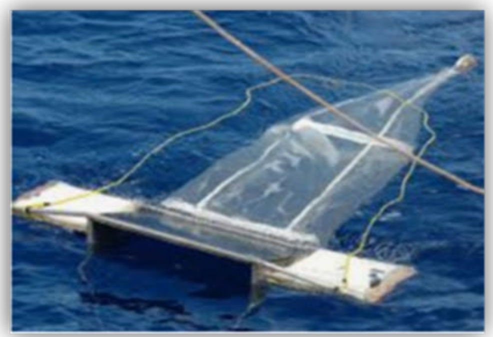
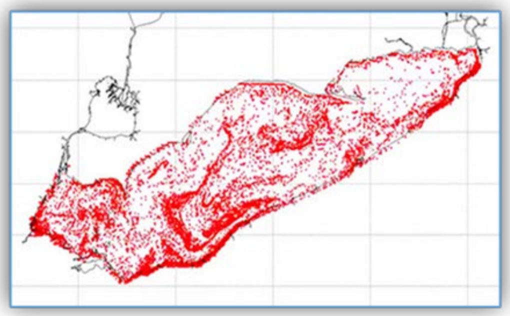
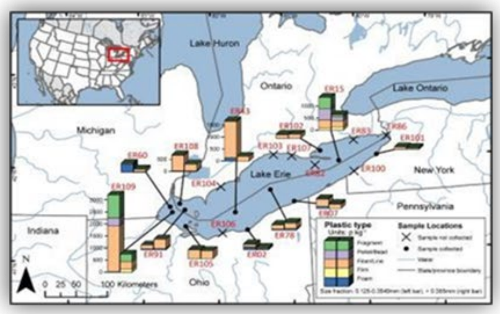
Final Report of the IJC Great Lakes Science Advisory Board Work Group on Microplastics

Monitoring, Ecological Risk Assessment, and Management of Microplastics in the Laurentian Great Lakes







A report submitted to the International Joint Commission by the Great Lakes Science Advisory Board

November 2024

Acknowledgments

The International Joint Commission Great Lakes Science Advisory Board acknowledges the efforts of the Great Lakes Microplastics Work Group, all workshop participants, the Southern California Coastal Water Research Project working groups, and the contractor team of Potomac-Hudson Engineering, Inc. and LimnoTech.

Primary Authors
Karen Kidd, Work Group Co-chair, McMaster University
Rebecca Rooney, Work Group Co-chair, University of Waterloo
Chelsea Rochman, Work Group Co-chair, University of Toronto
Eden Hataley, University of Toronto

Work Group Members
Austin Baldwin, US Geological Survey
Carlie Herring, National Oceanic and Atmospheric Administration
Carl Platz, US Army Corps of Engineers
Dale Hoff, US Environmental Protection Agency
François Houde (former member), Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs
Haley Dalian, National Oceanic and Atmospheric Administration
Molly Flanagan, Alliance for the Great Lakes

International Joint Commission Staff
Lizhu Wang (retired), Great Lakes Regional Office Windsor, ON
Matthew Child, Great Lakes Regional Office, Windsor, ON
Jo Werba, US Section, Washington, DC
Lyne Sabourin, Canadian Section, Ottawa, ON

Contractors
Erin Kouvousis, PHE
John Bratton, LimnoTech
Kathryn Meyer, formerly of LimnoTech
Ken Gibbons, LimnoTech
Pedro Da Silva, PHE
Samir Qadir, PHE

Cover Images

Top left: A collection of microplastic particles. Source: https://www.flickr.com/photos/oregonstateuniversity/21282786668 (Image by 5Gyres, courtesy of Oregon State University, License: Attribution-ShareAlike (CC BY-SA 2.0))

Top right: Researchers using a manta tow, a net that collects sea surface samples, during SEAPLEX. Taken on August 16, 2009. Source: https://www.flickr.com/photos/scrippsocean/3856797572
Scripps Institute of Oceanography, all rights reserved

Lower left: Matthew Hoffman, (https://www.rit.edu/directory/mjhsma-matthew-hoffman) assistant professor in RIT's School of Mathematical Sciences, used computer simulations to follow the volume of plastic debris moving across state and international boundaries—from Illinois to Michigan and from Canada to the United States (https://www.rit.edu/news/researchers-study-plastic-pollution-great-lakes).

Lower right: Figure 2 from: Lenaker, P.L., Corsi, S.R. and Mason, S.A., 2020. Spatial distribution of microplastics in surficial benthic sediment of Lake Michigan and Lake Erie. *Environmental Science & Technology*, *55*(1), pp. 373-384.

Table of Contents

List of Figures

List of Tables

List of Acronyms

CMC - Chemical of Mutual Concern

HC - hazard concentration

IAGLR - International Association for Great Lakes Research

IJC – International Joint Commission

GLWQA – Great Lakes Water Quality Agreement

LOD - limit of detection

MT - metric tons

QA/QC – quality assurance and quality control

SAB - Great Lakes Science Advisory Board

SCCWRP - Southern California Coastal Water Research Project

SOGL - State of the Great Lakes

SOP - Standard Operating Procedures

SSD - species sensitivity distribution

ToMEx - Toxicity of Microplastics Explorer database

µm – micrometer

UNEP - United Nations Environment Programme

USEPA – United States Environmental Protection Agency

WWTP – wastewater treatment plant

Executive Summary

Plastics are a diverse and ubiquitous group of materials that have seen a surge in production in the past century. The widespread use of plastics coupled with unsustainable materials management has led to plastic pollution, including the ubiquity of microplastics across the globe. Microplastics are generally understood to be smaller plastic particles, from 1 micrometer (µm) to 5 mm in size, that are diverse in their physical and chemical characteristics. Microplastics originate from industrial sources, the wear and tear of plastics during use (e.g., clothing, tires, paint), and from the breakdown of discarded plastic products in the environment. Research has shown that microplastics can have adverse effects on aquatic organisms.

This report outlines the results and deliverables from an International Joint Commission (IJC) Great Lakes Science Advisory Board (SAB) Work Group focused on microplastics in the Laurentian Great Lakes (hereafter called the Great Lakes), whose objectives were to:

1. Synthesize recent advances and knowledge in microplastic science relevant to the Great Lakes.
2. Develop a framework for monitoring microplastics that would enable harmonized monitoring and reporting across the Great Lakes region.
3. Advance a coordinated risk assessment and management framework for microplastic in the Great Lakes focused on ecological effects that would contextualize the results of a monitoring program.

The Great Lakes and their watersheds are home to much of North America's freshwater resources and a range of aquatic species of ecological, commercial and cultural importance. The Great Lakes Water Quality Agreement (GLWQA), established by the Governments of the United States and Canada (the Parties), is meant to help prevent and resolve issues threatening ecosystem health and water quality within the transboundary waters of the Great Lakes. Under Annex 10 of the GLWQA, the US and Canada monitor multiple indicators to assess the health of the Great Lakes ecosystem. To inform how microplastics could be included as a sub-indicator under the GLWQA framework, the IJC SAB convened a Work Group to synthesize recent advances in microplastic knowledge relevant to the Great Lakes and develop separate but coordinated microplastics monitoring and ecological risk assessment and management frameworks.

The objectives were successfully addressed through the following activities. The Work Group synthesized knowledge on the environmental occurrence of microplastics in the Great Lakes basin based on a review of published literature only, as no basin-wide, coordinated monitoring programs for microplastics currently exist. Work Group members held a session on microplastics at the 2023 Annual Conference of the International Association for Great Lakes Research (IAGLR). Data on the ecological effects of microplastics on aquatic organisms of relevance to the Great Lakes were reviewed and used to update the Toxicity of Microplastics Explorer (i.e., ToMEx 2.0, available early 2025) database. The Work Group organized two expert workshops. The first was held in September 2023 in Ann Arbor, MI and advanced a harmonized monitoring framework for microplastics through the development of standardized operating procedures for collecting water, sediment and biota for microplastics analyses. The second workshop was held in January 2024 in Windsor, ON and advanced a coordinated ecological risk assessment and management framework. Key findings about microplastics in the Great Lakes are listed below as well as tools developed by the Work Group (listed as project outcomes). Recommendations identified through these efforts are also presented below.

Key Findings

- Microplastics are ubiquitous in all environmental media (e.g., water, sediment, biota, and beaches) in the Great Lakes basin, and they are especially concentrated in more populated systems such as Lakes Michigan and Ontario. Microplastics are a diverse group of contaminants with varied shapes, sizes, and chemical compositions found in these matrices, making them challenging to measure and understand.
- Reconnaissance-level sampling for microplastics has been performed in the Great Lakes, but many questions remain about spatial and temporal variability, transport, sources and mitigation. Moreover, most of this data has been collected in a non-harmonized manner, as there is no basinwide, coordinated monitoring program for microplastics in the Great Lakes region.
- Existing studies measuring microplastics in the Great Lakes use highly varied sampling and analysis protocols. The lack of harmonized methods for sample collection and analysis, as well as reporting guidelines, applied to date limits current abilities to assess the status and trends of microplastics in the region.
- Microplastics are reported to be present in sources of drinking water and in fish collected from the Great Lakes and their watersheds. For fish, these levels are among the highest reported worldwide. This suggests human exposure to microplastics through Great Lakes resources.
- The peer-reviewed literature includes a growing number of laboratory toxicity tests that assess the impacts of microplastics on aquatic species. These studies have found that microplastics, including at environmentally relevant concentrations, can affect aquatic organisms relevant to the Great Lakes.
- Sufficient research on the ecological effects of microplastics enabled us to derive preliminary risk thresholds for ambient (surface) water using a species sensitivity distribution (SSD) approach. More data are still needed for sediments to populate robust SSDs and derive risk thresholds with confidence. The process followed approaches used by other groups and forms the basis for an ecological risk assessment framework for the Great Lakes.
- Experts in ecotoxicology and risk assessment expressed that risk thresholds should be derived from robust SSDs and expressed confidence in the approach used by the Work Group to develop an ecological risk assessment framework.
- Applying preliminary risk thresholds reveals that some ambient water samples from the Great Lakes have concentrations of microplastics that already exceed risk thresholds of ecological concern.

Project Outputs

Combined, the deliverables of this IJC SAB Work Group present the tools needed to monitor microplastics and assess their statuses and trends over time in the Great Lakes and their watersheds. These tools have been created to align with relevant frameworks, such as the State of the Great Lakes (SOGL) reports, and thus can be adopted by monitoring and management agencies for use with minimal adaptation. These tools have also been created in such a way that allows for iterative improvements as we increase knowledge, for example, on risk and/or local microplastic characteristics, or as program needs change.

1. An updated literature review of microplastics in the Great Lakes, including a proposed standard definition, field and lab measurement methods, environmental occurrence data, toxicity data for freshwater species, and regional policy and management considerations (Supplemental Materials A).
2. A proposed definition of microplastics as: "solid polymeric materials to which chemical additives or other substances may have been added, which are particles greater than 1 µm and less than 5,000 µm in all three dimensions. Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded." This definition aligns with the definition recently adopted in the State of California.
3. An updated publicly accessible database on measured concentrations of microplastics in various matrices across the Great Lakes basin (up to March, 2023; Dataverse Link).
4. An updated database on microplastics toxicity data available on an open-access platform that can be used to generate SSDs (up to January, 2023; Toxicity of Microplastics Explorer 2.0).
5. Standard Operating Procedures (SOPs) with reporting guidelines for sampling microplastics in lake water, tributary water, sediment, and biota (Supplemental Materials C). Several of these SOPs were available from a previous working group convened by the Southern California Coastal Water Research Project (SCCWRP) Authority and amendments have been proposed as appropriate for their use in the Great Lakes. These SOPs can be tailored to meet specific monitoring requirements and data objectives for each matrix.
6. A coordinated ecological risk assessment and management framework for microplastics in ambient water and sediment, adapted to align with the SOGL reporting framework and locally relevant guidelines (Supplemental Materials D).

Recommendations

- The Parties should include microplastics as a Toxic Chemicals sub-indicator for the triennial SOGL reports under Annex 10 of the GLWQA and consider microplastics for inclusion as a Chemical of Mutual Concern (CMC) under Annex 3 of the GLWQA to support the development and implementation of a coordinated action plan for reducing microplastic pollution in the Great Lakes.
- The Parties should create and implement a basin-wide, coordinated monitoring program for microplastics in the Great Lakes (in lake and tributary water, sediment and biota) that includes harmonization of field and lab methods among federal, state, provincial, local and Indigenous agencies. Such monitoring is critical for quantifying microplastic sources and emissions and understanding their transport and fate in the Great Lakes and its watershed to inform ecological risk assessments, mitigation and management strategies for microplastics. This program would benefit from the SOPs and reporting guidelines adopted and adapted by the Work Group. Importantly, in addition to total counts or concentrations, the following microplastic characteristics should be reported to facilitate comparison across studies:
    - Morphology, as percent of total
    - Polymer type (if identified), as percent of total
    - Size range assessed, based on field and lab methods
    - Size fractions (if distinguished), as percent of total
- Given the persistence and ubiquity of microplastics, the Parties should implement measures to prevent the emissions of plastic pollution to the Great Lakes watershed to reduce environmental concentrations and prevent further ecological risk.
- The Parties should support research that improves our monitoring and analytical capabilities (i.e., improving methods for better detection and characterization of microplastics) and expands our understanding of the toxicity of microplastics to species relevant to the Great Lakes watershed to collectively increase our ability to assess exposures and ecological risks. Supporting additional research into the effects of sediment exposures will address an important knowledge gap in microplastic toxicity.

In addition, a future IJC Work Group should consider how microplastics affect human health across the transboundary waters of the Great Lakes, and how other indicators assessed as part of the SOGL reports under Annex 10 of the GLWQA (e.g., Drinking Water, Beaches, and/or Fish Consumption) may be relevant to assessing human exposure to and risk from microplastics.

1.0 Introduction

Plastics are a ubiquitous material in modern life due to their versatility, durability, and low cost. Global plastic production and consumption have increased dramatically since the mid-20th century and are expected to continue increasing throughout this century (United Nations Environment Programme [UNEP], 2021). According to UNEP, approximately 9.2 billion metric tons (MT) of plastic were produced between 1950 and 2017, with more than half of this amount produced since 2004. Over 400 million MT of plastic were produced in 2020, and annual production is expected to increase to over 1,100 million MT by 2050. Only around 10 percent of these plastics are recycled and 14 percent are incinerated, with the remaining 76 percent landfilled or released into the environment (UNEP, 2021; Geyer et al., 2017). The inherent durability of plastics prevents them from breaking down fully in natural settings. This factor, coupled with rising production rates and improper disposal methods, is leading to substantial accumulation of plastics in the environment.

Microplastics, which generally include plastic particles less than 5 mm in size, have gained increased attention due to their widespread prevalence in the environment. Although microplastics may be present in some consumer products, the bulk of microplastics in the environment likely result from the degradation of plastic products during use (e.g., clothing, tires) and of plastics discarded or weathered from diverse sources (e.g., consumer products, construction sites, industrial uses, road and building paints). Due to their small size, microplastic particles are easily transported via wind, water currents, stormwater, and biota and have been found all over the world in marine, freshwater, and terrestrial environments and biota, and are even in the atmosphere (ITRC, 2023).

The impacts of microplastic contamination on humans and wildlife are not yet fully understood, but there is increasing evidence that microplastics can have adverse effects on organisms (Bucci et al., 2020). The effects of microplastics on aquatic species can vary since particles come in many different shapes and sizes and can have diverse chemical makeups, which include their base polymer, microstructure, and chemical additives (Thornton Hampton et al., 2022a; Rochman et al., 2019). Several laboratory studies have found effects of microplastics on organisms including tissue inflammation, changes to gene expression, reduced growth and feeding, decreased reproductive output, and increased mortality (reviewed in McIlwraith and Rochman, 2020 and Mehinto et al., 2022). Plastics can also leach additives or sorb contaminants present in the environment and may potentially act as vectors for other toxic compounds.

The Great Lakes ecosystem contains 84 percent of the available freshwater in North America, is home to 3,500 plant and animal species, and supports sectors such as fisheries, industry, tourism, and recreation in both Canada and the United States (USEPA, 2023; GLC, 2023). To protect this important resource, the Governments of Canada and the United States (the Parties) signed the Great Lakes Water Quality Agreement (GLWQA) in 1972. It was most recently amended in 2012. The GLWQA is meant to help the two countries better manage current environmental issues and prevent emerging issues from threatening ecosystem health and water quality within the Great Lakes (IJC, 2012). Mandated under Annex 10 of the GLWQA, the State of the Great Lakes (SOGL) reports are published every three years and describe nine indicators of ecosystem health. Each is supported by multiple sub-indicators to evaluate progress towards the general objectives of the GLWQA and report on indicator status and trends.

In 2016, the IJC, recognizing the potential urgency of microplastic contamination in the Great Lakes, held a workshop to discuss issues related to microplastics in the Great Lakes. This workshop included 33 experts from around the world and resulted in a report (IJC, 2017) that included four recommendations on science, pollution prevention, and education and outreach, including the following:

> *"The Parties should jointly undertake monitoring, science and research initiatives for a binational assessment of microplastics in the Great Lakes to inform decision-making by (1) developing and/or adopting standardized sampling and analytical methods (2) developing a transport model to determine the sources and fate of microplastics (3) assessing potential ecological and human health impacts and (4) investing in research for source reduction, improved recycling, and reduced release of plastic pollution."*

The general objective of the follow-on study described herein was to develop and advance separate but coordinated frameworks for monitoring microplastics and assessing and managing their ecological risk in the Great Lakes. This study aimed to align these frameworks with the SOGL reporting framework. The group did not include objectives regarding human health, with the hope that future efforts by IJC and others will focus on it. As part of this study, the IJC Great Lakes Microplastics Work Group (henceforth, the Work Group) carried out the following activities:

- Synthesized recent advances and knowledge in microplastic science relevant to the Great Lakes. This was done by conducting a literature review on the occurrence and ecological risks of microplastics in the Great Lakes, organizing a session on microplastics at the 2023 Annual Conference of the International Association for Great Lakes Research (IAGLR), creating a database (Rochman, 2024) of Great Lakes-specific monitoring data, and supporting updates to a database (Toxicity of Microplastics Explorer 2.0, or ToMEx 2.0, available early 2025) that summarizes available research on the ecotoxicology of microplastics.
- Advanced a framework for monitoring microplastics in the Great Lakes that would enable comparisons among sites and over time, and support its use as a Toxic Chemicals sub-indicator for the SOGL reports mandated under Annex 10 of the GLWQA. This included organizing an expert workshop (Workshop #1) on September 12 and 13, 2023 in Ann Arbor, MI, to agree on standard operating procedures for sampling and discuss considerations for a monitoring framework, including what compartments to sample, sampling methods and frequency, and quality assurance and quality control (QA/QC) considerations.
- Advanced an risk assessment and management framework for microplastics in the Great Lakes focused on ecological effects to contextualize the results of monitoring efforts. The ecological risk assessment and management framework was discussed and refined at an expert workshop (Workshop #2) held on January 17 and 18, 2024 in Windsor, ON.

This report presents the key findings of the Work Group, and is organized as follows:

- Section 2 provides an introduction to microplastics and their sources and pathways. It also includes a proposed standard definition of microplastics for use in the context of the Great Lakes. Additional details on the characteristics of microplastics can be found in Supplemental Materials A.

- Section 3 discusses our current understanding of the occurrence of microplastics in the Great Lakes environment, as well as the challenges associated with the sampling and analysis of microplastics. It also summarizes current knowledge on the risks of microplastics to freshwater organisms of relevance to the Great Lakes basin. Further details can be found in the literature review included in Supplemental Materials A and in the accompanying databases (Rochman, 2024 and ToMEx 2.0, available early 2025).
- Section 4 summarizes discussions and outcomes from Workshop #1, which focused on steps to create a monitoring framework for microplastics in the Great Lakes, harmonized with similar efforts in other parts of North America. A more detailed workshop summary report is included in Supplemental Materials B. Following the workshop, the Work Group adapted standard operating procedures for sampling microplastics in ambient (surface) water of lakes, tributary water, sediment, and biota for use in the Great Lakes region. These are included in Supplemental Materials C.
- Section 5 summarizes the results of Workshop #2, which focused on adapting an existing ecological risk assessment and management framework, including management tiers and risk threshold values against which environmental concentrations of microplastics can be compared to better understand the state of microplastic pollution in the Great Lakes ecosystem. A more detailed workshop summary report is included in Supplemental Materials D.
- Section 6 includes a conclusion, summarizing the products and tools created by this Work Group.
- Finally, Supplemental Materials E summarizes the oral and poster presentations that were given during a session on microplastics at the 2023 Annual Conference of the IAGLR.

2.0 What are Microplastics?

Microplastics are generally considered to include plastic particles smaller than 5 mm in size. Microplastics exhibit wide variation across a range of characteristics such as size, shape, density, polymer type, chemical additives, and color. These characteristics are discussed in more detail in the following sections. Each of these characteristics may influence the ecotoxicological effects and fate and transport of microplastics in the environment, as well as inform particle sources (Thornton Hampton et al., 2022a, Helm, 2017). Figure 2-1 illustrates this diversity by showing some of the shapes of microplastic particles commonly found in the environment.

Figure 2-1: Microplastic Particle Morphologies Include (a) Pellets, (b) Foams, (c) Film, (d) Fibers, (e) Fragments, (f) Fiber bundles, and (g) Spheres. (Courtesy Martindale et al., 2020.)

Sources of microplastics to the Great Lakes include marine traffic, road-wear, beach litter, urban areas, agriculture, and industry (Earn et al., 2021). Typically, microfibers originate from clothing and are likely to be transported via wastewater discharge or ambient air; other sources of fibers may include direct wear and tear on fishing nets, ropes, and other marine equipment and debris. Rubbery particles are typically associated with road tire wear and are likely transported via stormwater runoff; similarly, plastic pellets from industry can be easily recognized based on their shape and size. For other types of microplastic particles, however, it can be challenging to ascertain their origin and pathways because plastics are so ubiquitous in the environment (Helm, 2017). Many types of microplastics are formed from the degradation of larger plastic objects and particles over time. Industrial facilities are potential sources for plastic discharge, especially of pre-production pellets from plastics manufacturing facilities and fibers from textile mills. Plastics are also used in agricultural applications, e.g., as fertilizer pellets, and can degrade into microplastics over time (Wang et al., 2022). Figure 2-2 shows some examples of microplastic sources, as well as pathways for microplastics to enter the environment.

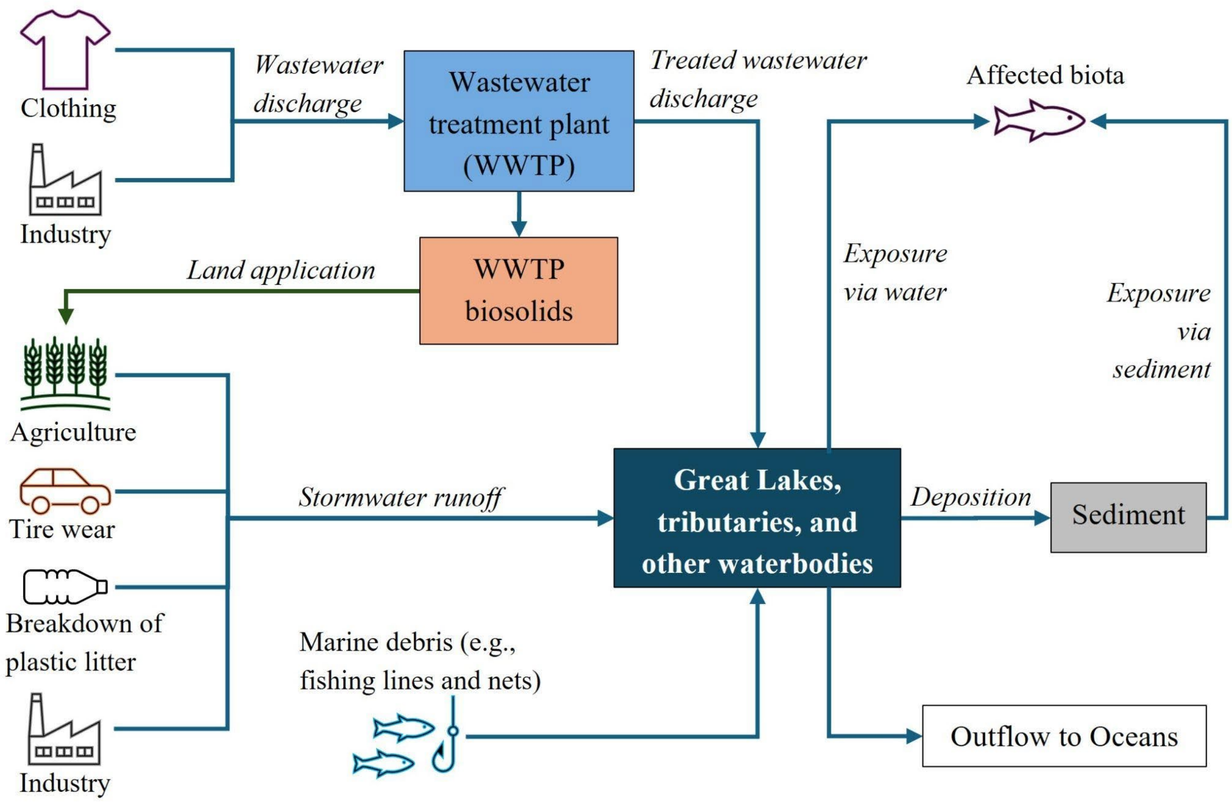


Figure 2-2: Examples of Microplastic Sources and Pathways

Pathways for microplastics to enter aquatic ecosystems include wastewater and stormwater (Holmes et al., 2020; Weir et al. 2024; Verdú et al., 2022). Additionally, wastewater treatment plant (WWTP) biosolids contain significant amounts of microplastic (Wang et al., 2022), which can be transported from land applications to water bodies via stormwater runoff. Once microplastics enter the aquatic environment in the Great Lakes basin, they are found on beaches, deposited in lake sediments, suspended in the water column, consumed by organisms, or exported out of the system to ultimately enter the ocean. Their transport is greatly influenced by their properties which can be altered through biofilm formation (e.g., bacteria, algae, and fungi) on their surfaces, ingestion by organisms, and weathering and degradation by various mechanisms (Helm, 2020). The fate of microplastics within aquatic systems remains an area of active research, although there is some evidence to show that the majority of microplastics entering a waterbody end up in sediment (Boucher et al., 2019).

2.1 Proposing a Standard Definition of Microplastics

Microplastics comprise a wide range of particle sizes, shapes, and materials, and as a result there are difficulties with consistent detection and identification of these particles (Frias and Nash, 2019). Efforts have been made for standardization, such as the United States Environmental Protection Agency's (USEPA) Draft National Strategy to Prevent Plastic Pollution, which includes recommendations on developing a definition for microplastics and standardized methods for their collection, extraction, quantification, and characterization; there is currently no generally accepted definition or standardized sampling method for microplastics. Because of this, data on microplastics are not currently harmonized (USEPA, 2023). This makes it difficult to compare studies across different regions and matrices, and challenging to implement effective monitoring and risk assessment and management frameworks to protect the health of the Great Lakes, wildlife, and the public. Thus, a standard definition of microplastics is needed.

This IJC study reviewed several definitions of microplastics currently used by various North American and other regulatory agencies. To harmonize microplastics monitoring and reporting across the Great Lakes, the following size-based definition is proposed, based on the regulatory definition adopted by the California State Water Resources Control Board (CA SWRCP 2020) but modified to focus on particles greater than 1 micrometer (µm), which reflects the current focus of microplastic monitoring and risk assessment programs in California and elsewhere.

Proposed Definition of Microplastics for the Great Lakes

"Microplastics are defined solid polymeric materials to which chemical additives or other substances may have been added, which are particles greater than 1 µm and less than 5,000 µm in all three dimensions. Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded."

Additional details on the characteristics and current definitions of microplastics can be found in Supplemental Materials A.

3.0 Microplastics in the Great Lakes

3.1 Occurrence in the Environment

This study reviewed scientific publications that performed sampling within the Great Lakes and their connecting waters and tributaries and reported on the presence of microplastics in water, sediment, and biota, as well as on shorelines. Monitoring data from these studies, as well as information on the sampling and analytical methods used, were extracted and compiled into an Excel database (Rochman, 2024). This database builds on previous work described in Earn et al. (2021) and McIlwraith et al. (2023). The field of microplastics research is relatively new, and the number of published studies continues to increase rapidly. Figure 3-1 shows the number of microplastic monitoring studies, by lake and medium, that were published as of 2023.

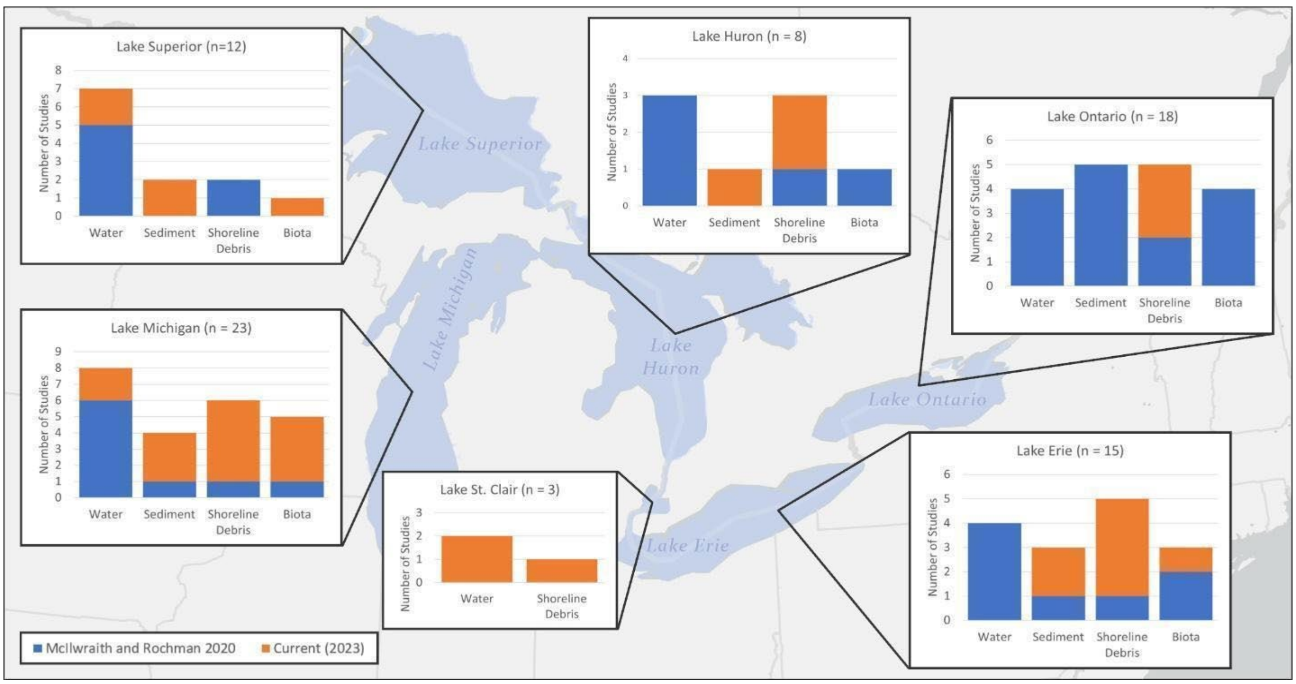


Figure 3-1: Microplastic Monitoring Studies, by Lake (including Lake St. Clair)

Based on available published data, it is clear that microplastics are present across the Great Lakes environment. Figure 3-2 illustrates the concentrations of microplastic particles reported in the ambient (surface) waters of the Great Lakes basin. Concentrations of microplastics range from less than 10 particles per m^3 to approximately 10,000 particles per m^3 in offshore waters and upwards of 100,000 particles per m^3 in certain tributaries. Generally, the most populated lake basins (i.e., Lakes Michigan and Ontario) had the highest concentrations of microplastic particles. Additionally, tributaries generally had higher microplastic concentrations compared to open waters of lakes.

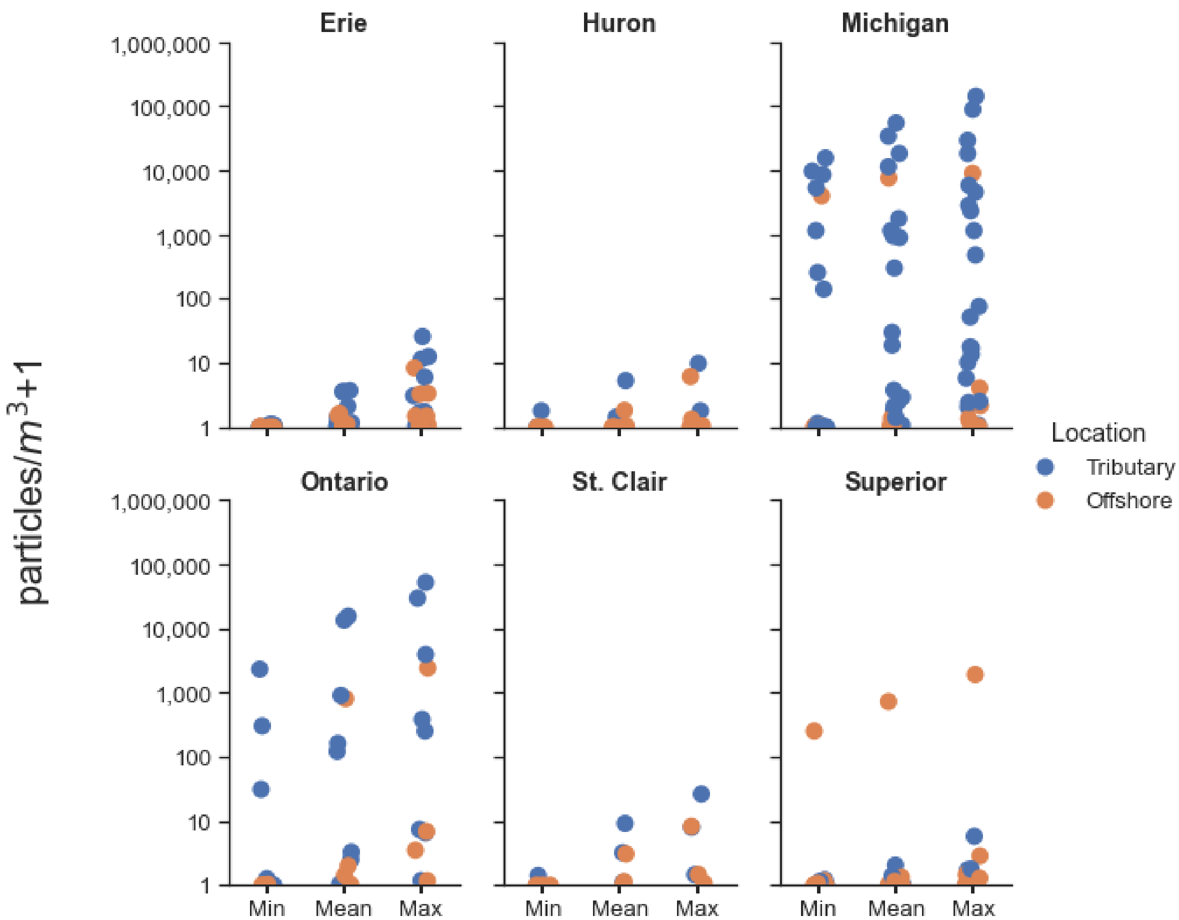


Figure 3-2: Microplastics Concentrations in Surface Water, by Lake (including Lake St. Clair)

The studies also detected microplastics in other environmental compartments including sediments and biota in the Great Lakes basin (see Supplemental Materials A for additional details). Among sediment studies, bottom sediments (i.e., from lake and river bottoms) had much higher reported concentrations of microplastics compared to beach sediment. While most beach sediment samples had less than 100 particles per kg of dry sediment, bottom sediment samples had close to 1,000 particles per kg of dry sediment, and one paper found over 10,000 particles per kg of dry sediment (D'Avignon et al., 2022). Microplastics have also been found in algae, fish, birds, amphibians, and invertebrates.

While there is strong evidence to suggest that microplastics are ubiquitous in the Great Lakes basin, across geographies and environmental compartments, much of this evidence is based on data from peer-reviewed literature, which is often geographically-limited in scope and opportunistic in nature. Neither a consistent monitoring program nor means of measurement for identifying microplastic trends has been developed. Therefore, there is a need to conduct more systematic monitoring of microplastics in the Great Lakes (Twiss, 2016; Office of the Auditor General of Ontario, 2023). This topic was explored further in Workshop #1, which is described in Section 4.

3.2 Sampling and Analysis of Microplastics

The sampling and analysis of microplastics are complex, involving many separate steps that can present some unique challenges. See Supplemental Materials A for a detailed description of microplastic methods; Brander et al. (2021) also provided an overview of sample collection methods. Sample collection methods may vary by the environmental media being sampled.

Water samples may be collected using surface trawls, by pumping water through a series of filters, or by collecting a grab sample in a bottle or other container. Sediment samples may be collected using a simple trowel on shorelines, but benthic (aquatic) sediments are typically collected using specialized sampling devices that capture the sediment-water interface, as well as deeper sediments if desired. Biota (plants and animals) can be collected by hand or using nets, through fishing and hunting, or may be obtained from other sources including fishing fleets, hunters, and museums.

Once samples are collected, they are typically stored in a closed glass or metallic container to prevent contamination and kept cool to prevent decomposition of biological samples until they are transported to the laboratory. Once at the laboratory, samples are processed depending on the matrix. Water samples are filtered. Sediment samples are typically filtered to remove any remaining water, sieved to separate debris, treated with chemicals to digest organic matter, and density-separated to extract lighter microplastics from heavier sediments. Biota may be dissected to remove the gut or other organs of interest, and tissues are then digested to remove organic matter. Samples may also be sieved using multiple mesh sizes to separate particles into size fractions.

After the sample has been processed, it is analyzed to identify plastic and non-plastic particles. Depending on the study goals, other characteristics may be determined including the polymer type, size, shape, and color. Particles can be analyzed using visual techniques such as microscopy, sometimes with the use of fluorescent dyes to stain microplastic particles and aid in identification. Specialized spectroscopic or other analytical chemistry techniques are required to determine the polymer type of microplastic particles. Manual analysis of samples to detect microplastic particles is a time-consuming process. Several automated techniques are being developed to speed up the process, although they require the use of specialized equipment.

The current review found that widely varying methods have been used to sample and analyze microplastics from water, sediment and biota in the Great Lakes. Recent publications (see, for example, *Chemosphere*, Special Issue: Informing methods for detecting and quantification of microplastics through the lens of a global intercalibration exercise) have proposed standardized methods for the laboratory analysis and subsequent reporting of microplastics. While some studies (see, for example, Brander et al., 2021) have similarly attempted to describe standardized methods for microplastics sampling, the Work Group determined that additional work was needed to harmonize microplastics sampling for the Great Lakes. Therefore, existing SOPs for sampling microplastics, where available, were adapted for the Great Lakes; where no existing SOPs were identified, the Work Group developed new SOPs. See Section 4 and Supplemental Materials C for additional detail.

3.3 Quality Assurance and Quality Control

Plastics are commonly used to manufacture clothing, as well as supplies and equipment that may be used in the field and laboratory. Therefore, steps must be taken to minimize, measure, and report the potential for sample contamination. Since analysis of microplastics involves multiple steps, care must also be taken to minimize sample loss at each step. Further, since the final analysis and detection step can be implemented using a wide range of methods, it is important to describe the methods and their key parameters such as the limit of detection (LOD).

Quality assurance and quality control (QA/QC) steps include the use of blanks and matrix spikes, and minimizing the use of plastic materials in sample collection and processing, and are described in further detail in Supplemental Materials A and in the SOPs included in Supplemental Materials C. There are several other resources available on this topic and microplastics lab analyses more broadly. Brander et al. (2020) discusses and recommends QA/QC steps associated with sampling. Recommendations for harmonized methods for lab analyses have been published elsewhere and are informing the development of standardized analytical methods. (See, for example, publications in *Chemosphere*, Special Issue: Informing methods for detecting and quantification of microplastics through the lens of a global intercalibration exercise.) Miller et al. (2021) also discusses QA/QC methods for the laboratory analysis of microplastics.

3.4 Effects of Microplastics on Great Lakes Ecosystems

Laboratory research shows that microplastics can have negative impacts on aquatic organisms of relevance to the Great Lakes. However, effects vary based on exposure concentration, particle properties, study organisms, and routes of exposure (Campanale et al., 2020). Microplastics can cause harmful biological effects, most prevalently via food dilution which is when microplastics fill the gut and reduce the nutritional quality of the diet, and tissue translocation or the uptake and accumulation of microplastic particles into tissues that can cause inflammation and oxidative stress (Koelmans et al., 2022). Additionally, due to their unique properties, microplastics may potentially act as vectors that can transport or leach toxic chemicals into organisms, although this remains an area of active research (Thornton Hampton et al., 2022a).

This study identified 62 scientific publications that evaluated the toxicity of microplastics on organisms found in the Great Lakes or that are analogous to other Great Lakes organisms. These articles were reviewed for information such as the microplastics particles tested, organisms and toxicity endpoints studied, and effects observed. Table 3-1 summarizes information from the literature review by taxon and plastic property, with higher numbers indicative of more studies having focused on a specific property of plastic and its effects on certain taxa. Additional field experiments and laboratory studies of Great Lakes species are needed to better understand the effects of microplastics on freshwater species.

Table 3-1: Freshwater Study Counts by Organism Group and Particle Characteristics

	Polymer Type						Particle Shape				Particle Size			
	Polyethylene	Polypropylene	Polystyrene	Polyamine	Polyvinyl Chloride	Mixture	Fiber	Nurdle (Sphere)	Fragment	Mixture	1 nm – 100 nm	100 nm – 1 µm	1 µm - 100 µm	100 µm – 1 mm
Zooplankton	10		8				3				2		9	
Nematode	2	1	4	1	1	1		1	1	2			3	
Amphipod	1	1	1			1	1	1		1				
Phytoplankton	2		5								1			
Macrophyte	1		2					1			1		1	
Macroinvertebrate	3		3			1		3		1		1	5	2
Mollusc	1		4			1		1	1	1	1		2	
Fish (fry, small)	2	2	3	1	1			2	1		1		3	

This IJC Science Advisory Board project also supported updates to a database that compiles information on the toxicity of microplastics. The Toxicity of Microplastics Explorer (ToMEx) database is an online repository of microplastic toxicity data developed by the SCCWRP. It includes data extracted from 162 microplastics aquatic organism ecotoxicity studies (Thornton Hampton et al., 2022b). In 2023, SCCWRP announced the development of ToMEx 2.0, which updated the database with over 150 new studies, including both marine and freshwater species. This updated database will be available early in 2025.

Figures 3-3 and 3-4 summarize results from all studies included in ToMEx 2.0 (current to January, 2023 and available early in 2025) that evaluated the impacts of microplastics on freshwater organisms, including the new studies added as described above. This study found that sufficient data exist to generate preliminary ecological risk assessment thresholds, as discussed further in Section 5. While the overall number of toxicity studies is still limited, they demonstrate that microplastics have the potential to impact freshwater species at environmentally relevant concentrations. Further research is needed to evaluate the effects of microplastics on additional Great Lakes relevant species, to understand differences between different sizes, shapes, and polymers, and to assess whether microplastics can play a role as vectors of other chemicals or pathogens.

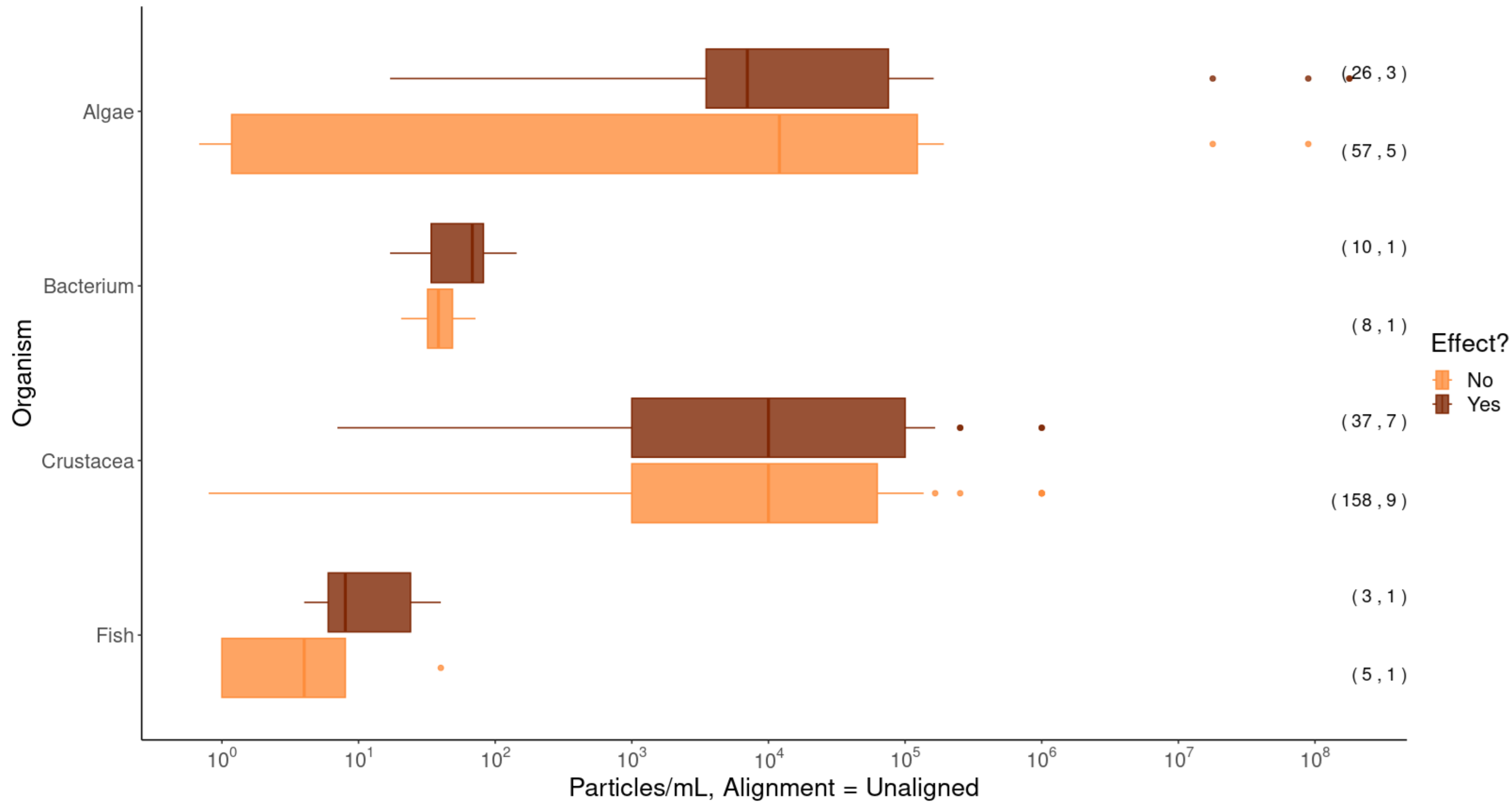


Figure 3-3: Summary of Selected Freshwater Ecotoxicological Studies, by Taxa. Results were filtered to include studies that passed minimum screening criteria built into ToMEx 2.0; considered the effects of microplastic particles with or without chemical co-exposure; reported effects on growth, mortality, and reproduction; and looked at chronic effects. Results have not been aligned to a standardized particle size range (see Supplemental Materials A and D for details on realignment and rescaling). Numbers in parentheses on the right represent the number of data points and the number of studies, respectively, for each group. The box represents the interquartile range (i.e., from the first to the third quartile), and the median is indicated by the centerline. Horizontal lines represent data within 1.5x the interquartile range from the median; outliers beyond this range are represented by dots.

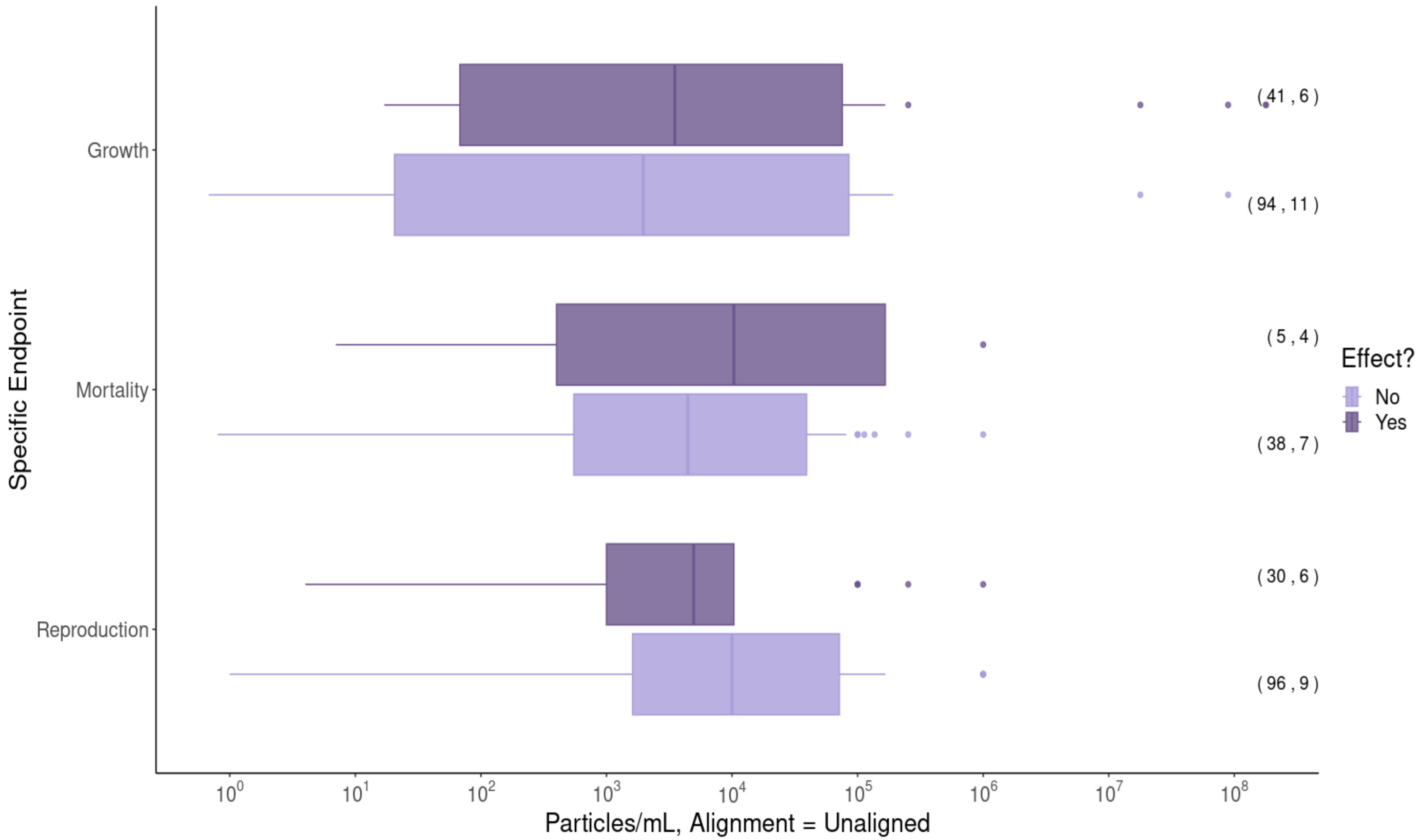


Figure 3-4: Summary of Selected Freshwater Ecotoxicological Studies, by Endpoint. Results were filtered to include studies that passed minimum screening criteria built into ToMEx 2.0; considered the effects of microplastic particles with or without chemical co-exposure; reported effects on growth, mortality, and reproduction; and looked at chronic effects. Results have not been aligned to a standardized particle size range (see Supplemental Materials A and D for details on realignment and rescaling). Numbers in parentheses on the right represent the number of data points and the number of studies, respectively, for each endpoint. The box represents the interquartile range (i.e., from the first to the third quartile), and the median is indicated by the centerline. Horizontal lines represent data within 1.5x the interquartile range from the median; outliers beyond this range are represented by dots.

4.0 Developing a Microplastics Monitoring Framework

Following the literature review and synthesis of data on microplastics occurrence and effects, the Work Group organized a workshop (Workshop #1) to solicit expert input, including recommendations and best practices that would support the development of a harmonized microplastics monitoring framework for the Great Lakes. This workshop focused on field collections and did not consider the subsequent lab analyses because considerable progress has been made in this area (see above). The Work Group decided to adopt what had already been developed by SCCWRP and others for laboratory analyses, and to harmonize with SCCWRP's current field collection protocols. The specific objectives of the workshop were to:

- Develop a harmonized monitoring framework for sampling microplastics in different media – lake and tributary waters, sediment, shorelines, and biota – and relevant to different pathways (e.g., WWTPs, runoff). The framework includes:
  - Methods for sampling each matrix.
  - Methods for QA/QC in the field.
  - Reporting requirements.
  - Advice on how monitoring programs should be designed to best capture spatial or temporal trends or to identify microplastic sources.
  - Advice on where microplastics may fit into existing Great Lakes monitoring programs to help facilitate action.

A total of 27 experts participated in the workshop, in addition to four IJC and three contractor staff. A detailed summary of workshop proceedings is provided in Supplemental Materials B. Workshop discussions focused on designing microplastics monitoring programs for a variety of settings and goals. The first session focused on designing monitoring protocols for different media including ambient lake water, tributary water, sediment, shorelines, and biota. Workshop participants were divided into five groups and each group was assigned one matrix. Participants shared their recommendations at the end of the session, which are summarized in Table 4-1

Table 4-1: Monitoring Recommendations Provided during the Workshop, by Matrix

Matrix	Sampling Methods	Other Considerations	QA/QC	Reporting Requirements
Ambient Lake Water	Use complementary methods (trawl + depth-integrated/grab). Use 6 mm tubing made of Tygon or silicon.	Use existing platforms or boats. Metal pump impellers might damage particles.	Sample blanks and duplicates. Matrix spike to determine recovery rates. Minimize plastic usages where possible.	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.	Horizontal and vertical profile measurements. Base flow measurements. Locations near monitoring stations.	Sample blanks and duplicates. Matrix spike to determine recovery rates. Minimize plastic usages where possible.	Report substrate type, conductivity, turbidity, and temperature if possible. Qualitative reporting of debris mats.
Sediment	Traps for loading rates and fluxes. Will be more responsive to source reduction interventions. Cores for time-integrated monitoring data and benthos exposure levels. Will reveal historical trends in contamination. Sampling needs to be standardized in terms of sediment core depth sampled	Co-locate traps with existing infrastructure. Use existing platforms for cores and grabs.	Field blanks to measure ambient contamination. Matrix spike to determine recovery rates. 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, waterbirds. For smaller species, sample whole animals. For larger species, collect guts and muscle tissues. Waterbird sampling opportunistically 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.	Field blanks to measure ambient contamination. Matrix spike to determine recovery rates. 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 is less important. Matrix spike to determine recovery rates.	Digital and paper records. Site photograph and GPS coordinates.

The second session focused on designing monitoring programs for three different program objectives: identifying spatial patterns, identifying temporal patterns and trends, and source apportionment and pathways. Workshop participants were divided into three groups that rotated through each of the program design objectives and shared their recommendations at the end. Table 4-2 summarizes the discussions in this session.

Table 4-2: Monitoring Program Design Recommendations for Various Objectives

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 media 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.

Day 2 of the workshop began with a review of the first day's activities. Selected workshop participants then gave "Lightning Talk" presentations on existing monitoring programs in the Great Lakes and other regions, some specifically on microplastics and others more broadly on monitoring contaminants. Participants were then asked to discuss opportunities and challenges related to implementing a harmonized monitoring strategy for microplastics within existing Great Lakes contaminant monitoring programs. 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 would responsibilities be divided between federal and state/provincial governments?" Table 4-3 provides a summary of this discussion.

Table 4-3: 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.

Following the workshop, the Work Group undertook the development of Great Lakes-specific SOPs for monitoring different media including ambient lake water, tributary water, sediment, and biota. The goal behind developing these SOPs was to provide standardized approaches for monitoring across the Great Lakes and to harmonize future Great Lakes monitoring with similar efforts being implemented in other parts of North America, including California and the Chesapeake Bay. As such, SOPs for ambient lake water, biota and sediment which were developed by the SCCWRP working group (which includes some overlapping participants to the IJC SAB Work Group and workshop participants) were adapted, with addendums included to note any specific modifications suggested for the Great Lakes. For tributary sampling, an SOP was written based on feedback at the workshop following the same outline and style as the SCCWRP SOPs. The group agreed not to include an SOP for shorelines because it was determined to be less relevant to the ecological risk assessment and management framework developed in Workshop #2. The proposed SOPs are included in Supplemental Materials C.

5.0 Developing a Microplastics Ecological Risk Assessment and Management Framework

A second workshop was organized to support the Work Group in the development of an ecological risk assessment and management framework for microplastics in the Great Lakes. The specific objectives of Workshop #2 were to:

1. Develop recommendations to inform a threshold-based ecological risk assessment framework for ambient lake water and sediment in the Great Lakes that would contextualize the results of a monitoring program and inform the potential inclusion of microplastics as a Toxic Chemicals sub-indicator for ecosystem health under the SOGL reporting.
2. Develop recommendations for a management framework linked to the threshold-based ecological risk framework.
3. Develop recommendations to inform decision-making about the inclusion of exposure and effects data as part of the coordinated ecological risk assessment and management framework.

A total of 20 experts participated in Workshop #2 (including four virtual participants), in addition to five IJC and three contractor staff. A detailed summary of workshop proceedings is provided in Supplemental Materials D.

The workshop was centered around the adaptation of an existing risk management framework for microplastic pollution recently developed by SCCWRP in California to the Great Lakes. The SCCWRP working group developed a tiered risk management framework for microplastic pollution and derived ecological risk threshold values for exposure to microplastics in ambient water (Mehinto et al., 2022) using a quantitative ecological risk assessment framework (Koelmans et al., 2020; 2022). Each management tier contains a recommended management action, which ranges from "no action required" under the "No Concern" tier to "implement pollution control measures" under the "Highest Concern" tier.

The Work Group adapted the SCCWRP framework to better align with SOGL reporting that evaluates both the *status* and *trends* of each indicator for each Great Lake. Under the Toxic Chemicals Indicator in the GLWQA, *status* is assessed based on concentrations of specific chemicals relative to thresholds of ecotoxicological concern or established guidelines. *Trends* are assessed based on the direction of concentrations over a 10 year monitoring period, recognizing that many of the sub-indicator chemicals are persistent in the environment.

Our proposed ecological risk assessment and management framework for microplastics includes two thresholds to delineate three management tiers (Figure 5-1). Thresholds for both ambient water and sediment were recommended based on available effects data for microplastics on aquatic species biologically relevant to the Great Lakes. This generally included temperate freshwater species, but with the inclusion of certain marine species where effects data on analogous Great Lakes species was not available. The thresholds were developed by constructing species sensitivity distributions (SSDs) and using the predicted hazard concentration (HC) values of HC_5 and HC_{30}, which are the estimated microplastics concentrations at which 5 percent and 30 percent of species in a community would be impacted, respectively. Workshop participants agreed that Threshold 1 should be equal to HC_5 while Threshold 2 should be equal to HC_{30}. Figure 5-2 and Table 5-1 show the SSD and corresponding HC_5 and HC_{30} values for water (along with the 95 percent confidence intervals), while Figure 5-3 and Table 5-2 show the SSD and HC_5 and HC_{30} values and confidence intervals for sediment. Overall, there was much less data available for sediment than ambient water, which is reflected in the 95 percent confidence intervals for the sediment thresholds.

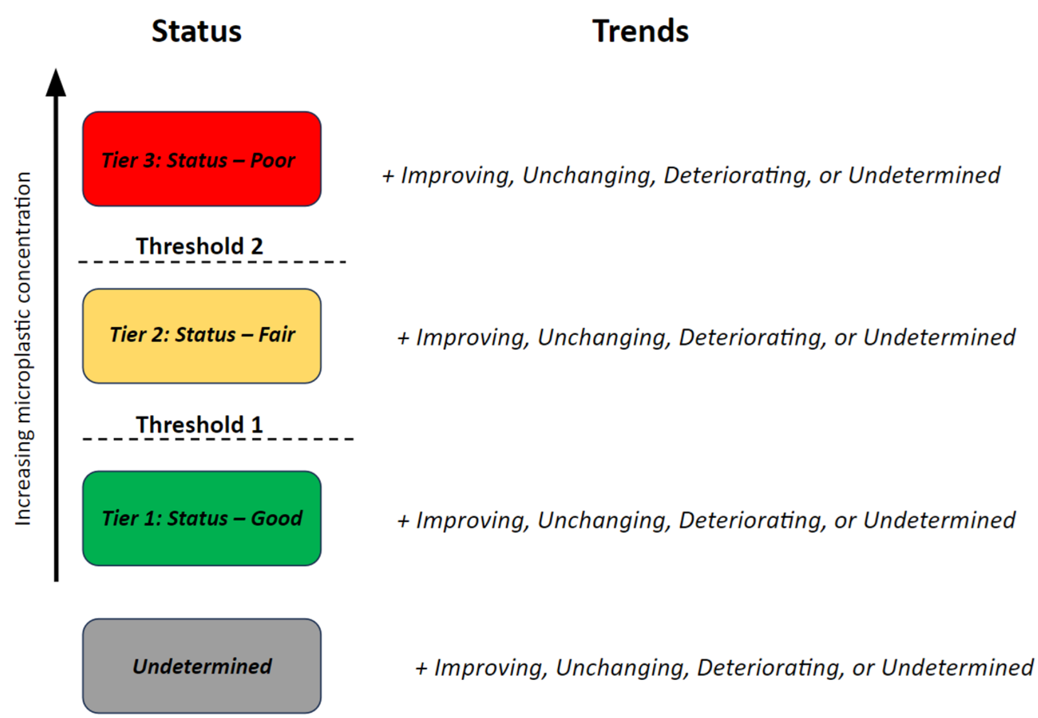


Figure 5-1: Proposed Ecological Risk Assessment and Management Framework for Microplastics in the Great Lakes

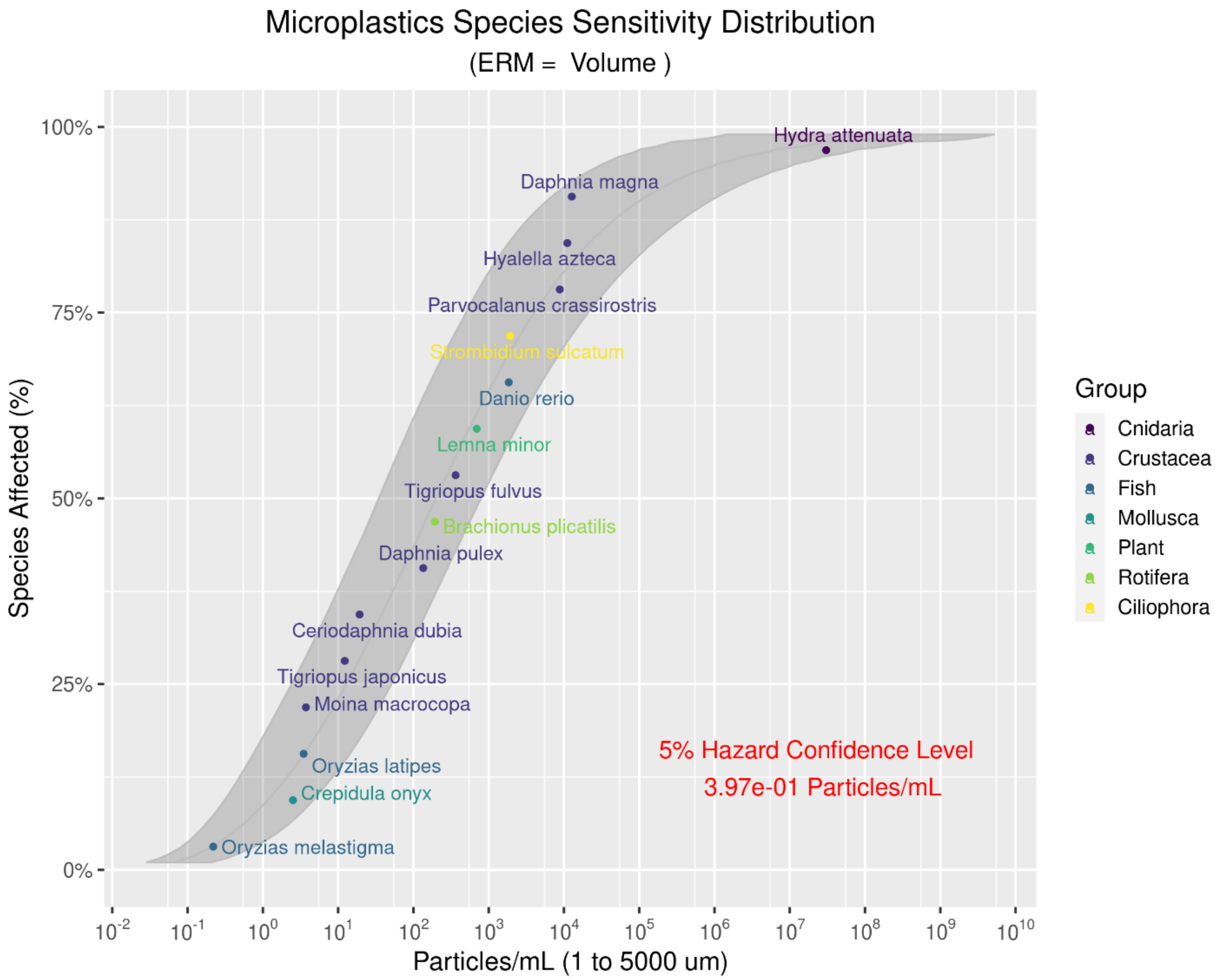


Figure 5-2[1]: Microplastic SSD for Ambient Water

Table 5-1: SSD-derived Thresholds for Ambient Water (With 95 Percent Confidence Intervals); Number of Species Included

	Hazard concentration (HC)	**Data collapsing**	**Point estimate**	**Value** (particle/L)
Threshold 1	HC_5	Geometric mean	Estimated mean	**397** (136-1,570)
Threshold 2	HC_{30}	Geometric mean	Estimated mean	**23,200** (4,320-90,500)
Total number of species: 16 • Cnidaria: 1 • Crustacea: 8 • Fish: 3 (no salmonid) • Mollusca: 1 • Plant: 1 • Rotifera: 1 • Cililophora: 1				

[1] Between Workshop #2 and the drafting of the Final Report, minor adjustments to the ambient water SSD were made after the final vetting of the data in ToMEx 2.0. As a result, the Final Report shows slightly higher HC values than those in the Workshop #2 Report.

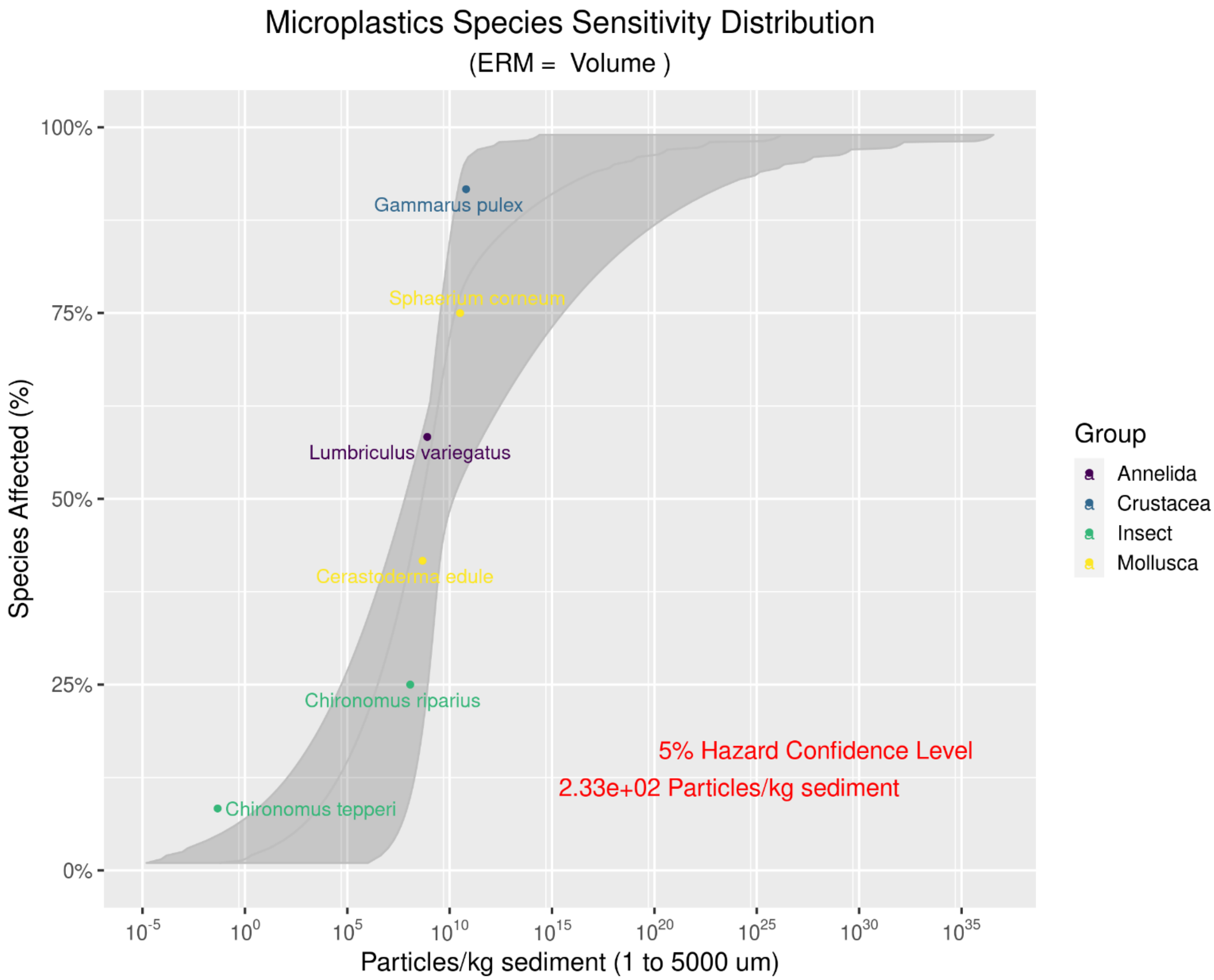


Figure 5-3: Microplastics SSD for Sediment

Table 5-2: SSD-derived Thresholds for Sediment (with 95 Percent Confidence Intervals); Number of Species Included

	Hazard concentration (HC)	**Data collapsing**	**Point estimate**	**Value** (particle/kg dw)
Threshold 1	HC_5	Geometric mean	Estimated mean	**62.6** (0.0136 - 1.78×10^7)
Threshold 2	HC_{30}	Geometric mean	Estimated mean	**6.09×10^6** (1.23×10^5 – 1.14×10^9)
Total number of species: 6 • Annelida: 1 • Crustacea: 1 • Insect: 2 • Mollusca: 2				

Workshop outputs also included a comparison of microplastics concentrations in the Great Lakes to the proposed SSD-derived thresholds (Figures 5-4 and 5-5). Lakes Michigan and Ontario appear to exceed Threshold 2 (HC_{30}) for water, while the other three lakes are approaching or exceeding Threshold 1 (HC_5). All four Great Lakes for which data are available (Erie, Huron, Michigan, Ontario) appear to exceed Threshold 2 (HC_{30}) for sediment.

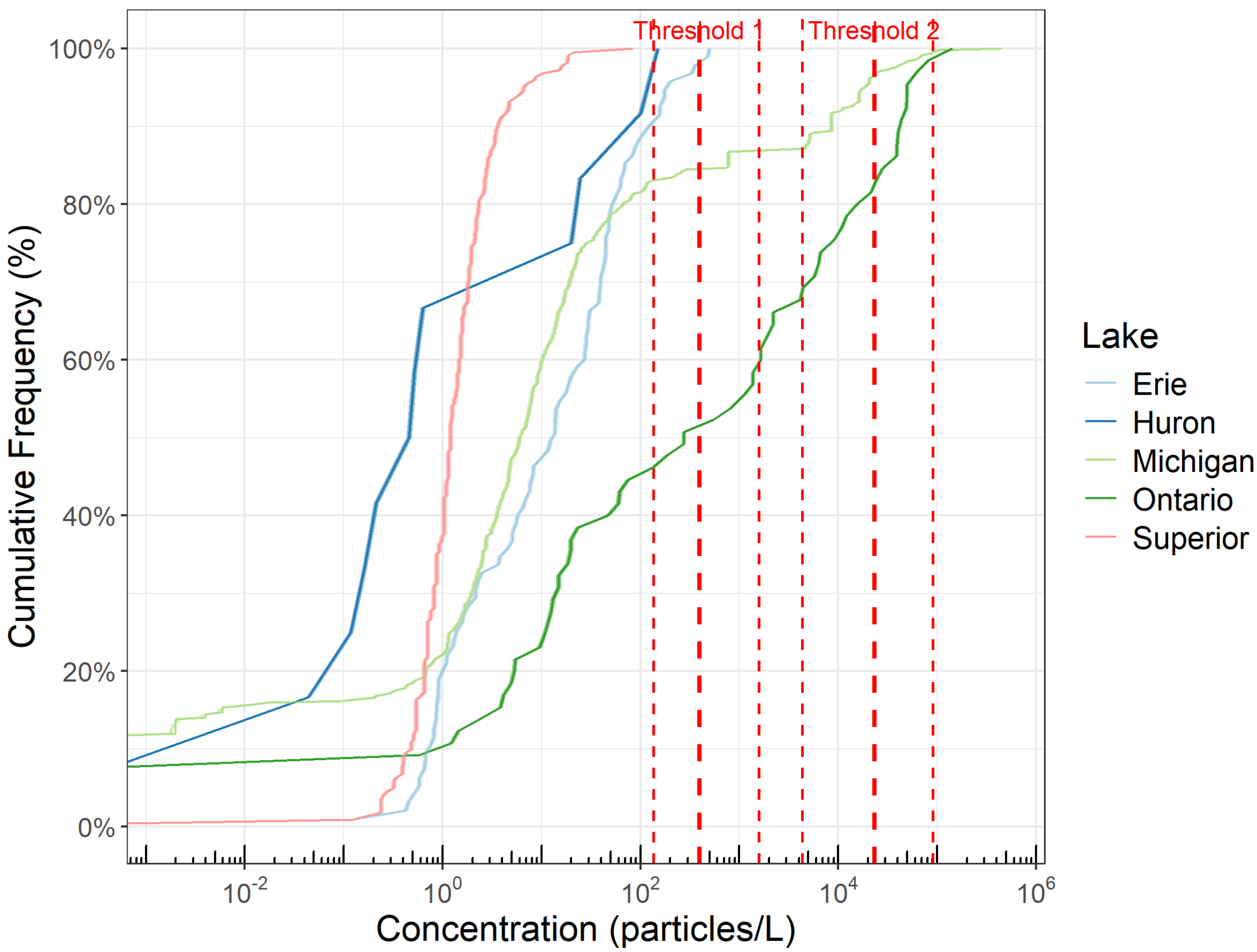


Figure 5-4: Comparing Great Lakes Microplastic Concentrations (including Tributary Data) to SSD-Derived Thresholds for Ambient Water (and their 95% CIs; see Table 5-1). Sample sizes for each lake are as follows: Lake Erie (95), Lake Huron (12), Lake Michigan (483), Lake Ontario (65), Lake Superior (220). Uncertainty in the estimates is shown by shading around the distributions (not visible here because the variability around the mean is small), and was calculated using the standard deviation of the freshwater surface water power law exponent value for particle length derived by Kooi et al. (2021; 2.64 ± 0.01).

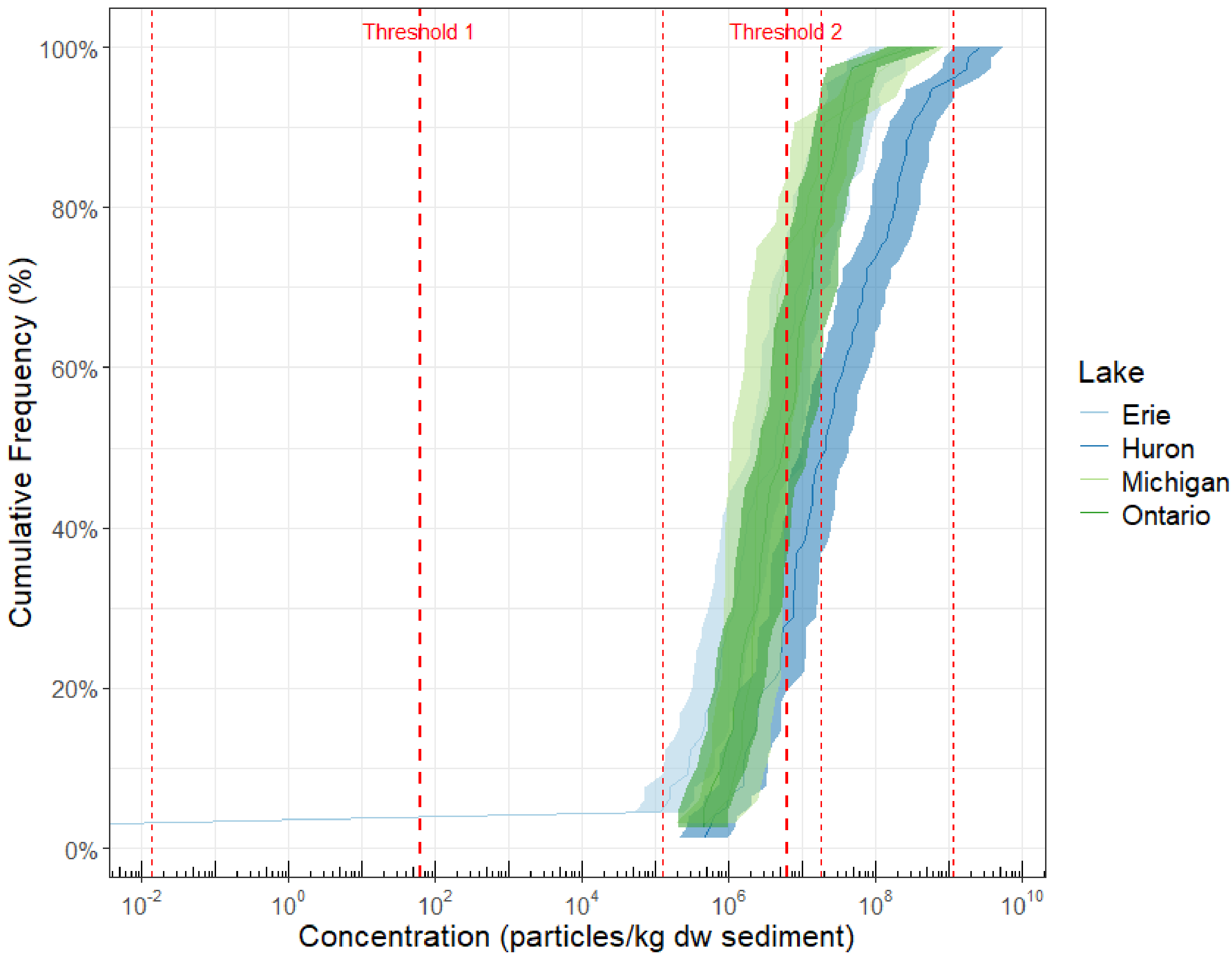


Figure 5-5: Comparing Great Lakes Microplastic Concentrations to SSD-Derived Thresholds for Sediment (and their 95% CIs; see Table 5-2). Sample sizes for each lake are as follows: Lake Erie (65), Lake Huron (76), Lake Michigan (32), Lake Ontario (40). Uncertainty in the estimates is shown by shading around the distributions, and was calculated using the standard deviation of the freshwater sediment power law exponent value for particle length derived by Kooi et al. (2021; 3.25 ± 0.19).

The workshop also recommended quality criteria for the screening and selection of studies to be used in future refinements of the SSD and risk thresholds, and for monitoring data that would provide ambient exposure concentrations for microplastics in water and sediment. Additionally, a post-workshop survey was conducted to determine participants' confidence in the ecological risk assessment framework and the threshold values. Fourteen participants completed the confidence assessment exercise. Overall, participants expressed a medium-high degree of confidence in the management framework, medium confidence in the threshold values for water, and medium-low confidence in the threshold values for sediment. See Supplemental Materials D for additional information.

Workshop #2 outcomes included an ecological risk assessment and management framework for microplastics in the Great Lakes that were based on work done by SCCWRP and that can be adopted to include microplastics as part of SOGL reporting. The framework aligns with existing reports on other sub-indicators and experts at the workshop were confident about using it to inform the GLWQA. Moreover, the ecological risk assessment tools can be iteratively updated and adapted as more toxicity data are available and/or more Great Lakes-relevant particle metrics are measured. We now have an ecological risk assessment tool for microplastics that can be used in parallel with monitoring data to measure patterns and trends, and to report the status of this contaminant within the Great Lakes.

6.0 Conclusion

An IJC Great Lakes Science Advisory Board Microplastics Work Group was established in 2022 to address growing concerns over the presence and potential ecological effects of microplastics in the transboundary waters of the Great Lakes. The main objectives of this initiative were to review the state of the science, examine and propose harmonized monitoring methods, and develop a coordinated ecological risk assessment and management framework of relevance for the Great Lakes basin. This work benefited considerably from contributions by experts at workshops and initiatives elsewhere, especially work led by several expert working groups convened by SCCWRP. Below is a summary of the findings, outcomes and recommendations of the Work Group.

Considerable progress has been made in recent years in understanding the presence of microplastics in the water, sediment and biota of the Great Lakes and their tributaries. These studies indicate that microplastics are found throughout the basin in all matrices, and that they are elevated in heavily populated areas. However, comparisons among studies and over time are hampered by the use of different sampling techniques and the lack of harmonized monitoring methods and reporting standards.

- Key outcome - A synthesis of the current state of microplastics contamination in the Great Lakes basin in a literature review (Supplemental Materials A) and database (Rochman, 2024).
- Key outcome - A standard definition of microplastics for use in Great Lakes programs.
- Key outcome - Standardized operating procedures for sampling, analyzing, and reporting microplastics in water, sediments and biota of the Great Lakes (Supplemental Materials C).

Laboratory toxicity tests show that microplastics can adversely affect species relevant to the Great Lakes. However, to understand and contextualize the ecological risk of this group of contaminants, a coordinated ecological risk assessment and management framework is needed based on the latest approaches that can assess statuses and trends for the basin within existing governance structures.

- Key outcome - Building on previous work, a coordinated ecological risk assessment and management framework was developed for the Great Lakes (Supplemental Materials D). This framework allows for the derivation of thresholds of concern based on species sensitivity distributions of toxicity data for water and sediments from a recently updated database (ToMEx 2.0, available early in 2025). This framework is aligned with SOGL reporting and uses approaches that are adaptable as more ecotoxicology data become available and local particle properties are better defined.
- Key outcome - Using this coordinated ecological risk assessment framework and existing data from the Great Lakes region, we found that some ambient water samples from the Great Lakes have concentrations of microplastics that already exceed risk thresholds of ecological concern.

Based on these findings and outcomes, we advance several recommendations to improve monitoring and ecological risk assessment regarding microplastics in the Great Lakes and their tributaries.

- Key recommendation - A regionally coordinated monitoring program following harmonized methods and adhering to consistent reporting guidelines should be implemented to inform ecological risk assessment, mitigation, and management of microplastic in the Great Lakes
- Key recommendation - The Parties should provide support for continued research by all sectors to refine monitoring and analytical capabilities as well as to strengthen ecological risk assessments. This will include developing laboratory techniques to improve detection and increase the throughput of microplastic analyses, using new laboratory methods to better understand the characteristics of microplastics in the Great Lakes to advance ecological risk assessments, testing the effectiveness and reproducibility of monitoring techniques, and expanding our understanding of the ecological effects of microplastic exposure on Great Lakes relevant species, particularly exposures in sediment.
- Key recommendation - The Parties should move to manage the risk of microplastics under the GLWQA by including microplastics as a Toxic Chemicals sub indicator under Annex 10 and as a Chemical of Mutual Concern under Annex 3.
- Key recommendation - The Parties should take steps to prevent the emissions of plastic and reduce plastic pollution in the Great Lakes, reducing environmental concentrations and preventing further ecological risk.

In addition, we suggest that IJC convene a Work Group to better understand the human health risks of microplastics in the Great Lakes basin, e.g., through drinking water and consumption of contaminated fish.

7.0 References

Boucher J., Faure, F., Pompini, O., Plummer, Z., Wieser, O., & de Alencastro, L.F. 2019. (Micro) plastic fluxes and stocks in Lake Geneva basin. TRAC-Trends Anal. Chem., 112, 66-74. https://doi.org/10.1016/j.trac.2018.11.037

Brander, S.M., Hoh, E., Unice, K.M., Bibby, K.R., Cook, A.M., Holleman, R.C., Kone, D.V., Rochman, C.M., & Thayer, J.A., 2021. Microplastic Pollution in California: A Precautionary Framework and Scientific Guidance to Assess and Address Risk to the Marine Environment. California Ocean Science Trust, Sacramento, California, USA.

Bucci, K., Tulio, M., & Rochman, C. M., 2020. What is known and unknown about the effects of plastic pollution: A meta-analysis and systematic review. Ecol. Appl., 30(2), 1–16. https://doi.org/10.1002/eap.2044

California State Water Resources Control Board (CSWRCB), 2020. Resolution No. 2020-0021 Adoption of Definition of 'Microplastics in Drinking Water'. https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2020/rs2020_0021.pdf

Campanale, C., Massarelli, C., Savino, I., Locaputo, V., & Uricchio, V. F., 2020. A detailed review study on potential effects of microplastics and additives of concern on human health. Int. J. Environ. Res. and Public Health, 17(4), 1212. https://doi.org/10.3390/ijerph17041212

D'Avignon, G., Gregory-Eaves, I., & Ricciardi, A., 2022. Microplastics in lakes and rivers: an issue of emerging significance to limnology. Environ. Rev., 30(2), 228–244. https://doi.org/10.1139/er-2021-0048

Earn, A., Bucci, K., & Rochman, C. M., 2021. A systematic review of the literature on plastic pollution in the Laurentian Great Lakes and its effects on freshwater biota. J. Gt. Lakes Res., 47(1), 120–133. https://doi.org/10.1016/j.jglr.2020.11.001

Frias, J. P. G. L., & Nash, R., 2019. Microplastics: Finding a consensus on the definition. Mar. Pollut. Bul., 138, 145–147. https://doi.org/10.1016/j.marpolbul.2018.11.022

Geyer, R., Jambeck, J. R., & Law, K. L., 2017. Production, use, and fate of all plastics ever made. Sci. Adv., 3(7), e1700782–e1700782. https://doi.org/10.1126/sciadv.1700782

Great Lakes Commission (GLC), 2023. About the Lakes. https://www.glc.org/lakes/

Helm, P. A., 2017. Improving microplastics source apportionment: a role for microplastic morphology and taxonomy? Anal. Methods, 9(9), 1328–1331. https://doi.org/10.1039/c7ay90016c

Helm, P.A., 2020. Occurrence, Sources, Transport, and Fate of Microplastics in the Great Lakes–St. Lawrence River Basin, in: Crossman, J., Weisener, C. (Eds) Contaminants of the Great Lakes. The Handbook of Environmental Chemistry, vol 101. Springer, Cham. https://doi.org/10.1007/698_2020_557

Holmes, C. M., Dyer, S. D., Vamshi, R., Maples-Reynolds, N., & Davies, I. A., 2020. A National-Scale Framework for Visualizing Riverine Concentrations of Microplastics Released from Municipal Wastewater Treatment Incorporating Generalized Instream Losses. Environ. Toxicol. and Chem., 39(1), 210–219. https://doi.org/10.1002/etc.4610

International Joint Commission (IJC), 2017, February. International Joint Commission Recommendations on Microplastics in the Great Lakes. https://ijc.org/en/international-joint-commissions-recommendations-microplastics-great-lakes

IJC, 2012, September 7. *Great Lakes Water Quality Agreement (GLWQA)*. https://www.ijc.org/sites/default/files/2018-07/GLWQA_2012.pdf

Interstate Technology Regulatory Council (ITRC), 2023. *Microplastics*. https://mp-1.itrcweb.org/

Koelmans, A. A., Redondo-Hasselerharm, P. E., Mohamed Nor, N. H., & Kooi, M., 2020. Solving the Nonalignment of Methods and Approaches Used in Microplastic Research to Consistently Characterize Risk. *Environ. Sci. & Tech.*, *54*(19), 12307–12315. https://doi.org/10.1021/acs.est.0c02982

Koelmans, A.A., Redondo-Hasselerharm, P.E., Nor, N.H.M. et al., 2022. Risk assessment of microplastic particles. Nat. Rev. Mater. 7, 138–152. https://doi.org/10.1038/s41578-021-00411-y

Kooi, M., Primpke, S., Mintenig, S. M., Lorenz, C., Gerdts, G., & Koelmans, A. A., 2021. Characterizing the multidimensionality of microplastics across environmental compartments. Water Res., 202, 117429. https://doi.org/10.1016/j.watres.2021.117429

Martindale, S., Weisberg, S. & Coffin, S., 2020. Guest Forum: Status of Legislation and Regulatory Drivers for Microplastics in California. Readout Horiba Technical Reports, 54: 17-22.

McIlwraith, H.K. & Rochman, C.M., 2020. Scoping Plastics as a Sub-indicator for State of the Great Lakes Reporting. University of Toronto, Department of Ecology and Evolutionary Biology, Toronto, ON, Canada

Mehinto, A. C., Coffin, S., Koelmans, A. A., Brander, S. M., Wagner, M., Thornton Hampton, L. M., Burton, A. G., Miller, E., Gouin, T., Weisberg, S. B., & Rochman, C. M., 2022. Risk-based management framework for microplastics in aquatic ecosystems. Microplast. and Nanoplast., *2*(1), 17–10. https://doi.org/10.1186/s43591-022-00033-3

Miller, E., Sedlak, M., Lin, D., Box, C., Holleman, C., Rochman, C. M., & Sutton, R., 2021. Recommended best practices for collecting, analyzing, and reporting microplastics in environmental media: Lessons learned from comprehensive monitoring of San Francisco Bay. J. Hazard. Mater., 409, 124770. https://doi.org/10.1016/j.jhazmat.2020.124770

Office of the Auditor General of Ontario, 2023. The State of the Environment in Ontario. https://www.auditor.on.ca/en/content/specialreports/specialreports/The_State_Of_The_Environment_EN.pdf

Rochman, C. M., Brookson, C., Bikker, J., Djuric, N., Earn, A., Bucci, K., Athey, S., Huntington, A., McIlwraith, H., Munno, K., De Frond, H., Kolomijeca, A., Erdle, L., Grbic, J., Bayoumi, M., Borrelle, S. B., Wu, T., Santoro, S., Werbowski, L. M., Zhu X., Giles, R.K., Hamilton, B.M., Thaysen, C., Kaura, A., Klasios, N., Ead, L., Kim, J., Sherlock, C., Ho A., & Hung, C., 2019. Rethinking microplastics as a diverse contaminant suite. Enviro. Toxicol. and Chem., 38(4): 703–711. https://doi.org/10.1002/etc.4371

Rochman, C., 2024. *IJC Microplastics Work Group 2024* [dataset]. University of Toronto Dataverse. https://doi.org/10.5683/SP3/MSXET0

Thornton Hampton, L. M., Brander, S. M., Coffin, S., Cole, M., Hermabessiere, L., Koelmans, A. A., & Rochman, C. M., 2022a. Characterizing microplastic hazards: which concentration metrics and particle characteristics are most informative for understanding toxicity in aquatic organisms? Microplast. and Nanoplast., *2*(1), 1–16. https://doi.org/10.1186/s43591-022-00040-4

Thornton Hampton, L. M., Lowman, H., Coffin, S., Darin, E., De Frond, H., Hermabessiere, L., Miller, E., de Ruijter, V. N., Faltynkova, A., Kotar, S., Monclús, L., Siddiqui, S., Völker, J., Brander, S., Koelmans, A. A., Rochman, C. M., Wagner, M., & Mehinto, A. C., 2022b. A living tool for the continued exploration of microplastic toxicity. Microplast. and Nanoplast., *2*(1), 1–11. https://doi.org/10.1186/s43591-022-00032-4

Twiss, M. R., 2016. Standardized methods are required to assess and manage microplastic contamination of the Great Lakes system. J. Gt. Lakes Res., 42(5), 921–925. https://doi.org/10.1016/j.jglr.2016.07.032

United Nations Environment Programme (UNEP), 2021, October 21. Drowning in Plastics – Marine Litter and Plastic Waste Vital Graphics. https://www.unep.org/resources/report/drowning-plastics-marine-litter-and-plastic-waste-vital-graphics

United States Environmental Protection Agency (USEPA), 2023. Draft National Strategy to Prevent Plastic Pollution. https://www.epa.gov/circulareconomy/draft-national-strategy-prevent-plastic-pollution

Verdú, I., Amariei, G., Plaza-Bolaños, P., Agüera, A., Leganés, F., Rosal, R., & Fernández-Piñas, F., 2022. Polystyrene nanoplastics and wastewater displayed antagonistic toxic effects due to the sorption of wastewater micropollutants. Sci. of the Total Enviro., 819, 153063. https://doi.org/10.1016/j.scitotenv.2022.153063

Wang, J., Bucci, K., Helm, P. A., Hoellein, T., Hoffman, M. J., Rooney, R., & Rochman, C. M., 2022. Runoff and discharge pathways of microplastics into freshwater ecosystems: A systematic review and meta-analysis. Facets (Ottawa), 7(1), 1473–1492. https://doi.org/10.1139/facets-2022-0140

Weir, E. M., Kidd, K. A., Hamilton, B. M., Wu, J., Servos, M. R., Bartlett, A. J., Tetreault, G. R., & Gillis, P. L., 2024. Microparticles in Wild and Caged Biota, Sediments, and Water Relative to Large Municipal Wastewater Treatment Plant Discharges. Enviro. Toxicol. and Chem., 43(5), 1047–1061. https://doi.org/10.1002/etc.5836