Effect of Initial Infestation of Zebra Mussels on Freshwater Drum Diets in Red Lake, MN

Marissa M. Pribyl
Aquatic Biology Program
Biology Department
Bemidji State University

Zebra mussel *Dreissena polymorpha* veligers were first found in the Red Lake system in Beltrami County in 2017, however no adult zebra mussels have been documented. When zebra mussels first invade a system, fish often switch their prey use to this new abundant resource. Freshwater drum *Aplodinotus grunniens* is one of these fish species known to consume physidae and bivalves, including zebra mussels, using pharyngeal teeth, the molar-like grinders in the back of their throats. This research aims to identify any presence of adult zebra mussels in the system and determine freshwater drum diet composition and feeding patterns by analyzing drum stomach contents. Freshwater drum stomachs were extracted, dissected, and preserved to further analyze and document species consumed. No evidence of adult zebra mussels were found in the diets of the freshwater drum collected, suggesting adult zebra mussels are not present in the system. Diets were primarily comprised of Chironomidae, Gastropoda, and Trichoptera. Additionally, feeding behaviors were found to be influenced by location, length of fish, and seasonal changes. These results provide a greater understanding of freshwater drum diet composition and baseline data for Red Lake DNR to use in future research on zebra mussel infestation in the Red Lake system.

Faculty Sponsor: Dr. Andrew W. Hafs

Introduction

Zebra mussels *Dreissena polymorpha*, part of the bivalve class, are native to parts of Eurasia and were first documented in Lake St. Clair, Michigan via ballast water from trans-Atlantic ships. (Bossenbruek et al. 2007). Zebra mussels are an invasive species that consume pelagic food through filter feeding and subsequently transfer this carbon into the benthic zone through feces (Nalepa et al. 1992). Zebra mussel colonization has been shown to cause a decline in phytoplankton and zooplankton populations by >50 % (Nalepa et al. 1992). This decline causes the water to increase in clarity, significantly affecting the surrounding ecosystem (Strayer 2008).

Since zebra mussels first appeared in North America 35 years ago, they have spread rapidly across the United States and have significantly impacted freshwater food webs and biogeochemistry (Strayer 2008). The economic impact of zebra mussels has also been extensive, exceeding $100 million in costs to remove and prevent implications for anglers, a significant component of monetary gain for fishing communities (Strayer 2008). In recent years the spread has slowed, but the most vulnerable freshwater ecosystems remain infested. The invasion is predicted to continue until zebra mussels are present in every system with potential (Strayer 2008).

When zebra mussels invade a new system, numerous molluscivorous fish have been shown to add this new abundant resource to their diets (Magoulick et al. 2009). Studies show blue catfish *Ictalurus furcatus*, freshwater drum *Aplodinotus grunniens*, yellow perch *Perca flavescens*, and adult redear sunfish *Lepomis microlophus* are known to prey on zebra mussels but not frequent enough to affect populations (Magoulick et al. 2009; Morrison et al. 1997). As zebra mussel populations increase, other fish species are likely to become predators (Magoulick et al. 2009).

Freshwater drum are part of the Sciaenidae family, native to parts of the Mississippi Basin and North America (Bur 1984). Although not typically considered a sport fish (Rypel et al. 2021),

freshwater drum are essential as animal food and bait for other species (Bur 1984). Freshwater drum are benthic, spending most of their time at or near the bottom. The freshwater fish spawn once a year in open water during warmer seasons to use warmer temperatures (Swedberg et al. 2011).

Planktonic cladocerans and larval midges (Chironomidae) are the dominant prey source for freshwater drum (Bur 2009). Drum are known to add decapods and pelecypods to their diet as they reach a more considerable length (Bur 2009). Research done in Lake Erie showed freshwater drum consume zebra mussels when reaching a length of 280 millimeters (Morrison et al. 1997). This could be attributed to the relationship between morphological features of prey and their pharyngeal gape increasing in size as length increases. In addition, freshwater drum have pharyngeal teeth in their throat that can aid them in grinding down shells from zebra mussels, snails, crayfish, and clams.

Zebra mussel veligers were first found in the Upper Red Lake system in 2017. However, the Red Lake system has no evidence of zebra mussels surviving to adulthood. For zebra mussel adults to be successful, the bivalves need access to considerable levels of pH and calcium to increase shell hardness and growth (Hincks et al. 1997). In addition, substrates, vegetation, and depth affect zebra mussel colonization. Zebra mussel larvae are dependent on appropriate substrates for survival, and survival tends to be lower in deeper water (Nalepa et al. 1992).

The relationship between freshwater drum and zebra mussels has been investigated since the 1990s after zebra mussels first invaded North America in 1988. Freshwater drum are a top candidate for consuming zebra mussels with the unique attributes of their pharyngeal teeth and gape. Therefore, the objectives of this study are to potentially identify the presence of zebra mussel adults in freshwater drum diets and gain a greater understanding of freshwater drum diet composition and feeding patterns in the Red Lake system.

Methods

The study was conducted in Upper and Lower Red Lake in Red Lake, MN, located in Beltrami County, during July and September 2022. The Red Lake system is one of Minnesota's largest inland lakes totaling 1168.73 km^2. The lake is separated into two sections by a peninsula on the eastern side. Lower Red Lake lies entirely within the Red Lake Indian Reservation, while Upper Red Lake is split between the reservation and Minnesota state territory. The lake system is famous for its walleye population and the area depends on anglers as a significant component of economic gain for the surrounding communities.

Zebra mussel larvae were first found in 2017 in Upper Red Lake using a zooplankton filtration cup by the Red Lake Water Resources Program. Samples were sent to a lab to analyze, where zebra mussel larvae were positively identified. Since 2017, zebra mussel veligers have been sampled in Upper and Lower Red Lake using the same zooplankton tow procedure. The Water Resources Department also used EXO1 sondes with a multiparameter sensor to collect pH levels. The sensors collect pH, optical dissolved oxygen, conductivity, temperature, chlorophyll, and depth. The agency took readings with the sondes at ten locations across Upper and Lower Red Lake.

For this study, five sites were randomly chosen to collect freshwater drum during Red Lake's annual sturgeon and fall surveys (Figure 1). Four sites were selected on Lower Red Lake and the fifth on Upper Red Lake. In July, three gill nets were set in the morning and collected 24 hours later, and two nets were set again in September on both Upper and Lower Red Lake. Two different types of gillnets were used for sampling. In July, horizontal gillnets with large mesh targeting sturgeon were used. For sampling in September, a standard experimental gillnet was used. Both styles of nets consisted of nylon floats and lead core "lead" lines. The nets were brought to a fisheries facility in Red Lake and picked through separating freshwater drum from other species.

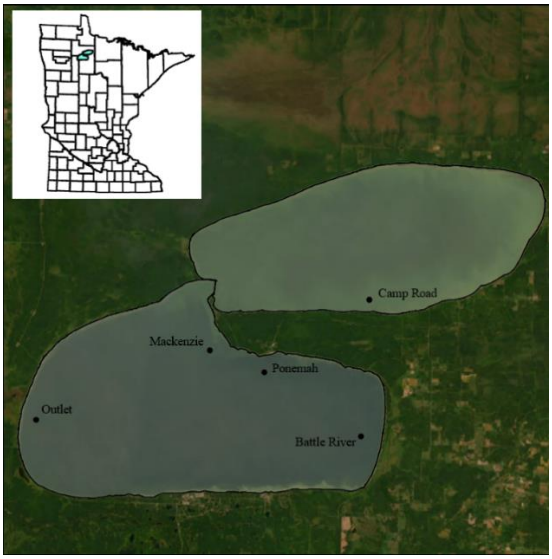

Figure 1. Marked sites where gill nets were set in Upper and Lower Red Lake for sampling and collection of freshwater drum stomachs.

During data collection, information on gear type, location, and length in mm of freshwater drum were recorded on a data sheet. Stomachs were collected through dissection and set aside in the freezer or ethanol stored in sterile whirl paks. A total of 159 freshwater drum stomachs were collected. Each stomach was dissected and evaluated for evidence of zebra mussels. Other diet contents, if present, were identified and counted for diet composition analysis.

Positive samples of zebra mussel veligers were analyzed using a trend line graph in program R to show the occurrence of larvae found in both Upper and Lower Red Lake from 2017 to 2021. Diets were quantified using non-parametric multi-dimensional scaling (NMDS) ordinations to visualize niche size and overlap among freshwater drum diets in both locations and months using prey abundance counts. The metaMDS function in the vegan package (Oksansen et al. 2020) was used to perform multivariate NMDS analysis. From the same package, envfit was used to fit environmental factors onto the ordinations. The ellipse package (Oksansen et al. 2020) was used to create ellipses to aid in visualization of the data. All freshwater drum with at least one diet item were included in data analyses.

Frequency of occurrence and prey-specific abundance were compared to show feeding strategy, relative prey importance, and niche variation based on the distribution of individual prey types (Amundsen et al. 1996; Costello 1990). Frequency of occurrence was calculated by taking the number of individuals that ate each specific prey type divided by the sum of individuals with diets. Prey-specific abundance was calculated for each prey type by dividing the total number of occurrences of the prey type by the total number of items in diets containing that specific prey type. These values were multiplied by 100 to get a percentage for each prey item.

Results

Since 2017, positive veliger samples have gradually increased in selected areas on Upper and Lower Red Lake (Figure 2). However, no adult zebra mussels have been documented. In addition, Water Resources reported historic pH levels for Upper and Lower Red Lake have been between 8.3 and 8.4. Calcium and bicarbonate levels have yet to be sampled on Upper and Lower Red Lake.

No evidence of zebra mussel adults were observed in the freshwater drum diets. Of the stomachs collected, 44.7% were considered empty, and 55.3% contained diets. Chironomidae (65.6%), Gastropoda (16.0%), Trichcoptera (11.8%), Arthropoda (3.2%), unknown vertebrate (1.9%), unknown invertebrate (1.1%), Hirudinae (0.2%), and Anisoptera (0.1%) made up the overall percentages of prey consumed. The niche size for freshwater drum does overlap when considering location and prey category. Although diets in certain sites were distinct, freshwater drum tended to consume similar prey among sampling locations (Figure 3).

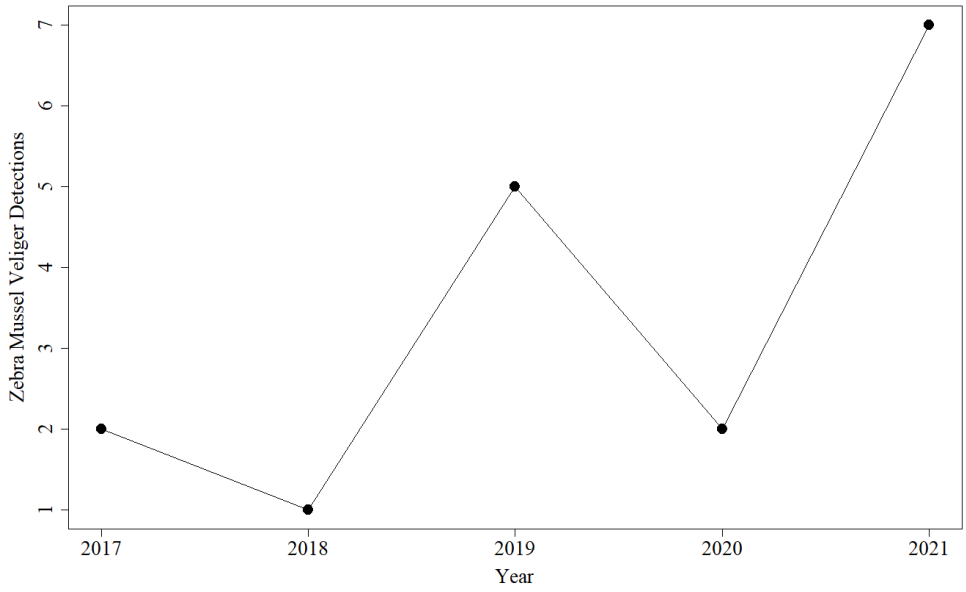

Figure 2. Positive samples of select locations of veliger's collected from 2017-2021 using a line graph. Number of positive samples gradually increases from 2017-2021.

In addition, there is evidence to suggest both length and seasonal changes have an influence on freshwater drum feeding patterns. Larger freshwater drum consumed more Gastropoda, Trichoptera, and Anisoptera, compared to smaller drum which consumed Chironomidae and Arthropoda (Figure 3). NMDS ordinations indicate that freshwater drum diets were different depending on sampling month (Figure 4). In July freshwater drum consumed Trichoptera, Gastropoda, Arthropoda, and Anisoptera. The proportion of Chironomids within the diets of freshwater drum were equal in both July and September. Hirudinae made up a small percentage of diet items consumed in September (Figure 4).

Chironomidae were the dominant prey item present in freshwater drum stomachs, with a frequency of occurrence reaching 62.5 % and a prey-specific abundance of 82.3 % (Figure 5). Gastropoda, Trichoptera, unknown invertebrate, and unknown vertebrate (fish) displayed a high degree of variation between individuals in diet breadth. Arthropoda, Anisoptera, and Hirudinea were rare diet items found in the freshwater drum stomachs (Figure 4). Based upon this data, freshwater drum display a mixed feeding strategy, where some individuals have a specialized diet, and others have a generalized feeding strategy.

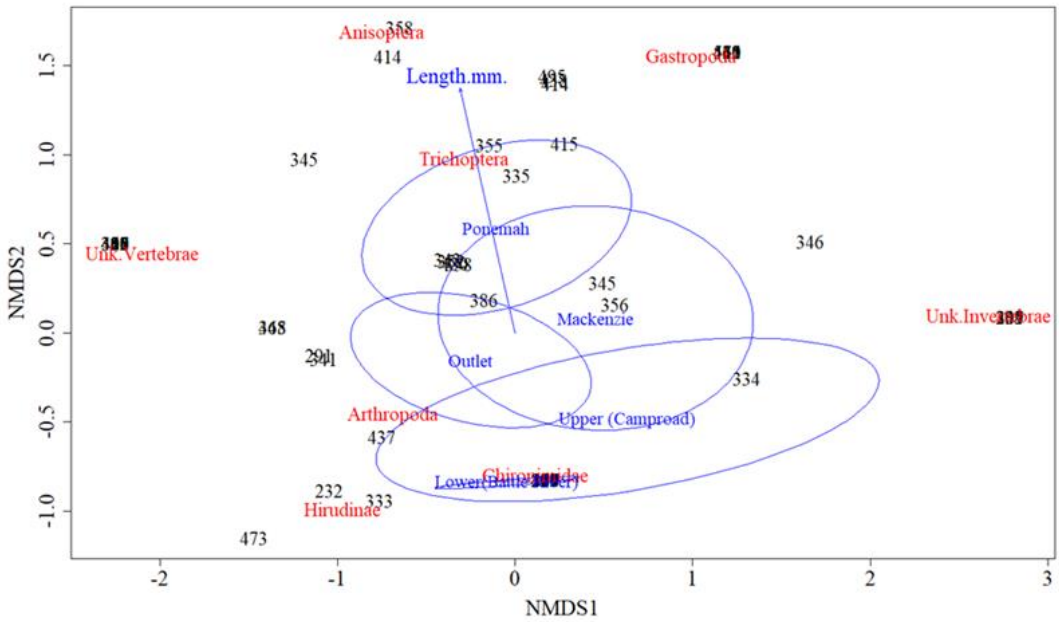

Figure 3. Nonmetric multidimensional scaling (NMDS) ordination of eight sampling plots in five different locations in Upper and Lower Red Lake. Numbers represent length (mm) of freshwater drum collected and the prey items present in those diets using prey abundance counts. Sample plots are prey species labeled Chironomidae, Hirudinae, Gastropoda, Arthropoda, Anisoptera, unknown invertebrate and unknown vertebrate.

Discussion

The recent invasion of zebra mussels in the Red Lake system has caused concern about how it might impact the large ecosystem. Since the first confirmation of zebra mussel veligers in 2017, no adults have been observed. However, the presence of zebra mussel veligers possibly presents a new prey item for freshwater drum, a species known to be molluscivorous (Morrison et al. 1997). Drum have used zebra mussels as a food source but not to the elimination of other prey. However, in Red Lake no presence of adult zebra mussels were documented in the freshwater drum stomachs collected. Data collected in Red Lake corroborates research done in Lake Erie that concluded the dominant prey in freshwater drum diets tend to be Diptera (Chironomidae), Trichoptera, and Gastropoda (Morrison et al. 1997).

Location does not seem to significantly affect freshwater drum diets. However, stomach contents reflect a relationship with length of fish and seasonal changes. In Lake Erie, freshwater drum consumed an extensive amount of zebra mussels in May and July compared to other months (Morrison et al. 1997). In Red Lake during July, drum consumed a higher proportion of Gastropoda and Trichoptera compared to September, yet chironomidae were extensively eaten in both July and September.

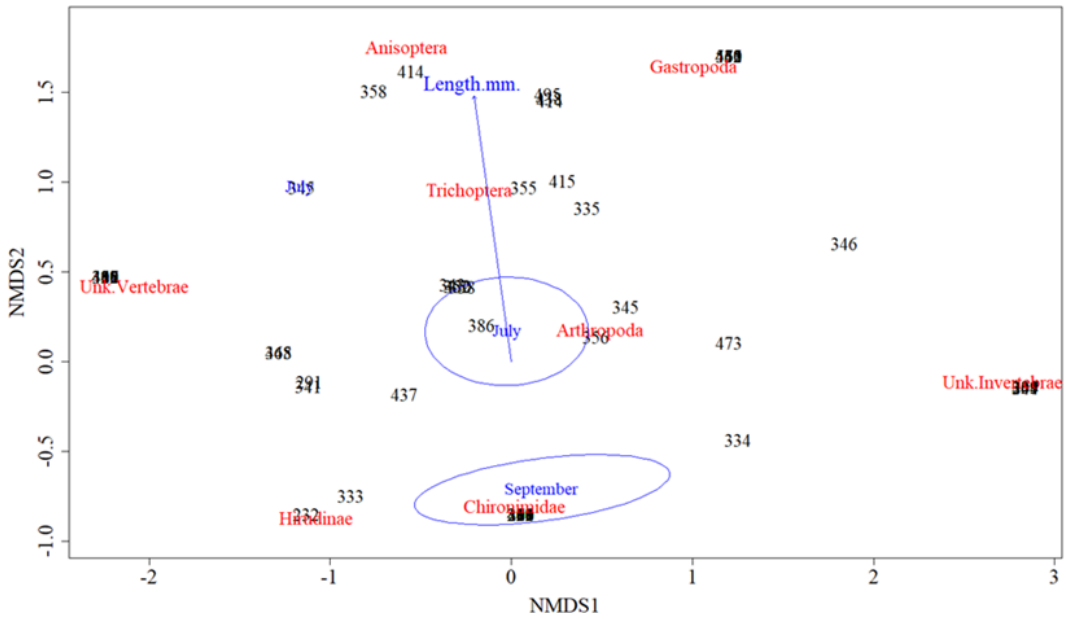

Figure 4. Nonmetric multidimensional scaling (NMDS) ordination of eight sampling plots in July and September where stomachs were extracted from freshwater drum for diet analysis. Numbers represent length (mm) of freshwater drum collected and the prey items present in those diets using prey abundance counts. Sample plots are prey species labeled Chironomidae, Hirudinae, Gastropoda, Arthropoda, Anisoptera, unknown invertebrate and unknown vertebrate.

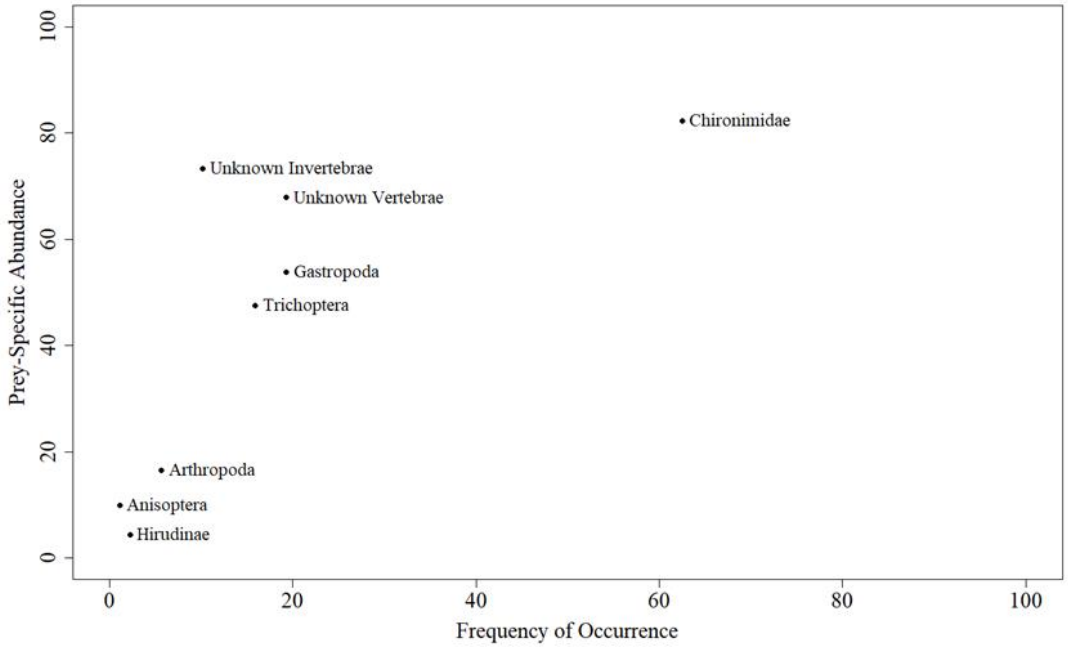

Figure 5. Each point represents a different prey type and is expressed as prey-specific abundance plotted against frequency of occurrence (Admundsen et al. 1996). Chironomids being the dominant prey, unknown invertebrae, unknown vertebrae, Gastropoda and Trichoptera being high prey between individuals and Arthropoda, Anisoptera and Hirudinae specfied as rare prey.

When investigating the effect of size on diet, French and Burr (1993) found that freshwater drum that are less than 375 mm in length do not feed on zebra mussels. It is then notable that, in Red Lake, larger drum consumed more Gastropoda, Trichoptera, and Anisoptera, whereas the smaller

drum consumed more Chironomids, and Arthropoda suggesting a potential for zebra mussel consumption by freshwater drum to differ by length if adult zebra mussels become present in the system.

Adult zebra mussel mortality is significantly related with calcium and pH levels of the aquatic system (Hincks et al. 1997). When calcium and pH levels are low, growth and hardening of adult zebra mussel shells is inhibited. In Red Lake, calcium or bicarbonate levels have not been sampled, however, pH levels historically range from 8.3 to 8.4. Growth and proliferation of juvenile zebra mussels only occurred at pH levels greater than 8.3, suggesting pH may be a limiting factor in their growth in the Red Lake system (Hincks et al. 1997).

Substrate type, depth, and vegetation presence can also influence the survival of zebra mussels. The lake substrate in Upper and Lower Red Lake is comprised mostly of clay and softer materials with rock and cobble present in some areas along the shoreline. In addition, Red Lake only reaches a maximum depth of 4.6 meters. Zebra mussels that settle on substrates other than stones, plants, and colonies of existing zebra mussels have a limited chance of survival (Nalepa et al. 1992). When zebra mussels colonize on sand and mud in shallow water during ice-on, the mussels can die due to exposure (Nalepa et al. 1992). Consequently, depth and substrate type in Upper and Lower Red Lake could attribute to the absence of adult zebra mussel colonization.

Similar to ongoing monitoring efforts on the Red Lakes, adult zebra mussels were not detected in freshwater drum diets, further suggesting physical characteristics of the system may be hindering the expansion of the zebra mussel population. Research provided by this study provides the Red Lake DNR with baseline data on the relationship between freshwater drum and zebra mussels. These results also provide the agency with insight into the diet composition and feeding behavior of freshwater drums present in the Red Lake system.

References

Amundsen, P.A., H.M. Gabler, and F.J. Staldvik. 1996. A new approach to graphical analysis of feeding strategy from stomach contents data-modification of the Costello (1990) method. Journal of Fish Biology 48:607-614.

Bossenbruek, J.M., L.E. Johnson, B. Peters, and D.M. Lodge. 2007. Forecasting the expansion of zebra mussels in the United States. Conservation Biology 21:800-810.

French III, J.R.P. and M.T. Bur. 1996. The effect of zebra mussel consumption on growth of freshwater drum in Lake Erie. Journal of Freshwater Ecology 11:283-289.

Hincks, S.S. and G.L. Mackie. 1997. Effects of pH, calcium, alkalinity, hardness, and chlorophyll on the survival, growth, and reproductive success of zebra mussel (*Dreissena polymorpha*) in Ontario lakes. Canadian Journal of Fisheries and Aquatic Sciences 54:2049-2057.

Magoulick, D.D. and L.C. Lewis. 2002. Predation on exotic zebra mussels by native fishes: effects on predator and prey. Freshwater Biology 47:1908-1918.

Morrison, T.W., W.E. Lynch Jr., and K. Dabrowski. 2021**.** Predation on zebra mussels by freshwater drum and yellow perch in Western Lake Erie. Journal of Great Lakes Research 23:177-189.

Nalepa, T.F. and D.W. Schloesser, eds. 1992. Zebra mussels' biology, impacts, and control. CRC Press.

Rypel, A.L., P. Saffarinia, C.C. Vaughn, L. Nesper, K. O'Reilly, C.A. Parisek, M.L. Miller, P.B. Moyle, N.A. Fangue, M. Bell-Tilcock, and D. Ayers. 2021. Goodbye to "rough fish": paradigm shift in the conservation of native fishes. Fisheries 46:605-616.

Strayer, D.L. 2008. Twenty years of zebra mussels: lessons from the mollusk that made headlines. Frontiers in Ecology and the Environment 7:135-141.

Swedberg, D.V. and C.H. Walburg. 1970. Spawning and early life history of the freshwater drum in Lewis and Clark Lake, Missouri River. Transactions of the American Fisheries Society 99:560-570.