	12	0	0	4.5
Montana	422	0	0	4.5
New Mexico	32	0	0	4.5
North Carolina	64	0	0	4.5
North Dakota	144	0	0	4.5
Wyoming	295	0	0	4.5
Texas	152	2	0.06	9
Virginia	67	1	0.07	10
South Dakota	269	7	0.12	11
Tennessee	256	21	0.367	12
Louisiana	348	29	0.37	13
Nebraska	280	33	0.527	14
Arkansas	294	35	0.53	15
Mississippi	173	23	0.60	16
Missouri	393	63	0.72	17
Kansas	240	42	0.78	18
Oklahoma	264	52	0.88	19
Iowa	322	64	0.89	20
Kentucky	208	48	1.03	21
Wisconsin	415	103	1.11	22
Minnesota	607	155	1.14	23
West Virginia	132	34	1.15	24
Illinois	350	108	1.38	25
Pennsylvania	106	34	1.43	26
New York	15	5	1.49	27
Ohio	186	95	2.29	28
Indiana	175	120	3.07	29

For the location quotient factor, there were several states which did not contain any infested waters and were therefore tied for first place. These states are the states that are located the furthest away from the Great Lakes, while the states that ranked the worse are those that are closest to the Great Lakes (Figures 10 and 11). When looking at Pearson Correlation values, a perfect correlation would have a value of ±1.00. The Pearson Correlation value for this relationship is -0.703, which is statistically significant, indicating that there are influences on the level of infestation other than distance. One possible explanation for this strong relationship is that the states further to the west of the Great Lakes have fewer connected and navigable[4] waterbodies and the introduction of zebra mussels would be more likely to require overland transport. The waterbodies are also more dispersed which would limit the interaction between waterbodies and therefore the risk of infestation.

My study area contained eight states that did not have an infested waterbody, resulting in eight states being ranked first for the location quotient factor. While this is technically correct, it may have been better to add one instance to each state, to achieve a location quotient other than zero, and help account for the varying number of waterbodies in each state. In theory, a state with fewer waterbodies would be able to concentrate their resources more than states with many waterbodies. For example, using that method, Colorado, having more waterbodies, would actually be ranked better than Alabama.

[4] Navigable waterways are those waterbodies that can be used for interstate commerce.

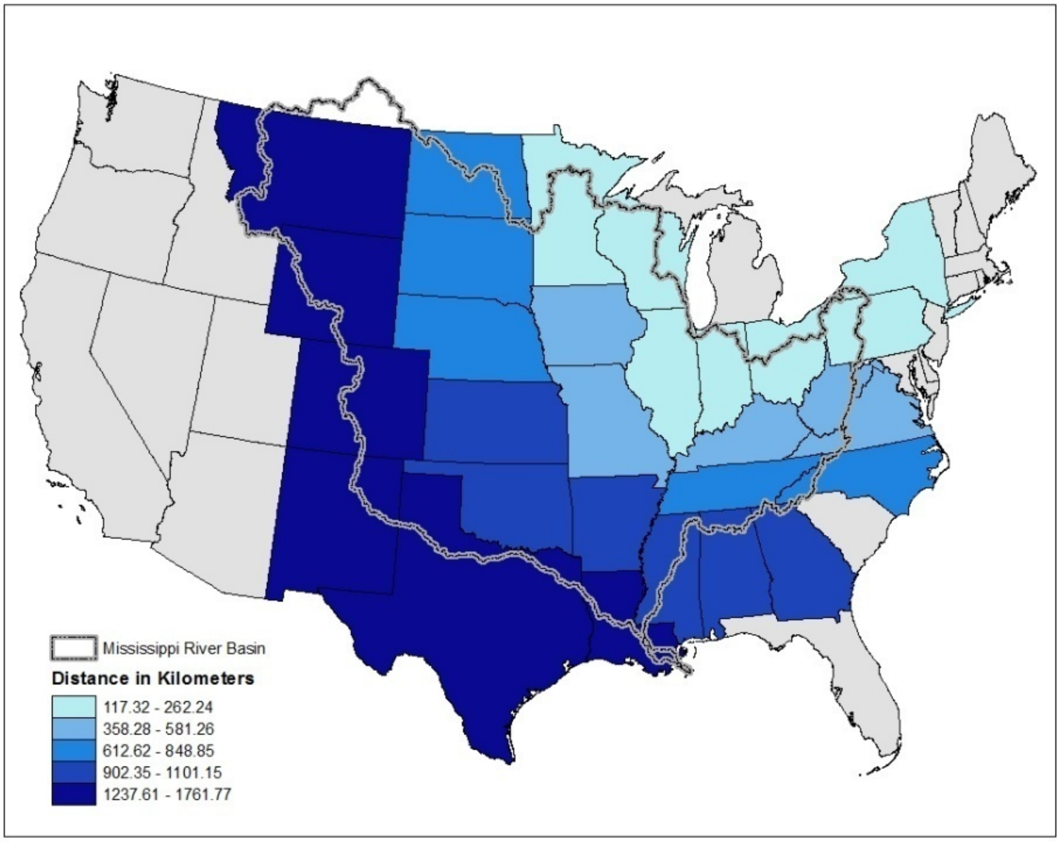

Figure 10: Map of Average Distance to the Great Lakes; determined from edge of the Great Lakes to the area centroid (as determined by calculating zonal mean).

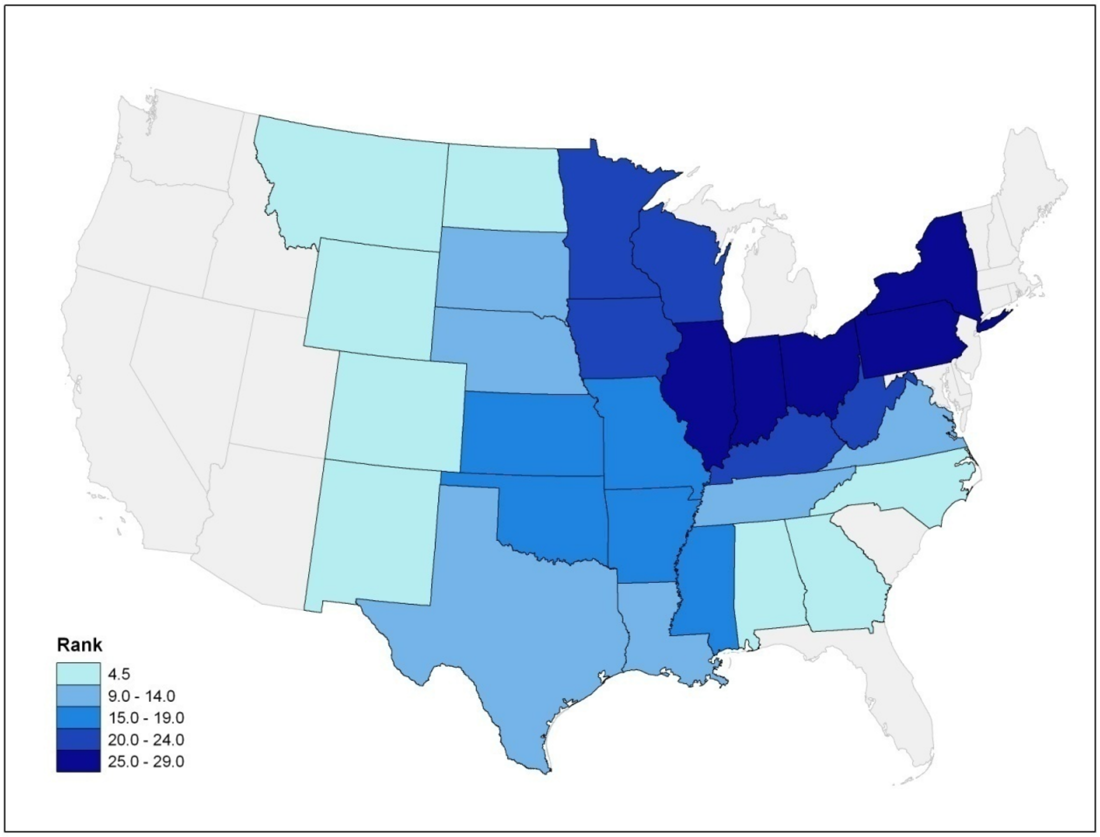

Figure 11: State Rankings for Location Quotient

The second factor, distance-time, was the ratio of the speed of dispersal from the nearest source to the speed of dispersal from the Great Lakes, is not as stratified in regards to distance from the Great Lakes, with one state near the Great Lakes (New York) even being ranked in the top half with a rank of 12 (Figure 12, Table 5 (page 53)). Interestingly, a state that is much further away, Montana, was ranked only two positions down for a rank of 14, while closer states such as North and South Dakota occupied better ranks. However, the general trend is that the states further away from the Great Lakes occupied many of the better ranks.

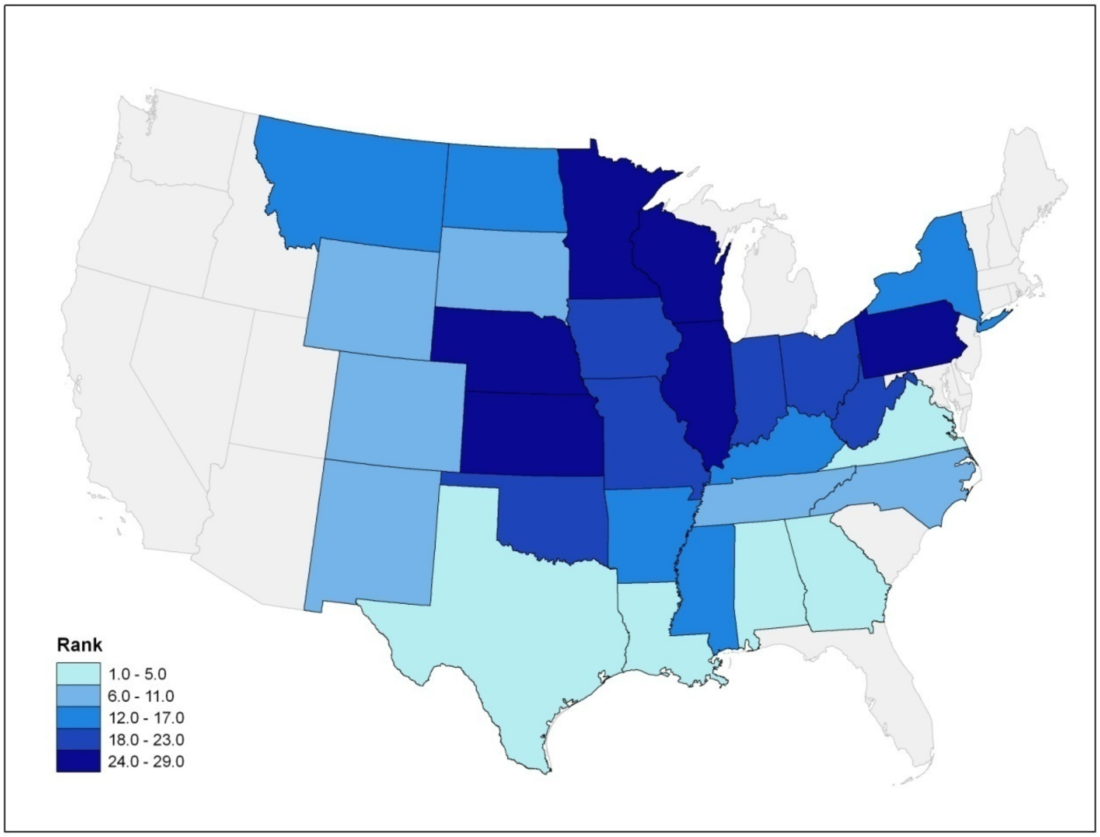

Figure 12: State Rankings for Distance/Time

Overall, the majority of the states saw ratio values of less than one, indicating that secondary dispersal events (those infestations that are likely to have resulted through transport from a previously infested waterbody other than the Great Lakes) are occurring at slower speeds than primary dispersal events. This seems to counter the notion that secondary events are more likely to occur than primary dispersal events. One possible cause of this relationship would be how proactive a state is in identifying waterbodies that have become infested. If a state relies entirely on reporting by the users of a waterbody, then many years could pass between introduction and reporting. However, if a state actively tests waterbodies for the presence of zebra mussels, especially once a discovery has been made in the state, then the result would be the appearance that mussels spread rapidly. However, assuming that this is not the case, then the results of this factor could be indicating that more attention should be paid to boats that are being transported into the state by visitors.

Table 5: Distance/Time Ranks
Rank assigned where 1 is best

STATE	D/T	RANK
Alabama	0.0003	1
Louisiana	0.0008	2
Georgia	0.0009	3
Texas	0.00269	4
Virginia	0.00273	5
New Mexico	0.003	6
Colorado	0.0041	7
South Dakota	0.0043	8
North Carolina	0.0046	9
Tennessee	0.005	10
Wyoming	0.006	11
New York	0.0069	12
North Dakota	0.0076	13
Montana	0.008	14
Mississippi	0.07	15
Arkansas	0.11	16
Kentucky	0.15	17
Missouri	0.16	18
West Virginia	0.17	19
Iowa	0.3	20
Ohio	0.39	21
Oklahoma	0.40	22
Indiana	0.514	23
Minnesota	0.52	24
Wisconsin	0.60	25
Nebraska	0.63	26
Kansas	0.90	27
Illinois	1.7	28
Pennsylvania	5.1	29

The last factor is an upstream factor that accounts for the diffusion of zebra mussels via natural water flow. As with the other factors, the states are farther from the

Great Lakes that ranked the best, in part because they had no mussels from which to determine an upstream occurrence (Figure 13, Table 5). As this factor served as a corrective factor meant to improve a score, it is unlikely that a big difference in rankings would have resulted from including a theoretical sighting. One feature to note is that, when compared against a map of navigable inland waters (as defined in a U.S. Corps of Engineers dataset (Vanderbilt Engineering Center for Transportation Operations and Research Vanderbilt University 2008)), states that lack navigable waterways have fewer upstream sightings and are therefore ranked worse than those with navigable waterways (Figure 14). This relationship speaks to the impact that commercial shipping potentially has on the distribution of zebra mussels, and how the constant movement of vessels through these states add to the difficulty of preventing introductions of zebra mussels. These navigable waters also constantly contain water through which zebra mussels can migrate, as opposed to smaller streams and rivers which can intermittently run dry. Additionally, on navigable rivers, the movement between waterbodies is facilitated through a series of locks[5] and dams, whereas when waterbodies are not connected, movement requires the loading of a vessel onto a trailer which is economically more expensive due to added trailer fees and gas costs and more time consuming.

[5] In a lock system, boats enter an area that is blocked off on both ends by solid gates. Water is then either allowed to flow in or out of the gated area to raise or lower the boat to the level of the waterbody they wish to enter.

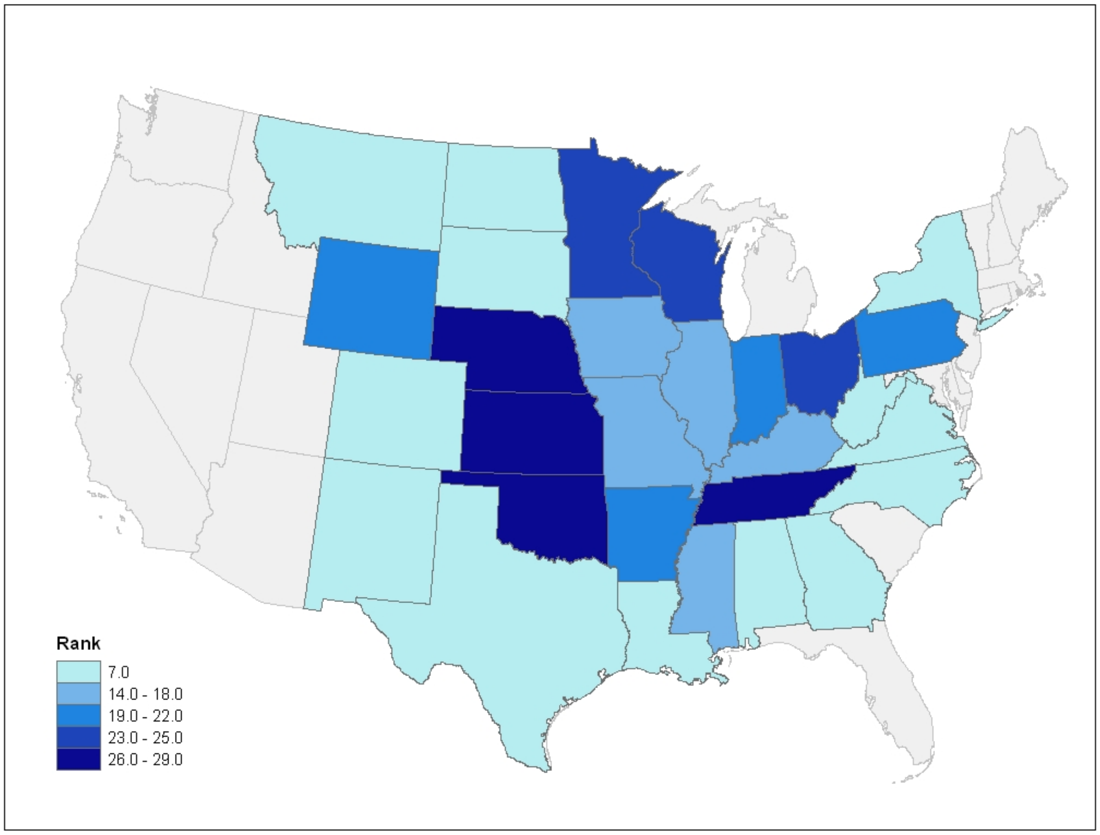

Figure 13: Map of Upstream Occurrence Rank

Table 6: Upstream Occurrence Ranks
Rank assigned where 1 is best

State	Rank
Alabama	7
Colorado	7
Georgia	7
Louisiana	7
Montana	7
New Mexico	7
New York	7
North Carolina	7
North Dakota	7
South Dakota	7
Texas	7
Virginia	7
West	7
Mississippi	14
Iowa	15
Kentucky	16
Missouri	17
Illinois	18
Indiana	19
Wyoming	20
Arkansas	21
Pennsylvania	22
Wisconsin	23
Minnesota	24
Ohio	25
Oklahoma	26
Kansas	27
Nebraska	28
Tennessee	29

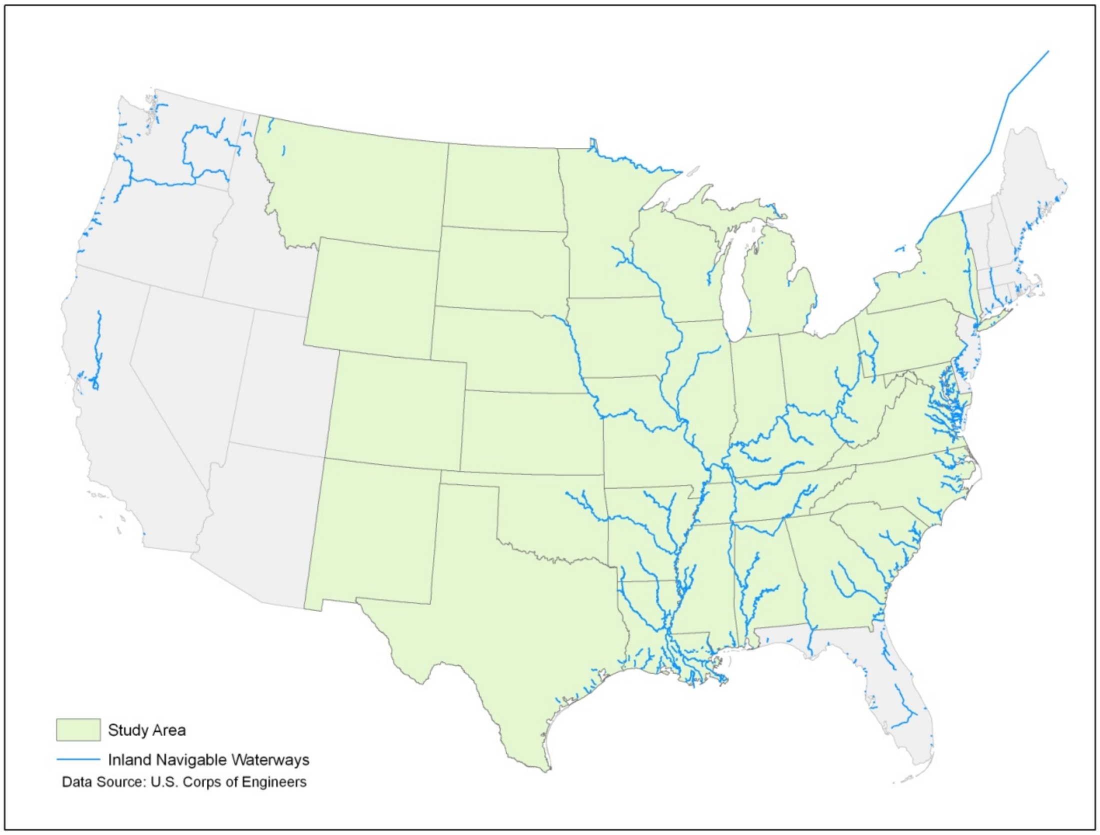

Figure 14: Navigable Waterways

In the states that lack navigable waters, reservoirs are prevalent as water storage facilities, especially in the rain shadow of the Rockies or the desert areas of the Southwest. These reservoirs alter the natural flow of water, and in some instances cause the outflow stream to become intermittent, especially in drier climates where it is not necessary to release water from the reservoir on a regular basis. This would affect the analysis of upstream sightings as those sightings would have been off my streams network and would have shown up as isolated sightings as opposed to a sighting that could potentially be related to an upstream sighting.

The 20 kilometer range expansion limit presented by Bobeldyke and colleagues (2005) was not included in the calculations for either the distance-time factor – which compares the speed of diffusion from the nearest source to that from the Great Lakes (Table 5 on page 52) -- nor the upstream factor that takes into account the number of occurrences that occurred upstream of a particular sighting (Table 6 on page 55). It is possible that had this feature of zebra mussel diffusion been included, some of the rankings would change. However, as this would be limited mainly to those states with a large amount of navigable waterways due to those states being most impacted by waterway connectivity, I do not feel that it would have made a large impact overall.

Figure 15 and Table 7 summarizes the overall state rankings for state effectiveness using equation 5 (pg 40), along with their rankings for each individual factor. It seems as if distance still played a relatively large role in the overall ranking as the states that are closer to the Great Lakes states are ranked worse and the states that are further from the Great Lakes states are better ranked. The central states were more random in their rankings.

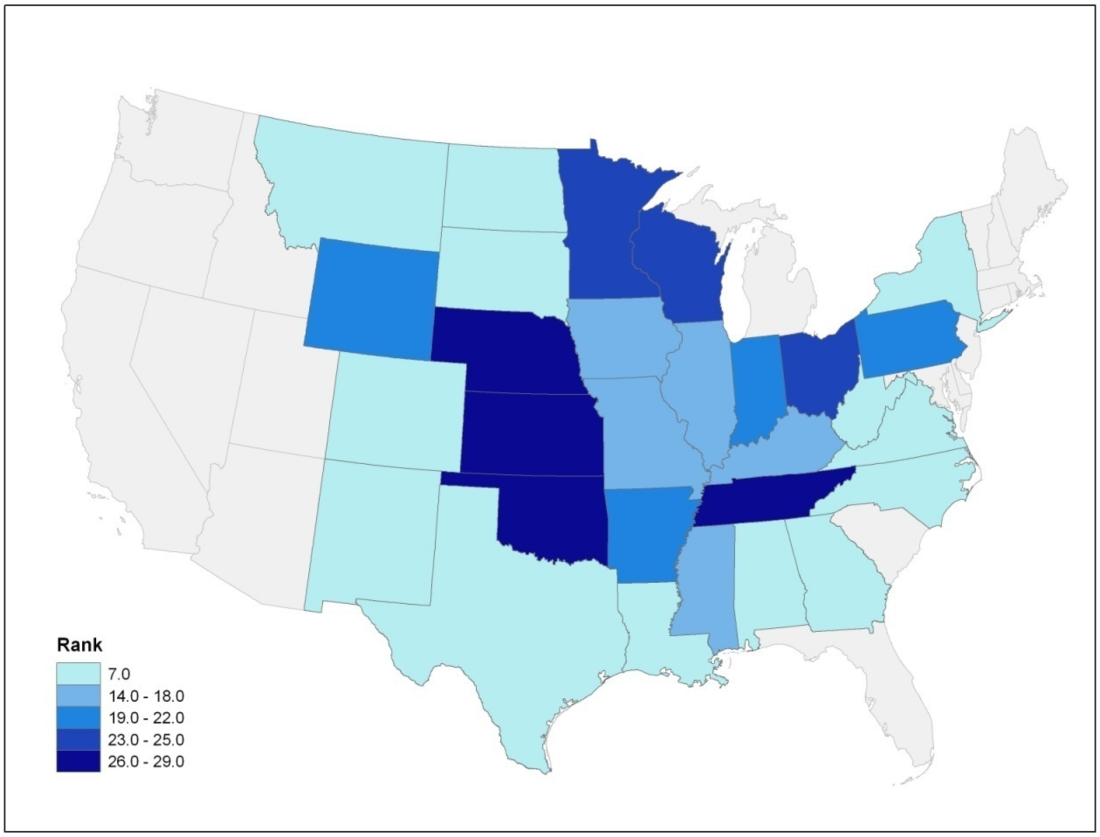

Figure 15: Map of Overall Ranks

Table 7: State Rankings
Rank assigned where 1 is best

State	D/T	LQ	Upstream	Rank-Score
Alabama	1	4.5	7	4.55
Georgia	3	4.5	7	4.95
New Mexico	6	4.5	7	5.55
Colorado	7	4.5	7	5.75
North Carolina	9	4.5	7	6.15
North Dakota	13	4.5	7	6.95
Montana	14	4.5	7	7.15
Texas	4	9	7	7.4
Virginia	5	10	7	8.1
Louisiana	2	13	7	9
South Dakota	8	11	7	9.2
Wyoming	11	4.5	20	10.45
Mississippi	15	16	14	15.2
Tennessee	10	12	29	16.7
Arkansas	16	15	21	17
Missouri	18	17	17	17.2
West Virginia	19	24	7	17.9
New York	12	27	7	18
Iowa	20	20	15	18.5
Kentucky	17	21	16	18.7
Nebraska	26	14	28	20.6
Oklahoma	22	19	26	21.7
Kansas	27	18	27	22.5
Wisconsin	25	22	23	22.9
Illinois	28	25	18	23.5
Minnesota	24	23	24	23.5
Indiana	23	29	19	24.8
Pennsylvania	29	26	22	25.4
Ohio	21	28	25	25.7

The best three states were Alabama, Georgia and New Mexico, the average three Arkansas, Missouri, and Tennessee (the 50th percentile state [Arkansas] and the one on either side), and finally, the worst three were Pennsylvania, Indiana and Ohio. New Mexico stands out as anomalous as it is geographically distant from the other best ranking states, unlike in the case of the average and worse ranking states which are all adjacent. It would be expected that Mississippi would be the third member of the best ranking group (with Georgia and Alabama being the first two), but what prevents this from being the case is that the adjacent Mississippi River contains zebra mussels which count against Mississippi's ranking, whereas New Mexico has no sightings. Mississippi has no sightings outside of those in the Mississippi River, so if those sightings had been treated differently, then Mississippi may have been grouped with the better ranking states (assuming not too many other states would be affected as well). Louisiana is another state that would have a possibility of having been ranked better were it not for its proximity to the Mississippi River. Its overall rank is actually better than that of Mississippi's, and yet it is still close enough that it would not seem as odd as New Mexico to be included with the best ranking states.

OBJECTIVE 2

The second objective was to determine if there were any differences in the aquatic nuisance species prevention policies that would contribute to one state being more effective than another at controlling the spread of zebra mussels. The state aquatic nuisance species management plans, as required by the national Aquatic Nuisance Species Task Force, includes a section that outlines agencies that are involved in invasive species and the activities in which they participate to accomplish their policy objectives. The more agencies that are recognized as participating in any particular type of activity represents more of an overall statewide effort. What is or is not included in the plans is also an indication as to the activities state task force members deemed important enough to include in the documentation. This is important because money and personnel hours would be limited on the activities not considered as important. Table 7 summarizes the number of times a policy or prevention activity is mentioned in a state's aquatic nuisance plan or in a questionnaire sent to the state's aquatic nuisance or invasive species expert.

Table 8: Number of Agencies Participating in Activities
Average Occurrence Per State
(Adapted from multiple sources[6].)

	Best	Average	Worse
Ballast Water	0.67	0.00	0.00
Authority	0.33	0.33	1.67
Law Enforcement and Penalties	0.33	0.67	0.00
Regional Organization Membership	2.00	1.00	1.33
Personal Contact	0.33	0.33	0.67
Coordinator	0.33	0.00	0.67
Website	0.33	0.00	0.33
Eradication	0.33	0.00	0.00
Public Service Announcements	0.33	0.00	0.00
Newsletters/Magazines	0.33	0.00	0.00
Research	0.67	0.00	1.00
Grants	0.67	0.00	0.67
Volunteer Monitoring	1.00	0.33	0.67
Workshops/Training	1.00	0.33	0.33
Education/Outreach	1.67	0.67	3.33
Site-specific plans	1.67	0.00	0.33
Signs	0.00	1.00	0.67
Rapid Response	0.00	0.00	0.33
Central Coordination	0.00	0.00	0.33

Light Blue: Activity level greatest in best group, least in average group.
Dark blue: Activity level greatest in best group, least in worse group.

[6] Table 7 adapted from Aquatic Invasive Species Management Plan Committee (2007), Tennessee Aquatic Nuisance Species Task Force (2007), Alabama Aquatic Nuisance Speices Task Force (2008), Seng and White (2003), Ryck (2007), New Mexico Aquatic Invasive Species Advisor Council (2008), "Ohio Comprehensive Management Plan.", Steve Rider (Aquatic Resources Coordinator, Alabama Division of Wildlife and Freshwater Fisheries, email, January 21, 2009), Keith Weaver (Aquatic Nuisance Coordinator, State of Georgia, email, January 22, 2009), Doug Keller (Aquatic Invasive Species Coordinator, Indiana Department of Natural Resources, Division of Fish and Wildlife, email, January 13, 2009), Tim Banek (Invasive Species Coordinator, Missouri Department of Conservation, email, January 27, 2009), Brian Lang (Invertebrate Zoologist, Interim AIS Coordinator. New Mexico Department of Game and Fish, email, January 13, 2009), John Navarro (Program Administrator. Ohio Department of Natural Resources - Division of Wildlife, email, January 13, 2009), Joseph Brancato (Water Pollution Biologist III, Pennsylvania Department of Environmental Protection, conversation, date), James Grazio (Great Lakes Biologist, Pennsylvania Department of Environmental Protection, conversation, date)

Looking at the table, it is clear that there is a large range of potential activities, with the result being that there was no activity in which all states of a group participated. However, when conglomerated together, some trends do emerge. The activities which would fall under a general education and communication heading in the commons literature are practiced the most by the states which ranked the best. This includes the use of public service announcements, newsletters and magazines, and training activities. This variety of activities ensures that the largest number of people are reached.

When evaluated on a state-by-state basis, some slightly difference trends start to emerge. The first of those is ballast. Alabama and Georgia both have guidance on how ballast water should be handled; however, this is in reference to the ports located along the Gulf Coast outside of what would have been included in my rankings. The next activity is law enforcement and penalties. All three of the states which ranked the most effective plus Missouri stated memberships in three regional groups which can assist in providing research and support in implementing their plans. Indiana also has membership in three regional groups; however, Pennsylvania is only a member of one and Ohio does not mention any. Georgia, especially, has some unique plans that help to differentiate it from some of the other states. Of the eight states that were examined, it is the only one to explicitly mention eradication (which would have little bearing on its ranking as my data was based off of sightings as opposed to persistence of populations) and the utilization of public service announcements and newsletters or magazines. Georgia also has provisions for developing site-specific plans as the need occurs which can help direct resources to those locations which are deemed susceptible to invasion. The state also has several organizations which utilize volunteer monitoring and hosts workshops and training activities which helps to increase overall awareness. Of the worse states, Pennsylvania is the most active; however, much of this could be simply trying to catch-up to a problem that was already getting out of control.

Because simply comparing activities lacked defined effective strategies, I looked at the date the latest version of each plan was released (Table 8). The states adjacent to the Great Lakes have older plans, which is not surprising given the overall invasive species situation. However, I would have expected that the states there were deemed more effective would have plans dating further back than 2008. The release dates for these states even occur after my distribution data was obtained. Ohio's Plan, however, has no specific date. According to an email from John Navarro (Program Administrator. Ohio Department of Natural Resources - Division of Wildlife, email, December 23, 2008), the plan has been in development since 1999 and is scheduled to be finished around 2011.

Table 9: Dates of State Invasive Species Management Plans

Date	State
October-03	Indiana
October-06	Pennsylvania
February-07	Missouri
September-07	Tennessee
July-08	Georgia
October-08	New Mexico
December-08	Alabama
1999-2005	Ohio

OBJECTIVE 3

The last objective was to determine how the knowledge and attitudes of boat owners may be affecting the effectiveness of states' policies. The states can really push their public education activities, but if they are not actually reaching the boaters, or if the boaters do not think that zebra mussels are a problem, then it won't make a difference.

Table 9 contains the average responses and P-values for the 10 questions and overall accuracy for the survey responses. The questions about respondents' perceptions of their knowledge of aquatic nuisance species and zebra mussels (Q1 and Q2) showed a difference significant to the 0.1 level as did their knowledge as to what size of mussels are a threat (Z4). Questions Q5 and Z5 (Do you take steps to avoid transporting zebra mussels? and "True or False: Scraping is sufficient for the removal of mussels?" respectively) were significant below the 0.01 level. Finally, the overall accuracy was significant to the 0.05 level. This indicates that the responses to these questions are different enough to gain some insight as to some differences between states. On the attitude questions, respondents from each group responded similarly as to the importance of preventing the introduction of zebra mussels and whether or not state resources should be used in accomplishing this goal. Additionally, the level of knowledge as to the ability of zebra mussels to live out of water in either dry or humid conditions as well as where they can be found was not different between the three groups.

Table 10: Average Scores and P-Values for Significant Questions for each group of states

	Best	Average	Worst	P-Values
Q1. Knowledge of aquatic nuisance species^	3.00	3.00	4.00	0.14
Q2. Knowledge of zebra mussels^	3.92	3.13	3.04	0.07
Q3. Importance of prevention#	1.83	1.67	1.65	0.63
Q4. Use of state resources#	2.17	1.80	2.15	0.50
Q5. Take steps to prevent the spread of aquatic nuisance spcies	16.67	60.00	42.31	0.02
Z1. Length of time zebra mussels can live out of water in humid conditions**	2.78	3.13	2.46	0.25
Z2. Length of time zebra mussels can live out of water in dry conditions.**	3.22	3.67	3.12	0.22
Z3. Where zebra mussels can be found+	0.87	0.27	0.92	0.32
Z4. Size of zebra mussels that are a concern+	77.27	84.62	70.83	0.12
Z5. Proper removal technique+	57.14	83.33	43.48	0.00
Percentage Correct	44.17	40.00	34.62	0.07

^Scale of 1 to 5, where 1 is Very Knowledgable
Scale of 1 to 5, where 1 is strong agreement
**Scale of 1 to 5, where 1 is the best answer
* Represents percentage of people who answered in the affirmative.
+ Represents percentage of correct answers.

Not Significant (shaded)

In terms of relative scores, it would be expected that the best group would score the best, followed by the average and finally the worst group. However, only one of the questions scored as such. As can be seen in Table 10, the respondents in the worse ranking states (Indiana, Ohio, and Pennsylvania) felt that they were more knowledgeable than their counterparts in the other states about zebra mussels specifically. This makes sense as those states share a coastline with the Great Lakes and the resident boaters would have been hearing about the need to prevent the introduction of zebra mussels for longer than the respondents in states further away. The overall accuracy was also as expected; the respondents in the best ranking states (Alabama, Georgia, New Mexico) scored better while the respondents in the worse states had an average score that was 10 percentage points lower. This indicates that, overall, the boaters from the best ranking states knew more about how to prevent the spread of zebra mussels than those from the lower ranking states. However, some bias was also introduced as many boaters in New Mexico declined to participate in the in-person survey, stating that they did not know anything about the subject. Because of this, the actual results for the best ranking groups for the overall accuracy could possibly be lower as it seems that the information is not reaching boaters, despite efforts such as the posting of signs near boat ramps.

The responses to the other questions were not what would be expected. For the most part, the respondents in the average grouping of states answered more favorably. For question Q5, "Do you take steps to prevent the spread of zebra mussels?", Missouri and Tennessee had the greatest number of people indicate that they did. Surprisingly, the best ranking states had the lowest number of affirmative answers, indicating that overall the boaters in those states do not take steps to prevent the spread of zebra mussels. However, the results from questions Z5 "True or False: Scraping is sufficient for the removal of zebra mussels?" sheds some light as to what is occurring. The boaters in the worse ranking states may be taking steps to prevent the spread of zebra mussels. However, less than half of the respondents recognized that it takes more than the physical removal of mussels to prevent spread them, as opposed to 57% from the most effective group having answered the questions correctly. The overall accuracy for the best ranking group was better than that than for the worse ranking group as well, so in general it can be inferred that while not as many boaters from the best ranking group take steps to prevent the introduction, those that do are more effective than the boaters in the worse ranking group. The average ranking group also had the best scores for knowing that zebra mussels of all sizes are of a concern and that it takes more than physically removing visible mussels from the boat, as well as actually taking steps to avoid transporting the mussels.

Perhaps what is a little bit more telling than quiz scores is the comments that were made while the survey was being conducted. For the first group, only one state was actually visited in person, New Mexico. As previously mentioned, boaters in New Mexico were not as willing to complete the survey as those in other places. However, one comment that was especially striking is that when informed that Colorado was discovered to have an infested lake in 2008, one boater responded, “Well, then it won’t be long before we get them.” Comments were also made amongst this group regarding the issue of whether state resources should be used. One person specified that they should, if money is available while another thought it was not the state’s responsibility, but rather the federal government’s.

Missouri, from the second group, also had some interesting comments. When asked about how knowledgeable they were about aquatic nuisance species and zebra mussels, one boater mentioned how he had read articles about zebra mussels in the Missouri Conservationist magazine (which is provided free to Missouri residents), as well as warning signs by Lake Taneycomo. Another respondent mentioned having seen a billboard in the Clinton Lake area. There was one boater in this group who did not see zebra mussels as a problem. He was aware of how the mussels decreased pollution in the Great Lakes, and stated that he had wondered how much they actually benefitted the fishing industry.

One respondent from the worst group had similar feelings. This particular person, while a boat owner, actually identified more with hunters. As a duck hunter, what he saw was that waterfowl in the Great Lakes were actually increasing in weight, which is a benefit for the sport. Like the respondent in Missouri, he cited the increased water clarity as well and the effect that had on the size of large game fish. Interestingly, another boater I spoke with complained about the boaters from the Great Lakes. In his eyes, they were the cause of many of the problems of the inland lakes because "Lake Erie boaters just don't care; they do whatever they want," including throwing trash into the lakes and not checking their boats for debris. This same respondent also made the observations that the crawdads (also known as crayfish) had disappeared from Brookeville Lake and that the number of mussels appeared to be down due to the depletion of their food source. Finally, there was some awareness of the mechanisms of dispersals. A story was told about how a respondent bought his boat from Kentucky, but when he went to pick it up he found that it was encrusted with zebra mussels. Knowing that the waterbody he intended to use it in had not yet been invaded, he arranged for the previous owner to have it cleaned prior to taking possession of the boat and transporting it to Pennsylvania.

The stories from the average and worst groups illustrate that there is some level of awareness. The boater who bought his vessel from Kentucky couldn't recall where he'd heard about it, but he was not alone in having some knowledge or at least recognizing the term "zebra mussels." The Missouri boaters were much more enthusiastic about having heard of zebra mussels, and the knowledge they received seemed to have made more of an impression. New Mexico boaters, on the other hand, appeared to have had no knowledge, despite signs around boat ramps warning of the potential for spreading invasive species, explicitly naming the zebra mussel as one of those species.

While it is evident that the issue is being communicated, it seems as if the information may not always be complete. The boaters from Missouri and Ohio who mentioned the biological impacts such as increased water clarity and increased weight of game fowl and fish were not aware of the economic impacts that are associated with the number of zebra mussels and their tendency to conglomerate. A boater from Indiana did have this knowledge as well as the concept of carrying capacity and the ability for zebra mussels to deplete a waterbody of nutrients. In order for the educational tactics to be the most effective, it is imperative that the recipients of the training and at whom the information is directed receive full and complete information, as opposed to just the results of a few studies that only present part of the picture.

LIMITATIONS OF STUDY

It is difficult to draw any strong, definitive conclusions from this study. First of all, there are several flaws in my method of ranking effectiveness that could be addressed which may give slightly different answers and perhaps more accurately rank the states to provide a better distribution of rankings. For example, a 20 kilometer limit in determining the number of upstream occurrences was not imposed due to GIS capability restrictions. Had this been done, it would better represent the salutatory dispersion pattern that is expected to occur from vessels as a vector and more accurately identify occurrences that may represent the start of a new population as opposed to just the expansion of range by an existing population.

In calculating the location quotient, a distinction between number of waterbodies and number of waterbody polygons should be recognized. A polygon is a GIS unit that represents areal features at the scale of interest. In this case, polygons represent lakes or rivers. The data for these polygon features was created using USGS topographic maps as a reference, and because of various factors such as the age of the photos or human error, some waterbodies may have been digitized as multiple polygons while in reality they are one waterbody. The result is that during the GIS analysis, each polygon was treated as a separate waterbody leading to some potentially inflated values. This concern was brought to light in correspondence from Doug Jensen (Minnesota Sea Grant, email, January 27, 2009) who mentioned that only five of Minnesota's inland lakes are infested, while my analysis determined that there were 155 waterbodies infested. However, because the same error would have been made when determining the total number of waterbodies and infested waterbodies, there would be minimal impact on the overall location quotient. However, there could be a discrepancy if one state has a disproportionate number of waterbodies that were split during data creation.

Additionally, I would want to determine what the risk of infestation is for each waterbody and incorporate that into the model. There are a variety physical and human factors that cause some waterbodies to be more susceptible to be infestation than others, such as chemical composition and boater migration and waterbody interaction. While these factors have been modeled for some areas, this data is not uniform enough in quality and coverage for my use. If it were, this would help to adjust the rankings according to the present risk.

CHAPTER V

CONCLUSION

The first objective was to determine how effective states have been at preventing the spread of zebra mussels. It was found that Alabama, Georgia and New Mexico have been the most effective at preventing the spread of zebra mussels, Missouri and Tennessee were moderately effective, and Indiana, Ohio and Pennsylvania have been the least effective. It is possible that this is at least in part due to the distance from the Great Lakes. States that are closer to the Great Lakes faced infestation before it was known a problem existed as boaters are more likely to visit waterbodies that are closer to home more often than those that are further away, increasing the risk of those waterbodies close to the Great Lakes. The presence of navigable waterways and the distribution of waterbodies may also play a role in effectiveness as downstream flow is an efficient dispersal mechanisms and the level of use from commercial traffic also increases the risk. Secondly, the policies from each state were evaluated to see if there were any common policies employed by the most effective states that was not employed by the least effective. There was no real clear trend, although Georgia had a wider range of outreach activities that could be contributing to its effectiveness, and therefore indicates that the wider range of methods that are employed increases the potential effectiveness at preventing the introduction of zebra mussels. Finally, the third objective examined how perceptions and knowledge of the zebra mussel problem may contribute to effectiveness. Overall, boaters from Alabama, Georgia and New Mexico scored better on the knowledge portion than the other groups of states. However, boaters from these states reported not taking as active of a role in preventing the spread of zebra mussels, but the indications are that those who do actively participate in prevention activities are more knowledgeable about the techniques of decontamination than participants in Ohio, Indiana and Pennsylvania, indicating again that complete education is an important component to developing successful policies. The best three states, Georgia, Alabama and New Mexico, had the best overall score on the knowledge portion of the survey, followed by Missouri and Tennessee, and finally, the worst three states, Ohio, Indiana, and Pennsylvania.

It has been interesting to see the various methods of planning and prevention activities that are employed by each state. It is easy to believe that Georgia would be successful and preventing the spread of zebra mussels given the wide range of activities the various state agencies participate in, most of those outreach and education as is suggested by the commons literature. Likewise, is not hard to imagine that Ohio would be having difficulty preventing the spread of zebra mussels given that their activities appear to be focused on invasive plants and their plan not seeming as complete as some of the other states. The commons literature states that communication and enforcement of rules are essential to successful commons management, and neither of these activities appears to be present in the Ohio management plan.

Another activity that the literature suggests should be present in the management of commons resources is enforcement. However, in all states this appeared to be lacking. There was no explicit mention of specific fines or penalties that could be levied against those who are negligent in checking their boats for aquatic hitchhikers. Part of this could be due to a lack of support from the courts. In a training session that I attended, a representative from Missouri relayed a story about how a ticket he had distributed to a boater was thrown out. According to the presiding judge, in order for an infraction to occur, malicious intent had to be proven.

I am doubtful about the use of the current methods to accomplish the goal of stopping the spread. In my capacity as instructor and vessel examiner with the U.S. Coast Guard Auxiliary, I have had the opportunity to informally discuss the issue with a wide range of people. There are people in my own flotilla who have expressed that they feel that it is inevitable that zebra mussels will make their way into any given waterbody, and so it is not worth the time and effort of pursuing the goal. Students in safe boating classes have reported receiving conflicting information on what really needs to be done, as well as how much of a problem it really is. Finally, there are those who just don't care. They have a limited amount of time they can spend at the lake and there is just no desire to take the time to properly inspect and decontaminate their vessels. While this is undoubtedly somewhat the result of ignorance, there will always be those who act in their own best interest (even if it is a "I don't mind having my utility expenses increase; I can afford it) or those that rally against any sort of government intervention ("no one is going to tell me what to do.") Until these attitudes and confusions are universally, 100% changed, the spread can only be slowed, not stopped. Probably the best influences are those who are passionate about the problem, be they state employees or concerned citizens, and champion the cause on their own and talk to people. Had it not been for a very persistent, enthusiastic Kansas auxiliarist constantly preaching the message at meetings, safe boating classes, and dragging me to training opportunities, it is unlikely that I would have picked up on the issue myself.

While attending a watercraft inspection and decontamination training session in April of 2007, a participant talked about prevention activities at Lake Meade, AZ following the discovery of a small population of zebra mussels. They are going beyond simply educating boaters and have set up monitoring and decontamination stations through which boats from high risk states must pass prior to launching their boat. If the boat is found to be contaminated and the boaters proceed to launch, then fines may be levied. This is likely to be the most effective overall policy as it gives boaters little choice but to participate in good zebra mussel prevention practices.

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APPENDICES

Appendix 1: State Activities
Tables 11 - 13

Table 11: Activities Allowed by State Statutes, Required for Bronze Standard (minus law enforcement)
(adapted from Filby et al. 2002, Tables 1, 5, 10-17, Appendix A)

State	Identify ANS*	Emergency Powers*	Funding*	ANS Councils*
Alabama				
Arkansas				
Colorado		X		
Georgia				
Illinois				X
Indiana				
Iowa				
Kansas				
Kentucky		X		
Louisiana				X
Maryland				GENERAL
Michigan				
Minnesota		X		GENERAL
Mississippi				
Missouri				
Montana		X		
Nebraska				
New York				
North Carolina				
North Dakota				
Ohio				X
Oklahoma				
Pennsylvania				
South Carolina			X	(PLANT)
South Dakota				
Tennessee		X		
Texas			X	(PLANT)
Virginia				GENERAL
West Virginia				
Wisconsin	X			GENERAL PENDING
Wyoming				
Total	1	5	2	9

Table 12: Other Activities Allowed by State Statute
(adapted from Filby et al. 2002, Tables 1, 5, 10-17, Appendix A)

State	Education	State Agency Control	State Plans/Programs	ANS Plans	Restoration
Alabama		X			
Arkansas					
Colorado					
Georgia		X			
Illinois		X	X	X	
Indiana		X			
Iowa		X		X	
Kansas					
Kentucky		X			
Louisiana		X	X	PENDING	
Maryland		X	X		
Michigan		X		HURON ONLY	
Minnesota	X	X	X		
Mississippi		X	X		
Missouri					
Montana		X			X
Nebraska					
New York		X	X	C	
North Carolina					X
North Dakota		X			
Ohio		X	X	X	
Oklahoma					
Pennsylvania		X			
South Carolina		X	X	PLANT	
South Dakota		X			
Tennessee		X			
Texas	X	X		PLANT	
Virginia		X	X		
West Virginia					
Wisconsin	X	X	X	GENERAL PENDING	
Wyoming		X			
Total	3	23	10	9	2

Table 13: Law Enforcement Activities Allowed by State Statute
* Tool required for Bronze Standard
(adapted from Filby et al. 2002, Tables 1, 5, 10-17, Appendix A)

State	Fines	Civil Penalties*	Prison*	Infraction*	Felony*	Damage Compensation	Positive Incentives
Alabama			X				
Arkansas							
Colorado	X			X		X	
Georgia							
Illinois							
Indiana		X					
Iowa	X			X			
Kansas							
Kentucky	X			X			
Louisiana	X	X	X	X		X	
Maryland	X		X	X			
Michigan	X		X	X			X
Minnesota		X		X		X	
Mississippi	X		X	X			
Missouri							
Montana	X		X	X		X	
Nebraska	X			X			
New York	X	X	X	X			
North Carolina			X				
North Dakota		X					
Ohio							
Oklahoma	X		X	X			
Pennsylvania				X			
South Carolina	X	X	X	X		X	
South Dakota				X			
Tennessee	X			X			
Texas							
Virginia				X			
West Virginia	X		X	X			
Wisconsin							
Wyoming							
Total	14	6	11	18	0	5	1

Appendix 2: GIS and Excel Steps
Details

Font Conventions: **Bold =** New file name *Italic* = Variable name/Input (*Generic Indicator*)

* Indicates model builder was used for the step

Delineating Study Area:

A geodatabase was set up and feature datasets utilize to ensure that all files are in the same projection. The projection and coordinate system used for each dataset is: GCS_North_American_1983, Albers Projection.

MS River Basin shapefile -
http://eros.usgs.gov/products/elevation/gtopo30/hydro/na_basins.html

1. Chose all sub-watersheds with a value of 8.
2. Export to new shapefile and dissolved using Level1 (**Basin**).

States (National Atlas)

1. Select by location: Features from States that Intersect with Basin
2. Export to new shapefile. (**MSRB_States**)

Hydrology (National Atlas)

Type refers to either streams (lines), LakesRivers or Water (polygons)

1. Select by location: Features from Streams that Intersect with MSRB_States
2. Export to new shapefiles (**MSR_St_***Type***)**
3. Identity
    a. Input features: MSR_St_*Type*
    b. Identity features: MSRB_States
    c. Output features: **MSR_St_*Type*_Identity**
    d. Join attributes: All
    e. Keep Relationships: No
4. Dissolve
    a. Input features: MSR_St_*Type*_Identity
    b. Output features: **Finale_MSR_St_*Type***
    c. Dissolve fields: Name, State_1, Name_1

MSR_Sightings

Year indicates the year for which analysis is being performed.

N indicates iteration number in model builder.

Iteration	Year
0	1998
1	1999
2	2000
3	2001
4	2002
5	2003
6	2004
7	2005
8	2006
9	2007
10	2008

1. Separated "New" from "Source"*
   a. SQL: "Year" = *Year* → **New*N*** e.g. "Year" = 1998 → **New0**
   b. SQL: "Year" < 1998 → **Source*N*** e.g. "Year" < 1998 → **Source0**
2. Near*
   a. Input: New*N*
   b. Near Features: Source*N*
3. Joined New*N* to Source*N* based on Near_FID and FID_1*
4. Exported Data: ***Year***
5. New Feature Class: **Near_Sightings**
   a. Imported fields from New1998
6. Loaded 1998 – 2008 files into geodatabase feature class
7. Export to Shapefile: **Dated_Sightings**
8. Added Time Field
   a. Add field: Time, Double
   b. Field Calculator: Full_Year - Full_Yea_1
9. Added GLDist Field
   a. Add field: GLDist, Double
   b. Selected features = Great Lakes
   c. Spatial Analyst: Euclidean Distance
   d. Extract to Points
   e. Field Calculator: GLDist = RasterValu
10. Select by Location: Dated_Sightings that Intersect Basin; buffer 1000 meters
11. Export Selected Features, **MSR_Sightings**

Waterbodies Within Mississippi River Basin (binary 0/1)

1. Add field: MSRB_Int (short integer)
2. Select by location: *Type* that Intersect with Basin; buffer 1000 meters
3. Field calculator: MSRB_Int = 1

Waterbodies with Mussel Sighting (binary 0/1)

1. Add field: ZM (short integer)
2. Select by location: *Type* that Intersect MSR_Sightings; buffer 1000 meters
3. Field calculator: ZM = 1

Notes: Idaho and South Carolina removed from analysis because they contain no waterbodies that intersect the MSRB.

Location Quotient

Analysis for this step is done within Excel.

1. Combine StreamTable and WaterTable into one Excel Spreadsheet.
2. Add new column, Count,
    a. Count = *IF(MSRB_Int=1, IF(ZM=1), 1, 0), 0)* which will give a value of 1 to any waterbody that is within the Mississippi River Basin and has a Zebra Mussel occurrence.
3. Subtotal "Sum" for each state under MSRB_Int and Count.
4. For each state, location quotient is then (Count/MSRB_Int)/(Total Count/Total MSRB_Int).

Distance/Time

Analysis for this step is done within Excel.

1. Sort by distance, remove all Near_Dist=0.
2. Sort by state.
3. Add column, T1988
    a. T1988 = Full_Year – 1988.5
4. Add column, D/T
    a. D/T = (NearDist/GLDist)/(Time/T1988)
5. Subtotal "Average" for each state.

Upstream Count (mussel_connectivity.mxd)

Water network: Center for Research in Water Resources, CRWR at the University of Texas Austin

Analysis for this step using Utility Network Analyst.

Analysis Options: Results format: Selection

1. Place edge flag just upstream from sight of interest.
2. Trace Task: Trace Upstream
3. Select By Location from All Sightings features that are within a distance of .5 miles from HydroEdge
4. In the attribute table fro All_Sightings, show selected sightings
5. Count and record number of sightings with Year < Point of Interest (NOT <=)

Appendix 3: Survey Guide and Survey for Recreational Boaters

Thank you for agreeing to help me conduct my research. Below, you will find some general instructions and explanations on how to conduct the survey and what it is I am looking for. On the next page, you can find answers to questions some people may have about the survey. Please feel free to work these into your approach script. I appreciate your assistance.

Survey Guide:

Whom to interview: Boat/pwc owners; operators will suffice if this is noted on the form.

How to conduct the interview: Either face-to-face, or you can hand it to them and let them write it in on their own.

Location of Interview: Need not be too specific. Just name the body of water you are on. Ex. Grand Lake. NOT Boomer Boat Launch. If conducted away from a waterbody, then list municipality or other feature that can be located on a map. It is preferable that these be conducted as close to a waterbody as possible.

Infested: This can be left blank; I have a database with this information.

How long have you owned your boat?: Any boat, not necessarily the one they currently have. Go back to the "first" boat they purchased.

Questions 1 – 4: Have them give you the number that corresponds to where they fall on the scale.

FAQ:

What is this survey for?

To learn about people's perceptions and knowledge of zebra mussels in the state of Georgia.

Who is this survey for?

Julie Carey, a master's student in Geography at Oklahoma State University

What is the project on?

The knowledge gained from this survey will be used for research, is conducting to evaluate how effective states have been at preventing the spread of these mussels

What are Zebra Mussels?

Zebra mussels are an invasive species that has been present in U.S. waters since approximately 1988. They quickly out complete native species as well as clog intake pipes for not only boats, but city water supplies and dams, and other utilities.

Why should I care?

To date, they have cost the U.S. billions of dollars. They also disrupt the natural ecosystem.

What is the goal of the project?

By determining what policies have been effective at preventing the introduction of these mussels, we can prevent the further distribution and save tax-payer money.

Will I be able to be identified?

No; we are not collecting any personal information (name, registration numbers, phone number, etc.)

I have more questions/concerns. Who can I contact?

Julie at 417-300-2949 (jcarey@okstate.edu) or her advisor, Dale Lightfoot at 405-7444-9170 (d.lightfoot@okstate.edu).

Location of Survey: ___________________ | Infested? Yes No |

Background Questions:

State of Boat Registration: ___________ State of Residence: ___________

How long have you been boating? ______________________________________

How long have you owned your own boat? _______________________________

In percent of time, where are the three places you boat the most?

____ ______%

____ ______%

____ ______%

Other ______%

Please answer the following questions about your perceptions and knowledge of zebra mussels using the provided scales.

1. How knowledgeable are you about aquatic nuisance species in general?

1	2	3	4	5
Very Knowledgeable				No knowledge

2. How knowledgeable are you about zebra mussels?

1	2	3	4	5
Very Knowledgeable				No knowledge

3. How important is it to prevent the introduction of zebra mussels?

1	2	3	4	5
Very Important		Neutral		Not Important

4. In your opinion, should state resources be used to prevent the spread of zebra mussels?

1	2	3	4	5
Strong yes		Neutral		Strong No

5. Do you take steps to prevent the spread of aquatic nuisance species?

Yes No

If yes, what? How often?

The following is a short quiz about zebra mussels and preventing their introduction into a waterbody. This will be used to determine the general level of knowledge among boaters in your state.

1. How long can zebra mussels live out of water in humid conditions?

Score: 4	**3**	**2**	**1**
24 hrs	48 hours	1 week	1 month

2. How long can zebra mussels live out of water in dry conditions?

4	**1**	**3**	**2**
24 hrs	48 hours	1 week	1 month

3. Zebra mussels can be located in what of the following places? Check all that apply. **Score according to number incorrect.**

___X__ Boat trailer ___X__ Boat hull ___X__ Live well

__X___ Cooling system __X___ Propeller/Impeller __X____ Trim flaps

4. Only zebra mussels that are large enough to be easily seen are a concern.

True **False**

5. Scraping is sufficient for the removal of mussels from a boat or personal watercraft.

True **False**

Appendix 4: Interview Questions

Name:
Title:
Agency:
Address:
Phone:
Email:

1. What is your role in aquatic nuisance prevention and mitigation?

2. Is there a plan to hire an ANS coordinator? If so, what is the status of that activity?

3. How much money is generally budgeted each year for the prevention and mitigation of aquatic nuisance species, specifically the zebra mussel?

4. Are there people employed to check boats for the presence of invasive species on recreational boats? How often do they participate in these activities? Do you utilize volunteers?

5. What sort of signage is used to warn of the threat of zebra mussels at infested lakes? Non-infested lakes?

6. When did legislation first get introduced in your state addressing the issue of zebra mussels? Who was instrumental in seeing that through?

Appendix 5: Institutional Review Board Paperwork

Oklahoma State University Institutional Review Board

Request for Determination of Non-Human Subject or Non-Research

Federal regulations and OSU policy require IRB review of all research involving human subjects. Some categories of research are difficult to discern as to whether they qualify as human subject research. Therefore, the IRB has established policies and procedures to assist in this determination.

1. Principal Investigator Information

First Name: Julie		Middle Initial: M	Last Name: Carey
Department/Division: Geography Graduate		College: Arts and Sciences	
Campus Address: 225 Scott Hall		Zip+4: 74078-4073	
Campus Phone: 49730	Fax:	Email: jcarey@okstate.edu	
Complete if PI does not have campus address:			
Address:		City:	
State:	Zip:	Phone:	

2. Faculty Advisor (complete if PI is a student, resident, or fellow) ☐ NA

Faculty Advisor's name: Dale Lightfoot		Title: Department Head
Department/Division: Geography		College: Arts and Sciences
Campus Address: 225 Scott Hall		Zip+4: 74078-4073
Campus Phone: 49170	Fax:	Email: d.lightfoot@okstate.edu

3. Study Information:

A. Title

A Decade of the 100th-Meridian Initiative: Examining the Effectiveness of Policies in the Mississippi River Basin Aimed at Preventing the Spread of Zebra Mussels

B. Give a brief summary of the project. (See instructions for guidance)

Zebra mussels are making their way into waters across the United States. To date, there is no known study that takes a systematic approach at determining what state policies have been effective at preventing the spread of zebra mussels. I am proposing an evaluation of which states within the Mississippi River Basin have been the most effective and what policies and techinques they employ. I will employ GIS to determine which states have been the most and least effective, and then interview industry professionals and state officials to find out what has been done in their state to prevent the introduction of zebra mussels. I will also interview recreational boaters to determine their perceptions of the problem as well as how much they know about zebra mussels.

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[redacted]

Oklahoma State University Institutional Review Board

Request for Determination of Non-Human Subject or Non-Research

C. Describe the subject population/type of data/specimens to be studied. (See instructions for guidance)

Industry professionals and state officials will be people that either work for an institution that deals with zebra mussels or have been appointed or elected to a position where they work on this problem.

Recreational boaters will be people who have registered their boats with the corresponding state and utilize waterbodies for enjoyment purposes.

4. Determination of "Research".
45 CFR 46.102(d): *Research* means a systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge. Activities which meet this definition constitute research for purposes of this policy whether or not they are conducted or supported under a program which is considered research for other purposes.

One of the following must be "no" to qualify as "non-research":

A. Will the data/specimen(s) be obtained in a systematic manner?
☐ No ☒ Yes

B. Will the intent of the data/specimen collection be for the purpose of contributing to generalizable knowledge (the results (or conclusions) of the activity are intended to be extended beyond a single individual or an internal program, e.g., publications or presentations)?
☐ No ☒ Yes

5. Determination of "Human Subject".
45 CFR 46.102(f): *Human subject* means a living individual about whom an investigator (whether professional or student) conducting research obtains: (1) data through intervention or interaction with the individual or (2) identifiable private information. Intervention includes both physical procedures by which data are gathered (for example venipuncture) and manipulations of the subject or the subject's environment that are performed for research purposes. Interaction includes communication or interpersonal contact between investigator and subject. Private information includes information about behavior that occurs in a context in which an individual can reasonably expect that no observation or recording is taking place, and information which has been provided for specific purposes by an individual and which the individual can reasonably expect will not be made public (for example, a medical record). Private information must be individually identifiable (i.e., the identity of the subject is or may be ascertained by the investigator or associated with the information) in order for obtaining the information to constitute research involving human subjects.

A. Does the research involve obtaining information about living individuals?
☒ No ☐ Yes
If no, then research does not involve human subjects, <u>no other information is required</u>.
If yes, proceed to the following questions.

All of the following must be "no" to qualify as "non-human subject":

B. Does the study involve intervention or interaction with a "human subject"?
☐ No ☒ Yes

C. Does the study involve access to identifiable private information?
☒ No ☐ Yes

D. Are data/specimens <u>received</u> by the Investigator with identifiable private information?
☒ No ☐ Yes

E. Are the data/specimen(s) coded such that a link exists that could allow the data/specimen(s) to be re-identified?

[redacted]

Oklahoma State University Institutional Review Board

Request for Determination of Non-Human Subject or Non-Research

☒ No ☐ Yes

If "*Yes,*" is there a written agreement that prohibits the PI and his/her staff access to the link?

☐ No ☐ Yes

6. Signatures

Signature of PI__________ **Date** 9-17-08

Signature of Faculty Advisor__________ **Date** 9-16-08
(If PI is a student)

☒ Based on the information provided, the OSU-Stillwater IRB has determined that this project **does not** qualify as human subject research as defined in 45 CFR 46.102(d) and (f) and **is not subject to oversight by the OSU IRB.**

☐ Based on the information provided, the OSU-Stillwater IRB has determined that this research **does** qualify as human subject research and **submission of an application for review by the IRB is required.**

____
Dr. Shelia Kennison, IRB Chair

9-18-08
Date

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[redacted]

VITA

Julie M. Carey

Candidate for the Degree of

Master of Science or Arts

Thesis: STOPPING THE SPREAD: EVALUATING THE EFFECTIVENESS OF POLICIES AIMED AT PREVENTING THE SPREAD OF ZEBRA MUSSELS

Major Field: Geography

Biographical:

Personal Data:

Education:
Completed the requirements for the Master of Science in Geography at Oklahoma State University, Stillwater, Oklahoma in May, 2009.

Completed the requirements for the Geographic Information Systems Certificate at Oklahoma State University, Stillwater, Oklahoma in May 2009

Completed the requirements for the Bachelor of Science in Geography at The University of Kansas in May 2007.

Experience:
Graduate Teaching Assistant, Oklahoma State University, 2007 – 2009
Student Technical Assistant, Kansas Geological Survey, 2006 – 2007

Vessel Examiner, U.S. Coast Guard Auxiliary, 2004 – Current

Professional Memberships: Association of American Geographers

Name: Julie Carey Date of Degree: May, 2009

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: STOPPING THE SPREAD: EVALUATING THE EFFECTIVENESS OF POLICIES AIMED AT PREVENTING THE SPREAD OF ZEBRA MUSSELS

Pages in Study: 99 Candidate for the Degree of Master of Science

Major Field: Geography

Scope and Method of Study: This was a study of the effectiveness of the policies aimed at preventing the spread of zebra mussels in the Mississippi River Basin. First, the states were ranked in effectiveness using three factors: location quotient, a distance-time factor, and an upstream occurrence factor. Once ranked, the most effective, average effective and least effective states were chosen for further study. Secondly, the states' aquatic invasive species plans were examined and experts consulted to determine what methods of prevention were utilized in each state. Lastly, a survey of boat owners was conducted to determine how their knowledge and attitude might affect how effective states have been at preventing the introduction of zebra mussels.

Findings and Conclusions: The most effective states were Alabama, Georgia and New Mexico. The average states included Missouri, Tennessee, and Arkansas and finally, the least effective were Pennsylvania, Ohio and Indiana. It was found that the most effective policies seemed to be those that employed a large range of public education and outreach activities, such as public service announcements and billboards. Correspondingly, these states corresponded with the boat owners that knew the most overall about zebra mussels, and even though the most effective states did not see the highest number of boat owners that actively took steps to prevent the spread of zebra mussels, the boat owners that did were likely more effective due to a greater knowledge base.

ADVISER'S APPROVAL: Dr. Dale Lightfoot