(Image credit: G. Paterson)

Michigan Sea Grant Project Final Narrative Report

Project Title: A novel method for quantifying dreissenid veliger energetic contributions to Lake Huron zooplankton communities

Project Investigators: Gordon Paterson, Michigan Technological University
Trista Vick-Majors, Michigan Technological University
Jill Olin, Michigan Technological University
James Junker, University of North Texas.

Section A: Summary

Project Title: A novel method for quantifying dreissenid veliger energetic contributions to Lake Huron zooplankton communities

Completion Date: December 31, 2024

Principal Investigator: Dr. Gordon Paterson

1) **Title & Position:** Assistant Professor
2) **Institution:** Michigan Technological University, Dept. of Biological Sciences
3) **Postal Mailing Address:** 1400 Townsend Drive, Houghton, Michigan 49931
4) **Email Address:** gpaterso@mtu.edu
5) **Telephone number:** 1-906-487-1120

Co-Investigators:

Dr. Trista J. Vick-Majors, Michigan Technological University, Dept. of Biological Sciences, 1400 Townsend Drive, Houghton, Michigan, 49931 906-487-1848, tjvickma@mtu.edu

Dr. Jill A. Olin, Michigan Technological University, Dept. of Biological Sciences, 1400 Townsend Drive, Houghton, Michigan 49931; 906-487-1121, jaolin@mtu.edu

Dr. James R. Junker, University of North Texas, Dept. of Biological Sciences, 1155 Union Circle, Denton, Texas, 940-369-5077; James.Junker@unt.edu

Abstract

The introduction and establishment of dreissenid species including zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels into the Laurentian Great Lakes has resulted in significant biological and ecological change over the past 30 years. Much of the dreissenid mussel research in the Great Lakes to date has focused on the adult life stages with less known about the larval veliger form. The goals of this project were to; i) investigate veliger energy densities and fatty acid profiles to compare and contrast these nutritional metrics against crustacean zooplankton and; ii) determine the fate of veliger carbon within zooplankton and bacterioplankton communities of Saginaw Bay, Lake Huron. Energy densities of veligers collected from Lake Huron's Saginaw Bay region averaged 1.49 ± 0.2 kJ/g and were approximately 21% lower relative to values determined for 64 – 150, 150 – 250, and > 250 µm zooplankton size fractions. Fatty acid profiles demonstrated veligers to have lower concentrations of α-linolenic and eicosapentaenoic essential fatty acids and lower unsaturation indices and n-3:n-6 quality indicators relative to zooplankton size fractions. Results of ^{14}C labeling experiments demonstrated uptake of veliger derived organic carbon by zooplankton and bacterioplankton but suggest that the predominance of veliger carbon is recycled into the dissolved organic phase. These results provide baseline information regarding the nutritional quality of veligers and help describe the fate of veliger production within the lower trophic levels of Lake Huron's Saginaw Bay.

Keywords: Energy density, fatty acids, quality, trophic transfer, zooplankton

Executive Summary: Invasive zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels have been highly successful invaders throughout the Michigan waters of Lakes Erie, Huron and Michigan. The biological and ecological impacts of the adult life stages of these species are well-established and include increased water clarity and aquatic plant growth, colonization of bottom habitats, and fouling of infrastructure and municipal and industrial water intakes. Mature adult mussels can also release up to 1 million larvae, known as veligers, that also pose potential risk to Great Lakes aquatic communities. For example, veligers have potentially replaced the biomass of small aquatic invertebrates that represent important prey and nutritional resources for juvenile fish species such as yellow perch and walleye. In this project, we measured the fatty acid and energy contents of veligers collected from Lake Huron's Saginaw Baw to provide estimates of their quality as a food resource for potential predators. We also used a radio-isotope tracer method to determine the extent to which veligers are consumed by invertebrate predators to understand how they may contribute to energy and nutrient transfer in a Great Lakes food web.

Fatty acid and energy density measurements demonstrated veligers to be of lower nutritional quality relative to similarly sized and larger natural aquatic invertebrate species from Saginaw Bay. Energy density comparisons demonstrated that veligers contain approximately 20% less food energy relative to crustacean zooplankton including the similarly sized invertebrates that veligers have replaced in Great Lakes food webs. Fatty acid analyses demonstrated veligers to have lower proportions of essential omega-3 compounds such as α-linolenic and eicosapentaenoic that are required for the normal growth and development of higher order consumer species including fishes. Our ^{14}C radio-isotope tracer experiments demonstrated that veliger biomass is consumed by but only minimally assimilated among invertebrate predators but with much of their biomass being recycled into dissolved organic carbon. Further, veligers were estimated to constitute > 75% of the planktonic invertebrate biomass in the size range from 64 – 150 µm in Saginaw Bay. Thus, the limited transfer of such substantial veliger biomass to higher order consumers represents a potentially significant bottleneck for energy availability in invaded ecosystems with abundant dreissenid mussels.

This project provides necessary data on the nutritional quality of dreissenid veligers as a potential food resource for Great Lakes invertebrate and fish predators and improves our understanding of their limited contributions to energy transfer in the Saginaw Bay food web. Specifically, these estimates of veliger dietary contributions and trophic linkages will help inform Michigan's Great Lakes managers toward forecasting, decision making strategies, and resource management approaches.

Section B: Accomplishments

Introduction: Dreissenid species including zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels have been highly successful invaders throughout the Michigan waters of Lakes Erie, Huron and Michigan (Schloesser & Nalepa 1994; Nalepa et al. 2007; 2009). While the role of adult mussels has been well quantified in terms of their capacities for ecosystem engineering and redirection of energy and nutrients through the benthos (Hecky et al. 2004), little is known regarding the ecological and energetic contributions of dreissenid veligers (herein veligers) to Great Lakes food webs. In recent years, Lake Huron's lower trophic levels have experienced significant ecological changes including a decline to ultra-oligotrophic status (Barbiero et al. 2011; Cha et al. 2011), reduced early season primary productivity, a shift to oligotrophic species in the zooplankton community (Barbiero et al. 2012), and lowered energy densities in forage fish such as rainbow smelt (*Osmerus mordax*; Paterson et al. 2014; Dai et al. 2020). Combined, these characteristics are representative of changed energy availability and flow with the potential for resource limitation in this ecosystem's lower trophic levels. Bowen et al. (2018) concluded that abundant veliger populations could spatially offset the loss of crustacean biomass such as those that have occurred across Lakes Huron, Michigan and Ontario since the early 2000's. However, despite this potential restructuring of Great Lakes planktonic biomass, the ecological role of veligers as an energetic resource in these communities remains generally uncharacterized.

Project Goals and Hypotheses

The goals of this research were to (1) determine the nutritional quality of veligers as a food resource, (2) identify pelagic zooplankton predators of veligers and their contributions to zooplankton diets, and (3) determine the proportional contributions of veliger production to pelagic consumption and heterotrophic bacterial production. The objectives of this research were to (1) assess fatty acid biomarker and total lipid composition of veligers; (2) determine veliger energy densities and; (3) compare assimilation of organic carbon from veligers to predatory zooplankton and from veligers to heterotrophic bacteria. Specific hypotheses to be tested include:

1) Veliger biochemical and energy density metrics will be representative of a low-quality food resource characterized by low proportions of polyunsaturated fatty acids (PUFAs), and energy densities;
2) Assimilation of veliger carbon by predatory zooplankton will be negligible relative to native prey assemblages;
3) Veliger carbon production will be predominantly processed through heterotrophic bacterial degradation.

Addressing these objective and hypotheses will further our knowledge regarding the roles of the early life-history stage of invasive dreissenid mussel in a Great Lakes food web. Our combined field and experimental approach will contribute to our understanding of the linkages between veligers and pelagic food web production, thereby advancing our knowledge of the ecological effects of non-native species on Lake Huron food webs. Given the invasion success of dreissenid mussels in the Great Lakes, research outcomes are expected to inform future management strategies basin-wide.

Project Narrative

Veliger Energy Densities and Fatty Acid Composition: Veliger and zooplankton samples were collected during the open water seasons of 2022 – 2023 from a total of four locations in Lake Huron's Saginaw Bay, and also from one location in the Kawkawlin River, a Saginaw Bay tributary (Fig. 1). All collections were completed using a 0.5 x 1.5 m zooplankton net equipped with 64 µm nylon mesh. For Saginaw Bay, samples were collected by vertical hauls completed from a depth near lake bottom (~5 m) to the surface. In the Kawkawlin River, the net was towed horizontally over a 10 m distance while keeping the net ~1 m above the river bottom. Horizontal tows were completed from the middle of the river to the shoreline. At each location, the contents of the net cod end were filtered through stacked 250, 150 and 64 µm metal sieves with the 64 µm fraction then transferred to a 2 L container held on ice and pre-filled with ~500 mL of 25 µm filtered Saginaw Bay or Kawkawlin River water. This process was repeated a minimum of 40 times in an effort to collect sufficient veliger biomass for experimentation and analyses with a total of 4 – 2 L containers filled in such a manner during each sampling trip. A single net haul was also completed and preserved in ethanol during each sampling trip for species identification and enumeration. Environmental conditions including temperature, dissolved oxygen, conductivity, pH and oxidation reduction potential, were measured from the

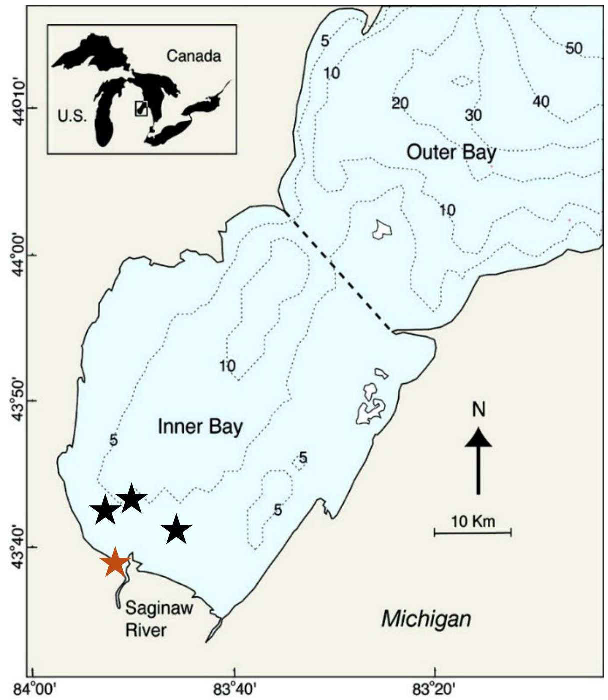

Figure 1: Location of veliger and zooplankton sampling locations in Saginaw Bay (★) and the Kawkawlin River (★)

water surface to bottom during each sampling event using a Yellow Springs Instrument ProDSS multiparameter water quality meter.

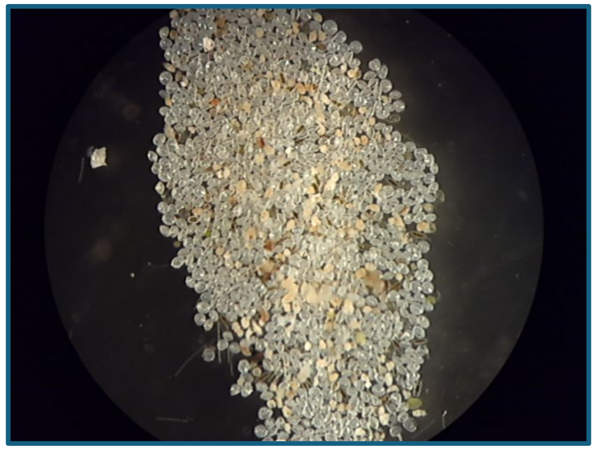

Figure 2: Saginaw Bay dreissenid veligers isolated via elutriation.

Veligers samples for energy density and fatty acid, analyses were separated from zooplankton using the modified elutriation process described by Bowen et al. (2018; Fig. 2). Zooplankton enumeration followed the general methodology outlined in Pothoven et al. (2013). In the laboratory, ethanol preserved 64 µm net haul samples were sequentially filtered through 250, 150 and 64 µm nylon mesh sieves with the biomass retained on each sieve subsequently rinsed into separate 250 mL beakers and brought up to a consistent volume of 100 mL in deionized water. Sub-samples were taken from each fraction using a Hensen-Stemple pipette and transferred to a gridded 1 mL Sedgewick-Rafter counting cell for identification and enumeration.

Fatty acid analyses followed a modified chloroform-methanol extraction procedure outlined in Indarti et al (2005) followed by gas chromatography mass spectrometry analysis. All fatty acid analyses were completed using freeze-dried sample materials. Energy density determinations were completed by first drying veliger or zooplankton biomass and then combusting at 550°C to determine sample ash-free dry weights. Sample ash-free dry weight values were then used to predict sample energy densities (kJ/g wet wt.) from established regressions between ash free dry weight and energy densities for aquatic invertebrates (Weil et al. 2019).

Across the sampling events, zooplankton community biomass in the 64 – 149 µm size fraction was dominated by veligers (79.2%) with nauplii (14.8 %) being the second most abundant biomass (Fig. 3). The rotifers *Asplanchna* spp. and *Keratella* spp. constituted 3.7 % of the total biomass in these samples with Bosmina (1.6 %) and the dinoflagellate *Ceratium* spp (0.7 %) representing the remaining biomass in this size range. In contrast, veligers only accounted for an average of 1.0 % of the total biomass in the 150 – 249 µm size fraction with

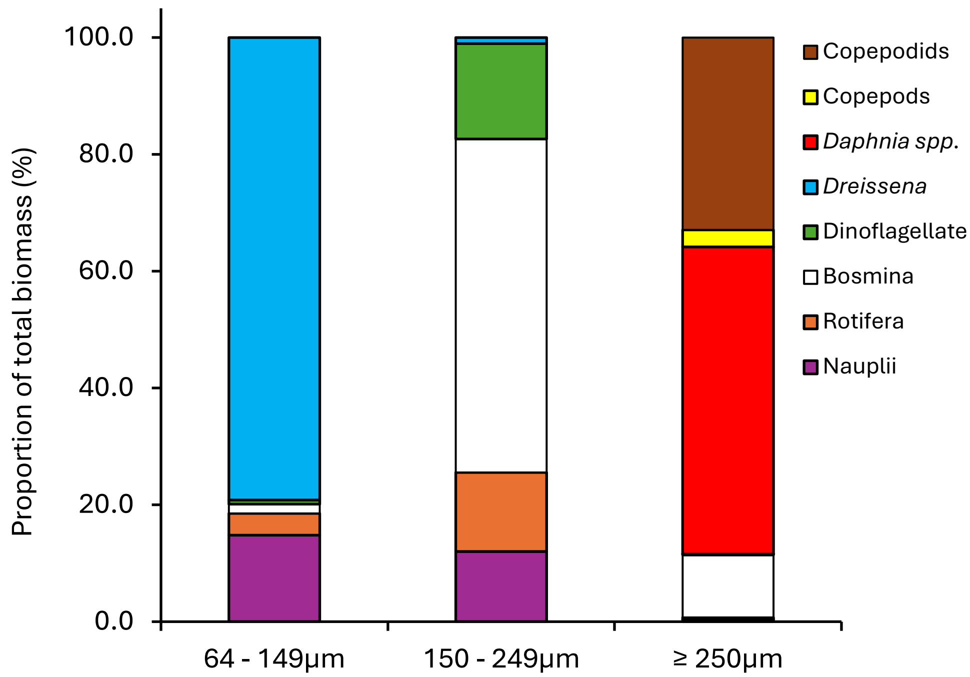

Figure 3: Taxonomic composition of Saginaw Bay zooplankton size fractions. Taxonomic contributions are presented as the proportion of total biomass estimated for each size fraction (mg/m^3).

Bosmina dominating this biomass (57.1 %). Dinoflagellates (16.3 %), rotifers (13.6 %) and copepod nauplii (12.0 %) combined to represent the additional 150 – 249 µm biomass. The largest size fraction (≥ 250 µm) was dominated by *Daphnia* spp (52.6 %) and copepods (32.9%) including *Mesocyclops edax*, *Leptodiaptomus minutus*, *Skistodiaptomus oregonensis* and *Cyclops* *bicuspidatus thomasi*. With the exception of *B. longirostris* (10.7 %), all other groups contributed < 3.0 % of the total biomass in this largest size fraction.

Sample energy densities ranged from 1.20 – 2.19 kJ/g (wet wt.) with a veliger and 64 – 150 µm zooplankton samples representing these minimum and maximum values, respectively (Fig. 4). Veliger sample energy densities averaged 1.49 ± 0.2 kJ/g and were significantly lower than values of 1.91 ± 0.2 kJ/g (64 – 150 µm), 1.94 ± 0.1 kJ/g (150 – 250 µm) and 1.85 ± 0.2 kJ/g

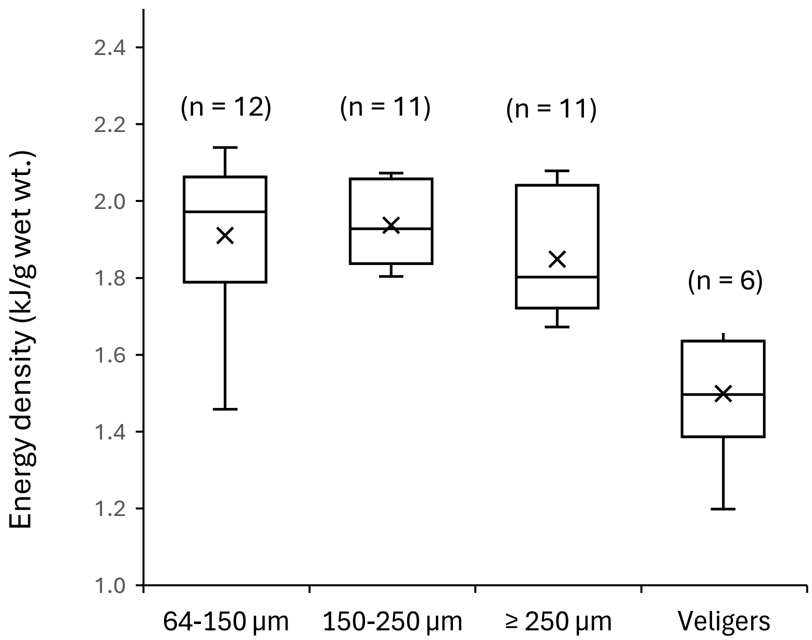

Figure 4: Box plots depicting energy densities for three size fractions of Saginaw Bay zooplankton and dreissenid veligers. Whiskers indicate minimum and maximum values. Upper and lower box limits represent the 75th and 25th quartiles, respectively, with the median values indicated by the solid horizontal line within the box. Mean values are indicated by the 'X' within each box with sample sizes provided in the parentheses.

(> 250 µm) for the zooplankton size fractions ($p = 0.003$). Fatty acid analysis demonstrated veligers to have lower proportions of essential polyunsaturated fatty acids (PUFAs) including essential α-linolenic (ALA) and eicosapentaenoic acids (EPA; Table 1). Veligers were, however, higher in the essential PUFA docosahexaenoic-acid (DHA). Nutritional quality indicators such as omega-3:omega-6 fatty acid ratios were also lower for veligers relative to zooplankton.

Table 1: Fatty acid composition (% of total fatty acids detected) of zooplankton size fractions and veligers collected from Lake Huron's Saginaw Bay 2023. Omega-3:omega-6 fatty acid ratio (Σn-3:Σn-6) and unsaturation indices are unitless. Abbreviations for α-linolenic (ALA), eicosapentaenoic (EPA) and docosahexaenoic (DHA) essential fatty acids are provided.

	64 – 150 µm (*n* = 10)	150 – 250 µm (*n* = 11)	≥ 250 µm (*n* = 11)	Veliger (*n* = 10)
Saturated fatty acids (%)				
12:0	0.4 ± 0.2	0.6 ± 0.4	0.4 ± 0.2	0.2 ± 0.1
14:0	1.8 ± 1.7	3.0 ± 1.7	4.1 ± 2.5	2.0 ± 0.8
15:0	0.3 ± 0.1	0.6 ± 0.4	0.8 ± 0.4	0.7 ± 0.3
16:0	15.2 ± 3.0	19.8 ± 7.1	20.3 ± 6.4	10.2 ± 3.6
17:0	3.0 ± 2.0	2.1 ± 1.4	1.3 ± 0.9	6.0 ± 4.6
18:0	2.3 ± 1.0	3.9 ± 0.9	4.8 ± 1.4	2.8 ± 0.8
20:0	6.1 ± 1.2	5.7 ± 1.4	5.2 ± 0.6	6.8 ± 1.6
22:0	1.3 ± 0.6	1.9 ± 1.0	0.7 ± 0.3	1.8 ± 0.8
25:0	5.4 ± 3.3	2.9 ± 1.5	2.4 ± 3.0	8.0 ± 3.6
ΣSAFA	35.7 ± 4.7	40.5 ± 6.0	40.1 ± 6.2	38.5 ± 1.7
Monounsaturated fatty acids (%)				
16:1n-9	3.2 ± 2.9	4.9 ± 4.3	6.7 ± 4.5	2.5 ± 1.5
16:1n-7	0.7 ± 0.9	0.8 ± 0.6	1.1 ± 0.7	0.5 ± 0.3
18:1n-9	3.2 ± 0.6	3.9 ± 1.6	4.6 ± 1.4	3.4 ± 1.3
18:1n-7	1.5 ± 0.6	1.7 ± 1.0	2.6 ± 1.4	2.2 ± 0.9
22:1n-11	2.0 ± 0.9	2.7 ± 0.7	2.4 ± 0.7	2.6 ± 0.6
22:1n-9	6.0 ± 2.8	5.4 ± 2.9	3.4 ± 1.3	7.2 ± 2.2
ΣMUFA	16.8 ± 1.8	19.0 ± 1.8	20.9 ± 2.0	18.4 ± 2.3
Polyunsaturated fatty acids (%)				
18:2n-6	3.6 ± 1.4	2.0 ± 0.9	2.8 ± 1.3	1.9 ± 0.7
18:3n-3 (ALA)	5.1 ± 1.7	2.1 ± 1.9	2.8 ± 1.5	1.6 ± 0.6
18:4n-3	3.9 ± 1.2	1.6 ± 0.6	2.1 ± 1.0	2.0 ± 1.2
20:2n-6	2.2 ± 0.6	2.6 ± 1.0	2.1 ± 0.5	2.1 ± 0.7
20:3n-6	1.8 ± 0.5	2.0 ± 0.8	1.4 ± 0.5	2.6 ± 0.7
20:4n-6	2.9 ± 0.3	2.6 ± 0.7	3.2 ± 1.1	2.4 ± 1.0
20:3n-3	3.2 ± 1.1	2.4 ± 0.7	2.1 ± 0.6	2.1 ± 0.7
20:4n-3	2.7 ± 0.5	2.0 ± 0.4	1.8 ± 0.5	2.8 ± 0.9
20:5n-3 (EPA)	4.4 ± 2.8	3.8 ± 2.6	3.8 ± 2.3	3.1 ± 1.2
21:5n-3	2.4 ± 1.6	6.7 ± 4.1	5.9 ± 2.4	4.2 ± 0.9
22:5n-6	5.6 ± 2.6	3.9 ± 2.2	3.1 ± 1.8	6.3 ± 3.2
22:5n-3	2.1 ± 0.8	1.7 ± 0.6	1.2 ± 0.6	2.8 ± 0.9
22:6n-3 (DHA)	7.7 ± 1.3	6.9 ± 1.3	6.7 ± 2.8	9.0 ± 2.2
ΣPUFA	47.5 ± 1.7	40.5 ± 1.8	39.0 ± 1.7	43.1 ± 2.1
Σn-3	31.4 ± 4.8	27.3 ± 4.8	26.4 ± 7.7	27.7 ± 4.8
Σn-6	16.1 ± 4.1	13.2 ± 3.3	12.6 ± 4.3	15.4 ± 3.4
Σn-3:Σn-6	2.2 ± 1.1	2.2 ± 0.5	2.1 ± 0.3	1.9 ± 0.5
DHA + EPA	12.0 ± 3.6	10.7 ± 3.0	10.5 ± 4.1	12.2 ± 3.0
Unsaturation index	219 ± 20	199 ± 27	192 ± 48	216 ± 25

Evaluating the fate of veliger carbon: Veligers for ^{14}C radiocarbon assimilation experiments were collected by vertical net haul from Saginaw Bay with the same elutration process used to isolate veligers for experimentation. Measurements of veliger carbon fate were evaluated by providing veligers ^{14}C radio-labelled algal food material and subsequently incubating the ^{14}C labelled veligers in 20 mL experimental vials with a 1 mL subsample of Saginaw Bay native zooplankton community added to the incubation tube. The experimental design included vial preparations for 2, 6, 12 and 24 hour sampling points with triplicate vials prepared for each of these time points. An additional subsample of the Saginaw Bay zooplankton included in each incubation was preserved in 95% ethanol for species identification and enumeration. At each time point, incubations were terminated by filtering incubation vial contents through a 150µm sieve to collect zooplankton, then a 64µm sieve to retain veligers, with the remaining aqueous volume passed through a 0.2 µm filter to capture the bacterial fraction. The remaining aqueous volume represented the dissolved organic carbon fraction (DOC) with each of the zooplankton, bacteria and DOC experimental fractions being analyzed for ^{14}C radioactivity using a scintillation counter.

Incubation experiments demonstrated the capacity of native Saginaw Bay zooplankton to assimilate ^{14}C labeled veliger biomass (Fig. 5). During the first set of incubation experiments, zooplankton assimilated over half (60.4 ± 2.0 %) of the total ^{14}C labeled veliger carbon radioactivity added to incubation tubes followed by bacteria (30.5 ± 2.4%) with the remaining ^{14}C activity sequestered into the DOC. In contrast, a greater proportion of veliger ^{14}C radioactivity was assimilated by the bacterial fraction (65.1 ± 6.5%) in the second set of incubations relative to zooplankton (31.9 ± 2.2%) and DOC (3.0 ± 0.6%). This difference was likely associated with the composition of the zooplankton communities added to the incubation vials. For example, during the first experiments higher biomass of the large calanoid copepod *S. oregonensis* was present in the Saginaw Bay zooplankton community and predominated the biomass present in the incubation vial. In comparison, the cyclopoid copepod *Diacyclops thomasi* predominated the incubation biomass for the second set of experiments and differences in feeding ecology between these species contributed to the. However, when proportions of the cumulative ^{14}C assimilated by zooplankton were corrected for carbon contents of each experimental fraction, this suggested that the majority of veliger carbon is predominantly recycled into the DOC phase (Table 2).

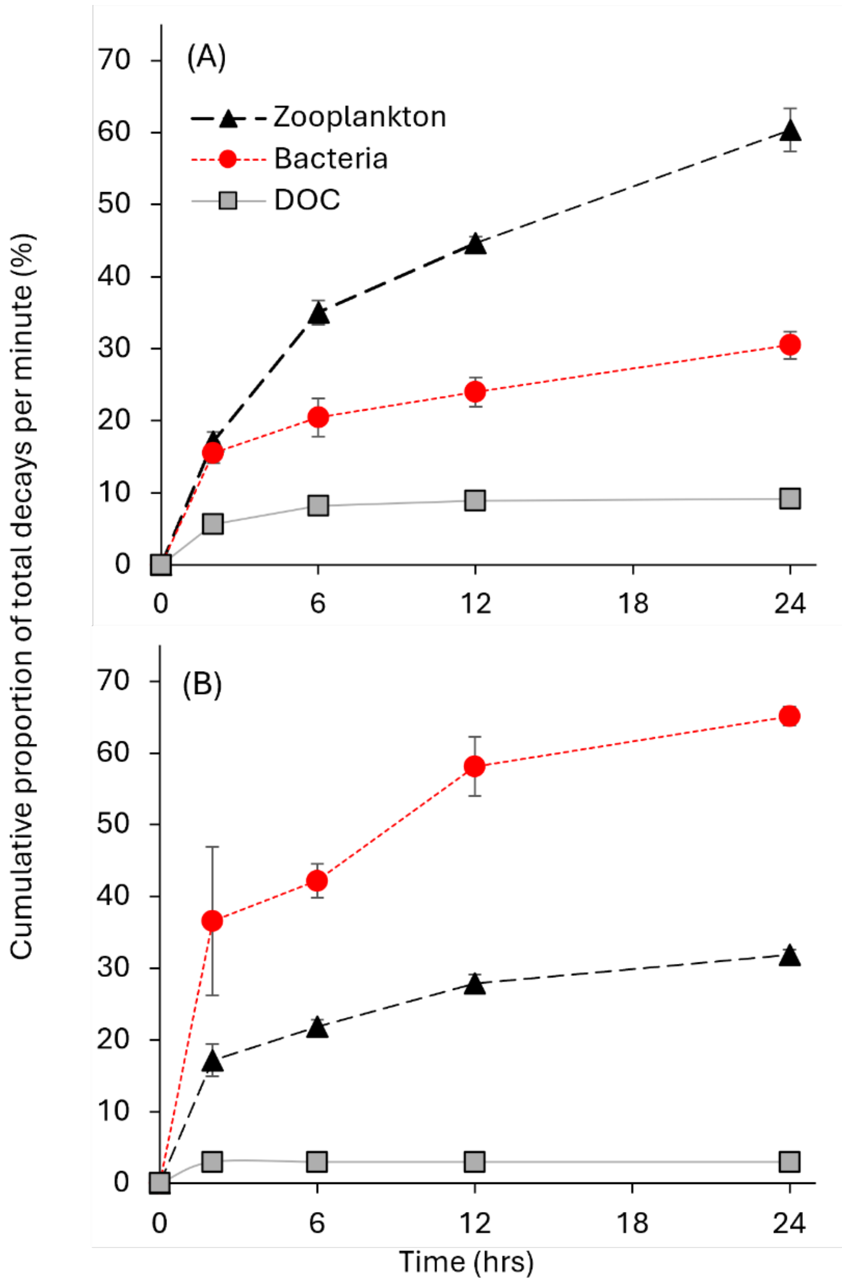

Figure 5: Cumulative proportions of total ^{14}C labeled veliger carbon assimilated by zooplankton, bacteria, and dissolved organic carbon (DOC) experimental phases during 24-hour incubation experiments. Panels (A) and (B) present the results of independent incubations with error bars indicating ± standard deviation in both panels.

Table 2: Mean assimilation rates of veliger carbon by incubation phases as proportion of total disintegrations per minute (DPM)

Incubation phase	Proportion of total DPM assimilated (%)	Rate of veliger carbon assimilation (/day)	Units
Zooplankton	92.1 ± 8.4	6.5 ± 3.0	μg/m^3
Bacteria	5.0 ± 0.4	22.6 ± 9.5	pg/cell
Dissolved organic carbon	2.9 ± 0.2	332.7 ± 88.3	μg

Research/Management Implications

Dreissenid mussel veligers have been proposed to account for the declines in crustacean zooplankton biomass that have occurred concomitant with the establishment of this non-native in the Great Lakes in the late 1980s (Bowen et al. 2018). In Saginaw Bay, veligers were demonstrated to be the predominant biomass among 64 – 150 μm plankton community generally throughout the open water season. Veligers were also of lower total energy content and generally a lower quality prey item in terms of fatty acid composition and content relative to all sizes of crustacean zooplankton sampled in Saginaw Bay. Significantly, veligers are similarly sized as many zooplankton life stages and species that represent important food resources for the newly hatched larval forms of Great Lakes fish species (Withers et al. 2015; Lucke et al. 2020; Pothoven and Olds 2020). For fisheries managers, such an abundant yet low quality prey resource has implications for energy, nutrient and biomass transfer that may be affecting progress toward achieving sustainability goals and maintaining ecosystem services provided by Lake Huron's Saginaw Bay.

Potential Applications, Benefits and Impacts

To the best of our knowledge, this project is among the first to generate energy density and fatty acid composition information for veligers in the Laurentian Great Lakes in addition to quantifying the overall fate of veliger production within the planktonic community of a Great Lakes food web. For resource managers, this information can help inform ecosystem-based and fisheries modelling approaches used by Michigan's resource managers and stakeholders to help support ecosystem-based planning and forecasting, decision making strategies, and management approaches.

Section C. Outputs:

Media Coverage

The primary graduate student supported by our project was awarded the Outstanding Student Poster Award at the 67th Annual Conference of the International Association for Great Lakes Research. This was announced in the association's Summer 2024 newsletter (https://iaglr.org/ll/2024-3_Summer_LL22.pdf)

Michigan Technological University issued a press release March 29, 2022 announcing the successful funding of our Michigan Sea Grant project. This was announced on the university's 'Tech Today' web page (https://www.mtu.edu/ttoday/?issue=20220329#new-funding)

Our Michigan Sea Grant funded project gained attention as I was interviewed by the Great Lakes New Echo for their article 'More Money Allocated for Great Lakes Research' published on March 1, 2022 (https://greatlakesecho.org/2022/03/01/more-money-allocated-for-great-lakes-research/)

Outreach

I participated as a guest speaker in the Western Upper Peninsula MI-STEM / Lake Superior Stewardship Initiative communicating the impacts of dreissenid mussels in the Great Lakes and potential risks posed to the fishery if established in Lake Superior. Primary audience K-12. July 11-13th 2024.

Journal Publications

Kehne MR., Olin, JA, Junker JR., Vick-Majors TJ., and Paterson. G. *In prep.* Energy densities and fatty acid composition of dreissenid mussel veligers from Saginaw Bay, Lake Huron. For submission to Limnology and Oceanography.

Kehne MR., Vick-Majors TJ., Junker JR., Olin, JA, and Paterson. G. *In prep*. Assessing the fate of dreissenid veliger production in the lower trophic levels of the Lake Huron planktonic food web. For submission to the Journal of Great Lakes Research.

Conference Presentations**:**

Kehne MR., Paterson G., Olin JA., Vick-Majors TJ., and Junker JR.. Assessing the nutritional quality and fate of Saginaw Bay dreissenid mussels. 67th Annual Conference of the International Association for Great Lakes Research, Windsor, ON, CANADA, May 20 – 24th, 2024. (Outstanding student poster award winner).

Graduate Student(s):
Mitchell R. Kehne. Master's Thesis, Michigan Technological University July 2024. ***Title***: Assessing the nutritional quality and fate of Saginaw Bay dreissenid mussel veligers. ***Abstract***: The introduction and establishment of dreissenid species including zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels into the Laurentian Great Lakes has resulted in significant biological and ecological change over the past 30 years. Much of the current research completed to date on understanding dreissenid mussel impacts in the Great Lakes has primarily focused on the adult life stages with less known about the larval veliger form. The goals of this thesis were to; i) investigate veliger energy densities and fatty acid profiles to compare and contrast these nutritional metrics against pelagic zooplankton and; ii) determine the fate of veliger carbon within zooplankton and bacterioplankton communities of Saginaw Bay, Lake Huron. Energy densities of veligers collected from Lake Huron's Saginaw Bay region averaged 1.49 ± 0.2 kJ/g and were approximately 21% lower relative to values determined for 64 – 150, 150 – 250, and > 250 µm zooplankton size fractions. Fatty acid profiles demonstrated veligers to have lower concentrations of α-linolenic and eicosapentaenoic essential fatty acids and lower unsaturation indices and n-3:n-6 quality indicators relative to zooplankton size fractions. Results of ^{14}C labeling experiments demonstrated uptake of veliger derived organic carbon by zooplankton and bacterioplankton but suggest that much of veliger carbon is recycled into dissolved organic carbon. These results provide baseline information regarding the nutritional quality of veligers and help describe the fate of veliger production within the lower trophic levels of Lake Huron's Saginaw Bay. MTU Digital Commons (https://digitalcommons.mtu.edu/etdr/1772/)

Graduate/Undergraduate volunteers:
Ryan Heines (MS - MTU): Field and lab assistant summer 2023
Hunter Roose (PhD - MTU): Field and lab assistant summer 2023
Garrett Lukosavich (MS - MTU): Field and lab assistant summer 2023
Brian Reeves (BS - MTU): Field and lab assistant summer 2022

Project partnerships
Great Lakes National Program Office (Dr. Annie Scofield) and Fisheries and Oceans Canada (Drs Kelly Bowen and Warren Currie), Cornell University (Dr. Lars Rudstam)

Awards and Honors
The primary graduate student supported by this project (Mitchell Kehne) was awarded the Outstanding Student Poster Award at the 67th Annual Conference of the International Association for Great Lakes Research. (https://iaglr.org/ll/2024-3_Summer_LL22.pdf)

Section D. Data Management Plan Form: Completion Phase
Please refer to attached PDF copy of Sea Grant data Management Form: Project Completion Phase (Paterson_MISG_Data Management Completion Form_03062025.pdf)

Section E. References

Barbiero, R. P., B. M. Lesht, & G. J. Warren. 2011. Evidence for bottom–up control of recent shifts in the pelagic food web of Lake Huron. Journal of Great Lakes Research 37:78–85.

Barbiero, R. P., B. M. Lesht, & G. J. Warren. 2012. Convergence of trophic state and the lower food web in Lakes Huron, Michigan and Superior. Journal of Great Lakes Research 38:368–380.

Bowen, K. L., A. J. Conway, & W. J. S. Currie. 2018. Could dreissenid veligers be the lost biomass of invaded lakes? Freshwater Science 37: 315 –329.

Cha, Y., C. A. Stow, T. F. Nalepa, & K. H. Reckhow. 2011. Do invasive mussels restrict offshore phosphorus transport in Lake Huron? Environmental Science and Technology 45:7226–7231.

Indarti, E., M. I. A. Majid, R. Hashim, & A. Chong. 2005. Direct FAME synthesis for rapid total lipid analysis from fish oil and cod liver oil. Journal of Food Composition and Analysis 18:161-170.

Dai, Q., D. B. Bunnell, J. S. Diana, S. A. Pothoven, L. Eaton, T. P. O'Brien, & R. T. Kraus. 2020. Spatial patterns of rainbow smelt energetic condition in Lakes Huron and Erie in 2017: evidence for Lake Huron resource limitation. Journal of Great Lakes Research. 45: 830 – 839.

Lucke, V. S., T. R. Stewart, M. R. Vinson, J. D. Glase, & J. D. Stockwell. 2020. Larval *Coregonus* spp. diets and zooplankton community patterns in the Apostle Islands, Lake Superior. Journal of Great Lakes Research 46:1391-1401.

Nalepa, T. F., D. L. Fanslow, & G. A. Lang. 2009 Transformation of the offshore benthic community in Lake Michigan: recent shift from the native amphipod *Diporeia* spp. to the invasive mussel *Dreissena rostriformis bugensis*. Freshwater Biology 54:466–479.

Nalepa, T. F., D. L. Fanslow, S. A. Pothoven, A. J. Foley, & G. A. Lang. 2007. Long-term trends in benthic macroinvertebrate populations in Lake Huron over the past four decades. Journal of Great Lakes Research 33:421–436.

Paterson, G., C. E. Hebert, K. G. Drouillard, & G. D. Haffner. 2014. Congruent energy density trends of fish and birds reflect ecosystem change. Limnology and Oceanography 59:1171 –1180.

Pothoven, S. A., & C. Olds. 2020. Spatial variation in feeding ecology of age-0 lake whitefish *Coregonus clupeaformis* in Lake Huron. Journal of Freshwater Ecology 35:349–366.

Pothoven, S. A., T. O. Höök, T. F. Nalepa, M. V. Thomas, & J. Dyble. 2013.Changes in zooplankton community structure associated with the disappearance of invasive alewife in Saginaw Bay, Lake Huron. Aquatic Ecology 47:1–12.

Schloesser, D. W., & B. F. Nalepa. 1994. Dramatic decline of unionid bivalves in offshore waters of western Lake Erie after infestation by the zebra mussel, *Dreissena polymorpha*. Canadian Journal of Fisheries and Aquatic Sciences 51:2234-2242.

Weil, J., M. Trudel, S. Tucker, R. D. Brodeur, & F. Juanes. 2019. Percent ash-free dry weight as a robust method to estimate energy density across taxa. Ecology and Evolution 9:13244–13254.

Withers, J. L., T. M. Sesterhenn, C. J. Foley, C. D. Troy, & T. O. Höök. 2015. Diets and growth potential of early stage larval yellow perch and alewife in a nearshore region of southeastern Lake Michigan. Journal of Great Lakes Research 41:197-209.