Final- Approved February 22, 2018

Memorandum

From: Lake Erie Partnership Management Committee
To: Annex 10 co-leads for submission to CSMI Task Team
Re: Research and Monitoring Priorities for the CSMI Field Year on Lake Erie 2019

Prepared by: Lake Erie Partnership Working Group

This memo communicates the Lake Erie Partnership Research and Monitoring Priorities for the CSMI Field Year on Lake Erie 2019 along with background on the current knowledge of the state of Lake Erie and the process used to establish these priorities The Lake Erie Partnership looks forward to working with the Annex 10 CSMI Task Team during 2018 to develop more specific research and monitoring plans to fulfill these science priorities as resources for the 2019 field year allow. A Lake Erie Lakewide Action and Management Plan will be developed in 2018 and its contents will include the finalized science and monitoring priorities.

Background

The binational CSMI involves an intensive, management-related, scientific examination of each Great Lake on a five-year rotational basis. As per Lakewide Management commitments, the Lake Erie Partnership coordinates efforts and engages stakeholders and the public to identify science and monitoring priorities in preparation for each year of intensive study. Science and monitoring results are used to assess and report on the state of the lake in Annual Reports and Lakewide Action and Management Plans. For Lake Erie, the last year of intensive science took place in 2014.

Lake Erie is responding to high levels of nutrients and other recent changes in the ecosystem. Data collected by Environment and Climate Change Canada and U.S. Environmental Protection Agency show that, while phosphorus concentrations in the Lake can be highly variable, the concentrations in the western and central basins consistently exceed the desired levels for a healthy ecosystem. Annual estimates of loading from tributaries and other sources indicate that the total annual amount of phosphorus entering the Lake varies significantly each year due to the corresponding variability in nonpoint runoff. Coinciding with the resurgence of algal blooms in the mid to late 1990s and shifting bloom dominance to potentially toxin producing *Microcystis* sp., there has been a significant increase in the proportion of the phosphorus load to Lake Erie that is in dissolved, as opposed to particulate, form. Dissolved phosphorus is more easily taken up by algae and contributes to increased algal growth.

Compounding this problem, the ecosystem has changed due to the spread of invasive zebra and quagga mussels that became established in the 1990s. Invasive mussels retain and recycle nutrients in nearshore areas through their filtering and excretion activities. In addition, the increased water clarity results in greater penetration of solar energy for chlorophyll production and warming of the water column, allowing algae to grow at greater depths. These alterations to water clarity and in-lake nutrient cycling are resulting in greater nuisance algal growth in the nearshore regions, closer to where humans interact with the Lake.

The binational CSMI has been instrumental in supporting adaptive management in Lake Erie under these changing conditions. The Lake Erie Partnership continues to need information on the status of nutrient and contaminant loading and cycling, the lower food web, and the health of the fishery. For 2019, consideration was given to ensuring that priorities related to eutrophication align with the science and monitoring needs of the state, provincial and federal agencies implementing Domestic Action Plans or other efforts to reduce and understand Phosphorus loads under the GLWQWA Nutrients Annex, including the connection between nutrient loadings and excessive algal production that negatively impacts recreational opportunities. Proposed priorities also include Lake Erie's connecting river systems, the St. Clair Detroit River System and Upper Niagara River[1].

As part of the reporting phase of the last Cooperative Science and Monitoring Initiative (CSMI) cycle, the Lake Erie Millennium Network hosted the State of Lake Erie conference in Windsor, Ontario on February 21-23, 2017 at which key science findings were shared and discussions of the prevailing needs for the 2019 intensive field year began. The conference was planned in conjunction with the Lake Erie Partnership and included reporting out on the 2014 Lake Erie CSMI field year efforts. On October 11-12, 2017 a Lake Erie Science Priorities workshop was held at Maumee Bay State Park in Ohio, again hosted by the LEMN in partnership with the Lake Erie Partnership. Planning for the workshop included a one- day prevailing issues workshop in August which identified main themes for developing science priorities. The Lake Erie Partnership used the information shared at these meetings to develop the summary of current understanding and the priorities listed below.

<u>Current Understanding of Lake Erie Nutrient Loading and Cycling</u>

Excessive algal growth in Lake Erie poses significant threats to the ecosystem and human health of a waterbody that provides drinking water for over 11 million people in the U.S. and Canada. Viewable from space, algae can persist for weeks during summer as blooms are carried by winds and currents eastward through the lake. Recent years have seen record-setting algal blooms as well as "dead zones" – oxygen depleted areas created when algae die and decompose. These events negatively impact the lake's critical $12.9 billion tourism industry and world class fishery.

The U.S.-Canada Great Lakes Water Quality Agreement sets goals and timeframes to address excess algal growth in Lake Erie through nutrient management. New phosphorus loading targets for the western and central basins were established in 2016. The need to control phosphorus is not a new problem; in fact, algal blooms in the 1970s were a major driver of the first Great Lakes Water Quality Agreement. Lake Erie is susceptible to excessive algal growth, in part, due to its physical characteristics – as the smallest of the Great Lakes by volume, the shallowest and southernmost, Lake Erie waters are the warmest and the most biologically productive.

Lake Erie also receives the highest loads of phosphorus of all the Great Lakes. Lake Erie is exposed to the greatest stress from urbanization, industrialization and agriculture. Lake Erie surpasses all the other Great Lakes in the amount of effluent received from sewage treatment plants and is also most subjected to sediment loading due to the nature of the underlying geology and land use.

Other factors contributing to the resurgence of algae and the new predominance of harmful species include the loss of wetlands and riparian vegetation that once trapped nutrients. Increasing temperature in recent years is creating a longer growing season for algae, and more frequent high-intensity spring storms are delivering nutrients at a critical time when they can promote the intensity and duration of summer algal blooms. While many factors contribute to algal growth, controlling phosphorus concentrations and loads remain the best management strategy to address these problems.

Phosphorus is the growth-limiting nutrient in freshwater and the primary focus of the domestic action plans. While many other nutrients are present in water, such as nitrogen, silica, carbon, and even trace metals, these nutrients are considered to be only secondarily or seasonally limiting in Lake Erie. There is increasing evidence that both N and P should be considered as part of a more comprehensive nutrient

[1] The priorities identified for the Upper Niagara River pertain to fisheries/habitat management needs.

management strategy to control harmful algal blooms. For instance, emerging research indicates that phosphorus reduction in the absence of nitrogen reduction would not reduce the toxicity of algal blooms. In other words, while *Microcystis* blooms would be smaller in spatial extent, they could continue to be toxic and possibly toxic longer through the season.

Science Priorities:

1. Watershed-based priorities to address Eutrophication

These information needs are consistent with needs identified during development of the Domestic Action Plans; understanding of these priorities would help target implementation where it will be most effective at achieving Annex 4 targets.

- **How do impacts of BMP implementation scale from edge-of-field to stream sub-basin to watershed? What factors control, and will allow us to forecast/predict, this scaling?**

  Significance: Will give a better understanding of effectiveness of different actions and allow more effective targeting of actions. Modeling of large watershed areas is useful in understanding the relationship of broad scale conditions such as rainfall to the total watershed loading. Edge-of-field research investigates the relationship between existing row crop agricultural practices (for example, planting, tilling and fertilizing) and pollutant reduction BMPs. The broad scale watershed modeling efforts have shown that implementation levels will have to increase basin wide to achieve the 40% load reduction target. For example, the NRCS CEAP report identified that 95% of cropland acres would have to be affected by a suite of BMPs to achieve a 43% reduction in total phosphorus (USDS NRCS, 2016). Without the links between the broad watershed and finer field scale it is difficult to understand the impact that specific types, amounts, and locations of management practices applied on individual fields have on total watershed loading.

- **How important is Residual Soil Phosphorus on agricultural land for feeding crops and how long does it last in soil?**

  Significance: Current fertility recommendations indicate at what soil test level no fertilizer addition is required from an agronomic perspective. There are limited recommendations in place for draw down of high soil test Phosphorus levels. There are known critical levels of soil nutrients that will maintain crop productivity. It would be advantageous to have improved soil tests that could determine the amount of P that each soil can retain and the total amount of P available to lose so that the quantity and timeframe that agricultural soil legacy P could potentially contribute to P loads to tributaries could be better determined.

- **What is the impact of legacy Phosphorus on water quality?**

  Significance: Will provide understanding of the significance of legacy Phosphorus as a source of Phosphorus to Lake Erie. The build-up of legacy P on agricultural land should be segregated from the topic of accumulation of legacy P in floodplain, river or lakebed sediments as the causes, management and contributions are likely very different. Incorporating currently stored P values on agricultural land (e.g. cumulative P component from IROWC-P model) into existing watershed *models would be a first step in determining the role and impact of legacy P on current water quality.*

- **How much of an impact does Phosphorus bioavailability and transport at the field scale impact the overall Phosphorus mass budget?**

  Significance: Effectively implementing best management practices requires an understanding of the fates and flows of nutrients. Knowledge about the nutrient budgets will enable more effective deployment of BMPs. Particulate phosphorus is known as a relatively well conserved component of runoff and can be readily tracked in time series using simple water sampling strategies as it is transported downriver. Dissolved Reactive Phosphorus has been identified as a key driver of the increase in Harmful Algal Blooms but it is so reactive that it is much more difficult to track when and how exactly it is moving through the streams and rivers out to the lake and how long it takes to get there. Better knowledge of the fate and transport of phosphorus in all its forms will enable more efficient placement of BMPs and a better understanding of how to monitor progress towards the targets and how long it will take to reach them.

  Notes: researchers need access to soil P test results to input into models; models should include SCDRS watershed

2. In-lake priorities to address Eutrophication

- **What are the biotic and abiotic factors that influence phytoplankton community composition, succession and nutrient retention in the three basins of Lake Erie?**
  - **Are cyanobacteria transported from Lake St. Clair and the Maumee River to the Western Basin of Lake Erie (determine role of local cyanobacteria production vs transport from upstream)**
  - **What influence does the winter, spring, and early summer succession of phytoplankton have on the timing and community composition of summer cyanobacteria blooms?**
  - **Are the existing hydrodynamic models sufficiently and accurately predicting water movement and other processes, including sediment dynamics, and can they be used to explain the observed variability in Lake Erie's biology?**
  - **What is the projected impact of nutrient reduction in the Western Basin on the primary and secondary productivity of the Eastern Basin?**
  - **What is the impact of herbicides on plankton communities within Lake Erie /SCDRS, and does/could this result in dominance by undesirable species (cyanobacteria)?**

  Significance: Lake Erie is a complex system that hosts many different mass proliferations of phytoplankton, some beneficial (diatoms) and some that are harmful. Currently, much of the winter ecology as well as the spring and early summer succession of phytoplankton are not well understood but could be important in order to understand the flow of nutrients through all three basins as well as the transfer of nutrients between the water column and the benthos, which may be important for determining the timing and community composition of summer cyanobacteria blooms. All predictive models for HABs in Lake Erie rely on hydrodynamic models, so knowledge of their accuracy is critical for determining the reliability of early *warning/predictive capabilities. Hydrodynamic models are also needed for predictive modeling of hypoxic zone formation and movement (*linkage with hypoxia priorities)*

- **What is the spatiotemporal availability of Phosphorus and Nitrogen in Lake Erie and how does it influence the onset and scale of harmful algal blooms?**
    - **How are the total phosphorus and nitrogen budgets partitioned among the various compartments in the water column and benthos throughout the year in Lake Erie?**
    - **What role does timing of nutrient delivery to Lake Erie have on cyanobacteria blooms that occur in the summer?**
    - **What is the status of Total and Soluble Reactive Phosphorus in the St. Clair Detroit River System (SCDRS) tributary mouths (Detroit, Thames, Maumee, Leamington Tributaries, River Raisin)?**

  Significance: Both phosphorus and nitrogen are delivered to Lake Erie in spring and early summer. However, cyanobacteria blooms do not form until mid- to late summer. As such, there are several months during which nutrients are present in the lake, but it is unclear how these compounds are being used/transformed. A better understanding of this dynamic may aid in understanding bloom initiation as well as phytoplankton succession. There is a need to fill data gaps in eutrophication status at the mouths of the SCDRS tributaries.

- **What are the biotic and abiotic influences on toxin production, concentration, distribution and fate in Lake Erie?**
  Significance: Bloom toxicity is the foremost threat to human health during cyanobacteria bloom events. Currently, we do not adequately understand the factors controlling toxin production, concentration, distribution and fate. As such, we cannot accurately or confidently model/forecast toxins associated with blooms.

- **What is the spatiotemporal distribution of *Cladophora* in Lake Erie and temporal shifts in epiphytes on *Cladophora*? What are the drivers of summer *Cladophora* production? What is the role of benthic and epiphytic algae in phosphorus and nitrogen retention?**

  Significance: Cladophora is widespread throughout Lake Erie and select areas of the Great Lakes and has been implicated in the occurrence of the bacterium that causes avian botulism, as well as other pathogens that may contribute to degradation of water quality in recreational areas (e.g., at bathing beaches). Better understanding of the spatiotemporal distribution and ecology of Cladophora and its associated flora, especially epiphytic diatoms and heterotrophic bacteria is needed. Data will inform Phosphorus target setting for Eastern Basin.

- **What is the spatiotemporal extent of hypoxia in the Sandusky sub-basin, northwestern basin (north of the islands), and Lake Erie central basin?**

  Significance: Lake Erie hosts the second largest hypoxic zone in the nation. However, there is not currently a predictive model that can forecast hypoxic zone formation and movement, which could compromise drinking water intakes, as well as impact fish community stock assessments.

- **The 2019 CSMI field year should be used as an opportunity to collect additional data to groundtruth satellites and models to determine that they are accurately estimating the 3-D distribution of plankton and cyanobacteria biomass in Lake Erie**

Significance: Remote sensing is an important component in predictive models of plankton and cyanobacteria biomass. However, we know that these models are not 100% accurate, nor will they ever be; however, data collected by groundtruthing in 2019 can lead to a better understanding of the three-dimensional movement of blooms. These data will aid in improving models that serve as critical management tools for water managers in the western basin.

Current Understanding of the Lake Erie Food Web (as based on Markham and Knight 2017, with some modifications)

Variation in physical features and biological productivity within and among the basins of Lake Erie affects fish ecology and community diversity, stock structure, behavior (movements), and ultimately how fisheries are managed (Ryan et al. 2003; Tyson et al. 2009). Generally, mesotrophic areas of Lake Erie support cool-water fish communities of walleye, yellow perch, smallmouth bass, northern pike, and muskellunge, with a soft-rayed shiner forage base. *Hexagenia* mayfly populations are sentinels of mesotrophic conditions in Lake Erie (Edwards and Ryder 1990). The arrival of *Dreissena* spp. (quagga and zebra mussels) in 1987 and their subsequent expansion throughout the lake brought further changes to the Lake Erie ecosystem, including increases in water clarity, declines in chlorophyll a, and the alteration of rocky-bottom areas used by fish for spawning. Phytoplankton biomass declined 68-86% (Makarewicz 1993; Johannsson and Millard 1998), primary production declined 22-55% (Millard et al. 1999), and energy flow shifted from the pelagic to the benthic food web (Ryan et al. 2003). By the late 1980s, the combined effects of TP load management and *Dreissena* spp. proliferation caused the western basin to return to a mesotrophic state while the central basin became oligotrophic (Bertram 1993), which was unfavorable for percids (Ryan et al. 2003). The eastern basin became ultra-oligotrophic periodically in the 1990s, adversely affecting yellow perch (Charlton 1994; MacDougall et al. 2001) but benefiting lake whitefish and burbot. *Dreissena* spp. biomass generally stabilized in most areas of Lake Erie by 2002 (Patterson et al. 2005) perhaps because of predation by native fishes (freshwater drum and yellow perch) and invasive round goby.

Eutrophic-area fish communities are characterized by black basses, white perch, white bass, channel catfish, freshwater drum, and a prey base dominated by gizzard shad and age-0 spiny-rayed fishes (yellow perch, white perch, white bass, and freshwater drum). Oligotrophic areas sustain cold-water salmonids (lake trout, lake whitefish, steelhead, cisco) and burbot with a forage-fish community dominated by naturalized rainbow smelt and soft-rayed shiners. Deep-water amphipods Diporeia spp., an indicator of healthy oligotrophic food webs, are no longer found in Lake Erie (Barbiero et al. 2011). Lake sturgeon occupy nearshore areas across the lake but remain rare. Nearshore fish communities tend to organize around dynamic coastal habitats, such as wetlands, bays, rivers, and estuaries, whereas offshore fish communities are strongly influenced by thermal stratification, dissolved oxygen levels, bottom structure (reefs), and circulation patterns (gyres).

Hypoxia in Lake Erie can affect food webs and fisheries. Roberts et al. (2009) determined that anoxia and hypoxia caused short-term changes in the vertical distribution of yellow perch and rainbow smelt, reducing their food consumption, condition, and growth (smelt only). Hypoxia may affect fishery catch rates by altering the amount of available habitat and, therefore, the distribution or density of targeted species (Kraus et al. 2015).

Other factors that have affected the capacity of the Lake Erie ecosystem to support desired fisheries include manageable factors (habitat quality/quantity and harvest) and unmanageable factors (ice cover, climate etc.), both of which contributed to the productivity of native fish stocks (Ryan et al. 2003; Tyson et al. 2009). While harvest for most high focus species is regulated by agencies, and likely not a factor impacting productivity of native fish stocks, spawning and nursery habitats in rivers, estuaries, wetlands, and nearshore coastal areas are most affected by human activities. Lost productivity of stocks of lake trout, walleye, cisco, lake whitefish, and lake sturgeon are attributed in large part to declining recruitment due to degradation of critical habitats for reproduction. Understanding the distribution of critical habitats for these species, how they contribute to overall fisheries production, and how manageable and unmanageable factors affect this production are critical within the context of the changing Lake Erie food web. Lastly, information on the abundance of key aquatic invasive species is critical to understanding current and potential impacts of these species on production potential for Lake Erie fishes.

3. Priorities to address the Changing Food Web

- **What is the production of various habitats and stocks to the overall fisheries in the St. Clair Detroit River System (SCDRS), Lake Erie and Upper Niagara River?**
    - **What areas of SCDRS and Lake Erie and Upper Niagara River are important for fish production of species of interest?**
    - **What actions could be taken to enhance production/increase stability?**
    - **Continue the recreational creel survey effort in the SCDRS and implement/align binationally.**

  Significance: Addressing these priorities allows for better identification of habitat/stock restoration opportunities in a recruitment-driven species complex.

- **What habitat components are limiting production for important species and stocks of fish?**
    - **How does loss of habitat (rivers/coastal wetland/nearshore/offshore) equate to losses in fish production potential?**

  Significance: Addressing this priority advances the quantification of distribution of fish habitat in Lake Erie, allows for development of more geographically precise fish production habitat models to guide habitat/stock restoration opportunities; improved substrate and vegetation mapping, particularly in priority management areas (the nearshore, rivermouth plumes, reefs, wetlands) supports a better understanding of the extent of both habitat and fishes. Offshore, hypoxia-based habitat compression links fish movements and population dynamics with water quality goals to reduce the extent and severity of hypoxia.

    - **How effective are current habitat restoration efforts, such as the SCDRS and Niagara River natural habitat (i.e. reefs, islands, and wetlands) restorations, at producing fishes?**

  Significance: This priority can inform targeted implementation of conservation/rehabilitation strategies by answering questions regarding scale and what habitat conservation/rehabilitation strategies for fish are most successful.

- **How do environmental variables (i.e. ice cover, warmer temperatures, increased water clarity, hypoxia) and other non-manageable factors impact fish recruitment in SCDRS, Lake Erie and Upper Niagara River?**

Significance: Allows for better understanding of recruitment variability which will inform fisheries assessment programs and management. This understanding would allow for management agencies to explore harvest strategies that are robust to environmental regime changes.

- **What are the effects of HABs on SCDRS and Lake Erie age-0 fishes?**

Significance: Addressing this priority allows for an improved understanding of the potential impacts of HABs on recruitment variability, which will inform fisheries assessment programs and management.

- **Can GLATOS be leveraged effectively to determine variability in behavior? Does it need to be expanded to increase coverage in rivers and include more fine-scale coverage in the coastal areas?**

Significance: Addressing this priority advances the quantification of fish and habitat distribution in Lake Erie, allows for development of more geographically precise fish production habitat models to guide habitat/stock restoration opportunities. It also allows for a better identification of habitat/stock restoration opportunities in a recruitment-driven species complex.

- **What are the population levels of invasive species such as Grass Carp and dreissenid mussels?**

Significance: These data are needed for model estimation of current impacts, understanding where each species falls on its invasion curve, and to inform management options.

Current Understanding of Contaminant Loading and Cycling in Lake Erie

Progress at restoring Areas of Concern and remediating other contaminated sites continues to reduce chemical loadings to the lake. Long-term monitoring results of contaminant concentrations in environmental media (air, water, sediment, fish and wildlife) show decreasing trends. However, fish consumption advisories continue to be required to protect human health. Contaminants of emerging concern continue to warrant surveillance due to their wide distribution and high persistence in the environment.

4. Priorities to address Contaminants

- **Lakewide monitoring of environmental contaminants in media (air, water, sediment, fish and wildlife) to examine exposure, distribution and bioaccumulation trends**

  Significance: These data are needed to track progress of restoration, to better understand Lake Erie's contaminant load to Niagara River and Lake Ontario, and inform environmental protection, natural resource management, and human health programs. In the SCDRE, there is a need to understand prevalence and severity of contamination in fishes compared to reference locations.

- **Lakewide efforts to assess the transport, fate and effects of mercury and chemicals of emerging concern, including Per- and Polyfluoroalkyl Substances (PFAS).**
  Significance: There is a need to determine the presence and potential accumulation of new contaminants (replacements) for managed chemicals. Data are needed to determine residence time, persistence, occurrence, distribution and fate uncertainties.

- **Are microplastics, macroplastics, marine litter, nanoparticles significant vectors for inter/intra basin transport of contaminants and bioaccumulation?**

  Significance: It is important to determine sorptive capacity and associated contaminant interaction as well as physical/toxicological effects. We need to determine the contribution to contaminant distribution/bioaccumulation from plastics relative to that from contaminated solids/sediments.

Current Understanding of Beach Health in Lake Erie

The *2017 State of the Great Lakes* Report sub-indicator for Beach Advisories was assessed as "poor, deteriorating" for Lake Erie. U.S. State and Canadian county health unit bathing beach and recreational waters monitoring programs are designed to protect the bathing public from risks of contracting waterborne diseases from exposure to contaminated waters or public health exposure to cyanotoxins. Rapid detection methods and modeling efforts are being used at several Great Lakes locations to provide the public with real time beach water quality information. Identification of significant predictors of water quality at beaches will improve current models and Nowcasts for Lake Erie beaches.

5. Priorities to address Beach Closings:

- **Monitor pathogen and toxin concentrations at tributaries to Lake Erie and track storm event plume water quality**

  Significance: Data will improve model and Nowcast predictions of water quality at beaches.