2022

Research Brief on Invasive Water Species

Labib Tahmid Alam
University of Wisconsin - Milwaukee, ltalam@uwm.edu

2022

RESEARCH BRIEF ON INVASIVE WATER SPECIES STUDIES

Labib Tahmid Alam

University of Wisconsin - Milwaukee, ltalam@uwm.edu

Research Brief on Invasive Water Species Studies

Introduction

The following is a paper on invasive species in the waters of Milwaukee. Our lakes and rivers provide so much. They are home to countless fish and aquatic species. They give us recreation, beauty, and a place to get away. But nature does not have it so easy these days. The lakes and rivers are facing one of their biggest challenges yet: **Invasive Species**. An invasive species can be any kind of living organism—an amphibian (such as the cane toad), plant, insect, fish, fungus, bacteria, or even an organism's seeds or eggs—that is not native to an ecosystem and causes harm. They can harm the environment, the economy, or even human health. Species that grow and reproduce quickly, and spread aggressively, with potential to cause harm, are given the label "invasive" Most invasive species have come from Europe or Asia, largely by accident but sometimes on purpose. Ships can carry aquatic organisms in their ballast water, while smaller boats may carry them on their propellers. The quagga and zebra mussels blanketing the bottom of the Great Lakes filter water as they eat plankton and have succeeded in doubling water clarity during the past decade. Clear water may look nice to us, but the lack of plankton floating in the water means less food for native fish. Clearer water also allows sunlight to penetrate to the lake bottom, creating ideal conditions for algae to grow. In this way, zebra and quagga mussels have promoted the growth and spread of deadly algae blooms. Zebra mussels and quagga mussels are virtually identical, both physically and behaviorally. In this paper we are introducing some research conducted relating to the Mussels and their influence on the food web and chemical imbalance in Lake Michigan.

Background

In the late 1980s, two invading bivalve mollusks, the zebra, and quagga mussel, became established in the Great Lakes and have since spread into a wide range of habitats in all five lakes. The zebra mussel expanded rapidly and reached greatest abundances in shallow, nearshore regions, and bays; quagga mussels expanded more systematically but over time have become abundant in both nearshore and offshore regions. Originally from Eastern Europe, these tiny trespassers were picked up in the ballast water of ocean-going ships and brought to the Great Lakes in the 1980s. They spread dramatically, outcompeting native species for food and habitat, and by 1990, zebra mussels and quagga mussels had infested all the Great Lakes. Now both quagga mussels and zebra mussels have spread to 29 states by hitching rides on boats moving between the Great Lakes and Mississippi River Basins. Artificial channels such as the Chicago Area Waterways System facilitate their spread. The capacity of both species to filter large volumes of water, assimilate suspended material, and excrete nutrients has caused broad scale and fundamental changes in the cycling of energy and nutrients through the Great Lakes system. Zebra and quagga mussels harm native fish populations, ruin beaches and attach to boats, water intake pipes, and other structures, causing the Great Lakes economy billions of dollars a year in damage. They devastate native species by stripping the food web of plankton, which has a cascading effect throughout the ecosystem. Lack of food has caused populations of alewives, salmon, whitefish, and native mussel species to plummet. (Nalepa, 2010)

Quagga Mussels' influence on chemical imbalance in Lake Michigan

The Carbon Dynamics of Lake Michigan

In a study Conducted in 2016 Stephen E. DeVilbiss and Laodong Guo at the School of Freshwater Sciences, University of Wisconsin Milwaukee, i) examine filtration rates and retention efficiency of macromolecular organic matter by invasive quagga mussels using model compounds and/or nanoparticles; ii) determine the excretion/egestion rates of DOM (Dissolved Organic Matter) by quagga mussels through incubation experiments; iii) characterize the size spectrum and organic composition of excreted-DOM from quagga mussels; and iv) provide insights into a better understanding of the role of invasive quagga mussels in regulating the carbon dynamics in the Great Lakes.

Since colonizing Lake Michigan, quagga mussels have caused extraordinary biological and environmental changes, including a drop in primary production and fish biomass, rising water clarity, food web adjustments, and carbon and nutrient cycling changes. Quagga mussels couple benthic and pelagic systems by filtering phytoplankton and zooplankton and excreting/ingesting nutrients in the benthos. Quagga mussels excrete particulate and soluble inorganic and organic phosphorus, ammonia, and increase benthic oxygen demand. Carbohydrate composition of excreted DOM As shown in **Fig. a**, the majority of excreted DOM, or 78% of the bulk DOC, consisted of carbohydrates after the 48-h excretion experiment. Within the total dissolved CHO pool (**Fig. b**), polysaccharides including acid-hydrolysable and acid-resistant PCHO dominated with 60% HR-PCHO and 24% HCl-PCHO. Monosaccharides made up 16% of the dissolved CHO pool, suggesting they are more metabolically significant or easily digested by quagga mussels. PCHO, especially HR-PCHO, which is primarily structural CHO, may be difficult for quagga mussels to digest, leading in significant excreted-DOM.

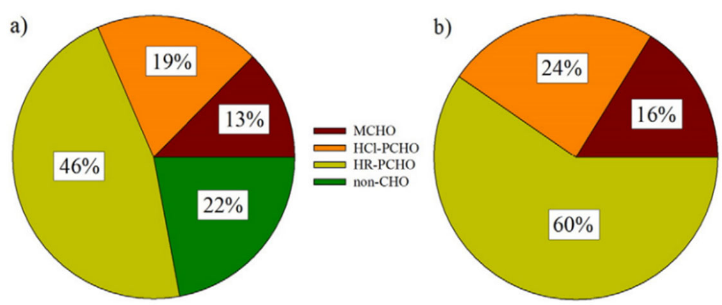

Figure 1: Percent composition of carbohydrates in Bulk DOC a) before and b) after 48 hours excretion by quagga mussels

In their research, DeVilbiss and Guo used mass specific DOC excretion rates for each mussel size class to predict annual DOC excretion in southern Lake Michigan to compare to current data and develop a broad sense of the possible effects of quagga mussels on the Lake Michigan ecosystem. Mussel densities and size distributions in depth classes 0–15 m, 16–30 m, 31–50 m, 51–90 m, and N90 m were utilized to derive areal DOC fluxes (inmol-C/m2/d), which were integrated across the southern basin of Lake Michigan and extrapolated to one year. 5.9 107 kg C/y of DOC was excreted in the southern basin, accounting for 4% of total OC consumption in southern Lake Michigan assessed using dissolved O2 consumption. 96% of eaten OC would be respired as CO2, egested as feces/pseudofeces, converted to biomass, or allocated to reproduction, indicating a loss of OC from the water column. Similarly, POC egestion accounts for just 8% (1.0 104 kg C/y) of ingested organic matter. This shows most absorbed OC may be respired as CO2, supporting high absorption efficiencies that allow quagga mussels to live under low food conditions in open

Lake Michigan. These estimates confirm quagga mussels can be a major sink for OC but a source for CO_2 in Lake Michigan. High OC absorption and CO_2 release by benthic quagga mussels are consistent with changes in CO_2 dynamics in Lake Michigan after invasive mussel colonization. By metabolizing and respiring most of their OC intake, invasive quagga mussels may have disrupted carbon dynamics in the water column.

The Methylmercury production in Lake Michigan

In a study conducted in 2014 Ryan F. Lepak and David P. et al. at the University of Wisconsin-Madison identify the sites with high density of quagga mussel beds. They collected samples to conduct experiments and find out the influence of quagga mussels in methylmercury production. Recent invasive mussel growth in Lake Michigan has disrupted nearshore primary production, leading to green algae blooms (cladophora glomerata). Cladophora and quagga mussel assemblages and sloughed cladophora increase MeHg production. A river mouth coastal transect through quagga-rich zones exhibited elevated MeHg concentrations despite river dilution. Cladophora, as primary producers, had 0.6 to 7.5 ng g1 MeHg, higher than offshore seston. In decaying cladophora accumulating onshore, MeHg concentrations ranged from 2.6 to 18.0 ng g1 and from 0.1 to 3.0 ng g1 in a nearshore topographical depression. Nearshore quagga mussels had more MeHg than offshore mussels. Recent changes in nearshore primary production lead to Lake Michigan MeHg generation and bioaccumulation.

Due to their great filtration capacity, quagga mussels are bioindicators of bio accumulative pollutants. Some fish eat quagga mussels, hence MeHg-rich locations may have more predators. Nearshore epiphytes, cladophora, and phytoplankton are all consumed by quagga mussels. They probably consume decomposing and settling phytoplankton in offshore regions during thermal stratification. The tissue composites of nearshore quagga mussels are higher than those of offshore mussels because they inhabit dense Cladophora beds. Quagga mussels' influence on primary production and nearshore organic matter cycling led to additional Lake Michigan MeHg production sites. "Nearshore shunt" organic matter and nutrients promote lake MeHg production. After senescence, Cladophora biomass builds up in nearshore zones and decomposes, releasing MeHg. If nearshore and offshore primary production migrates to the benthos, Lake Michigan's food web will get more MeHg. Quagga-cladophora assemblages will have greater MeHg concentrations. So, this research tells us how Invasive mussels have modified Lake Michigan's productivity distribution, creating a mercury bioaccumulation zone. Offshore Lake Michigan MeHg is low. Understanding MeHg dynamics and nearshore methylation enhancement relative to offshore processes is key to understanding whole-lake Hg bioaccumulation.

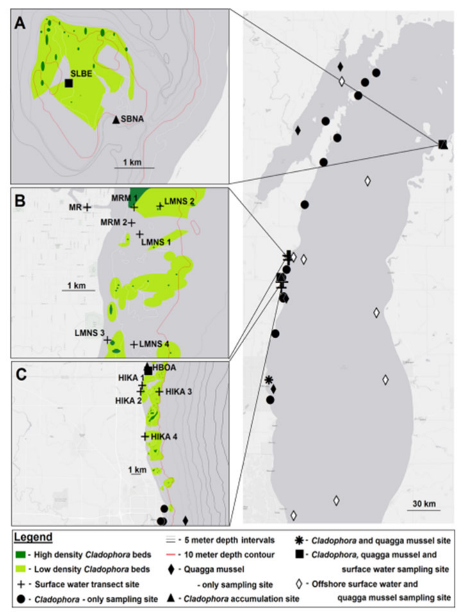

Figure 2: Study sites on Lake Michigan. Insets A and B detail sites sampled during nearshore transect sampling and at the onshore accumulation site at Hika Bay (HBOA). Inset C identifies sites at the nearshore accumulation site (SBNA) near Sleeping Bear Dunes. Cladophora intensity was translated from Michigan Technological Research Institute's Satellite Derived Submerged Aquatic Vegetation (SAV) Map.

The Phosphorus Circulation in Lake Michigan

Something else was also happening in the 1980s—farmers surrounding the Great Lakes were pouring massive amounts of fertilizer into their soil. One of the ingredients in the fertilizer was phosphorous, which was making its way into the Great Lakes via rivers and streams. The addition of the phosphorous into the water led to algae blooms, which, besides being unsightly, led to fish die-offs. Once the problem was recognized, governments began restricting the use of fertilizers containing phosphorous, but the algae blooms did not recede. The researchers with this new effort found that the reason the algae was not diminishing was because the phosphorous that had already been dumped into the lakes was still present. They found the quagga mussels had been recirculating it, preventing it from being buried in lakebed sediment. Their model also showed that due to their huge numbers, quagga mussels have become the dominant regulator of phosphorus cycling in the lower four Great Lakes (Yirka 2021).

A master's thesis submitted by Rae-Ann MacLellan-Hurd at the school of freshwater sciences at UWM discusses the circulation of phosphorus in Lake Michigan: "quagga mussel induced phosphorus cycling changes in lake Michigan."(Rae-Ann MacLellan-Hurd, 2020) Since the spread of mussels in Lake Michigan, there has been limited study of changes to internal phosphorus loading despite documented alterations in physical and chemical processes, including the absence of calcite whiting events, decreased nepheloid layer, and increased benthos nutrient retention. This study assesses internal phosphorus loading at two sites: one with high mussel density and one with considerable deposition. Total phosphorus burial rates are similar to those of the 1980s, indicating a decrease in water column phosphorus residence time. 60% of phosphorus is recycled through sediment-water interaction. Apatite-bound phosphorus sank dissolved phosphorus at the shallower site and provided it at the deeper site. By merging sediment and mussel fluxes, a new model of internal phosphorus cycling in Lake Michigan was produced. Heterotrophic bacteria dominate benthos phosphorus cycling role. Invading dreissenid mussels changed ecological functions such as nitrogen cycling in the 1980s. No research has evaluated sediment phosphorus regeneration since quagga mussels spread into Lake Michigan's depths. A hypothetical model was created to depict the effect of dreissenid mussels on the Lake Michigan P cycle (**Fig. 3**). The post-mussels conceptual model shows that mussels have considerably boosted the benthos' role as a P recycling site.

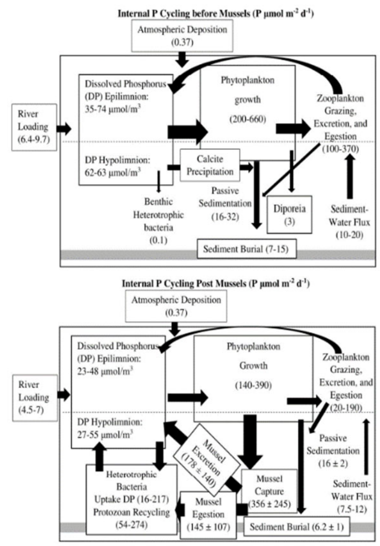

Figure 3: Conceptual model of phosphorus cycling at a 55-meter site before and after the establishment of dreissenid mussels. Components of the model are described in the text.

This study examined mussel effects on phosphorus internal loading at two sites with high mussel densities (55m) and high deposition rates (100m). Both locations recycled P-rich sediments. Apatite reduced P at 55m. P was provided at 100 meters by apatite dissolution or conversion. Dissolved phosphorus increases apatite adsorption/precipitation. Mussels dominate nearshore Milwaukee phosphorus. Mid-depth Muskegon receives more nutrients and phytoplankton than nearshore. This location may be a nearshore and mid-depth nutrient sink, decreasing offshore transmission. Mussels in the region excrete more phosphorus than in the Milwaukee River, contributing to the resurgence of Nuisance Cladophora. Incubations show heterotrophic bacteria eat offshore phosphorus. Mussels increase bacteria, affecting phosphorus cycle. Mussels may affect apatite dissolution; however, phosphorus burial rates remained the same despite decreased P concentrations and a shorter residence time of 3.2 years. Mussels filter smaller particles with longer residence periods to settle phosphorus.

Food Web and Diet Complexity of Lake Michigan

Diet complexity of Lake Michigan

The research article published in 2020 by Benjamin S. Leonhardt et al, “Diet complexity of Lake Michigan Salmonines: 2015–2016” gives us a better insight about the diet complexity of Lake Michigan. In Lake Michigan, invasive species, for example, zebra mussels, quagga mussels, round goby and reduced nutrient input have affected nutrient dynamics, system productivity, and community composition. These factors, along with prolonged predation pressure, have contributed to the collapse of several forage fish species, notably alewife (Alosa pseudoharengus), which has dominated the diets of Lake Michigan's five salmonid species for 50 years. If alewife decreases continue, salmonines with rigid diets may struggle. They studied salmonid stomach contents from Lake Michigan's main basin in 2015 and 2016 to determine diet composition, diversity, and alewife length consumption. Chinook salmon primarily ate alewife, whereas the other four species also ate round goby aquatic and terrestrial invertebrates. Although patio-temporal feeding trends occurred, most meal composition and diversity were individual. Salmon populations ate all sizes of alewife, but individual stomachs contained a small range. Due to their dependency on alewife, Chinook salmon may be more badly affected than other salmonine species if alewife abundance in Lake Michigan declines.

Invasive species including dreissenid mussels, predatory cladoceras, and round goby have changed Lake Michigan's food web dramatically in the past two decades. Lowered nutrient loading and strong filtering by dreissenid mussels have reduced offshore output. Invasive predatory cladoceras have had a major influence on Great Lakes zooplankton populations, with smaller species dominating. Amphipods, a key prey for lake invertebrates, are nearly extinct. In the absence of energy-rich prey, invertivores have used lower energy prey, causing alewifes to lose condition. Populations of alewife, bloater, rainbow smelt, slimy sculpin, and Deepwater sculpin have plummeted since the early 2000s. Nearshore habitats feature high numbers of benthic invertebrates due to the sequestration of nutrients and greater water clarity by dreissenid mussels. High round goby concentrations in many nearshore regions may limit food and cover for other benthic fishes. Because round goby prefers rough soils, densities are hard to estimate. Collectively, these changes have enhanced the importance of nearshore trophic routes in Lake Michigan and may have limited pelagic prey available to higher food webs.

Changes in the Lake Michigan Food Web

The expansion of quagga mussel populations into deeper waters, which began around 2004, lowered phytoplankton abundance and primary output by 35% by 2007. Nearshore primary output presumably dropped due to the quagga mussel's predatory effects. The fall in Diporeia abundance in Lake Michigan throughout the 1990s and 2000s has been related to dreissenid mussels, although the specific process remains unexplained. In a 2015 scientific publication, Charles P. Madenjian et al. describe how the Quagga

Mussel Invasion in Lake Michigan affects different species. Annual primary output in Lake Michigan's offshore waters declined by 35% between 1983–1987 and 2007–2008 due to quagga mussels' spring filtration. During spring isotherms, quagga mussels may filter the whole water column. Diporeia numbers in Lake Michigan declined drastically from 1994–2005, but quagga mussels increased rapidly from 2000–2010. (**Fig. 4**). The processes by which dreissenid mussels may have reduced Diporeia abundance are unknown. In the southern basin, quagga mussel biomass density was highest in the 31–50 m depth range and reached N40 g/m2 by 2008, then fell somewhat throughout 2008–2010.

The negative effect of mussels on primary production has led some ecologists to consider dreissenid mussel invasions as triggering bottom-up effects throughout the food web. However, alterations in the Lake Michigan food web following the invasions were inconsistent with classic bottom-up theories. According to this theory, a fall in primary output would reduce the population biomass of first-order consumers, second-order consumers, and apex predators of the food web. After dreissenid mussel invasions, Lake Michigan's primary production fell due to quagga mussel grazing. More research is needed to detect and quantify the consequences of dreissenid mussel invasions on Lake Michigan's food web, including some fish species. These populations must be monitored to meet research demands. In some circumstances, survey effort or new monitoring techniques may be needed to improve lake-wide estimates of population abundance or biomass. Deepwater sculpins in Lake Michigan may have relocated recently. The quagga mussel proliferation may have sparked this movement. Bloaters may have shifted to deeper waters because of quagga mussels. To get more accurate lake-wide biomass estimates, the bottom trawl survey must be expanded to deeper waters and the effect of increased water clarity must be recognized.

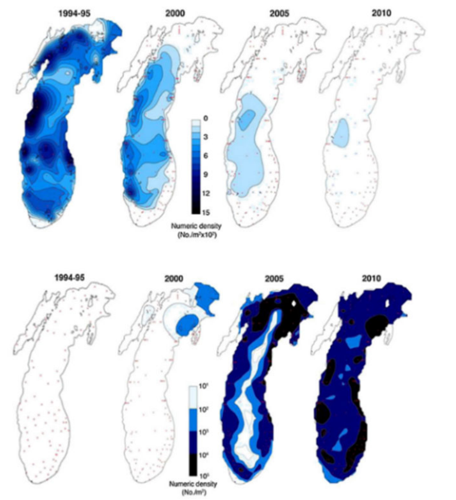

Figure 4: Changes in Diporeia numeric density in Lake Michigan during 1994–2010 (upper panel) and in quagga mussel numeric density in Lake Michigan during 1994–2010 (lower panel). Note difference in numeric scales between the panels. This figure was modified from one presented by Nalepa et al. (2014b).

Discussion

The Great Lakes' quagga and zebra mussel invasions were explored in this white paper. It is essential to remember that anything that occurs in Lake Michigan affects Milwaukee's rivers. Likewise, dreissenid mussels infest the rivers of Milwaukee. This article explains how mussels have generated a chemical imbalance in the waters. The first section shows how the invasive quagga mussel's ability to ingest and exhale organic carbon (OC) has altered carbon dynamics in the water column. The next section explains how mussels promote Cladophora growth. Cladophora biomass decomposes nearshore, releasing MeHg. If nearshore and offshore primary production shifts to the benthos, Lake Michigan's MeHg contribution will rise. The third research shows that heterotrophic bacteria can use offshore-released phosphorus. By generating bacteria, mussels have an indirect effect on the phosphorus cycle. In addition to humans, high quantities of phosphorus in the water can poison fish and other species. Furthermore, we discuss the Lake Michigan diet's complexity. Invasive species like dreissenid mussels, Cladocera, and round goby have changed Lake Michigan's food web. Offshore output is inversely related to nutrient input, and dreissenid mussel filtering has shifted offshore pelagic production to nearshore benthic pathways. Since dreissenid mussel invasions, Lake Michigan's principal production has reduced due to quagga mussel grazing management. More research is needed to detect and quantify the consequences of dreissenid mussel invasions on Lake Michigan's food web, particularly fish populations.

Works Cited

Introduction and Background

“Invasive Species.” National Wildlife Federation, https://www.nwf.org/Educational-Resources/Wildlife-Guide/Threats-to-Wildlife/Invasive-Species#:~:text=Invasive%20species%20are%20primarily%20spread,carry%20them%20on%20their%20propellers

Nalepa, Thomas F., et al. “Recent Changes in Density, Biomass, Recruitment, Size Structure, and Nutritional State of Dreissena Populations in Southern Lake Michigan.” Journal of Great Lakes Research, vol. 36, no. SP3, 2010, pp. 5–19, https://doi.org/10.1016/j.jglr.2010.03.013

The Main Sources

DeVilbiss, Stephen E., and Laodong Guo. “Excretion of Organic Matter and Nutrients from Invasive Quagga Mussels and Potential Impact on Carbon Dynamics in Lake Michigan.” Journal of Great Lakes Research, vol. 43, no. 3, 2017, pp. 79–89, https://doi.org/10.1016/j.jglr.2017.03.002

Lepak, Ryan F., et al. “Influence of Cladophora-Quagga Mussel Assemblages on Nearshore Methylmercury Production in Lake Michigan.” Environmental Science & Technology, vol. 49, no. 13, 2015, pp. 7606–13, https://doi.org/10.1021/es506253v

Leonhardt, Benjamin S., et al. “Diet Complexity of Lake Michigan Salmonines: 2015–2016.” Journal of Great Lakes Research, vol. 46, no. 4, 2020, pp. 1044–57, https://doi.org/10.1016/j.jglr.2020.05.010

MacLellan-Hurd, Rae-Ann. Quagga Mussel Induced Phosphorus Cycling Changes in Lake Michigan. UWM Digital Commons. https://wisconsin-uwm.primo.exlibrisgroup.com/permalink/01UWI_ML/13nukll/alma991013082489402124

Madenjian, Charles P., et al. “Changes in the Lake Michigan Food Web Following Dreissenid Mussel Invasions: A Synthesis.” Journal of Great Lakes Research, vol. 41, 2015, pp. 217–31, https://doi.org/10.1016/j.jglr.2015.08.009

Yirka, Bob. “Quagga Mussel Found to Be Primary Regulator of Phosphorus Cycling in Lower Four Great Lakes.” Phys.org, Phys.org, 26 Jan. 2021, https://phys.org/news/2021-01-quagga-mussel-primary-phosphorus-great.html#:~:text=Their%20model%20also%20showed%20that%20due%20to%20their,10%2C100%20per%20m%202.%20Credit%3A%20John%20A.%20Zalusky

Further Reading

Durlak, Mary A. “The Importance of Understanding the Interactions of Invasive Species and Native Species.” Phys.org, Phys.org, 15 Dec. 2014, https://phys.org/news/2014-12-importance-interactions-invasive-species-native.html

“Freshwater Research; Study Results from University of Wisconsin in the Area of Freshwater Research Reported [Phosphorus Recycling by Profunda Quagga Mussels (Dreissena Rostriformis Bugensis) in Lake Michigan].” Ecology, Environment & Conservation (Atlanta, Ga.), 2016, p. 1018–. https://wisconsin-uwm.primo.exlibrisgroup.com/permalink/01UWI_ML/1c042gi/cdi_proquest_wirefeeds_1758587576

Lin, Peng, and Laodong Guo. “Do Invasive Quagga Mussels Alter CO2 Dynamics in the Laurentian Great Lakes?” Scientific Reports, vol. 6, no. 1, 2016, pp. 39078–39078, https://doi.org/10.1038/srep39078

"New Freshwater Research Study Results Reported from UNESCO." Ecology, Environment & Conservation, 18 Nov. 2011, p. 109. Gale Academic OneFile, link.gale.com/apps/doc/A272846514/AONE?u=milwaukee&sid=bookmark-AONE&xid=91e7992a

Winn-Ritzenberg, Noah, et al. Great Lakes Aquatic Invasive Species and Their Impacts on Milwaukee: A Policy Framework. 2010.
https://wisconsin-uwm.primo.exlibrisgroup.com/permalink/01UWI_ML/13nukll/alma991022644593102122