Lake Ontario Cooperative Science and Monitoring Initiative (CSMI) 2023 Science Priority Planning Workshop Report

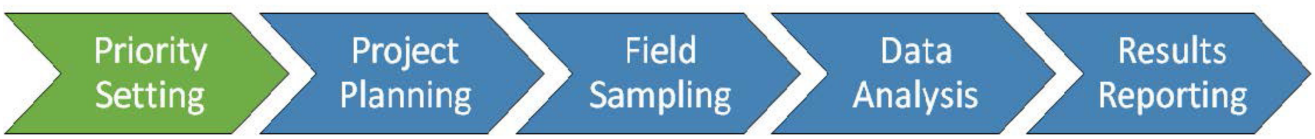
CSMI Lake Ontario

Report by:

James Watkins (Cornell University - DNRE)

Stacy Furgal (New York Sea Grant) and

Lars Rudstam (Cornell University - DNRE)



Sea Grant New York

*Funding for this workshop was provided with a grant from the International Joint Commission (IJC).

www.nyseagrant.org

TABLE OF CONTENTS

Workshop Description and Executive Summary

Description

This report summarizes the 2-day virtual workshop on “Research Priority Planning for Lake Ontario” held June 28-29, 2021. Funding was provided by the International Joint Commission (IJC) and the workshop was organized and hosted by Cornell University and New York Sea Grant with 130 participants from US and Canada. The primary goal of the workshop was to identify science priorities for the 2023 intensive sampling field year of Lake Ontario, following the Cooperative Science and Monitoring Initiative (CSMI) five-year rotation specified in Annex 10 (Science) of the Great Lakes Water Quality Agreement. This workshop was part of the CSMI priority-setting process and builds on the 2018-2022 Lakewide Action and Management Plan (LAMP) (Environment and Climate Change Canada (ECCC) and US EPA, 2018). The LAMP identified four areas for management actions to protect the Lake Ontario ecosystem including 1) nutrient and bacterial-related impacts, 2) loss of habitat and native species, 3) aquatic invasive species, and 4) contaminants. The LAMP also identified six general science, and monitoring priorities including 1) characterize nutrient concentrations and loadings, 2) improve understanding of nearshore nutrient related problems, 3) evaluate aquatic food-web status, 4) improve understanding of fish dynamics, 5) characterize critical and emerging contaminants, and 6) evaluate coastal wetland status. The 2021 workshop assembled a large number of scientific experts, managers, and students from the Lake Ontario community to continue to refine these priorities and identify others to develop science priorities for the 2023 CSMI field year.

The workshop started on the afternoon of June 28, 2021 and continued in the morning of June 29, wrapping up at noon. Anne Scofield of Region 5 and Kristina Heinemann of Region 2 of the US Environmental Protection Agency (US EPA) began by providing context for Annex 10 (CSMI monitoring) efforts for all five Great Lakes and the specific cycle for Lake Ontario and the role of the workshop.

US and Canadian agencies have supported lake-wide science and monitoring of Lake Ontario for more than three decades, so it is important to recognize what has been learned from previous efforts. Previous knowledge gaps have been investigated, however new concerns (e.g., new invasive species or sudden loss of native species) have emerged over the years to realign and adjust priorities. Recent developments in new technologies provide new potential to answer previously unanswered questions. Therefore, an important component on Day 1 of the workshop was to report out from the work done during the previous LO CSMI cycle (from the 2018 LO CSMI-field year). This included an update based on the draft report by Sea Grant summarizing US efforts funded by the Great Lakes Restoration Initiative (GLRI) as well as a synopsis of 2018 binational efforts by the River Institute. In addition, two special Lake Ontario 2018 CSMI issues in scientific journals are in preparation, one in the Journal of Great Lakes Research and the other in Aquatic Ecosystem Health and Management.

The structure of this workshop was planned with a committee with representatives from US EPA, ECCC, USGS, USFWS, OMECP, and NYSDEC. The workshop structure closely followed the format of a pair of IJC decadal science workshops held in April 2021. It focused on structured conversations between scientists and managers within six breakout groups over two days. The themes of the six groups generally aligned with the management actions, monitoring and science priorities and threats identified in the LAMP.

- Nutrient Loading (co-moderators Nadine Benoit and Dave Depew)
- Primary Production (Greg Boyer and Andrew Bramburger)
- Coastal Wetlands and Connecting Channels (Michael Twiss and Jeff Ridal)
- Contaminants and Pathogens (Roxanne Razavi and Wayne Richter)
- Native Species and Habitat (Tim Johnson and Brian Weidel)
- Fish Communities and Ecosystem Connections (Lars Rudstam and Kelly Bowen)

Initially the co-moderators presented a series of six topical five-minute “lightning” talks for the entire group to spark later discussions. After an update of 2018 CSMI reporting by Matthew Windle of the River Institute, each breakout group met with the co-moderators leading discussions using a standard list of questions and with dedicated note-takers for each group. The next morning these discussions continued. At the end of the workshop, the co-moderators reported out to the whole group in a “recap” presentation. In the appendices we provide a list of the participants of each breakout group as well as the full set of notes from the breakout group discussions. Within this report we provide summaries of both the “lightning” and “recap” for each breakout group, as well as a summary of overall conclusions from the collective discussion.

References

Environment and Climate Change Canada and the U.S. Environmental Protection Agency. 2018. Lake Ontario Action and Management Plan, 2018-2022.

Executive Summary

A virtual workshop for identifying Lake Ontario research priorities for the upcoming 2023 CSMI field year was held June 28-29, 2021. The workshop was funded by the International Joint Commission and hosted by Cornell University and NY Sea Grant. Staff of the US EPA and the River Institute provided context for the CSMI and LAMP and the 2018 CSMI field year efforts. Over 150 participants were registered and 130 participated in six breakout groups.

Common broad overall CSMI themes identified in discussions

- Desire for more transparency and communication about the general CSMI process and the distribution of funds. A large component of the scientific community that work in Lake Ontario and connecting channels were largely unaware of the extent of such efforts during extensive sampling years and its coordination with other annual monitoring programs.

- Need for generational shift in leadership and hence a need for additional communication, contact, and coordination. There is recent and anticipated future turnover of lead researchers and agency staff (e.g., retirement of Fred Luckey, US EPA Region 2).
- Improve CSMI planning. Comes up every cycle but can always do better to coordinate efforts and share resources (i.e., research vessels). The nearshore monitoring and coregonid assessment done in 2018 were good examples of coordinated approaches.
- Improve coordination of annual monitoring efforts across agencies and programs towards informing CSMI planning.
- Prioritize and fund CSMI data analysis/reporting/publishing/communicating as much as sample collection.
- Involve Indigenous communities in CSMI research.
- Changing past approaches to setting priorities - Keep in mind what is feasible in a single year and focus on projects that can be done in that time frame.
- Add winter sampling to fill a persistent data gap.

Exploration of research priorities, and crossover topics for 2023.

- Observed phosphorus concentrations in Lake Ontario are much lower than expected relative to loading estimates.
- Although there is always room for improvement of loading estimates from the Niagara River and tributaries, continued declines in offshore phosphorus are likely due to shifts in nutrient cycling. We need a better understanding of the role of the continued expansion of dreissenid mussels.
- In response to nutrient declines algal communities have shifted to smaller forms and towards lower overall primary productivity.
- Increasingly oligotrophic conditions promote high water quality and clarity but may impact higher trophic levels including limiting fish production potential. We need more attention to the coupling between productivity at lower trophic levels and fish/fisheries.
- Alewife declines may happen as a result of declines in offshore lake productivity and increased wild production of Chinook salmon and other piscivores. A better understanding of the risks of such declines under different management scenarios need to integrate lower trophic level dynamics, mussel effects, and predator-prey interactions between alewife and salmon.
- Nearshore habitats are still subject to nutrient enrichment and nuisance blooms of filamentous algae (*Cladophora*) as well as blue green algae blooms in embayments.

- Dreissenid mussel populations are closely monitored but given their dominance in the Lake Ontario ecosystem, there is need for further research on their ecosystem effects and population dynamics. This includes their capacity to store and release phosphorus, their ability to grow in profundal habitats, their reproduction and dispersal of veliger larvae, the importance of veligers in the pelagic food web, and possible declines in the effects of mussels due to changes in size structure and predation by invasive round gobies. All these topics have important ramifications for the future of the lake.
- Native lake trout appear to be benefitting from round goby but still struggle towards sustainability.
- Legacy contaminants such as PCBs and mercury have consistently declined over time in water, sediment, and biota, but observed food web shifts may mask some of the improvements.
- Monitoring of emerging contaminants such as PFAS reveals how pervasive these new compounds can be with unknown ramifications.
- Climate change effects, such as increased epilimnetic temperature, longer periods of stratification and decreased ice cover need to be taken into account in any prediction of the future structure of the Lake Ontario ecosystem and the ecosystem services it provides.

Nutrient Loading

Co-Moderators

Nadine Benoit (Ontario Ministry of the Environment, Conservation, and Parks)

David Depew (Environment and Climate Change Canada)

Note-taker Beth Whitmore (Cornell)

Background

Phosphorus stimulates algal production, the main primary producers in Lake Ontario, and thus drives the productivity of the entire food-web. However, too much phosphorus leads to eutrophic conditions with characteristic nuisance algal blooms. The Great Lakes Water Quality Agreement in the 1970s set a target for phosphorus loadings to Lake Ontario of 7000 Metric Tonnes Per Annum (MTA) towards lowering offshore lake concentrations to a target of 10 ug/L. These targets were met in the 1990s, but concentrations continue to decrease in the offshore (Figure 1). In contrast, nearshore areas in contact with land and tributaries are often still nutrient enriched with nuisance levels of attached algae and in certain embayments with Harmful Algal Blooms (HABs). These areas can be impaired for human uses such as drinking water, swimming, and boating.

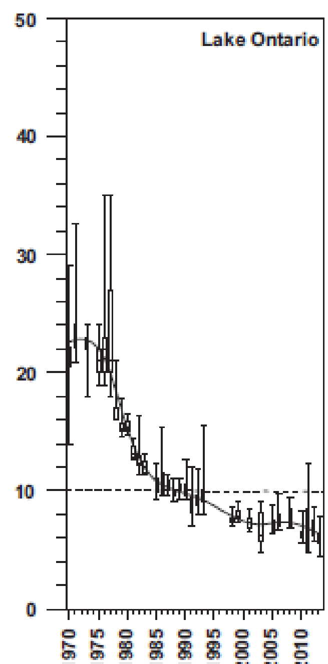


Figure 1. Phosphorus trend for Lake Ontario from 1970-2015 (Dove and Chapra, 2015). Concentration goal of 10 ug/L is delineated.

The Niagara River is recognized as the primary source of incoming water and nutrients to Lake Ontario. Interestingly, modeled loads for the Niagara River using the standard loading calculations developed by Dolan and Chapra are lower than the loads measured by ECCC. Some of these measured Niagara River loads can exceed the total loading target for all of Lake Ontario (7000 MTA) and with known other P loads into the lake, the total P load has to be higher than the GLWQA target. Even so, phosphorus concentrations in the offshore continue to decrease and are now well below the concentration objective. This discrepancy suggests that either: (1) the coupling between load and in-lake concentrations in the original models was too simplistic and not sufficiently understood; or (2) changes in the lake since the 1980s affected the coupling between loads and concentrations. For example, the large increase in dreissenid mussels may retain and trap P in the nearshore, as suggested by recent modeling efforts. Canada is also evaluating long term monitoring data (from 1976 on) from the output from Lake Ontario, the St. Lawrence River, for clues.

Other sources of P loading include point sources such as municipal wastewater treatment facilities and nonpoint sources including tributaries draining urban and rural watersheds, and groundwater input. Most point sources are consistent and well quantified however, nonpoint sources have characteristic variation due to land use and seasonality. Both of these loads mix closely to the shoreline throughout the lake.

Efforts to Fill Data Gaps

Towards improving understanding of the roles of tributaries, the Canadian agencies assembled a Lake Ontario Tributary Monitoring Initiative on the northwest side of the lake in 2018 (Figure 2). The goals include: 1) determine tributary loads, 2) quantify event discharges, and 3) examine land-river interactions. MECP also has a multi-watershed study with year-round sampling of agricultural watersheds in Ontario.

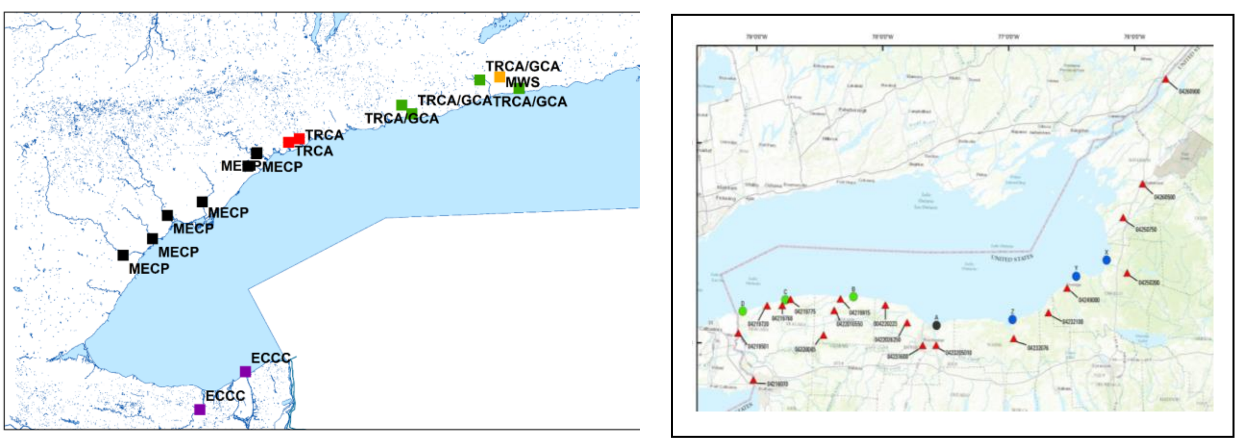


Figure 2. Canada (left panel) and US (right panel) nearshore monitoring sites around Lake Ontario. (MECP, TRCA, ECCC, City of Toronto, GCA, OMAFRA), USGS (right panel).

USGS monitors tributaries and watersheds on the south shore of Lake Ontario following earlier work by Todd Howell and Joe Makarewicz, Brett Hayhurst and the 2018 Lake Ontario Nearshore Nutrient Study (LONNS)

These monitoring networks support watershed modeling platforms such as SWAT and SPARROW that can help to fill spatial gaps to improve lakewide loading estimates. Maintenance and expansion of the network of river gauges are high priorities.

Overall questions were posed to stimulate discussion in the breakout session. These questions were generally organized into “spatial”, “temporal” and “conceptual” information and data needs.

<u>*Spatial needs*</u>

- *River loads of suspended solids discharge on shallow-water mussel beds- are dreissenid lakebeds a substantial interceptor and processor of this material?*
- *The fate of a substantial portion of the tributary P load is unaccounted for, relative to Cladophora nutrition. What do we know about the potential for time offsets between deposition of Particle Bound Phosphorus and its regeneration into bio-available phosphorus? And how far away from the source does this occur?*
- *What is the role and effect of onshore circulation on productivity?*
- *What about the influence of smaller, but more abundant discharges from shoreline storm sewers and drains?*
- *What about AOCs and their nutrient contributions to the lake? Does internal cycling of phosphorus in these AOC systems have an impact?* The Bay of Quinte and Hamilton Harbour for example, have made progress in reducing external inputs– but now they are showing signs of internal loading from legacy phosphorus deposition, largely driven by redox sensitive forms of phosphorus. In these circumstances *what are the barriers to AOC recovery? And what is the impact of these barriers [?] on P inputs to LO?*
- *What about other P sources that have not been studied extensively for Lake Ontario – are they important here? For example, greenhouse agriculture is extensive on the Canadian side. Are wetlands sources or sinks? What about groundwater input?*

<u>*Temporal needs*</u>

- *What can we say about winter loadings and storm events to the lake? How do these relate to climate change?*

<u>*Conceptual needs*</u>

- *Issues such as pelagic oligotrophication, resilience of the nearshore phosphorus shunt conceptual model (or paradigm or hypothesis), and the ramifications of increasing nitrate offshore are all gaps we may want to explore further.*
- Where do models fit in? Given recent data from Hill and Dove should they be updated?
    a. Watershed level models SWAT SPARROW
    b. Hydrodynamic (lake circulation) models?

Breakout Discussions

Recommendations from Day 1:

- Genesee River is the largest P contributor to the Lake outside of the Niagara River and needs more monitoring
- More tributaries need to be monitored around the Lake
- Additional seasonal and event-based sampling recommended.
- Better sampling of tributary flows and discharge including the winter season – more complete information that can be useful for modeling.
- Explore the extent of *Cladophora* in the nearshore and connections to the nearshore shunt hypothesis. How phosphorus input and load contributes to *Cladophora* growth.

Recommendations Day 2:

- Synchronize and standardize sampling across agencies and tributaries

Names of potential collaborators for working on various tributary loading studies projects around the lake:

  - George Thomas (GThomas@geneseeriverwatch.org)
  - Joe Makarewicz (Jmakarew@brockport.edu)
  - Lake Ontario Collaborative – western basin:
    - Todd Howell (Todd.howell@ontario.ca)
    - Lauren Barth (lauren.barth@utoronto.ca)
    - David Depew (David.depew@canada.ca)
    - Calvin Hitch (calvin.hitch@trca.ca)
  - Dale Robertson (does SPARROW loading) dzrobert@usgs.gov
  - Greg Koltun USGS does the majority of loading estimates - recent publication on US loads: https://pubs.er.usgs.gov/publication/ofr20201145
  - Tracie Greenberg (ECCC) – tracie.greenberg@canada.ca
  - Contact for Lake Erie Basin drone work would be Jody.Mckenna@ec.gc.ca or jocelyn.sherwood@ec.gc.ca

Resources/references that were shared with the group:

Dove and Hill (2021). Concentrations and loads of nutrients and major ions for the Niagara River, 1975-2018. J. of Great Lakes Res. 47: 844-861.

- https://reader.elsevier.com/reader/sd/pii/S0380133021000496?token=8AF1B8CE24D489B9E760C4C4831ABFC5CE8AA134F69B22A0EDEAD9BE31C3C9DB0C52E338D239BEB22C022B7F53F7443B&originRegion=us-east-1&originCreation=20210628173600

- Binational SPARROW model for 2002 water year. https://www.usgs.gov/centers/umid-water/science/sparrow-watershed-modeling-binational-uscanada-models?qt-science_center_objects=0#qt-science_center_objects
- Greg Koltun USGS publication on US loads: https://pubs.er.usgs.gov/publication/ofr20201145
- North, R. L., Guildford, S. J., Smith, R. E. H., Havens, S. M., & Twiss, M. R. (2007). Evidence for phosphorus, nitrogen, and iron co-limitation phytoplankton communities in Lake Erie. Limnology and Oceanography, 52(1), 315-328
- Robertson et al. 2018: https://www.sciencedirect.com/science/article/pii/S038013301730165X?via%3Dihub
- Data for several NY LO tributaries available at https://www.sciencebase.gov/catalog/item/55ce0c7ae4b08400b1fe159b
- https://mtri.org/cladophora.html

Identified Research Priorities

1. **"Nested" monitoring approach**
    - Improve whole lake loading estimates.
    - Target support for selected tributaries – monitoring/load estimation/impact on nearshore.
    - Requires collaborative effort to identify existing efforts, identify objectives, prioritize and plan.
2. **Improve confidence in nutrient loads**
    - Extend monitoring to "shoulder" seasons and winter.
    - Identify under-monitored (but important) tributaries (e.g., Genesee River).
    - Develop a consistent approach for load estimation method (where resources permit).
    - Use of surrogate measures where applicable (turbidity/conductivity).
    - Application of broad scale assessment techniques to pinpoint areas of Cladophora growth with potential nutrient sources.
3. **Improved understanding of nutrient footprint in the nearshore**
    - Plume behavior/dilution and impact on benthic environment.
    - Form and speciation of P with emphasis on the fate of particulate material.
    - Interaction with broader hydrodynamic features (upwelling/downwelling and more).

Primary Production

Co-Moderators

Greg Boyer SUNY Environmental Science and Forestry (ESF)

Andrew Bramburger- Environment and Climate Change Canada

Notetaker Steph Figary (Cornell University)

Background

Primary production by algae is the foundation of energy for the entire aquatic food web. However, too high a level is associated with harmful algal blooms, benthic cladophora, and eutrophication. How much primary production is desirable depends on the prioritized ecosystem services – less for drinking water, swimming, and boating, a little more for fish production. A happy medium may be the definition of a healthy ecosystem.

As nutrient loading was reduced since the 1970s, primary production in Lake Ontario has also decreased moving the lake from a mesotrophic to an oligotrophic state. Higher water clarity (as a result of less nutrients and dreissenid mussel filtering/grazing) has led to the increased importance of deep chlorophyll layers (DCLs) and benthic production that now has sufficient light, to grow, thus expanding the range of habitat for primary producers. Lower primary production, if trophic transfers remain the same, will lead to less production in higher trophic levels including fish. Lake Ontario, as the most downstream of the Great Lakes, has higher nutrient concentrations and thus higher primary production relative to lakes Superior, Huron, and Michigan.

Generally simple measurement of the biomass proxy pigment chlorophyll-a is a primary monitoring index, but taxonomic counts of phytoplankton, including biovolume, are important in identifying community shifts. Primary production can also be quantified using C14 or C13 techniques. Optical sensors can provide continuous measurements of chlorophyll, phytoplankton pigment classes, and primary production. Primary production varies spatially from nearshore to offshore, seasonally (winter is poorly understood) and vertically (epilimnetic, DCL, and benthic).

Key Research Areas Identified

- Quantification/Characterization of Primary Production
- Epilimnetic/DCL/Benthic Contributions
- Winter- Seasonal Dynamics

Research emphases have shifted over the CSMI rotation timeline for Lake Ontario. For example, 2008 efforts had a focus on nearshore impacts, but 2013 efforts shifted toward the offshore and an interest in the importance of deep chlorophyll layers. Take home messages in 2018 included the loss of spring diatom blooms and summer increases of offshore dinoflagellates and cyanobacteria.

Identified Research Priorities

1. Do we know the impact of the DCL on overall Primary Production?
2. Nearshore versus offshore – are we dealing with two different lakes?
3. Are our sampling technologies and regimes sufficient to capture production?
    a. Role of picoplankton in Lake Ontario
    b. What is happening in the winter?
        i. Has our spring diatom bloom become a winter diatom bloom?
4. Are our food web patterns changing with changing conditions?
    a. Will shifting from diatom to cyanobacterial biomass in the offshore disrupt the food web, trophic efficiency?
    b. What about rotifers? Biomass is small but are they insignificant?
5. What do we know about benthic primary production versus pelagic primary production?
6. How do we calibrate/incorporate new technologies into 2023?

Contaminants and Pathogens

Co-Moderators

Roxanne Razavi, SUNY Environmental Studies and Forestry (SUNY-ESF)
Wayne Richter, NYS DEC

Notetaker Joe Connolly (Cornell University)

Background

Historically, legacy and emerging contaminants reached levels of concern in Lake Ontario within the water column, sediments, and/or biota. Long-term monitoring provides data for managers and scientists to identify sources and sinks to support efforts to lower contaminant concentrations and reduce harmful impacts. For many compounds, recent decreasing trends are encouraging, but for others there is still cause for concern. Understanding contaminant passage through the food web and changes due to ecosystem shifts have become increasingly important towards maintaining human and wildlife health. Biomagnification of many pollutants highlights the compounding effects for larger organisms including fish, birds, and humans.

Research areas within this topic are broad. Human consumption guidelines are informed by monitoring of fish species contaminant level differences, particularly in Areas of Concern (AOC). Sediment levels represent long-term bioaccumulation of contaminants and is thus an important focus. Identifying contaminant sources, both regional and remote, and remediation approaches are essential. Remote transports often rely on the atmosphere. Detection of emerging contaminants that may not be currently monitored are under development.

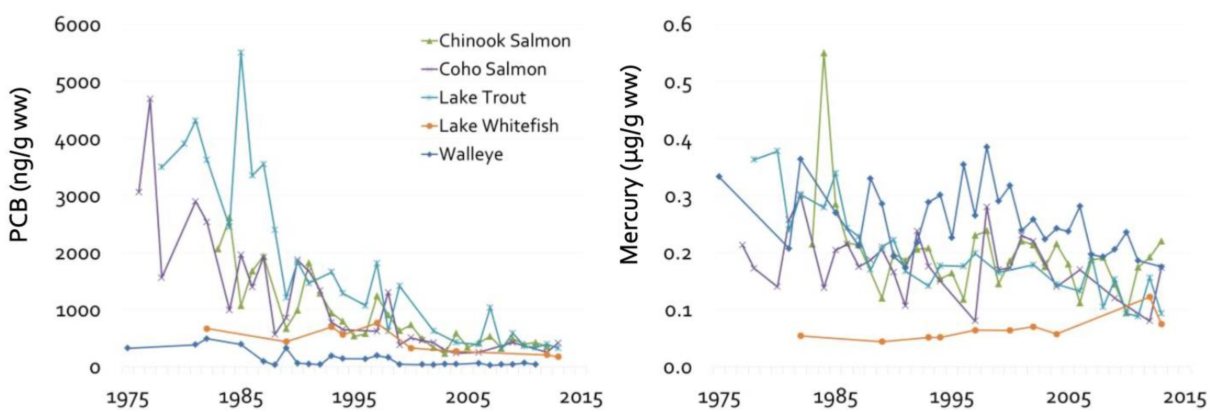


Figure 3. Development of contaminant concentrations in mussel tissues of several fish species. Left panel – PCB, right panel – mercury. (LAMP Lake Ontario 2018-2022 Report)

Fortunately, we have seen continued decreases in the contaminant loading of PCBs and mercury in fish over the past 40 years (Figure 3). The Niagara River has seen 50-70% reductions of ten targeted toxins. The trend of decline depends on our ability to identify and reduce sources as well as the persistence of the contaminant in the system. For example, remote and atmospheric sources are often difficult to regulate, and continued releases from legacy contamination of sediment persist. New contaminants emerge all the time, including microplastics, pesticides, and PPCPs.

In planning for the future, we must prioritize the most harmful chemicals, particularly ones that exhibit biomagnification. We need to recognize that new invasive species and climate change can mask improvements. Communication and coordination between stakeholders are key in mitigating harmful effects.

Discussion

-There is a need to coordinate with existing monitoring programs and not to duplicate efforts. Euan Reavie of UM Duluth described one such sediment monitoring program run by US EPA including a map of stations and list of sediment parameters in Lake Ontario. *See appendices for an extensive list of existing programs and contacts.

-Improve ability to share data across various research programs, perhaps in a central location (data registries, databases, repositories).

-Food web shifts such as the observed declining biomass of alewife may have large ramifications for contaminant cycling in Lake Ontario.

-Impacts of contaminants are often poorly defined in Great Lakes. We may learn from approaches developed in Arctic monitoring where biomagnification is a particular concern even in such a remote habitat.

-This breakout group recognized that expertise in pathogens was lacking, so encourages reaching out to specific experts on pathogens.

Crossover to other breakout groups

- Nutrient loading: tributary sampling of CECs, nearshore sampling of contaminants.
- Primary production: trophic status can affect bioavailability, hypoxia/anoxia can affect contaminant bioavailability.
- Connecting channels: Consider downstream, e.g. sampling below Wolf Island. Need to seek out participation of indigenous communities and those who regularly consume fish in the drainage.
- Wetlands: Consider contaminant flux in wetlands as it may relate to flooding and water levels.

Identified Research Priorities

Contaminants and pathogens is a very broad topic that can be approached though different, non-mutually exclusive frameworks:

1. A contaminant by medium by spatial location three-way matrix.
2. Legacy versus emerging contaminants
3. Point versus non-point source.
4. Targeted studies versus understanding general prevalence in the ecosystem.
5. Inputs versus what is already present.
6. Reduction versus source identification versus adding to the time series.
7. Persistent, bioaccumulative and toxic versus persistent, mobile and toxic (recognizing that non-bioaccumulative contaminants need attention).
8. Focus on effects.

Consider that avoiding potential public health impacts would be another return on investment for this research.

Can we use indicators to reduce the complexity of so many contaminants? How would we do this?

Wetlands and Connecting Waters (Niagara River and Upper St. Lawrence River)

Co-Moderators:
Michael Twiss (Clarkson University)
Jeff Ridal (River Institute) (Cornell), notetaker
Notetaker: Patrick Boynton (Cornell University)

Background

Wetlands and connecting waters are an important, but sometimes overlooked, category for CSMI investigations. In the early 1950s, The International Joint Commission (IJC) approved the order to create the Moses-Saunders and Iroquois dams, as well as the locks of the St. Lawrence Seaway as part of the "St. Lawrence Seaway Project". The Moses Saunders Dam supplies water that is used to generate hydroelectric power, and the Iroquois Dam is used to limit high water levels on Lake St. Lawrence and for ice management. These man-made constructions greatly benefit the economy, but also alter the surrounding environments.

In 1984, a comprehensive report was completed by Patch and Busch (The St. Lawrence River—Past and Present: A review of historical natural resource information and habitat changes in the International Section of the St. Lawrence River. U.S. Army Corps of Engineers, Buffalo, NY, US Govt. Accession No. AD-A147119). This report provided an extensive review of natural resource data related to the international section of the St. Lawrence River, including both published and unpublished sources. This report was written post-dam construction, but pre-dreissenid mussel invasion.

Plan 2014 is another important resource to consider when working in the realm of wetlands and connecting channels. This plan, approved by the IJC, manages water levels and flows in Lake Ontario and the St. Lawrence River. The previous plan was created in the 1950s, and included water level regulation that was unnaturally compressed, which had negative implications for the ecosystem. Plan 2014 was first implemented in 2017, which also happened to be a year of historic flooding due to high water levels.

When planning for the upcoming field year, there are many possible research topics to consider. As mentioned when introducing Plan 2014, water regulation plans have changed in very recent time, and evaluation of impacts would be beneficial. With more water level fluctuations, Plan 2014 potentially increases contaminant and nutrient mobilization in coastal wetlands. Data collected during the winter season is often limited but would provide insight into the impacts of climate change.

Breakout Discussion Summaries

Day 1 discussions covered water levels and Plan 2014, winter/spring sampling, linkages to contaminants and nutrient loading, and the beginnings of research themes for both wetland and connecting channels. Plan 2014 was only recently (2017) implemented, and assessment is needed to determine whether the new water level plan will bring about desired transition from cattail marshes (or whether direct interventions are needed). Urban wetlands are constrained by shoreline development and may not be impacted by Plan 2014. Public understanding related to ecosystem response and changing water levels is still limited, a science communication plan would assist with educational aspects. Thinking more broadly, how do we parse out climate change impacts from impacts of Plan 2014? Monitoring of wetlands in the winter season is extremely limited, therefore there are many data gaps that could be addressed by conducting winter sampling during the 2023 CSMI field year.

Day 2 discussions focused on topics such as modeling, the development of standardized procedures and methodologies, and funding. Metadata analyses are difficult to conduct for connecting waters (large rivers), as data is limited. Time was spent honing the list of final research priorities for this theme. This topics crosses into almost all others from this workshop.

Common ideas expressed in both days included:

- Engagement with Indigenous communities and researchers to carry out CSMI research priorities
- Science communication
- Communication and collaboration between North and South shores
- Linking Lake Ontario to connecting channel and wetland themes

Identified Research Priorities

1. Evaluate whether current high and low water fluctuations are promoting wetland biodiversity?
2. Impact of a changing winter season due to climate change on ecosystems.
3. Potential role of increased water level fluctuations in mobilizing contaminants and nutrients in coastal wetlands.
4. How does the nearshore P shunt operate in a lateral system such as the SLR? Do nutrients accumulate in the nearshore downstream?
5. There is a need for bi-national funding mechanism to build capacity in a historically neglected topic (connecting channels).

Native Species and Habitat

Co-Moderators

Brian Weidel (U.S. Geological Survey)

Tim Johnson (Ontario Ministry of Natural Resources and Forestry)

Note-taker Taylor Brown (Cornell University)

Background

Historically, many factors have been attributed to the decline or extirpation of native species, including (but not limited to) overfishing, invasive species, habitat degradation, climate change, and more, beginning in the 1800s. While the declines and losses at an individual scale are significant, cumulative losses and declines have contributed to overall diminished ecosystem health and resiliency. When considering only the last decade, there have been few species losses, but also few instances of native species recoveries. Noteworthy recoveries include deepwater sculpin and bald eagles. Species that have been identified as imperiled often have species-specific restoration plans guiding their recovery. Often emphasis is made on monitoring, with less emphasis on the more difficult effort of elucidating the mechanism(s) needed to recover the population. Restoration of native fish species, such as lake trout, utilized stocking to create a sizeable adult population, but stocking alone has not addressed the root of the problem, as little successful natural reproduction has occurred.

The story of habitat in Lake Ontario is much the same, with drivers and disruptions beginning in the 1800s. However, there are still many examples of ongoing habitat loss and impairment. Successful restoration efforts tend to be localized, not benefiting lake-wide production and function. Several projects such as the Great Lakes Nearshore Framework and Lakebed 2030 are working on inventory and characterization of habitat, but currently habitat remains poorly described at the lake-wide scale due to coverage that is often limited in scale or outdated. Habitat mapping and characterization was identified as a research priority for the CSMI 2018 in Lake Ontario, however, limited capacity (knowledge and resources) prevented a focused effort. However, much was learned.

The themes of native species and habitat are closely intertwined.

Breakout Discussion Summaries

General Notes:
The group was composed of those with more “fish-centric” viewpoints, so discussion tended to lean towards fish.

Discussions were had over what exactly guides the decision-making process for the selection of CSMI research priorities with regard to native fish (ex. Lake Committee Fish Community Objectives, LAMP report, etc.). Should we consider whether a species is declining or more stable when setting priorities? Current data suggests native species are limited at earlier life stages (ex. egg and larval stages). Instead of taking a species-specific approach, it would be more useful to consider guilds or functional solutions (e.g., how sedimentation influences spawning habitat of many species). Alternatively, one species (e.g., lake trout) could be selected as a focal species to represent many species. There is a hypothesis that spawning habitat is the impediment to a suite of native species; spawning substrate may be a limiting bottleneck for fall spawning lithophilic species (lake trout, lake whitefish, cisco, bloater). Lake trout are slightly easier to study because of their earlier fall spawning time (compared to coregonines that spawn in the winter). This gives us the opportunity to observe actual spawning and egg deposition patterns. Nearshore species such as walleye are utilizing similar habitats for spawning, but often receive less attention as they are not a species with a recovery plan (like Atlantic salmon, lake trout, lake sturgeon).

Since non-native species make up a huge amount of the biomass in the lake, could ecosystem models be used in-lieu of biomass-based approaches? Is the best approach to study habitat directly, or to let fish observations (for example, movements/use during spawning) guide the direction of what habitat is studied? What criteria is used to assess habitat as “good”? Discussions were had as to what factors might be driving fish habitat specifically (hypoxia, substrate distribution, wetland habitat). Considerations should be made for what management “levers” exist. While stocking and harvest adjustments are common, large scale habitat restoration is much rarer.

The 2013 CSMI year utilized Ecopath/Ecosim modeling software to generate predictions, but these tools were less useful for questions of native species and habitat. Other population growth models might be used to understand production/growth potentials/limitations and linkages across trophic levels and life-stages. There is a need to understand how reproductive habitat and/or lake productivity may limit native fish expansions. Spatially, there are well documented historic fish spawning locations to help inform current research. Spawning habitat is obviously important, but nursery habitat (sometimes within rivers and wetlands) may also be worth investigating.

Time was spent discussing what worked well in the 2018 CSMI field year, and how that could be improved upon for 2023. For example, the 2018 CSMI larval coregonine project, had many local collaborators pitching in to sample in order to achieve comprehensive lakewide results. It was a defined information need within a larger framework, and fieldwork apportioning was reasonable for most groups (able to utilize small research boats, limited time input to collection). This model allowed groups that may not have participated in previous CSMI years to contribute.

Points of note:

- Communication of projects that are already ongoing related to habitat is important when selecting future research priorities (LakeBed 2030, spawning shoal surveys, etc.).
- What is feasible in a 1-year CSMI field year? Instead of focusing on collecting more data in large on-going datasets, it might be more beneficial to define

projects that are achievable in a single year, or ones that significantly progress our way of thinking about a topic (not just another point on a times series).
- All the identified priorities have elements that tie into other breakout session themes.

Identified Research Priorities

1. Physical drivers of fish habitat - temperature, ice cover, substrate, anthropogenic changes (e.g., climate, land use).
2. Sediment changes to habitat: inputs, distribution, and resuspension.
    - Influences multiple fish habitats (tributaries, wetlands, in-lake spawning).
    - Possibly most-impactful, but least-studied driver.
3. Lack of substrate information (nearshore or offshore) limits our ability to quantify how habitat limits native species.
    - Same need as 2018.
4. Identify where habitat bottlenecks native fish.
    - Focus on spawning, incubation, or early life history.

Fish Communities and Ecosystem Connections

Co-Moderators

Kelly Bowen (Department of Fisheries and Oceans Canada)

Lars Rudstam (Cornell University)

Note-taker Kimberly Fitzpatrick (Cornell University)

Background

The species composition of the Lake Ontario food web has changed dramatically since the early 1900s and is now dominated by non-native species. Dreissenids mussels are over 90% of the benthic biomass; alewife, rainbow smelt and round goby are the dominant forage fish; and various non-native salmonids are the dominant piscivores. These changes are continuing as both quagga mussels and round goby became very abundant in this century and ecosystem effects of these new players are still playing out. Further, the system is changing with climate change effects and decreased P concentrations (but perhaps not P loads, see group 1 discussions). This group discussed ecosystem connections in general terms without a direct emphasis on fish communities. The background presentation highlighted some major occurrences within Lake Ontario that had broad-scale ecosystem implications:

- Decreased P loading from 1960s to current levels is believed to affect ecosystem productivity, including fish.
- Dreissenid mussels invaded in the late-1980s, and quagga mussels have dominated since the mid-2000s with effects on ecosystem structure and function (bottom structure changed, P cycle affected, water clarity increased).
- *Diporeia* declined from dominant benthos in early 1990s to being almost extirpated by 2020.
- Mussels affect nearshore ecosystems through increased *Cladophora*.
- Invasive predatory cladocerans increased in 1998 (*Cercopagis* – fish hook water flea) and 2005 (*Bythotrephes* – spiny water flea).
- The zooplankton community changed from dominance of small cladocerans and cyclopoid copepods to dominance of calanoid copepods, daphniids and the invasive spiny water flea. Since mid-2000s the zooplankton community has become more similar to the community in the upper Great Lakes.
- Round goby – new invader since mid-2000s with effects not fully understood.
- Naturalized production of Chinook salmon increased and has contributed to declines in alewife.

Breakout Discussion Summaries

Over the course of two days, five major topics emerged: 1. Role of mussels, 2. Fish recruitment variability, 3. Winter dynamics, 4. Pelagic ecosystems and plankton, and 5. Deepwater ecosystem.

1. Role of invasive dreissenid mussels
    - Dreissenid mussels are the dominant contributor to biomass in Lake Ontario.
        - How do they affect P cycling and effects of changes in depth distribution of mussels?
        - Local and whole-lake time trends the same? Mussel density, growth, fecundity, diets.
        - Role of goby predation – are mussels declining due to gobies limiting reproduction? Is this a local or whole lake scale effect? Alternatively, is declining mussel recruitment due to limited veliger production or competition with adult mussels?
        - In either case, what is the role of changes in mussel demographics (biomass consisting of fewer but larger mussels)?
        - Role of mussels in increasing nearshore Cladophora and the nearshore/offshore nutrient differences – do mussels prevent nutrients from reaching offshore and/or strip nutrients from offshore?
        - Importance of veligers for the pelagic food web?

2. Fish recruitment variability
    - Which factors regulate fish recruitment success?
    - Is there sufficient high quality spawning habitat? Are fish using it?
    - At what stage is recruitment "set" for key species? Is information on recruitment dynamics from smaller lakes (e.g., Oneida Lake) useful in the much larger Lake Ontario?
    - Importance of growth and survival during early life stages (eggs, larvae) compared to the first summer and winter (YOY).
    - Food web connections – need to get a better handle on seasonal diets of prey fish, in particular of fish age-0 and age-1.
    - Mapping spawning and nursery habitat. Habitat used by age-0 fish in first summer and fall not always known.

3. Winter dynamics
    - Is the spring diatom bloom declining because it has shifted to be a winter bloom?
    - Does a temperature increase, even a minor one, affect recruitment and over winter survival of both eggs and juvenile fish?
    - How do changes in ice cover affect coregonine and salmonine egg survival?
    - Do changes in river flow dynamics (seasonality, amount) affect river spawners?

4. Pelagic ecosystems and plankton

- Transformation of nutrients/primary production by pelagic/benthic food web (to produce fish). Basic structure and function of pelagic ecosystem is changing with oligotrophication, increasing water clarity, and new invaders.
- Large- and small-scale distributions - hydrodynamics and biology (large scale horizontal, and small-scale vertical). Small scale distributions are important for understanding predator-prey dynamics.
- Causes and consequences of shifts in zooplankton community structure to larger calanoids – productivity, distribution, energy transfer, fish feeding.
- Importance of small grazers – veligers, rotifers, ciliates.
- Bacteria, microbial food web and transfer efficiency may change in more oligotrophic systems

5. Deepwater ecosystem
   - Dominated by quagga mussels, this species may be 95% of the biomass and affect bottom structure, compete with other benthic invertebrates, provide food for benthic fish, and may increase P burrowing in sediment (or increase P recycling rates).
   - Why did *Diporeia* decline? Will they return?
   - What is the role of deepwater sculpin and gobies during the winter period?
   - Can we predict the ecosystem effects of increasing bloater abundance?
   - Mysids are a major food resource for deepwater fish but vulnerable to predation due to slow reproductive rates. How are mysids connected to the benthic food web? What proportion of the population stay on the bottom during the night? How much of the mysid diet is derived from benthic resources?

Identified Research Priorities

1. Use CSMI to study specific mechanisms and unknown interactions that are suggested by existing monitoring programs.
2. Extensive benthic survey is already included in CSMI planning for each lake.
3. Studies of invasive dreissenid mussel dynamics with and without being accessible by predators. Should be done in different depth zones.
4. Evaluate current food web structure – diet analysis of prey fish throughout the basin, stable isotopes/fatty acids across food web components.
5. Sedimentation study (year-round) – what proportion of pelagic production sinks to the deepwater benthos.
6. Winter limnology – a major unknown for ecosystem dynamics in Lake Ontario.
7. Fish recruitment studies – mechanisms and comparisons across the Lake Ontario basin.
8. Habitat mapping (see group 5).

Appendices

Appendix 1: Workshop Agenda

Virtual Lake Ontario Cooperative Science and Monitoring Initiative (CSMI)2023 Research Priority Planning Workshop │AGENDA

Workshop Purpose and Objectives:

- Identify research, data, and information needs in order to set priorities for the 2023 CSMI intensive fieldyear on Lake Ontario.
- Facilitate communication and coordination between U.S. and Canadian research and monitoringgroups.

Workshop Outcomes:

- Breakout Groups: each will develop a list of top research priorities.
- Create a workshop summary report which identifies issues, knowledge gaps, and information andresearch needs and details rationale to support them.

DAY 1: June 28th, 2021

Time (ET)	Activity
12:30 – 1:00 pm	**Logging In and IT Assistance** A time set aside for participants to make sure they are able to properly login to the Zoom platform and troubleshoot any issues prior to workshop activities beginning.
1:00 – 1:15 pm	**Welcome and Workshop Overview:** • Opening remarks, agenda and objectives overview: *Stacy Furgal, Jim Watkins, Lars Rudstam* • Review CSMI: *Annie Scofield*
1:15 – 2:15 pm	**Lightning Talks** A selection of 10-minute talks aimed at summarizing historical hypothesis development in Lake Ontario. • Nutrient Loading: *Nadine Benoit and David Depew* • Primary Production: *Gregory Boyer and Andrew Bramburger* • Coastal Wetlands and Connecting Channels: *Michael Twiss and Jeff Ridal* • Contaminants and Pathogens: *Roxanne Razavi and Wayne Richter* • Native Species and Habitat: *Brian Weidel and Tim Johnson* • Fish Communities and Ecosystem Connections: *Lars Rudstam and Kelly Bowen*
2:15 – 2:25 pm	**Recap of 2018 CSMI Results:** *River Institute*
2:25 – 2:35 pm	**BREAK**

2:35 – 4:30 pm	**Breakout Sessions** Four concurrent breakout sessions with facilitated discussion. The goal is for each session to result in a list of potential research questions and data gaps related to the specific breakout room themes below. • Nutrient Loading • Primary Production • Coastal Wetlands and Connecting Channels • Contaminants and Pathogens • Native Species and Habitat • Fish Communities and Ecosystem Connections
4:30 – 5:00 pm	**Recap and Day 2 Agenda Overview:** *Stacy Furgal, Jim Watkins, Lars Rudstam*

DAY 2: June 29th, 2021

Time (ET)	Activity
8:30 – 9:00 am	**Logging In and IT Assistance** A time set aside for participants to make sure they are able to properly login to the Zoom platform and troubleshoot any issues prior to workshop activities beginning.
9:00 – 9:15 am	**Welcome** • Day 1 recap • Day 2 overview
9:15 – 11:15 am	**Breakout Sessions Continued** • Nutrient Loading • Primary Production • Coastal Wetlands and Connecting Channels • Contaminants and Pathogens • Native Species and Habitat • Fish Communities and Ecosystem Connections
11:15 – 11:25 am	**BREAK**
11:25 am – 12:30 pm	**Large Group Discussion of Breakout Summaries** Moderators will present 5-minutes of highlights from their sessions, with additional time allowed for comments.

*Workshop hosted by Cornell University and New York Sea Grant, supported with funds provided by a grantfrom the International Joint Commission (IJC).

Appendix 2: Breakout Room Summary Notes

These are the raw notes provided by the moderators of the breakout sessions of theLake Ontario Cooperative Science and Monitoring Initiative (CSMI) 2023 Research Priority Planning Workshop that occurred virtually on June 28-29, 2021.

1.) Nutrient Loading
Moderated by Nadine Benoit (MECP) and David Depew (ECCC). Beth Whitmore (Cornell), notetaker.

Lightning talk:

The lightning talk presentation aimed to bring the audience up to speed on the issues at hand, starting with the historical context of nutrient loadings to lake Ontario, decreases in TP loadings after the GLWQA controls and a subsequent second wave of TP concentration decreases following the arrival of dreissenid mussels. The context of loadings in Lake Ontario is a contrast in conditions between offshore (near desertification and low TP concentrations) and the nearshore (nutrient enrichment that varies widely over the shoreline and coastal areas)

The Previous Nutrient Loadings priorities under the 2018 Lake Ontario CSMI were aimed at collecting information to improve our understanding of nutrient loading impacts. Monitoring priorities identified included:

1) characterizing concentrations and loadings in nearshore and offshore waters, and loadings from tributaries, point and non-point sources
2) improving our understanding of nearshore nutrient-related problems including the role of internal phosphorus loadings in driving Cladophora biomass and production and characterization of triggers of cyanobacterial blooms in nearshore and embayment areas

The Lightning talk gave an update on current known conditions with respect to the Loadings of Nutrients to Lake Ontario and set the stage for questions that needed to be considered in the Breakout session:

1) Niagara river mass balance
    - Hill and Dove (2021) show that loadings from the Niagara River to Lake Ontario may have been chronically underestimated based on the Dolan model (Dolan and Chapra, 2012). Measured phosphorus loads were 3.8-5.2 times higher than modeled loads, sometimes accounting of the entire target load for the Lake (7000 MTA). ***What are theimplications given apparent low TP, especially in offshore regions? Are phosphorus deficits larger than originally thought?***

2) Impact on nearshore from inputs, and Nutrient speciation
    - Along the nearshore of the lake, nutrients are loaded from various sources (e.g. Tributaries, WWTPs, Shoreline stormwater drains, surface runoff, shallow groundwater)with varying spatial features and varying forms that range from high to low variability:

- Shoreline stormwater drains, and surface runoff have Phosphorus discharges that are strongly attenuated with lake depth – however they are widely distributed around the lake. Episodic loadings from the sources are difficult to assess, but they are possibly

  among **the most numerous sources of external loading .** ***What is their relevance toCladophora growth?***
- The western basin of Lake Ontario is **most influenced by external loadings, as seen in the water chemistry.** Loadings from the Wastewater treatment Plants in this area arethe highest in the lake, and several large urban rivers influence water quality in the area.Nearshore studies conducted under CSMI 2008 showed that Cladophora was more abundant in developed areas around the lake. Phosphorus loadings overlap due to the many different sources.
- Nutrient loadings from creeks, storm drains and rivers are primary drivers of nearshorewater quality with respect to nutrients and particulates .
- *Given the large number of such sources,* ***what is the total load relative to othersources****?*

What is the speciation of constituents?

- ***Are fine scale models required to understand the impact of these sources onbenthic algal growth and other water quality concerns?***
- ** Joe DePinto comment: I thought it was already determined that we need whole-lake,fine-scale models that include the entire lower food web including Cladophora and Dreissenids.

3) Efforts to fill in some of the gaps in information regarding loadings:
   - Following the 2018 CSMI year, collaborative monitoring has taken place in the western basin of Lake Ontario through the **Inter-agency Lake Ontario Tributary Monitoring Initiative.** This working group (MECP, TRCA and Other CAs, City of Toronto, ECCC, OMAFRA) has focused on setting up tributary flow and monitoring stations along severalwestern basin tributaries with the goals of determining tributary loads to the lake, quantifying and characterizing event discharges to the nearshore and examining land to River interactions. Sampling began in the spring of 2018 and continued monitoring is planned for an additional 2-3 years, including the expansion of the monitoring network aspartnerships and funding permit.
     - Joe DePinto comment: How close does the sampling and analysis protocol for these tributaries compare with that used for Lake Erie tributaries?
   - Closely related, the multi-watershed nutrient study (MWNS) monitors an agricultural watershed station at Gage creek that provides year-round event-based sampling.
   - Monitoring Efforts have been undertaken in U.S. tributaries through the USGS.

4) Overall questions that were posed to stimulate discussion in the breakout session, These questions were generally organized into Spatial, temporal and conceptual information needs

   <u>Spatial needs</u>
   - *With river loads of suspended solids on shallow-water mussel beds, are dreissenid lakebeds a substantial nutrient pathway? (internal loadings)*
   - *The fate of a substantial portion of tributary load is unaccounted for, relative to Cladophora nutrition. What do we know about the potential for time offsets between deposition of Particle Bound Phosphorus and its regeneration into bio-available phosphorus? And how far away from source does this occur?*
   - *What is the role of onshore circulation for productivity?*
   - What about the influence of smaller, but more abundant discharges from shoreline stormsewers and drains?

- What about AOCs and their contributions to the lake? Does internal cycling of phosphorus in these systems have an impact? The Bay of Quinte and Hamilton Harbourfor example, have made progress on reducing external inputs– but now they are showing signs of internal loading from legacy Phosphorus deposition, largely driven by redox sensitive forms of Phosphorus. *What are the barriers to AOC recovery? And What is the impact of these on P inputs to LO ?*
- *What about other sources that have not been studied extensively for Lake Ontario – arethey important here? Greenhouses? Are Wetlands sources or Sinks? What about Groundwater ? And Beaches?*

  Temporal needs
- *What can we say about winter loadings and storm events to the lake? How does thatrelate to Climate change?*

  Conceptual needs
- *Issues such as pelagic oligotrophication, resilience of the nearshore phosphorus shunt,and the ramifications of increasing nitrate are all part of GAPS we may want to explore further.*
- Where do models fit in? Given recent data, from Hill and Dove, should they be updated?
  a. Watershed level swat sparrow
  b. Lake side circulation models, hydrodynamic?

Breakout sessions: Moderated by David Depew and Nadine Benoit – Notetaking by BethWhitmore

Breakout sessions were given guiding questions with which to spark the conversations

1. (30 mins) What is your general reaction to the research and monitoring priorities that havebeen put forward to date related to the topic that is the focus of this breakout? --Key (top 5) process questions?

- The session began with one overarching question: ***Have we captured tributary variabilityand loadings?***
- Contributions of Niagara River to nutrient loading and severity between nutrients and phosphorus loading.
- Mike Haugh (Genesee river watch) speaking for Joe Mackarewicz – there has been an emphasis on monitoring Niagara River. **Genesee River is the largest contributor to LakeOntario**. (Joe Depinto comment: GR is important load of phosphorus, but not bigger than Niagara River). But very little monitoring going on there. Genesee River contributions were calculated but more sampling and monitoring needed. Monroe County has done some long-term monitoring. We need to make sure that long-term monitoring continues.
- Other tributary contributions. USGS and EPA monitored 7 tributaries and data are available.Need to continue monitoring nutrients. We identified a need to get an update on these datasets as current status is not known. Brett Hayhurst was previously involved with USGS.NYSDEC (J. Lehnen) does not do regular water quality monitoring as it is more of a federal program. They did partner on the Genesee for a 5-year monitoring program.
- Brett Hayhurst: USGS in last CSMI did a survey to mimic JM's work within embayments andtributary data. 7 tribs have been monitored consistently since 2011.
- Long-term monitoring is needed to add to current data sets and for developing models.

- LONNMs supplemental data release – might be something to revisit into next CSMI, wasstarted by Joe M.: Nutrients, sodium chlorophyll A and light attenuation and HABs/Cladophora

Other Comments from participants:

- Nutrient management is not a silo, the quantity management is also important? Most ofAOCs are embayments. It's important to see what AOCs are contributing as nutrient retention? What are we are missing in the regular monitoring?
- Whole lake model- 2019 workshop status update but no word since. Are the outcomes ofthe model informing on the questions that need responses for?
    - Kristina H. A2M hydrodynamic modeling. Joe Atkinson Limnotech. Completed model,prelim runs. Can share final report but there is a need for more funding to move ahead
    - Derek Schlea Limnotech – Lake Ontario Ecosystem model – report completed insept 2020. As part of that effort – external datasets presented In SOLO in March2021.
    - Joe Atkinson – acoustic telemetry surveys, WQ surveys replicated at stations duringthe growing period. Data maybe not yet released, has the potential to be coupled with WQ with actual movement.
- Pradeep Goel (MECP) suggested a clarification: is our underestimating of load a data issue ? Long term monitoring program for smaller tributaries for lake Ontario. We need consistent data for loading or we'll be continue to have issues with data.
- What is the objective of watershed scale modelling? Or actions within lake Ontario watershed?
- Focus is probably more on the lake vs actions within watersheds itself.
- Nutrient loading changes (Derek Schlea) -
- Is the scope too phospho-centric? Total carbon and nitrogen, concerns about monitoringsodium contributions from tributaries.
    - Brett Hayhurst Additional outside of P. Carbon and Sodium? USGS has quarterly data of inorganic ions and major ions group. Might be something to be continued,because in harbours they are seeing chlorides are rising in sediments. Somebodymay have mentioned issues with P and Carbon and Na. important for small estuaries.
- Better hydrograph monitoring and looking into snowmelt driven pulses. Get a more complete seasonal perspective. Timing nutrient loading into the lake with the hydrodynamics of the lake.
- Bill Snodgrass (Toronto Water): at the macro level – dichotomy: urban areas, different measurements with a range of factor of 5 between loading estimates from tributaries. Sowhat range of loadings can we accept as part of modelling lakewide in order to accept vsrural estimates within the current measurements we have?
- We do not have a consistent set of measurements of P in lake Ontario. One needs real-time measurement of P loadings within a week from each tributary and from each major source tolook at P level, plus estimates of upwelling in real time to be able to finely complete the picture of how nutrients working within the system of the nearshore
    - Look at Heidelberg Lake Erie protocol as a model for tributary loadings.

- Brett H.: There is an urban-rural distinction: rural – winter. 20-30 % more load.
- Katie Merriman- USGS - Modeling for the Eastern Lake Erie basin shows the vast majorityof nutrient loads there comes from snowmelt
- Also Dale Robertson See Midwest SPARROW mapper, https://sparrow.wim.usgs.gov/sparrow-midwest-2012/

Embayments and internal loadings/particular emphasis on AOC embayments:

- What are the major mechanics? Zebra mussels, anoxic conditions and P diagenesis.
- Anoxia, ability to sequester more phosphorus. In Hamilton: water column stability, persistentlow 0xygen and not much Fe going into the system right now. Are they important to considertowards the total to the lake? Not necessarily new work.

Kristina Heineman: is there a need to enhance ongoing monitoring?

- Long term – monitoring – year round sampling is pretty recent from Ontario's PWQMN. Databeing used to estimate loading for Lake Ontario – but limitation because only grab sampling program.
- Brett H: The effort focusing on temporal sampling, revisiting long term sites – equal amount of samples across year, or at least a combo of base flow and event flow. Bad storms will create bad sediment plumes in systems but they are somewhat short lived. If we're revisitinglong-term sites temporally.
- It's important that if we come out to a CSMI year, that we get baseline sites because infomay be varied. Soluble P changes a lot because of groundwater. But you can see that during baseflow in the growing season.
- On the US side, after Joe M.'s 2008 csmi efforts, they augmented the number of sites inwestern NY, interactions\ from groundwater. The yields of P light up during that period.

- Lauren Barth (U of T/MECP) provided an overview of current western basin tributary monitoring:
  - 13 Tributaries currently monitored; 3 of them started in 2018. Level weighted composite samples. Trying to do targeted sampling but work is difficult with COVIDrestrictions.
  - Turbidity and conductivity Sondes working in the tributaries – we are working to develop good relationships between P and turbidity to get better estimations butneeds more samples.
  - 5-6 tributaries in GTA are equipped with Turbidity and Conductivity Sondes. Eventbased sampling and continuation – surrogate sensor approach. Biggest issue is man-power and lab allocation .
  - We need to look at timing – when are nutrients coming to the lake and what is stratification like? With dynamics in hydrographics of the lake – thermal bar period, trapping in nearshore. What's temperature of water mass - where will nutrients go? Alot of this is particulate P. P can be released from Temperature increases and pH can allow P to be released. Timing – is important.

Recommendation from Day 1:

- Genesee River is the largest contributor to the lake outside of the Niagara River. Needsmore monitoring
- More tributaries need to be monitored around the lake
- Additional seasonal and event-based sampling recommended.
- Better sampling of hydrographs, winter seasons – Better separation of the hydrographs will provide more complete information, that can be useful for modeling.
- Extent of Cladophora in the nearshore and connections to the nearshore-shunt. How the phosphorus input contributes to Cladophora growth.

2. (30 mins) Are there any topics that you think should be upgraded/downgraded in terms of priority, or added to the list that are not? --Key (top 5) process questions?

- Potential need for a finely tuned spatial scale model that incorporates local management influence. Fine scale modelling at some point in the future needed to assess how local management of an input source might behave in fostering control of Cladophora – locally influential scale. E.g. LE modelling between tributary inputs and shading.
- **Groundwater sources** is a gap in the data, Some sampling has been done by USGS. In the Toronto area monitoring it shows that groundwater has flowed into the tributaries beforethe Lake.
- Kristina H. (USEPA) What role do buoys play? Enhanced support? Instrumentation?
  - Brett Hayhurst – it's come up a lot on US side. But cost and effort to maintain buoysgets pushed to the side. But more to Hydrodynamic model, it is important for plume mechanics.
- Direct stormwater contributions to the lake, some areas have very little stormwater infrastructure. Rochester, Buffalo, and Syracuse areas treat their stormwater, but otherurban centers may not. More of an embayment issue on the US side.
- Toronto is currently constructing a system for overflows, they have a reasonable handle onthe input to the waterfront.
- Brett H. USGS had pulled baseline sites with baseflow conditions. They did see higher levels of DP. Several formations of Karst, hard to measure if no discharge being recorded?Eg. Black river.
- Bill Snodgrass – Oak ridges moraine GW program – working with MECP to determine – 80-90% of GW flows into tributaries before flowing into the lake. Are you iclduing baseflow as part of your assessments?
- GW not particularly overwhelming – drinking water with P for anti-scaling? In areas with fractured bedrock. Perhaps more interesting to look at on a more local scale?
- ECCC: Other monitoring (as part of Ad hoc collabortive group):have ISCOs at the Rouge,Little Rouge and Credit Rivers, capturing storm events, sampling at Welland and 20 mile creek.
- Continuing longer term tributary monitoring increases chances at capturing and characterizing the rarer extreme weather events. Efforts should continue to be ready andmaximize monitoring of these infrequent larger events.
- Question: *direct stormwater contributions to the lake – significant? Lakefront pipes?*
  - Brett Hayhurst. Rochester experiences 1-7 Combined sewer overflow events a year;Buffalo had 20-30 to CSOs 20 years ago; Syracuse has done well.
  - It is an issue with urban centres where particulate loads are an issue. But it's more ofan issue in embayments than the open lake.

- Bill Snodgrass: 2600 stormwater outfalls. 70 discharge directly to LO, others to water courses. To deal with CSOs, Toronto started building tunnel system that will be donein 2038. CSOs represent a calculatable mass of nutrients to the waterfront that is enriched relative to stormwater outfalls. Modelling approach to report to ECCC for CSOs that combine to the waterfront.

3. (30 mins) What sorts of research are needed to advance your understanding of this topic?

Nearfield discharges and impacts:

- Part of the question is how nearfield does discharge from a runoff/tributary source flow into nearshore zone before mixing?
    - When is it no longer measurable?
    - Can we project the bioavailability of Phosphorus?
    - How does it affect the Cladophora bed?

- A2EM model? Water quality modeling?
    - Derek Schlea: Water Quality component to hydrodynamic model – is there an available dataset that can be found for both the Canadian side US side that permitscalibration? 2018 CSMI data were not available at the time of calibration – *Requestto point modelers to the data if available*
        - Joe DePinto comment: This is really important; we need at least two modelslike the LimnoTech LOEM to synthesize all the data and assess the whole lake response to load management options/scenarios. Another is ELCOM- CADYM being developed by ECCC.

- MECP and ECCC – developed approach of <u>Nearshore Sentinel sites</u> – one of the key questions: How representative of the nearshore zone are those sentinel sites or does one need to develop research design in which extent and density of Cladophora beds are morefrequent? Dave: Sites picked based on an aggregate knowledge on some of the aspects mentioned. Project is still ad hoc, but the main feature was to try and capture the more subtle trophic gradient from west to east along the north shore of lake Ontario. They have similar temperature, water quality and benthic habitat. Degree of urbanization to site and outfalls. Preliminary data complicated by water level fluctuations from 2017 until now, but there is some level of support that the information is being adequately captured.

Ram Y.: are you seeing gradients? What would be the gradients to drive this kind of issue?

- Remote samplers at Cobourg and Scarborough in 2018. Gradients are subtle. Vertically, sometimes there are gradients. Light and dark fluctuations –

Shan M - How does stormwater related P loads to LO compare to agriculture based NPS loads?

- Pradeep – urban and rural areas – NPS loads from urban vs agricultural – not sure wehave that info available.
- Bill – when you urbanize a rural area does the concentration change? Runoff coefficientwill be the major difference? Deterministically –
- Pradeep – normally consider 1.5 for urban, but that includes point sources.

4. (30 mins) What resources would be most needed to advance scientific understanding and management effectiveness related to this topic? Breakout – Day 2 (15 min) Day 1 recap andreality check

Dave provided interim summary page for the information shared in day 1

- What are the Objectives of the monitoring? We need to standardize program the objectives.Are they related to update the loading information or related to understand factors causing changes?
- James Pauer: concentration and flows, then models SWAT, Sparrow, Dolan approach – allresulting in different loads. We need to see *which method is the most consistent that everyone believes in*? A lot of management decisions are based on the Dolan loads. Perhaps this needs to be revisited

- *What is our objective?*
  - different methods can give 5x the amount as others...what range of loading can weaccept for lake models?
  - are we really using models to estimate loads? Are Models are being used to ID the contributing areas?
  - What's on the docket for load monitoring? We need iterative feedback. We have tobe able to work the objective components in the dialogue between who's doing monitoring and who's doing work
- Bill – what is our hypothesis about linkage between nutrient loads and Cladophora andissues? Cladophora – perhaps not 100% focus. There is a continuum of positive and negative effects.
- In broader discussions – what do we see to be a eutrophic vs mesotrophic vs oligotrophic for Cladophora targets for whether Cladophora is excessive vs acceptable vs impoverished?
  - When first targets were set, we had an idea. But now we're struggling with Cladophora. *You can't remove density of mussels from the density vs density of Cladophora*

- Shan M. I've seen few papers that observe that sudden influx of significant amount of P (e.g.internal sediment reflux or storm related inflows) contribute to growth of harmful algae such as Microcystis. Perhaps, more research needs to be done on this topic?
  - Bay of Quinte? Sudden influx of P, higher level of water concentration P levels coinciding with HABs. Perhaps may indicate nutrient limitation from P to N, competitive advantage to mycrocystis?
  - Dave- periodic reports along the open shroelines but not clear it's blue green algae. Hamilton Harbour sometimes have Microcystis – it's but very cosmopolitan but not

dominant. Last year was Euglena. But a lot of those dealt with *AOC related programs.*

- Lauren – at Cyano-HAB workshop – Suzie Wood presented. Cyanobacteria can colonize high levels within low level P. *they can trap P within sediment* so they can release. ***So can Cladophora trap sediment within their mats****?* Where is that P going? Bound up in sediments, stay closer to shore, trapped within mussel beds, trapped within Cladophora andreleased when needed? Particulate P plays an important role due to lake transfers through currents and through Dreissenid mussel-Cladophora interactions.
- Lou Molot was talking about redox potential in sediments. High redox potential If we focuson Nitrate it lowers redox potential as well. *But we need to look at redox as a potential mechanism*. Tends to be the joining factor between oligotrophic and eutrophic systems.
    - *Perhaps sewage plants should think about not employing denitrification.*

- James Pauer – getting back to the lake IJC target 7000 Dolan showed *TP below target*. But NR measurements exceeded that several times*.* ***Have we done a comprehensive lakewide loadings assessment since 2008? Should we revisit lakewide loads? What isconsensus on existing loads?***
- Bill S. *suggests figuring out what loads are on a section by section basis as a recommendation?*
- Mary Thorburn – *We also need to make sure Targets and ecosystem objectives align*. Makesure that the groups want to be on the same page. There are data gaps on what the real numbers are. Lots of objectives and unknowns. There's a lot of work here.

Dave – ***Perhaps we need a nested approach***. It's been a while since we've done loads. Do we have tribs with criteria? Difficulty is that there is ambiguity in target re how many filaments grow per area? Setting a numerical target with steep bathymetry may have a completely different outcome. Trying to set a regional target from a loads perspective against arbitrary in-lake response might be premature.

Pradeep – when we are talking about loading estimate, we have to think beyond this 5 yr cycle. Science perspective vs management perspective.

Lauren: ***Seasonality of loads - is most of the P coming during spring thaw***? Sampling regime since 2018 - The 13 Ontario tributaries have time integrated, level weighted samples. The ISCO samples over 42-48 hrs, 2-3 hours per bottle. This is based on event sampling over the full year (including winter). We also do grabs during low flow. We will need to calculate loads using these data so it's very important to use best available methods.

- We need to take advantage of CSMI monitoring efforts plus existing loading data to providea provide consistent dataset.
    - *Given limitations on resources, what are the best ways to calculate loads with the*data that can be collected?

Dave – *what are our bulleted recommendations*?

- larger scale picture and recognizing that some areas in lake will address issues with Near-shore water quality – it all boils down *how well we ID what we have and how to make connections.*

If you were given dataset? What would you need?

- Whole lake loading estimates
- Use sites with sufficient monitoring and frequencies to address. ID undersampled locations.Make sure we have sufficient tangible resources.
- Pradeep Goel (MECP) – daily sampling good enough for certain conditions. PLUARG collected 500+ samples. Where response times are for days, but perhaps need differentfocus with different approach
- Total loads – vs land use changes in loads?
- Mix of approaches of monitoring larger system with daily frequency, smaller streams attargeted frequencies. Ultimately we need an approach where loading estimates can becalculated from other areas.
- Those that are in the room should work together to inform where monitoring is happening,type, which stations might be amenable?
- Hydrological data, watershed conditions causing changes in flow and water quality – *landcover, land use, and how management practices are resulting in changes*. So secondary data is also important.
- Concern: we have *limited labload and capacity to monitor year round*. Prioritize that work butalso get it supported. ***Nesting and prioritizing is necessary***. Representative areas and tributariess. We still require better data to calculate loads. Additional resources needed.
- Manpower, labload, getting things done. ***What's important right now is trying to figure out where that should occur***. Looking at what we have to date and learning from that. TSSmodelling . using these nested approaches to get to ideas of possible surrogates for monitoring purposes. **How to improve strategically given lack of resources, manpower and labload etc.**
- Because a lot of the samples are flow weighted, regression estimates would work fairly well.
- Brett H. lots of statistical software has done better with discrete measurements with respectto flow. If you are using autosamplers and flow weighting based on some level of rise, you could have more information. If you really want to get data across lake and watersheds, ***standardizing method would be key.***
- Lauren – flow weighted event-based methods are good for urbanized areas. Agricultural orrural areas are not very flashy. You need a separation tool. You can't rely on lab tech to go in, separate the hydrograph. It is challenging – messy hydrograph

- James Pauer - Are P probes ready for primetime yet? If so, it can save a lot of time andmoney when estimating loading (I think?)
    - BH- probes work well in open oceans but in tribs sensors get clogged very quickly.Would need frequent cleaning.
    - Andrew Kowalzicz Our limited experience with deployed remote P analyzers is notgreat so far- they are decent for low-sediment but clog up quickly. Have not sortedthat issue out- even with settling tanks.
    - Niki Saveedra to Andrew- That is consistent with discussions we (NYSDEC) have had with Greg Boyer and Upstate Freshwater Institute on LO buoys in US nearshore.High turbidity seems to decrease effectiveness of P probes but still in discussion on possibilities for improved real-time monitoring.

Where is cladophora growing and accumulating?

- Jim Lehnen –Citizen-science based programs but we still don't' have a good handle on that.SAV as means to estimate Cladophora (Michigan tech) – ***should we revisit our understanding of where Cladophora isoccurring?*** NY nearshore areas not considered impaired, maybe impairments in empayments, but general shoreline – we need a better understanding of where this may be a problem. Where are manifestations of nutrient loads?Michigan Tech project mentioned: https://mtri.org/cladophora.html
- BH – ***drone fly-over by USACE*** – perhaps leverage to refine what tribs need to be monitored more thoroughly? ***AI imagery tool***? Teach a software to learn how to peerthrough water. Stich it all together.
- ECCC Burlington office was looking into dronework for lake erie. There are issues around Canadian shoreline with transport Canada restrictions on when and where.
- Mark Rowe NOAA – hyperspectral camera on small airplane –potential approach. Potentialfor quantification of Cladophora using small airplane flyover with hyperspectral imaging; *Andrea Vanderwoude NOAA GLERL, Mike Sayers Michigan Tech Research Institute, Bob Shuchman Michigan Tech Research Institute*
- Mari Clair Doyle: ECCC RDGO Contact for Lake Erie Basin drone work would be **Jody.Mckenna@ec.gc.ca** or **jocelyn.sherwood@ec.gc.ca**

Questions indirectly addressed in discussion

5. (30 mins) What improvements or innovations to research management and associated infrastructure would best support our ability to synthesize data from each cycle to inform future priorities?

6. (30 mins) How does this topic cross over to other breakout groups?

7. (15 mins) Consider how these research priorities and approaches would best support theLake ecosystem and the possible ecosystem services (which provide benefits to human populations) that would result.

Recommendations Day 2:

- Synchronize and standardize sampling across agencies and tributaries

Names of potential collaborators for working on various tributary loading studiesprojects around the lake:

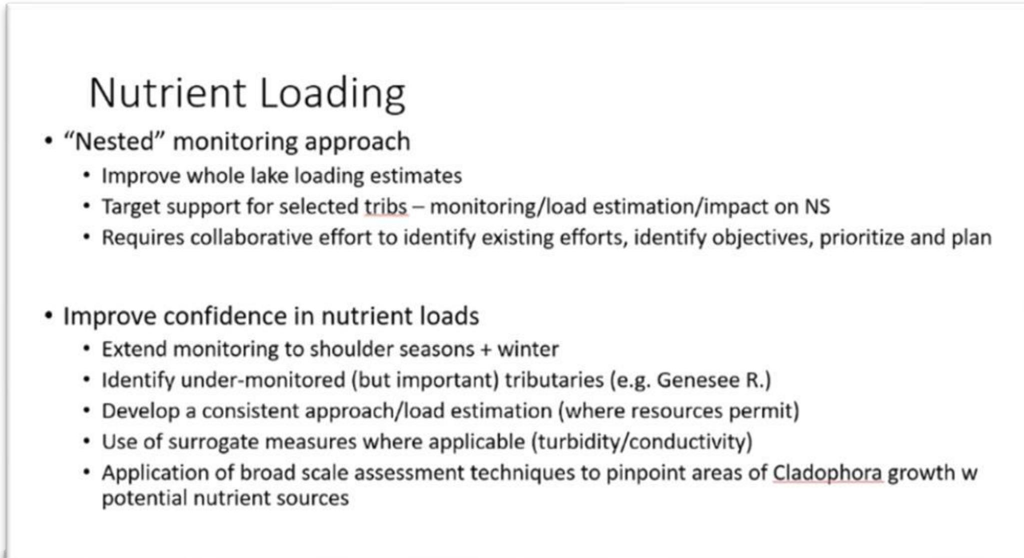
- George Thomas (GThomas@geneseeriverwatch.org)
- Joe Makarewicz (Jmakarew@brockport.edu)
- Lake Ontario Collaborative – western basin:
  - Todd Howell (Todd.howell@ontario.ca)
  - Lauren Barth (lauren.barth@utoronto.ca)
  - David Depew (David.depew@canada.ca)
  - Calvin Hitch (calvin.hitch@trca.ca)
- Dale Roberston (does SPARROW loading) dzrobert@usgs.gov

- Greg Koltun USGS does the majority of loading estimates - recent publication on USloads: https://pubs.er.usgs.gov/publication/ofr20201145
- Tracie Greenberg (ECCC) – tracie.greenberg@canada.ca
- Contact for Lake Erie Basin drone work would be Jody.Mckenna@ec.gc.ca or jocelyn.sherwood@ec.gc.ca
- Guy Foster (gfoster@usgs.gov) – NYWSC does all of the tributary sampling forUSGS

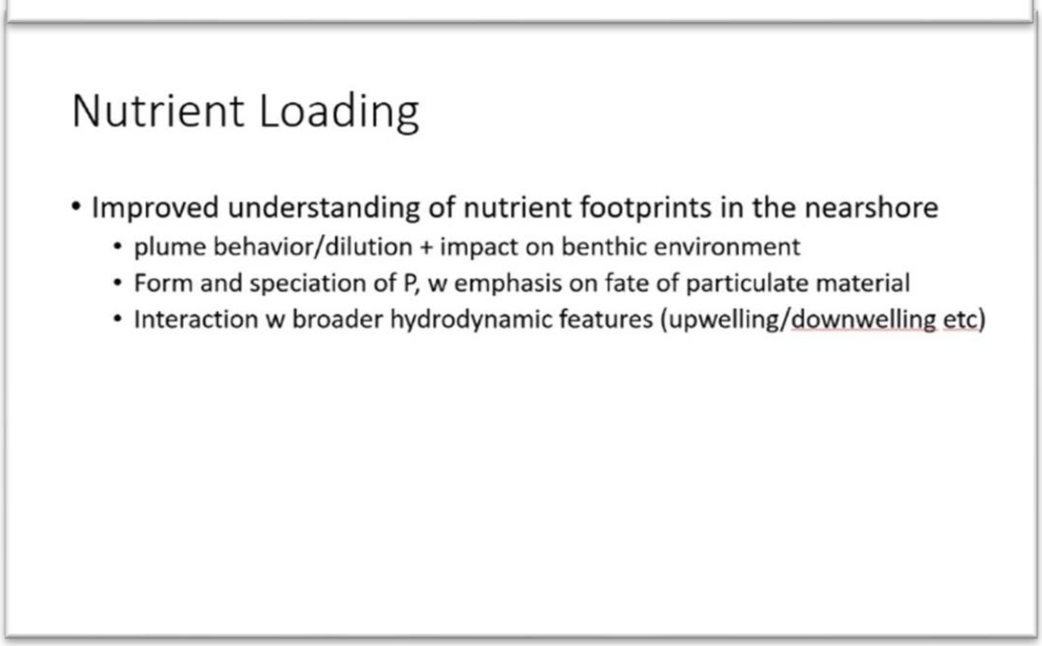
Resources that were shared with the group:

- https://reader.elsevier.com/reader/sd/pii/S0380133021000496?token=8AF1B8CE24D489B9E760C4C4831ABFC5CE8AA134F69B22A0EDEAD9BE31C3C9DB0C52E338D239BEB22C022B7F53F7443B&originRegion=us-east-1&originCreation=20210628173600
- Binational SPARROW modelfor 2002 water year. https://www.usgs.gov/centers/umid-water/science/sparrow-watershed-modeling-binational-uscanada-models?qt-science_center_objects=0#qt-science_center_objects
- Greg Koltun USGS publication on US loads: https://pubs.er.usgs.gov/publication/ofr20201145
- North, R. L., Guildford, S. J., Smith, R. E. H., Havens, S. M., & Twiss, M. R. (2007). Evidence for phosphorus, nitrogen, and iron colimitation phytoplankton communities in LakeErie. Limnology and Oceanography, 52(1), 315-328
- Robertson et al 2018: https://www.sciencedirect.com/science/article/pii/S038013301730165X?via%3Dihub
- Data for several NY LO tribs available at https://www.sciencebase.gov/catalog/item/55ce0c7ae4b08400b1fe159b
- https://mtri.org/cladophora.html
- Science in the Great Lakes mapper

8. (30 mins) Prepare a five-minute summary of your discussions from Day 1 and Day 2 for presentation to the large group. Moderators and note takers can do this alone or with help fromthe group, just be sure to save some time to put together the summary.



of



2.) Primary Production

Moderated by Greg Boyer (SUNY ESF) and Andrew Bramburger (ECCC). Stephanie Figary (Cornell), notetaker.

Day one: Slides from the presentation that were used to start the discussion:

Proposed Questions for the 2023 breakout group:

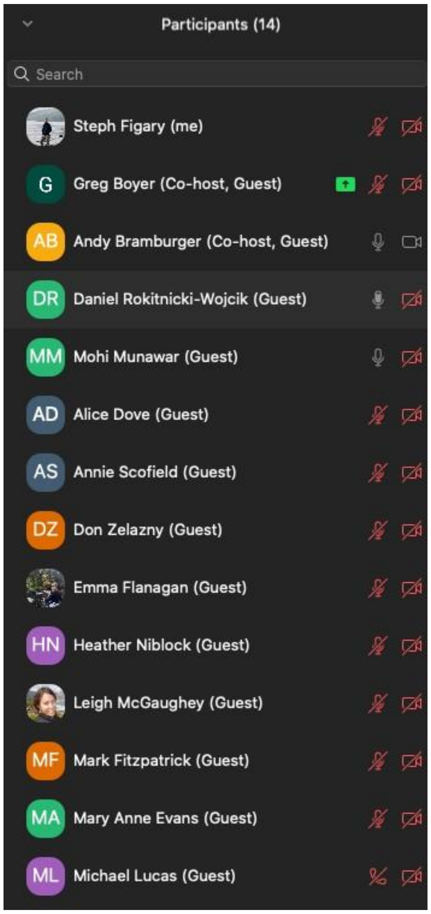
1. Do we know the impact of the DCL on overall Primary Production?
2. Nearshore versus offshore – are we dealing with two different lakes?
3. Are our sampling technologies and regimes sufficient to capture production?
   - Role of picoplankton in Lake Ontario
   - What is happening in the winter?
     - Has our spring diatom bloom become a winter diatom bloom?
4. Are our food web patterns changing with changing conditions?
   - Will shifting from diatom to cyanobacterial biomass disrupt the food web, trophic efficiency?
   - What about rotifers? Biomass is small but are they insignificant?
5. What do we know about benthic primary production versus pelagic primary production?
6. How do we calibrate/incorporate new technologies into 2023.

*DCL=Deep Chlorophyll Layer

Similarly, key knowledge gaps identified by Annex 4 Nutrient Task Team:

- Nearshore-offshore interactions and nutrient cycling.
- Quantify primary production.
  - How much, where does it come from? (Nearshore vs Offshore vs embayments)
  - Seasonal contributions (winter primary production)
  - Vertical water column contributions (epilimnetic vs DCL vs benthic)
- Trophic transfer, efficiencies, links.
- Data and knowledge to support ecosystem models.
  - Phosphorus budget, monitoring, TP and prey fish assoc.
- How much productivity do we need to sustain food webs?
- What does our target healthy system look like?

Day one: Participant list



Day one: These are the running comments from the screen during the discussion (G. Boyer)

1. Mixed results with C14 in the DCL; What is the contribution to overall productivity. Howdoes physical factors affect the DCL. What is the phytoplankton composition,
2. Need to validate the fluorescence measurements in the DCL. Maybe the F measurements are over emphasizing biomass. Are the Chlorophyll signals aligned withdifferent algal biomass. (see point 6)
3. Need to move past the DCL exists to studies on why it forms, who contributes and howthat affect management decisions
4. Need to better understand the Niagara River inputs. How will changes in lake Erieimpact lake Ontario. What are the interactions between Near Shore and Off Shore? How does management deal with those differences. Do we have sufficient information to adequately model the transport between the nearshore and offshore in terms of nutrients.
5. Need a better understanding of the contribution of picoplankton in both the near and offshore. ~estimates that 50% of primary production may be done by picoplankton. How does this impact foodwebs (does it impact foodwebs?)
6. What is the tradeoff between benthic and production between lower and upper water column. How do managers use that information? They need to know whether to go back to an agency and say from a regulatory standpoint, how do you respond. More

monitoring at Tribs? Bioavailable phosphorus? What is actually driving the primary production and how is the system responding?

1. What is the impact of the thermal bar in trapping the phosphorus into the nearshore region. How does the timing of inputs affect primary productivity.

7. Bacterial bioactivity seems to be increasing. How does this fit into our understanding ofthe foodweb. Is heterotrophy increasing and how does that impact carbon flux.
8. Do our sampling technologies capture the contributions of winter primary productivity. Ask the foodweb people does winter production matter? Has our spring bloom moved earlier into the late winter? We need to lead climate change modelling to include the winter productivity.
9. Are there areas that we have not been studying that we need to study?

Overarching question

Based on what we have – how would we change our monitoring approach to better understand/ quantify primary productivity in Lake Ontario?

- Can we expand the Guardian monitoring closer into the nearshore region, recognizing limitation in ship draft capabilities and timing.
- Expand the first monitoring cruise earlier into the season (prior to spring stratification. May need to consider using different ships, resources. Recommendation needs to incorporate what data we need.
- CSMI offers opportunity to do more targeted river plume studies and expand our knowledge on how tributary inputs are impacting nearshore primary productivity.
- Need to maintain the traditional cruises but also ensure consistency in analytical methods.
- Need to have more basic data on primary productivity, including comparison between traditional and newer primary productivity measurements.
- Continue or increase size fractionated productivity work to better understand the contribution of the pico/nano plankton.
- Incorporate Paleo-approaches. CSMI allows us to revisit places to look at changes. Need to also move these approaches in the nearshore regions to look at changes there also.
- Can we create a long-term monitoring station for lake Ontario.

Resources Needed:

- Winter capable to expand the sampling season earlier in the year.
- Vessels that can get closer into the nearshore region
- Gauging on the tributaries to determine the nutrient contributions
- Winter current data.
- Other autonomous assets, can we put out a network of autonomous samplers during theCSMI year?
- Would drones assist in data collection and surveying

Day one: Notes from the notetaker: (S. Figary)

(30 mins) What is your general reaction to the research and monitoring priorities thathave been put forward to date related to the topic that is the focus of this breakout? -- Key (top 5) process questions?

- Impacts of DCL (proposed question 1 from slide): Mixed results with studies in the DCL.Some studies show that the DCL is less productive and others show it is more productive. Ontario may be more variable in where the DCL is occurring in comparison to the Upper Lakes and may be occurring at a shallower depth than the upper lakes. Some measurements are not matching the expected patterns. Questions on the composition of the DCL as well. The DCL does not always match the biomass peak, butsome datasets do show that the DCL peak is aligned with the biomass maximum as well. The community structure also seems to be different at the DCL in comparison to other layers. Chlorophyll measurements are not enough to understand the DCL. The DCL is variable throughout the lake (spatially and temporally). Could be over emphasising the importance of the DCL. Questions on the production, biomass, and composition here. Also do not know the impacts of a warmer climate here either.
    - Overall: Need more research
- Nearshore/offshore (2): Lots of monitoring data shows the difference between the nearshore and offshore. Eutrophication in the nearshore/oligotrophication in the offshore.Need to understand the Niagara River inputs and the possible impacts in Lake Ontario ofreducing nutrients in Lake Erie. Need to think about this with a management perspective.What information are managers missing to be able to make decisions? Understanding ofthe nearshore is limited. Nearshore modeling is limited and complicated. Managers needto be able to link P loadings to how the lake could change with increases or decreases in P. Composition of phytoplankton is different between nearshore and offshore. Overdominance of picoplankton in the offshore compared to the nearshore. High amounts of picoplankton in Lake Ontario as well. Also a question of benthic vs pelagic production here as well. Need to connect with the overall food web here too. Differences in the nearshore/offshore zooplankton community composition as well. Also need a better understanding of P inputs and the impacts of the thermal bar timing.
    - Overall: Need more research
- Sampling technologies/incorporating new technologies (3/6) Need to better understand picoplankton to better understand production in Lake Ontario. New technologies can help, but the standard techniques are important and should not be replaced. New technologies need to be calibrated back to microscopy. There is also the lab/analyst effect from microscopy.
    - Overall: New technologies could be helpful, but need to be standardized with traditional methods
- Food webs (4): Increases in the heterotrophs since 1990's. We don't have a good understanding how these changes are impacting the overall food web and bacteria arenot monitored as much as other aspects of the food web. Question on the idea that biomass is shifting from diatoms to cyanobacteria, but not true in the offshore (nearshore/offshore divergence). This is common in the embayments, but not offshore. Also, not all algal blooms are cyanobacteria. Other phytoplankton also bloom. Also a question on how climate change will impact the food webs, including changes in stratification timing and changes in upwelling patterns.
    - Overall: Need more research
- Benthic/pelagic production (5): skipped

2.) (30 mins) Are there any topics that you think should be upgraded/downgraded in termsof priority, or added to the list that are not? --Key (top 5) process questions? >>Break, asnecessary

- Cyanobacteria offshore = not a priority

- Winter: The definition of winter is changing with climate change. Technologies could helpbetter understand winter limnology. Would need more capacity to include winter sampling/monitoring. Generally don't have a complete understanding of winter productivity to know how important winter productivity is for higher trophic levels.
- Productivity to sustain food webs: Importance of both temporal and spatial dynamics forfood webs. Generally overproduction in the nearshore (human impact dynamics) and underproduction if the offshore (food web dynamics).
- Climate change: Any modeling will start at the base of the food web and needs to be a priority. This another reason to better understand winter productivity.

3.) (30 mins) What sorts of research are needed to advance your understanding of this topic?

- What can we do in CSMI that can jump-start our understanding of Lake Ontario andlong-term monitoring? Sometimes approaches from CSMI are adopted into GLNPO.CSMI can also help with the organization/partnerships for expanded monitoring.
- What are the gaps in monitoring that prevent us from better quantifying primary productivity?
    - Spatial: nearshore
        - Monitoring exists in some long term sites (e.g., ~8 meters, Hamilton harbor). These have been important for primary production.
        - Smaller ships are useful here (vs Guardian/Limno)
        - Paleolimnology (expanded on below)
        - River inputs and plume studies. Niagara, but also the other larger rivers.
        - nearshore/offshore = #1 management priority for the next few years.Need expanded spatial monitoring, including into areas that have not been included in monitoring programs so far,
    - Temporal: Adding in winter/early spring.
        - Will always maintain the Guardian schedule (April/Aug), but could consider adding to the current schedule.
    - Paleolimnology: Could add these approaches to CSMI. These approaches havebeen useful for better understanding primary production in the offshore zones and could be expanded on in the nearshore/embayments.
    - Climate change: Everything above is linked to climate change as well.
    - Creation of long term datasets: Need for an index station (e.g. site 41 or 81 for DFO). However, may not fit into the CSMI framework that is limited to one year.

4.) (30 mins) What resources would be most needed to advance scientific understandingand management effectiveness related to this topic?

- Winter sampling/capable vessel
- Expanded nearshore monitoring and monitoring in areas that have not been monitored in the past. Need smaller vessels for this. Could also consider gages at stream outflows.
- Continuous monitoring equipment for winter/seasonal data.
- Autonomous samplers/monitoring equipment
- Drones

2. (30 mins) What improvements or innovations to research management and associated infrastructure would best support our ability to synthesize data from each cycle to inform future priorities?

Are there any changes that need to be made on our research priorities from yesterday?

1: embayments:

- We have been looking at the nearshore productivity as how it contributes to the overall productivity, but we should also consider how the benthic areas contributeto nearshore productivity (e.g., Cladophora washing onto the nearshore)
  - Cladophora is certainly a concern for Lake Ontario, particularly at the eastern and western end of the lake.
  - This also crosses into other breakout topics.
  - Cladophora blooms are also a function of water levels, another large topicfor L Ontario.
  - Drones/remote sensing could be helpful with monitoring and possibly estimating biomass. CSMI could be a good time to try this in Lake Ontarioand ground truth the data (‘training’ the drones/standardizing)
    - This monitoring is also happening on Erie and Michigan.
    - ECCC had been doing cladophora monitoring along L Ontario foryears using drones/hyper infrared technology/remote sensing data. Ground truthing has already been done to build their algorithms.
    - GLNPO is working with NOAA and TRI to help with ground truthing data.
    - A coordinated effort to ground truth all of this would be very helpful. CSMI is a good venue for this.
    - Need to be clear about what the role for these technologies areand what the expectations are when using remote sensing data
    - Research need: Efforts to improve our confidence in remote sensing data.
  - Should be clear here that we specifically want to target benthic algae, particularly Cladophora
- This is mostly talking about it as a spatial aspect, but maybe we need to consider the temporal changes as well? This is in point three here too. Would benice if CSMI occurred more than once every five years; however, it seems unlikely that this will change.

2: epi/bentic/DCL:

- Whiting events have been large discussions of previous CSMIs, but it’s not clearhow/if this impacts productivity. May impact really small plankton and could reduce productivity
  - Have used paleo studies to look at these more. Whiting events tend to bea result of high productivity. The intensity of these events have gone down since the mid 1980s
  - Whiting events do not always happen and can be very patchy. Could be difficult to study them because they are difficult to predict.

3: winter/seasonal/temporal

- At a minimum it would be good to be able to quantify the community compositionin the winter and even better to get productivity estimates. This is a gap in our knowledge and has also been identified as a gap by Annex 4.
- Remote sampling/autonomous samplers has been attempted to get at this question without the safety issues of monitoring in person during the winter months.
  - These are already in the lakes in some areas. CSMI would be good for coordinating this effort
- Need an earlier cruise (before April) to capture the spring bloom. Due to climate change we are likely missing these blooms. Should not move the current surveyand interrupt the long term data, but an additional survey earlier in the season would be very beneficial.
- Are there places we could monitor year-round that are not ship based? Could use intakes for this depending on the depth of the intakes. Some treatment facilities monitor their intakes for phytoplankton. Could these be used to get a handle on winter productivity? Depends on the depth/location, but it is certainlyhelpful. It’s a good starting point for getting into the winter limno question
- Could have two sets of data- DFO could take the western basin and EPA couldtake the eastern basin.

3. (30 mins) How does this topic cross over to other breakout groups?1:

Embayment/nearshore/offshore:
  - Links to the larger foodweb, including invasive mussels and upper trophiclevels.
  - Connection with the habitat section and the shoreline.
  - Clear connection with nutrients (bottom up processes)
  - Habitat can be impacted by macrophytes/Cladophora as well2:

Epi/DCL/benthic:
  - Clear connection with the invasive species topics, particularly benthic ecology with invasive mussels. Mussels have huge impacts on productivity and there are distinct nutrient dynamics in mussel beds. P islikely recycling in the benthos and in mussel beds
    - Information from other lakes could be helpful here

3: Seasonal:
  - Could use fatty acids to determine the importance of the diatom bloom inthe winter to the upper trophic levels

- Across all topics- What is the reliance of the upper trophic levels on primary productivity? Fatty acids can be really help here. There are ways we can start tolook at the different contributions of primary productivity up the food web to fish.

- Linkage to contaminants with microplastics. Microplastics can be surfaces for bacteria and may change primary production. Also, could be ingested by zooplankton and reduce the amount of phytoplankton uptake by zooplankton?

Herbicides are another question that link to contaminants. These may be relatively low in Lake Ontario (based on Lake Erie studies).

4. (15 mins) Consider how these research priorities and approaches would best support theLake ecosystem and the possible ecosystem services (which provide benefits to human populations) that would result.

- The topics in this breakout room covers many management issues and priorities
- Management challenges
  - Primary productivity issues: nearshore/offshore, HABS, Cladophora
  - Overall productivity: food webs and offshore oligotrophication and that's impact on fish communities
  - How does the nutrients coming from the land of Niagara River impact the nearshore or offshore?
- What does our 'healthy lake ecosystem' look like? In Ontario it's almost two different lakes between the nearshore and offshore that likely need to be managed separately. We need to understand these dynamics better to managethe lake better. This includes the seasonal dynamics between the two lakes.
- Major nutrients beyond P:
  - Role of nitrogen as a driver for primary production.
    - This differs between nearshore/offshore and seasonality
  - Role of silica as well and its importance for diatom blooms
- Supporting the upper trophic levels, including native fish and the recreational fishery.
- Drinking water as another ecosystem service that can be impacted by primary productivity and particularly HABS
- Management question: The research that we have outlined, does this help us decide how to manage the lake with the regulatory tools that we have available(e.g., point sources with permits and non-point sources with watershed best management practices)?
- Quality of life and aesthetics are another ecosystem service to keep in mind here
- Do we need one overarching objective for the lake, or is a patch work of objectives (local-level) okay?
- Current target for Lake Ontario (10 ug/L of P) was determined about 40 years ago. Do we need to revise this to better support primary productivity objectives?We know more now and the system has changed with new invasives (e.g. mussels). Additionally, the system will continue to change with climate change. Do our current models reflect the current or future reality?

5. (30 mins) Prepare a five-minute summary of your discussions from Day 1 and Day 2 for presentation to the large group. Moderators and note takers can do this alone or with help fromthe group, just be sure to save some time to put together the summary.

Day two: notes on screen during discussion

Primary Production: Key Research Areas:

Quantification / Characterization of Primary Production
Epilimnetic / DCL / Benthic contributions
Winter - seasonal dynamics

Quantification / Characterization of Primary Production

1. Embayment - nearshore - offshore contributions / dynamics.
   Questions:
   - What are current rates and trends of phytoplankton biomass / productivity in embayments vs. nearshore vs. offshore areas?
   - What are the contributions of embayments/nearshore/offshore areas to total lake production and C cycle dynamics? What transfers exist among regions?
   - What is the relative reliance of higher trophic levels upon production originating in embayments/nearshore/offshore areas?
   - How does nearshore algal growth impact the use of the shorelines (aka algalwash-up on to the beach)?
   - What is the connection between water levels and nearshore algal growth?
   - What is the role of remote sensing in research and management decisions surrounding our understanding of Cladophora productivity in nearshore and algalproductivity in offshore waters.
   - What are the temporal changes in nearshore and offshore productivity. Can aone-year CSMI based monitoring approach capture these temporal changes?

   Research Needs:
   - Expanding Limnos/Lake Guardian program to nearshore areas, support with smaller regional class vessels or small vessels as appropriate.
   - Expand paleolimnology efforts to nearshore regions.
   - Expand monitoring in nearshore areas beyond AOCs.
   - Coordinated ground-truthing campaign to validate remote sensing data and increase the acceptance of remote sensing data in both deep water and near-shore regions

   Resource Requirements:
   - Ships capable of nearshore work or a network of small vessels.
   - Increased stream gauging capabilities.
   - Support for paleo work.
   - Support for remote sensing or drones to evaluate nearshore benthic algae occurrence (both in water and wash-up on the beach)
   - These questions may require resources outside of the 5-year CSMI cycle.

   Linkages to other CSMI topics
   - Improved understanding of nutrient cycling within the nearshore-offshore connection, internal loading and impacts of dreissenids.
   - Role of nitrogen versus phosphorus (and other major nutrients, e.g. silica) in supporting primary production.

- Impacts of nearshore eutrophication on fisheries dynamics and invasive species
- Relationship to habitat degradation (Phragmites)

2. Epilimnetic / DCL / Benthic contributions

Questions:

- What are current rates and trends of phytoplankton biomass / productivity in different portions of the water column?
- What are the contributions of epilimnion/DCL/Benthos to total lake productionand C cycle dynamics? What transfers exist among strata?
- What is the relative reliance of higher trophic levels upon production originating in Epilimnion/DCL/benthos?
- DCL formation and who is active down there?
- How does our information obtained from other lakes on benthic /Cladophora /dressenid interactions apply to Lake Ontario?

Research Needs:

- Expanding Limnos/Lake Guardian program to support higher spatial resolution sampling - improved coordination between Canada/US federal agencies.
- Expanded capacity for harmonizing molecular/sensor work with microscopy counts.
- Trace the contribution of primary productivity to higher trophic levels (fatty acidand other biomarkers)

Resource Requirements:

- Improved instrumentation for comparing productivity/composition/light climate through water column
- Support for newer techniques to track foodweb transfer

Linkages to other CSMI topics

- Improved understanding of nutrient cycling within the nearshore-offshore connection, internal loading and impacts of dreissenids. (repeated)
- What is the reliance of higher trophic levels to primary productivity in these regions?
- What is the impact of other contaminants (microplastics, herbicides) on primary productivity?
- How does benthic algal productivity impact larval fish habitat.

3. Winter - seasonal dynamics

Questions:

- What are current rates and trends of phytoplankton biomass / productivity in different seasons
- What are the contributions of winter productivity to total lake production and C cycle dynamics? What teleconnections exist across seasons
- What is the relative reliance of higher trophic levels upon production originating in winter/under ice

Research Needs:

- Expanding Limnos/Lake Guardian program to sample beyond the existing April/August or May/September framework. There is a need for the first cruises tobe earlier in the growing season. This should not replace this existing cruises.
- Under ice/open water winter productivity studies.

- Improved sampling to represent winter communities
- Evaluate the contributions of intake data to our understanding of phytoplankton ecology on the shoulder seasons.

Resource Requirements:

- Ships capable of winter work - icebreaker availability when not engaged elsewhere in LGL. Dedicated winter R/V?
- Expanded use of available ship resources in the shoulder seasons (Cisco?)
- Winter missions from AUVs; deploy remote automated samplers over the winter season.
- Autonomous samplers and coordinated efforts among remote automated sampling programs to harmonize with CSMI and assist in the recovery of units.

Management challenges

- Cross cutting across many of the areas
- Connections between primary production and ecosystem services such as fish production, drinking water, recreational use, quality of life, etc.
- How do we ensure healthy waters free of harmful algal blooms
- How does nearshore primary production impact nearshore (beach) use.
- Is there a way to mitigate what we see on the shoreline?
- Can we affect the endpoints and ecosystem services by our actions on the land(how much external control do we have)
- What actions best support a healthy lake ecosystem. Do we manage the lake as a whole or do we need separate management actions for nearshore and offshore regions? Do we need one overarching objective or should we employ apatchwork of regional objectives?
- What can we manage for and what factors are important? There are many stressors (eg. climate change, invasive species) that may be impacting our abilityto “manage” the system where we may not have any control.
- Our major tool on the state/provincial side to meet these goals are regulatory. Isthe science that we have outlined going to give us a “target” that we can impact through a regulatory process and/or voluntary measures to improve the lake water quality?

Report back slides:

Primary Production: Key Research Areas:

Quantification / Characterization of Primary Production

Epilimnetic / DCL / Benthic contributions

Winter - seasonal dynamics

Embayment - nearshore - offshore contributions / dynamics.

Questions:

- What are current rates and trends of phytoplankton biomass / productivity in embayments vs. nearshore vs. offshore areas?
- What are the contributions of embayments/nearshore/offshore areas to total lake production and C cycle dynamics? What transfers exist among regions?
- What is the relative reliance of higher trophic levels upon production originating in embayments/nearshore/offshore areas?
- How does nearshore algal growth impact the use of the shorelines (aka algal wash-up on to the beach)?
- What is the connection between water levels and nearshore algal growth?
- What is the role of remote sensing in research and management decisions surrounding our understanding of Cladophora productivity in nearshore and algal productivity in offshore waters.
- What are the temporal changes in nearshore and offshore productivity. Can a one-year CSMI based monitoring approach capture these temporal changes?

Research Needs:

- Expanding Limnos/Lake Guardian program to nearshore areas, support with smaller regional class vessels or small vessels as appropriate.
- Expand paleolimnology efforts to nearshore regions.
- Expand monitoring in nearshore areas beyond AOCs.
- Coordinated ground-truthing campaign to validate remote sensing data and increase the acceptance of remote sensing data in both deep water and near-shore regions

Resource Requirements:

- Ships capable of nearshore work or a network of small vessels.
- Increased stream gauging capabilities.
- Support for paleo work.
- Support for remote sensing or drones to evaluate nearshore benthic algae occurrence (both in water and wash-up on the beach)
- These questions may require resources outside of the 5-year CSMI cycle.

Linkages to other CSMI topics

- Improved understanding of nutrient cycling within the nearshore-offshore connection, internal loading and impacts of dreissenids.
- Role of nitrogen versus phosphorus (and other major nutrients, e.g. silica) in supporting primary production
- Impacts of nearshore eutrophication on fisheries dynamics and invasive species
- Relationship to habitat degradation (Phragmites)

Winter - seasonal dynamics

Questions:

- What are current rates and trends of phytoplankton biomass / productivity in different seasons
- What are the contributions of winter productivity to total lake production and C cycle dynamics? What teleconnections exist across seasons
- What is the relative reliance of higher trophic levels upon production originating in winter/under ice

Research Needs:

- Expanding Limnos/Lake Guardian program to sample beyond the existing April/August or May/September framework. There is a need for the first cruises to be earlier in the growing season. This should not replace this existing cruises.
- Under ice/open water winter productivity studies.
- Improved sampling to represent winter communities
- Evaluate the contributions of intake data to our understanding of phytoplankton ecology on the shoulder seasons.

Resource Requirements:

- Ships capable of winter work - icebreaker availability when not engaged elsewhere in LGL. Dedicated winter R/V?
- Expanded use of available ship resources in the shoulder seasons (Cisco?)
- Winter missions from AUVs; deploy remote automated samplers over the winter season.
- Autonomous samplers and coordinated efforts among remote automated sampling programs to harmonize with CSMI and assist in the recovery of units.

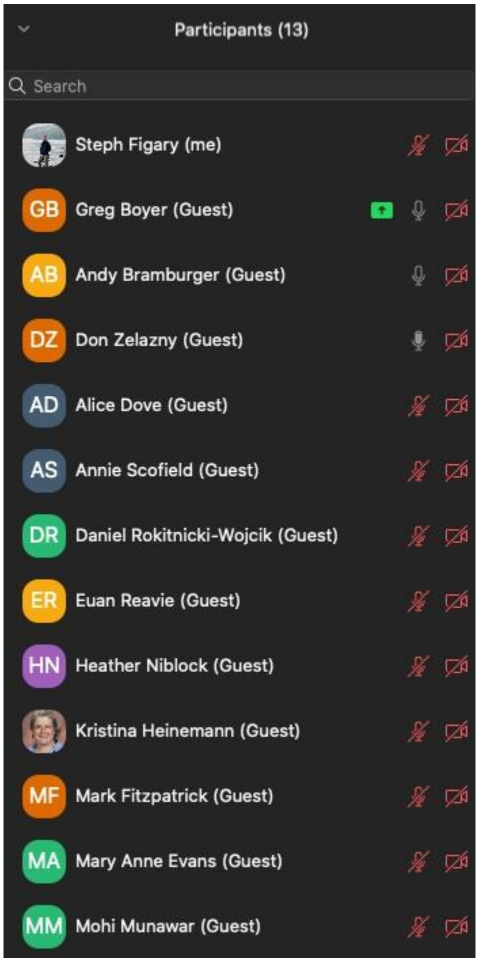
Management challenges

- Cross cutting across many of the areas
- Connections between primary production and ecosystem services such as fish production, drinking water, recreational use, quality of life, etc.
- How do we ensure healthy waters free of harmful algal blooms
- How does nearshore primary production impact nearshore (beach) use.
- Is there a way to mitigate what we see on the shoreline?
- Can we affect the endpoints and ecosystem services by our actions on the land (how much external control do we have)
- What actions best support a healthy lake ecosystem. Do we manage the lake as a whole or do we need separate management actions for nearshore and offshore regions? Do we need one overarching objective or should we employ a patchwork of regional objectives?
- What can we manage for and what factors are important? There are many stressors (eg. climate change, invasive species) that may be impacting our ability to "manage" the system where we may not have any control.
- Our major tool on the state/provincial side to meet these goals are regulatory. Is the science that we have outlined going to give us a "target" that we can impact through a regulatory process and/or voluntary measures to improve the lake water quality?

Comments from report back:

- Michael Twiss: For nearshore: Use R/V *Lampsilis* (UQTR; used in 2018 to examine nearshore of SLR from Kingston to near Quebec City); great vessel - overnight capacity,seine net, labs onboard, galley...)

- Jim Watkins: Highlighted the importance of the change of timing for what is 'spring' in thefuture of climate change
- Shan Mugalingam: Have you seen N limitation in PP research?
    - Michael Twiss: Co-limitation with Fe (in lake Erie). North, R. L., Guildford, S. J., Smith, R. E. H., Havens, S. M., & Twiss, M. R. (2007). Evidence for phosphorus,nitrogen, and iron colimitation of phytoplankton communities in Lake Erie. Limnology and Oceanography, 52(1), 315-328.
- Lars Rudstam: Did you talk about/consider underwater vehicles or automatic samplers?
    - Yes. There was a lot of discussion about this, how to fit them into CSMI and howwe can increase our capacity for using this technology
- Warren Currie: DFO has winter limnology capabilities and those interested in winter limnology should reach out to him.
- Brian Weidel: RE: winter 'limnology' our coregonine and native fish habitat projects are sampling from Dec - April, most is embayment work, some is offshore in LM and LO



Day two participant list

3.) Wetlands and Connecting Waters (Niagara River [NAR] and Upper St.Lawrence River [SLR])

Moderated by Michael Twiss (Clarkson) and Jeff Ridal (River Institute). Patrick Boynton(Cornell), notetaker.

Lighting Talk –

Historical Context:

1952: IJC approves order to create the Moses-Saunders hydropower dam and Iroquoisdam (completed 1958), and locks of the St. Lawrence Seaway (completed 1959).

1978: Superfund created: Love Canal is first Superfund site.

1984: Comprehensive post-dam/pre-dreissenid study by Patch, S.P., and Busch W.-D.1984. *The St. Lawrence River—Past and Present: A review of historical natural resource information and habitat changes in the International Section of the St. Lawrence River.* U.S. Army Corps of Engineers, Buffalo, NY, US Govt. Accession No.AD-A147119.

1987: IJC designates Niagara River and St. Lawrence River Areas of Concern

2000-2005: International Lake Ontario-St. Lawrence River Study Board develops planto restore biodiversity in SLR & LON

2014: Plan 2014 approved by the IJC; first year of operation coincides with historic floodyear (2017)

Current State of Knowledge: LAMP MGT Actions (Annex 2C; GLWQA)

Nutrient and bacterial-related impacts (Annex 4)

- NAR as 1° inflow & SLR as 1° outflowLoss

of habitat and native species (Annex 7)

- Coastal wetland quality degradation due to stable water levels
- Impact of dams on fish population (American eel) & habitats

Aquatic invasive species (Annex 6)

- Invasive wetland plants, invasive mollusks, etc. Critical

and emerging chemical contaminants (Annex 10)

- Continued legacy pollution from NAR
- Mobilization of Hg from coastal wetlands (e.g., Hg in SLR)
- Persistent fish consumption advisories (Hg, POPs)

Breakout – Day 1

1. (30 mins) ***What is your general reaction to the research and monitoring priorities that have been put forward to date related to thetopic that is the focus of this breakout?*** --Key (top 5) process questions?

Water Levels (relates to Annex 10.D. Ecosystem Indicators)

Plan 2014 is working as conceived to restore fluctuations that promote wetland biodiversity.

- In Lake Ontario, we don't see the historical (pre-project) low water levels that we theorize is needed for increasing biodiversity
- Research is necessary to assess whether Plan 2014 will bring about transition from cattail marshes or whether direct interventions are needed to effect the tipping points
- Urban wetlands are constrained by developed shoreline, is Plan 2014 relevant in these scenarios?
- Sci-Comm: Time-scale constraints to public understanding and ecosystem response to changing water levels.
- How do we differentiate Plan 2014 effects from Climate Change?
- Phosphorus & contaminant mobilization issues are undefined
- 2021 provides the opportunity to look at the effects of low water years regarding wetlands
- North shore vs south shore differences in ecological dynamics and funding (using comparable methodologies)
- Collaborative studies of north shore and south shore wetlands are necessary.
    - which aspects of wetland health needs to be compared north vs south that is not captured by the Great Lakes coastal wetland survey?
    - GL Coastal Wetland Monitoring Program (CWM) does not measure specific elevations and vegetation communities as Greg Grabas and his team does in Canada. CWM is designed for assessing IBIs, but not shifts in communities in direct response to water levels.

Winter/ Spring ecology (relates to Annex 9 – Climate Change Impacts)

A changing winter season will alter ecosystems in ways we can predict.

- Gap in monitoring wetlands during winter
  - Under ice DO and biogeochemistry
- Designing wetland restoration to consider winter ecology
- Need to establish model wetlands that have sensor arrays to observe changing biogeochemical conditions over annual seasonal cycles. Wetlands selected to reflect the diversity of wetland morphological types and restoration versus non restoration.
- Wintertime stranding and ice effects: Amphibians/less motile animals may be stranded compared to fish. Muskrat (keystone species) housing issues (water level, trapping regulations, supports water level decision making).
- How do plankton and submerged aquatic vegetation communities respond to changes in ice/over wintering and springtime warming? How is microbial diversity and function altered by wintertime ecological variables in the rivers and wetlands?
- Technology and further model development to better predict and measure land-fast ice formation in NAR and SLR

Contaminants (relates to Annex 10)

Plan 2014 increases contaminant and nutrient mobilization in coastal wetlands.

- Changes in water level resulting in chemistry changes in wetlands
- Erosion mobilizes nutrients and contaminants; identifying the mechanisms and causes of erosion in different river environments
- How much nutrient (P) and contaminant (Hg) will be mobilized? How fast? Where will it go? And in what form?
- Impacts of water level regimes on greenhouse gases (CH_3, NO, N_2O) emitted from wetlands: areal extent of SLR, NAR, and LON wetlands is high. Links Climate Change and Plan 2014
- Relative importance of wetlands, tributaries and shoreline inputs of Hg to the SLR and how do these inputs factor in Hg methylation and the patterns of fish contamination?
- Are wetlands sources and sinks of nutrients & contaminants? How does this function change with water level and weather events and season?

- In urban wetlands, chloride accumulates in wetlands, and can be discharged in pulses. How does elevated chloride affect contaminant biogeochemistry (e.g. HgCl+, etc.)

[Research needs of Niagara River wetlands?

- Upper Niagara River is rich in wetlands – the lower river reach is more of a gorge.
- Majority of restoration focused on upper wetlands: This region gets attention during CSMI for Lake Erie. The IJC Commissioners have approved a report[1] that recommends that the Upper Niagara River be part of Lake Erie CSMI rather than Lake Ontario?
- How impactful is water in the Erie Canal on Lake Ontario?

Nutrient Loading (relates to Annex 4)

The nearshore P shunt operates in a lateral sense in the St. Lawrence River with nutrients accumulating in the nearshore downstream.

- Phosphorus transported down the St Lawrence River: is there an accumulation in the nearshore that is influencing proliferation of Cladophora? (see NYSDEC *Cladophora* in the nearshore - citizen science project[2]).
- Are wetlands source or sink of nutrients (as a function of water levels)?
- How do wetlands alter P bioavailability?
- Nutrient spiraling: how long do nutrients stay in the river and over what timescales is nutrient spiraling taking place in different river environments?

<u>Wetlands</u>

1. Plan 2014 is working as conceived to restore water level fluctuations that promote wetland biodiversity.
   a) Understanding dynamics between wetlands and connecting waters
   b) ID of indicators for setting water level guidance

---

[1] Twiss, M.R., Ridal, J.J., and Rooney, R. 2021. Monitoring Infrastructure and Activities of Great Lake Connecting Waters: An Assessment and Recommendations, A report submitted to the International Joint Commission by the Great Lakes Science Advisory Board Research Coordination Committee, May 21, 2021, 11 pp.

[2] https://www.dec.ny.gov/lands/117838.html

c) Wetland types and understanding their functions and responses to Plan 2014

2. Engagement with 1st nations: Two-Eyed Seeing
    1. Harvesting rights

Connecting Waters

1. What are wintertime phyto- and zoolankton dynamics ?
2. Extend plankton studies from lakes into rivers.
3. Known leaky contaminant sources (Niagara River?)
4. Bacteria diversity and rivers as sources of bacteria contamination

2. (30 mins) ***Are there any topics that you think should be upgraded/downgraded in terms of priority, or added to the list that arenot?*** -- Key (top 5) process questions? >>Break, as necessary

(None)

3. (30 mins) ***What sorts of research are needed to advance your understanding of this topic?***

Monitoring

- Need winter observations (in wetlands, in connecting waters)
    - Develop methods to track changes
        - Remote sensors
        - Acoustic telemetry-tags with temp and pressure sensors (limited by sample size)

Experimentation

- Understanding relationships between wetlands and connecting channels [Effects of changes to water level/cycling]. Winter and summer.
- Can ground water exchanges be incorporated into studies?
- Wetland restoration of meadow marsh at upland/wetland boundary
- Nearshore Shunts operating in Connecting Channels. Horizontal water masses at confluences withtributaries.
- Sources and potential sinks in wetlands for phosphorus and other nutrients to understand flux of nutrients [relevance of anoxia in these wetland systems]. Impacts on fish that utilizethis habitat.

- New tech to look at oxygen cycling
- Comparison and contrast of conserved and non-conserved wetlands (Should some wetland complexes be nominated for Ramsar designation? Or be incoproated into the National Estuarine Reserve or UN Biosphere reserves?).

Metadata analysis

- There is not a lot of data available for connecting waters (largerivers) compared to wetlands (in GL and worldwide) so metea-data analyses may be challenging to complete.

Modeling

- Needs state and rate variables to support mechanistic models
- Losses in wetlands can lead to increases in contaminants (mercury). What does this look like?

DAY 2 (Tuesday morning)

4. (30 mins) What resources would be most needed to advance scientific understanding and management effectiveness related to this topic? Breakout – Day 2 (15 min) Day 1 recap and reality check

- Develop model wetlands - instrumented test-beds - that can be usedfor long-term observation, and testing hypotheses on wetland ontogeny with changing climate, and how physical and biological conditions affect chemical fluxes (nutrients and contaminants).

5. (30 mins) What improvements or innovations to research managementand associated infrastructure would best support our ability to synthesizedata from each cycle to inform future priorities?

- Coordinated methodologies and resources across the region (NAR-LON-SLR).
- Include Indigenous peoples' knowledge and culture to help diversify and strengthen research priorities that respects their relationship withthis environment
- Issues with bi-national distribution of funding?

6. (30 mins) How does this topic cross over to other breakout groups?

- Habitat, native species, invasive species, contaminants

7. (15 mins) Consider how these research priorities and approaches wouldbest support the lake ecosystem and the possible ecosystem services (which provide benefits to human populations) that would result.

- Align research needs with UNSDGs

8. (30 mins) Prepare a five-minute summary of your discussions from Day1 and Day 2 for presentation to the large group. Moderators and note takers can do this alone or with help from the group, just be sure to save some time to put together the summary.

SUMMARY

PRIORITY Hypotheses for Niagara River, Lake Ontario and St.Lawrence River wetlands and connecting water ecosystems

- Plan 2014 is working as conceived to restore fluctuations that promote wetland biodiversity. (Question: Is Plan 2014 effective?)
- A changing winter season in the face of climate change will alter ecosystems in ways we can predict. (Question: Do we understandwhat occurs in winter and is it important to know?)
- Plan 2014 increases contaminant and nutrient mobilization in coastal wetlands. (Question: Will Plan 2014 have unintended consequences?)
- The nearshore P shunt operates in a lateral sense in the SLR with nutrients accumulating in the nearshore downstream. (Question: Dowe have a conceptual gap in understanding P dynamics in connecting waters?)

Funding: Need for bi-national funding mechanism to build capacity in a historically neglected topic.

4.) Contaminants and Pathogens
Moderated by Roxanne Razavi (SUNY ESF) and Wayne Richter (NYSDEC). JosephConnolly (Cornell), notetaker.

Draft questions for Lake Ontario workshop breakout groups

Participants Day 1

Moderators: Roxanne Razavi and Wayne Richter
Notetaker: Joseph Connolly

Emily Sheridan
Roxana Suehring
Evie Brahmstedt
Don Ford
Paul Helm
Stephany Tatrevich
Brad Hill
James Watkins
Tana McDaniel
Katie Lynch
Don Zelazny

Day 2

Euan Reavie
Steve Clement
Evie Brahmstedt
Emily Sheridan
Don Ford
Tanya Long
Stephany Tatrevich
Brad Hill
Stacy Cherwaty-Pergentile
Tana McDaniel
Jim Watkins
Euan Reavie
Jennifer Fornell

Draft Date: 21 June 2021 Breakout – Day 1

1. (30 mins) What is your general reaction to the research and monitoring priorities that have been put forward to date related to the topic that is the focus of this breakout? --Key (top 5) process questions?

- Legacy vs CMC's as a focus of agencies for monitoring

- How to tailor site selection to answer specific questions
- Reduction vs source identification vs next long term data point
- Microplastics: focus on specific impacts, drinking water, biotic effects, chemical analysis
- PBT (persistent, bioaccumulative and toxic) vs PMT (persistent, mobile and toxic), PFAS, 6PPD, 6PPDQ (tire additive and transformation product demonstrated to kill coho salmon)
- Emerging contaminants vs ubiquitous contaminants: Mercury, Lead
- Targeted questions for legacy contaminants: Form a baseline study for emerging contaminants
- To what extent are there plans to study multiple pressures as it relates to legacy and emerging contaminants, climate driven exacerbation of contaminant impacts, compared to legacy contaminants
- Fieldwork: sample collection for nutrients could be utilized to gather contaminants data
- How can current long term monitoring projects benefit CSMI
- Nearshore vs offshore gradient in contaminants
- Consider contaminants from non-point source
- Wastewater/stormwater vs atmospheric
- Pathogens to consider: E. coli, cryptosporidium, microcystins, viruses (additional expertise needed in this area)
- Ambient PFAS concentrations of Lake Ontario approaching drinking water guideline limitations
- Consideration of persistence, bioaccumulation, toxicity, carcinogenicity, concentrations (especially relative to toxicity), environmental effects when prioritizing chemicals
- Perhaps we need a prioritization scheme in place of the "contaminant of the day"
- Effects based monitoring
- Mixtures important to address

Research areas from Roxanne’s introductory talk and relevant discussion.

#1 CHEMICALS WITH POTENTIAL FOR TROPHIC TRANSFER

- CMCs and Chemicals of Emerging Concern pose a threat to humans and wildlife. Identify which chemicals are likely to exhibit biomagnification.

#2 FOOD WEB SHIFTS AFFECTING CONTAMINANT TRANSFER

- Changes in species abundances (at the base of the food web and in forage fish) and introduction of invasive plant and animal species have the potential to mask improvements from emissions regulations in top predatory fish (especially by altering growth rates) and birds

#3 CLIMATE CHANGE IMPACTS

- Changes in precipitation patterns, water quality, water levels, and temperature will affect contaminant bioavailability. Increasing temperatures may increase contaminant bioavailability and increase hazard.
- Climate change impacts: longer ice-free period, change in precipitation patterns, increased erosion, possible impacts on contaminants.

#4 COMMUNICATION

- Without better coordination among stakeholders, achieving objectives will be slow. Education/public outreach, dispelling misinformation. Target message to specific audiences (elementary, middle, high school), community engagement. Share findings in a way that is meaningful.

2. (30 mins) Are there any topics that you think should be upgraded/downgraded in terms of priority, or added to the list that are not? --Key (top 5) process questions? >>Break, as necessary

- Added food web shifts in general to #2 (e.g., changing alewife abundances)
- Impacts ill-defined at this point. Arctic Monitoring and Assessment Program may offer a beneficial guide as projects for Great Lakes research are developed.

3. (30 mins) What sorts of research are needed to advance your understanding of this topic?

- Did not have time to address this question.

4. (30 mins) What resources would be most needed to advance scientific understanding and management effectiveness related to this topic?

- Identify current long term monitoring projects that are on-going by agencies as to not reproduce them

- Expertise in pathogens.

Breakout – Day 2

Breakout – Day 2 (15 min) Day 1 recap and reality check

- 5. (30 mins) What improvements or innovations to research management and associated infrastructure would best support our ability to synthesize data from each cycle to inform future priorities?

  Improve ability to share data across various research programs perhaps in a central location (data registries, databases, repositories).

6. (30 mins) How does this topic cross over to other breakout groups?

- Nutrient loading: tributary sampling of CECs, nearshore sampling of contaminants
- Primary production: trophic status can affect bioavailability, hypoxia/anoxia can affect contaminant bioavailability
- Connecting channels: Consider downstream, sampling below Wolf Island. Need to seek out participation of first nations communities and those who regularly consume fish in the drainage.
- Wetlands: Consider contaminant flux in wetlands as it may relate to flooding and water levels.

7. (15 mins) Consider how these research priorities and approaches would best support the Lake ecosystem and the possible ecosystem services (which provide benefits to human populations) that would result.

- Did not have time to address this question.

8. (30 mins) Prepare a five-minute summary of your discussions from Day 1 and Day 2 for presentation to the large group. Moderators and note takers can do this alone or with help from the group, just be sure to save some time to put together the summary.

Contaminants and pathogens is a very broad topic that can be approached though different, non-mutually exclusive frameworks:

A. A contaminant by medium by spatial location three-way matrix.

B. Legacy versus emerging or currently monitored versus in need of monitoring.

C. Point versus non-point source.

D. Targeted studies versus understanding general prevalence.

E. Inputs versus what is already present.

F. Reduction versus source identification versus adding to the time series.

G. Persistent, bioaccumulative and toxic versus persistent, mobile and toxic (recognizing that non-bioaccumulative contaminants need attention).

H. Focus on effects.

Consider that avoided public health impacts would be another return on investment for this research

Day 2 Notes:

- Consider wetland and tributary sampling for contaminants

- Water and fish sample collection for contaminants in addition to sediment sampling
- US EPA (EPA head Brian Lenell) fish contaminant survey: Clarkson University (Bernie Crimmins) aboard the Lake Guardian, additional fish sources include: USGS (LOBS), NYSDEC, OMNRF Glenora, SUNY Brockport (Jacques Richard)
- Wetland sampling: Central Michigan University (Don Uzarski), SUNY ESF (John Farrell)
- Atmospheric sampling: perhaps lacking in the monitoring of the Great Lakes,
- Regional surveillance programs
- Atmospheric Deposition Network (IADN), Great Lakes Basin (GLB) Monitoring and Surveillance Network under Canada's Chemicals Management Plan (CMP) and the Mercury Deposition Network (MDN)
- Harmful algal blooms monitoring: https://www.dec.ny.gov/chemical/83310.html#Locations
- 2018 CSMI Access database included zooplankton data, water column data, nutrients data, Chlorophyll-a data
- Canada's Open Data portal: https://open.canada.ca/en/open-data
- source for Connecting Channels data specifically: https://open.canada.ca/data/en/dataset/90e5f624-520a-4bd9-bedb-79b03c516a4d
- https://data.ontario.ca/dataset/sediment-chemistry-great-lakes-nearshore-areas
- Consider adding data to binational.net which is the Parties (US and Canada's) platform to report on progress under the GLWQA.
- Floating debris: microplastics among algae
- Winter sampling: under ice hypoxia/anoxia
- How does ice cover (or lack of ice cover) effect contaminants within lake bottom sediments? e.g. sediment disturbance affecting PCBs?
- Consider contaminants within sediment, water, fish, zooplankton, macroinvertebrates
- Need to identify chemicals with potential for trophic transfer, requires water sampling
- Need for broader contaminant analytical screening tools for identifying new or emerging contaminants.
- UQAM vessel (RV Lampsilis) that can navigate shallow waters (wetlands) and can traverse SLR and Lake Ontario
- Euan Reavie: Planned CSMI sediment contaminant study (Trace metals, SVOC, PFAS, elector-chemical analyses, pathogens). Sampling to be done primarily by ponars with cores at select stations. Primarily deep (>30 m) stations. Benthic macroinvertebrate and zooplankton samples also to be collected. Lead Project PI: Chris Filstrup
- Euan Reavie Contact Information:
  Natural Resources Research Institute (NRRI)
  Office 218.788.2692 | Mobile 218.349.4945 | Email ereavie@d.umn.edu

Comments and Questions from group discussion:

- Question: "Do you have examples of changed food web structures or food web pathways? Perhaps mediated by invasive species?" -Shan Mugalingam

- Comment: “Also the increased prevalence of the predatory zooplankton Bythotrephes and Cercopagis lengthening the food chain. They are a preferred prey item of some forage fishes.” - Kelly Bowen

Recap: Good group, lively discussion. Thanks to Roxanne for keeping us on track and Joe for taking notes.

We perhaps had more questions and ideas than answers.

S1: Grey Boyer also mentioned the idea of the extra value of CSMI.

- How do we go from our discussion to operational recommendations?
- Need to coordinate with other breakout groups.
- Where does CSMI fit in with other efforts?

S2: Contaminants and pathogens is a very broad topic that can be approached though different, non-mutually exclusive frameworks:

- A contaminant by medium by spatial location three-way matrix.
- Legacy versus emerging or currently monitored versus in need of monitoring.
- Point versus non-point source.
- Targeted studies versus understanding general prevalence.
- Inputs versus what is already present.
- Reduction versus source identification versus adding to the time series.
- Persistent, bioaccumulative and toxic versus persistent, mobile and toxic (recognizing that non-bioaccumulative contaminants need attention).
- Focus on effects

S3:

#1 CHEMICALS WITH POTENTIAL FOR TROPHIC TRANSFER

- CMCs and Chemicals of Emerging Concern pose a threat to humans and wildlife.

#2 FOOD WEB SHIFTS AFFECTING CONTAMINANT TRANSFER

- Changes in species abundances (at the base of the food web and in forage fish) and primary productivity, and introduction of invasive plant and animal species have the potential to change contaminant transfer and accumulation.

#3 CLIMATE CHANGE IMPACTS

- Changes in precipitation patterns, water quality, water levels, and temperature will affect contaminant bioavailability. Increasing temperatures may increase contaminant bioavailability and increase hazard.
- Climate change impacts: longer ice free period, change in precipitation patterns, increased erosion, possible impacts on contaminants .

#4 COMMUNICATION

- Without better coordination among stakeholders, achieving objectives will be slow. Education/public outreach, dispelling misinformation. Target message to specific audiences (elementary, middle, high school), community engagement. Share findings in a way that is meaningful.
- Registry or other mechanism for data coordination.

Lot of cross over with other topic areas: in addition to climate change, changes in water regulation (Michael Twiss: Plan 2014 increases contaminant mobilization), primary productivity, nutrient input, species and food web changes (Andy Bramburger: poor understanding of trophic transfer). Notion of co-locating sampling with other efforts.

Can we use indicators to reduce the complexity of so many contaminants? How would we do this?

Euan Reavie joined us briefly to talk about an extensive project to look at a wide variety of contaminants in sediments in multiple locations.

Participants lack expertise in pathogens and this group is not well-equipped to address them.

5.) Native Species and Habitat
Moderated by Brian Weidel (USGS) and Tim Johnson (OMNRF). Taylor Brown (Cornell),notetaker.

Questions for Lake Ontario workshop breakout groups

28 June 2021 Breakout – Day 1

- Habitat and native species are intertwined
- If we had a perfect census or inventory, would that improve species restoration?
- Single species vs functional solutions
  - What do we mean by functional? Is that a single species problem or does the problem affect a broad multitude of species? How many species are affected in asystem and what can we do to broadly alleviate it, which will help each species the most?
  - Many issues affecting fish also affect other functional components of the ecosystem - look at how they interact
  - Even for single species foci, you need to consider their habitat and the ecosystems they live in more broadly. Understanding threats/impediments tonative species (single species focus) often requires a broad lens. System approach
  - Can we take a “single species” focus and hope that allows for lessons to belearned for other species of interest?
  - Tough to tackle the broader scale issues without knowing baseline conditions (eg offshore habitat)
  - Habitat functionality: hydrological and physical (allows the habitat to persist); geodiversity of intact habitats (see report by Jody McKenna’s group)
    - Role of legacy (sedimentation) versus emerging habitat disturbancesWhat

can we do in a 1-year CSMI?

- What actions can we take to gain traction and broadly assess habitat, not just the physical aspects?
- Play off “habitat-finding” projects to conduct lake-wide habitat mapping, characterization
  - Eg lake trout acoustic telemetry project (Alex Gatch) to find LT spawning aggregations in the contemporary, compare to historical, assess characteristics of those habitats
  - Could be multi-species...many species utilize similar habitat
    - Let these fishes of interest let us know where they are currently aggregating with the “habitat finding” and then quantitative assessment of habitat quality?
  - Technology and standardized methodology has been a stumbling block
  - “Geological” habitat mapping may not be the “biological” habitat that species interact with (eg rocky habitat now covered in dreissenids)
  - Could help identify bottleneck in their life cycle...where is reproduction occurring across incubation and/or spawning habitat?
  - May be more feasible to do targeted assessments of specific habitats of interest

-
    - Localized studies may obscure broader habitat use (eg studies in tributaries for fish that also interact with main lake habitats and other tribs,bays)
- Spawning habitat versus habitat for juveniles --- which is limiting?
    - We don't know either well, but spawning habitat is maybe the bigger unknown???
    - Depending on species, could be the same habitats
    - For some species nursery habitat could be more limitingIs

CSMI the correct vehicle to tackle native species and habitat?

Available habitat info at broader scales is very coarse resolution (eg GLAHF)

Impact of hypoxia - is it a problem? What is the extent of the impacts?

**Moderator note-hypoxia appears to have a lot of notes, but wasn't a long conversation.

- One of the LEO's specifically targets hypoxia, but also need to understand theextent
- More localized in nearshore harbors and embayments rather than a large-scaleissue (as in Erie)
- Ex. Hamilton Harbour - historically important spawning habitat for coregonines, walleye, etc, but habitat impediments have degraded. Is the loss of Hamilton impacting broader metapopulation success? Stock-scale or lake-scale impacts?
- Hard to assess hypoxia during the spawning periods of many of these species (iethose that have early life stages over winter)...can do sediment assessments, butonly very local in scale
- Hypoxia is likely a contributing impediment, but hard to measure/assess by itself(versus in assessing the role of sediment, Cladophora, etc more broadly)
- Is hypoxia -- or lack of oxygen (suffocation) -- a bigger problem than we thinkbecause it's hard to assess?

Lots of spatial driven questions...move into predictions?

1. (30 mins) What is your general reaction to the research and monitoring priorities that havebeen put forward to date related to the topic that is the focus of this breakout? --Key (top 5) process questions?

2. (30 mins) Are there any topics that you think should be upgraded/downgraded in terms of priority, or added to the list that are not? --Key (top 5) process questions?

- Brainstorming:
    - More predictive modeling...eg Ecopath/Ecosim (priority from 2013)
        - Past lessons of importance of understanding major fish players for informing modeling efforts, else model balancing/outputs suffer
        - Need to understand native species and habitat responses to future ecosystem/climate change
        - Flexibly test hypotheses about specific bottlenecks/interactions and resulting population/ecosystem responses
        - Need to understand how habitat links into population-level responses and limitations
        - The issue of space: whole-lake models quickly become an offshore model, ie a Chinook-alewife model. Is Ecopath an appropriate frameworkfor the native species and habitat questions we're asking here?
            - Can we do restricted Ecopath models rather than whole-lake models? Eg the Bay of Quinte model for restricted spatial scale,

restrictions for focal species [mass-balance/input-output approach may limit the ability to constrain models with any certainty]

        - What about other population growth models to understand production/growth potentials/limitations and linkages across trophic levels and life-stages?
        - *Moderator note: This same idea comes up in the final breakout (Fish communities and ecosystem) – life-history based energetics / population models – identify the critical life stage and bottlenecks and then address the drivers
            - Need to understand reproductive habitat/nutrient limitations populations may face with expansions [habitatand/or competitive factors may be more important than nutrient limitations]

- Fall spawning for lithophilic species (a suite of which is already ongoing, but limited in their spatial extent...is CSMI a solution?)
- Moving from single-species or stage-specific to functional?
    - Understanding where habitat mismatches are likely to occur?
    - Understanding spatial extent of habitat and linkages among habitats
    - Historic context to understand the baseline and priorities for habitat restoration; contemporary context to understand where habitat restorationwill be effective
    - Understanding higher-level threats/stressors that may impact the functional health of the nearshore and the suite of species that use thosehabitats
    - **Moderator note: This "system scale" is key – much of this breakout discussion wrestled with using a focal species (say lake trout) that reflectsmany aspects of ecosystem "health" (native, restoration plan, apex predator, long-lived, known historic stressors (habitat, exploitation) but new issues as well (thiamine, competition) and governed by clear mgmt. plan
- Identify areas of high ecological value (geospatial analysis)
    - Identification of specific factors or priorities (eg fish habitat priorities) to identify these areas
    - Build upon local and/or single species studies to understand higher-level systems context

3. (30 mins) What sorts of research are needed to advance your understanding of nativespecies and habitat?

- In parallel to higher level understanding, Lake Ontario has very specific priorities (eg FCOs) for specific imperiled species or guilds. What actually constitutes good spawninghabitat for focal species? Where are contemporary utilized habitats and how are they being used? Do we know enough about availability/quality of offshore habitats to justify stocking/other restoration actions?
    - We have candidate reefs (Stony, Galloo, Stony Creek reef, Port Weller…others) that have previous years of assessment data (eg Goodyear reefs and follow up studies in the 90s) to compare to today. Can start to ask some of those questionshere
- Is understanding habitat for lake trout as a focal species a reasonable starting point to understanding broader multispecies habitat extents/statuses, even in the nearshore?

- Research priorities for nearshore species habitats that wouldn't be addressedunder the umbrella of characterizing lake trout habitat?
- What makes good spawning habitat? What makes a good coastal wetland? Understanding the attributes
- Can we apply the Toronto model/approach to understanding other Lake Ontario habitats? Is this a tractable approach? Use what data was available to gain a better understanding. Do we have that data in other places? [much less information in other parts of the lake, eg southern embayments]
- St Lawrence River project as another model (Matt Windle)

- Big picture: Physical understanding of habitat and understanding what broader factors makes good "Habitat." Extent, attribute characterization, interacting factors. What factorsare currently impairing the habitat from functioning, and can we design restoration to remedy those impairments? Need to know the threats and the levers that will be most effective in reducing those threats and meeting management objectives. What can we do to actually make a desired impact? Can we manipulate existing local models to benefit more species?

4. (30 mins) What resources would be most needed to advance scientific understanding and management effectiveness related to native species and habitat?

Breakout – Day 2

(15 min) Day 1 recap and reality check

<u>Spatial extent:</u>

- Identify focal site(s) informed by history (e.g. Goodyear 1982, past agency work) butwhere good data exists
  - Need to know the threats and levers to meet management objectives
- Habitat is more than just rocks (examples from Nearshore <u>Framework</u> (ECCC), andToronto (TRCA)
  - *What makes a good spawning site (or coastal wetland)?*

<u>Species / function:</u>

- A focal species (e.g. lake trout) that reflects habitat functionality for a broader suite of species (e.g. "offshore", rocky, shoal spawners). Lake trout also guided by clear management plan and objectives
  - Other research pending and on-going that could inform any CSMI efforts
- Knowing what impairs a top predator should inform about health of other ecosystem elements (e.g. benthic and pelagic inverts, *Cladophora*, water quality (e.g. sediment,hypoxia, temperature))

Focus on spawning habitat? What other types of habitat are we interested in?

- Early life-stage assessment of some salmonids (eg Atlantic salmon)
- Not just mapping spawning habitat -- also nursery habitat
- Response to a suite of stressors across life stages
  - Predation

- Hypothesis that spawning habitat is the impediment to a suite of native species; suite of ongoing projects; spawning substrate may be a limiting bottleneck for fall spawning lithophilic species (lake trout, lake whitefish, cisco, (?)bloater(?))
  - LIDAR can tell you a lot about physical, but you need others to follow the life-history and other biophysical interactions
  - Describe spawning habitat and utilization
  - Lake trout has the benefit of not spawning in December --- ability to observeactual spawning & egg deposition patterns
  - Availability of suitable spawning habitat...spawning in the *most* suitable habitat available, even if it's not actually optimal
  - Idea of assessing the egg stage as the "integrated" outcome of spawning success. Not just where the adults are spawning.
- Can we find common characteristics/processes?
  - Other species of interest: Atlantic salmon, warmwater fishes that also utilizethese nearshore habitats.
  - Other habitats of interest: tribs, wetlands
  - Adult habitat also of interest
  - But early life stage interactions and bottlenecks are an unknown for many species
  - The role of substrate (sediment, oxygenation, interstitial space, vegetation)?
- Are the waterfront habitats available of good quality, how are they impaired, is there sufficient good quality habitat of various types to allow warm or cold water fish to carry out their life stages (spawning, young, feeding, overwintering) and are those habitats sufficiently connected, are they limited? On early life history - are there physical barriersin the lake to early life success (Andrew Ramesbottom - from chat)
- Cross-basin connections with CSMI
  - Opportunity to bring more resources to monitoring large-scale ecosystem effects(eg shoreline hardening)
- Nearshore - you can more easily observe it and measure it in comparison to the offshore. But CSMI helps bring those resources to overcome those barriers.
- Ecosystem approach: Look at the environmental variables that affect fish -- ice cover, storms, etc -- across species and habitats to understand how processes impact habitat
- Use remote sensing to predict and then in situ sampling to verify
  - Remote sensing is coarse, can be spotty with weather. But may be a good starting point to then do boots-on-the-ground work. Confirmation, ground-truthing.
  - Glider observations for remote sensing for habitat variables with better resolutionand reliability than we've had previously? But even the glider has relatively restricted scope -- trade-off with that resolution
  - Spatially extensive drop camera observations to ground truth or provide additional information for future studies (glider, ship-based)?
    - Would be useful to multiple groups, and at small scale, but collectively powerful across the lake
    - Contact Lake Bed 2030 Team
    - Derek Niles (Orange Force Marine) is leading the effort to provide "loggers" for shipboard seabed classification
    - Ecological classification approach (geodiversity - see Day 1 Notes)
    - https://iocm.noaa.gov/standards/cmecs-home.html
      - Particularly useful for habitats with mussels

- Seasonal considerations
    - Cladophora season versus non-Cladophora season
    - Might not be feasible with ship/tech time, but cross-season sampling could be important
- Are the groups already focused on Cladophora also taking substrate observations?
    - Cladophora extent, growth, interactions with mussels
    - Marry local-scale dynamics with ecosystem-level dynamics

Sediment supply and transport on the lake-scale

- Gap in nearshore models. Currently only work-arounds are available to help understand.
- Ground-truthing to marry nearshore-offshore sediment models
- Sediment as an important but less recognized driver in Lake Ontario
- Maybe a focus of other groups on the supply/transport scale. Coordination across groups?

Do we want to hone in to "cross something off the list"? Or what can we do collectively that we couldn't otherwise do across broad spatial scales? Cooperative SMI!
Projects that would have an ideal fit with repeated monitoring on the 5-year CSMI scale, supplemented with ongoing and smaller scale projects in the interim?
What worked well last time (CSMI 2018, coregonine larval assessment)

- Structured framework with a specified information need
- Common science info need with work that can be done locally by each partneracross the lake
- Each group only put in a small amount of time/labor to collectively understand thelake-wide dynamics
- Not just collect data and monitor - analyze it! Use it!

What are the targets/priorities?

- FCOs -- lake trout, lake whitefish, cisco, sturgeon, atlantic salmon, (bloater), lotsof other native species
-

- Sediment and its role in influencing habitat; large-scale factors and their role in local success in cross-species, cross-habitats (includes sediment); spawning/early life historyhabitat across life stages and species;
- Habitat supply and condition (but may be able to be deferred to other groups)??
- Understanding landscape dynamics -- where is sediment coming in and from
- What about nearshore species (eg walleye)?
    - Focus on other species (lake trout, coregonines, sturgeon, Atlantic salmon) is largely due to their status as restoration species. Added focus and managementplans dedicated to restoring these species and identifying science needs. The framework is already there. These species are also declining compared to morestable species like walleye, bass.
    - May be important to understanding connections between nearshore-offshore dynamics; tributary-open lake dynamics
    - Also of higher interest in specific areas like Hamilton Harbour - understanding specific impediments in disturbed habitats
    - Shoal spawning walleye may even overlap with the fall spawning lithophilic fish. Different seasons but same reefs. Also lake trout spawning in rivers, etc..

5. (30 mins) What improvements or innovations to research management and associated infrastructure would best support our ability to synthesize data from each cycle to inform future priorities?

6. (30 mins) How does this topic cross over to other breakout groups?

7. (15 mins) Consider how these research priorities and approaches would best support theLake ecosystem and the possible ecosystem services (which provide benefits to human populations) that would result.

8. (30 mins) Prepare a five-minute summary of your discussions from Day 1 and Day 2 for presentation to the large group. Moderators and note takers can do this alone or with help fromthe group, just be sure to save some time to put together the summary.

Summary

Discussion points

What guides our decision making w/ regard to native fish (and others) ? FCO's?

- Careful in being species specific, consider guilds, consider functional solutions, like sedimentation influencing ma

Do we study habitat directly, or observe the fish (spawning) and let that guide us.

Coastal wetlands & lithophilic spawners (LT, Cisco, LWF, Sturgeon, Walleye)

- What makes a good spawning shoal and or what makes a good coastal wetland?

Offshore vs Nearshore, lets not forget about the deeper habitats (Bloater, DWS, LT)

Consider where the levers exist?

- Shoreline habitat changes could be influenced to help native fish habitat
- Fish Manag. Levers: stock, adjust harvest, adjust habitat
    - most main lake efforts on stocking, habitat of increasing interestMust

know what other groups are working on (LakeBed2030, TNC Shoal assessment)

- where are they at, how can we help?

Approaches

2018 CSMI Larval coregonine model - everyone pitches in and works locally to sample

- What worked: defined information need within a bigger framework, field work was tractable for most groups (small boats, gear in hand, short time input), lots of small cooperative inputs yielded lakeside results

Consider spatial scale

- Large Scale / Remote Sensing - keep it big - that doesn't really allow local or coordination
- Ground truth remote sensing; check with remote sensors for what they need, not everyone has million dollar robots be most have drop cameras, would this help?
- Put backscatter loggers on all ship sounders, better substrate, better depth!

Be careful about seasonally dependent sampling, if needed it can complicate

<u>Research priorities (all have cross group elements)</u>
Physical drivers of fish habitat - temperature, ice cover….
Sedimentation, inputs & resuspension, how is this driving habitat
- Has role across fish habitat (tribs, wetlands, inlake spawning)
- possibly biggest driver that is least studied

Lack of substrate information 'nearshore and offshore' limits our understanding
- Same as 2018

Identify where habitat acts as a bottleneck to native fish population abundance (spawning or early life history)

<u>Questions/Comments from Main Group Reporting</u>

<u>Discussion points</u>
- Admittedly fish centric, consider other organisms (e.g. native mussels)
    - native fishes & habitat changing since 1800's, few native fishes have turned around
    - coastal wetlands & lithophilic spawners (LT, coregonines, Lake Sturgeon, Walleye)

- Consider what guides decision making for this process w/ regard to native fish (and others) ?
    - Lake Committee FCO's? apnd other biodiversity strategies
    - Declining species relative to more stable should maybe guide
    - Data suggests natives are limited at early life (egg, larvae)

- Careful in being TOO species-specific
    - Think guilds or functional solutions (e.g. sedimentation influences spawning habitat of many species)
    - Would ecosystem models help? Nonnative swamp out natives w/ biomass approaches

Do we study habitat directly or observe the fish (spawning) and let that guide us what habitat we study?
- What makes a good spawning shoal and or what makes a good coastal wetland?
- Which physical factors are driving fish habitat? hypoxia, substrate distribution, wetland habitat

Consider where the management levers exist?
- Fish : lots stocking, some harvest adjustment, much less habitat restoration
- Shoreline habitat changes could be influenced to help native fish habitat (or hurt)

Know what other groups are working on RE: habitat (other CSMI's, LakeBed2030, Spawning shoal surveys)

Approaches

2018 CSMI Larval coregonine model - many pitch in, sample locally, what worked
- defined information need within Coregonine Framework
  (lake wide extent of successful coregonine spawning and impediments)
- field work was tractable for most groups (small boats, gear in hand, short time input)
- multiple, distinct, cooperative, but lake-wide efforts yielded lot of learning (do new things!)
- $$ for what no group had, sample processing and write up

Should we focus on lake wide (e.g. remote sensing) approaches
- doesn't readily allow local coordination
- Could local ground truth remote sensing; check with remote sensors for what they need
  - not everyone has million dollar robots be most have drop cameras
- Put backscatter loggers on all ship sounders, better substrate, better depth!

Be careful about seasonally dependent sampling, if needed it can complicate

Research priorities (all have cross group elements)

Physical drivers of fish habitat - temperature, ice cover, substrate, anthropogenic changes (e.g. climate, land use)

Sediment changes to habitat: inputs, distribution, resuspension
- Influences multiple fish habitats (tribs, wetlands, in-lake spawning)
- Possibly most-impactful, but least-studied driver

Lack of substrate information (nearshore or offshore) limits our ability to quantify how habitat limits native species
- same need as 2018

Identify where habitat bottlenecks native fish
- focus on spawning, incubation, or early life history

- Emily Sheridan: by “bottlenecks” are you referring to needing enhanced connectivityamong lake habitats?
    - No, population-level survival bottleneck at certain life-stages
    - Follow up: but is that an additional research need?
        - Potentially an issue for specific species (eg tributary spawners rather thanbay spawners), but we didn’t talk about it.
        - Less effort for main lake species that don’t use the tributaries

Michael Twiss: Any talk of native species and habitat in connecting waters?

- Tried to stay away from focuses of other groups, but elements of what we talkedabout (e.g. sediment, water levels) are highly relevant to connecting waters and diverse habitats. Cross-region drivers that are relevant to both.
- BW thinks more studies done in connecting channels by area than in bays
- Identified places where research priorities were needed that work across thosezones

Lyubov Burlakova: What about freshwater mussels?

- Highest densities of native fish are spawning on mussels or mussel hash!
- Tied into cross group elements of substrate mapping
- Haven’t yet been able to assess in a way to actually tackle the impedimentsLars

Rudstam: What’s Lakebed 2030?

- Effort to map all of the Great Lakes’ lakebed mapping by 2030
- https://www.glos.us/lakebed-2030/
- Follow up: do we need to do this as part of CSMI?
    - Need to coordinate with them directly to understand goals, needs, andhow we can help

Kristina Heinemann: GLOS, USGS and NOAA developed a priority setting tool to identify areas for bottom mapping in the GLs. Obviously the entire lake bottom cannot be mapped so the agencies reach out to the larger community to solicit input. As far as I know that process has concluded. I don't know what the findings/results are.

6.) Fish Communities and Ecosystem Connections
Moderated by Lars Rudstam (Cornell) and Kelly Bowen (DFO). Kimberly Fitzpatrick (Cornell), notetaker.

Draft questions for Lake Ontario workshop breakout groups

Draft Date: 21 June 2021 Breakout – Day 1

1. (30 mins) What is your general reaction to the research and monitoring priorities that havebeen put forward to date related to the topic that is the focus of this breakout? --Key (top 5) process questions?

- What is the effect of redistribution of mussel biomass on P budget? Interactions with physics?
- Will mussel biomass decline in some areas and if so why?
- What is the importance of different areas (embayments, nearshore, offshore) to current dominant fish species?
- Linkages between gobbies and mussels, seasonality, movement between near shoreand offshore. Quantify abundance/biomass.
- Will mussels decline over time? Seen in small lakes but not in Lake Ontario. (Biomass? Density?) Overall density is increasing, overall size is increasing.
- Regional differences in mussel density even at the same depth. Based on prior surveys,are there hotspots we should target? Western basin vs rest of the lake - different growth rates, reproduction? Near-shore to off-shore distribution of veligers.
- Mussel growth rates relative to food and temperature, interaction.
- Mussel funcundity.
- Changes in zooplankton community structure due to oligotrophication, water clarity, or invasive cladocerans? Build on 2018 survey. Confounding between potential drivers. Prioritize figuring out relationships. Tracking the fate of energy through the system. Regime shift? Nutrient -> forge fish: how does this cycle change when nutrient levels aredeclining.
- Detail vertical and horizontal distribution of productivity and zooplankton.
- Why did Diporeia decline, and will they return? Sasha has found some, what does this mean for Lake Ontario and applications to other lakes. Are they showing up in the fish diets and can they be used with ponars to help answer questions? Fish are better samplers than ponars. Do we see a decline in Diporeia in fish diets as well as in the surveys? Links with deep water sculpin. Diets might be better for presence/absence, notfor index of abundance.
- Prey fish diets. Diporeia hasn't been found recently in the diets of fish (Alewife, sculpin),but lack of comprehensive diet studies. Lake whitefish diets. OMNRF has some incoming data on cisco/whitefish diets. Goby diets - connect to mussel consumption. Sculpin diets.
- Forge fish diets. Age-0 predator and prey fish diets.
- Why is alewife declining – oligotrophication or naturalized salmonid production? Effectson sustainable fisheries? Winter distribution, N-S changes in alewife distribution.
- Will increasing deepwater fish affect benthos and mysids?
- Impacts of increasing temperature and seasonal shifts?
- Recruitment variability: Lake Trout, Coregonids, Pacific Salmonines
- Corregonine distribution and spawning distribution - use of tributaries.
- Winter surveys…? Can gliders run in winter?

- Distribution of habitats across the lake? Tributary habitat and impact of connectivity. Drivers of recruitment.
- Development of genetic tools for distinguishing species, otolith microchem for understanding reproduction patterns. Rapid assessment of mussels. More gliders.

- Comment from Tim Johnson: Great list of topics but what is missing is the food web and interconnectedness / linkages. If you spent a year on mussel questions (or any other) would you be able to move on. See comment above re "Focus on priorities not what people want to work on". IMO, CSMI should be focused effort to address a critical question that can't be done in out years (lake of resources – ships, people, and / or spatial and temporal intensity). But at the end of the CSMI we should have something toshow for it, not just a new list of questions.

2. (30 mins) Are there any topics that you think should be upgraded/downgraded in terms of priority, or added to the list that are not? --Key (top 5) process questions? >>Break, as necessary

- Mussels: Role of mussels in Lake Ontario food web
    - Spatial distribution
    - Fecundity: production, fate, and transportation of veligers
    - Growth rates: growth rates of veligers. Important component of zooplankton biomass. Temperature impacts. Seasonal dynamics. Zebra vs Quagga.
    - Mussel diet/feeding rates in different regions of the lake. Fatty acid analysis.
    - Impact on the nearshore shunt.
    - *Sedimentation vs productivity vs consumption by mussels
    - *Winter food supply
- Recruitment variability of fish species
    - Fish diets: niche species (we don't need well studied species e.g. Chk+LKT, butless studied species such as sculpin, alewife, lake whitefish, cisco)
        - Prey species diets
        - Links to mussel questions - goby
        - Links to Diporeia
    - Age-0 dynamics
    - Is this feasible with one year of sampling?
    - Embayments and near-shore areas

Missing Data

- Basic mapping that is missing
    - Substrate and habitat data - seasonal changes
    - Nearshore and tributaries
- Winter sampling?
    - Remote sensing tools, Gliders
    - Climate change, spring bloom
    - Temperature profiles - small changes could have big impacts for overwintering species
        - Nearshore and offshore
- Hydrodynamics of the lake
    - Zooplankton, larval fish, nutrient distributions
    - Some active projects on this (NOAA, environment Canada)
    - Take existing models that are focused on nutrient and chlorophyll dynamics and link them to (general) zooplankton and larval fish dynamics.

        - E-W differences in upwelling
        - Water level impacts on zooplankton
            - Mix depth
    - Rates - primary and secondary production
        - Bacterial, microbial, veligers
        - Need to have rates taken at the same period of time
        - Flux of nutrients and general sediments from tributaries and impact on primary and mussels

Zooplankton

- Day/Night sampling and impacts on estimates
- Gliders
- How do the layers of zooplankton change over the course of a day
- Diets of zooplankton -
    - Veligers?
    - Importance of bacteria in the diets
    - Increased length of food chains?
    - Efficiency and cycling
- Rotifer sampling
    - Mesh size 64 vs 20 micron nets, are we missing a lot of them
- Fate of energy

Deep Water

- Deep water sculpins
- Bloaters
- Diets of sculpins, gobys
- Is it changing and what is going to become?
- Mysids!
    - Declined in Huron and Michigan, is that going to happen in Lake Ontario?
    - Deep water habitat for mysids
- Burbot - declined

3. (30 mins) What sorts of research are needed to advance your understanding of this topic?

4. (30 mins) What resources would be most needed to advance scientific understanding and management effectiveness related to this topic? Breakout – Day 2 (15 min) Day 1 recap andreality check

- Funds
- Ship time
- **Tim Johnson comment: Worth noting, with exception of Lake Guardian (and maybe others) there is no “ship / staff appropriation” related to CSMI (i.e. existing schedules andstaff supported through other funding). Ship of opportunity works well and thus pre- planning / coordination well in advance is critical.
- Gliders (Lars wants 10)
- Improved technology
- Multibeamed/side scanning sonor
- Staff time for processing, analysing, and reporting/publishing on data.
- Data management system - time and funding. How did last CSMI’s system work out?
- GLEON style meetings may help with structuring projects and progressing projects.[Time for agency staff to attend/participate/lead]. Must work with collaborators.
- Standardization of sampling methods
- Comparison to other lakes - what is the same and what is different

- Biological reference points
- Using the CSMI framework to compare values across lakes.

5. (30 mins) What improvements or innovations to research management and associated infrastructure would best support our ability to synthesize data from each cycle to inform future priorities?

- How to get the data off of the computer and into the literature.
- Appropriate staffing to focus on CSMI data sharing, synthesis, and storage
    - An "in-kind" position, term biologist to work on this project
- Over-arching network would help GLEON-esque
    - Project leaders with a large cooperative group
    - Post-docs and grad students have the time to clean and prepare the data
- Each agency/group has their own guidelines for managing and making data accessible.
    - Only publish data once in one place and figure out how to direct everyone elsethere so time isn't spent trying to clean/document the data for different data management systems.
    - Use the existing data portal instead of reinventing the wheel. Set up processes in advance. Helps the agency folks as well since downloads via the data portals aretracked. Makes sure ownership is tracked more so that collecting agencies are credited with collection and data is used with the appropriate licensing.
    - Set up templates so that the data can be somewhat standardized.
    - Database of metadata with information on where to get the data from the individual agencies.
    - Create research networks so that graduate students can be supported and workwith agencies and focus on the CSMI data.
    - Caveat: How do we make sure that researchers outside the group have accessto the data.
    - Caveat 2: We've tried both approaches and gathering all the data in one placehas not gone well and have short lifespans. While ideally the data would be inone place, using the agency groups have had longer lasting better managed databases.
    - We can use open data management systems and data report/papers to get thedata out there and accessible. Not set up for time series data.
- Data management clause in grants, when will data be published? Before publication isbetter for making the data accessible.
- Coordination of research vessels
    - Planning cycles are well in advance, stagger cruises unless there is a need tohave multiple boats out at the same time.
    - Temporal coverage
    - Work around other annual projects for different groups, these times are knownfar in advance. Good coordination can result in better data.
    - Have a meeting specifically on planning vessel times, needs to be worked out ayear or more in advance.
    - Lake Explore available for assisting with CSMI - Talk to Jill Scharold

6. (30 mins) How does this topic cross over to other breakout groups?

- basic assessment of the current distribution of some of these native species

- It crosses over into all of them.
- Nutrients - important for ecosystem structure pelagic and benthos
- Primary production - basis of ecosystem - fa
- Native species - coregonenes, sculpin, deep water ecosystems
- Contaminants - how does ecosystem structure impact contaminants
    - Pathogens - less work done
        - Dieporia decline driver?
        - Daphnia
        - Viruses leading to blooms

Wetlands and connecting - are our open lake fish using them. Utilization of connecting channels. Zooplankton communities are heavily impacted by connecting channels. Understudied ecosystem processes. Fish spawning habitat.
Invasive species fit into many topics - mussels!

- Non-native species (Pacific salmonids, alewife…) important ecosystem drivers
- Nuisance species (Cladophera)

7. (15 mins) Consider how these research priorities and approaches would best support theLake ecosystem and the possible ecosystem services (which provide benefits to human populations) that would result.

- Winter dynamics - what goes on and how it may change under climate change conditions
- Recruitment variability - better understand the ecosystem services related to fish production
    - whitefish/cisco fisheries
    - Lake Trout
    - Non-native have high ecosystem service benefits
        - Chinook Salmon and Alewife

Mussels

- Phosphorus uptake
- Need to understand what will happen if mussels increase or begin to decline

Fate of energy through the system

- Microbes -> zooplankton -> prey fish -> predators
- Microbial collapse would have a big impact on services

Nearshore vs offshore benefits

- Different communities benefit from different drivers
- Nearshore - clean water without cladophera
- Offshore - salmonid fisheries and recreational boating
- Perceptions of the health of the lake may change based on areas of the lakeused.
- Understanding link between the two can increase our understanding of ecosystem services
- Interface between nearshore/offshore

Habitat mapping to understand fish dynamics

- I don't know if you saw my last chat comment, but here it is: Habitat mapping would help us to identify locations where fish occur more frequently than others areas and the associated habitat conditions. this would give us an understandingof the extent and distribution of those conditions favorable to various species at different times of year, and whether any can be protected and/or rehabilitated to enhance fisheries and ecosystem services.

- An important aspect of this is connectivity (or resistance) between habitat patches -- we know almost nothing about that and it will vary considerable between species, especially pelagic vs. demersal/benthic species.
- We would benefit from more directed and controlled telemetry work on fish movement to better associate "important" habitat patch locations with fish usage.

Acknowledge ecosystem services related to water treatment

- Cladophera
- Mussel
- Nuclear plants - must shut down if cladophera gets into the intake.
- Drinking water

Spiritual and cultural benefits

- Indigenous communities have not been involved with CSMI in the past
- Anglers have been more actively involved in management groups

8. (30 mins) Prepare a five-minute summary of your discussions from Day 1 and Day 2 for presentation to the large group. Moderators and note takers can do this alone or with help fromthe group, just be sure to save some time to put together the summary.

- What can be done as a CSMI project
  - E.g. sedimentation project w. Mussels and the deep water
  - Diet studies and age-0 fish (non-predators)
  - Gliders looking at zooplankton distributions
  - Dreissena growth (adults and veligers)
  - Winter fluxes (production)
  - Dreissena abundance/density
  - Diets of zooplankton, esp predatory zooplankton
  - Habitat mapping
  -
  -
- basic assessment of the current distribution and ecology of some of these native species
  - Fish behavior
  - Fish diets
  - Lean on technical groups to develop ideas/projects
  - Caveat: We do have existing datasets that we need to use and may be relevant.If 50 years of data haven't provided it, what can we do in one year. How can these resources be used to compliment these long term data and knowledge.
    - Impact of climate change, identifying drivers

9. Comments and questions from the larger group discussion

Summary

Mussels

- P cycling and change over depth
- Local vs whole-lake
  - Density, growth, fecundity, diets
- Goby predation
- Nearshore impacts
- Veligers - survival, dispersal, and filtering impacts

Fish recruitment variability
- Coregonines, Salmonids, Alewife
- Survival
- Diet of prey fish and age-0 fish
- Habitat availability

Winter
- Spring bloom -> winter
- Temp increase impacts on survival of fish
- Ice cover
- Runoff dynamics
- Gliders!

Pelagic ecosystems and plankton
- Nutrients -> plankton -> prey fish -> predators
- Local vs lake-wide
- Combine ecological knowledge with hydrodynamic models
- Impact of small grazers
- Bacteria, viruses, and microbs

Deepwater ecosystem
- Quagga mussels
- Dipoeria decline - why did they decline and are they coming back
- Deepwater sculpin and gobbies
- Mysids

Need tools!
- Habitat maps
    - https://coast.noaa.gov/llv/#/lake/ontario
    - Combine telemetry and mapping to understand what areas fish are using
- Genetic tools
- Rapid assessment of mussels
- Method comparisons
- GLEON-esque working groups to push projects forward

Ecosystem services
- Impact of climate change
- Non-native species are important for ecosystem services
    - Mussels, salmonids, alewife
- Spiritual and cultural beliefs of indigenous communities
    - Should figure out how to involve members of indigenous communities, whichhave not been included in past years.
- Water intakes

Potential Projects
- Add to existing monitoring programs
- Benthic surveys
- Mussel effects models
- Sedimentation study - year round
- Winter limnology
- Recruitment
- Habitat mapping

Questions

T. Brown - Mechanisms for fish recruitment?
- A life cycle approach could be useful

- Link drivers of recruitment to bottlenecks

W. Richter - Knowledge of fish movement would help target and interpret contaminant monitoring in fish.

Appendix 3: Workshop Attendance

Name	Breakout Room	Affiliation
Lars Rudstam	Fish Communities and Ecosystem Connections	Cornell University
Tana McDaniel	Contaminants and Pathogens	Environment Canada
Euan Reavie	Contaminants and Pathogens	University of Minnesota
Michael Twiss	Coastal Wetlands and Connecting Channels	Clarkson University & IJC Science Advisory Board
Alexander Karatayev	Native Species and Habitat	SUNY Buffalo State
Susan Daniel	Native Species and Habitat	Great Lakes Center
Kimberly Fitzpatrick	Fish Communities and Ecosystem Connections	Cornell University
Andrea Kirkwood	Coastal Wetlands and Connecting Channels	Ontario Tech University
Christopher Fidler		NYSDEC
Marten Koops	Fish Communities and Ecosystem Connections	Fisheries and Oceans Canada
Stacy Furgal	Host	NYSG
Greg Boyer	Primary Production	SUNY-ESF
Katie Lynch	Contaminants and Pathogens	EPA, Region 2
Nadine Benoit	Nutrient Loading	Ontario Ministry of the Environment, Conservation and Parks
Jessica Goretzke	Native Species and Habitat	NYSDEC
Angela Wallace	Fish Communities and Ecosystem Connections	Toronto and Region Conservation Authority
Tom Hollenhorst	Nutrient Loading	EPA GLTED
Michael Lucas	Contaminants and Pathogens	NYSDEC
Brian Rahm	Nutrient Loading	NYS Water Resources Institute
Sonya Kranzl	Fish Communities and Ecosystem Connections	MNRF Lake ontario
Matt Windle	Coastal Wetlands and Connecting Channels	River Institute
Stacey Cherwaty-Pergentile	Contaminants and Pathogens	Environment and Climate Change Canada
Mark Fitzpatrick	Primary Production	Fisheries and Oceans Canada
Aman Basu	Fish Communities and Ecosystem Connections	York University, Canada
Katelynn Johnson		University of Windsor
Lizhu Wang	Native Species and Habitat	IJC
Calvin Hitch	Nutrient Loading	Toronto and region conservation authority

Michael Connerton	Native Species and Habitat	NYSDEC
James Lehnen	Nutrient Loading	NYSDEC
Taylor Herne	Contaminants and Pathogens	Cornell University
Derek Schlea	Nutrient Loading	LimnoTech
Leigh McGaughey	Coastal Wetlands and Connecting Channels	St Lawrence River Institute
Thomas Evans	Fish Communities and Ecosystem Connections	SMCM
Sapna Sharma	Primary Production	Associate Professor
Rae-Ann MacLellan-Hurd	Native Species and Habitat	ORISE Participant at EPA GLNPO
Kelly Bowen	Fish Communities and Ecosystem Connections	Fisheries and Oceans Canada
Tanya Long	Contaminants and Pathogens	Ontario Ministry of the Environment, Conservation and Parks
Emily Sheridan	Contaminants and Pathogens	NYSDEC
Jonathan Ruppert	Fish Communities and Ecosystem Connections	TRCA
David Klein	Coastal Wetlands and Connecting Channels	The Nature Conservancy
Steve Clement		ECCC
Barry Madison	Nutrient Loading	Queen's University / River Institute of Environmental Sciences
Brian Weidel	Native Species and Habitat	USGS
James Pauer	Nutrient Loading	USEPA/ORD
Ram Yerubandi	Nutrient Loading	Environment Canada
Alex Gatch	Native Species and Habitat	U.S. Fish and Wildlife Service
Mike Haugh	Nutrient Loading	Genesee RiverWatch
Jake La Rose	Native Species and Habitat	OMNRF
Megan McCusker	Primary Production	ECCC
Samantha Paquette	Primary Production	Region of Peel
Kevin Blagrave	Nutrient Loading	York University
Erin Brown	Fish Communities and Ecosystem Connections	OMNDMNRF
Christopher Marshall	Primary Production	Cornell University
Stephany Tatarevich		NYSDEC
Philippa Kohn	Native Species and Habitat	The Nature Conservancy
Krista Chomicki	Primary Production	Toronto and Region Conservation Authority

Lauren Barth	Nutrient Loading	University of Toronto, MECP
Harold Peterson	Coastal Wetlands and Connecting Channels	Bureau of Indian Affairs
Kathryn Amatangelo	Native Species and Habitat	SUNY Brockport
Katie Merriman	Nutrient Loading	USGS
Guy Foster	Nutrient Loading	U.S. Geological Survey
Brett Hayhurst	Nutrient Loading	ERDC and Cornell University
Brian Lantry	Native Species and Habitat	USGS
Beth Whitmore	Nutrient Loading	Cornell Biological Field Station
Chris Pennuto	Fish Communities and Ecosystem Connections	Great Lakes Center, Buffalo State
Matthew Child		International Joint Commission
David Clarke	Coastal Wetlands and Connecting Channels	NYSDEC
Jennifer Graham	Primary Production	U.S. Geological Survey
Tracie Greenberg	Nutrient Loading	Environment and Climate Change Canada
John Farrell	Fish Communities and Ecosystem Connections	ESF Thousand Islands Biological Station
Daniel Rokitnicki-Wojcik	Primary Production	Environment and Climate Change Canada
Cass Stabler	Coastal Wetlands and Connecting Channels	Parks Canada, Ontario and the Waterways
Jim Martherus	Nutrient Loading	ECCC
Don Ford	Contaminants and Pathogens	Toronto and Region Conservation
Luke Moslenko	Nutrient Loading	
Emma Flanagan	Nutrient Loading	MECP
Catherine Masson	Native Species and Habitat	Trent University
Mark Burrows	Nutrient Loading	IJC - Great Lakes Regional Office
Ashley Elgin	Fish Communities and Ecosystem Connections	NOAA GLERL
Ralph Toninger	Coastal Wetlands and Connecting Channels	Associate Director, Restoration and Resource Management Toronto Conservation Authority
Mary Thorburn	Nutrient Loading	MECP
Mike Yuille	Fish Communities and Ecosystem Connections	Ontario Ministry of Natural Resources and Forestry
Jill Scharold	Native Species and Habitat	US EPA
Christopher Seslar	Fish Communities and Ecosystem Connections	US EPA Region 2

Trevor Krabbenhoft	Native Species and Habitat	University at Buffalo
Jeremy Holden	Fish Communities and Ecosystem Connections	OMNRF
Doran Mason	Fish Communities and Ecosystem Connections	NOAA GLERL
Lyubov Burlakova	Native Species and Habitat	SUNY Buffalo State College
Roxanne Razavi	Contaminants and Pathogens	SUNY ESF
Mark Rowe	Nutrient Loading	Michigan
Meredith Nevers	Primary Production	U.S Geological Survey
Joseph Connolly	Contaminants and Pathogens	Cornell University
Andrew Kowalczk	Nutrient Loading	USGS
Allison Hrycik	Native Species and Habitat	Buffalo State College
Andrew Ramesbottom	Native Species and Habitat	Toronto and Region Conservation Authority
Mohi Munawar	Primary Production	fisheries & oceans
Ora Johannsson	Native Species and Habitat	UBC/DFO
Jeff Ridal	Coastal Wetlands and Connecting Channels	St. Lawrence River Institute
Cailin Burmaster	Fish Communities and Ecosystem Connections	University of Windsor - RAEON
Chris Gazoorian	Coastal Wetlands and Connecting Channels	U.S. Geological Survey
Wayne Richter	Contaminants and Pathogens	NYS Department of Environmental Conservation
Bogdan Hlevca	Coastal Wetlands and Connecting Channels	Ontario Ministry of the Environment
Sarah Beech	Fish Communities and Ecosystem Connections	Lake Ontario Management Unit OMNRF
Rachel Schultz	Coastal Wetlands and Connecting Channels	SUNY Brockport
Brad Hill	Nutrient Loading	Environment and Climate Change Canada
Jun Zhao	Coastal Wetlands and Connecting Channels	ECCC
Tim Johnson	Native Species and Habitat	OMNDMNRF
Lisa Fogarty	Nutrient Loading	Michigan
Steph Figary	Primary Production	Cornell
Georgina Kaltenecker	Nutrient Loading	Ministry of Environment, Conservation and Parks
Emma Tahirali	Nutrient Loading	Ontario Ministry of the Environment, Conservation and Parks
Greg Kronisch	Native Species and Habitat	US Fish and Wildlife Service
David Depew	Nutrient Loading	Environment and Climate Change Canada
Yasi Hassanzadeh	Contaminants and Pathogens	NYSDEC

Brian O'Malley	Fish Communities and Ecosystem Connections	USGS
Joe Atkinson	Nutrient Loading	University of Buffalo
Shan Mugalingam	Nutrient Loading	Lower Trent Region Conservation Authority
Warren Currie	Fish Communities and Ecosystem Connections	Fisheries and Oceans Canada
Daniel Gurdak	Fish Communities and Ecosystem Connections	EPA R2
Jennifer Dunn	Coastal Wetlands and Connecting Channels	New York
Nikki Saavedra	Nutrient Loading	NYSDEC
Paul Helm	Contaminants and Pathogens	Ontario Ministry of the Environment, Conservation and Parks
Jennifer Fornell	Native Species and Habitat	United States Army Corps of Engineers
Jim McKenna	Fish Communities and Ecosystem Connections	USGS TLAS
Melissa Tarasiewicz	Native Species and Habitat	U.S. Army Corps of Engineers
Kristina Heinemann	Primary Production	USEPA
Marie-Claire Doyle	Nutrient Loading	ECCC
Shannon Dougherty	Coastal Wetlands and Connecting Channels	NYSDEC
Jim Watkins	Host	Cornell University
Andy Bramburger	Primary Production	Environment and Climate Change Canada
Douglas Wilcox	Coastal Wetlands and Connecting Channels	SUNY Brockport
Bernard Crimmins	Contaminants and Pathogens	Clarkson University
Brent Metcalfe	Fish Communities and Ecosystem Connections	Ontario Ministry of Natural Resources and Forestry
Dawn Dittman	Native Species and Habitat	USGS
Roxana Suehring	Contaminants and Pathogens	X University
Bill Snodgrass	Nutrient Loading	Ontario
Heather Niblock	Primary Production	Fisheries and Oceans Canada
Steve Ruberg	Primary Production	Michigan
Don Zelazny	Primary Production	NYSDEC
Mary Anne Evans	Nutrient Loading	USGS
Joe Fiorino	Coastal Wetlands and Connecting Channels	Environment and Climate Change Canada
Jacques Rinchard	Native Species and Habitat	Brockport
Pradeep Goel	Nutrient Loading	Ontario Ministry of the Environment, Conservation and Parks
Evie Brahmstedt	Contaminants and Pathogens	Clarkson University

Evan Rundle	Coastal Wetlands and Connecting Channels	St. Lawrence River Institute
Alice Dove	Contaminants and Pathogens	Environment and Climate Change Canada
Patrick Boynton	Coastal Wetlands and Connecting Channels	Cornell Biological Field Station
Jody McKenna	Nutrient Loading	Environment and Climate Change Canada
Taylor Brown	Native Species and Habitat	Cornell University
Monir Hossain	Primary Production	DFO
Annie Scofield	Native Species and Habitat	EPA GLNPO
Luca Cargnelli	Nutrient Loading	Environment and Climate Change Canada