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Use of GIS to Determine Potential Sources of Aquatic Invasive Species Invasions into Western South Dakota Reservoirs

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Abstract

The spread of Aquatic Invasive Species (AIS) is a constant threat for western US waters. The state of South Dakota detected zebra mussels (*Dreissena polymorpha*) for the first time at Lewis and Clark Reservoir in 2014. Since then, efforts have been towards preventing their further expansion. To determine possible avenues of infestation westward, we used ArcGIS to map the home zip codes of boaters using four western reservoirs (Belle Fourche Reservoir, Pactola Reservoir, Sheridan Lake and Angostura Reservoir). A 60-mile buffer was used to determine spatial relationships of boater zip codes to establish zebra mussel populations and was considered areas of high risk. We found that there were three instances where a boater came from a high-risk area during the study period. Our results show possible pathways for *Dreissena* expansion into western South Dakota reservoirs. Most notably is that exposure can occur from either an inter- or intra-state vector. This information confirmed that there is a risk of additional water bodies in South Dakota becoming infected. Based on past studies, prevention is the best method in slowing the expansion of zebra mussels in South Dakota. We suggest three actions, strategically placed decontamination stations, continued public awareness efforts and differentiating boat registration tags on watercraft that are near infested water bodies.

Keywords

GIS, South Dakota, Invasive Species, Zebra Mussel

1. Introduction

Most scientists agree that released contaminated ballast water into the Great Lakes from a cargo ship was the initiation of *Dreissena* mussels into North

America. Since that time, the expansion of *Dreissena* mussels (zebra mussels *Dreissena polymorpha* and quagga mussels *Dreissena rostriformis bugensis*) has been a major issue in the United States [1] [2] [3]. Lacking natural controls, these mussels have thrived in this new environment while spreading throughout water bodies connected to the Great Lakes and secondarily spreading through carriers of *Dreissena* mussels [2] [4] and [5]. Zoological spreading of these mussels occurs through different life-history stages.

These two *Dreissena* mussels have similar life history characteristics including high reproductive potential, planktonic free-swimming larvae [6], and an attached benthic adult stage [1]. Range expansion occurs in these two life stages, during the free-floating veliger larval stage and in attached adult stage [3]. During the larval stage contaminated water is a potential source of infestation. As adults, *Dreissena* mussels can be spread by attaching themselves to a transferrable object (e.g. rock, boat hull, trailer) by its byssal threads [7]. Spatial analysis has allowed researchers to visualize the spread of *Dreissena* mussels across the United States.

Geographic Information System (GIS) has been used to track *Dreissena* mussels [8] and to predict infestation by mapping major access points [9], and predict areas of potential colonization [9] [10] [11] and [12], and zebra mussel's development/reproduction success rates per lake [13]. The use of GIS mapping has reinforced past theories that zebra mussels can move through connected waterways but also by other methods of dispersal (*i.e.* recreational boaters) [4] [14] and [15]. As a tool, GIS allows for various analysis that would be difficult otherwise (e.g. buffer analysis). Our objective was to determine the potential pathways of *Dreissena* mussel introductions into western South Dakota reservoirs using GIS and to provide direction towards limiting or delaying these infestations.

2. Methods

Four popular recreational lakes (Belle Fourche Reservoir, Angostura Reservoir, Pactola Reservoir and Sheridan Lake) in western South Dakota were sampled between May 19 and July 15, 2018 and were selected based on high boating use and multiple launching sites (**Figure 1**). Boaters were interviewed, normally before launching, a series of questions used later in analysis.

We used three data layers and two processes within ArcGIS to perform our analysis of greatest potential *Dreissena* pathways to western South Dakota reservoirs (**Figure 2**). First, we combined 5-digit zip code data from boater interviews to data from the Esri Digital Line graph data for the USA to provide a geographic location to user zip codes. The centroid of each zip code polygon was used as a standard location in which to determine proximity of other factors. Zebra and quagga infestation sites were imported from US Geological Service Nonindigenous Aquatic Species and were spatially associated to the nearest zip code [16]. Next, a buffer analysis was processed in ArcGIS based on a 60-mile unit. This distance was used based on the assumption that most boating activity

would be within an hour of a person's normal residence (*i.e.* zip code) and resembled distances found by [17]. Based on this estimation, a 60-mile radius buffer zone was placed around each zip code point. Lastly, all the *Dreissena* infested water bodies that were not inside the buffer zones were eliminated from the map leaving only high-risk zip code areas.

3. Results

Throughout the study, 107 boater surveys were taken between the four lakes which yielded 26 unique user zip codes. Boaters to these four waters were from six different states (**Figure 3**). Additionally, zip codes were used to show spatial orientation to *Dreissena* infested waterbodies. Seven zip codes were not within South Dakota, coming from five different states (North Dakota, Wyoming, Colorado, Iowa and Arkansas), with three of these states (South Dakota, Colorado and Arkansas) having *Dreissena* infested waters. By using a 60-mile buffer to the center of the boater zip codes we determined that three of the zip codes are in high risk areas with *Dreissena* mussel infested water bodies in easy driving distance and could be considered high-risk for potentially spreading *Dreissena* mussels into western South Dakota.

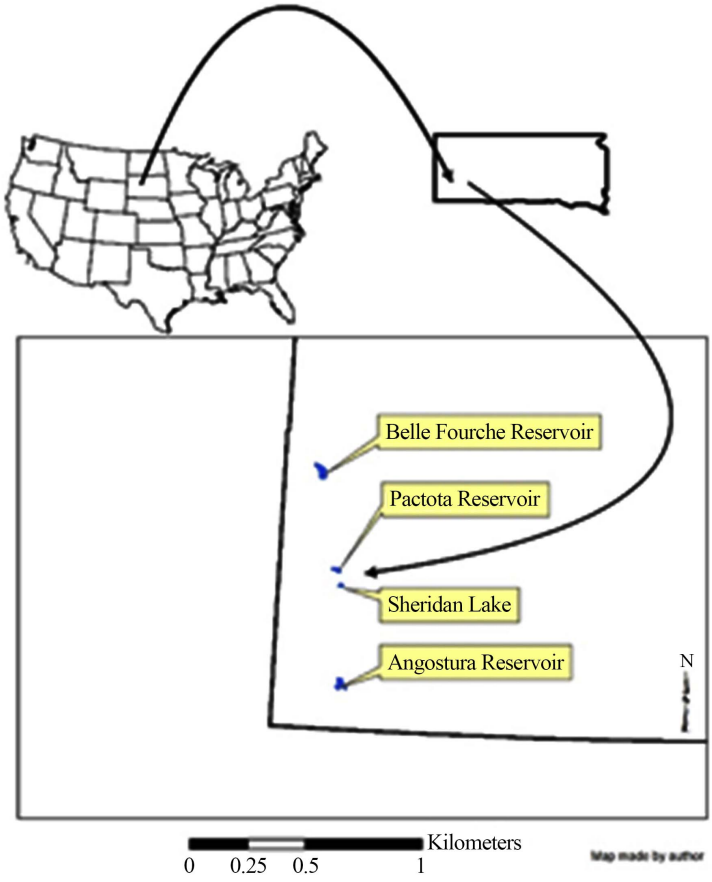

Figure 1. Study area of western South Dakota and four specified waters used in data collection. Figure made by author.

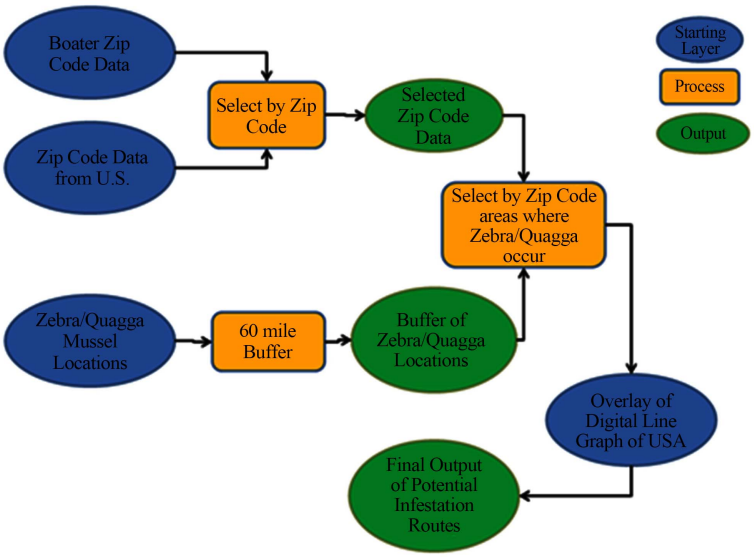

Figure 2. Model schematic of layers, processes and final output for determining potential sources of Zebra and Quagga mussel spread into western South Dakota. Figure made by author.

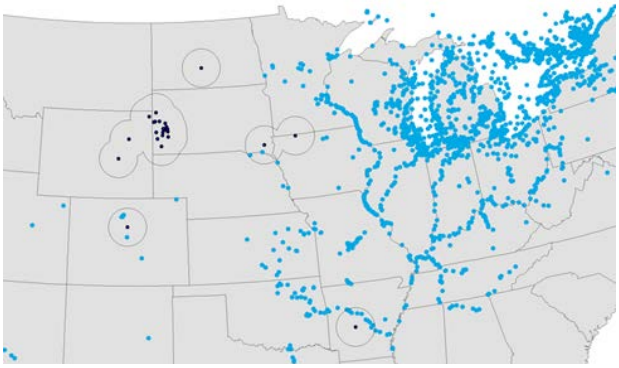

Figure 3. Geographical locations of 60-mile buffered areas around zip codes where zebra mussels were within the specified distance (black dots with buffered areas) and total area in the central US where Zebra and Quagga mussels are located (blue dots). Figure made by author.

4. Discussion

Expansion of the invasion of *Dreissena* mussels across the United States has been relatively unsuppressed. Continued efforts to address the extension of infected waters are hampered by water movement of infested water or possibly even attached adults themselves. This means that any boat carrying water containing veligers, or that has adult mussels attached to any part of the boat or trailer, could initiate the establishment of *Dreissena* mussels in any new waters.

Zebra mussels were first discovered in South Dakota at Lewis and Clark Reservoir in 2014 [17]. Since 2014, multiple water bodies in the eastern side of South Dakota have been noted as being contaminated with *Dreissena* mussels [18]. In order to delay or stop the spread of *Dreissena* mussels in South Dakota, certain actions should be taken. One such action is disinfection stations or com-

pletely closing access points to affected reservoirs until a disinfection station can be put in place. These disinfection stations would allow either officials or boaters to disinfect their boat upon arrival to an uninfected lake or before leaving an infested one [18]. Public awareness is also an effective way to prevent the spread of mussels. The simple act of informing the public about the issues that these mussels cause, how to identify if their equipment as possible infection points can reduce the chance of dispersal caused by lack of knowledge [18]. Also, an educated public can be used as a tool to identify early detection of invasive species spread [19]. Another prevention method is to specially mark registration stickers on boats coming from areas infested with *Dreissena* mussels. Having differentiated registration stickers would allow law enforcement to easily identify high risk boats and inspect them before they are launched [18].

From our analysis, there are three areas of concern that might be a source of *Dreissena* infestation into wester South Dakota lakes (**Figure 3**). Two are these areas are out-of-state (Colorado and Arkansas) with one lone presence coming from the southeastern part of South Dakota. This indicates that to reduce the presence in western South Dakota waters, at least a bimodal approach including boat inspections within state and incoming will be required. This information could also allow for the targeting of specific educational awareness efforts directed at boaters to reduce chances of *Dreissena* expansion. Additional efforts directed towards determining if waters are suitable for expansion [20] and to determine early detection of invasive species [21] [22] [23].

Since a single contaminated boat can infect a water body, without prevention measures in place, there is an imminent threat of our waters becoming infected. Using the Great Lakes as the initial infestation site, scientists were able to trace the spread of *Dreissena* mussels through connecting water bodies and traveling south in streams using the ArcGIS system. Western expansion can be seen throughout the country and elsewhere that can only be attributed to an unnatural movement created by recreational boaters [22] [24] [25]. Based on the infestation map given by the US Geological Service Nonindigenous Aquatic Species it is apparent that there is a greater concentration of *Dreissena* mussels on the eastern and southern borders of South Dakota [22].

5. Conclusions

We suggest that efforts be more focused on boaters coming from the Missouri River and State of South Dakota's southern border. Much of the potential for infestation is likely to come from established populations from these regions. As a tool, GIS can aid in understanding potential infestation pathways and perhaps allow for evidence of need for specific regulations to limit AIS expansion within South Dakota.

Our results show possible pathways for *Dreissena* expansion into western South Dakota reservoirs (**Figure 3**). Most notably is that range extension can occur from either an inter- or intra-state vector. Normal efforts are to educate

and boaters with "spot checks" of vessels entering the waters. Knowing the potential pathways of *Dreissena* mussels into western South Dakota will allow managers to target educational outreach, boat checks and allocate resources in a fiscally responsible manner. These results of this study would have been difficult to determine without the use of GIS.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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