Project Title
Quantifying microbial trophic pathways in a changing Lake Huron ecosystem

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PI Name
Hunter J. Carrick

Institution
Central Michigan University

Report Period Start
2023-03-30

Report Period End
2025-09-30

What type of report are you submitting?
Final Report

What are the major goals of this project?
1. Determine the size-specific biomass and bulk chemical composition of the microbial food web. 2. Evaluate the abundance and phylogenic composition of the entire microbial food web using both traditional microscopy methods and DNA barcoding. 3. Identify and quantify trophic pathways between dominant microbial taxa and key mesozooplankton and Dreissena veliger populations.

Have any major goals changes since the initial award or previous report?
Completed work on microplankton sample analysis Completed work on plankton barcoding

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What was accomplished within these goals?
Goal 1. Determine the size-specific biomass and bulk chemical composition of the microbial food web. 1a.Objectives and Activities: The samples to address this goal have been collected and analyzed. Dr. Carrick has made all size-specific carbon uptake, phosphorus uptake, and chlorophyll measurements at NOAA stations TB10, TB18 and TB46 (at 2-3 depths per station) along the Thunder Bay transect during (June 2024), mid (August 2023) and late (September 2023) thermal stratification periods. 1b. Results, Outcomes, Achievements: Phytoplankton biomass was low at all stations along the Thunder Bay transect (<1 ug/L) and most of the Carbon and Phosphorus uptake was attributed to pico-sized algae. These findings confirm that the base of the food web in Lake Huron is dominated by small plankton and confirm the strongly oligotrophic nature of the offshore region of Lake Huron (see Barberio et al. 2016. J. Great Lakes Res.). The combination of low standing biomass and dominance of pico-sized uptake indicates that the pelagic system is functioning as a low nutrient, small cell dominated food web, consistent with prior observations for offshore Lake Huron. Goal 2. Evaluate the abundance and phylogenic composition of the entire microbial food web using both traditional microscopy methods and DNA barcoding. 2a. Objectives and Activities: Results from the June field samples are being analyzed in a 3 phases. Samples for pico and nanoplankton have been analyzed for samples taken along the transect using microscopy techniques. The remaining microplankton samples were analyzed using phase microscopy during the remainder of the project. DNA barcoding (genomic analysis) of the field samples has been completed. 2b. Results, Outcomes, Achievements: The abundance of smaller picoplankton (on the order of 1,000 to 10,000 cells/ml) and nanoplankton (on the order of 100 to 1,000 cells/ml) was relatively low compared with historic sampling done in this location in the lake (see Carrick and Fahnenstiel 1989 Can. J. Fish Aq. Sci., 1990 J. Great Lakes Res.). The picoplankton assemblage showed some differences compared with past characterizations- while pico-cyanophytes became more abundant during stratification, pico-eukaryotes are more abundance year-round compared with the past (see Fahnenstiel and Carrick 1992 Can. J. Fish Aq. Sci.). In general, there was good agreement between microscopic versus DNA analyses for key phylogenic groups. Across the Thunder Bay transect, bacterial alpha diversity was comparatively stable, with 16S Shannon H ranging from ~3.6 to 4.6, whereas eukaryotic alpha diversity was much more variable, with 18S Shannon H ranging from ~1.5 to 4.5. The narrower 16S range indicates that the bacterial assemblage retained relatively high

evenness across stations, depths, and seasons despite taxonomic turnover, while the broader 18S range indicates stronger restructuring of the eukaryotic community. The most pronounced eukaryotic shifts occurred at the deeper station TB46, where several samples showed reduced evenness and apparent dominance by fewer taxa. The bacterial data indicate that the small-cell planktonic fraction remained important throughout the transect. In particular, Cyanobium, a small freshwater picocyanobacterial genus typically 1–2 µm in size, increased in summer and is consistent with stronger representation of the picoplankton fraction under stratified, oligotrophic conditions. A notable summer pattern was the decline in Actinomycetota and increase in Pseudomonadota. This pattern is best interpreted as a seasonal shift in community composition, not a decline in total bacterial diversity. Actinomycetota represent a characteristic oligotrophic background assemblage, whereas several Pseudomonadota are more responsive to fresh phytoplankton-derived dissolved organic matter. This shift likely reflects stronger phytoplankton-bacteria coupling under warmer, stratified summer conditions. The eukaryotic community showed much stronger seasonal and depth-dependent variability than the bacterial community, indicating that most of the biological restructuring occurred within the eukaryotic compartment. Lower 18S Shannon values at several TB46 samples suggest temporary dominance by fewer taxa rather than a uniform decline in biodiversity. The Dreissena-associated signal was especially notable and is plausibly explained by seasonal spawning and the presence of planktonic veligers in the water column. Increased Dreissena signal during summer or early fall likely reflects a larval pulse, which would reduce eukaryotic evenness by increasing the relative abundance of a single metazoan group. Overall, these results show that offshore Thunder Bay is characterized by a relatively stable small-cell bacterial and picoplanktonic background, while most seasonal and vertical variability is expressed through eukaryotic community reorganization, including changes among nanoeukaryotes, larger plankton, and seasonal Dreissena veliger inputs. 3.Identify and quantify trophic pathways between dominant microbial taxa and key mesozooplankton and Dreissena veliger populations. 3a. Objectives and Activities: Field work was performed in June 2024 to retrieve samples for both field and laboratory aspects of the project. Field samples were collected along the Thunder Bay transect to estimate. Water and zooplankton samples were returned to the laboratory to run our third and final experiment. These experiments manipulated zooplankton presence and absence to ascertain the effects of zooplankton along, and in the presence of the top invasive invertebrate predator Bythotrephes. Experiments were done in replicate bottles incubated under controlled light and temperature conditions on a plankton wheel situated in the walk-in growth chamber at GLERL NOAA in Ann Arbor. Immediate results from the experiment were monitoring by assessing phytoplankton biomass and gross phylogenic group composition using a BBe Fluoroprobe. This experiment yielded both expected and unexpected results. 3b. Results, Outcomes,Achievements: The microplankton assemblage present in our bottles during all three experiments are being analyzed in a series of steps. Samples for pico and nanoplankton have been analyzed for all three experiments using epifluorescence microscopy techniques (see Carrick et al. 2015 J. Great Lakes. Res.). These sampled were analyzed immediately following the experiments to avoid fading of the natural autofluoresence present in these organisms. This assures more accurate estimates of both plankton groups. Larger celled microplankton were analyzed during the remainder of the project (microplankton samples). Interesting, the abundance of smallerpico and nanoplankton appeared to be enhanced by the presence of Bythotrephes. This pattern suggests Bythotrephes exerts a top-down pressure that releases pico and nanoplankton from predation by microplankton (ciliates, and possibly rotifers) and mesozooplankton (crustaceans). This pattern is consistent with a trophic cascade in which predation on intermediate grazers reduces pressure on the smallest planktonic size classes. Taken together, these results support a model of an ultra-oligotrophic, post-Dreissena Lake Huron system in which the small-cell bacterial and picoplanktonic background remains relatively stable, while eukaryotic composition changes more strongly with season and depth. The results are consistent with a lake in which offshore productivity is low, stratification creates vertically structured habitats, picocyanobacteria such as Cyanobium contribute to the small-cell fraction, summer Pseudomonadota increases reflect stronger coupling to fresh organic matter, and Dreissena veligers intermittently impose a strong seasonal eukaryotic signal. Overall, these findings indicate that the principal ecological response along the Thunder Bay transect is not a broad decline in microbial diversity, but a depth- and season-dependent reorganization of community composition, particularly within the eukaryotic assemblage.

For this reporting period, is there one or more Revision/Supplement associated with this award for which reporting is required?

The budget was modified in order to provide time for Dr. Carrick to dedicate more time to the project and its

completion in the fall 2025. We chose not to use Dreissena veligers in our experimental treatments because their natural densities in Lake Huron were very low.

What other activities have occurred?
Dr. Carrick has used some of these preliminary results to supplement his teaching materials in the following classes he teaches at Central Michigan University: BIO 500 Biostatistics, BIO 523 Limnology.

What opportunities for training and professional development has the project provided?
Four undergraduate students, one technician, and two postdoctoral fellows benefited from this project through direct participation in lab work and data analysis. Dr Carrick supervised three undergraduate student theses (3) that were completed as part of this project. Their work is summarized below: Ross, Wyatt. Undergraduate Sophomore in Biology at CMU - Effects of zooplankton grazing on planktonic bacterial assemblages in Lake Huron. Wilkie, Madison, Undergraduate Senior in Electron Microscopy at CMU - Morophological analysis of dominant planktonic diatoms in Lake Huron. Wells, Dominic, Undergraduate Senior in Biology at CMU - Changes in microplankton as a function of micro and macro-zooplankton grazing in Lake Huron Dr Carrick supervised two technical staff (Aaron Vlasak and Chris VanCuren) and one student (Dominic Wells), who assisted with the field work and sample collection. Dominic Wells and Chris VanCuren also assisted in setting up experiments and analyzing the resulting samples. Two CIGLR postdoctoral fellows (Dr. Kristie Mitchell and Aldo Arellana) under the supervision of Dr. Subba Rao Chaganti participated in the project. Dr. Kristie Mitchell helped with conducting the experiments and processing the genetic samples. Dr. Aldo Arellana, CIGLR postdoctoral fellow, helped with conducting part of the data analysis.

How have results been disseminated to communities of interest?
We are developing a professional presentations that will be given at future conferences. Also, we have two draft manuscripts that will be published in the primary literature shortly after the completion of this project.

What do you plan to do for the next reporting period to accomplish the goals?
This is the final report, so the project will be complete. We do plan to continue working on finalizing manuscript for publication and developing conference presentations.

Are there any events, programs, or initiatives that have occurred related to this project?
None

People or Groups Participating
None

Type of Participation
None

Number of Resource Managers Involved
None

Name
Hunter Carrick

Role (PI)
Project management, field sample collection, experimental set up, sample processing, data analysis and training.

Time spent on project in months, rounded to the nearest one-tenth
4.0 months

Name
Subba Rao Chaganti
Role (PI)

Project management, field sample collection, experimental set up, sample processing, data analysis and training.

Time spent on project in months, rounded to the nearest one-tenth
3.0 months

Name
Aaron Vlasak

Role (PI)
Technician- field work, lab work

Time spent on project in months, rounded to the nearest one-tenth
0.10 months

Name
Chris VanCuren

Role (PI)
Technician- field work, laboratory work, plankton counts

Time spent on project in months, rounded to the nearest one-tenth
0.50

Name
Wyatt Ross

Role (PI)
Undergraduate Technician- lab work, bacterials counts

Time spent on project in months, rounded to the nearest one-tenth
0.50

Are there any foreign partners involved?
None

What are actual or anticipated challenges or delays and what are the actions or plans to resolve them?
The release of funding for this project was delayed. I managed to stay on track by dedicating additional time to the project.

Are there human subjects, vertebrate animals, biohazards, and/or select agents involved in the project?
Yes

Please describe the human subjects, vertebrate animals, biohazards, and/or select agents involved in the project.
14-C bicarbonate and 32-P phosphorus were used in this study in accordance with National standards and regulations.

Where are the project/performance sites?
NOAA- GLERL in Ann Arbor Michigan and Central Michigan University at main campus in Mount Pleasant, Michigan.

Is there any additional information that you did not have a place to submit? Please submit that here with the information asked in the question.
None

Number of Acres
None

Location
None

Program / Initiative
None

Number of People
0

Notes
None

Have you gotten any certifications during your porject period?
None

Program / Event / Initiative
None

County Names
None

Number of Communities
None

Type of Participation
None

Additional field for another Program / Event / Initiative
None

County Names
None

Number of Communities
None

Type of Participation
None

Name of Coastal Community
None

County
None

Number of Resiliency Training or Technology Provided
None

Community Resiliency Improve? (Y/N)
N

Name of Coastal Community
None

Certification Type
None

Location
None

Presenter Name
Hunter Carrick

Event Name
Case study on invasive species effects on Great Lakes water quality and fisheries

Number of Students
18 graduate and undergraduate students

Where did this occur? (Classroom, workshop, science center, etc)
Classroom

Was it mandatory that participants attend?
Yes

Materials Title
Great Lakes Eutrophication and Harmful Algal Blooms

Publisher- if applicable
CMU, Biology: Incorporated in college course curriculum- Case Study

Description/Type
Lectures given in BIO 523 Limnology and BIO 525 Plant Ecology

Materials Title
invasive species effects on Great Lakes water quality and fisheries
Publisher- if applicable
CMU, Biology: Incorporated in college course curriculum- Case study
Description/Type
Lectures given in BIO 523 Limnology and BIO 525 Plant Ecology

Name of Product
Food Chain Checkers

Description
An educational game aimed at teaching graduate and undergraduate college students ecological principles that regulate food web dynamics.

Developed (yes/no)
Yes

Used (yes/no) - Someone has told you this has benefited them during Feb 2024- Jan 2025.
Yes

Presenter Name
Ross, W., Kourtev, M., Chaganti, S.R., and Carrick, H.J.

Event Type
Conference, Regional

Event Name
Student Creative and Research Endeavors Exhibition, SCREE, Central Michigan University

Focus Area
Application of flow cytometry for bacterioplankton measurements in freshwater lakes.

Number of Attendees
1,000

Program / Event / Initiative
None

Number of Volunteers
None

Volunteer Hours (total)
None

Notes
None

Title
NOAA support of CSMI Lake Huron 2022

Author(s)
Elgin, C. Godwin, T., Rowe, M., Ruberg, S., Rutherford, E. Almquist, Z., Alsip, P., Biddanda, B., Camilleri, A., Carrick, H., Chaganti, S.R., Glyshaw, P., Mason, D., Pietscher, R., Sayers, M.

Publication Year
2025

Journal Title
NOAA Final Report

Submitted on
20205-11-30

Title
Seasonal interactions between quagga mussel grazing and phytoplankton in western Lake Erie: the view from different measuring technologies.
Author(s)
Vanderploeg, H.A., Glyshaw, P., Carrick, H.J., Carter, G., Dahal, N., Denef, V.J., Fanslow, D., and Godwin, C.
Publication Year
2023
Journal Title
Aquatic Ecosystem Health and Management
Journal Volume/Issue
26: 111-119
Name of Product
Plankton barcoding

Description
Educational curriculum Database of phylogenic groups (using DNA barcodes) distributions for microplankton. Database of taxonomic group (using microscopic identifications) distributions for microplankton.

Developed (Yes/No)
Yes

Used (Yes/no) - Someone has told you this has benefited them during Feb 2023- Jan 2024 even if this was developed at a different time. Who?
In the process

Name
None

Description of Impact
None

Economic Impact ($)
None

Businesses Created (#)
None

Businesses Retained (#)
None

Jobs Created (#)
3

Patents/Licenses
None

Name
Cooperative Institute for Great Lakes Research, CIGLR

Support Type
Data and materials

Type of student (undergrad, graduate, etc.)
Post doctoral Fellows

Did this student get a job after involvement in this project or are they anticipating such?
Yes

Partner/Organization Name
Cooperative Institute for Great Lakes Research, CIGLR

Partner Type
University

Partner Scale
National

Description
Our project interacted with post-doctoral fellow at CIGLR

Name
Madison Cree
Support Type
Materials

Type of student (undergrad, graduate, etc.)
Undergraduate
Did this student get a job after involvement in this project or are they anticipating such?
Yes
Name
Wyatt Ross
Support Type
Salary and Materials
Type of student (undergrad, graduate, etc.)
Undergraduate
Did this student get a job after involvement in this project or are they anticipating such?
Student, continuing
Name
Dominic Wells
Support Type
Salary and materials
Type of student (undergrad, graduate, etc.)
Undergraduate
Did this student get a job after involvement in this project or are they anticipating such?
Yes
Project Title
Quantifying Microbial Biodiversity and Trophic Pathways Along a Gradient of Lakes on Beaver Island

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Fund Amount ($)
5,110.00

Source of Funds
Institute for Great Lakes Research, Central Michigan University Biological Station

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Fund Type
Research

Primary Focus Area
Sustainable Fisheries and Aquaculture

Start Date
2023-06-30

End Date
2024-05-30

Project Title
Influence of zooplankton grazing on seasonal succession of microplankton and HABs in Lake Erie
Fund Amount ($)
60,000.00
Source of Funds
Department of Commerce, NOAA
Fund Type
Research
Primary Focus Area
Healthy Coastal Ecosystems
Start Date
2023-04-01

End Date
2025-12-30

What dollar amount of the award's budget is being spent in foreign country(ies)?
None

Is there any additional information that you did not have a place to submit? Please submit that here with the information asked in the question.
None

Do you have any suggestions on how to make this form better? Did you experience any issues?
None
