Overview:

Aquatic invasive species, known also as nonindigenous aquatic species, are aquatic plants, vertebrates, and invertebrates that invade ecosystems outside of their natural and historic range. (FWS, 2015). Management of such species is necessary and crucial to protect native species and their ecosystems. The presence of aquatic invasive species can cause harm to other activities dependent on the ecosystem, including commercial, recreational, and agricultural activities. (FWS, 2015). Invasive species are classified in part by taking over an ecosystem, which means that not all non-native species are considered invasive species.

Much of aquatic invasive species management is species specific, since the spread and management of each species can have fundamental differences. This overview focuses on both aquatic invasive species management as a whole, while also looking at the specific management of zebra mussels (Dreissena polymorpha). Zebra mussels are a particularly interesting aquatic invasive species that were first introduced to the United States through ballast water discharges in the Great Lakes in the 1980s. These tiny mussels can clog water intake pipes and damage boating equipment by attaching themselves to motors and other hard surfaces. Zebra mussels can also harm local ecosystems by smothering local mussels and crayfish, harming fisheries and scattering beaches with their sharp shells. (Minnesota Sea Grant, 2015). By 1993, the population stretched from Quebec to Louisiana and today they can be found as far west as California. (USGS, 2015).

Management of aquatic invasive species, including zebra mussels, requires a holistic approach. This includes detection, prevention, and eradication. GIS is an important factor in an overall management plan as well. GIS can be utilized in many ways in invasive species management, as illustrated by Holcombe et al. (2007). A basic and effective way to start is to use to view data. By simply viewing data, it is easy to visualize spatial patterns. The United States Geological Survey (USGS) has created many maps out of species-specific data that indicate where certain aquatic invasive species are located throughout the country. This use of GIS requires no statistical analysis.

Holcombe et al. also presents various other ways in which GIS can be utilized in invasive species management. They include uses for data summary, spatial field data, simple GIS models, statistical models, regression models, and Environmental Envelope Models. Statistical models, such as Species Environmental Matching (SEM) models, in particular have proven very useful for determining current and potential distributions and abundances of aquatic invasive species. SEM models can either be created in a GIS or displayed in a GIS to give a visual representation of the data. (Holcombe, 2007).

For the management of zebra mussels, prediction models utilizing GIS have proven very effective. For example, an early use of prediction models was used by Buchan & Padilla to calculate the likelihood of long-distance dispersal of zebra mussels. Knowledge of boater movements and diffusion models helped predict the likely pathways for long-distance dispersal of the species throughout Wisconsin. (Buchan, 1999). Early detection and rapid response (EDRR) programs created through the use of GIS can also help limit introduction, establishment, and impact of these harmful species. (Davidson, 2015).

There are several sources of data that are used for aquatic invasive species management and its application to GIS. The USGS has its own Nonindigenous Aquatic Species Program that contains a plethora of information and data regarding aquatic invasive species throughout the country. They have also set up an alert system that allows the public to report sightings of these species.

Another source of data that has proved very effective is the use of surveys. In Buchan & Padilla, as well as Davidson et al., surveys were used to gather information regarding recreational boating behaviors and activities.
Recreational boating is a major avenue for the spread of aquatic invasive species, especially zebra mussels, and the surveys helped plot the movements of boaters and their overall habits. Quantifying such behaviors allows us to utilize GIS to predict the areas with a high likelihood of species transfer.

There are a couple of issues that arise from the use of GIS in management planning. First, availability can be a hindrance to many users. GIS software can be costly and therefore lessen availability for smaller scale invasive species management plans. Data availability can also be an issue, since some data is collected for private use or is simply not publicly available without a fee. This limits the knowledge base for future studies. A final issue identified in the use of GIS is the user friendliness of such systems.

Going forward, I see GIS being used with even more frequency in charting the presence and abundance of aquatic invasive species. Providing visual representations of the data to the public, so they can do their own simple spatial analysis, will also be an emerging use of such systems. The more that the data is used and shared with the public, the more in depth policy analysis can be done for aquatic invasive species management. As systems become more readily available and user friendly, scientists as well as management planners will be able to use the systems to help control the population and spread of aquatic invasive species.

Annotated Bibliography


Buchan & Padilla look at the invasion sources of zebra mussels in Wisconsin, through the use of boater movements and diffusion models. In order to predict the spread of zebra mussels, both in terms of abundance and geographic location, this paper tells us we need to look towards long-distance dispersal events. One way to predict these dispersal events is to monitor recreational boating. According to Buchan & Padilla, long distance boater movement can predictable in both time and space. Using a survey to collect data on boater movements and behavior, the data for the diffusion model predictions were then mapped using GIS. I found the hypothesis of this paper to be very convincing, and thought that the methods would still be useful today. GIS technology has improved in the 16 years since this article was published, but the use of surveys to collect the data to map was a good way to get as near an accurate answer as possible. It is difficult to accurately predict the pattern and rate of spread of invading species, which Buchan and Padilla acknowledge. When a species disperses long distances, that prediction becomes even more difficult. Overall, I thought this paper presented a good argument for prediction models in aquatic invasive species management.


In this paper, Clarke Murray et al. explore the influence of environmental, demographic, and vector variables on the spatial distribution of nonindigenous species in coastal marine ecosystems, with a focus on coastal British Columbia. GIS was utilized to create spatial patterns for the different environmental, vector, and population variables and show the richness of nonindigenous species in certain areas throughout the coast. Their research and results suggest that recreational boating is the most likely source of distribution for nonindigenous species in the area, which correlates with other papers I reviewed for this project. One of the most interesting aspects about this paper was the discussion of the role aquaculture might play in the distribution and dispersal of nonindigenous species. Overall, the collected data showed that aquaculture could not explain the secondary spread on nonindigenous species. I believe that Clarke Murray et al. get it right with their overall conclusion that recreational boating is responsible for the contemporary spread of these species. As such, I believe GIS will be instrumental in the further plotting and projection of further species spreading through recreational boating.

In this paper, Davidson et al. undertake the development of an empirical mapping tool, which incorporates boater movement and behavior. With this information, the tool can prioritize the bodies of water that are at higher likelihood of invasive species introduction. Surveys were conducted in order to retrieve information on boaters’ movements and behavior. ArcGIS was then used to map the different responses received from the survey and visualize the data. Throughout the paper, Davidson et al. encourage the development of early detection and rapid response (EDRR) programs in an effort to combat aquatic invasive species. I believe they are correct for encouraging the use of such programs, especially if they are utilized in conjunction with other management efforts. One of the most important features of the paper, in my opinion, is the emphasis that the mapping tool illustrated in the paper should be thought of as an adaptable tool, one that can be adjusted for different areas and utilized after a basic introduction of ArcGIS. To me, this will increase the likelihood of success for this mapping tool since it does not require complete expertise in GIS in order to reap the benefits of such a mapping tool.


In their paper, Drake and Bossenbroek model the potential distribution of zebra mussels in the United States. The model is based on various environmental and geological factors and the modeling variables were mapped using GIS to illustrate the predictions. The results in this study suggest that the western United States will not be a habitable environment for zebra mussels, except for certain areas along the West Coast. I found this to be a good generalization, although in the years since this paper was published zebra mussels have spread to several western communities. Still, the spread isn’t as intense as the spread in the Great Lakes region, making the general results still applicable.


Holcombe et al. use this paper to describe the different methods for utilizing GIS in invasive species management. GIS can be used to view data, to summarize large datasets, manage and display field data, create simple models using buffers and thiessen polygons, create statistical models and regression models, and develop Environmental Envelope Models. Holcombe et al. give a brief overview of each application, which helps create a basis of understanding. I found this paper very helpful in terms of understanding the different types of GIS methods as they are applied to invasive species management. It is a good introductory paper on the capabilities of GIS in the management realm. I also found it helpful that it was not limited to applications for aquatic invasive species management, but rather applied to invasive species management as a whole.


In this paper, Quinn et al. used species distribution models (SDMs) to model the potential distributions of two related aquatic invasive species, the zebra mussel and quagga mussel. The SDMs were based on dispersal and environmental related factors. GIS was utilized to predict the species distribution when certain environmental and dispersal factors were taken into account. Certain patterns arose that led Quinn et al. to predict that quagga and zebra mussels will occur in different areas, depending on climate, geography, and geology of the area. Population density of the area, as well as the proximity to reservoirs and commercial ports, were also taken into account. One of the most interesting outcomes of this article was how two closely related species had slight differences that affected their overall dispersal. Overall, Quinn et al. found that because there are still many similarities between the two types of mussels, it will be important to predict the spread of both species jointly to make effective precautionary management plans.
Other referenced works

Minnesota Sea Grant - http://www.seagrant.umn.edu/ais/zebramussel