THE EFFECT OF ZEBRA MUSSELS ON MINNESOTA FISH COMMUNITIES

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***Abstract*— Zebra mussels *Dreissena polymorpha* are an aquatic invasive species that has been spreading quickly throughout Minnesota water bodies since 1989. Zebra mussels are known to change certain morphological conditions in lakes such as turbidity, phytoplankton abundance, and aquatic invertebrate populations. However, studies showing impacts of the infestation of zebra mussels on the health of a fish community have been hard to prove due to a lack of repeated surveys and a suite of other confounding variables such as natural and seasonal variability, plant community, and lake morphometry. Therefore, the objective of this study is to determine whether zebra mussels have an impact on fish communities in Minnesota lakes. The Minnesota Department of Natural Resources (MN DNR) has been collecting Fish Index of Biological Integrity (FIBI) scores since the early 2000's to measure the health of the lakes fish community throughout Minnesota. Lakes in Minnesota that had an FIBI survey taken both before and after the introduction of zebra mussels were included in this study. The scores from these lakes were then graphed and analyzed by a paired t-test to determine changes in fish community health. Additionally, years since infestation and the change in the FIBI score was graphed and analyzed using regression statistics. This regression model determined the predicted change in score for every year that the lake has been infested. Variables included in FIBI calculation for each lake type were then ranked and plotted using NMDS plots as well to determine if one variable significantly influenced scores more than others. A significant difference in FIBI was found in scores before, versus after infestation ($P < 0.01$), however, no significant relationship was found between the years since infestation and change in FIBI score ($P = 0.68$). No single metric was influencing scores more than another.**

I. Introduction

Zebra mussels *Dreissena polymorpha* are an invasive freshwater mussel to North America and have been spreading in Minnesota since 1989. When this bivalve first invades a system, populations will increase rapidly in the first one to two years (Strayer 2019). They will spawn multiple times a year, producing and releasing over a million eggs per individual in one year. Zebra mussels are primarily filter feeders and can filter up to one quart of water a day that feed primarily on algae, macroinvertebrates, bacteria, and other organic compounds (Vanderbush et al. 2021). They will often outcompete native mussels for food and space, along with changing the biology of aquatic systems (Borchedring 1991).

While fish community changes in at least one Minnesota lake have been hard to track due to lack of repeated community surveys (Jones 2020), evidence of the impacts of zebra mussels has been looked at across different lakes in other regions and shown mixed results. In Lake Oneida in New York, gillnet catches of pelagic fishes were reduced while catches of littoral and benthic fishes were not (Irwin et al. 2011). In Lake Erie, walleye *Sander vitreus*, white bass *Morone chrusops*, yellow perch *Perca flavescencs*, and freshwater drum *Aplodinotus grunniens* populations did not change after the introduction of zebra mussels (Gopalan 2014). However, the populations of gizzard shad *Dorsoma cepedianum* in Lake Erie might have been affected (Gopalan 2014).

Indices of biological integrity are used to help monitor the overall composition of a water body by utilizing multiple community attributes from the water body. They have been used for a wide variety of ecological systems and communities using many different indicators (Karr 1981). FIBIs have been used in Minnesota since the early 2000s and allow agencies to better understand fish communities and their health. Four different FIBIs are currently being used in Minnesota to describe ecological condition in the diverse lakes across Minnesota (Bacigalupi et al. 2021). IBIs can also be used by system managers to identify different stressors potentially harming the lake (MN DNR Fish IBI Program 2018).

New infestation of zebra mussels in freshwater systems can lead to many changes, especially in fish communities and their dynamics (Vanderbush et al. 2021). No published studies have used an FIBI score to look at the impact of zebra mussels on fish communities. The objective of this study is to compare how the infestation of zebra mussels changes fish-based IBI scores and the respective fish communities in certain Minnesota lakes.

I. Methods

Four different types of traditional fisheries gear were used to obtain FIBI scores for each of the

surveyed lakes. Wadeable, nearshore stations were surveyed with seines measuring 15.2 or 4.6 m long by 1.5 m deep with 3 mm bar mesh and backpack electrofishers for the 30.5 m station. Backpack electrofishing was done in two passes, the first pass being completed as close to the shoreline as possible and the second pass being completed in water ~1 m deep. In the case of steep shorelines or heavy aquatic vegetation, boat assisted seines and/or boat assisted backpack electrofishing were completed instead. The number of sites from lake to lake ranged from 10-24 based on the lake size and morphological conditions. Fish captured in nearshore gears were identified to species and counted, with a subset of each specimen being vouchered to be independently verified in a lab setting (Bacigalupi et al. 2021). To sample the littoral area of the lake, double frame 19 mm mesh trap nets were used, with 9-15 locations selected according MNDNR lake survey methods (MNDNR 2017). Standard graduated mesh gill nets (15.2 m long with 1.8 m deep panels of 19, 25, 32, 38, and 51 mm bar mesh) were set to sample the limnetic areas. Gill nets were completed in sets of 6-15, and sites were chosen to represent available habitat in each lake (Bacigalupi et al. 2021; MNDNR 2017). Fish from gill and trap nets were identified to species, weighed to the nearest gram, and measured to the nearest mm.

Lakes were then fit into one of the four fish-based IBIs used by the MN DNR; applied to four different lake groups, and scored appropriately (Drake 2007; Bacigalupi et al. 2021). Group 2 lakes are the deepest of the lakes, spanning a wide range of sizes and locations in Minnesota, having the highest average fish species diversity, and most will thermally stratify. Lakes in group 4 are also deep and often thermally stratify, although they are smaller in size (>200 ha), and are located in the central and northern portions of the state. Group 5 lakes are found most often in central and northern Minnesota and are typically shallow, with a range of sizes and few experiencing partial and infrequent winterkill events. Group 7 lakes are the shallowest, with some experiencing a partial winterkill event at some point (Bacigalupi et al. 2021).

Lakes with completed FIBI surveys were then cross-referenced with the MN DNR infested waters database to find lakes that had both FIBI surveys completed before and after the infestation of zebra mussels (MN DNR 2025). In the case of multiple surveys before a lake was infested, the survey closest to the date was taken to give the most accurate representation of the lake beforehand. For the case of multiple surveys after, the last survey taken was used, to measure the effects of the infestation over the longest possible period. This method resulted in 87 surveyed lakes.

To test for a difference in FIBI score before and after infestation, a paired t-test was used. To test for relationship between change in FIBI score and years since observed infestation, a regression test was used. Variables used in each FIBI model across the four lake groups for score calculation were then plotted using non-metric multidimensional scaling (NMDS) to look for similarities between variables in before and after surveys of the lakes.

III. Results

Survey scores from the 87 lakes increased an average of 5 points (SD = 10.14) after an observed infestation of zebra mussels (Figure 1; $P < 0.01$). FIBI survey scores ranged from 11.00 to 89.00 before infestation and 18.00 to 81.00 after infestation. Statewide, lakes had an average score of 49.19 before infestation and 53.70 after.

Regression analysis showed no significant relationship was observed in the change in last FIBI score compared to the time since infestation of the zebra mussels ($P = 0.68$; Figure 2).

Trends in NMDS modeling based off 95% confidence ellipses were used for each lake group and identified that lake group 2 did not have any specific variable from FIBI calculation that impacted scores more significantly than another. Lake groups 4, 5, and 7 also showed to this same trend, however more lakes would need to be sampled to confirm this (Figure 3).

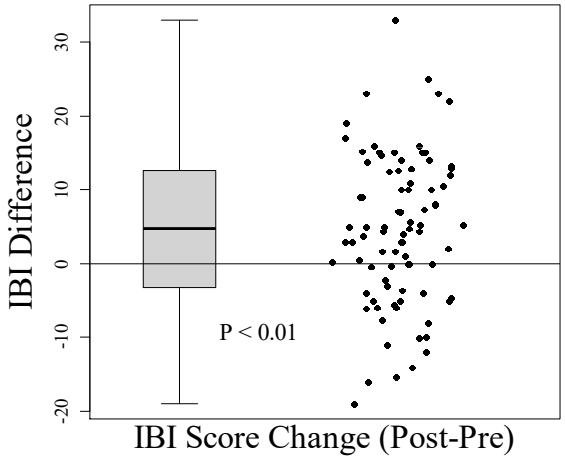

Fig. 1. The change in FIBI score (Score after-score before) for each lake with corresponding box and whisker plot. The rectangle of the box and whisker plot represent the 25th and 75th percentiles, bars are 5th and 95th percentiles and horizontal midline is median.

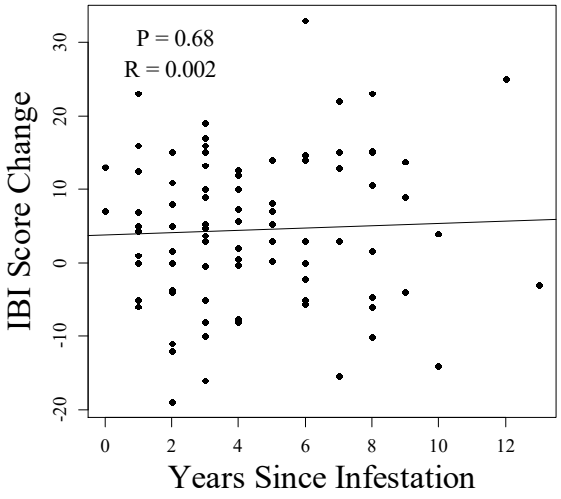

Fig. 2. Relationship of change in IBI score and years since infestation.

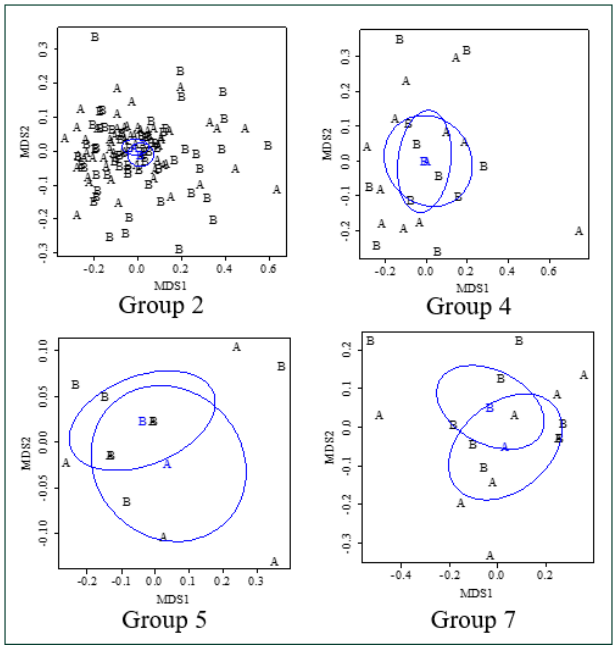

Fig. 3. Total number metrics compared against each other to see if one metric is affecting the FIBI score more. B represents lakes score before and A represents a score after. Ellipses represent 95% confidence.

IV. Discussion

Overall, when zebra mussels were introduced, a change in FIBI score was seen, yet we do not know why this change happened

Besides zebra mussels, there are quite possibly other variables that also contribute to the rise in FIBI scores that are not included in the calculation of scores. No stressor variables such as lake eutrophication, riparian shoreline development, aquatic plant removal, etc. are included in the calculation of an FIBI score (Bacigalupi et al. 2021). However, the premise of an FIBI is that it responds predictively to a stressor gradient. Changes in FIBI score over time could be explained from stressors not associated with the impacts of zebra mussel infestation.

Water quality across the state of Minnesota has generally stabilized in the past 20 years along with over 75% of lakes meeting water quality standards (Minnesota Pollution Control Agency, unpublished data). This trend of stability can decrease the stress on fish and allow them to thrive better (Adams 2003). Additionally, lake groups 2 and 4 make up most of our survey lakes (73 of our 87 lakes). These lakes are much deeper than lakes in group 5 and 7, leading to less nutrient accumulation and higher oxygen levels (Kramer 1987), leading to better habitat conditions for most fish (insectivores, plant dwellers, small benthic dwellers; Kramer 1987).

Although no increase was seen in any specific metric in this study, other studies have found specific populations of fish to benefit from or be damaged from the presence of zebra mussels. Populations of muskellunge *Esox masquinongy*, smallmouth bass *Micropterus dolomieu*, other centrarchids, and yellow perch have benefited from the presence of zebra mussels (Vanderploeg et al. 2002). Yellow perch and centrarchids are classified as insectivores (Bacigalupi et al. 2021), potentially benefiting from the increase of different invertebrate populations that also increase when zebra mussels are present (Vanderbush et al. 2021). Additionally, muskellunge and smallmouth bass are both classified as intolerant species according to FIBI classifications (Bacigalupi et al. 2021), potentially increasing FIBI scores when populations increase. Fish species such as walleye were shown to decrease with the presence of zebra mussels, potentially altering FIBI scores as well.

The ecological response of fish communities across Minnesota lakes to zebra mussels is largely site and species specific. Lakes did show a general increase after an infestation of zebra mussels, although it was widely variable (SD = 10.14). Besides zebra mussels, it is quite possible that other factors are influencing the health of fish communities more (MN DNR Fish IBI Program 2018; Adams et al. 2003).

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