Towards a Monitoring Program for Microplastics in the Laurentian Great Lakes

IJC Microplastics Workshop #1 – Developing a Monitoring Framework

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Workshop Report

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1 Background

Plastic debris is accumulating in aquatic and terrestrial systems worldwide, including within the Laurentian Great Lakes. In 2016, the International Joint Commission (IJC) conducted a project on microplastics in the Great Lakes, which included a workshop of experts and a report (published in 2017) summarizing its presentations, discussions, and recommendations. Among other recommendations, the report identified the need for ecological and human health risk assessment and monitoring frameworks (with guidelines for harmonized and/or standardized methods) specific to the Great Lakes to improve our understanding of the issue and inform policy and mitigation efforts.

As a follow up to the 2017 report, in 2022 the IJC established a Microplastics Monitoring and Risk Assessment Working Group. The IJC Working Group consists of subject matter experts, working in a voluntary capacity, helping to develop recommendations that will inform microplastics management for the IJC's Science Advisory Board (SAB). The SAB, in turn, will consider these recommendations when advising the IJC. With the Working Group's guidance, the IJC has launched this project to synthesize our understanding of microplastics in the Great Lakes, including their prevalence and the potential for ecological impacts, and to develop recommendations for policy actions including monitoring and ecological risk assessment frameworks that can help standardize microplastics research across the Great Lakes. The overarching objectives of this project are to:

1. Synthesize recent advances and knowledge in plastics science relevant to the Great Lakes through events that bring together researchers to share the latest information on plastics.
2. Develop a framework for monitoring plastic pollution in the Great Lakes that would support its use as a sub-indicator for State of the Great Lakes reporting under Annex 10 of the Great Lakes Water Quality Agreement (GLWQA).
3. Develop a risk assessment framework for plastic pollution in the Great Lakes focused on ecological effects that would contextualize the results of a monitoring program.

The current focus of the IJC Working Group is on environmental monitoring and ecotoxicological effects, and it is hoped that future groups will build on this work to focus on human exposure and risk.

Activities that have been conducted related to Objective 1 include a synthesis of studies that report on the prevalence and toxicity of microplastics in the Great Lakes; the organization of a conference session on microplastics and a summary of the session proceedings; and updating a database[1] of ecotoxicological studies on the effects of microplastics on marine and freshwater biota. As a follow-up to these activities, the IJC Working Group organized this workshop (Workshop #1) to solicit expert feedback on the outcomes of Objective 1 activities, including recommendations and best practices that would support the development of a microplastics monitoring framework in the Great Lakes (Objective 2). This report summarizes Workshop #1 proceedings and key outcomes. At a later date, the IJC Working Group plans to organize a second workshop (Workshop #2) to solicit feedback from experts to support the development of a risk assessment framework for plastic pollution in the Great Lakes (Objective 3).

[1] ToMEx Is an open-source database and accompanying R Shiny web application that enables users to search and visualize microplastics toxicity data as well as model ecosystem-specific risks pertaining to aquatic organisms.

2 Workshop #1 Objectives, Overview, and Proceedings

Workshop #1 Objectives and Overview

This workshop was organized to support the IJC Working Group in the development of Objective 2 (develop a framework for monitoring plastic pollution in the Great Lakes). The specific objectives of the workshop were to:

1. Develop a harmonized monitoring framework for sampling microplastics in different matrices - ambient water (lakes and tributaries), sediment, shorelines, and biota – and relevant to different pathways (e.g., wastewater treatment plants (WWTPs), runoff).
   a. Methods for sampling each matrix
   b. Methods for quality assurance and quality control (QA/QC) in the field
   c. Reporting requirements
2. Advise on how monitoring programs should be designed to best capture spatial or temporal trends or to identify microplastic sources.
3. Advise on where microplastics may fit into existing Great Lakes monitoring frameworks and programs to help facilitate action.

Day 1 of the workshop began with welcome and introductory comments by the hosts, organizers, and facilitators. The workshop team, composed of contractors, IJC staff, and the Working Group Co-chairs, outlined the objectives and approach and reviewed materials sent to the group in advance. This included a synthesis report describing the results of a Great Lakes-focused microplastics literature review. Background information on project progress to date was provided by the contractor team, followed by a morning round of breakout groups to discuss microplastics sampling design in different media (ambient lake water, ambient tributary water, sediment, aquatic biota, and shoreline debris). After a lunch break and regroup of the morning discussions, another round of breakout group discussions occurred. These discussions focused on microplastics sampling design to capture spatial and temporal variations, as well as different types of sources and transport pathways.

Day 2 of the workshop began with a recap of Day 1 activities and a review of workshop objectives. The opening session was followed by "Lightning Talk" presentations regarding relevant current work on microplastics monitoring from other regions in the U.S. (Chesapeake Bay and Southern California) and on existing Great Lakes contaminant monitoring programs from different government agencies and ministries operating in the region. These talks were followed by a question-and-answer session.

Overarching Workshop Themes

The following themes emerged as overarching topics regarding microplastics monitoring expressed by participants. They were brought up multiple times during the workshop in various contexts.

- Multiple sampling methods may need to be combined to achieve monitoring goals.
  - The monitoring method used impacts the results and relevant interpretation—one method cannot fully characterize microplastic contamination in a way that is relevant to different monitoring and research objectives.
  - Discussion of the potential use of a tiered approach consisting of primary and complementary sampling protocols. For example, surface trawl and grab sampling can be

used primarily to evaluate contamination extent and locate hotspots. Sediment traps can be used to look at flux.

- Emphasis of importance of QA/QC.
    - The volume of the sample should be determined by the Limit of Quantitation (LOQ) based on background contamination and the amount of microplastics within a monitoring location and/or matrix.
    - Use field blanks to evaluate background contamination and matrix spikes to quantify the recovery of methodology, respectively.
    - Minimize source contamination with procedures such as using non-plastic equipment and filtered water.
- Standardized data and reporting requirements.
    - Information such as equipment dimensions and sampling metadata (date, time, weather conditions, water temperature, sampling location and depth, etc.) is very important for modeling and unit conversion.
- Accessibility and safety of sampling.
    - Safety during sampling should be prioritized (e.g., sampling rivers during storm events).
- Use existing infrastructure and monitoring programs where possible.
- Barriers of using private labs for analysis.
    - Currently most programs use academic labs for analysis. Few for-profit service labs currently offer fee-for-service enumeration of microplastics.

Day 1 Proceedings

Introductory Sessions

The workshop was opened by Heather Stirratt, the Director of IJC's Great Lakes Regional Office, who welcomed workshop participants and stressed the importance of harmonizing approaches for microplastics management. She reminded those present that IJC has been working to address microplastic pollution in the Great Lakes for many years, including a 2017 report on this topic. She noted that there have been many initiatives to combat microplastics and plastic pollution in recent years and stressed the importance of harmonizing Great Lakes initiatives with those developments.

The Working Group Co-chairs (see agenda in Appendix A for names) shared their thoughts and perspectives on the need for harmonization in microplastics sampling methods, both across the Great Lakes and between the Great Lakes and other regional microplastics monitoring efforts (e.g., California, Chesapeake Bay). They also provided an overview of the GLWQA, the IJC's advisory role, and how the present project fits within that role, including any recommendations that may ultimately be developed. The Co-chairs also provided a brief discussion on California legislation recently passed to support efforts to estimate the ecological risk of microplastics and work already performed in this area for the Southern California Coastal Water Resources Project (SCCWRP) and Environment and Climate Change Canada (ECCC). Their remarks served to stimulate thought and frame discussions during the subsequent breakout groups. All workshop slides can be downloaded here.

Next, the contractor team provided a summary of the literature review on microplastics monitoring in the Great Lakes that was recently completed under this project. Key points from the literature review that were highlighted during the workshop include:

- There is an accelerating number of microplastics publications that sample and measure microplastics in the Great Lakes. The field is rapidly evolving. However, it is important to note that most of these studies (and the associated data) are being driven by academic research. There is little monitoring of microplastics being done by government agencies in the Great Lakes on a consistent basis.
- The five Great Lakes (and their connecting waters and tributaries) are not all equally well-studied. Generally, more monitoring of microplastics has been done in Lakes Ontario, Michigan, and Erie than Lakes Superior and Huron.
- Different sampling methods are not all equally effective in capturing different shapes and size ranges of microplastics. For example, trawling samples much larger volumes of water, but does not collect particles smaller than the net mesh size. Conversely, grab samples may capture a larger particle size range, but cannot sample as large a volume as trawls. Therefore, the choice of sampling method is key and should be informed by study goals. Additionally, plastic polymer types have different physical properties (e.g., density) and are also often correlated with shape, and therefore the choice of sampling method can influence the polymer types and shapes that are identified and reported.
- Studies focusing on biota were the least common of all the matrices reviewed. Studies focusing on microplastics in surface water were the most common.
- Microplastic concentrations vary across the five Great Lakes. Based on the data available, Lakes Ontario and Michigan generally appear to have the highest concentrations of microplastics in ambient lake water and sediment, followed by Lakes Erie, Superior, and Huron.

Following the contractor team's presentation, a presentation by SCCWRP summarized efforts underway in the State of California to develop a statewide microplastics monitoring framework. Key points included:

- California has passed two bills that prioritize the need to better understand microplastics in drinking water (SB 1422) and coastal habitats (SB 1263). The current focus is on developing standard monitoring methods that can inform exposure and risk assessments.
- SCCWRP conducted an international inter-laboratory comparison study that assessed the accuracy of different lab methods when analyzing "spiked" samples of drinking water, ambient (lake or tributary) water, sediment, and biota (tissue). The results of the study led to standard methods for the analysis of drinking water samples for both Raman and Infrared spectroscopy that was adopted by the state. Standard methods for ambient water, sediment, and biota are currently being developed. The study also provided some recommendations for further research.
- SCCWRP also organized a workshop to develop harmonized sample collection methods for surface water, storm water, sediment, and biota in coastal waters. From this workshop, comprehensive methods for sediment, surface water, and biota are being developed. Workshop participants recommended a study to evaluate methods for stormwater sampling and, once implemented, will provide recommendations for harmonized methods. The last step is formal adoption of these monitoring methods by the State of California.
- SCCWRP also organized a workshop to develop a microplastic risk assessment and management framework for aquatic ecosystems and human health. This will inform the work done under Objective 3 for this working group.

Breakout Session 1

Following the introductory talks, workshop participants were divided into five breakout groups (numbered 1 through 5). Each group was assigned one matrix and tasked with discussing sample design considerations for that matrix. The matrices included were the following:

1. Ambient Lake Water
2. Ambient Tributary Water
3. Sediment
4. Aquatic Biota
5. Shoreline Debris

The groups were tasked with discussing sampling methods, QA/QC recommendations, and data reporting requirements for each matrix. The groups were asked to keep the following approaches in mind:

- Operational approach—this is not a research project design (although data generated can also be used for research)
- Frequency of sampling: e.g., annually in summer? More intensive 5-year cycle by lake?
- Realistic monitoring costs including labor, equipment, and sample preparation
- Minimum number and types of sites/samples for meaningful results
- Simplicity of implementation, leveraging of existing programs and assets, consistency across programs, and training needs
- Relevance of results to microplastics-source control policy development and refinement

Priorities and key themes identified for each group are listed below. The breakout groups used flipcharts to document their ideas and discussion. Screenshots of the flipcharts can be found here, along with more detailed notes. At the conclusion of the discussions, each breakout group reported back to the whole group. These reports are summarized in Table 1 below. Note that some groups also identified topics that are not directly relevant to microplastics monitoring methods but could form the basis for future research. Where applicable, these topics are listed within the following sections.

Table 1. Breakout Session 1 Discussion Summary

Matrix	Sampling Methods & Techniques	Other Considerations	QA/QC	Reporting Requirements
Ambient Lake Water	• Use complimentary methods (trawl + depth-integrated/grab).	• Use existing platforms. • Metal pump impellers might damage particles. • The size and material of the inlet tube may matter.	• 10% sample blanks and duplicates. • Isopropyl alcohol for storage. • Field spikes to measure recovery.	• Should be enough information to convert between units. • Other metadata, equipment, date, time, weather, etc.
Ambient Tributary Water	• Depth-integrated pumping. • 30-L sample volume. • 50-µm sieve size. • Minimum 6-mm tube size. • Collect sediment or install trap as supplement.	• Horizontal and vertical profile measurements. • Base flow measurements. • Locations near monitoring stations.	• 10% sample blanks and duplicates. • Field spikes to measure recovery.	• Report substrate type, conductivity, turbidity, and temperature if possible. • Qualitative reporting of debris mats.

Matrix	Sampling Methods & Techniques	Other Considerations	QA/QC	Reporting Requirements
Sediment	• Traps for loading rates and fluxes. Will be more responsive to source reduction interventions. • Cores or grab samples for benthos exposure levels. • Sampling needs to be standardized in terms of sediment depth sampled and whether the sediment-water interface is collected or not	• Co-locate traps with existing infrastructure. • Use existing platforms for cores and grabs.	• Use field blanks to measure ambient contamination. • Sampling needs to account for roots and rocks.	• Covariates for traps include deployment duration, water depth, temperature, water currents, season, and date. • Reporting units should include number of microplastic particles per unit of sediment surface area, sediment volume, and sediment dry-mass to account for differences in bulk density among locations and habitat types.
Aquatic Biota	• Sample bivalves, small-bodied fish (benthic & pelagic), large-bodied fish, water birds. • Use existing methods, materials, and QA/QC for field sampling and sample preservation where applicable. • Water bird sampling opportunistic as part of ongoing programs.	• Gut sampling indicates shorter-term exposures. • Focus on localized or sessile species for stronger links to source control. • Focus on larger species including birds for ecological and human health risks. • For smaller species, sample whole animals. • For larger species, collect guts and muscle tissues.	• Use field blanks to measure ambient contamination. • Minimize use of plastic equipment. • Euthanize animals quickly. • Power analysis to determine mass of organism required for reliable sample.	• Site photographs and information such as GPS.
Shoreline Debris	• Quadrats with subsamples combined to form a composite. • Quadrats may be placed along transect line. • 53-µm to 5-mm sieves. • Use stainless steel trowel to collect top 5 cm.	• Focus on shoreline or back beach, depending on program goals. • April – October sampling window. • Comparison between beaches over comparison of locations within a beach.	• Ambient contamination less important. • Matrix spike to determine recovery rates.	• Digital and paper records. • Site photograph and GPS coordinates.

Additional details from each of the breakout discussions are provided below.

Ambient Lake Water

- Sampling Method: Needs to consider the platforms available, monitoring objectives, and data quality objectives. Combination of trawl and pump/grab can provide complementary information on particle morphologies and sizes and provide surface and depth coverage.

  - The monitoring method used impacts the results. Use a combination of methods to cover monitoring objectives and provide complementary information on particle sizes, depths, morphology, etc. Potentially use a tiered approach. Some methods may be done more frequently as "tier one" and supplemented by a "tier two" method that is done less frequently. Determined based on ease of sampling and analysis.
  - Consider using a combination of trawling to cover the surface and depth-integrated pumping to sample the water column. Further research may be needed to characterize the differences in monitoring results (i.e., particle counts and characteristics) using trawling and bulk water sampling at the same location, including better understanding of the distribution of microplastic particles at the water surface and throughout the column.
    - Trawls give a better idea of distribution of particle types and sizes over an area and are likely more representative of the overall level of contamination. Mesh sizes to be kept standard with field, i.e., 300 µm. We recommend trawling be considered as a "tier one" method, to remain consistent with much of the historic monitoring that has been done in the Great Lakes basin.
    - Pumping or grab sampling over an integrated depth to cover water column and provide information that is missed by trawls. Potentially sample at bottom and thermocline to harmonize with general water quality sampling. Potential issues with pumping include clogging of the filter and access to platforms from which to sample. We recommend pumping be considered as a "tier two" method, to be used when information on microplastic particles < 300 µm is required.
    - Minimum filter mesh sizes for volume reduced sampling should align with the sampling method, i.e., around 300 µm for trawls and 50 µm for pumping.
- QA/QC Recommendations
  - Sample volume should be determined by the level of contamination in blanks and amount of microplastics in samples (which informs the LOQ).
  - The group suggested 10% blanks and duplicates (i.e., 1 blank sample and duplicate sample taken every 10 samples), or enough to get an average (i.e., if sampling 20 sites, do this at 3 so that an average can be taken).
  - Matrix spikes can also be used to understand how well the sampling equipment is capturing particles (i.e., as a measure of recovery).
  - Minimize sources of contamination. Use procedures such as avoiding plastic sampling equipment and clothing made from synthetic materials, avoiding atmospheric contamination by covering samples, ensuring sampling equipment is cleaned, rinsing with water that is filtered to a known minimum size range, use of preservatives, and keeping samples away from ultraviolet light.
- Data Reporting Requirements
  - Converting trawling results to units per volume requires reporting of the correct information. Information reported is very important for modelers who want to use the data. Some auxiliary data that should be reported, including the net opening size, immersion depth, distance covered, etc.
- Potential Research Topics

- The use of a passive sediment trap to measure microplastics moving through the water column.
- Performing a study to compare sampling methods between laboratories in the Great Lakes area.
- Leveraging existing platforms and creating a platform network for spatial coverage of pumping and grab samples.

Recommendation: There is a comprehensive SCCWRP protocol that is being developed for collecting ambient water for microplastic analyses that includes methods, materials, QA/QC for field sampling and sample preservation, and field data reporting requirements. We support the use of this protocol and will be including an addendum with recommendations from this workshop on considerations of relevance to the Great Lakes basin.

Ambient Major Tributary Water

- Sampling Method
  - Blanket minimums for sieve size (50 µm) and sample volume (30 L). Can adjust sample volume from this baseline, based on method LOQ and amount of microplastics at a monitoring site.
- Spatial and Temporal Design
  - A United States Geological Survey (USGS) study found particles were fairly homogeneous in the water column in flowing water. Autosamplers could then be used to get temporal variations of particles during flow. Depth-integrated sampling like pumping would need to be considered for slower flow conditions or non-flowing rivers.
  - Sampling at multiple places across the horizontal of the river would be ideal. Need to consider how to deploy samplers (standing in the water, bridges, or boat) and what type of flow to sample (baseflow or stormflow). Worker safety should take priority, and baseflows should be sampled.
  - Sediment samples should be collected in conjunction with tributary samples to give insight on stormflows and ecosystem level effects. Cores and/or sediment traps could be used.
- QA/QC
  - A field blank should be taken every 10 samples that would capture contamination throughout the full process (field, equipment, trip, and integrated blanks). Equipment should be cleaned, and special care should be taken to prevent cross-contamination. Duplicate samples can be taken to measure variability in method.
  - Water for blanks should be filtered to minimum particle size to be measured.
  - Tubing size should also be reported and be at least triple the size of the largest particle targeted.
  - Use 10% isopropyl alcohol to preserve samples. Do not use formalin, acid, or ethanol as it may affect the plastic.
- Data and Reporting Requirements
  - Report particles by volume for water and particles per kg dry sediment weight for sediment.

- Mass measurement is highlighted for ecosystem budgeting and comparisons with waste management and other parameters.
- Emphasis on the necessity of reporting volume sampled and mandatory reporting of discharge, substrate type, and optionally temperature, turbidity, salinity/conductivity, time, date, and time since the last wet event.

USGS, in conjunction with the state of Minnesota, is conducting a statewide surface water and groundwater monitoring program for microplastics using neuston nets with 100-µm mesh for sampling tributaries deployed from bridges or boats while anchored. Sampling occurs under various flow conditions, with a focus on baseflow stability. USGS also employs an autosampler with a peristaltic pump and tygon or silicone tubing, as well as sediment core sampling. Other sampling approaches include pumping 200 L from a river, spanning nets across streams, and depth-integrated water sampling before, during, and after storms. The discussion highlighted the potential importance of studying the streambed ecosystem and mention ongoing research by SCCWRP to develop suitable methods.

Recommendation: Sample ambient water during baseflow in tributaries using a peristaltic pump. The sampling should be taken in such a way that the sample is depth-integrated from just below the surface to just above the bed (if feasible) and also horizontally integrated across the channel. The sample should be sieved through a 50 – 100-µm stainless steel sieve *in situ*. The volume sampled should be based on blank levels – aiming to achieve samples that have contamination at least triple the levels in the field blanks. The group stressed being safe, and this is why we recommend sampling at baseflow. The group also discussed the possibility of adding one sediment sample at each location, which could be collected using a sediment trap deployed at each site and sampled periodically at an interval to be decided upon based on management objectives.

Sediment

- Sampling Method
  - Core samples conserve fine particles the best and are superior to Ekman or Ponar grab samples, which are subject to wash effects and may miss the critical sediment-water interface where microplastics are expected to be most concentrated. Core samples also enable measurement of sediment bulk density, which is important for reporting microplastic particle concentrations in comparable units. A consideration with core sampling includes whether to remove roots, sand, and gravel. Core samples can be taken from larger Ponar or Ekman grab samples if gravity corers or push cores are not effective in the particular sampling environment.
  - Consider collecting at least ~100 g wet sediment per core sample. It is essential that the depth of sediment collected be standardized to make exposure risk assessments comparable among sampling campaigns and monitoring programs, as incorporating deeper sediment will dilute the estimate of microplastic concentration in the biologically active zone (~ upper 5 cm)..
  - Sediment traps can be used to sample under ice, in non-wadable environments, and can be useful for understanding seasonality and sources. Traps may be quicker to count but require expertise and cost to deploy and operate. There may be issues with fouling and cleaning out during long-term deployments.
  - Traps can be used to answer different questions than core samples (e.g., traps catch loading rates, but grab samples note exposure levels and identify hotspots or changes in exposure).

  - Cores have a lower barrier to deployment and could be the initial stage in a tiered approach to surveying an area (e.g., initial sampling through cores to find issues, then subsequent trap sampling to capture delivery rates and sources).
- Spatial and Temporal Variation
  - Traps can be used to measure instantaneous sedimentation and deposition rate, seasonality, and sources. Not indicative of historical loading.
  - Core sampling can be used to get a snapshot of a larger spatial area and a more time-integrated measure of contamination, which can complement existing sediment monitoring.
- QA/QC
  - Field blanks are used to determine reporting limits, can be used to flag outliers, and determine if equipment is "shedding" plastic or if there is ambient contamination.
  - Emphasis on matrix spikes and contaminant control by using cotton clothing or brightly-colored clothing or material that is easily identified. The polymer type, shape, and size used in spikes should match what is expected in the sample (e.g., don't use microbeads as a spike when measuring fibers).
  - In core sampling, it is important to conserve the sediment-water interface. Also, standardizing core depth is important because deeper sediments should represent more historic deposition and the surface sediments will reflect more recent loading. Taking core samples that are too deep will dilute the recent microplastic contamination with cleaner historic sediments. The appropriate coring depth will depend on the sedimentation rate in that region or habitat.
  - Remove any large rocks or roots from sample which would otherwise dilute the measured concentration of microplastic particles by reducing the actual volume of sediment sampled.
- Data and Reporting Requirements
  - Importance of development of a data management plan and working with stakeholders to achieve data objectives.
  - Importance of collecting parameters such as bulk density, water depth, sediment core depth, surface area of sediment sampled, sample dimensions/volume, location, deployment duration, time/date, and organic material. It is crucial that sediment concentrations be reported in both units of sediment surface area or volume and units of dry-mass of sediment because of the influence of bulk density on the microplastics concentration per gram of sediment dry-mass. In organic sediments, the lower bulk density will inflate the concentration of microplastics because the mass of the sediment will be low compared to the same volume of a mineral (sand, silt or clay dominated) sediment. The practice of reporting microplastic concentrations in units of particle count per gram of dry sediment thus limits comparability of samples collected in lake, beach, tributary, and wetland environments.

Recommendation: A comprehensive SCCWRP protocol is being developed for sampling bottom sediments in wadable and non-wadable environments. This recommended protocol includes valuable guidance on quality control and quality assurance practices but recommends grab samples in non-wade able environments and does not include sediment traps to sample settling sediments. Amendments to the SCCWRP protocol are likely necessary to make it suitable for the Great Lakes environment.

If the objective of monitoring is to measure loading rates to the sediment, then sediment traps should be used. The trap shape and deployment duration should reflect the habitat (e.g., profundal vs. littoral) and expected turbulence of the water (Bloesch and Burns 1980, Gust et al. 1996, Hoellein et al. 2019).

If the objective of monitoring is to assess exposure and risk to benthic organisms, collect sediment cores with an intact surface-water interface and including the surface sediments (top 2-10 cm). If a gravity corer cannot be used, an Ekman or Ponar grab can be used, but this can disturb the water-sediment interface leading to underestimates of microplastic concentration. More, collecting multiple smaller-diameter cores are a better way to assess exposure levels than collecting a single, larger dredge sample due to the heterogeneous distribution of microplastics in sediments.

With core samples, matrix spikes are essential to track recovery rates, as lab methods will likely require digestion and/or density separations to enable microplastics counts.

Another key consideration in the protocol needs to be the reporting units for the eventual microplastics counts. Because the density of organic matter is relatively low, bulk densities will be much lower in organic-rich sediments. When microplastic counts are reported in units of mass, this will tend to inflate concentrations in more organic sediment and deflate concentrations in more mineral sediments. It is recommended that microplastic counts be reported per square centimeter of sediment area sampled or per cubic centimeter of sediment volume sampled, rather than simply per gram. Counts per gram of sediment may be reported to enable comparison with published literature, but bulk density must be considered to avoid organic content of sediment confounding measures of microplastic concentration in the environment, especially where samples from coastal wetlands or profundal areas will be compared with littoral areas or tributaries.

Aquatic Biota

- Sampling Method
    - Key considerations include trophic level, risk to animals and humans, abundance of species, and ecological importance.
    - Discussed a tiered approach and choosing species to sample based on considerations above. Four general groups considered included: bivalves, small fish, large fish, and water birds (if possible, through existing programs).
    - Use collection methods that are already in use for biota, i.e., no need for specialized sampling (but see QA/QC considerations and standard operating procedure).
    - Gut and muscle examinations for larger species and whole-body analysis for smaller species.
- QA/QC
    - Euthanize animals quickly to minimize egestion/emptying of gut contents and wrap and freeze samples immediately.
    - Avoid use of plastic equipment, and pre-filter any rinse water.
- Data and Reporting Requirements
    - Make sure to report location; site conditions; collection and preservation processes; animal characteristics such as size, sex, etc.; and special notes on parasites and tumors.
- Potential Research Topics
    - Do microplastics in macroinvertebrates reflect environmental levels?

  - Do microplastics in digestive tracts reflect those in muscle for fish and birds?
  - Are primary producers a valuable group to include in monitoring programs?
  - Are microplastics correlated to measures of health (e.g., liver somatic index, condition index)?
  - How does migration influence exposures for fish and birds?

Recommendation: There is a comprehensive SCCWRP protocol that has been developed for collecting shellfish (oysters and mussels) and fish from coastal waters for microplastics analyses that includes methods, materials, and QA/QC for field sampling and sample preservation. We support the use of this protocol and will be including an addendum with recommendations from this workshop on other species of relevance to the Great Lakes basin.

Shoreline Debris

- Sampling Method
  - The discussion focused on why microplastic indicators are relevant, and the potential risks of microplastics present on shorelines and their specific impact to ecosystems and human health.
  - Shorelines are highly variable, and beaches change all the time but are fairly homogenous. As such, one should aim to characterize the beach itself rather than a specific site on a beach if sampling is done repeatedly.
  - Use stainless steel trowels to subsample surface in quadrats and create a composite.
  - Sampling should occur in areas with little movement/wave action. Wet sand cannot be sieved so dry, coarse sand is preferred.
  - Could coordinate microplastics sampling in conjunction with beach cleanups and citizen science. However, samples would need to be sent somewhere to be processed.
- QA/QC
  - Discussion included field blanks, spikes, duplicates, and preservation. Clothing guidelines for field activities may be developed, but sample contamination concerns from clothing were perceived by the working group as negligible.
- Data and Reporting Requirements
  - Development of a standardized sampling protocol, including details like beach size, sampling materials, global positioning system (GPS) coordinates, and sub-sampling procedures. It is also important to document characteristics like beach type, location, and time of sampling.
  - Emphasis on digital record-keeping and the need for training resources.

Recommendation: There is a National Oceanic and Atmospheric Administration (NOAA) protocol that has been standardized for shoreline macrodebris that gives recommendations for microplastics. We will be recommending this protocol in general, but will not be including it as a deliverable from this working group. This is because the group decided to deprioritize this matrix for monitoring of microplastics. .

Breakout Session 2

In the afternoon, workshop participants were divided into three different breakout groups (identified as A through C). Each group was tasked with discussing sampling design for the objectives below. In this breakout session, the groups rotated through the three topics, world-café style, so that each group had the opportunity to consider all three objectives.

A. **Spatial patterns:** where to sample, how to prioritize, site access issues
B. **Temporal patterns and trends:** frequency, time of year, wet weather/dry weather
C. **Source apportionment, pathways, and vectors:** hypotheses about magnitudes, distinguishing sources in mixed samples, transformations along pathways, lag times

The groups were asked to keep the following approaches in mind:

- Operational approach in monitoring vs. research program design
- Relationships to existing regulatory frameworks and monitoring requirements
- Anonymity (or not) of sampled manufacturing plants, industries, or landowners
- Relevance of results to microplastics-source control policy development and refinement

Priorities and key themes identified for each group topic are listed below. The breakout groups used flipcharts to document their ideas and discussion. Screenshots of the flipcharts can be found here, along with detailed notes. At the conclusion of the breakout discussions, each of the breakout groups reported back to the whole group. These reports are summarized in Table 2.

Table 2. Breakout Session 2 Discussion Summary

Program Objective	Sampling Locations	Sampling Times / Frequency	Other Considerations
Spatial patterns	• Consider a random distribution to identify hot spots or do strategic sampling in high-risk areas. • Use a tiered/hybrid system (i.e., random within geographical compartments). • Consider fixed monitoring stations.	• Sample multiple matrices from one location at the same time. • Consider temporal variations (e.g., storm flow, seasonal changes) in selecting sampling locations/times.	• Consider prioritizing areas with disadvantaged communities. • Access to sampling locations may be a concern. • Don't assume hotspots are known, sample for reference conditions. • Statistical sampling for larger areas, consider land use, population, etc.
Temporal patterns and trends	• Consider sampling some sites more often.	• Consider frequency in relation to matrix and questions being asked (short-term nature of water vs longer-term nature of sediment). • Consider "hot moments," e.g., storm events, meltwaters that can pulse a load of microplastics.	• Consider strategic objectives as well as opportunistic sampling. • Consider historical information, museum specimens/sediment cores. • Other opportunities – cruise ships, die off of organisms, temporal trends in animals. • Tie into existing programs in place with cyclical sampling where possible (e.g., Mussel Watch).
Source apportionment, pathways, and vectors	• Management strategy focused on sources. After reaching a threshold, enhance sampling, trigger management strategies. • Consider recreational activity, hydrology, trash bins, outflows, manufacturing, etc.	• Consider seasonal variability • Lag times? What about transient storage along pathways?	• Reporting requirements can help identify sources. • Can also go with top-down approach to estimate loadings. • Involve community or citizen science programs. • Consider what metadata is relevant.

Generally, workshop participants did not arrive at consensus decisions or recommendations in Breakout 2. Rather, these breakouts had general discussions about the key monitoring program considerations. Participants generally agreed that the policy landscape is not yet ready for a dedicated microplastic monitoring program, in the absence of an agency (or agencies) with the authority or responsibility for a monitoring program. Rather than attempt to design a stand-alone program with no lead agency in mind, participants felt that it would be best to leverage existing programs. The considerations identified during this breakout session are presented to assist with adding microplastics to existing monitoring programs. Decisions about the considerations above will be, and should be, based on monitoring objectives.

Spatial Design

- Targeted vs. Random Sampling
    - Emphasis on understanding hot spots (and cold spots?). Not trying to sample everything everywhere, but instead focusing on priority areas. Known hot spots in high-risk locations include harbors, nearshore, depositional zones, and highly urbanized areas.
    - Depending on program goals, high-risk areas may be preferred sampling locations. However, focusing on high-risk areas could miss other aspects, and a hybrid approach could be used that combines random sampling with targeted sampling.
    - Locations chosen based on program goals and risk assessment.
    - Sources can inform sampling locations. Should consider particle size, polymer type, and temporal variation in determining sampling locations.
    - Fixed monitoring stations that sample at intervals. Can be collocated with stream gauges, etc. and can collect multiple sample types (sediment, biota, water) all at same time.
- Other Considerations
    - Important to prioritize areas involving disadvantaged or Indigenous communities, and areas in which human and animal lives are potentially most at risk such as drinking water sources.
    - Importance of access considerations, particularly in public versus private areas.
    - Differing sampling strategies when considering the entire Great Lakes area or specific lake. Different level of development in lakes impacts sampling approaches.
    - Use of pumps to account for depth-related variability.

Temporal Patterns and Trends

- Effects of Storm Events & Seasonality
    - First flush collection is most important, but most difficult to sample. Requires autosampler.
    - Difficulties with sampling in ice/snow. Sampling melt events can help with determining plastic lifecycle.
- Long Term Trends/Historical Sampling
    - Water and biota better suited for short-term temporal trends. Sediment is better for integrated sample and determining long-term trends.
    - Use of museum samples and sediment archives have proven successful. Can also analyze samples from well water repositories and acid rain archive samples.

- Monitoring Strategy
  - Incorporate microplastic monitoring into an existing recurring program such as Mussel Watch, for measuring biological uptake on an annual basis. Collect biota samples during times of active feeding.
  - Using existing infrastructure like WWTPs that can be sampled frequently.
  - Some sites may need to be sampled multiple times to overcome variation. Study size, site locations, and frequency should be dependent on time scale trying to measure. Short-term or long-term? Temporal trends are used to determine if management actions are having an effect.

Source Apportionment, Pathways, and Vectors

- Monitoring Strategy
  - Source data can inform management action. Potentially part of tiered or stratified sampling approach.
  - Choose sites based on land use, upstream/downstream of point sources, distance from sources/pathways. Can potentially target runoff or storm events. Also targeted sampling of different matrices such as agricultural runoff, aerial deposition, bioretention cells, etc.
  - Monitoring for specific characteristics: morphology, size, color, polymer, etc.
  - Citizen Science to determine sources of larger materials.
- Top-Down Approach
  - Can determine source through emissions inventories or watershed loadings.
- Other Considerations
  - Seasonality and lag time.
  - Temporary accumulation and transient storage zones.

Day 2 Proceedings

Opening Discussion

Day 2 began with a review of Day 1 workshop activities and outcomes, followed by lightning talks and a panel discussion on program integration. Participants were asked to discuss opportunities and challenges related to implementing a harmonized monitoring strategy for microplastics within existing Great Lakes contaminant monitoring programs.

Day 2 “Lightning Talk” Presentations

After the introductory session, select workshop participants gave “Lightning Talk” presentations on existing monitoring programs in the Great Lakes and other regions, some specifically on microplastics and other more broadly on monitoring contaminants. Each presentation was 5-10 minutes long, and all presentation slides can be downloaded here. The presentations included the following:

- Overview of Great Lakes Monitoring Programs – Daryl McGoldrick, ECCC

  - There are long term monitoring programs in the Great Lakes to survey biological conditions that have been ongoing since the 1960s. Include measurements of nutrients, metals, etc. in sediment and water.
  - The sediment surveillance program runs on a 10-year cycle (5 on, 5 off) and resumes in 2024 in Lake Erie.
  - Fish sampling is coordinated with the United States Environmental Protection Agency (USEPA) annually to collect prey and top predators.
  - There are fixed shore stations at Niagara, Wolfe Island, St. Clair River, and new station at the Detroit River is being added in 2024. Used to monitor interlake ion transport.
  - New contaminants are added to monitoring plan or as a sub-indicator through Annex 3 and Annex 10 of the GLWQA.
- Chesapeake Bay Plastic Pollution Action Team (PPAT) – Kelly Somers, USEPA
  - Emphasis on increased coordination between PPAT and IJC.
  - Striped bass was selected as assessment endpoint for microplastics since it is a species with large ecological impact, has a large tie-in to human health via fish consumption, and likely to receive more funding.
  - Funding for monitoring can come from a variety of sources. Trash goals in the region have been motivating stakeholders to implement monitoring.
- California Microplastic Method Standardization – Leah Thornton Hampton, SCCWRP
  - SB1263 is new statewide strategy to address microplastic pollution and involves "no regret" solutions. There is still a need for monitoring, new solutions, risk, sources/pathways to understand extent of pollution.
  - Leveraging existing monitoring programs such as Bight which began in the 90s. Per- and polyfluoroalkyl substances (PFAS) and microplastics have since been added. Runs on a 5-year cycle and some preliminary work on microplastics has been done, but nothing large scale. Extent of microplastics in sediments and shellfish is planned for Bight '23. Will be first large-scale occurrence dataset for microplastics.
  - Pros of leveraging existing programs include use of logistics that are already in place, avoids duplication of efforts, and places microplastics within context of other contaminants. Cons include time, cost, and lack of standardization of analytical effort. Academic labs doing analysis, not efficient enough for businesses.
  - Trash is a big problem in Southern California. Northern California and state less interested and want to see extent before further action. Only able to do monitoring through BIGHT through good connections.
- Microfiber Considerations: Field & Lab – Carlie Herring, National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program
  - Save Our Seas Act prompted the development of a report on microfiber pollution that will develop recommendations for a standardized methodology to measure microfibers in the environment.
  - Microfiber specific procedures should be included within the larger framework of microplastic methodology, with specific considerations for the recovery and analysis of microfibers.

- Proper field and laboratory QA/QC considerations are vital to properly enumerate fibers and prevent sample contamination. These include active filtration and passive surface measurement to quantify and prevent microfiber contamination from the air, matrix spikes to evaluate recovery of methods, and fiber identification to identify sources.
- Some microplastics are microfibers, but not all microfibers are microplastics. Different definitions of microfibers were discussed.

- Upper Midwest Water Science Microplastics Projects – Pete Lenaker, USGS
    - Projects included a study of 29 different tributaries, vertical distribution in the Milwaukee River, Lake Erie and Michigan sediments, spatial assessment of surface water and surficial sediments in Minnesota, and source characterization of microplastics based on certain land-use types in Milwaukee, WI.
    - USGS is currently working with private labs on some microplastics projects. Some participants expressed concern that lack of interest of private labs in scaling up capacity for microplastics analysis may be a barrier to broader monitoring efforts moving forward.
- Ontario Ministry of the Environment, Conservation and Parks (OMECP) Monitoring Programs – Paul Helm, OMECP
    - Monitoring programs involving other contaminants mostly in nearshore and shoreline assessment in place. Water quality studies are rotational, i.e., 3 years in the lower lakes (Lakes Ontario, Erie, and Michigan), and 6 years in the upper lakes (Lakes Huron and Superior) and take measurements three times per year. Investigative studies by place.
    - Fish contaminant monitoring program serves as a long-term monitoring program for contaminants such as mercury, polychlorinated biphenyls (PCBs), PFAS, etc. This program mostly focuses on sport fish to determine which species are safer to eat.
    - Other programs include stream monitoring, drinking water surveillance, and air monitoring.

Following the lightning talks, all presenters were prompted with the following question: "What would it take to create and add a monitoring strategy? What would you need? If a program goes forward, how does that fall on federal, state, provincial, and how to divide." Table 3 provides a summary of this discussion.

Table 3. Summary of Panel Discussion

Engagement
Building confidence with managers and keeping them and stakeholders active and engaged. Goal is to demonstrate that developing a monitoring program is actionable and achievable. Emphasis on collaboration between different organizations. Public buy-in is also important. There is already grassroots activism, volunteering, and huge public support.
Monitor First?
Should monitoring work be performed first, or should toxicological and analytical methods be improved first? Improvement of analytical methods and toxicological data are needed, but not necessary to start monitoring. Thresholds are a big driver for monitoring programs, but not necessary to do spatial work. Because baselines and long-term trends are important, monitoring now would be useful.
Resources
There need to be more resources and mandates to support the work. Funding and delegation of who does what is also necessary.
Scale

This problem is large, nuanced, and overwhelming. Progress has been and continues to be made incrementally.

This discussion was followed by the final workshop activity, which consisted of all participants sharing one word or phrase describing their impression of microplastics following the workshop. The words shared by participants are summarized below:

- Direction of research to policy; bottom up or top down
- Grateful for interaction and learning a lot and collaboration
- Synergy and learning
- Boats, lack of research vessels within the Great Lakes
- Validated, thinking what other people are thinking
- Overwhelming, how do we focus on most important aspects
- Synergy, need to standardize to mesh size etc.
- Great Lakes Water Quality Agreement, how it is still important
- Buoys, robot
- Exciting potential, at the beginning stages of the field
- Data management, need to think about what needs are for storing, editing, manipulating data
- Nuanced and tiered issue
- Consistency, and identify what priorities lie next for monitoring program. What if there isn't a risk threshold developed, what can still be agreed upon? Microbeads is a good example.
- Encouraged and optimistic, lot of steam coming out of idea coming for it. Things taking a turn.
- Heartened, large number of smart people. Need to continue to pursue through formalized and structured opportunity.
- Systems level issue. More awareness on impacts is needed.
- Privileged and grateful to be here and share information. Identify priorities and with limited resources, need to pick and choose.
- Engagement, making sure end users are engaged.
- Collective brain power, impressed with the progress we made on thoughts to set-up program.
- Opportunity, learned a lot. Lots needs to be done. Lots of concern about microplastics and good opportunity for research and management.
- Chicken or egg, do we start monitoring without understanding how to interpret or do we figure out the threshold of programs? Start to monitor to figure out program. Progress. Same questions being asked but better.
- Mandating and monitoring, how best to achieve monitoring.
- Progress, using scientific advancements in a formal way.
- Folding a new contaminant into an existing program. Complicated to add microplastics, the simpler it can be the better.
- Persistence, keep it going.
- Grateful and overwhelmed.

3 References

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Appendix A:
Workshop Agenda

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Towards a Monitoring Program for Microplastics in the Laurentian Great Lakes – Developing a Monitoring Framework
Workshop Agenda
September 12th (full day) and 13th (am only), 2023

This workshop is being held as an activity of the IJC Microplastics Monitoring and Risk Assessment Working Group. The IJC Working Group consists of subject matter experts, working in a voluntary capacity, helping to develop recommendations on microplastics management for the IJC's Science Advisory Board.

Overarching objectives of the IJC Working Group are to:

1. Synthesize recent advances and knowledge in plastics science relevant to the Great Lakes through events that bring together researchers to share the latest information on plastics.
2. ****Develop a framework for monitoring plastic pollution in the Great Lakes that would support its use as a sub-indicator for State of the Great Lakes reporting under GLWQA.**
3. Develop a risk assessment framework for plastic pollution in the Great Lakes focused on ecological effects that would contextualize the results of a monitoring program.

This workshop will support the IJC working group in their Objective 2. The objectives of this workshop are to:

1. Develop harmonized monitoring frameworks for sampling microplastics in different matrices - ambient water, sediment, shorelines, and biota – and for different pathways (e.g., WWTPs, rivers, runoff).
    a. Methods for sampling each matrix
    b. QA/QC
2. Advise on how monitoring programs should be designed to best to capture spatial or temporal trends or to identify microplastic sources
3. Advise on where monitoring programs for microplastics may fit into existing frameworks and programs to help facilitate action.

***Workshop Agenda*:**
DAY 1: MONITORING FRAMEWORKS FOR MATRICES AND SOURCES
8:30am – 9:30am Welcoming remarks + Introductory talk

9:30am – 12:00pm (groups break for coffee at ~10:30) - **Session #1: Protocols – no rotation of groups**

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The objective of this breakout is for smaller groups to get together to outline the components of a harmonized sampling plan for each matrix. Each group will discuss a sampling design for one matrix, and should come up with the following:

- **sampling method**: pumping, net tows/trawls, coring, traps, transects, species/tissues
- **temporal and spatial design**: background, gradients, hot spots, hot moments, consideration of sources (also below)
- **QA/QC for field sampling and reporting**: duplicates, blanks, matrix spikes, standard reference materials, clean sampling
- **data reporting requirements**: parameters, units, uncertainty, detection limits, data management, sample archiving

Groups (note – air and terrestrial biota are recognized media but excluded for this exercise):

1. Ambient lake water
2. Ambient major tributary water
3. Sediment
4. Aquatic biota
5. Shoreline debris

Keep in mind for optimizing approaches:

- Operational approach—this is not a research project design (although data generated can also be used for research)
- Frequency of sampling: e.g., annually in summer? More intensive 5-year cycle by lake?
- Realistic monitoring costs including labor, equipment, and sample prep
- Minimum number and types of sites/samples for meaningful results
- Simplicity of implementation, leveraging of existing programs and assets, consistency across programs, training needs
- Relevance of results to microplastics-source control policy development and refinement

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12:00pm – 1:00pm – Lunch (preordered, on site)

1:00pm – 2:00pm – Report out to full group on discussions, Q&A, feedback
Questions of the full group:

1. Is the method appropriate locally?
2. Are there recommended changes or additions?
3. Do we need more research to validate methods?

2:00pm – 4:00pm (coffee available at 3 pm) – **Session #2: Program Design – world café rotation**

The objective of this breakout is for smaller groups of people to get together to design a harmonized monitoring program for point sources (wastewater plants, industries) and nonpoint sources (urban stormwater, agricultural runoff) of microplastics. Each group will discuss a sampling design for one objective below:

Groups:

A. **Spatial design:** where to sample, how to prioritize, site access issues
B. **Temporal patterns and trends:** frequency, time of year, wet weather/dry weather
C. **Source apportionment, pathways, and vectors:** hypotheses about magnitudes, distinguishing sources in mixed samples, transformations along pathways, lag times

Keep in mind for optimizing approaches:

- Operational approach in monitoring vs. research program design
- Relationships to existing regulatory frameworks and monitoring requirements
- Anonymity (or not) of sampled manufacturing plants, industries, or landowners
- Relevance of results to microplastics-source control policy development and refinement

4:00pm – 4:45pm -- Report out to full group on discussions, Q&A, feedback
Questions of the full group:

1. What program design would best achieve each monitoring goal?
2. Are there recommended changes or additions?
3. Do we need more research to inform program design (e.g., power analysis)?

4:45pm – 5:00pm -- Wrap-up
Overview of what we accomplished today and goals for Day 2

Group dinner off-site (location TBD).

DAY 2: INTEGRATING MICROPLASTICS MONITORING INTO EXISTING GREAT LAKES MONITORING PROGRAMS

8:15am – 8:45am (continental breakfast and coffee in meeting room) - Welcome and time for monitoring program managers in the room to share any perspectives from Day 1

Session #3: Program Integration – panel discussion in plenary
The objective of this plenary session is for workshop participants to discuss opportunities and challenges related to implementing a harmonized monitoring program for microplastics within existing Great Lakes programs.

8:45am – 9:15am – "Lightning Talk" presentations from participants on example programs from other regions (e.g., Chesapeake Bay, California) (5-10 min each, then joint Q&A)

Coffee available, 9:15-9:30

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9:30am – 11:15am - Panel of "Lightning Talk" presentations from different Great Lakes monitoring programs that could incorporate microplastics sampling, then panel style Q&A.

11:15am – 11:45am -- Reporting out, wrap-up, thanks, and next steps

11:45 Adjourn

Appendix B: Workshop Participants

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Participants listed in italics are IJC and contractor staff who helped organize and facilitate the workshop.