Cooperative Science and Monitoring Initiative Lake Michigan Sampling Prospectus

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The Lake Michigan Partnership Working Group, which comprises representatives from federal, state, and tribal agencies in Michigan, Indiana, Illinois, and Wisconsin, identified 14 research priorities for the 2020 Cooperative Science and Monitoring Initiative (CSMI) Field Year on Lake Michigan. The worldwide COVID-19 pandemic delayed most sampling plans in 2020; however, CSMI-related sampling plans have been generated for Lakes Michigan *and* Superior in 2021. The following describes planned activities for Lake Michigan, to be completed by scientists from the NOAA Great Lakes Environmental Research Lab (NOAA-GLERL), the US Geological Survey Great Lakes Science Center (USGS-GLSC), the US Environmental Protection Agency's Great Lakes National Program Office and Office of Research and Development (EPA-GLNPO and EPA-ORD, respectively), and university partners.

The activities described herein are supplemental to regular, annual monitoring efforts. They focus on the six "Priorities to Address Nutrient-Food web Dynamics in a Changing Ecosystem" identified by the Lake Michigan Partnership Working Group (Table 1, 1-6), but may also contribute to addressing three "Priorities to Address Watershed/Tributaries Connections to Lake Michigan Water Quality" (Table 1, 11-13). Partners from NOAA-GLERL, USGS-GLSC, EPA-GLNPO, and EPA-ORD, are in regular communication with each other as they seek to maximize opportunities to gather relevant data in a timely, efficient, and complementary manner. For example, the EPA-ORD Great Lakes Toxicology and Ecology Division lab plans to analyze most if not all CSMI water chemistry samples for nutrients, cat/anions, silica, TSS/VSS, DOC, and particulates concentrations, to promote sampling efficiency, sample accountability, and data integrity, and EPA-ORD may coordinate the taxonomic analysis of biological (particularly zooplankton) samples to simplify sampling tracking and promote data integrity for partners.

Every effort will be made to achieve goals laid out below. In reality, the proposed frequency and coverage of parameters measured will likely need to be reduced, as determined by the operating status of vessels and obtaining approval to conduct work as the COVID-19 situation evolves over the course of the field season. In addition, the focus on multiple lakes in a single year may cause backlogs in collection or processing of samples.

Some of the Lake Michigan sampling locations may be captured alongside Lake Superior sampling locations here:
https://umn.maps.arcgis.com/apps/View/index.html?appid=76b6d0c2d23c42539429979051481a33.

The following research vessels will likely be involved in sampling efforts:

- R/V Lake Guardian (EPA-GLNPO)
- R/V Lake Explorer II (EPA-ORD)
- R/V Arcticus (USGS-GLSC)
- R/V Sturgeon (USGS-GLSC)
- R/V Laurentian (NOAA-GLERL)
- Plus a suite of smaller vessels

Table 1. Summary of activities planned to address CSMI Lake Michigan research priorities.

Priority	Activities to address priority
1. Advance the understanding of nutrient dynamics (i.e. loading, transport, and cycling, spatial and temporal variability, and gradients) that directly influence lower trophic level productivity and offshore fish production.	EPA-GLNPO Lakewide Benthic Survey EPA-GLNPO Nearshore Phytoplankton Survey EPA-ORD Glider Missions EPA-ORD Lower Food Web Survey EPA-ORD Video Benthic Assessment NOAA-GLERL Biophysical Modeling NOAA-GLERL Food Web and Nutrient Surveys USGS-GLSC Synthesizing Nearshore to Offshore Transect Data from Previous CSMI Efforts
2. Identify and quantify the role of biological 'hot spots' (e.g., Green Bay, major tributaries/nearshore areas, reefs, and upwelling events) and substrate heterogeneity in supporting Lake Michigan productivity. Seek opportunities to leverage existing work in these areas, including the large array of acoustic receivers in Green Bay.	EPA-ORD Glider Missions NOAA-GLERL Biophysical Modeling NOAA-GLERL Observing Systems USGS-GLSC Lake Whitefish Habitat Selection in Grand Traverse Bay USGS-GLSC Lake Whitefish Habitat Selection in Green Bay
3. Investigate understudied but potentially important components of the food web, including: fall/winter/early spring and nearshore (including shallow shoreline areas) community structure, dreissenid veligers (including their nutrition as a prey for larval fish), Limnocalanus copepods, Mysis, the microbial loop (bacteria and microzooplankton), and round gobies (which are undersampled by traditional gears).	EPA-GLNPO Lakewide Benthic Survey EPA-ORD Glider Missions EPA-ORD Lower Food Web Survey EPA-ORD Video Benthic Assessment NOAA-GLERL Dreissenid Surveys NOAA-GLERL Food Web and Nutrient Surveys
4. Investigate evidence for recruitment bottlenecks for key fish species such as lake whitefish and alewife. Seek opportunities to leverage the ongoing multi-year nearshore larval lake whitefish sampling efforts by Lake Michigan Technical Committee agencies and tribes.	EPA-ORD Lower Food Web Survey NOAA-GLERL Biophysical Modeling NOAA-GLERL Food Web and Nutrient Surveys USGS-GLSC Exploring the Bottleneck for Larval Alewife USGS-GLSC Exploring the Bottleneck for Larval Lake Whitefish
5. Further understanding of the current and future impacts of terrestrial and aquatic invasive species upon the health of the Lake Michigan ecosystem.	EPA-ORD Video Benthic Assessment
6. Continue nearshore to offshore monitoring of key food web components (e.g., phytoplankton, zooplankton, Diporeia and dreissenid mussels).	EPA-GLNPO Lakewide Benthic Survey EPA-GLNPO Nearshore Phytoplankton Survey EPA-ORD Glider Missions EPA-ORD Video Benthic Assessment NOAA-GLERL Biophysical Modeling NOAA-GLERL Dreissenid Surveys NOAA-GLERL Food Web and Nutrient Surveys NOAA-GLERL Observing Systems
11. Quantify land cover/land use changes and their spatial distribution in the Lake Michigan basin 12. Better understand the connections among upland ecosystem changes (observed or predicted), Lake Michigan water quality, and habitats for rare species or critical life stages. 13. Quantify the effects of land cover/land use changes on terrestrial and aquatic cycling of nutrients, carbon, and mercury.	EPA-ORD Watershed Land Use/Land Cover Change Detection

EPA-GLNPO Lakewide Survey

Contact: Annie Scofield

From July 13-24, 2021, EPA, Buffalo State College, and NOAA will use the R/V Lake Guardian to monitor and map the distribution of bottom-dwelling organisms in Lake Michigan. Researchers will use underwater video and PONAR samples of the lake bottom sediment to estimate the presence and abundance of bottom-dwelling species, particularly the distribution and condition of the native amphipod *Diporeia* and invasive Quagga mussels. The 2021 data will be compared to results from intensive surveys conducted in 2005, 2010, and 2015, and depth-zone distribution maps for these species will be updated. This is part of an EPA long-term monitoring effort and complements other CSMI efforts by NOAA and USGS. During this survey, EPA and NOAA will also collect dreissenid mussel samples for stable isotope analysis. These data will support food web studies in the Great Lakes by providing lake-wide baseline isotopic values for dreissenid mussels, and will contribute to multiple collaborative projects, including assessments of dreissenid mussel feeding behavior led by SUNY Buffalo State researchers (PI: Dr. Lyubov Burlakova) and quantification of energy pathways to preyfish led by University of Wyoming (PI: William Fetzer).

EPA-GLNPO Nearshore Phytoplankton Survey

Contact: Annie Scofield

CSMI phytoplankton sampling in Lake Michigan at 12 nearshore stations, 10-62 m deep, will consist of integrated sampling of the homogeneous water column in spring (April) and summer (August). Summer sampling will further include collection of a discrete deep chlorophyll layer sample. Samples will be collected for phytoplankton community analysis, total and dissolved nutrients, and chlorophyll-a. This CSMI sampling augments similar sampling at deep water, offshore locations that are sampled annually as part of a long-term EPA monitoring effort.

EPA-ORD Glider Missions

Contact: Tom Hollenhorst

Researchers will investigate the relationship between conductivity, algal fluorescence, dissolved oxygen, resuspension of sediment, organic matter, and chemical species by completing multiple autonomous glider (AUV) deployments (each 2-3 weeks duration) over the course of the stratified season. Data collected by the gliders will be used to characterize habitat quality for fish larvae in both nearshore (Coregonines) and offshore (alewife). Gliders may also be deployed in Green Bay to examine potential for hypoxia.

EPA-ORD Lower Food Web Survey

Contact: Joel Hoffman

To examine the potential for source and sinks of nutrients to affect larval fish production, researchers will collect larval fish and zooplankton samples, and quantify water chemistry, at each CSMI station. Towed sensor data and samples for the quantification of carbon, nitrogen, and sulfur stable isotope ratios of algae, sinking organic matter, dreissenid mussels, zooplankton, and key fish species may also be collected to characterize food web interactions.

EPA-ORD Video Benthic Assessment

Contact: Joel Hoffman and Annie Scofield

Researchers will map and quantify dreissenid populations across Lake Michigan using drop cameras in order to augment PONAR sampling by GLNPO. Video also will be used at assess the presence of round goby, vegetation, and hard substrates.

EPA-ORD Watershed Land Use/Land Cover Change Detection

Contact: Joel Hoffman

ORD researchers will work with partners to examine associations between watershed land use/land cover change and in-lake parameters.

NOAA-GLERL Biophysical Modeling

Contact: Mark Rowe

Larval fish are notoriously patchy and thus difficult to sample. In 2021, biophysical models linked to the Lake Michigan Huron Operational Forecast System (LMHOFS) model will help visualize transport of water likely to contain larval fish from presumed nearshore spawning areas, using a Lagrangian particle model linked to LMHOFS; and transport of river inputs of phosphorus. In 2022, modeling will be used to assess likely hatch locations of aged larval fish collected in 2021 and transport of nutrients from tributary inputs and associated production of phytoplankton and zooplankton biomass to interpret field observations from 2021.
https://www.glerl.noaa.gov/res/glcfs-fvcom/larval-tracker-csmi2020/

NOAA-GLERL Dreissenid Surveys

Contact: Ashley Elgin

To understand population dynamics of dreissenid mussels, researchers will repeatedly sample settled mussels plus pelagic veligers near Muskegon, MI, and calculate lake-wide mussel length-weight relationships. They will also establish a long term (5+ year) series of moorings in the Muskegon region to study mussel growth, mortality, and shell dissolution rates.

NOAA-GLERL Food Web and Nutrient Surveys

Contact: Ed Rutherford

Researchers will conduct high frequency surveys to estimate density, diet, growth and relative survival of larval and juvenile fish; monthly measurements of nutrient concentrations and biomass of prey fish, fish larvae, zooplankton phytoplankton (biomass, nutrient content, primary productivity), and microbes at nearshore, mid-depth and offshore sites near Muskegon. Fine-scale (5-10m) diel vertical samples of biota in mid-depth and offshore regions using MOCNESS, hydroacoustics, midwater trawl, UV radiometer, fluorometer, nets and LOPC will reveal effects of UV, CDOM, and light on movement and predator-prey interactions within the lower food web. Our intensive bi-weekly sampling will document abundance of dreissenid veligers in the environment and in larval fish diets, and when combined with lab experiments will measure veliger selectivity by larval fish and the resulting effect on larval fish growth. Estimates of primary productivity and chlorophyll a using historical and contemporary methods will be made at nearshore, mid-depth and offshore sites in coordination with the Observing System efforts described below. These activities also will inform biophysical modeling of nutrient loads, dispersal and effects on primary and secondary productivity.

NOAA-GLERL Observing Systems

Contact: Steve Ruberg

In support of other efforts, researchers will (1) deploy a coordinated program of buoys (Muskegon LTER transect at 20 and 45 meter depths), drifters and autonomous vehicles in the near- and off-shore to measure lake-wide primary production and community metabolism through dissolved oxygen changes; (2) compare in-lake estimates of primary production and phytoplankton biomass among shipboard measurements, deployed instrumentation, and remote sensing; and (3) provide continued support for the Muskegon Lake Observing System

ecosystem observations. The Muskegon 45m buoy also has the capability to provide high-resolution fish and mussel observations.

USGS-GLSC Exploring the Bottleneck for Larval Alewife

Contact: Bo Bunnell

2015 CSMI results showed that larval alewife growth rates were at least 40% lower than rates measured in the 2000s and that veligers dominated alewife diets. In 2021, researchers will repeat and expand the 2015 offshore July lake-wide sampling for larvae and zooplankton, and collaborate with state and federal agencies and universities conducting at least biweekly sampling of alewife (and other species like yellow perch) in the nearshore waters by processing their zooplankton and larval fish samples. Given the doubling of water clarity in Lake Michigan since 2004, researchers will also measure profiles of ultraviolet radiation to determine whether increased exposure has increased mortality of larval alewife. These data will help test the hypothesis that declining zooplankton prey and increased exposure to ultraviolet radiation have increased larval mortality of alewife in a changing ecosystem.

USGS-GLSC Exploring the Bottleneck for Larval Lake Whitefish

Contact: Bo Bunnell

Working directly with the Little Traverse Bay Band of Odawa Indians that sampled larval lake whitefish and zooplankton in at least three sites annually between 2015 and 2019, researchers will process archived zooplankton samples that will be combined with diet analyses of larval coregonines (subsequently identified with genetics) processed by Purdue University (PI Paris Collingsworth). Increasing understanding of the success of larval feeding during a potential critical period will help test the hypothesis that lake whitefish recruitment is declining due to declining spring zooplankton availability in the nearshore since the proliferation of dreissenid mussels.

USGS-GLSC Lake Whitefish Habitat Selection in Grand Traverse Bay

Contact: Darryl Hondorp

Researchers will use acoustic telemetry to compare movements and seasonal habitat use of adult cisco and lake whitefish in Grand Traverse Bay (GTB) with the goal of relating differences in species status to variation in their spatial ecology. This project leverages existing acoustic receiver networks and acoustic-tagged Cisco already present in GTB and will generate information that can be compared with results of an ongoing acoustic telemetry study of Lake Whitefish in Green Bay.

USGS-GLSC Lake Whitefish Habitat Selection in Green Bay

Contact: Richard Kraus

By leveraging the existing Great Lakes Acoustic Observation System (GLATOS) network, researchers will obtain depth-resolved high-frequency water quality measurements, support modeling of abiotic parameters in Green Bay. Additionally, results will be linked to telemetry of key coregonine species (Lake Whitefish and Cisco) to better understand habitat selection. Comparison of the results with coregonine telemetry in Grand Traverse Bay will support improved conservation and management of these species. Although work was delayed due to the pandemic, lake whitefish tagging efforts in Green Bay have been coordinated successfully with Wisconsin DNR and the Wisconsin USGS COOP, and acoustic telemetry tags with sensors (n=100) were deployed in Fall of 2020. The Green Bay GLATOS telemetry working group is finalizing a new sampling design for acoustic receivers, and deployment of temperature and

dissolved oxygen loggers on the new observation grid is planned in 2021 to coincide with collection of tagged lake whitefish detection data.

USGS-GLSC Synthesizing Nearshore to Offshore Transect Data from Previous CSMI Efforts

Contact: Yu-Chun Kao

During previous CSMI cycles, USGS has partnered with EPA to conduct monthly (Michigan 2010, Huron 2012) or seasonal (Michigan 2015, Huron 2017) sampling of chlorophyll, zooplankton, and prey fish across nearshore to offshore transects (from 18 m to 110 m in depth). Researchers will synthesize existing data to determine whether differences in primary and secondary production exist along this depth gradient and could influence growth and survival of larval fishes, and whether sampling in more-nearshore (< 18 m depth) stations should be conducted to see the effects of nutrient loads on lower-trophic-level productivity.