Plastic Pollution in the Canadian Great Lakes: Drivers, Barriers and Policy Recommendations

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Plastic pollution is detrimental to the economy, the environment and human health. More research has been conducted on marine plastic pollution than on freshwater plastic pollution, even though rivers and lakes have been discovered as substantial sources and sinks for plastic debris, transporting plastics to the oceans. Through Canada's voluntary international pledges at the G20 and G7, and national legislative development such as the Microbeads in Toiletries and Single-use Plastic Prohibition Regulations, there are currently commitments towards full waste recovery and plastic pollution prevention. Plastic pollution in the Great Lakes is a complex problem because of the ubiquity of plastic debris and the myriad of plastic transportation pathways. Moreover, there is a scarcity of studies on the incorporation of local stakeholder engagement in pollution prevention decision-making. Because local stakeholders are agents of change, it is vital to investigate and utilize local perceptions and diverse expertise in decision-making. This study intends to fill this gap by exploring current challenges and interpreting best practices for pollution prevention, through eliciting local experts' perceptions. To do so, this study adopted a hybrid methodology that combines a desk-based literature analysis and semi-structured interviews (n=21). Semi-structured interviews were performed with key informants from the private sector, public sector, non-profit organizations or NGOs, and academia, who have knowledge of or have participated in plastic pollution prevention in Canada. Content analysis using inductive and deductive coding of qualitative interview data yielded practical information on current challenges and suggestions to address them. Qualitative interview data were supplemented by triangulation of a Canadian national and Ontario provincial policy review and cross-validating concepts proposed by key informants. Results revealed a multifaceted picture of stakeholders' perspectives, including parallels and contrasts in viewpoints. Using the CCME waste hierarchy as a methodological framework, this study revealed stakeholders' preference for preventive instruments above value recovery or clean-ups of plastic waste. First, respondents identified two significant sources of pollution that must be addressed, being (1) multi-source plastic leakage and (2) individual consumer consumption and poor behaviors that led to plastic leakage. Second, important barriers to overcome were highlighted as (1) deficiency in enforceable binational, national, and provincial policies, (2) inaction from the private sector, governments, and the average consumers, and (3) a lack of capacity on several frontiers, particularly in accommodating alternatives to using single-use plastics. Third, taking multiple

perspectives into account, the findings of this study identified relevant rights-based, policy-based, and behavior-based action framework items that would assist policy development and future action plans in the Canadian Great Lakes. Future inter-disciplinary investigations should include assessing the effectiveness of voluntary and regulatory instruments, building consensus among stakeholders from various sectors, and investigating effective techniques to facilitate behavior changes that can be incorporated into all future preventive efforts.

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List of Abbreviations

ECCC	Environment and Climate Change Canada
CCME	Canadian Council of Ministers of the Environments
CEPA	Canadian Environmental Protection Act
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
GLPC	Great Lakes Plastic Clean-up
GLWQA	Great Lakes Water Quality Agreement
LAMP	Lake-wide Action and Management Plan
MECP	Ministry of the Environment, Conservation and Parks
PPE	Personal Protective Equipment
RPRA	Resource Productivity and Recovery Authority
RPUC	Responsible Plastic Use Coalition
SUPPR	Single-use Plastic Prohibition Regulations
The Strategy	Canada-wide Strategy on Zero Plastic Waste and Action Plan

Chapter 1: Introduction

1.1: The Problem

Plastic waste is not being recycled sufficiently in Canada, and it is leaking into the Great Lakes. Data has shown that in 2010, the estimated amount of plastic waste generated globally was around 275 million tones (Deloitte et al., 2019a; Jambeck et al., 2015). Most of this waste was transported to landfills or travelled into other terrestrial or marine environments. Only about 9% of discarded plastic got recycled (Jambeck et al., 2015). A national investigation into the Canadian's plastic flows commissioned by Environment and Climate Change Canada (ECCC) estimated that in 2016, Canada only recycled 9% and incinerated another 4% (for energy recovery) of its total plastic waste. This left 86% of plastic waste to accumulate in landfill, and at least 1% leaked into the environment (Deloitte et al., 2019a). Globally, North America alone contributed to 14% (valued at $14.3 billion USD) of plastic waste export to China. However, as of 2017, China passed regulations that enhance management and decrease quantities of international plastic imports (Yoshida, 2022). With this change that hinders international plastic export, Canada now seeks alternative methods to deal with its plastic waste output. Storing plastics in landfill is only a temporary option as space will soon run out (CCME, 2019).Plastic debris from urban centers leaked into rivers and lakes, which can then be transported into oceans. Meijer et al. (2021) utilized both field observations and existing data sources to estimate that the global network of rivers contributes from 0.8 to 2.7 million tons of plastics to the annual leakage into oceans (Meijer et al., 2021). With a predominantly poor recycling and repurposing rate, the growing quantities of plastics ultimately pollute the surrounding environments and threaten the economy, the environment and human health.

Plastic pollution in the freshwater environment is a costly problem (Brouwer et al., 2017). Beaumont et al. (2019) estimated that collection efforts could cost within a range from USD 3,300 to 33,000 per 1 ton of marine plastic debris, based on analysis of the 2011-level marine ecosystem economic values and 2011 input of plastics into the oceans globally (Beaumont et al., 2019). Hoffman and Hittinger (2017) estimated an annual input of plastic waste of 9,887 metric tons for the Great Lakes waterways (Hoffman & Hittinger, 2017). Theoretically, if the analysis of Beaumont et al. (2019) applies to the Great Lakes region, tackling plastic pollution within the Great Lakes can cost from $32,627,100 to $326, 271, 000. Pollution Probe, a

Canadian charitable environmental organization, reports that managing plastic pollution in the Great Lakes might require up to $400 million annually (Pollution Probe, 2020).

There is a disproportionate focus on the marine plastic problem when compared to that on plastics in freshwater environments (Blettler et al., 2018). Rivers are an important source for marine plastic pollution (Lebreton et al., 2017). Due to the magnitude of plastic pollution across all waterways, a focus on freshwater plastic will help to provide a balanced picture in examining pollution within the plastic-sphere. This study's focus on freshwater plastic was inspired by not only knowledge gaps but also emerging Canadian federal and international-level commitments. Canada is currently a member in the G7, a group that unites the largest economies globally including France, Germany, Italy, Japan, the United Kingdom, the United States, and the European Union, pledging to coordinate responses towards global crises (Government of Canada, n.d.-a, p. 7). During Canada's presidency of the G7 in 2018, it introduced the Ocean Plastic Charter, which lays out guidance to effectively address and solve the marine plastic pollution crisis. Canada provides ambitious commitments towards a life cycle-based approach for plastic management, improving reuse and recycling, and engaging multiple partners such as international organizations, different levels of government and the private sector (Government of Canada, 2018a). At the national level, The Government of Canada has updated the List of Toxic Substances under Schedule 1 of the Canadian Environmental Protection Act CEPA (1999) as of May 12th, 2021 to include item #133 "plastic microbeads that are < or = to 5mm in size", and #163 "Plastic manufactured items" (Government of Canada et al., 2021). This allows plastics to be further regulated. Recent international and national pledges made on plastic pollution from the Government of Canada propel growing interest in tackling plastic pollution. National voluntary and mandatory measures towards plastics would have impacts on freshwater plastic pollution.

1.2: Knowledge Gaps

Examining stakeholders' perceptions is essential in determining further actions for freshwater plastic pollution. According to existing investigations, researchers have classified plastic pollution as a complex socio-environmental issue. Therefore, plastic pollution in the Canadian Great Lakes requires the collaboration and contributions of several people who may be affected by the problem (Heidbreder et al., 2019; Nielsen et al., 2020; Yusuf et al., 2022). Thus, understanding how stakeholders perceive the plastic pollution problem within the Great Lakes

watershed in Canada is necessary. Yet, existing literature examining stakeholder knowledge and values within the Great Lakes watershed context is especially scarce, even though the Great Lakes are home to approximately 20% of the planet's freshwater resources (EPA, 2022). Actors who are involved in all steps within the plastic cycle (Nielsen et al., 2020) are from various sectors; they play essential roles in pollution prevention (Heidbreder et al., 2019). Additionally, technical interventions such as clean-up technologies or innovative bio-degradable alternatives that would decrease plastic circulation within the natural environment cannot overlook the human behavior and perception dimensions, because they can undermine the effectiveness of such interventions through conflicts of interests or actions like littering (Heidbreder et al., 2019). Canada's growing interest in tackling plastic pollution necessitates the incorporation of local stakeholders' wide range of knowledge and values (Reed, 2008). Eliciting stakeholders' understanding and viewpoints on an environmental issue enhances the ethic and trust of decision-making for environmental considerations (Reed, 2008).

Moreover, the need to explore stakeholders' diverse viewpoints and incorporating them into solution development for pollution prevention ensures the relevance and comprehensiveness of potential solutions for plastic pollution in the Canadian Great Lakes (Reed, 2008). There are conflicting responses towards Schedule 1 of the Canadian Environmental Protection Act CEPA (1999)'s amendment to include some types of plastics. While many environmental groups and activists express support (Fawcett-Atkinson, 2021; Oceana Canada, 2020), some other stakeholders oppose it. Recently, several petrochemical companies and plastic packaging producers have co-founded the Responsible Plastic Use Coalition (RPUC) to "pursue legal action against the federal government" following the Schedule 1 amendment (Fawcett-Atkinson, 2021; RPUC, 2021). Interestingly, Canada is not the first country to implement such legislation as the United States have passed similar regulations at state and nation-wide levels (Schroeck, 2016). In an article analyzing political responses towards microplastics in water, Schroeck (2016) analyzed concerns in the United States over the phrasing or choices of words within American regulations. Schroeck (2016) highlighted potential loopholes as results of word choices for defining regulated products and the complexity of the regulation networks that could negatively compromise the effectiveness of these regulations (Schroeck, 2016). These conflicts resulting from a change in policy may complicate future roadmaps for freshwater plastics (Frantzi et al.,

2021; Schroeck, 2016), thus signaling a need to explore diverse perspectives from stakeholders who have had experience with freshwater plastic across sectors.

Emerging literature increasingly pays attention to capturing perspectives and ideas from interviewing diverse groups of experts who may be involved in plastic pollution. For example, Cowan et al. (2021) conducted semi-structured interviews and workshops with participants from diverse backgrounds in Norway and Slovenia focusing on marine plastic pollution. Participants were asked about their perceptions, drivers of change and recommendations towards both an innovative product and the issue of plastics in the environment. Results yielded meaningful conceptual "mind maps" containing themes of preferences, opportunities for innovation, and suggestions for further actions in terms of consumer behaviors, policy development, business investment and technological innovation (Cowan et al., 2021). This study, among others, supports a need for exploring stakeholders' knowledge and opinions towards sustainably addressing plastic pollution. This is particularly important when conflicting perspectives, levels of knowledge and personal values of people engaged in the plastic cycle can both alter plastic actions and provide valuable insights into sustainable solutions (Frantzi et al., 2021; Oceana Canada, 2020; Wagner & Lambert, 2018; Walker, 2021). Cowan et al. (2021) boasted an extensive scope that encompassed several workshops spanning two countries and participant groups with experts and concerned citizens (students). To keep the scope of this study manageable and ensure relevant data is collected, prospective participants for this study excludes concerned citizens. There is a lack of studies that can deliver an overview of the rapid changes in the freshwater plastic landscape, or an analysis of stakeholders' perspectives and knowledge, similar to that of Cowan et al. (2021), with a focus on plastics in freshwater habitats. Therefore, this study aims to contribute to the existing literature by filling this gap.

1.3: Research Objectives

This study aims to elicit stakeholder perceptions and attitudes of freshwater plastics pollution in the Canadian Great Lakes to inform decision-making and policy development, through exploring current challenges and interpreting best practices and recommendations. A "stakeholder" was defined broadly as a person or group who bears a risk or a "stake", and has the potential to influence or is influenced by an "organization's objectives" (Mitchell, 2022). This criterion has now been used more generally in environmental studies to explain the involvement of specialists from many fields (Mitchell, 2022; Stanghellini, 2010). Furthermore, it is becoming

increasingly clear that working with stakeholders and incorporating varied knowledge is required for more effective and equitable natural resource management (Stanghellini, 2010), which includes plastic pollution control to safeguard the integrity of freshwater environments. To keep the scope of the study manageable and data collection relevant, a "stakeholder" or "participant" within this study is defined as an expert who has had varying degrees of exposure to plastic pollution and stands to gain or lose benefits from plastic pollution outcomes within the Canadian Great Lakes context. To best prepare for this purpose, this study answers the following research questions:

1. What are major drivers behind plastics pollution in the Canadian Great Lakes?
2. What are perceived key challenges by different groups of stakeholders to manage plastic waste more sustainably before it ends up in the water and once it is in the water?
3. What can be done to address these challenges?

This study employs a mixed-method methodology, in which the primary data collection through semi-structured interviews is supplemented by secondary data collection in the form of a literature review to answer the above research questions. In addition, to answer these research questions, this study differentiates between a "driver" and a "barrier". A "driver" in this study is regarded as a process, an object or other driving factors that contribute or accelerate plastic pollution within the Canadian Great Lakes. A "barrier" is any processes, persons or elements that prevent Canada from taking further actions towards addressing and preventing plastic pollution in the Great Lakes. The literature review results delivers an overview of plastics as emerging pollutants within the Canadian Great Lakes, opportunities, and barriers to advance plastic pollution prevention within the Canadian Great Lakes context. The data analysis reveals themes and trends of not only a comprehensive understanding on plastic pollution within the Canadian Great Lakes, but also the drivers and recommendations for solutions that best represent real-world experiences and perceptions of the various stakeholders involved.

1.4: Structure of This Thesis

The Literature Review chapter proceeds the Introduction chapter. The Literature Review chapter has multiple purposes. First, it aims to provide an overview of the plastic pollution-related policy landscape within Canada. Second, it examines the Canadian Council of Ministers of the Environment (CCME)'s waste hierarchy framework and shows how it will be implemented within this study. Third, it represents a brief analysis of the gaps and related

implications posed by this policy landscape, and how these affect freshwater plastic pollution in Canada. Fourth, this section seeks to explain the drivers and magnitude of freshwater pollution in the Great Lakes, which will help to emphasize the importance of the study's objective. Moreover, results from this section will be used as secondary data collection, thus supporting the primary data analysis. Next, the Methodology chapter provides further information about the rationale behind the selected mixed-method methodology and clarifies mechanisms of data collection. The Result chapter of this thesis presents the empirically obtained results and observations from both primary and secondary data collection. Furthermore, these two data streams will help to further unravel differences in stakeholders' perspectives, themes, and the resulting voluntary and mandatory actionable items to support the study's main objectives. The fifth chapter demonstrates a discussion of results, policy implications and opportunities for future research. Finally, the Appendix contains the interview protocol and supporting tables of data.

Chapter 2: Literature Review

2.1: Plastics in the Canadian Great Lakes

Plastic is ubiquitous in both marine and freshwater environments. Ample evidence from literature suggests that freshwater plastic pollution is as large of an issue as marine plastic pollution. Researchers have declared microplastics an emerging contaminant of the Great Lakes (Wagner & Lambert, 2018). A popular approach in identifying plastics in the environment is by size. Plastic debris is generally broken down into three types: macro-plastics, microplastics and nano-plastics. Macro-plastics are large pieces of trash, greater than 5mm in size, that are easily visible to the human eye such as water bottles, plastic bags, and plastic straws (M. Cole et al., 2011). Micro-plastics refers to plastic particles that are 1 μmm to 5mm (Vassilenko et al., n.d.) . Nano-plastic is defined as "particles unintentionally produced (i.e., from the degradation and the manufacturing of the plastic objects) and presenting a colloidal behavior, within the size range from 1 to 1000 nm" (Gigault et al., 2018). Most anthropogenic pollutants within marine habitats are plastics, with an annual 14-million-ton discharge approximately (UNEP, 2020). For example, microplastics are present in surface and sub-surface marine environments as well as sediment beds (Gago et al., 2020; Oceana Canada, 2020). Similarly, plastics are found in surface water, sub-surface zones and sediment beds within the Great Lakes' waterways (Earn et al., 2021).

Plastic litter threatens freshwater biota. Plastics visible to humans are either a nuisance or a fatal threat to many marine species due to risks of entanglement and ingestion (Browne et al., 2011). When exposed to the external environment with varying factors such as bacteria and solar radiation, macro-plastics break down into much smaller macro and nano-sized plastics (Driedger et al., 2015; Lebreton et al., 2017; Waring et al., 2018). Due to their persistence in the environment, plastic litter could act as an ideal transportation pathway for invasive species, potentially altering biodiversity (Jambeck et al., 2015). Additionally, micro-plastics disrupts the freshwater food chain. Munno et al. (2022) investigated fish plastic ingestion in the Great Lakes. They detected microplastics in fish samples from Lake Ontario, Humber River and Lake Superior, with a sample of fish containing 915 anthropogenic and plastic particles, "the highest concentration (…) ever found in a bony fish" (Munno et al., 2022). Moreover, there is a significant risk of bioaccumulation and toxicity. Depending on their composition, microplastics can absorb significant quantities of heavy metals within their surrounding water. Species that

mistake microplastics for food can suffer endocrine disruption, modified hunting behaviors or growth inhibition (Naqash et al., 2020). With impacts on freshwater biota still under investigation, preventive measures against plastics in rivers and lakes are necessary to protect the well-being of freshwater organisms.

In addition to presenting ecological concerns, plastic pollution is also a threat to human health. Instances of humans ingesting plastic particles through drinking water, atmospheric deposition, and consumption of seafood are raising alarms and concerns (Waring et al., 2018; Wright & Kelly, 2017). Microplastics may contain bacteria and carcinogens that accumulate in drinking water and food sources (Azoulay et al., 2019; Waring et al., 2018), potentially entering human bodies as early as the human placenta (Ragusa et al., 2021). Wright and Kelly (2017) and Waring et al. (2018) suggested bioaccumulation of micro and nano-plastics within the human body could potentially have chronic toxicity or trigger adverse reactions in the central nervous system or reproductive system. Although future investigations into several impacts of plastic ingestion on human health are necessary (Ragusa et al., 2021; Waring et al., 2018; Wright & Kelly, 2017), it's reasonable to regard the presence of plastics in drinking water sources within the Great Lakes a human health concern.

Plastics can leak into the environment through multiple pathways, such as atmospheric deposition, leakage from landfills (Hoellein & Rochman, 2021), littering, stormwater (Werbowski et al., 2021), wastewater treatment plants' effluent (Meng et al., 2020), sewage sludge or biosolids (Windsor et al. 2019), leakage from manufacturing and transportation processes and agriculture through irrigation (Crossman et al., 2020) to name a few (Borrelle et al., 2020; Hoellein & Rochman, 2021). While there are environmental mechanisms (such as degradation due to UV light or abrasion due to friction) that break down macro-plastics into microplastics or smaller particles, land-based anthropogenic activities also release plastics into waterways (Eriksen et al., 2018). For example, littering at beaches was found to be a notable cause for on-shore plastic pollution (Vincent & Hoellein, 2021).

Although existing literature on plastic pollution in the Great Lakes investigates both macro and micro-plastic pollutants, a priority towards microplastics emerges. In their systematic review of papers from 2000 to 2017 across the Laurentian Great Lakes watershed, Earn et al. (2021) reported highest microplastic concentrations within the Great Lakes system (Earn et al., 2021). For surface water, existing peer-reviewed sources estimated Lake Erie to have the highest

concentration of microplastics at up to 1,264,293 particles/km^2, followed by Lake Huron at up to 885,599 particles/km^2, and Lake Superior at up to 318,241 particles/km^2 (Earn et al., 2021). In addition, Mason et al (2020) sampled microplastic particles on surface water of the Great Lakes over a two-year period and illustrated an average concentration for Lake Erie of about 45,000 particles/km^2 and for Lake Ontario at 230,000 particles/km^2. Consequently, on average, Lake Ontario was found to have the highest concentration of microplastics on surface water. Fragments were the most common (about 63% of samples), followed by pellets, line, film and foam (Mason et al., 2020). Regarding a mixture of macroplastics and microplastics' quantification, other findings classified dominant plastic types in the Great Lakes to be single-use plastic garbage, fragments, microfibers, and pellets (Earn et al., 2021). Earn et al. (2021) also analyzed clean-up results from Ocean Conservancy's International Coastal Cleanup, obtained from clean-up occasions between 2016 and 2018. Single-use plastics were the most prevailing pollutants. Specifically, identifiable plastic debris sorted from highest to lowest concentrations were cigarette butts, food wrappers, bottle caps, bottles, plastic bags, and drink stirrers. Pollutant capture data showed variety in sizes, as these fragments can be large or small (Earn et al., 2021; Rochman et al., 2021). Due to a disparity in quantifying microplastic particles within the Great Lakes (for example, reporting on either high or low concentrations, or mean concentration rates), it is difficult to aggregate and compare data sets. Both macro and micro-plastic fragments, along with other plastic types, are prominent pollutants within the Canadian Great Lakes.

Additionally, existing literature presented increasing details on the transportation pathways, fates, chemistry, and other related scientific aspects of plastic pollution. Significantly fewer sources elaborated on other aspects such as stakeholders' perceptions, legislative and regulatory instruments for pollution prevention, and economic impacts. Aside from scientific investigations on topics such as systematic literature review on the state of plastic pollution sciences, plastic pollutant identification, transportation pathway modeling, and pollutant quantification, few sources presented objectives that were tailored to either the Great Lakes or the Canadian legislative and geographic contexts. Notably, searches on (1) the pandemic's influence on plastic pollution in the Great Lakes and (2) measuring the impacts of the Microbeads Ban on the same issue yielded no relevant results. Therefore, peer-reviewed paper search on these two topics, along with the following information, extended to international sources: to provide background information on the ecological and human health impacts of

freshwater plastic pollution, systematic reviews on freshwater plastic pollution science investigations, and the effectiveness of policy instruments on reduction of plastic pollution.

Microplastics dominated scientific investigations due to their ubiquitous nature within freshwater and their minuscule sizing, posing great difficulties in tracking and removal. Microplastic extraction from water has primarily been done through scientific investigations using sophisticated physical collection (such as specialized netting or microplastic trawl) or chemical-based tools (Kurniawan et al., 2021). For sediment beds, data prominently identified the highest concentration of microplastics in Lake Ontario and second highest in Lake Erie (Corcoran et al., 2015, 2020). Plastic compositions of existing samples were uncertain; however, Earn et al. (2021) noted the presence of microfiber (Earn et al., 2021). Elaborating further, Athey and Erdle (2021) analyzed peer-reviewed research papers on microfiber detection and concluded that microfibers existed in both marine and freshwater, on surface water and in sediment beds. The distinction between natural microfibers (for example, from plant matter) and synthetic microfibers (for example, in textile with plastic materials) was indeterminate (Athey & Erdle, 2021). Kurniawan et al. (2021), Earn et al. (2021) and Athey and Erdle et al. (2021) also emphasized major complexities in examining microplastics, as they required specialized and expensive equipment, researchers with expertise in operating such equipment and following strict collection/identification protocols, and overall, the sampling process was time-consuming (Athey & Erdle, 2021; Earn et al., 2021; Kurniawan et al., 2021).

There were various factors that influenced the plastic pollutant concentrations within the Canadian Great Lakes. Combined sewer overflows, stormwater inputs, and flow patterns of each lake collectively affect concentrations of plastic debris in surface water. Overall, the three most common drivers of plastic pollution from the literature are proximity to plastic industries, proximity to urban centers, and retention time of each lake, according to (Corcoran et al., 2020; Earn et al., 2021; Mason et al., 2020). For instance, within the Lake Ontario watershed, 415 plastic industries near its shorelines are speculated to play a role in pellet distribution. Plastic industries here are inclusive of plastic pellet distributors, manufacturers, suppliers and "combined" (businesses being involved with more than one task, so for example being both a supplier and transporter of plastic pellets). For Lake Huron and Lake Ontario, another transportation pathway is the tributary network of river mouths (Corcoran et al., 2015, 2020). This is consistent with results from Earn et al. (2021). River tributaries have been shown to

transport plastics (and more generally debris in surface water) into the Great Lakes. This is in line with international reviews identifying rivers as a major source of terrestrial debris (e.g., (Lebreton et al., 2017). Corcoran et al. (2020) and Mason et al. (2020) suggest that Lake Erie's short retention time of approximately 2.6 years may have influenced the higher distribution and traveling rates of pellets and other microplastics, whereas Lake Superior's long retention time of 191 years was predicted to cause the prolonged occurrence, circulation, and retention of pellets within the surface water column, as well as in sediment bed and shorelines (Corcoran et al., 2020). Hence, both environmental and anthropogenic factors affect the magnitude of plastic pollution in the Great Lakes.

The COVID-19 pandemic is also expected to have intensified plastic pollution in the Great Lakes region, which has more than 30 million people, approximately 10% of the U.S's population and more than 30% of the Canadian population (EPA, 2022). A search for peer-reviewed scientific investigations on quantifying the pandemic's impacts on plastic pollution within the Great Lakes from 2019 to 2022 yielded no results. Therefore, this assessment broadened the scope of literature review to peer-reviewed sources from other countries. Recent studies conducted outside of North America provided evidence of the pandemic's detrimental impacts on human perception and the intensity of plastic pollution for freshwater watershed. Mejjad et al (2021) investigated potential environmental impacts of increased usage of plastic personal protective equipment (PPE) in Morocco. Analysis was based on an online questionnaire surveying Moroccan communities' usage and disposal behaviors. Although the study results extended beyond plastic pollution, they exhibited that mismanagement of plastic PPE waste (face masks, gloves etc.) could lead to increased landfilling and plastic leakage. Thus, a combination of quantity increase, lack of management infrastructure and discarding behaviors of the studied Moroccan communities could worsen plastic pollution within the region (Mejjad et al., 2021). Furthermore, Silva et al. (2021) discussed the challenges posed by the COVID pandemic towards plastic pollution. The increasing use of single-use and problematic plastic products (health care waste, PPE, single-use items not designed with recycling in mind) (Prata et al., 2020) resulted in (1) an increase in landfilling and prospective pandemic-related waste mismanagement, and (2) a spike in plastic PPE entering the environment with examples from Morocco, Hong Kong, and Peru (Patrício Silva et al., 2021; Prata et al., 2019). In North America, it was estimated that citizens disposed of more than 244 million face masks daily, which led to more than 24 million

tons of additional plastic waste (Benson et al., 2021). Consequently, it is reasonable to hypothesize that significant portions of single-use PPE may intentionally or unintentionally enter the environment, polluting rivers, and lakes such as the Canadian Great Lakes.

Lastly, several other socio-economic factors make solving plastic pollution complex. The plastic manufacturing sector is a big driver of Canada's economy. Consumption behavior and social norms are another factor contributing to plastic pollution in the Great Lakes region. The Delphi Group was commissioned by the ECCC to develop a technical report titled "*Circular North America: Accelerating the Transition to a Thriving and Resilient Low-carbon Economy*". The report stated that an ignorant attitude, or a lack of urgency, towards the quantity of plastics being consumed and the possibility of these plastics leaking into the environment exacerbates plastic pollution. Similarly, the North American consumerism culture, demonstrated in part by exorbitant amounts of plastic exports and imports (Ritchie & Roser, 2018), complicates plastic waste reduction and pollution prevention. Another factor that inhibits effective pollution prevention is the poor infrastructure capacity to sustainably recover and recycle plastic waste (ECCC, 2019a). Moreover, waste value recovery is significantly behind the rate of manufacturing and handling plastic products. Plastics production as well as maintaining the current linear system of produce-use-dispose are still cheaper, creating a plastic impediment. The current plastic economy fails to recognize existing economic and environmental externalities of plastic consumption (for example, the cost of pollution, health care impacts, etc.). Consumers and citizens generally, including future generations, ultimately bear the costs of these externalities (Deloitte et al., 2019b).

The complexity of plastic pollution within the Canadian Great Lakes has been summarized here through the types of plastic pollutants present in the lakes, underlying sources, pandemic-related complications, and other socio-economic trends that drive growing plastic inputs. Plastics of varying sizes enter the Canadian Great Lakes from various terrestrial sources such as stormwater or point-source discharges, or from large plastics breaking down into tiny particles (as seen in for example Earn et al., 2021 and Mejjad et al., 2021). Furthermore, studies suggested multiple contributors to plastic pollution within the Great Lakes watershed. Having prospectively negative economic, environmental, and human health impacts, plastic pollution affects many. Therefore, it requires a multi-faceted approach, with stakeholders from all sectors being agents of change. Understanding stakeholders' perspectives, in addition to getting an

overview of existing regulatory instruments, is critical to supplement future actions that can ameliorate plastic pollution. A review of existing Canadian plastic agendas and regulations, will be investigated in the sections below.

2.2: Theoretical Framework

The term "waste hierarchy" refers to an inverted triangle representing a general framework for solid waste management. The waste hierarchy was coined by the European Commission's Waste Framework Directive 2008/98/EC published and amended in 2008 (Gharfalkar et al., 2015). It organizes five major steps, matching with a waste item's life cycle, into five ladders within a typical waste management process. The inverted shape outlines the order of preference from most (the widest ladder at the top) to least preferred (the smallest ladder at the bottom), and similarly most and least beneficial for the environment, sustainability, and value recovery. Aside from being central to the European Commission's members' collaboration, reporting, and solid waste management tools, it influences global investigations into sustainable waste management as a catalyst for pollution prevention (Gharfalkar et al., 2015; Penca, 2018; C. Zhang et al., 2022). Moreover, the framework prioritizes environmental and human health, sustainability and relevance to a circular economy (Gharfalkar et al., 2015), which would be suitable for consideration within the Canadian plastic waste and plastic pollution context.

Figure 1. EU Waste Framework Directive waste hierarchy.

Waste hierarchy

PREVENTION — PRODUCT (NON-WASTE)

PREPARING FOR RE-USE

RECYCLING

RECOVERY — WASTE

DISPOSAL

Preventing waste is the preferred option, and sending waste to landfill should be the last resort.

Note. Source: (DG Environment, n.d.).

The Canadian Council of Ministers of the Environment (CCME) Canada-wide Strategy on Zero Plastic Waste ("The Strategy")'s waste hierarchy has been selected as the theoretical framework for this study. This waste hierarchy has been employed for development of regulatory and voluntary instruments for sustainable waste management in Canada as seen in the Canada-wide Strategy on Zero Plastic Waste ("The Strategy"). The CCME waste hierarchy also informs methods for reaching zero plastic waste goals and transitioning towards a circular economy. The adoption of the waste hierarchy is consistent with Canada's Ocean Plastic Charter commitment in preventing oceanic plastic pollution (CCME, 2019). There are five priority areas divided by two general categories: prevention (better) which includes reduce (most preferred with largest cost-benefit potential), repair and reuse; and value recovery (worse) that encompasses remanufacture, refurbish (more preferred), recycle and energy recovery (least preferred, least cost-beneficial). Unlike the EU Waste Framework Directive 2008/98/EC's hierarchy that includes landfilling or waste disposal, the last step in the CCME waste hierarchy is energy recovery, matching Canada's goal to become zero plastic waste by 2040 (Canadian Council of Ministers of the Environment (CCME), 2020). Because of its flexibility and comprehensiveness in accounting for various aspects relating to plastics waste and pollution prevention guidelines, this study utilizes the CCME's waste hierarchy as its theoretical framework.

Figure 2. CCME waste hierarchy as a plastic waste management framework.
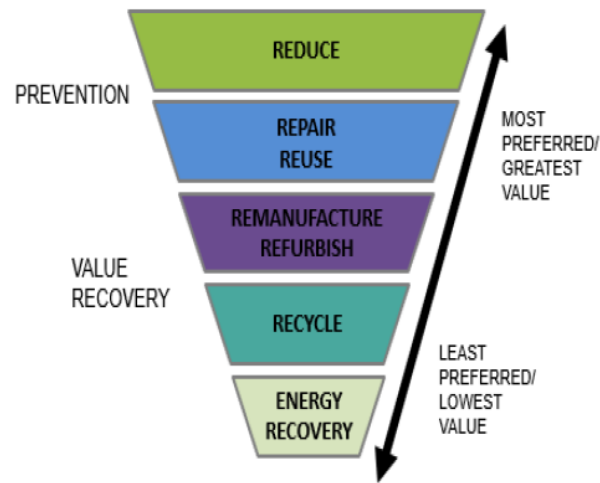
Figure 2: Waste Management Hierarchy

Note. Source: (Canadian Council of Ministers of the Environment (CCME), 2020)

  The waste hierarchy is a well-known framework for both legally binding and voluntary measures towards addressing plastic litter in the environment. This paper employs the CCME waste hierarchy framework to address plastic pollution within the Canadian Great Lakes due to its generality and transdisciplinary potential (Penca, 2018; C. Zhang et al., 2022). This allows for flexible adoption of the principles to guide development of instruments for plastic pollution prevention (Rasmussen, C & Vigsoe, D, 2005) within the terrestrial-aquatic plastic nexus. It is not explicit whether the CCME adopts the EU Waste Framework Directive's waste hierarchy. The two frameworks bear many similarities with similar ladders and the same preference. However, the CCME's hierarchy lacks a "landfill" ladder. Further discussion on the differences between the CCME's hierarchy and that of the EU Waste Framework Directive can be found in the Discussion chapter.

  The five ladders of the CCME waste hierarchy will guide qualitative data analysis and development of conclusions. Past studies have been able to employ versions of the waste hierarchy to identify shortcomings that enable the status quo of plastic pollution, posing harm to environmental and human health (Penca, 2018; Wurm et al., 2020; C. Zhang et al., 2022). Therefore, the CCME waste hierarchy will be a critical framework for this study's primary and secondary data collection and analysis. First, it will assist with demonstration of whether provincial and federal mandatory or voluntary instruments are within the more cost-effective and

preventive ladders. Second, the ladders will guide a coding protocol for interview transcripts. Informants' responses will be compared to the waste hierarchy framework. This can illustrate whether there's consistency with recommendations from experts for Great Lakes-specific actions. Lastly, the waste hierarchy will govern formation of recommendations, using both stakeholders' responses and literature review, with a focus on preventive measures and a potential expansion of existing efforts.

2.3: Plastic-Water Policy Context in Canada

2.3.1: Bi-national Agreements

Considering the shared ownership of the Great Lakes system between Canada and the US, The Great Lakes Water Quality Agreement (GLWQA) is a bi-national water quality protection mechanism that can address plastic pollution as a transboundary issue. The GLWQA is a commitment between the US and Canada to "restore and maintain the chemical, physical, and biological integrity of the Waters of the Great Lakes (ECCC, 2013). It provides guidance and a means of accountability to two countries to coordinate and collaborate on policy development and action plans that support the binational management and protection of the Great Lakes (Government of Canada, 2022b). Within the GLWQA, water quality monitoring centers on nine annexes: Areas of Concerns, Lake-wide Management, Chemicals of Mutual Concern, Nutrients, Discharge from Vessels, Aquatic Invasive Species, Habitat and Species, Groundwater and Climate Change Impacts. These annexes represent nine priority areas for the US and Canada to tackle conservation of water quality and ecosystem health. Canada and the US must publish a Progress Report detailing the current state of the Great Lakes, achievements in protecting water quality and an overview of action plans every three years. The International Joint Commission (IJC) has been tasked with analyzing and assessing the progress reporting. The governments are required to undergo this process every three years. Unfortunately, the latest amendment of the GLWQA in 2012 did not encompass plastics as a pollutant (ECCC, 2013).

Microplastics have been identified as "Additional Substances of Concern" or "Contaminants of Emerging Concern" in individual Lake-wide Action and Management Plans (LAMPs) (Government of Canada, 2022b). LAMPs outline priorities in conservation for each lake within the Great Lakes network. The most recent LAMPs for Lake Ontario, Lake Superior and Lake Huron reported some details about plastics. The 2015-2019 Lake Superior LAMP,

2017-2021 Lake Huron LAMP, and the 2018-2022 Lake Ontario LAMP included sections that acknowledge the rationale behind plastics being harmful and identify sources of microplastics through surveying peer-reviewed scientific publications. Plastics are known to carry chemicals (additives, plasticizers, and paints) such as perfluorinated chemicals or chlorinated paraffins (which were designated as "chemical contaminants"), affecting water quality and human health (Ballinger et al. 2016). A concrete action plan with enforceable policy instruments to add plastics into a management agenda is lacking. One strategy of adding microplastics as a priority pollutant is dependent on a nomination process, and ultimately the decision of the federal governments in Canada and the USA to decide on an action plan. Neither specific actions nor responsible parties have been assigned. Canada's national commitments made in the "Canada-wide Strategy on Zero Plastic Waste and Action Plan" as well as international commitments in the G7 and G20 have not been linked to or translated into further actions within the GLWQA.

2.3.2: National Regulatory Instruments

A modification of Schedule 1 under the Canadian Environmental Protection Act (CEPA) adopted in 1999 sets the foundation for federal regulatory actions towards plastic products and waste. As of May 2021, the Government of Canada has updated the List of Toxic Substances under Schedule 1 of CEPA to include item number 133 as "plastic microbeads that are < or = to 5mm in size", and number 163 as "Plastic manufactured items" (Government of Canada et al., 2021). This enables the federal government to further regulate and prohibit the use, production, and emission of plastic products. Additionally, amending Schedule 1 to encompass "plastic manufacturing items" allows the government to employ instruments or collaborate with partners to reach management and pollution prevention goals that align with other federal guidelines. This is foundational to allow further federal actions against plastic pollution (Krantzberg, 2019).

In 2018, the Canadian government enacted the Microbeads in Toiletries Regulations. This prohibits the manufacturing, sales, and imports of personal care products used for cleansing and hygiene that contain plastic microbeads. According to Clement et al. (2018), this law encompasses non-prescription drugs and natural health products (Clement et al., 2018). This does not account for products that are in transit through but not for sale within Canada (Government of Canada et al., 2021). An outcome of this national regulation would be to also reduce and gradually stop the amount of microbeads entering the Canadian Great Lakes.

However, the legislation's official publication by the Minister of Justice (SOR/2017-111) does not outline what punishments are for violations. Similarly, to date, no measurements of possible reductions in microbeads in the Great Lakes' water network as a result of the introduction of the new regulation have been published.

The federal government has taken a step further regarding single-use plastic items that are both prominent freshwater pollutants and problematic for value recovery through the development of the Single-use Plastics Prohibition Regulation (SUPPR). This is a federal regulation that bans the production, import and sale of 6 single-use plastic items: check-out bags, cutlery, food containers that are made from "problematic plastics", 6-rings beverage holder, stir sticks, and straws. It is being incrementally implemented in phases. Prohibition of production and imports for commercial use of check-out bags, cutlery, straws, certain food containers and stir sticks will take effect in December 2022. Next, similar prohibition on 6-ring carriers will take place on June 2023. For retail sales of straws that are "flexible" and "packaged with beverage containers", a ban will be in effect by June 2024. Lastly, by December 2025, a ban on imports and exports of all mentioned plastic products will come into force (Government of Canada et al., 2021). Following the Microbeads in Toiletries, this is the second legally binding action that addresses plastic pollution at the source, potentially having significant impacts on reducing plastic leakage into the Canadian Great Lakes (King et al., 2022).

Integrating stakeholder feedback is essential to enactment and revision of political instruments, as demonstrated through the latest amendments to SUPPR. The exclusions and caveats noted in SUPPR's recent amendment address comments from stakeholders listed under the "A proposed integrated management approach to plastic products to prevent waste and pollution: What We Heard Report". This report was published by the ECCC in 2021, following the release of the Strategy for Zero Plastic Waste and the discussion paper detailing commitments towards an integrated approach for plastic waste management nationally (Government of Canada & ECCC, 2021). Special considerations towards vulnerable groups, in particular people with medical needs or who have disabilities support accessibility and equity. In addition to accessibility, this ban displays clear considerations towards the plastic industry. Considering private-sector concerns, plastic exports and flexible straws sold by retailers in certain settings are exempt (Government of Canada & ECCC, 2021). These exemptions, coupled with a national ban on manufacturing of single-use items, may mean that Canada will increase

reliance on plastic imports. This would complicate other priority areas, mainly recycling capacity, end-of-life waste management and plastic design standards of foreign plastics. Moreover, a lack of restrictions on plastic exports may be considerate towards the plastic production industries, but it undermines Canada's international commitments.

2.3.3: Provincial Regulations

In addition to federal regulations, Ontario has province-specific regulations for dealing with plastic waste and taking preliminary steps to address certain types of plastics as water pollutants. The regulations currently being enacted are Bill 228 - Keeping Polystyrene Out of Ontario's Lakes and Rivers Act, and the Waste-Free Ontario Act.

In 2016, the Legislative Assembly of Ontario passed Bill 151 - Waste-Free Ontario Act, which addresses plastics at their end-of-use stages, aiming to improve waste diversion, to enhance support for federal and provincial transitions towards a circular economy, and to balance responsibilities among governmental and private-sector stakeholders. Bill 151 enacts two regulations: the Resource Recovery and Circular Economy Act and the Waste Diversion Transition Act (Government of Ontario, 2016). Through this Bill, the following changes will take place. First of all, this Bill provides a provincial foundation for landfill diversion, value recovery and recycling within Ontario, including the identification and implementation of further actions in these domains. Secondly, this Bill allows the transition towards an Extended Producer Responsibility (EPR) framework (Resource Productivity & Recovery Authority, 2021). This EPR framework shifts administrative and financial responsibilities from that of the provincial and municipal governments to the private sector partners, otherwise known as the producers and importers of plastic products (Government of Ontario 2016). Registered businesses will handle collection and value recovery measures such as reuse, refurbishing, and recycling of "blue box materials". Under the 2016 Resource Recovery and Circular Economy Act, Ontario's Blue Box recycling program will also be amended. Changes to the current Blue Box program encompass holding producers (identified as a person or entity that's associated with a product commercially, at any stages) fully accountable and financially responsible for management and disposal of products at their end-of-use (RPRA, 2021). Products being regulated must have a "Blue Box material" status, which may vary by municipality. Exemptions based on revenue and weight thresholds apply. For example, a business making less than $2 million in gross annual revenue

from products and services is excluded from the program (Resource Productivity & Recovery Authority, 2021). Overall, Bill 151 primarily supports value recovery of some plastic waste considering the waste hierarchy. However, it fails to consider "convenient packaging" (as listed by the Resource Productivity and Recovery Authority (RPRA)) which may prevent the most prominent plastic pollutants of the Great Lakes such as cigarette butts, plastic bags, plastic food wrappers (Earn et al., 2021), microfibers (Athey & Erdle, 2021) or microplastic and macro-pellets (Corcoran et al., 2020; Rochman et al., 2021) from being recovered or diverted from landfills. To date, there is a lack of explicit specifications on mandatory diversion rates or plastic leakage prevention measures associated with a provincial waste management protocol. The RPRA reported a 49.2% total waste diversion in Ontario in 2016 (Resource Productivity & Recovery Authority, 2018). However, the Waste-Free Ontario Act did not specify a diversion target, and the RPRA has not published plastic waste diversion target while administering EPR transition (Government of Ontario, 2021b). Consequently, this has yet to be translated into concrete pollution prevention measures within the Great Lakes.

Another important step towards the protection of the Great Lakes is Bill 228, passed on May 20th 2021 with the aim to keep polystyrene out of Ontario's lakes and rivers. This Bill mandates that floating docks, floating platforms or buoys used as floating devices on waterways within Ontario that are made of polystyrene must be fully encapsulated and protected. This is to avoid any shedding of polystyrene into the water, preventing one source of plastic pollution. Any individuals or businesses in charge of producing, handling, or selling these products must comply. However, neither the instruments for holding responsible entities accountable nor the personnel responsible for operation and management of this bill are identified in the official publication by the Legislative Assembly of Ontario.

2.3.4: Non-binding Commitments

Canada is a member of The Group of Twenty (G20), an international assemblage of the largest economies (Government of Canada, n.d.-b). Canada values participation in the G20 due to opportunities for building discussion and consensus on economic growth-related topics and issues. Since 2017, the G20 has had discussions that recognize the magnitude and importance of marine plastic pollution. During the G20 Germany presidency, at the 2017 Hamburg Summit, G20 members pledged actions against marine litter through a published G20 Action Plan. This

collaborative agreement avoided shadowing individual nation's efforts, while targeting litter encompassing plastic debris and other pollution sources in marine and terrestrial environments (Government of Canada, n.d.-b). This agreement marked Canada's commitment to abate marine plastic pollution, much of which ends up in the oceans bordering Canada in the east and west through the rivers draining into them. This includes the plastics pollution in the Great Lakes that ultimately might end up in the Atlantic Ocean via the St. Lawrence on the east coast. The G20, however, does not specify plastic pollution in freshwater environments. There is a lack of specificity when it comes to the mechanisms available to hold each nation accountable.

In addition to the G20, Canada championed the introduction of the Ocean Plastic Charter as a member of the G7 to further develop commitments towards sustainable plastic waste management and pollution prevention in marine environments. The G7 is an international group with members such as the US, United Kingdom, Japan, and a limited number of European Union member states. The Ocean Plastic Charter contains a framework that offers guidelines for national and international collaborations, as well as cross-sectoral cooperation, towards more sustainable plastic-related practices along their life cycle: design, production, end-of-life, coastal and shoreline clean-ups. Additionally, the framework highlights preventive and capacity-building measures such as plastic management infrastructure, stakeholder engagement, strengthening market-based instruments to better manage plastics, education and outreach, and research and innovation (Government of Canada & ECCC, 2021). This framework also presents a timeline for key achievements towards zero-plastic-waste: "Working with industry towards 100% reusable, recyclable, or, where viable alternatives do not exist, recoverable, plastics by 2030"; "Tackling designs of plastics by aiming for 50% of secondary plastics in products by 2030; and adopt a full zero-waste plastic cycle with 100% plastic waste recovery by 2040". Further inspection of the Ocean Plastic Charter commitments reveals an emphasis on engaging the private sector in all stages of the plastic cycle. The charter's framework supports both preventive and value recovery measures. There is some variety in the scope of plastic pollution being addressed. In some guideline points, the focus is on plastics in general, while for others the scope specifically centers around oceanic plastic (Government of Canada, 2018a). For some guidelines, such as "supporting platforms" and amplifying education, the specific focus on marine plastic can undermine freshwater plastic pollution. Similar to the G20, this is not a legally

binding agreement, and there exist no punitive measures in case of co-signatories' non-compliance.

From 2019 to 2020, the Canadian Council of Ministers of the Environment (CCME) released Phase 1 and Phase 2 of a federal plastic management action agenda titled "The Canada-wide Strategy on Zero Plastic Waste" or "The Strategy". The Strategy outlines key actionable items branded "Priority Actions" to support Canada's Ocean Plastic Charter adoption. Additionally, it contains recommendations to help Canada reduce plastic pollution while advancing a circular economy. A circular economy refers here to a closed-loop material flow system in which the use of virgin materials is minimized, being replaced with complete waste value recovery and a consumption loop that utilize post-consumed materials (CCME, 2019). The definition of a circular economy is consistent throughout federal and provincial action frameworks (Canadian Council of Ministers of the Environment (CCME), 2020). Although the circular economy framework applies to all materials (metals, glass, etc.), it is used as a foundation for a plastics management strategy by the Canadian federal and provincial governments.

The Strategy based its action framework on a waste hierarchy that bears many similarities to that of the EU Waste Directive. Moreover, The Strategy also understands and utilizes the importance of stakeholder engagement (Canadian Council of Ministers of the Environment (CCME), 2019). However, the instruments through which the CCME will implement the Canada-wide Strategy on Zero Plastic Waste and Action Plan ("The Strategy")'s framework, as well as coordinating actions with stakeholders, are not explicitly identified. The Strategy also does not convey mechanisms and the government bodies who would be responsible for implementing regulatory instruments or punishments or building consensus among stakeholders how to best define and achieve the objectives involved. Despite having commitments from The Strategy to support better management of single-use plastics, developing a management roadmap, or investigating plastic products that are deemed harmful there are no enforceable measurements written into legislation or provincial regulations. The Strategy is a comprehensive investigation that shapes federal approaches towards plastic pollution more generally. Further research is needed to clarify The Strategy's roles in preventing plastic pollution within the Great Lakes.

To further advance goals within the Strategy, the Canadian federal government proposed a "Integrated Management Approach to Plastic Products to Prevent Waste and Pollution" guideline that is not enforceable. This proposal introduces guidelines for managing single-use plastics and relevant engagement of governmental and private-sector stakeholders. The approach recognizes the complexity of plastic pollution and identifies barriers facing Canada in solving the problem. Currently, the approach focuses on the following challenges (ECCC, 2019a):

- Current reliance and dominance of virgin plastics
- Insufficient markets for recycled plastics and other non-virgin plastic materials
- Low collection and recovery rates across the nation
- Lack of options for value recovery
- Consumers bear the monetary burden of plastic pollution.

The scope of this approach is single-use plastics, which extends beyond plastic pollution in the Canadian Great Lakes. There's a need to explore whether stakeholders experience or understand a similar set of barriers facing plastic pollution in the Great Lakes. Based on the stakeholder engagement outcomes from "A proposed integrated management approach to plastic products to prevent waste and pollution: What We Heard Report", the ECCC plans on providing leadership in enhancing value recovery and markets for post-consumer recycled plastics. In doing so, it released a technical paper on "Recycled content for certain plastic manufactured items Regulations". This technical paper responds to existing action frameworks and commitments such as the international G7 and G20 involvement, The Strategy, and the Proposed Management Approach towards Single-use Plastics (CCME, 2019; Government of Canada, 2022a). The ECCC proposes legislation that would create a minimum recycled content threshold of 50% for certain plastic manufactured items. Currently, items that are proposed to contain a minimum recycled content are: beverage containers, bottles (other than those in direct contact with food), some rigid plastic containers and trays (other than those in direct contact with food), foam packaging (other than those in direct contact with food), garbage bags and waste bins. If a consensus is reached and a mandate is published, it may apply to anyone (an individual or a company) who manufactures, imports, or sells these items in Canada (Government of Canada, 2022a).

Lastly, the only framework that targets the Great Lakes is the Canada-Ontario Great Lakes Agreement between the federal government and Ontario provincial government.

Microplastics and plastic pollution were present on the agenda, being recognized as an area of concern to be addressed. Collaborative actions would support the implementation of The Strategy encompassing all ladders of the waste hierarchy. Specific actions highlighted supporting clean-ups and captures (value recovery), promoting research, monitoring of plastics within the Great Lakes basin, and enhancing education and awareness of stakeholders (prevention). For individual commitments, each level of government pledged to offer comprehensive support aligning with The Strategy. Actionable undertakings put higher emphasis on the value recovery component of the waste hierarchy, addressing Extended Producer Responsibility, and investing in tools, guidelines, and innovation for better management of plastics in their end-of-life stages. Most pledges are in early stages of development, as they are general promises that offer no specific guidelines or instruments for enactment. Notably, the Government of Ontario promised to offer "strong enforcement for repeated offenders" when considering specific plastic pollution discharge points but offer no further details on what possible enforcement measurements might be (Government of Ontario, 2017, 2021a).

Bill 279, Environmental Protection Amendment Act (Microplastics Filters for Washing Machines) was introduced to the Legislative Assembly of Ontario in 2021. Bill 279 proposes a mandate that requires an entity (an individual or a business) to sell or offer for sale washing machines within Ontario that must have specified microplastics' filters. The bill also outlines monetary fines for non-compliance. While an individual may be fined up to $2000 per product sold, a business can be fined up to $5000 per unit of product sold not having a microfiber filter (Arthur & Bell, 2021).

Bill 82 – Single-Use Plastics Ban Act (2019) was introduced to the Legislative Assembly of Ontario in 2019. The development of this Act supports provincial and federal commitments stated in The Strategy for Zero Plastic Waste by amending the Resource Recovery and Circular Economy Act to be inclusive of more clauses. If passed, the Minister must develop a detailed roadmap with realistic timelines, as well as measurable targets, to support the phasing out of the distribution and supply of single-use plastic items in Ontario by 2025. Additionally, the Act would require the Minister to amend and publish amendments to The Strategy for public viewing. The Act has only undergone an initial review. Furthermore, the Act does not suggest punishments for non-compliance (Arthur, 2019).

2.4: Impacts of the Policy Landscape

Provincial and federal-level policies extend beyond the focus on plastic pollution within the Great Lakes. Moreover, existing plastic waste strategies have not been clearly translated into local actions targeting pollutants present within the environment. Given the complexity of the problem, a single ban such as the SUPPR or the microbead ban only seems to scratch the surface. Rather, a more inclusive approach with a broader diversity of pollution prevention instruments and involving many more actors is recommended (Pahl et al., 2017; Schnurr et al., 2018; Stock et al., 2022). Theoretically, preventive measures are preferred because they tend to be more cost-effective (Canadian Council of Ministers of the Environment (CCME), 2019; Deloitte et al., 2019a). Moreover, there are fragmentations in the development of plastic strategies across jurisdictions. The multi-layered governance structure and jurisdictional controls across Canada, plus a lack of one systematic and harmonized plastic waste management structure, calls for further works to be done. Further collaboration among provincial and federal entities in shaping and coordinating instruments to "tilt the playing field" for better pollution prevention measures is necessary (Deloitte et al., 2019b).

Globally, the politics of plastic items is shifting away from relatively easily managed and easily phased-out products (such as plastic bags or microbeads in personal care products) towards more complicated ones (e.g., food packaging, textiles, and tires) (Gattringer, 2018; Nielsen et al., 2020). However, this trend is not yet reflected in Canadian legally binding instruments as they are still in a preliminary stage of dealing with "easy" single-use items. Furthermore, current legislation does not encompass all prominent single-use plastic pollutants within the Great Lakes, as it leaves out food containers, single-use water bottles, macro, and micro-pellets and more.

There is a need to present findings from analysis of stakeholders' perspectives. Schurr et al. (2018) aggregated regulative instruments on plastics before 2019. The prohibition of microbeads has become a regulatory instrument across North America without much resistance from industries. However, moving beyond microbeads has been challenging. Particularly, there have been conflicting responses on restricting the use of some plastic items like plastic straws (Schnurr et al., 2018). For example, some stakeholders criticized the straw ban as ineffective in some circumstances. Vulnerable populations such as the homeless, citizens with low income, or citizens with disabilities may disproportionately be affected by this ban, as they often rely on

single-use plastic items due to their convenience and cheap prices (Deloitte et al., 2019a; Schmaltz et al., 2020; Schnurr et al., 2018). Similarly, past attempts at enacting regulatory instruments to limit some single-use plastics such as plastic check-out bags have been met with opposition from industry associations (Schnurr et al., 2018). For example, the addition of "plastic microbeads" and "plastic manufactured items" to Schedule 1 of CEPA 1999 allowing plastics to be further regulated has been met with pushbacks. The plastic industry plans to challenge this decision in court. They are also suing the ban of items, calling it "unconstitutional" because of discrepancies in managing plastic items being under municipal and provincial governments (Walker, 2021; Xanthos & Walker, 2017). Plastic industry advocates and representatives have also made efforts to delay or resist similar regulations from being passed at provincial and municipal scales. For example, Nova Scotia introduced the Bill 152: Plastic Bag Reduction Act in 2019 that prevents businesses from using single-use plastic check-out bags with a few exceptions (Government of Nova Scotia, 2020). This was met with opposition from the Canadian Plastics Industry Association, with their representative calling it "not beneficial to the environment" (Walker, 2021). Another national opposition attempt is the formation of the Responsible Plastic Use Coalition (RPUC) by 33 petrochemical industries and plastic packaging manufacturers. The RPUC challenged the Government of Canada's regulatory instruments, and advocated for establishing a "Board of Review" to determine the toxicity, reliability, and sufficiency of scientific evidence against their plastic products (RPUC, 2021). On the other hand, other stakeholders (primarily from other sectors or general consumers) support the Government of Canada's actions, while some call for even stricter measures (Government of Canada & ECCC, 2021; Oceana Canada, 2020; Walker, 2021). Responding to the RPUC's argument based on the federal government over-reaching, local government stakeholders are against unjust burden associated with waste management. These conflicting perspectives have not been clearly illustrated in government proposals or Canadian government commissioned reports. Additionally, evidence from scientific studies is scarce. Addressing the nuance in stakeholder voices regarding plastic pollution and instruments for change, as well as their impacts on shaping current and future solutions, remains to be explored.

Chapter 3: Method

According to the preliminary literature review above, (1) legislation recognizing Canadian Great Lakes plastic pollution is underwhelming, and (2) findings and analysis on local stakeholders' viewpoints are crucial and yet lacking. There are gaps in identifying connections between peer-reviewed pollution prevention measures and stakeholders' understanding and opinions, as well as what initiatives has already been executed in Canada. This study aims to fill these gaps using a mixed methodology that combines primary and secondary data collection. Interview results are utilized as primary data, displaying viewpoints on perceived constraints and recommendations from local experts and specialists with expertise in dealing with freshwater plastic contamination in the Canadian Great Lakes. The CCME waste hierarchy assists with data analysis through development of key words and important ideas to identify among primary data. Secondary data collection is done through a desk-based literature review. Literature review highlights existing voluntary and mandatory instruments within Ontario and at the federal level that influences plastic pollution within the Great Lakes watershed and aggregates peer-reviewed solutions to clarify and expand on qualitative interview findings. This study seeks to generate descriptive results and analysis that add to existing knowledge on freshwater plastic pollution prevention in the Canadian Great Lakes.

This study employs a mixed method, consisting of semi-structured interviews and literature review, to bridge the knowledge gaps identified above. A mixed method was defined as an approach that centers on "collecting, analyzing, and combining both quantitative and qualitative data in a single study or series of studies" by Creswell and Clark (2017). However, mixed methods have diverged over time to encompass a variety of implementations, with the mixing of methods remaining constant. An outstanding benefit of mixed methodology is that it paints a clearer picture for explaining trends and phenomena and drawing conclusions from both types of data than using one single methodology alone (Creswell, John W & Clark, Vicki L. Plano, 2017). Characteristics of a mixed method are applied within this study, for example, through quantification of the percentages displaying levels of agreement or disagreement among interviewees on one theme, or calculations on similarities and differences among sectors of participants, and so on. Frequency counting of key words or ideas (as "themes") is another popular quantitative method (as demonstrated for example by Fakis et al. (2014)) that will be used here (Fakis et al., 2014). Mixed methods are expected to be especially beneficial in

enhancing the credibility and replicability of a study, analyzing study results from varied perspectives, and strengthening findings through triangulation of various sources (Creswell, 2014; Creswell, John W & Creswell, David J., 2018).

Similar mixed methodologies combining qualitative interviews with literature review have been successfully implemented by various studies within environmental sciences and environmental studies, for example, in Frantzi et al. (2021). Frantzi et al. (2021) utilized a combination of desk-based literature and existing regulatory documents' review with semi-structured interviews, to effectively analyze the institutional, regulatory, and economic barriers and drivers for implementing plastic recovery technologies within the EU. First, Frantzi et al. (2021) conducted a systematic literature review on regulatory frameworks and voluntary instruments that exist in countries that border the Baltic and Mediterranean seas. The literature review served two purposes: (1) to identify a framework and/or regulatory barriers or drivers of marine litter clean-up, and (2) to identify strategies and incentives that support (in economic, social, regulatory etc. capacities) marine litter technologies. Second, Frantzi et al. (2021) conducted semi-structured interviews with key informants from governments, private sector, NGOs, non-profit organizations, and academia. Results triangulated content analysis of primary and secondary sources as mentioned to draw suggestions through pinpointing shared constraints and opportunities for implementing plastic collection technologies within the Baltic and Mediterranean seas (Frantzi et al., 2021). This study is a great example to demonstrate that mixed methodology is a viable method to answer the study questions: "What are (1) the drivers, (2) the barriers and (3) the recommendations to address the drivers and barriers towards plastic pollution in the Canadian Great Lakes?". This study implements similar elements of the mixed methodology applied by Frantzi et al. (2021) but tailors the scope of study to freshwater plastic pollution (instead of marine plastic pollution) within the Canadian Great Lakes, focusing on Canadian legislation, barriers, and recommendations for Canada.

Figure 3. A summary of this study's methodology.
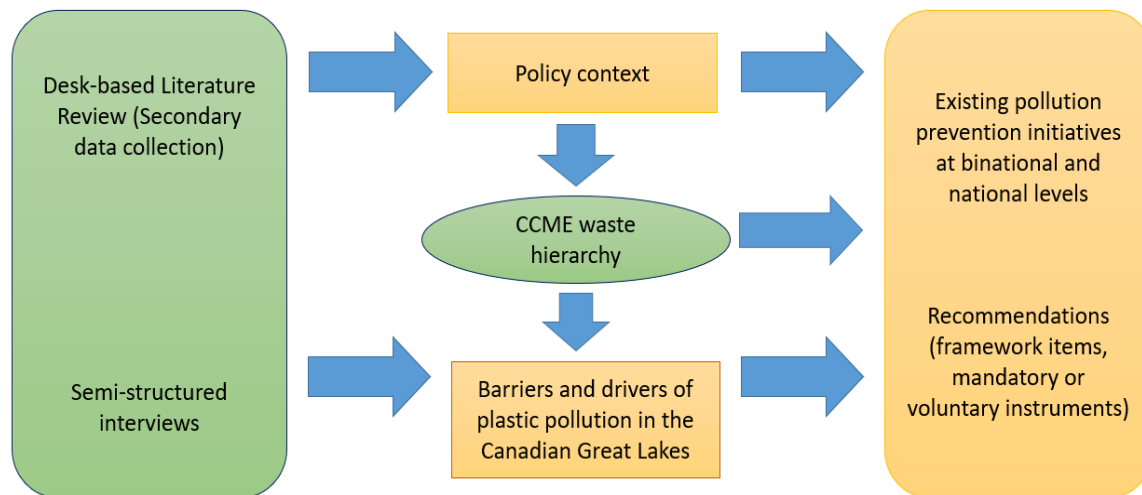
Note: Both primary and secondary data collection (semi-structured interviews and literature review) would result in demonstration of trends and patterns signifying the drivers of plastic pollution in the Canadian Great Lakes, and constraints and opportunities towards pollution prevention. Literature review was shown to be complementary to qualitative and quantitative content analysis of the interview transcripts, and to set the political context for the shortcomings of plastic pollution in the Great Lakes. The waste hierarchy ladders are guiding pillars for data analysis and development of conclusions.

3.1: Primary Data Collection

3.1.1: Participant Selection

Selection of key informants to participate in this study is guided by the Great Lakes Plastic Cleanup ("GLPC"), hereby addressed in abbreviation as the GLPC. The GLPC is a "first-of-its-kind" initiative that unites partners from academia, private sector, and governments to monitor and remove plastics at Lake Ontario and Lake Superior. Its core mission is to test and use plastic collection technology within the Great Lakes watershed to remove plastics from the water and to collaboratively prevent plastic pollution (The Great Lakes Plastic Cleanup). Because the GLPC's mission aligns greatly with the study's objectives, its stakeholder network is a great source for consultation. GLPC partners are stakeholders who have a variety of expertise related to plastic pollution and plastic waste within Canada, thus they are qualified to act as key informants.

For meaningful qualitative data acquisition, a purposive sampling method is employed. Purposive sampling is defined by Etikan et al. (2016) as "the deliberate choice of a participant due to the qualities the participant possesses", which "involves identification and selection of individuals or groups of individuals that are proficient and well-informed with a phenomenon of interest" (Creswell, John W & Clark, Vicki L. Plano, 2017; Etikan et al., 2016). This sampling method is beneficial for this study because it can be used when the sampling pool is small (Etikan et al., 2016), as there would be limited individuals to contact, and potentially a small population who would join the interview process. Informant search begins with contacting the organizations and entities listed on the Partners' page of the GLPC's website . In addition to GLPC stakeholders, snowball sampling and targeted key informant search is incorporated in the search and screening process. Snowball sampling is employed by asking for a recommendation at the end of each interview, until no new additional contacts are offered. Stakeholders are also identified as a part of the literature review process, in searching for efforts existing within Canada that targets freshwater plastic pollution. To ensure relevance of perspectives collected regarding the objectives of this study, prospective interviewees must meet two or more of the following criteria: (1) be involved in the past, or currently being involved, with the Great Lakes Plastic Clean Up initiative, (2) have conducted or are conducting research on freshwater plastic pollution within the Canadian Great Lakes and/or (3) be affiliated or involved in influencing and/or developing frameworks and/or policies that specifically address freshwater plastic pollution within Canada. The targeted demographic is English speaking adults (age 18+). Although Canada is a bi-lingual country, participants must be able to speak and understand English as this is the only language used throughout the interviewing process and this study. Prospective interviewees encompass those working within four sectors: the public sector, the private sector, academia, and non-profits and non-governmental organizations (NGOs). Participants may include academic researchers, policy developers, and non-profit and NGO employees.

Applying the search criteria above, the screening process yields contacts along with information on local, national, and binational plastic pollution prevention efforts in Canada. Individual email contacts is identified through the GLPC website, Google and LinkedIn. Communication with stakeholders is done through emails, with a procedure that allowed two rounds of follow-up. Participants are sent invitation emails, which were followed up by a

detailed Information and Consent letter clearly outlining the purpose of this study, data analysis and retention process, and participants' rights. Once consent is obtained prior to the interview, participants are engaged in virtual one-on-one semi-structured interviews through videoconferencing using Microsoft Teams, and interviews were to be video recorded. Each interview lasts 45 minutes to an hour. Participants are notified that anonymous quotation may be displayed as data in this study. During an interview, participants are asked a set of questions that seek to understand their involvement in freshwater plastic pollution in Canada, their understanding of the problem, their perspectives on barriers to elimination of plastic pollution and what would need to be done, following recommended probes for meaningful data collection (Creswell, John W & Creswell, David J., 2018). Six interview guides for six groups of participants are created: researchers, government workers, and others (businesses and non-government organizations) who are partnering with the GLPC, and the same groups but for those who are not involved with the GLPC. At the end of each interview, participants are asked to pass the researcher's contact information to those who would be a great fit for this study. After each interview, participants receive an email highlighting the transcript obtained, an appreciation letter, and any clarification requested for points mentioned during the interview as needed. Interviewees' identities (their names, contact information, specific titles, and employers) remain strictly confidential and are not included in either the results or the discussion of this study.

3.1.2: Semi-structured Interviews

This study employs semi-structured interviews. Interviewing is a popular method that has been employed in past peer-reviewed literature spanning multiple fields (Mannan, n.d.; Young et al., 2018). There are three types of interviews: unstructured (open-ended), semi-structured and structured interviews (Wilson, 2012). In an unstructured interview, researchers allow for qualitative observation and collecting data verbally in a non-restricted, conversation-like manner. However, this type of interview risks providing unsystematic, irrelevant information that would not be helpful for studies with specific sets of research questions (Wilson, 2012). On the other hand, structured interviews rely on a close-ended set of questions that would be presented to all participants within one study. Structured interview questions often take the form of surveys and allow little to no room for in-depth, nuanced expansion for any answers. Therefore, the most fitting interviewing method for this study would be semi-structured interviews. This type of interview is the perfect medium of the previous interview types. This method allows for diversity

in the scopes of answers collected, granting flexibility in how each participant can expand on answering a question (for example, beyond a "Yes/No" answer) (Mannan, n.d.; Wilson, 2012). This study aims to avoid steering participants in a particular direction while providing their input. Thus, structured interviews are not employed. Semi-structured interview, therefore, is useful to create a general boundary (in this study, this would be any answers that pertain to topics in freshwater plastics within a Canadian context), but are still welcoming of flexible for variety within the answers. Lastly, semi-structured interviews minimize missing or incomplete data sets (Bryman, 2012).

3.1.3: Interview Question Development

Interview design follows Creswell and Creswell (2018)'s recommended practices in developing an interview protocol, including the following components:

Providing an overview of the interview such as date, time, names.

Developing an opening question or an icebreaker to establish rapport with the interviewee. Recommended types of questions tend to ask about the interviewee.

Carefully crafting content questions: consider sub-questions that should be rephrased to be less technical, to be clearer and more interviewee-friendly

Using probes: ask for an expansion of an answer or explanation of ideas.

Providing closing instructions. (Creswell, John W & Creswell, David J., 2018)

Interview questions development follows a three-step framework which constitutes opening questions (to establish rapport), content questions (gathering relevant qualitative data) and closing questions (reiterate participants' rights, further instructions and ending the interview) (Creswell and Creswell, 2018). Content questions are crafted to allow interviewees to elaborate on their knowledge, exposure, and personal viewpoints on plastic pollution in the Canadian Great Lakes. Specific probes embedded in the content questions pursue answers that are helpful for addressing the following components of the study's research questions: (1) drivers for plastic pollution into the Great Lakes, (2) outlooks on plastic pollution-related legislation, (3) difficulties and barriers observed by the interviewee that prevent sustainable pollution prevention and (4) perspectives on actions to be implemented to address the challenges and move forward. Additionally, questions are formatted to avoid confusion, steering participants, or to leave a simple "Yes/No" response without room for elaboration. Details on the topics addressed through

the interview protocol, as well as the specific question templates to be used, can be found in the Appendix.

3.1.4: Qualitative Data Analysis

Drivers, barriers, and recommendations for plastic pollution within the Canadian Great Lakes are explored in interview transcripts by using content analysis. Content analysis is a method often used to "make replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use' (Krippendorff, 2004). It allows the use of either deductive or inductive (or both) approach, and can be a stand-alone method or combined with other approaches (White & Marsh, 2006). It's also preferable because it's straightforward, not demanding in terms of resources, time, and availability of samples (Krippendorff, 2004), which will fit with this study's limited sampling size. Content analysis has been widely implemented in different fields, for example in library in information sciences as demonstrated by White and Marsh (2006), due to being a "systematic, rigorous approach to analyzing documents obtained or generated in the course of research" (White & Marsh, 2006). Content analysis is particularly helpful in helping researchers to find and describe the use of themes, trends, patterns or common characteristics within communication (Krippendorff, 2004). Thus, it is appropriate for analyzing interview transcripts for this study.

This study employs a mixture of inductive and deductive coding approaches following instructions presented in Linneberg and Korsgaard (2019) and Guest et al. (2012). First, the deductive approach utilizes the waste hierarchy to structure, categorize and predict patterns that emerge from interview questions' responses, with each idea being one "code". All predicted ideas are then compiled to create a preliminary codebook. Second, an inductive approach using open coding is used to identify emerging ideas that are not identified by the preliminary code book (Guest, Greg et al., 2012; Skjott Linneberg & Korsgaard, 2019). The last data analysis step involves axial coding (Blair, n.d.; Skjott Linneberg & Korsgaard, 2019) to merge patterns that are uniquely identified by interviewees and those that are identified by the preliminary codebook. Then, this prompts revisions to develop the final codes or themes as parts of this study's results, with codes organized by each interview questions' probe: drivers, barriers, and recommendations.

Content analysis begins with a pre-determined set of themes (following the waste hierarchy) and ends with a second, revised set through repeated reviews of interview transcripts. A "theme" is defined by Ryan and Bernard (2003) as "abstract (and often fuzzy) constructs that link not only expressions found in text but also expressions found in images, sounds, and objects". "Some themes are broad and sweeping constructs that link many kinds of expressions. Other themes are more focused and link very specific kinds of expressions" (Ryan & Bernard, 2003). If there are words or expressions that are repeated throughout multiple interview transcripts, they are noted as a theme. Themes are organized in a hierarchical order with each interview question be one guiding inquiry (Guest, Greg et al., 2012). Identification and analysis of themes would utilize NVIVO for a systematic process. NVIVO can identify each theme to be a "code", following a coding protocol adopted from Guest et al. (2012):

> Read the interview transcripts and identify themes that are similar to the pre-determined themes below.
>
> Review the transcripts again to identify additional emerging themes.
>
> Refine themes into codes with well-developed definitions
>
> Adjust the codes, codes' definitions, or the use of codes accordingly. Or, re-code as needed. Repeat as necessary (Guest, Greg et al., 2012).

The waste hierarchy ladders (for example "Reduce") guided the development of the following codes:

Theme: Prevention

Refuse,
Rethink,
Redesign,
Reduce,
Reuse,

Theme: Value Recovery

Recycle,
Capture or clean-up,
Energy recovery/ incineration,

Theme: Instruments

Legislation (including, but not limited to "bans", "levies", "taxes"),
Capacity enhancement (including, but not limited to "infrastructure", "responsible personnel"),

In addition to qualitative coding, quantification of data complements content analysis. Quantification of data encompasses word counting, counting of themes mentioned, and comparing the number of participants who agreed or disagreed on one theme displayed as percentages. This not only fits within the traditional mixed methodology framework, but also is regarded as an enhancement for "validity and persuasiveness" (Guest, Greg et al., 2012). Quantifying stakeholders' responses aids in describing and clarifying empirical patterns from qualitative data and illustrating a range of variability in answers. Quantification of participants' responses to display similarities and differences in individual viewpoints regardless of sectors, and sectoral perspectives, is done by calculating proportions (%) (Guest, Greg et al., 2012).

3.2: Secondary Data Collection – Literature Review

Secondary data acquisition through literature review is performed through a desk-based literature review prior to collection of interview data, and cross-validation that proceeds qualitative content analysis of interview results. First, a preliminary literature review investigates what has been done in Canada to address plastic pollution, setting the scientific and political contexts for the Canadian Great Lakes. Results from this part of literature review also help to guide creation of interview scripts for participants. The inclusion criteria for finding resources for setting the scientific and legislative context are: systematic reviews or environmental policy-focused peer-reviewed papers as cross references, published documents from the Government of Canada, Government of Ontario, and relevant regulatory authorities' official websites (such as lois-laws.justice.gc.ca/eng/ or canada.ca). On the other hand, the exclusion criteria are: (1) documents or studies done on countries other than the US or Canada, (2) sources with no citations, (3) non-peer-reviewed sources. Finally, cross-validation is employed to further clarify important ideas cited by most interviewees. Cross-validation is done to clarify specific recommendations mentioned during interviews and enhance correctness of conclusions developed from primary data when interviewees do not follow up with sufficient explanation. This ensures the analysis of recommendations to address plastic pollution challenges within the Canadian Great Lakes are realistic and relevant.

Ethics Clearance:

This study has been reviewed and received ethics clearance through the University of Waterloo Research Ethics Board REB [ORE # 44001].

Chapter 4: Results

4.1: Participant Overview

Participants interviewed in this study present a diversity in perspectives. To provide a variety of perspectives for answering the research questions, key informants (hereby referred to as either "participants" or "interviewees") from four sectors were invited. An overview of sectoral representation and response rate is demonstrated by Table 1. The highest response rates belonged to key informants that identified to work in non-profit organizations, non-government organizations (NGOs) and academia. Similarly, informants within these sectors had the highest numbers of members. Public sector informants occupied the lowest response rate. The private sector occupied the lowest number of participants. Additionally, there were eleven participants who were affiliated (in varying degrees as funders, researchers, or active members) with the Great Lakes Plastic Cleanup (GLPC) initiative, while ten participants were independent (as shown in Table 1). Snowball sampling reached saturation in this study because (1) no new participants were recommended to the student researcher and (2) either some participants did not follow up to provide consent or some referrals did not respond to the study's invitation. The public sector interviewees represented provincial and national entities. The private sector interviewees represented small, medium, and large enterprises who are not plastic manufacturers. Non-profit organizations and non-government organizations interviewees represented organizations that either work exclusively in Canada, or binationally. Academia interviewees were all from post-secondary institutions.

Table 1. Participant summary.

Sectors	Prospects Invited	GLPC Partner Interviewees	Non-GLPC related Interviewee	Overall response Rate (%)
Public	21	2	3	24
Non-profit and NGO	15	3	3	40
Academia	9	3	3	67

Private	14	3	1	29
Total	59	11	10	36

Note. A summary of key informants who were invited and who participated in the study. Sectoral representation, response rates, and demonstration of participants whose work within plastic pollution were affiliated with the GLPC compared to those who were not were displayed.

The section below presents an overview and analysis of participants' perspectives on the major drivers for plastic pollution in the Canadian Great Lakes, critical barriers and recommendations that would address challenges and help Canada move forward with pollution prevention. Themes for consideration within this section would assist concerned citizens and experts in future decision-making.

4.2: An Overview of Existing Voluntary and Mandatory Instruments

Addressing plastic pollution at national or binational scales is more effective for sustainable plastic waste management than fragmented efforts at local levels (Kranzberg, G., 2019). Therefore, this section primarily focuses on provincial (i.e., Ontario where the Great Lakes are located) and national Canadian policies, with honorable mentions of relevant and influential international commitments. A summary of both non-binding and legally binding instruments are presented in Table 2 and Table 3 below.

Table 2. Regulations corresponding to each ladder of the CCME waste hierarchy.

Corresponding Waste Hierarchy Tier	Official Legislation
Prevention - Reduce	**National:** CEPA (1999) Toxic Substances List Schedule 1 (updated in 2021) (Government of Canada, 2021)**,** Microbeads in Toiletries (enacted in 2018) (Government of Canada, 2018b), Single-use Plastics Prohibition Regulation (SUPPR) (Government of Canada, 2022c) (enacted in 2022). **Provincial:** Bill 228, Keeping Polystyrene Out of Ontario's Lakes and Rivers Act (Government of Ontario, 2022) (enacted in 2021).

Prevention – Repair and Reuse	National: None
	Provincial: None
Prevention and Value Recovery – Remanufacture and Refurbish	National: None
	Provincial: None
Value Recovery – Recycle	National: None
	Provincial: Bill 151 - Waste-Free Ontario Act (Government of Ontario, 2016, p. 151) (enacted in 2016)
Value Recovery – Energy Recovery	National: None
	Provincial: Waste-Free Ontario Act (Government of Ontario, 2016)

Note. Compilation of national and provincial binding legislation in Ontario and their connection to the Canadian Council of Ministers for the Environment's waste hierarchy. The hierarchical tiers are sorted by most preferred to least preferred.

Table 3. Voluntary commitments and proposed regulations corresponding to the CCME waste hierarchy.

Corresponding Waste Hierarchy Tier(s)	Scale	Voluntary Frameworks and Proposed Regulations	Scope
Prevention - Reduce Value Recovery - All tiers	International	G20 The Group of Twenty (D. Silva, 2021) (2019)	Marine Plastics
Prevention - Reduce Value Recovery - All tiers	International	G7 Ocean Plastic Charter (Government of Canada, 2018a) (2018)	Marine Plastics
None	Bi-National	The Great Lakes Water Quality Agreement (Government of Canada, 2022b) (GLWQA)	Freshwater Plastics

Prevention - All ladders Value Recovery - All tiers	National	CCME's Plastic Science Agenda (ECCC, 2019b) (2019)	All Plastic Waste
Prevention - Reduce Value Recovery - Recycle and Energy Recovery	National	Proposed Integrated Management Approach to Plastic Products to Prevent Waste and Pollution (ECCC, 2019a) (2020)	Single-use Plastics
Prevention – Reduce Value Recovery – Recycle	National	Recycled content for certain plastic manufactured items Regulations (Government of Canada, 2022a) (2022)	Single-use Plastics
Prevention – Reduce	Provincial	Bill 279: Environmental Protection Amendment Act (Microplastics Filters for Washing Machines) (Arthur & Bell, 2021) (2021)	Plastic microfibers in Ontario
Prevention – Reduce Value Recovery – Recycle	Provincial	Bill 82: Single-Use Plastics Ban Act (Arthur, 2019) (2019)	Single-use plastics in Ontario

Note. Compilation of action frameworks and guidelines proposed regulations (that have not received Royal Assent or passed) published by Canadian governments that demonstrate commitments towards plastic pollution within Canada. These are either non-binding without mechanisms for holding non-compliance accountable, have not been legislated, or have been drafted but are without mechanisms for holding non-compliance accountable.

Table 2 and Table 3 displayed an overview of existing mandatory (regulatory) and voluntary (commitments) instruments in Canada that influence plastic pollution in the Great Lakes. Regulatory instruments are implemented at several levels of governance, ranging from municipal (such as a check-out bag levy as investigated in (Rivers et al., 2017), provincial (Bill 228 and Bill 151) to federal (CEPA (1999), Microbeads in Toiletries regulation, Single-use Plastics Prohibition Regulation). On the other hand, voluntary commitments largely employ a

top-down approach with predominantly international and national action plans. National commitments correspond to and align with the Ocean Plastic Charter (CCME, 2019; Government of Canada, 2022a). Despite offering comprehensive guidelines for scientific, educational, regulatory and collaborative actions (as seen in for example (Canadian Council of Ministers of the Environment (CCME), 2019, 2020), Table 3's proposals are not enforceable. Therefore, further actions from these commitments towards preventing or adapting to plastic pollution within the Great Lakes are not guaranteed. National regulations predominantly act as instruments to fulfill the first ladder under Prevention, and all Value Recovery ladders within the CCME waste hierarchy. These regulations can assist prevention of plastic pollutants by regulating the production and consumption of certain plastic items. Next, provincial regulations address both prevention and value recovery, as in addition to regulating one type of plastic pollutant (polystyrene foam), Bill 151 covers plastic items eligible for the Blue Box recycling program.

4.3: Stakeholders' Perspectives on Drivers of Pollution:

The most critical driver of plastic pollution in the Canadian Great Lakes was identified to be multi-source plastic leakage. Two contributors to leakage emerged: consumers' poor behaviors (which included littering, pandemic-related leakage, and a general lack of awareness), point-source inputs, and a general lack of actions among the governments and the private sector. Contribution towards leakage and reinforcing the dominance of single-used, non-necessary plastics were identified to be from consumption of single-used plastics by businesses, plastic industry, fishing industry, textile industry, and leakage from waste management system. The following paragraphs will explain why these are significant drivers of plastic pollution.

All interviewees agreed that several forms of plastic leakage were prominent factors contributing to the severity of pollution: "It's (plastics) ubiquitous" and it's present "in all environmental media" (Participant 10 in Academia). Several forms of leakage were discussed more specifically, with the most mentioned forms being runoff from stormwater or sewer overflows, household grey water discharge ("laundry") (Participant 20 in the Private Sector), mismanagement or accidental spills from the waste management system, leakage from residential garbage collection points because of weather or animal meddling, spillage from transportation of plastic pellets, and atmospheric deposition ("wind blowing" plastics into water surfaces) (Participant 10 from Academia). Twenty (95%) interviewees provided specific

examples of dominant types of plastic pollutants as drivers, which ranged from broad categories such as all plastics or all single-use plastics to specific categories such as nurdles (pre-production pellets), dock foam, microfibers from clothing, cigarette butts, bottle caps, fragments, films, and construction materials. Interviewees were more concerned about microplastics, particularly plastic pellets, than any other types of plastics, due to various factors such as being hard to recover or having ecological and human health implications, such as being reactive with toxins in the environment. A list of highlighted plastic pollutants identified by participants as major drivers contributing to plastic pollution within the Canadian Great Lakes is demonstrated in Figure 4 below. Pollutants were organized from left to right, most to least mentioned by participants.

Figure 4. Pollutants as Drivers in the Canadian Great Lakes.
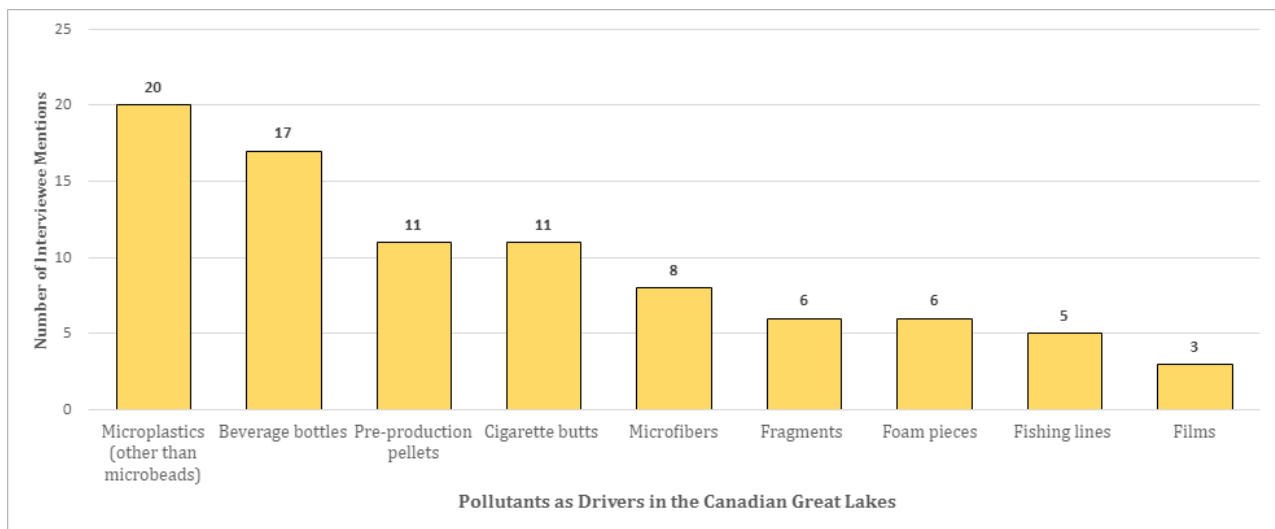
Note. Pollutants identified encompassed a general category of "Microplastics (other than microbeads)" to specific types (the rest of the pollutants). Existing investigations such as Corcoran et al. (2020), Cox (2018), Mason et al. (2020), Earn et al. (2021), Athey and Erdle (2021) confirmed these were prominent pollutants that were typically found along shorelines, on surface water, and within sediment beds of the Canadian Great Lakes.

Nine interviewees (43%) (five from academia, two from the public sector and two from non-profits/NGOs) noted that the severity of each pollutant getting into the lakes varied by location. Lake Erie, Lake Ontario, and Lake Superior's Thunder Bay bordered cities with high population and plastic industry facilities compared to other areas bordering Lake Superior and Lake Huron. This was consistent with findings from Mason et al. (2020), Corcoran et al. (2020)

and Earn et al. (2021) on both the dominant plastic pollutants in the Canadian Great Lakes and factors influencing the magnitude of pollution (Corcoran et al., 2020; Earn et al., 2021; Mason et al., 2020). For cross validation of dominant plastic pollutants within Lake Erie, Lake Ontario, Lake Superior, and Lake Huron, please refer to Chapter 2: Literature Review. Construction waste emerged as a new driver that has not been extensively discussed in literature. Helm (2020) analyzed 31 peer-reviewed articles surveying plastic concentrations across the Great Lakes from 2015 to 2019 and data from the Great Canadian Shoreline Clean Ups in 2018, and linked foam particles (being among the twelve most frequently found plastic pollutants) to polystyrene foam boards used in construction insulation (Gago et al., 2020; Munno et al., 2022). Cox (2018) and Earn et al. (2021) also reported on polystyrene foam particles in Lake Superior and across the Canadian Great Lakes respectively, however neither developed linkage to construction waste (Cox, 2018; Earn et al., 2021). Current discrepancies in data collection and data reporting called for the development of standardized procedures, units of measurement, and a systematic set of criteria for identifying input sources (Gago et al., 2020).

Eighteen (86%) of all interviewees cited poor consumption habits as the ultimate driver for pollution in the Great Lakes. Fourteen (67%) of the interviewees discussed two drivers within this topic. All private sector interviewees (four), three from academia, two from non-profits/NGOs and one from public sector felt strongly that littering (and two even mention "illegal dumping" of waste) was the primary driver, as one commented:

"Litter is probably the biggest source of plastic entering Great Lakes" (Participant 5 from the public sector).

Next, some concerns were raised about industry and manufacturers producing an abundance of plastic products that could possibly be avoided or are unnecessary. Moreover, the availability of plastic products contributed to society's heavy reliance on them. Nine interviewees (43%) (three from the public sector, two from academia, one from private and three from non-profit/NGOs), discussed the nuance and complication in putting the onus of plastic pollution on the individual consumers. Participant 3 from the public sector remarked:

Consumers can play their part. But, ultimately, I am not one that likes to pin it all on individual consumers because we are all very busy people. We all have different concerns and preoccupations […]. We may not have the financial means to make those informed decisions or better decisions for the environment. And so, I do not think consumers

should be punished for that. So ultimately, a lot of that leadership guidance and development of alternatives needs to come from governments and the private sector (Participant 3 in the public sector).

Interviewees discussed the complexity of the issue through acknowledgement of various players being involved. The private sector, including plastic manufacturers and other producers, and businesses that employed single-used plastics for their products, play critical roles in generating plastics in the market, which would ultimately lead to leakage.

Interviewees also extensively discussed the status quo – lack of enablers for transitioning towards better pollution prevention practices and more sustainable handling of plastics throughout their life cycle. The widespread availability, usefulness and versatility of plastic ingredients, and the fact that many plastics are cheaper than other materials, makes it almost impossible to replace plastics in daily lives:

But unfortunately, there is always going to be members of the public that pick something that is really convenient and inexpensive and I do not think it should all be put on consumers to make the right choices. (Participant 11 from the public sector).

Five academia interviewees, three public sector interviewees, four from non-profits/NGOs and two from the private sector observed the increased usage and demand for single-used plastics, including personal protective equipment (PPE) and cleaning supplies, and expected that this might have had impacts on plastic pollution in the Great Lakes. Three public sector and two academia interviewees explicitly described their concerns with the pandemic accelerating plastic pollution as a personal observation and prediction rather than a fact. Overall, pandemic-related consumption of plastic was deemed "a push back" on the fight against plastic pollution.

In addition to increasing consumption, landfilling and leakage of single-use plastics, COVID-19 influenced human perceptions that prospectively impact plastic pollution in the Great Lakes negatively. Results from Silva et al. (2021) reflected a shift in consumers' priorities, with a much higher regard for health and safety over environmental considerations. This was demonstrated partly through a delay in or withdrawal from single-use plastic regulations and taxes, with examples from the province of Newfoundland and Labrador in Canada, states of New York, Delaware, Maine, Oregon, Connecticut, in the U.S. (Patrício Silva et al., 2021; Zambrano-Monserrate & Ruano, 2020). There has been little consideration of plastic pollution over the past years as this was overshadowed by the centrality of public health, and fear and anxiety caused by

the pandemic (Grodzińska-Jurczak et al., 2020). This phenomenon existed in Canada as well. Researchers at Dalhousie University's Agri-Food Analytics Lab surveyed 1,014 Canadians on their perceptions on single-use plastics in food products from 2019 to 2020. Results demonstrated varying opinions and levels of knowledge. Moreover, on average, there's a notable decline in support for banning single-use plastics after COVID-19 (Walker et al., 2021). With the pandemic influencing the choice of using more single-use plastics, more investigations are necessary to reveal pandemic-related impacts on plastic pollution in the Great Lakes.

The intersection between social factors and plastic consumption and waste mismanagement (including behaviors such as littering) has been explored, for example as explored in Heidbreder et al. (2019). Heidbreder et al. (2019) were able to identify a myriad of social, cultural, and economic influences that further contributed to the status quo of plastics. Refusal of using single-used plastics and mindfulness of littering varied by consumers' cultural background, social contexts in which they were in while making decisions, level of education and income, and beyond. People with higher levels of education and higher economic means were more inclined to refuse using plastic bags. The higher convenience of single-used products than that of reusable options also made plastics more attractive (Heidbreder et al., 2019). Another study examining consumption choices of Brazilian immigrants in Canada concluded that cultural norm and personal habits meant using plastics were unavoidable or often not being questioned (Romero et al., 2018). Interview qualitative data offered no further explanations than that found in Heidbreder et al. (2019) and Romero et al. (2018). Nevertheless, further research is needed to explore and address social and income-related factors influencing consumers' affinity to using single-used plastics, and how these influences can alter attitudes towards reducing consumption and littering.

4.4: Stakeholders' Perspectives on Barriers

Major drivers and barriers from interviewed stakeholders' perspectives expanded on existing analysis investigating challenges towards sustainable plastic pollution prevention in Canada, such as the government of Canada's "A proposed integrated management approach to plastic products: discussion paper" (Government of Canada, 2020).. Table 4 illustrates a comparison between the results of this study and that of the technical issue paper:

Table 4. Comparison of barriers from this study's results to that of the ECCC's "Technical issues paper: Recycled content for certain plastic manufactured items Regulations".

	This Study's Results	*Technical issues paper: Recycled content for certain plastic manufactured items Regulations*
Similarities	1. Primary and secondary plastics compete. 2. Weak end-markets for recycled plastics. 3. Insufficient recovery options.	1. Primary and secondary plastics compete. 2. Weak end-markets for recycled plastics. 3. Insufficient recovery options.
Differences	4. Lack of consumers' awareness and understanding that lead to increased plastic disposal and plastic leakage. 5. Inadequate enforceable policy instruments at binational, national and provincial levels. 6. Multi-source plastics' leakage. 7. A lack of industry (manufacturers, producers, and single-used plastic users) responsibilities. 8. Lack of funding for research in developing, and maintaining innovative solutions. 9. Infrastructure incapacity.	4. Collection rates (of recyclable plastics) are low. 5. The cost of plastic pollution is shouldered by individuals and communities.

Note. Comparison of the most critical barriers to tackling plastic pollution in the Great Lakes in Canada, between results of stakeholders' interview analysis within this study and that of the "Technical issues paper: Recycled content for certain plastic manufactured items Regulations". This study's findings exhibited some similar barriers while unraveling other barriers (ECCC, 2019a).

Both national and Ontario provincial legislation are deemed inefficient and unable to comprehensively address this issue. This was a theme that emerged as interviewees were asked about the effectiveness of current regulations on plastic pollution prevention in the Great Lakes in Canada. Eighteen (86%) of interviewees believed that current legislation was lacking in addressing plastic pollution. Seven interviewees specifically identified that recycling regulations

and guidelines were fragmented, confusing and sometimes poorly communicated to consumers. Other barriers that current legislation imposed on plastic pollution had several setbacks, such as a lack of support for citizen concerns, lack of incentives for innovation, lack of involvement of non-profits and businesses, legislation being "punitive" rather than "enabling" (Participant 13 from non-profits/NGOs), and presenting aspirational goals that were not enforceable. Overall, the general opinion was that the upstream drivers were not comprehensively enough addressed. Many plastic pollutants that were both identified by existing literature investigating plastic pollution within the Great Lakes watershed and participants within this study (as seen in Figure 4) were not regulated by any municipal, provincial, or federal regulations within Canada. . Moreover, binational accords, particularly the Great Lakes Water Quality Agreement, do not yet classify plastic pollutants as either chemicals of concern, or add them under any Annexes. Although the Microbeads in Toiletries ban was considered a success, current legislation and regulations were considered limited to effectively address plastics pollution through waste management and were incapable of addressing critical upstream drivers such as stormwater runoff. The latter was believed by three interviewees from the private sector, two respectively from academia, public and non-profits/NGOs to be an important source.

Sixteen (76%) interviewees agreed that a fundamental lack of awareness and willingness to take actions from the general consumers was a critical barrier. Eleven interviewees (52%) (all private sector interviewees, four from academia, two from non-profits/NGOs and one from the public sector) explained that consumers in general may not understand the magnitude of their consumption impacts. Moreover, two interviewees from the private sector and two from the public sector mentioned there was a general lack of public environmental stewardship and urgency, which further hindered overall willingness to modify consumption habits. It was worth noting that the prevalence of this barrier was either referred to generally as "people", "population", or specifically a portion of the population within the watershed who enjoyed the ecological services provided by lakes. Ecological services impacted by plastics pollution in the Great Lakes were not elaborated in detail, but two examples were provided: boating and fishing.

Another critical barrier that interviewees identified was factors contributing to maintenance of the plastic status quo: impediments in engaging the private sector, prevalence of single-used plastic designs, lack of alternatives, financial implications of changes, and timing.

Seventeen (81%) interviewees raised the issue of lack of alternatives and the costs of alternatives and the financial burden this may cause. The status quo of plastics is that they are cheap and convenient. Very few other alternatives, including products made of glass, metals, or even bio-based plastics, can compete with the widespread accessibility and the affordability of plastics. Recycled plastics may be an option, but compared to virgin plastics, the availability and market for this is much more diminutive (Deloitte et al., 2019b). Moreover, improving recycling is costly when considering investments needed for contamination removal, sorting, and accommodating differences in processing procedures due to the huge variety of additives, fillers, and compositions of ingredients in plastic products. Many businesses take advantage of low-cost plastics, and there are not enough incentives or capacity for many to switch to alternatives (Deloitte et al., 2019b). Lastly, four non-profits/NGOs, two private sector, three academia and two public sector interviewees argued for a shortage of finance for research, development, and implementation of innovative technologies for effective pollution prevention or pollutant capture within the watershed. It is worth noting that this barrier was referred to as "funding" generally, and interviewees generally did not specify whether this should come from governments, corporate sponsors, or other means.

Sixteen (76%) participants discussed industry-related setbacks. Many businesses did not appropriately address plastic leakage from transport or operation at their facilities:

There's a lot of industries that pay fines because they pollute, but they're allowed to keep

polluting as long as they pay the fines. (Participant 1 from the non-profits/NGOs group)

When prompted for further explaining how or why businesses allowed for plastic leakage, the statement above was a sole specification, insinuating that paying fines was not a strong deterrent to plastic leakage from facilities. Additionally, many businesses benefited from using plastics or plastic production. They either did not voluntarily engage in rethinking plastic consumption or fail to perform due diligence before manufacturing plastic products, resulting in many items being hard to impossible to be recycled or recovered. Notably, three interviewees from the private and three from non-profits/NGOs acknowledged that there are a few willing participants within the sectors who are looking into plastic alternatives or looking to support pollution prevention programs. However, the barrier is that many businesses still support the status quo of current cheap plastic inputs, sustaining plastic flows that majorly contributed to pollution, and resist changes to more expensive alternatives. The Canadian economic dependency on fossil fuel

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and its by-products means that there will be no easy fix. According to the "Economic Study of the Canadian Plastic Industry, Market and Waste" report, most plastic production still relies on virgin plastic, with a production value estimated in 2017 to be CAD 10.1 billion (Deloitte et al., 2019a). The report estimated that while non-recyclable plastic packaging accounted for about 33% of all plastics in the market, this accounted for 47% of landfill plastic input in the same year. Interestingly, the report points out that plastic recovery from industry and commercial sectors generally is not within municipal waste collection and management systems, and that overall, the recovery rates are low. Only about 8% of total plastic waste generated in 2016 was diverted and recycled. Investigation into the diversion rates based on sectors also yielded low numbers: about 21% are recovered from plastic packaging, 7% for textile and 6% for construction in 2016 (Deloitte et al., 2019b).

Twelve (57%) interviewees (four from academia, four from non-profits or NGOs, three from the private sector and one from the public sector) cited the inability of the current infrastructure to accommodate effective pollution control and fully recover plastics once they either leaked into the water or entered the waste streams. Predominantly, waste collection and recycling infrastructure in Canada could not handle all types of plastics or effectively prevent leakage. Another discussion referred to there not being any cost-effective technologies implemented at provincial or watershed scales to either effectively prevent plastics entering the Great Lakes waterways or to capture macro and micro plastics. According to the mentioned report prepared for ECCC in 2018, there only exist 11 facilities across Canada for recycling plastics (Deloitte et al., 2019a).

The status quo is such that the recovery and recycling systems within Canada are unable to recover all plastic waste. Twelve interviewees (57%) (five from the public sector, three from the public sector, three from academia, and one from the private sector) agreed the inability and complexity in recycling plastics is a major barrier to developing incentives for recycling and to meet provincial or national goals of full waste recovery. The "recyclability" of a product is also dependent on its mixture of ingredients, which makes some waste types much more recyclable than others. Single-used nonrecyclable plastics still dominate the plastic product market, and the sheer variety of additives, fillers, and designs of plastics available in the waste streams poses significant complications to the current limited recycling capacity (Deloitte et al., 2019b). Moreover, as discussed in the previous chapter, plastics do not decompose and instead break

down into minuscule plastic particles. Due to their miniscule size, three interviewees from the non-profits/NGOs, two from the public sector, three from academia and two from the private sector expressed concern that no technology to date has been implemented locally or on a larger scale in the Great Lakes watershed to filter out microfibers and similarly other small plastic fragments. Complex designs of plastics rendering them hard to be recycled, and the incapacity of infrastructure to handle full waste recovery, are important barriers that need to be addressed in order to be able to move towards more effective incentives to stop leakage coming from waste streams.

Finally, timing was a concern raised by multiple participants without it being identified explicitly as a hindrance or a challenge. As twelve interviewees (four from non-profits/NGOs, three from academia, three from the public sector and two from the private sector) explained, consumers and politicians do not seem to understand the urgency and magnitude of the plastic pollution problem in the Great Lakes. Thus, if discussions surrounding the issue and the development of concrete actions or additional regulations would "take a long time", plastics are expected to continue to leak into waterways at "such a high magnitude" (Participant 7 from Private sector). Community-based and government-based initiatives aiming at plastic pollution in the Great Lakes are only "at (a) beginner stage" (Participant 13 from Non-profits/NGOs). Changes may "take years" or even "decades"(Participant 16 from Non-profits/NGOs). There remain many pieces of the puzzle to be solved through further research and collaborations, including better quantifying the effectiveness of measures already in place.

4.5: Stakeholders' Shared Recommendations

Plastic pollution in the Great Lakes would require a binational approach. Eighteen interviewees (86%) discussed that the shared use of the lakes has led to plastics inputs from both countries. However, some cited a lack of binational leadership, pointing out discrepancies in the level of efforts in pollution prevention. The International Joint Commission (IJC) was mentioned to potentially play a critical role in accelerating and harmonizing actions from both countries. The IJC hosted a workshop in 2016 focusing on microplastics in the Great Lakes. With feedback from this workshop and public comments, the IJC developed a report in 2017 detailing recommendations for both the US and Canadian governments (IJC, 2017). The suggested action framework encompassed a binational plan to prevent plastics from entering the Great Lakes,

funding and additional support for research and development of innovations, collaborations among all levels of government as well as with expert and Indigenous partners and adding microplastics to the national K-12 curriculum (IJC, 2017). Three interviewees from non-profit organizations, two from academia, and two from the private sector suggested education towards students should entail: negative impacts of plastic pollution to wildlife and potentially to human health, preferred practices to reduce consumption of single-use plastics, why and how to stop littering.

Nevertheless, there was neither a binational monitoring agreement, nor a commitment to integrate plastic pollutant education into the K-12 national curriculum. Nominating plastics as either an annex or a chemical of mutual concern within the Great Lakes Water Quality Agreement (GLWQA) was a desired outcome. Yet, the GLWQA does not officially recognize plastics or microplastics within any annexes, Lake-Wide Action and Management Plans, or within the "Chemicals of Mutual Concern" list (ECCC, 2013). Due to binational inaction, six interviewees from the non-profits/NGOs, four from academia, three from the public sector and two from the private sector called on additional recognition and actions from the GLWQA's Great Lakes Executive Committee and the IJC to enhance advocacy and political will from both sides.

A sub-group of participants cited specific instruments that could assist in achieving desirable outcomes for effective plastic pollution prevention and plastic waste recovery. A summary of recommended mandatory, voluntary (or both) instruments was given in Table 6 through combining content analysis of interview data and cross-validation with existing peer-reviewed literature. The CCME's waste hierarchy framework stated the most valued solutions to sustainable waste management and pollution prevention would be three preventive measures: to reduce, reuse and repair. This study participants elaborated on preventive measures (most prominently benefiting the "Reduce" ladder), and the recycling ladder under value recovery within the waste hierarchy vigorously. Consistent with the waste hierarchy's value recovery preference, much less attention was given towards recycling and energy recovery ladders. Notably, no interviewees mentioned remanufacturing and refurbishing. A key word search for these two ladders throughout all interview transcripts yielded no results. Table 5 comprehensively addressed major barriers and drivers as discussed in earlier sections of the Result chapter. Table 6 demonstrates clearly mandatory and voluntary instruments that emerged

from specific interviewees' suggestions. No other instruments were explicitly named within the interview data. Alpizar et al. (2020)'s framework for identifying pollution prevention instruments assisted the development and categorization of the instruments into four categories: price-based (economic instruments), policy-based (legislative or regulatory instruments), rights-based (stakeholder engagement and delegating responsibilities), and behavior-based (education, raising awareness) (Alpizar et al., 2020).

All participants advocated for changes in either legislation or regulation landscapes in Canada for effective preventive efforts, addressing legislation inadequacy. The major consensus was that legislation and regulations needed to create a "level-playing field" in which responsibilities were better distributed among all stakeholders and opportunities were present for all to contribute (Participant 13 from non-profits/NGOs). Responding to a major discontentment with legislation and regulations' lack of comprehensiveness, many suggested stricter measures, or additional instruments to be added in the future. Sixteen interviewees (76%) (five academia, one private sector, two public sector, and four non-profit and NGO interviewees) advocated for the "carrot and stick" approach, in which legislation or regulations both disciplined individuals or entities that mismanaged plastic waste releasing plastics into the environment, and enabled rewards or exemptions for those who practiced best management practices and displaying environmental stewardship. A summary of examples provided were referred to generally as the following: bans, taxes and levies, exemptions or rewards, and stakeholder engagement, as seen in Table 5. In addition, two interviewees from the public sector and three from academia advocated for the Government of Canada's latest proposal of developing a minimum recycled content requirement. Likewise, additional industry standards for re-designing recyclable and durable plastics were highly praised:

> There have to be governing regulations as to how (plastics) can be produced and if you cannot demonstrate that it can be recycled, and build a marketplace for that recycled material, then you cannot introduce it into the marketplace. (Participant 14 from the Non-profits/NGOs).

This is a solution to creating attractive markets for recycled plastics and theoretically decrease virgin plastic production and leakage in the future. Likewise, for effective reduction in the use of virgin plastics, interviewees suggest several methods: encouraging innovations, subsidizing alternatives, facilitating wider markets for recycled materials putting taxes on virgin plastic, or

building environmental costs into product costs to make non-essential products more expensive. For example, provincial minimum recycled content was expected to nudge improving recovery schemes and increase investments in infrastructure, and changing plastic designs:

> As targets increase or become more ambitious, that means that producers are required to capture more and more of their materials. And with that requirement drives the sighting of new facilities or the upgrading and retrofitting or you know, just increase in capacity of the current facilities that are located in Ontario. (Participant 3 from the public sector).

Collaboration of national and provincial authorities was recommended to enact punishment or prohibition for leakage from production, transportation, or storage of plastics at facilities or landfill sites. Overall, preventive measures were more strongly supported compared to value recovery options.

To encourage willing participation from the private sector, a suggestion was to appeal to large corporations' appetite for sustainable campaigns in which they could associate their brands with positive changes. Customers' perception of a brand's impacts and values are valuable and can be an important driver of change. Discussions on customers' actions will be done below. On the other hand, three interviewees from the public sector, three from non-profit/NGO and four from academia stressed the criticality of enforcing and maintaining compliance:

> Even with all the best legislation and rules, it means nothing if they don't get enforced. And if you don't fund enforcement, then no matter what your protective acts are, you're not going to have an impact (in reality) because you won't insist on any behavior change (Participant 14 from the Non-profits/NGOs)

For value recovery measures, two interviewees from the private sector, one from the public sector, three from academia and three from non-profits/NGOs specifically supported the extended producer responsibility (EPR) scheme. It was never clarified whether the support was for this system to be implemented provincially or nationally. Interestingly, under Ontario's Resource Recovery and Circular Economy Act enacted in 2016, the RPRA is leading the transition of the province's Blue Box program from municipal-controlled to EPR. The transition timeline is expected to be from 2023 to 2025 (Resource Productivity & Recovery Authority, 2021). Unfortunately, there was not enough data to conclude whether interviewees were aware of this transition. However, two interviewees from the public sector, four from academia and two from non-profits/NGOs recommended harmonizing municipal, provincial and national waste

management (including recycling schemes) policies, which may encompass EPR. While discussing support for EPR, an interviewee explicitly distanced himself from the sector he identified with, stating that his support should not be representative. His choice was excluded from representing a sector but did not significantly affect this result.

Feedback from interviewees in the private sector, academia and non-profits/NGOs also stated that positive supports for stakeholders should consider enhancing engagement (see discussion below) through providing a clear timeline and instructions for transitioning away from plastics, financially support small businesses to phase out single-used plastics, and remove "red tape" hurdles for NGOs (Participant 2 in non-profits/NGOs), non-profits and industry leaders who would be active participants in pollution prevention. There are regulatory and voluntary frameworks in place such as CEPA and the GLWQA. Provincial and federal governments should be willing leaders in implementing and promoting changes.

Twenty (95%) of interviewees thought collaboration among partners of various backgrounds would be critical to successful operation. Existing collaborative efforts such as the GLPC were greatly welcomed. Eighteen (86%) interviewees endorsed more collaborative efforts and engagement among various levels of governments, NGOs representing both consumers and the private sector. Four interviewees from non-profits/NGOs and three from academia also mentioned important co-operations with grassroot community groups, the First Nations, Inuit, and Metis communities, and even individuals from different discipline (such as artists). In Section 4.7, this study attempted to understand what opportunities for collaboration exist in Canada or in North America.

Many highlighted the importance of education and consumer awareness. Since consumer-level behaviors and mismanagement of plastics at their end-of-use was deemed among the most critical barriers and drivers, nineteen (91%) of interviewees strongly supported better education for consumers, suggesting further works to be done to improve understanding on the impacts of littering and consuming non-essential single-used plastics. Similar to the International Joint Commission's recommendation, interviewees continued to push for K-12 curriculum to include "big picture" (Participant 19 in non-profit group) lessons on plastics pollution. One interviewee from the private sector, three from the public sector, four from academia and three from non-profits/NGOs suggested not only consumption reduction but also advocating for benefits of switching to alternatives, given the rationale that businesses would respond to what consumers

desire and produce less plastics. Likewise, education should encompass informing and influencing businesses to lessen plastic dependency. One academia and three non-profit sector interviewees added engaging and informing non-profit organizations and NGOs as well to enrich advocacy. No specific instruments to spread awareness were described other than general terms such as "the news", "social media", or community-focused programs where people can join as volunteers.

Analysis of interviewees' answers in this study corresponded with peer-reviewed examinations into behavior-based interventions. As mentioned previously, studies done on this topic focusing on the Great Lakes watershed are scarce. However, lessons from literature on marine debris intervention are relevant and adaptable. Bartolotta and Hardy (2018) examined the barriers and recommendations for encouraging changes in consumption habits for single-used plastic bags and plastic water bottles within Ontario's Lake Erie basin (Bartolotta & Hardy, 2018). The most prevalent reasons for consuming plastics here was described to be a mixture of habits, such as "forgetting to bring" alternatives (Participant 17 in non-profits/NGOs).specific Social factors including positive and repeated messages to endorse benefits of not using plastics (for example, the argument between tap water and bottled water on perceived "cleanliness") play important role in supporting or diminishing positive behavior changes (Bartolotta & Hardy, 2018; Heidbreder et al., 2019). Economic drivers of disincentives, such as taxes or fines to make single-used plastics more expensive and to deter littering, were deemed most desired yet risky in the long term (Bartolotta & Hardy, 2018; Oosterhuis et al., 2014). Researchers cautioned the complexity of social influences and willingness to pay, that the levies on harmful plastics should be high enough to cause changes. Therefore, a combination of solutions was encouraged, including facilitating using reusable products into social norm, having informative and positive reminders in news outlets and social media, taxes and/or levies and regulatory prohibition (Bartolotta & Hardy, 2018; Heidbreder et al., 2019). Punitive instruments (fines, raising prices) may face backlash from consumers (Bartolotta & Hardy, 2018; Matheson, 2022; Payne et al., 2019). Therefore, a balance between informing consumers of pollution prevention and recovery incapacity and increasing the values of reusable alternatives or having positive economic reinforcement (an example given was a deposit-refund scheme), was recommended (Bartolotta & Hardy, 2018).

Community based social marketing (CBSM) is among educational tools recommended by one academia interviewee and peer-reviewed interdisciplinary literature to effectively correct consumers' poor behaviors. CBSM's framework aims to change individual-level and community-level behaviors to support environmental stewardship (McKenzie-Mohr, 1999). Effective frameworks for CBSM may vary by goals and targeted audience. Generally, an effective CBSM framework should contain the following elements: (1) an initial stage of identifying barriers for change, (2) clear and diverse communication efforts with visual audio and/or in-person reminders (social media platforms, radio, podcasts, printed signage or newsletter etc.), (3) built-in convenient strategies for desired actions, (4) incentives for compliance, (5) punishments or warnings for non-compliance, (6) commitment nudges, and (7) strong connections to existing social norms (Based on literature such as (E. J. Cole & Fieselman, 2013; Kennedy, 2010; McKenzie-Mohr, 1999). Kennedy (2010) suggested CBSM would be an effective tool for raising awareness and compliance with environmental guidelines, laws, and legislation. Kennedy (2010) offered several successful case studies including Kamloops (British Columbia)'s water consumption reduction campaign aiding its water restriction by-law, which resulted in a 15% decrease in water usage. In another example, Cole and Fieselman (2013) implemented a CBSM campaign at Pacific University Oregon to facilitate a decrease in paper consumption, enhance paper recycling and purchasing of environmentally preferred paper products. Cole and Fieselman (2013) witnessed a 74% increase in positive changes within the studied demographic (university staff). Future developers of plastic pollution focused CBSM can utilize findings of critical drivers and barriers in this study's results, coupling with their own analysis on the targeted audience (E. J. Cole & Fieselman, 2013). This study does not seek to thoroughly explain CBSM. Nevertheless, this study's investigation into stakeholders' feedback and peer-reviewed literature suggests further examination into this method, as well as other educational tools, would be necessary to inspire sustainable consumer behavior changes.

There were several research implications being suggested for supporting and accelerating changes. Two interviewees in the private sector, four in the public sector, three in academia and three in non-profits/NGOs believed stakeholders should acquire more information through supporting additional research into the subject matter. Topics for further research included source-specific preventive measures such as quantifying plastic inputs into the Great Lakes to "turn off the tap" upstream (Participant 6 from academia), identifying original emitting sources,

and developing a long-term monitoring plan. To inform legislative decisions, we would need academic partners to investigate different potential solutions. This pinpoints relevant stakeholders to take part in pollution prevention, and develops rationale to further exploring micro and/or nano-plastics' harmful impacts on human health. These are all suggestions for research topics belonging to upstream, preventive side. When being questioned about research on pollutants in the water, interviewees in academia and public sector suggested further examinations into (1) how to remove microplastics, (2) how to effectively remove plastics through wastewater treatment plants, and (3) removing plastics without habitat disturbance.

Thirteen interviewees (two from the private sector, four from the public sector, four from academia and three from non-profits/NGOs) discussed "stop using plastics", which is directly related to the Reduce ladder in the waste hierarchy. "Refusing" referred to the idea that customers had the ability to choose not to consume plastics, in some cases, specifically non-essential single-used items such as wrappers, plastic bags, straws, cutlery, party balloons and beyond:

> We choose. It is not forced upon us. We choose to use plastics. They are not forced upon us. We don't understand how critical it is to stop that choice. (…) There are real cost issues associated with switching from plastics to other things. With that said, there's a cost of not doing it. (Participant 6 from Academia).

To help consumers make better choices, alternatives should be in place. Details on specific single-use plastic replacement were scarce, with a few honorable mentions of "bamboo" cutlery (Participant 15 in academia), "cloth bags" (Participant 6 in academia), food containers made of leaves (Participant 19 in non-profits/NGOs) and "non-PVC banners" (Participant 7 in the private sector). To make alternatives more attractive, suggestions ranged from making production and consumption of plastics more expensive while incentivizing and supporting large-scale development of alternatives. Items recommended to be phased out include plastic bags, straws, banners, single-used packaging, beverage cups and lids, and cutlery. There are nuances when considering switching to alternatives without being mindful of usage behaviors or decreasing consumption in general. In its report titled "Single-use plastic bags and their alternatives: Recommendations from Life Cycle Assessments", the UNEP compiled reports from various countries comparing life cycle analysis of different single-used plastic bag (SUPB) alternatives. Results showed that environmental benefits varied among environmental criteria (littering, CO_2

emission, acidification, eutrophication, toxin emissions, and resources required) (UNEP, 2020). The SUPB worsened littering and associated impacts, yet scored better than alternatives on acidification, eutrophication, toxin emissions, and resources required. Biodegradable plastics performed better in waste management, but worse in greenhouse gas footprint, "acidification, eutrophication, and toxic emissions". Surprisingly, single-used paper bags were found to be the worst alternative in all criteria. Finally, cotton bags must be reused multiple times to account for its greenhouse gas emission during the production stages (UNEP, 2020).

Two interviewees from the private sector, two from the public sector, three from academia and four from non-profits/NGOs advocated for more funding. Suggestions included maintenance and implementation funding for monitoring of toxic substance emissions (including plastic leakage), and implementation and maintenance of regulatory and action commitments towards preventing plastic pollution for long-term solutions. Likewise, there needed to be financial support for municipalities, non-profits, and collaborations to enhance research and gather more data into plastic pollution impacts and cost-effective solutions and enhance advocacy for this issue. In addition to prioritizing innovations and community-based programs, pollution prevention would benefit from a binational or international funding effort to support focus groups of experts in investigations. There was little elaboration made towards specific steps for increasing government funding capacity. However, a few have suggested that governments or non-private funders could start by engaging corporate sponsors, reduce funding of other less-pressing revenues and focusing more on issues like pollution, or stopping "subsidizing oil" (Participant 12 from academia). The OECD estimated that in 2020, the fossil fuel industry received an estimated CAD 4.50 billion, with about 62% directed to the private sector, in tax deductions, tax credits and direct funding (OECD, 2022). Consequently, reevaluating the allocation of subsidies, coupled with political will, is necessary to enhance necessary resources towards pollution prevention.

The least recommended step, in agreement with the least preferred option in the waste hierarchy, was increasing recovery capacity. Three interviewees from the private sector, two from the public sector, three from academia and two from non-profit or NGOs believed circular economy or extended producer responsibility would call for inevitable investments in enhancing recovery infrastructures including collection, mechanical or chemical recycling. Suggestions encompassed enhancing clean-up infrastructures, with some specific suggestions in additional

investment in large-scale implementation of various clean-up or removal devices across the Great Lakes watershed, or that there should be more public receptacles for plastics and cigarette butts. Revenue, legislative or collaborative instruments necessary to implement these ideas were not elaborated on. Zhang et al. (2021) assessed performances of various techniques currently available, either heat-based, physical, or chemical processing, wet and dry processing. Results warned that the integrity and overall quality of many nonbiodegradable plastic waste lessened through most cycles of recovery processes (F. Zhang et al., 2021). Therefore, this should be taken into consideration, that perhaps in the long term, recovery should not be the focus of future efforts.

4.6: Sectoral and Great Lakes Plastic Cleanup Perspectives

This section sought to further demonstrate potential similarities and differences among interviewees' perceptions based on their diverse backgrounds. This would be beneficial to recognize in stakeholder engagement and collaborations.

As discussed previously, interviewees generally agreed on the following: multi-source leakage is the most important driver of plastic pollution; insufficient enforceable legislation is a significant obstacle; pollution poses numerous financial implications ("Costs of Pollution Prevention"); and action framework items to overcome these challenges should include (1) more or stronger legislation or regulations, (2) collaborations among sectors and across disciplines, and (3) raising consumers' awareness on pollution and (4) having binational approaches for pollution prevention. As previously discussed, "Costs of Pollution Prevention" included an absence of funding for solution creation and deployment (including technological innovations, academic-led research, and cost-effective plastic alternatives), in addition to the shortage of financial incentives to render single-use plastics (particularly those that leaked in large quantities into the Great Lakes from Canada) less appealing to businesses and general consumers. Interviewees referred to national and binational legislation. Interviewees did not explicitly recommend provincial or municipal by-laws, when being inquired about policy-based recommendations.

Nevertheless, there are discrepancies in perceptions of critical plastic pollution challenges to be addressed within the Canadian Great Lakes as shown in Table 5 and Figure 5, Figure 6, and Figure 7. 100% of the private sector participants in this study regarded that consumers' lack of awareness is a significant barrier to pollution prevention. This viewpoint was shared among 80%

of the public sector, 71% of non-profits/NGOs and 60% of academia interviewees. Similarly, 50% of the private sector interviewees most strongly expressed concern towards a challenge that depicted plastic debris (particularly microplastics such as microfibers) being difficult to be captured once they have entered the lakes, followed by 43% of non-profits/NGOs, 40% of the public sector and 40% of academia interviewees. Academia and the private sector's interviewees most significantly expressed concern on the inadequacy of current infrastructure (at 80% and 75% respectively), followed by 57% of non-profits/NGOs and 20% of public sector interviewees. As discussed, infrastructure inadequacy encompassed the inability of existing municipal waste management systems to handle large quantities of plastic waste (particularly single-use plastics), efficient waste sorting and waste recycling, and implementation of innovative technologies that would either prevent or capture plastic debris within the Canadian Great Lakes watershed. On the other hand, 80% of the public sector and 80% of academia interviewees agreed that participation from the private sector in pollution prevention needed improvement. Fewer non-profits/NGOs and private sector interviewees shared this belief, at 71% and 75% of interviewees from each sector respectively. Similarly, the public sector and academia (60% of interviewees in each sector) evidently discussed the "time factor", representing the sentiment of "changes take time". 80% of academic interviewees believed the low availability of cost-effective single-use plastic alternatives was a significant barrier, followed by 50% of the private sector, 40% of the public sector and 29% of non-profits/NGOs interviewees. Finally, 71% of non-profits/NGOs interviewees identified single-use plastic designs (with additives and fillers and other chemical compositions that render products hard or impossible to be recycled) a major barrier. This was shared among 60% of the public sector, 60% of academia and 25% of private sector interviewees.

Furthermore, different sectors advocated vigorously for distinct suggestions, as demonstrated through Figure 7. Although a theme of a higher preference towards pollution prevention (comparing to value recovery of plastic waste and cleaning up plastic debris) emerged from data, 75% and 71% of private sector and non-profits/NGOs interviewees (respectively) explicitly mentioned this approach, followed by 60% of academia and 20% of the public sector interviewees. All interviewees from academia and the private sector advocated for the development of incentives for better prevention and stakeholder engagement for solving plastic pollution, while the level of advocacy remained at 71% and 60% of non-profits/NGOs and public

sector interviewees respectively. Participants within academia advocated the strongest for refusing to use single-use (harmful) plastics altogether (especially products listed in earlier discussions that were frequently sighted as pollutants) at 80% in agreement. Only 75% of private sector, 57% of non-profits/NGOs and 40% of public sector interviewees also recommended this strategy. Similarly, academia interviewees most vigorously advocated for using more sustainable single-use plastic alternatives (with some specific suggestions such as metal reusable mugs or cutlery instead of single-use plastic counterparts). On the other hand, 86% of non-profits/NGOs interviewees recommended the reframing of discourse of plastic pollution. The term discourse was utilized to describe the language used in policies, in prevention frameworks, and in communication of plastic pollution to stakeholders (inclusive of all sectors and the general consumers). Two non-profits/NGOs and one academia interviewee discussed how the construct of national legislation should be reconsidered to be much more "preventive" and "responsive" towards averting pollutants from entering the Great Lakes, rather than the common practice of "setting thresholds" for pollutant discharges. This included collaboration with the Indigenous communities and rethinking environmental response frameworks (as done by CEPA or many other federal environmental acts), as one non-GLPC interviewee in the non-profit sector explained:

> Whereas the First Nations come and say, look, if you wouldn't drink that thing, then don't put it in the water. Like, don't even think of putting it in the water. The water should be clean and respected, because it's in a living entity. I mean, I hate to even say the two-eyed approach (that) kind of comes in because it's really not. It's just opening our ears and listening to the First Nations' perspective that's going to educate a lot more people on the Western side of the equation to really understand that you can't just keep setting thresholds for now, 1000 chemicals. (Participant 14 from Non-profits/NGOs).

Additionally, two non-profits/NGOs' interviewees suggested a better communication strategy with delivering positive messages coupled with precautions and negative messages about plastic pollution to the general public. Two public sector, one academia and one non-profit interviewees also cautioned against placing the "onus" on the general consumers to be mostly responsible for pollution prevention (as discussed above). "Reframe discourse" was shared among 50% of the private sector, 40% of the public sector and academia interviewees respectively. Non-profits/NGOs interviewees also advocated for financial support towards collaboration,

development and implementation of technologies, research, or other solutions more strongly than other sectors. Uniquely, 60% of the public sector interviewees recommended plastic design reforms ("Plastics' redesign") as a solution for Canada plastic manufacturing. This was shared among only 43% of non-profits/NGOs, 40% of academia and 25% of the private sector interviewees. No further elaboration on how single-use plastics should be redesigned were provided, other than some explicit mentions of reducing the number of additives and fillers, or that plastics should be designed to be 100% recyclable. Finally, in this study, the private sector was the most supportive of value recovery. 75% of private sector participants called for investments in plastic waste, recycling, and pollutant capture infrastructure. This was lesser shared, at 60% from academia, 29% from non-profits/NGOs and 20% from the public sector. 50% of the private sector interviewees supported future considerations into better recovery of plastic waste (to reduce waste leakage), followed by 43% of non-profits/NGOs, 40% of the public and 40% of academia interviewees.

Figure 5. Sectoral perspectives on identified barriers.
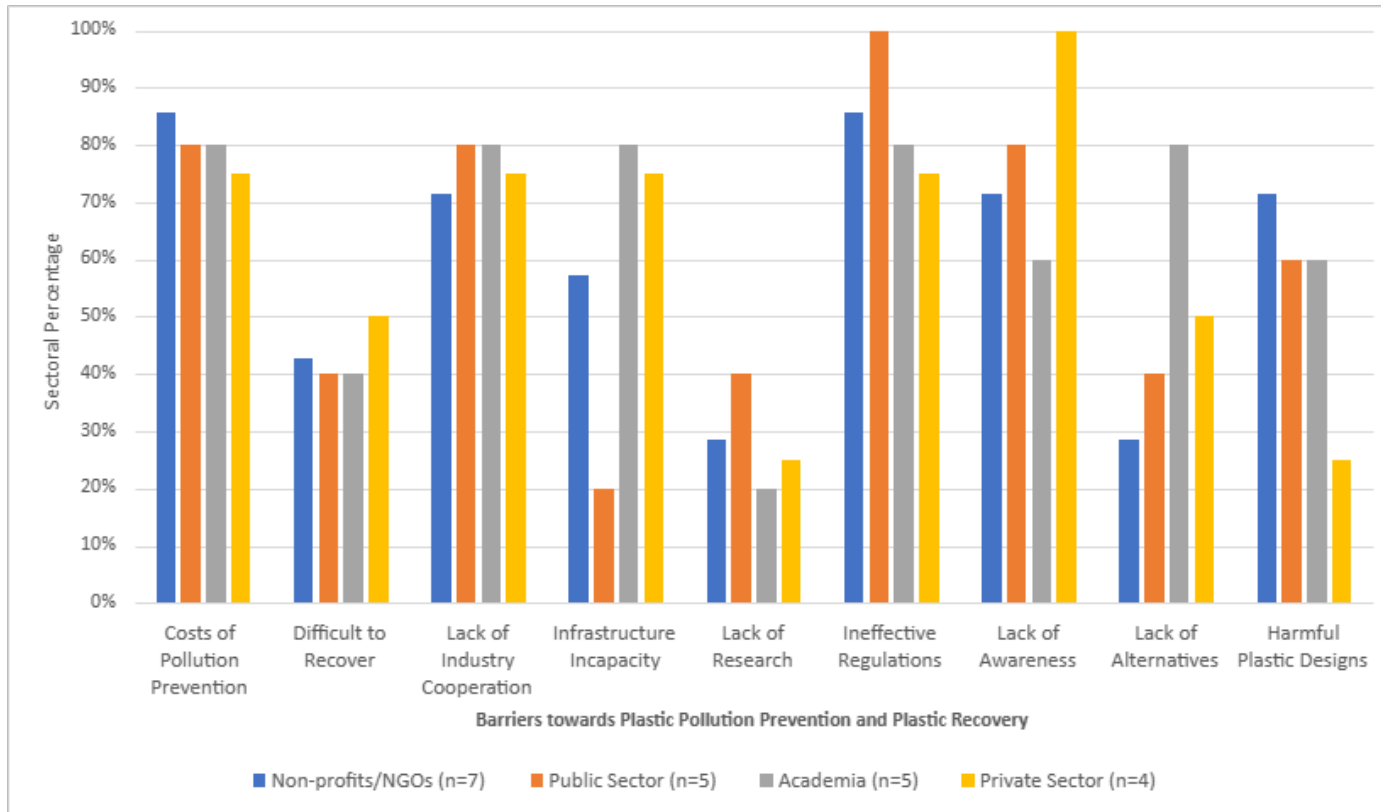
Note. All barriers identified by participants. Barriers were factors that prevented effective plastic pollution prevention or plastic waste recovery in Canada

Figure 6. Sectoral perspectives on drivers of plastic pollution and roles of the GLPC.
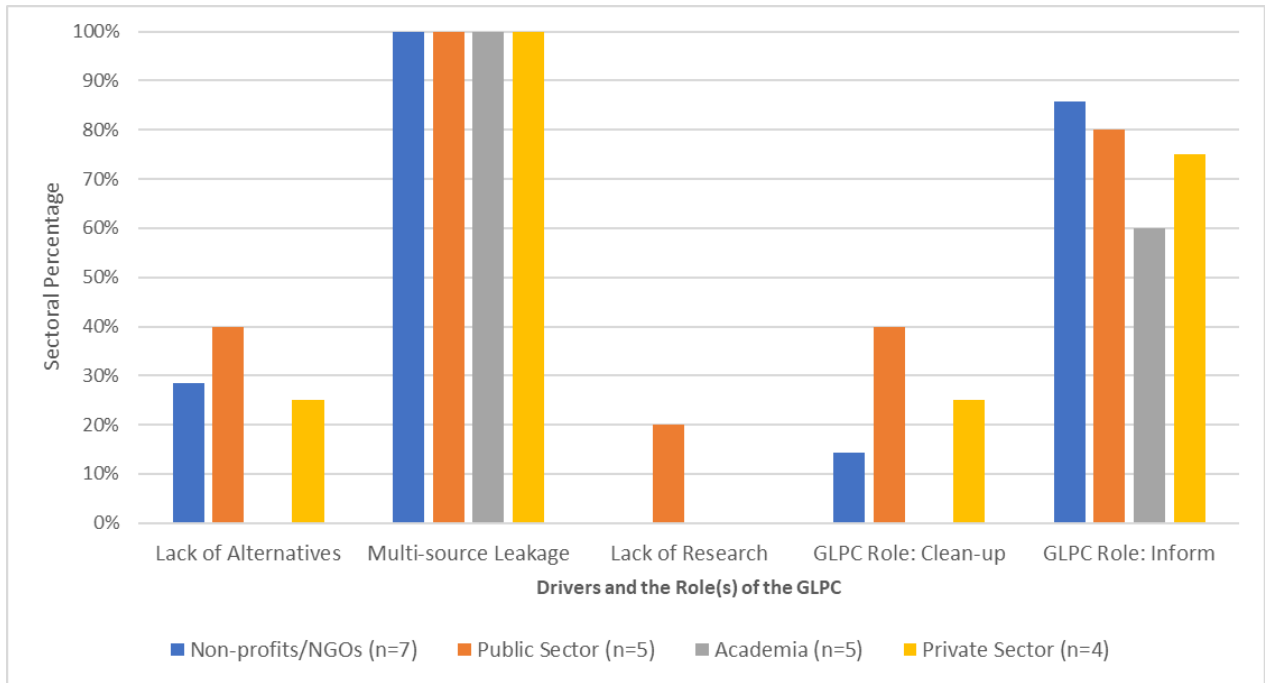
Note. Drivers identified to be critical factors that contributed (increased in magnitude) to plastic pollution within the Canadian Great Lakes. Participants also discussed the roles that the GLPC played in ameliorating plastic pollution in Canada (presented by the codes "GLPC Role: Inform" and "GLPC Role: Clean up")

Figure 7. Sectoral perspectives in recommendations for plastic pollution in the Canadian Great Lakes.
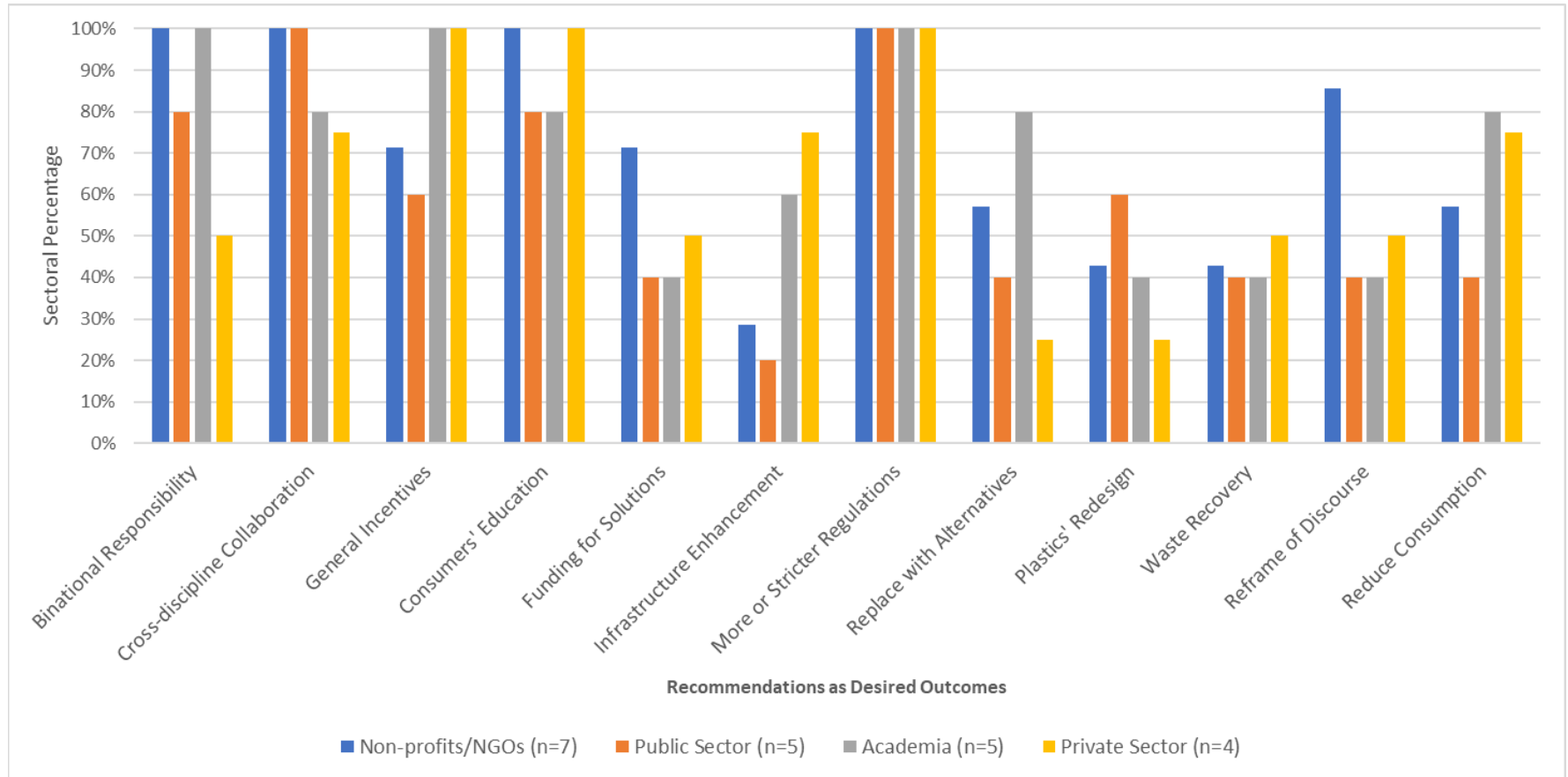
Note. This figure demonstrated general recommendations as desired outcomes being discussed by participants within interviews for this study

In addition to sectoral perspectives, results found involvement with the GLPC to create some differences as well as shown in Figure 8 and 9. Participants who were partners within the GLPC were generally more vocal and understanding of the roles of the initiative. Additionally, they generally advocated more vigorously for improving consumer awareness and altering consumption habits, establishing incentives for stakeholders for better engagement, and continuing to support partnerships than those who were not GLPC partners. Non-GLPC partners more strongly believed in these barriers than others: industry-related complications, and a lack of enforceable legislation and regulations. Academic interviewees who were not part of the GLPC was more supportive of the following recommendations than those GLPC-affiliated: more or stricter regulations or legislation, more corporate responsibility-based actions, supporting alternatives, phasing out unnecessary and harmful plastics, and addition of industry standards on designing plastic items. The private sector on both sides, and the non-profits, NGOs and public sector members that were not affiliated with the GLPC, endorsed downstream solutions in the form of better plastic waste recovery and investment in recycling. The GLPC partners, particularly non-profits, NGOs, and the private sector, advocated more vigorously for the creation of incentives for nudging compliance, voluntary actions, and improved stakeholder engagement. Interviewees from non-profit organizations, NGOs, and academia advocated for more financial support in innovating, developing, and testing solutions, along with research. Non-GLPC interviewees strongly support the enhancement of both mandatory and voluntary instruments to enlist more corporate commitments from the private sector as powerful participants of change; they also advocated more than GLPC partners for consumption reduction, phasing out unnecessary and potentially harmful plastic products, incentivizing and supporting more alternatives, and mandating design standards to modify the compositions of plastic types in the market.

Figure 8. GLPC perspectives on barriers to plastic pollution prevention and plastics' recovery.
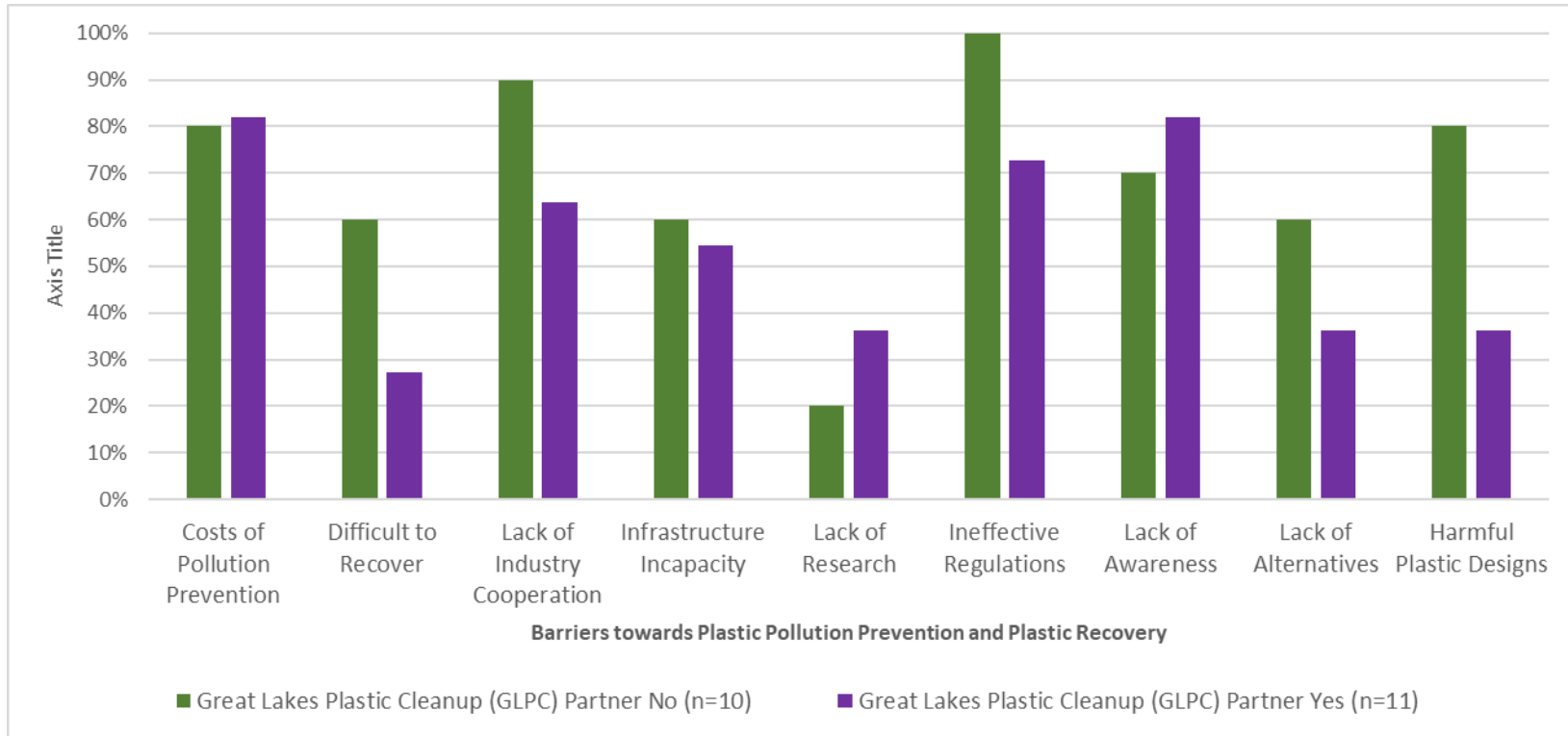
Note. Discrepancies and similarities in viewpoints based on whether participants were partners with the Great Lakes Plastic Cleanup (GLPC) initiative or not.

Figure 9. GLPC perspectives on general recommendations as desired outcomes.
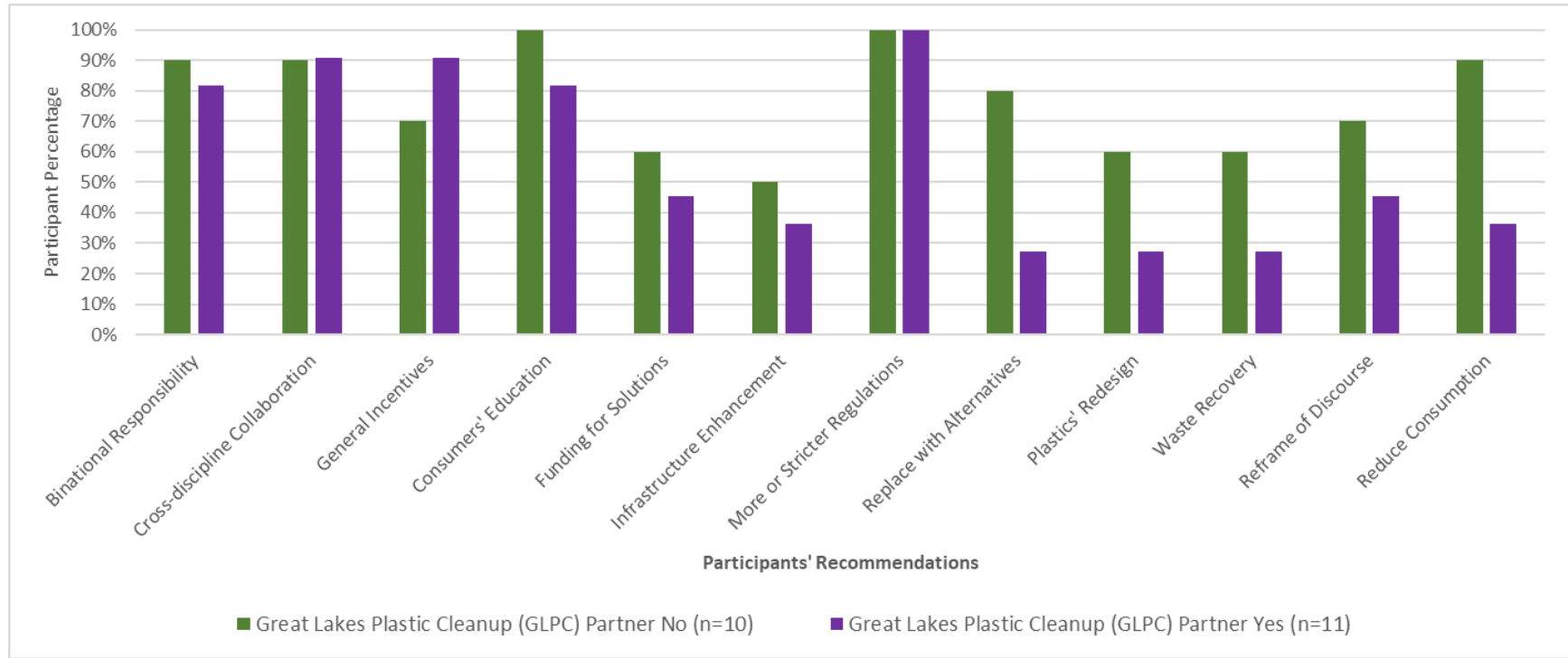
Note. Discrepancies and similarities in viewpoints based on whether participants were partners with the Great Lakes Plastic Cleanup (GLPC) initiative or not.

Sixteen interviewees, when inquired about their perceptions on the GLPC's impacts, agreed that this initiative best served educational purposes. The popular recognition was the GLPC has spread positive influences in raising awareness about the severity of plastic pollution in the Great Lakes, identifying and quantifying plastic pollutants present in the four lakes on Canadian side: Lake Ontario, Lake Erie, Lake Huron, and Lake Superior. This corresponds with the various goals underlying the initiative, as stated in its 2021 Great Lakes Plastic Cleanup Year One Final Report:

Capture and remove plastic litter from the environment.

Study the types and quantity of materials removed at each marina location in order to deepen our understanding of plastic pollution in the Great Lakes.

Educate boaters and outdoor enthusiasts in local communities about the role they can play in preventing and reducing plastic litter (Pollution Probe & Council of the Great Lakes Region, 2021)

Moreover, the imitative also educates policy makers and other partners through the collection and publication of reports and clean-up data. A provincial regulation was enacted as the result of the initiative's work. From 2020 to 2021, a large component of debris found in several trash capture points at Lake Ontario, Lake Huron and Lake Superior was small polystyrene foam pieces. Through the GLPC members' advocacy, MPP of Parry Sound Norm Miller introduced Bill 228: "Keeping Polystyrene Out of Ontario's Lakes and Rivers Act" as a private member's bill and it was enacted in May 2021.

Table 5. Participants' perception on the drivers, barriers and recommendations towards plastic pollution in the Canadian Great Lakes.

Codes	GLPC Partner (n=10)				Not a GLPC Partner (n=11)				Total (n=21)
	Non-profit/NGO (n=3)	Public Sector (n=3)	Academia (n=3)	Private Sector (n=1)	Non-profit/NGO (n=4)	Public Sector (n=2)	Academia (n=2)	Private Sector (n=3)	
Drivers									
Multi-source Leakage	100%	100%	100%	100%	100%	100%	100%	100%	100.00%
Consumers' lack of awareness	100%	100%	100%	100%	100%	100%	100%	100%	100.00%
Pandemic	100%	33%	67%	100%	75%	100%	50%	33%	67%
Lack of alternatives	67%	33%	0%	0%	0%	50%	0%	33%	24%
Lack of research	0%	0%	0%	0%	0%	50%	0%	0%	5%
Barriers									
Ineffective regulations	100%	100%	100%	100%	75%	100%	50%	67%	86%
Consumers' lack of awareness	67%	67%	67%	100%	75%	100%	50%	100%	76%
Lack of industry cooperation	100%	67%	100%	100%	50%	100%	50%	67%	76%
Costs of Pollution Prevention	100%	67%	67%	100%	75%	100%	100%	67%	81%
Harmful plastic designs	100%	67%	67%	100%	50%	50%	50%	0%	57%
Infrastructure incapacity	33%	33%	100%	100%	75%	0%	50%	67%	57%

Difficult to recover	67%	67%	33%	100%	25%	0%	50%	33%	43%
Lack of research	33%	0%	0%	100%	25%	100%	50%	0%	29%
Lack of alternatives	67%	67%	67%	0%	0%	0%	100%	67%	48%
Recommendations									
More or Stricter legislation	100%	100%	100%	100%	100%	100%	100%	100%	100%
Educate consumers	100%	100%	100%	100%	100%	50%	50%	100%	90%
Binational Responsibility	100%	67%	100%	100%	100%	100%	100%	33%	86%
Cross-discipline collaboration	100%	100%	100%	0%	100%	100%	50%	100%	90%
Development of general incentives	33%	67%	100%	100%	100%	50%	100%	100%	81%
Corporate Responsibilities	100%	67%	100%	100%	75%	50%	0%	100%	76%
Reduce consumption	100%	67%	100%	100%	25%	0%	50%	67%	62%
Reframe discourse	100%	67%	67%	0%	75%	0%	0%	67%	57%
Build more infrastructure	33%	33%	67%	100%	25%	0%	50%	67%	43%
Products redesign	33%	100%	33%	100%	50%	0%	50%	0%	43%
Plastics' recovery	67%	67%	33%	100%	25%	0%	50%	33%	43%

Note. Quantifying the similarities and differences in perspectives based on interviewee sectors and GLPC affiliation. The "codes" represent common ideas found in interview transcripts or topics of discussion raised by participants. "Recommendations" were given by participants describing desired outcomes.

4.7: An Overview of Initiatives

Literature review discovered number of plastic pollution-centered initiatives that are being carried out within Canada or internationally that would specifically benefit the Great Lakes. Although most of these initiatives focus on clean-up efforts, their outcomes encompass spreading awareness and collecting pollution data, similarly to that of the Great Lakes Plastic Cleanup. By understanding an overview of existing initiatives, stakeholders can make informed decisions on what they can further support, as well as considering additional efforts to supplement.

Interviewees from the non-profit organizations, academia and one interviewee from the public sector, all being GLPC partners, mentioned the International Trash Trap Network and Operation Clean Sweep, which are two examples of ongoing binational voluntary initiatives that help with both upstream and downstream pollution prevention goals. To promote voluntary clean-up efforts around the world, The Great Lakes Plastic Cleanup, University of Toronto, and the U.S. Ocean Conservancy joined forces under the International Trash Trap Network (Ocean Conservancy, n.d.). The initiative also provided systematic guidance to harmonize data collection and expanding one common pool of plastic pollution data through a visual waste characterization protocol and a mobile application called "Clean Swell" to record and publish data. The scope of this initiative encompasses both marine and freshwater plastics. Operation Clean Sweep is a voluntary educational program designed to provide plastic producers and manufacturers' best management practice and training manuals to prevent pre-production pellet leakage (American Chemistry Council, n.d.). Within the program, there are also multiple levels of voluntary pledges that firms can sign to encourage compliance with the manuals and to receive a certification logo. No periodic third-party verification is present to ensure compliance. Canadian companies are eligible to take on the Employee Pledge and Supporter Pledge.

One GLPC affiliated interviewee from an NGO discussed the Clean Marine Eco-Rating Program. Boating Ontario, a non-profit representing the recreational boating industry, operates the Clean Marine Eco-Rating Program to provide Clean Marine certification to businesses within the recreational boating industry practicing best management practices (Boating Ontario, n.d.). The program now covers not only boats and facilities but also marinas. These initiatives can assist in tackling critical pollution drivers such as single-used plastic packaging, plastic litter and fishing gears.

Two interviewees from the public sector and one from a non-profit organization mentioned The Canadian Plastic Pack (CPP). It is a voluntary initiative in which private-sector members, supporting of non-profits, NGOs, municipal and federal government partners collaborate and voluntarily support transitioning towards a circular economy in Canada through "rethink" "design, use, and reuse plastic packaging" (Canada Plastics Pact, n.d.). Members of the CPP share an action plan, in which they would take measures to meet 30% of minimum recycled content in plastic packaging, increase composting or recycling of plastic packaging by 50%, and phasing out harmful products by 2025. The CPP members included both Canadian and international corporations such as Loblaw Companies Limited, Maple Leaf, Unilever, Coca Cola and General Mills (Canada Plastics Pact, n.d.).

To support an on-going demand for research, The ECCC and NSERC have held opportunities to financially support collaborative research efforts and small-medium enterprises to develop solutions tackling plastic waste, as listed by three public-sector interviewees. First, the ECCC held its "Canadian Plastics Innovation Challenges" to encourage companies to develop proofs of concept or prototypes of innovative solutions. So far, 4 companies have been awarded to develop proofs of concept: one for a paper-based plastic bag alternative, and three for material recovery and recycling of textile waste (ECCC, 2021). These solutions address microfibers and plastic bags, which were identified as major drivers of plastic pollution in the Great Lakes. The NSERC and ECCC also offer a national grant titled "Plastics science for a cleaner future" to financially support academic research efforts that would benefit Canada's zero waste goals outlined in the Ocean Plastic Charter (Government of Canada, 2018a). To date, there are 7 higher-education institutions who received NSERC funding for plastic research, including University of Waterloo with its Microplastic Fingerprinting Research Project (Ghosh & University of Waterloo, n.d.). Funded projects are advertised to investigate sources, transportation pathways, identification, and ecological and human health impacts of small plastics (micro and nano-plastics). These projects would be practical in building a case for further pollution prevention actions within Canada.

Finally, collaborations extend to community-based volunteering and educational efforts. All interviewees who were GLPC partners (except one from the private sector and one from an NGO) mentioned the University of Toronto's Trash Team, who focuses on plastic pollution solution research and community outreach (U of T Trash Team, n.d.). In addition to researching

and tracking plastic pollutant types, the program delivers K-12 education materials. It also offers collaborative educating activities for students and a residential waste audit voluntary sub-program. Extending on raising awareness, there are non-profit organizations as identified by non-profit interviewees who were not partners within the GLPC such as A Greener Future or EcoSuperior, who are offering both volunteering opportunities and services to educate the community, capture trash, and contribute to plastic litter data collection. Notably, as two interviewees from academia specifically advocated for cross-discipline collaborations, A Greener Future has facilitated a collaboration with local artists called "The Litter Art Project" (A Greener Future, n.d.), turning the litter volunteers captured during clean-ups into art pieces to innovatively raise awareness.

Chapter 5: Conclusions

It was apparent through several investigations into potential incentives and disincentives for plastic pollution prevention that effectiveness varied depending on many factors. More importantly, the consensus was that incentives and disincentives must be used in conjunction with raising awareness, supporting beneficial norms of best management practices, and other legislative and regulatory instruments (Homonoff et al., 2018; Oosterhuis et al., 2014; Rivers et al., 2017; Tudor & Williams, 2021). This was consistent throughout literature review and participant perspectives analysis. Alpizar et al. (2020) constructed a comprehensive policy selection framework, which was relevant to this study as it echoed many interviewees' perspectives on freshwater plastics in Canada.

Table 6. Suggested voluntary and mandatory instruments for effective prevention and adaptation to plastic pollution within the Canadian Great Lakes.

Waste Hierarchy Ladder	Preference	Instrument Type	Instrument (based on interview data)	Implementation
Prevention	Higher	Policy-based	Industry standards for recyclable, durable and non-toxic plastics (also in Alpizar et al., 2020, Tudor and Williams, 2022)	Mandatory and Voluntary
Prevention	Higher	Price-based	Funding for research and innovation development (also in Alpizar et al., 2020, IJC, 2017)	Voluntary
Prevention	Unclear	Price-based	Virgin plastic tax (also in Deloitte et al., 2019, OECD, 2018, (Patridge et al., 2018)	Mandatory
Prevention	Higher	Price-based	Deposit-refund scheme (also in Oosterhuis et al., 2014, Homonoff et al., 2018)	Voluntary

			Subsidize single-use plastic alternatives (also in Oosterhuis et al., 2014, Alpizar et al., 2020, Tudor and Williams, 2021)	Voluntary
Prevention	Higher	Price-based	Subsidize single-use plastic alternatives (also in Oosterhuis et al., 2014, Alpizar et al., 2020, Tudor and Williams, 2021)	Voluntary
Prevention	Higher	Price-based	Tax and levy on single-use non-necessary plastic items and derelict fishing gear (also in Rivers et al., 2017, Homonoff et al., 2018)	Mandatory
Value Recovery	Lower	Rights-based	Extended Producer Responsibility (EPR)	Mandatory
Prevention and Value Recovery	Higher	Policy-based	Minimum recycled content (also in (Government of Canada, 2022a)	Mandatory and Voluntary
Prevention	Higher	Rights-based	Best housekeeping practices to regulate and eliminate pellet spills (also in Oosterhuis et al., 2014, Alpizar et al., 2020)	Voluntary
Prevention	Higher	Policy-based	Expanding the Single-use Plastics Prohibition Regulations to encompass more items	Mandatory
Prevention	Higher	Policy-based	Nominate "plastics" to be recognized under an Annex or as chemicals of concern in the binational Great Lakes Water Quality Agreement, with the latest revision of the agreement to be in 2023 (also in Kranzberg, 2019)	Voluntary

			Harmonizing recycling schemes and waste management guidelines among provinces (also in (Hopewell et al., 2009), Rivers et al., 2017)	
Value Recovery	Lower	Policy-based	Harmonizing recycling schemes and waste management guidelines among provinces (also in (Hopewell et al., 2009), Rivers et al., 2017)	Mandatory
Prevention	Higher	Behavior-based	Educate students about plastic pollution and preventing littering (also in IJC, 2017)	Voluntary and Mandatory
Prevention	Higher	Behavior-based	Educational campaigns and cross-discipline collaborations (also in Heidbreder et al., 2019)	Voluntary
Prevention	Higher	Behavior-based	Community based social marketing (also in (E. J. Cole & Fieselman, 2013; Kennedy, 2010)	Voluntary
Value Recovery	Lower	Price-based	Investments in waste management infrastructure (also in Deloitte et al., 2019b)	Voluntary

Note. Potential instruments that can be useful for Canadian adoption to sustainably prevent plastic pollution in the Great Lakes. Results summarized here triangulated analysis from literature cross-validation, qualitative interview data, and Alpizar et al. (2020)'s framework for choosing policy-based instruments for pollution prevention. The CCME's waste hierarchy also guided the examination and organization of the instruments. Interview data consisted of instances in which some interviewees clarified specific tools to address plastic pollution challenges. Despite prompts and post-interview follow-ups, not all interviewees provided suggestions that can be included in this table.

Investigations into global implementation of several economic instruments suggested three that could potentially help reducing consumption and preventing leakage of plastic waste in Canada: taxes on single-used items, pay-as-one-throw, and deposit and refund scheme.

There was a noticeable absence from examining the private sector's corporate responsibility-based instruments. There needs to be significant consumer push and strong

political will to enact private sector-based instruments as suggested by Alpizar et al. (2020). While it is extremely difficult to get away with single-use plastic consumption completely, additional industry standards should be in place to better regulate plastic designs and manage plastic pellets to prevent leakage into the environment and facilitate more incentives for higher quality products, more alternative options, and better recovery. Making sure the private sector players are engaged and making changes in their operation also ensures a level-playing field for all stakeholders. Moreover, economic incentives can also apply. Perhaps tax credits or other forms of subsidies can be awarded to members who have met standards for enacting best management practices (for example, stop spillage) or for recoverable plastic designs (Oosterhuis et al., 2014, Alpizar et al., 2020, Tudor and Williams, 2021). Results supported the adoption of Alpizar et al. (2020)'s framework to engage diverse actors from regular consumers to governments and the private sector, which would be beneficial in fairly distributing responsibilities among users of plastics and comprehensively addressing all drivers of pollution.

No explicit connections of benefits to one specific sector are made through the discrepancies in levels of advocacy. However, recommended solutions from each sector all require co-operation from at least one other sector. Moreover, potential solutions (as shown in Table 6) comprise both mandatory (through legislation and regulation) and voluntary measures. Academia and non-profits/NGOs more strongly support mandatory measures than other sectors. Therefore, there must be willingness in collaboration and building consensus across all sectors moving forward. Table 6 would assist the development or adjustment of policy or action frameworks. Results achieve this outcome through exhibiting both incentives that would encourage collaboration and deterrents to avoid misconduct or to lessen quantities of plastics leaking into the Great Lakes. It is evident that in addition to consensus, each sector regards the significance of each barrier differently, despite most barriers being consistent with results found in peer-reviewed papers. Participants discuss the drivers and barriers in a broader view, rather than making clear links that the barriers were encountered by specific individuals or sectors. This may have influences on the types of adaptive or preventive actions for solving plastic pollution in Canada. Therefore, there is a need for further investigations into external influences that supported the status quo of single-use plastic leakage and low plastic waste recovery.

Sectoral perspectives suggests that support for economic, educational, and regulatory preventive measures may vary. Researchers reflect that effective pollution prevention calls for a

reduction in single-use plastics' consumption from both the private sector and the general consumers. On the other hand, interviewees from the public sector and the non-profits/NGOs generally prefer different approaches. The public sector most strongly prefer engaging more corporate responsibilities through re-designing plastic products to be fully recoverable. Non-profits/NGOs would like to address funding deficiencies for the development and application of solutions. Balancing discrepancies in levels of support for either voluntary or mandatory instruments translates to a need for implementation of a diverse, coordinated network of pollution prevention actions across Canada.

Chapter 6: Discussion

6.1: The Waste Hierarchy as a Theoretical Framework for Pollution Prevention

The waste hierarchy is a fitting framework to guide analyzing the drivers of plastic pollution in the Canadian Great Lakes, existing barriers, and recommendations to ameliorate challenges. The waste hierarchy assists in identifying highlights on significant upstream drivers, challenges to successfully prevent plastic leakage, and preventive measures. Likewise, the waste hierarchy is an appropriate framework to address plastic pollution in the Great Lakes because it upholds significant drivers, barriers and recommendations that were identified through existing literature and stakeholders' perspectives. Study participants strongly support preventive or upstream measures. On the other hand, participants do not recommend value recovery ladders to be optimal solutions. To "reduce", "reuse" and "recycle" are the ladders extensively and explicitly discussed within interviews. Other ladders are either relevant to the challenges and recommendations mentioned but are not explicitly addressed, or not discussed at all. Therefore, while many aspects of the waste hierarchy reflect desired approaches, the waste hierarchy employed by the CCME in planning roadmaps for plastic pollution may benefit from revisions.

It is beneficial to harmonize the CCME's waste hierarchy with the European Waste Framework Directive's hierarchy. Results demonstrate that the CCME waste hierarchy does not comprehensively address stakeholders' perceptions on current challenges and how to overcome them. Moreover, through displaying the status quo (illustrated by the drivers) and infrastructure incapacity barriers, it is aspirational and unrealistic to not have "landfill" as a ladder (albeit it is the least preferred, worst option according to the hierarchy). In addition, the predominant recycling method in Canada is mechanical shredding or production of secondary resins (Deloitte and ECCC 2018), which is different than what the last ladder suggests. The EU's Waste Framework Directive's waste hierarchy consists of high-level yet pragmatic ladders that not only reflect the current state of waste management (some portions of waste still get landfilled), but it is also mindful of the evolving technological developments. It is recommended that similar studies in the future focusing on freshwater plastic pollution in Canada to employ the European Waste Framework Directive's waste hierarchy.

6.2: Discussion on Regulatory Instruments

Rivers et al. (2017) investigated the effectiveness of Toronto's CAD 0.5 plastic bag levy enacted in 2009. Researchers found only a 3.4% increase in using reusable bags. Moreover, effectiveness of this levy varied when considering external factors such as income, level of education, and attitudes towards reusable bags. The levy was more effective with a portion of Torontonians who possessed post-secondary education degrees, higher socio-economic statuses, and those who were already switching to reusable bags. The levy did not deter people from the opposite spectrums (lower education levels, lower income) from using plastic bags. Furthermore, there have been arguments that financial sanction disproportionately would affect residents of low income as they would be more dependent on the low costs of plastic than others (Rivers et al., 2017).

The bag tax disincentive has been implemented globally in both developed and developing countries and succeeded. Homonoff et al. (2018) examined the effectiveness of a bag levy of just seven cents per single-used plastic bag and paper bag from November 2016 to March 2018, and calculated a 27.7% decrease in the use of the items, and increases of 15.5% and 12.6% of using reusable bags or refusing bags respectively (Homonoff et al., 2018). Likewise, a bag tax was successful in reducing consumption across both developing and developing countries, including Africa, Denmark, Ireland, and China. It's worth noting that a tax should be high enough to account for inflation and to catch attention of consumers (Homonoff et al., 2018; Oosterhuis et al., 2014; Tudor & Williams, 2021) and that impacts were often higher in populations with already high social and environmental ethics (Homonoff et al., 2018). Taxes can extend to other items such as derelict fishing gear or single-used food containers and cutlery.

Banning single-used plastic items without consumption behavior changes, proper use of alternatives, or without more sustainable alternatives available, can result in higher components of other plastics in the waste stream and would not help reducing pollution (Macintosh et al., 2020). Therefore, the ECCC, OECD and Environment Canada support a tax on virgin plastic (Deloitte et al., 2019b; Lee et al., 2019; Patridge et al., 2018). It was recommended that while considering this economic instrument, other measures must accompany to reduce several risks due to potential fluctuation in oil prices and to the heavy investments in virgin plastic production. Measures may include market price fixing, improvement in market data delivery, having

enforceable and traceable recycling targets, and an existing EPR scheme. More research is necessary to create an action framework or investigating mechanisms to reduce risks and to build consensus among stakeholders (Patridge et al., 2018).

Lastly, the deposit-and-refund scheme for some plastic items was mentioned by one interviewee from academia and one from the private sector, loosely based on the successful implementation in Germany. The deposit-and-refund scheme was successful to some extent with better waste handling for a financial reward (Schuyler et al., 2018), but was cautioned against high operational and maintenance costs (Schuyler et al., 2018) due to potential high rates of contamination, or limited by consumers' unwillingness to put more effort into the collect-clean-return process (Oosterhuis et al., 2014).

Cross validation plays a critical role in developing potential solutions within the Results. This is because there are still data gaps in the assessment of the effectiveness of some policy-based and voluntary instruments (virgin plastic tax or educational campaigns for example). As a result, results generally advise using preventative measures that have produced favorable outcomes according to past investigations in literature. In addition, Rivers et al. (2017)'s research demonstrates that some policies that make sense in theory may not be effective in Canadian Great Lakes watershed communities. Plastic leakage identified in qualitative data being consistent with peer-reviewed investigations is significant in building preventive measures to decrease harmful plastics entering the environment via transportation, waste streams or mishandling by users.

6.3: Moving Forward

Overall, upstream or preventive measures (both voluntary and mandatory) to stop plastic leakage into the Great Lakes at the federal level or binational level must receive priority (Kranzberg, G., 2019). Economic (price-based) instruments and mandatory enforceable instruments, despite potentially being controversial or in need of further research, are the most prominent among recommendations. Improving waste management alone does not solve the pollution problem, as it cannot balance out the much higher rate of plastic production and consumption (Borrelle et al., 2020; Syberg et al., 2021). To address these challenges, additional educational efforts to raise awareness among children and consumers, as well as strengthening collaborations among actors with diverse discipline, are highly recommended. The governments

play essential roles in enacting policy-based tools, supporting educational campaigns, and punishing non-compliance to create a level-playing field for pollution prevention responsibilities among all sectors. Changes take time so action frameworks should be accompanied by maintenance plans and proper timelines. Practical solutions to sustainably address plastic pollution in the Canadian Great Lakes involve:

- Expanding SUPPR to strictly phase out unnecessary products such as: Styrofoam food packaging, microfibers, single-use food wrappers, and plastic water bottles.

- Mandatory harmonization of plastic waste and plastic pollution policies across Canada.

- Both voluntary and mandatory industry standards for: (1) best housekeeping practices on facilities to stop leakage of pellets or fragments, and (2) re-design of plastic products to have minimum recycled content, creating viable markets for recycled plastics, advancing towards higher recovery of waste through increasing recyclability, and meeting the commitment of recovering all plastic waste by 2040 (Government of Canada, 2018a).

- Voluntary financial and policy-based incentives (subsidies for alternatives to virgin plastics, funding for innovations, and national policies such as EPR) to expand collaboration and maintain willingness to practice pollution prevention measures within the private sector.

- Voluntary and prohibitive financial instruments such as deposit-refund scheme for rigid plastics and taxes/levies on non-necessary single-use plastic items to deter consumption and leakage of single-use plastics.

- Voluntary educational campaigns (such as community based social marketing) to raise awareness on pollution impacts and littering, and to decrease individual and house-hold plastic leakage.

- Due to diversity of ingredients in plastic items, there needs to be further research to identify toxic additives and fillers to be added under the GLWQA's list of Chemicals of Concern. Likewise, "plastics" should be nominated as an Annex to propel binational political will.

- Voluntary investments in research, development, testing and implementation of innovative solutions for preventing plastic from entering the Great Lakes, as well as potentially capturing debris within the lakes' waterways.

Theoretically, prohibition or limitation placed on plastic products gradually reduce the quantity of waste, thus decreasing the risk of them getting into waterways (da Costa et al., 2020; Prata et al., 2019). Similarly, setting minimum recycled content thresholds for plastic products, in principle, expand markets for used plastics. Consequently, this enhances opportunities for effective plastic waste recovery. Plastic waste recovery leads to an increase in plastic waste collection and diversion from landfill, which prevents landfill-associated plastic waste leakage into the Great Lakes (Chhabra, n.d.; da Costa et al., 2020). However, the implementation of plastic legislation is recent and thus is in need of further data collection and examination to assess the cost-effectiveness of pollution prevention (Nielsen et al., 2020; Stock et al., 2022). It is also critical for stakeholders to share consensus on barriers, actions within a framework and whether the proposed instruments align with their visions (CCME, 2019; ECCC, 2019a). Significant drivers of pollution within the Great Lakes are consistent with peer-reviewed studies on the most investigated plastic items which would be plastic bags, plastic bottles, disposable cups, food packaging, microbeads (Nielsen et al., 2020), microfibers (Athey & Erdle, 2021), single-used wrappers, cigarette butts (Earn et al., 2021) and large and microscopic pellets (Corcoran et al., 2020). Current policies can only take concrete action on a few pollutants: microbeads, plastic bags, plastic straws, and some other problematic items that could pollute the Great Lakes. However, national legislation and Ontario's regulations do not comprehensively address all pollutants within the Great Lakes watershed.

Results connects major barriers to future focus of research and actions. There are high-level agreements among stakeholders on major barriers to overcome and suggestions moving forward. The current legislative landscape (insufficient to address challenges and to sustain pollution prevention comprehensively and effectively) and cost-related factors (price competitiveness of virgin plastics and single-use plastics, taking actions may require costly investments, and lack of funding for development and adaptation of solutions) are major barriers that must be prioritized within current and future action frameworks. Likewise, consumers should be aware of their contributions to plastic pollution within the Great Lakes through their consumption of plastic products and poor behaviors handling plastic waste. Discussions then expand to the sharing of responsibilities among all stakeholders, including the private sector, the governments, researchers, and non-governmental organizations. Therefore, implementing steps to ensure equitable distribution of roles and responsibilities among different stakeholders (users

and producers of plastics within Canada) must remain essential throughout international and national plastic pollution frameworks.

Despite greater support for preventive measures (reduce, deny, utilize alternatives, etc.), there are still approval of some plastic waste recovery solutions. It should be noted that this viewpoint does not reflect that of plastic manufacturers or big corporate plastic users, who stand to gain the most from single-use plastic production. Interestingly, both peer-reviewed resources (such as the EU Waste Framework Directive, Schnurr et al., 2018; Steinhorst & Beyerl, 2021; F. Zhang et al., 2021) and The Strategy (CCME, 2019) confirm that preventive measures are more cost-effective. Results exhibit that while priorities should likely be given to preventive measures (as recommended by earlier discussions and as in Table 5), further investigations should examine selecting the most cost-effective plastic waste recovery options.

This study seeks to provide an overview of current drivers, barriers, and opportunities to address existing challenges in preventing and ameliorating plastic pollution within the Great Lakes, with a focus on the Canadian context. Plastic pollution in the Canadian Great Lakes is a complex and multi-faceted challenge. Plastic pollutants pose significant ecological and human health threats. Several factors such as proximity to urban centers, plastic chemistry, transportation pathways and each of the Great Lakes' residency time contributed to the complexity of identifying and turning off the tap (Pahl et al., 2017) on plastic inputs into the Great Lakes. Several actors play important roles in pollution prevention, including regular consumers and stakeholders from the public sector, private sector, non-profit organizations, NGOs, and academia. Interests in plastic pollution prevention within the Great Lakes were established through national and international commitments. Using a comprehensive approach combining literature review and stakeholder feedback analysis, this study provides an overview of plastic pollution in the Canadian Great Lakes, and useful suggestions for audiences of various backgrounds to explore challenges and opportunities to further engage with pollution prevention. The exhibition of similarities and differences in perspectives of actors of change better conveys existing perceptions, bridging knowledge and uncertainty. Thus, results can demonstrate clear actionable framework items and research implications that are fitting for Canada to pursue.

6.4: Limitations

The sample size acquired for this study was 21, which was consistent with recommended sample size ranges from existing inquiries for qualitative research (Marshall et al., 2013). This study does not seek to represent all perspectives regarding plastic pollution in Canada to keep the scope manageable. However, this study recognizes that plastic pollution prevention in Canada has grown nationally, which means valuable insights may be provided by experts outside of the organizations and entities represented here. Notably, this study could not invite stakeholders who identified as being within the First Nations, the Métis, or Inuit communities due to limits in time and scope. Moving forward, it is recommended that Indigenous knowledge and perspectives to be included in future studies on similar topics. Due to reasons outside of the researcher's control, the number of participants in each sector was not equal. The findings gave a clear explanation of the influences of each sector, as well as their affiliation with the GLPC, on the analysis and presentation of results. However, biases are unavoidable due to differences in knowledge, personal experiences, and beliefs entrenched in participants' inputs (Galdas, 2017). Nonetheless, the perspectives themselves, which presented unique knowledge, would still enhance evidence-based decision making (Galdas, 2017, (Canadian Council of Ministers of the Environment (CCME), 2020, Marshall et al., 2013).

Some interviewees answered "No" or skipped the questions that were irrelevant to them. When being asked to elaborate on specific details of rationale for barriers and drivers, and what instruments should be employed to address the challenges that were mentioned, the level of details provided was superficial except for a few specific mentions. Follow-up inquiries were sent proceeding interviews to further clarify ideas mentioned. However, not all interviewees responded to follow-ups.

A limitation in utilizing content analysis with open and axial coding was falling on either coding "in splinters" or identifying too many key words, or risking overlooking nuanced data (Guest, Greg et al., 2012). This study's methodology attempted to address this shortcoming through implementing both inductive and deductive approaches, ensuring an accurate and comprehensive capturing of interviewees' perspectives. These steps were done solely by the student researcher. It's also recommended that more than one researcher should be involved in the coding process to increase validity and trustworthiness of the code development and analysis (Guest, Greg et al., 2012; Skjott Linneberg & Korsgaard, 2019). This study's limited time and

scope did not allow for a second coder. Therefore, it is recommended that future research attempts of similar methodology and objectives employ more than one researcher.

6.5: Research Implications

There are several knowledge gaps that must be filled. First, researchers should investigate the socioeconomic factors influencing plastic pollution prevention. Future investigations should consider examining educational campaigns in communities with a higher level of education, higher income or purchasing power, and a high consumption of single-used plastics. Other knowledge gaps include quantifying the impacts of the pandemic within the Great Lakes watershed, as well as building alliances with stakeholders of various sectors within Canada and those within the U.S (who share the use of the lakes). Second, there is a need to evaluate the efficacy of legislative instruments such as the North American Microbead Ban. Further research into innovative plastic designs and developing educational materials for K-12 curriculum on the negative impacts of plastic pollution, along with best preventive practices, would also be essential in implementing effective upstream solutions.

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Appendices

Appendix A: Recruitment Material

Attachment 1. *Recruitment and Introduction Email. Recruitment was done strictly via email. Snowball sampling encompassed the interviewer requesting the interviewee to forward the template below to interested prospects.*

Hello [Insert Name],

My name is *Trang Le* and I am a master's student working under the supervision of *Dr. Roy Brouwer* in the Department of Environment at the University of Waterloo. As part of my master's degree, I am conducting a research study on recommendations, opportunities and barriers to support the prevention of the Canadian Great Lakes' freshwater plastic pollution problem. I was able to find your email address through [LinkedIn/the Great Lakes Plastic Cleanup website]. Given your work/research on this matter, I feel that you are well suited to provide insights into this topic and I would like to invite you to participate in this study.

If you decide to volunteer for this study, your participation will consist of a one-on-one semi-structured interview through video-conferencing that will take approximately 30-45 minutes via MS Teams. During the interview you will be asked questions about an overview of your expertise, perspectives, and relevant inputs pertaining to the topic of freshwater plastic pollution as above. With your permission, I would like to record the interview via MS Teams to ensure accurate transcription and analysis. You can choose to turn off your camera.

Please be assured that this study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board REB [44001].

Please read the attached Information Letter for more details regarding what participation will involve. If you would like to participate, or you require additional information to assist you in reaching a decision about participation, please do not hesitate to contact me at t52le@uwaterloo.ca. You may also contact my supervisor, Dr. Roy Brouwer, at rbrouwer@uwaterloo.ca.

Sincerely,

Trang Le

t52le@uwaterloo.ca

Appendix B: Semi-structured Interview Protocol

Attachment 2. *Interview protocol encompassing interview questions*.

Protocol Step	Interview Question for GLPC Stakeholders	Interview Question for non-GLPC-affiliated stakeholders	Purpose and Topic Addressed
Opening question	What drives your participation in the Great Lakes Plastic Cleanup (GLPC)? What do you think are driving initiatives like the GLPC?	How is your role related to plastic pollution within Canada and in the Great Lakes watershed/basin? What do you think are driving your work?	Establish rapport between the interviewer and interviewee
Content Question	To what extent do you think current policies address freshwater plastics (effectively)?	To what extent do you think current policies address freshwater plastics (effectively)?	Probe: legislation landscape, potential barriers or opportunities
Content Question	**Potential Follow Up question:** Who currently and who should perhaps be responsible for managing freshwater plastics?	**Potential Follow Up question:** Who currently and who should perhaps be responsible for managing freshwater plastics?	Probe: legislation landscape, potential barriers or opportunities
Content Question	**Potential Follow Up question:** Do you have examples of success stories for managing and/or preventing plastic pollution in our lakes? If yes, can you elaborate? In your perspective, what roles does the GLPC initiative currently play in plastic pollution within Canada? How effective is this initiative to address freshwater plastics in the Great Lakes?	**Potential Follow Up question:** Have you heard of the GLPC? Do you have examples of success stories for managing and/or preventing plastic pollution in our lakes? If yes, can you elaborate?	Probe: drivers, barriers and opportunities

Content Question	In your opinion, does the pandemic have an impact on the intensity of plastic pollution in our lakes? How so?	In your opinion, does the pandemic have an impact on the intensity of plastic pollution in our lakes? How so?	Probe: drivers and barriers
Content Question	Alternatively: how does the pandemic affect your work/effort in curbing plastic pollution in our lakes?	Alternatively: how does the pandemic affect your work/effort in curbing plastic pollution in our lakes?	Probe: drivers and barriers
Content Question	What do you think are some key challenges to prevent plastics from: (1) getting into the water and (2) getting them out of the water?	What do you think are some key challenges to prevent plastics from: (1) getting into the water and (2) getting them out of the water?	Probe: drivers and barriers
Content Question	How does sharing the use and governance of some of the lakes with the US affect plastic pollution management?	How does sharing the use and governance of some of the lakes with the US affect plastic pollution management?	Probe: drivers, barriers and opportunities
A selection of content follow-up questions	To what extent do you think current policies help or accentuate challenges? Do you find current information, for example information that is science-based or behavior-based, is enough for decision making? If not, how so? (If yes, can you elaborate?) Do you think that there are some social challenges (based on how society regard and work with plastics?) Do you think current financial	To what extend do you think current policies help or accentuate challenges? Do you find current information, for example information that is science-based or behavior-based, is enough for decision making? If not, how so? (If yes, can you elaborate?) Do you think that there are some social challenges (based on how society regard and work with plastics?) Do you think current financial resources to address freshwater	Probe: drivers, barriers and recommendations. Avoid "Yes/No" responses.

	resources to address freshwater plastics efforts are enough? If not, how so? If yes, can you elaborate?	plastics efforts are enough? If not, how so? If yes, can you elaborate?	
Content Question	How should water policy be adapted or modified to address these challenges that we have talked about?	How should water policy be adapted or modified to address these challenges that we have talked about?	Probe: recommendations
Content Question	Expanding from this, what else do you think needs to be done to support plastic pollution management in the lakes? Follow Up: how important do you think these changes are to our lakes? Are there any other ways that can address plastic pollution?	Expanding from this, what else do you think needs to be done to support plastic pollution management in the lakes? Follow Up: how important do you think these changes are to our lakes? Are there any other ways that can address plastic pollution?	Probe: recommendations
Closing Questions	Is there anything else that you would like to add? Do you have any questions for me? If possible, would you be able to forward my contact information and the information letter to	Is there anything else that you would like to add? Do you have any questions for me? If possible, would you be able to forward my contact information and	Ending the interview. Reiterate participants' rights and further instructions as necessary.

	someone who you think I should speak to?	the information letter to someone who you think I should speak to?	

Appendix C: Content Analysis Supplemental Data

Table 7. *Sectoral perspectives on barriers, drivers, the roles of the GLPC, and recommendations.*

Codes	Non-profits/NGOs (n=7)	Public Sector (n=5)	Academia (n=5)	Private Sector (n=4)	Total (n=21)
Barriers					
Costs of Pollution Prevention	86%	80%	80%	75%	81%
Difficult to Recover	43%	40%	40%	50%	43%
Lack of Industry Cooperation	71%	80%	80%	75%	76%
Infrastructure Incapacity	57%	20%	80%	75%	57%
Lack of Research	29%	40%	20%	25%	29%
Ineffective Regulations	86%	100%	80%	75%	86%
Lack of Awareness	71%	80%	60%	100%	76%
Lack of Alternatives	29%	40%	80%	50%	48%
Harmful Plastic Designs	71%	60%	60%	25%	57%
Drivers					
Lack of Alternatives	29%	40%	0%	25%	24%
Multi-source Leakage	100%	100%	100%	100%	100%
Lack of Research	0%	20%	0%	0%	5%
Roles of the GLPC					
GLPC Role: Clean-up	14%	40%	0%	25%	19%
GLPC Role: Inform	86%	80%	60%	75%	76%
Recommendations					
Binational Responsibility	100%	80%	100%	50%	86%

Cross-discipline Collaboration	100%	100%	80%	75%	90%
General Incentives	71%	60%	100%	100%	81%
Consumers' Education	100%	80%	80%	100%	90%
Funding for Solutions	71%	40%	40%	50%	52%
Infrastructure Enhancement	29%	20%	60%	75%	43%
More or Stricter Regulations	100%	100%	100%	100%	100%
Replace with Alternatives	57%	40%	80%	25%	52%
Plastics' Redesign	43%	60%	40%	25%	43%
Waste Recovery	43%	40%	40%	50%	43%
Reframe of Discourse	86%	40%	40%	50%	57%
Reduce Consumption	57%	40%	80%	75%	62%

Table 8. *Perspectives on barriers, drivers, the roles of the GLPC, and recommendations based on whether participants were partners with the GLPC or not.*

Codes	Great Lakes Plastic Cleanup (GLPC) Partner		Total (n=21)
	No (n=10)	**Yes (n=11)**	
Barriers			
Costs of Pollution Prevention	80%	82%	81%
Difficult to Recover	60%	27%	43%
Lack of Industry Cooperation	90%	64%	76%
Infrastructure Incapacity	60%	55%	57%
Lack of Research	20%	36%	29%
Ineffective Regulations	100%	73%	86%
Lack of Awareness	70%	82%	76%

Lack of Alternatives	60%	36%	48%
Harmful Plastic Designs	80%	36%	57%
Drivers			
Lack of Alternatives	30%	18%	24%
Multi-source Leakage	100%	100%	100%
Lack of Research	0%	9%	5%
Roles of the GLPC			
GLPC Role: Clean-up	20%	18%	19%
GLPC Role: Inform	50%	100%	76%
Recommendations			
Binational Responsibility	90%	82%	86%
Cross-discipline Collaboration	90%	91%	90%
General Incentives	70%	91%	81%
Consumers' Education	100%	82%	90%
Funding for Solutions	60%	45%	52%
Infrastructure Enhancement	50%	36%	43%
More or Stricter Regulations	100%	100%	100%
Replace with Alternatives	80%	27%	52%
Plastics' Redesign	60%	27%	43%
Waste Recovery	60%	27%	43%
Reframe of Discourse	70%	45%	57%
Reduce Consumption	90%	36%	62%

UNIVERSITY OF WATERLOO

Notification of Ethics Clearance to Conduct Research with

Human Participants

Principal Investigator: Roy Brouwer (Economics)

Student investigator: Trang Le (School of Environment, Resources

and Sustainability) File #: 44001

Title: Plastic Pollution in the Canadian Great Lakes: Opportunities, Barriers and Policy Recommendations

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The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

Initial Approval Date: 02/24/22 (m/d/y)

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Expiry Date: 02/25/23 (m/d/y)

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board

Erin Van Der Meulen

Erin Van Der Meulen, Research Ethics Advisor, ervandermeulen@uwaterloo.ca, 519-888-4567 x37046

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or

received for information: file: 2021_LeTrang_Recruitment Email_revised.docx

file: 2021_LeTrang_Interview Guide v1_GLPC

GovernmentWorkers_revised.docx file:

2021_LeTrang_Interview Guide v1_GLPC Others_revised.docx

file: 2021_LeTrang_Interview Guide v1_GLPC

Scientists_revised.docx

file: 2021_LeTrang_Interview Guide v1_Government

Workers_revised.docx file: 2021_LeTrang_Interview

Guide v1_Others_revised.docx

file: 2021_LeTrang_Interview Guide

v1_Scientists_revised.docx file:

2021_LeTrang_Oral Consent Script

revised.docx

file: 2021_LeTrang_Letter of Information and Consent

v2_GLPC_revised.docx file: 2021_LeTrang_Letter of

Information and Consent_general_reviseda.docx file:

2021_LeTrang_Participant Appreciation

Letter_revised.docx

Approved Protocol Version 2 in Research Ethics System

You are responsible for obtaining any additional institutional approvals that might be required to complete this study.