Evaluating Canada’s single-use plastic (SUP) mitigation policies via brand audit and beach cleanup data.

by

Lisa Baxter

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Abstract

Single-use plastics (SUPs) represent a major threat to marine environments and require proactive policies to reduce consumption and improper disposal. A range of SUP mitigation strategies are available to deter SUP use and mitigate environmental impacts, including extended producer responsibility (EPR), deposit-return schemes, SUP bans, and public outreach and education. Within Canada, current SUP management is fragmented, and proposed federal approaches may be insufficient to adequately minimize SUPs. Through this study, brand audit and beach cleanup data were analyzed for multiple locations across Canada including densely populated cities and a remote island (Vancouver, Toronto, Montréal, Halifax, and Sable Island) to determine efficacy of ongoing SUP mitigation measures in Canada. Results support that current Canadian SUP measures do not adequately address EPR, and overall, current measures appear to be insufficient to address improper disposal of SUPs into the environment. Recommendations to strengthen current SUP management strategies and mitigate marine plastic pollution are suggested with the goal of improving future Canadian SUP reduction policies.

Keywords: Single-use plastics (SUPs); marine litter; SUP policy; SUP mitigation; Canada; brand audit; beach cleanup; citizen science.

List of Abbreviations

ALDFG – Abandoned, Lost, and Discarded Fishing Gear

BFFP – Break Free From Plastics

CEPA – *Canadian Environmental Protection Act*

ÉEQ – Éco Entreprises Québec

EPR – Extended Producer Responsibility

GCSC – Great Canadian Shoreline Cleanup

GP – Greenpeace

GPA – Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities

GPML – Global Partnership on Marine Litter

HDPE – High Density Polyethylene

HRM – Halifax Regional Municipality

LDPE – Low Density Polyethylene

MARPOL – International Convention for the Prevention of Pollution from Ships

MT – Million Metric Tonnes

PET – Polyethylene Terephthalate

PP – Polypropylene

PPP – Polluter Pays Principle

PROs – Producer Responsibility Organizations

PS – Polystyrene

PVC – Polyvinyl Chloride

SII – Sable Island Institute

SUP – Single-use Plastic

UNCLOS – United Nations Convention on the Law of the Sea

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1. Introduction

1.1 Marine Plastics

Plastic is pervasive in modern society with global plastic production accelerating at an unprecedented rate (Geyer et al. 2017; ECCC, 2020c). Plastic usage has increased by twenty-fold in the past 50 years and is anticipated to double within the next 20 years (WEF, 2016). Cumulatively, ~6,300 million metric tonnes (MT) of plastic waste have been generated globally since 2015, of which only about 9% of plastic waste is recycled and 12% incinerated, with the remainder accumulating in landfills or leaking into natural environments (Geyer et al., 2017; Walker et al., 2021). Currently, plastic production accounts for 6% of global oil consumption (Zhu, 2021); however, if plastic production grows as anticipated, this sector will account for about 20% of total oil consumption and 15% of annual carbon budgets by 2050 (WEF, 2016).

Due to their wide-spread use and environmental leakage, plastics have become ubiquitous in the marine environment (Barnes et al., 2009; Galgani et al., 2015; Ostle et al., 2019; Linnebjerg et al., 2021). Marine debris are now commonly observed throughout marine ecosystems and are comprised of ~90% plastics (Leite et al., 2014; Pasternak et al., 2017; Jang et al., 2018; Ambrose et al., 2019). It is estimated that 150 MT of plastics circulate in the ocean, including approximately 23 MT of additives such as stabilizers, plasticizers and pigments (WEF, 2016), which cause a range of impacts on marine ecosystems. In 2016, it was projected that 19-23 MT of plastics entered aquatic environments (Borrelle et al., 2020). By 2030, annual emissions are predicted to reach 53 MT (Borrelle et al., 2020).

The characteristics of plastics, such as buoyancy, allow plastic particles to be transported long distances in the ocean with the aid of wind and currents (Galgani et al., 2015). Accumulation of plastic debris is based on a variety of parameters including presence of urban centres, hydrodynamics, and maritime activities (Galgani et al., 2015). However, approximately two-thirds of buoyant plastic debris is located on shorelines, where plastics can be stranded, buried, or undergo cycles of capturing and resurfacing (Lebreton et al., 2019).

The transboundary, pervasive nature of marine plastics make its implications a global issue (Walker, 2018; Beaumont et al., 2019; PAME, 2019). It remains a challenge that needs to be addressed at regional, national, and international levels; current global political climates are favourable for implementing further action to combat marine plastics (Schnell et al., 2017).

1.1.1 Types of Plastics

Plastics are synthetic, organic polymers that offer many consumer advantages, such as durability and versatility; however, these characteristics directly result in recycling challenges and promote persistence in natural environments (Shen & Worrell, 2014). Plastics exist in various resin types (Table 1), as well as composites that include multiple resins and additive materials (Shen & Worrell, 2014). The large variety of plastic types, in addition to additives, contribute to waste management challenges and low recycling rates, where plastics often must be recycled into lower-grade products that cannot be subsequently recycled (WEF, 2016). Recyclability varies across resin types, with higher recycling rates for PET and HDPE, whereas recycling rates for films remain lower (Shen & Worrell, 2014).

Table 1: Summary of Plastic Types, Proportions, and Primary Uses.

Plastic Resin[1]	**Global Production[2]**	**Primary Uses[1,3]**
Polyethylene Terephthalate (PET)	8%	Beverage bottles, plastic jars, medicine containers.
High-density Polyethylene (HDPE)	13%	Milk bottles, grocery bags, shampoo containers, fishing nets.
Polyvinyl Chloride (PVC)	9%	Pipe/tubing, commercial cling wrap, cosmetic containers.
Low-density Polyethylene (LDPE)	16%	Cling wrap, produce bags, sandwich bags.
Polypropylene (PP)	17%	Food storage containers (such as Tupperware), margarine tubs, straws.
Polystyrene (PS)	6%	Take-out food containers, Styrofoam cups, disposal cutlery.
Other	31%	Multi-material packaging, flexible films.

[1](WEF, 2016) [2](Yeo et al., 2018) [3](Banerjee et al., 2014)

1.1.1.1 Macroplastic vs Microplastic

Plastics can be broadly classified into two size categories: macroplastics (>5mm) and microplastics (<5mm) (Piehl et al., 2018). Further, microplastics can be distinguished as primary microplastics (manufactured at sizes less than 5 mm, such as microbeads) or secondary microplastics (result from fragmentation of larger plastics) (Talvitie et al., 2017; Piehl et al., 2018). Fragmentation of macroplastics can occur through various chemical and biological environmental processes, such as photo and thermo-oxidative stresses (Fotopoulou & Karapanagioti, 2017; Prata et al., 2019); extent of degradation is reliant on environmental factors, such as temperature and chemical composition of the plastic (Eubeler et al., 2010; Andrady, 2015).

Microplastics can be transported over long distances via wind and currents (Galgani et al., 2015), facilitating the dispersal of invasive species (Padervand et al., 2020). Further, microplastics have been found in a variety of marine life, including mussels, shrimp, and fish, eventually entering human food chain pathways (Wu et al., 2017). The consequences of microplastic ingestion are still largely unknown, however some preliminary studies indicate potential adverse health effects (Karbalaei et al., 2021), including alternation of neurotoxic response pathways and lipid metabolism (Deng et al., 2017).

1.1.1.2 Single-use Plastics

Single-use plastics (SUPs) are designed to be discarded after one use and include items such as packaging and bags. An estimated 40% of global plastic products are designed as single-use products (Geyer et al., 2017), and SUPs represent a major contributor to global solid waste (Walker et al., 2021). Packaging in particular accounts for over a third of global plastic production (Geyer et al., 2017), and due to its complex composition are generally challenging to recycle (Diggle & Walker, 2021).

1.1.2 Sources of Marine Plastics

1.1.2.1 Land-based vs Sea-based

Plastic waste is known to leak into the ocean through activities at sea, such as direct disposal of waste from ships or fishing activities, and through land-based sources via in-land waterways, wastewater, and transportation by wind or tides (Jambeck et al., 2015). The majority of marine plastic debris (80%) originates from land-based sources (Jambeck et al., 2015), indicating the importance of strategies that target land-based leakage, such as improved waste management or plastic-use reduction. Strategies for sea-based marine debris can target abandoned, lost, and discarded fishing gear (ALDFG) through approaches such as implementation of convenient and affordable disposal methods, Fishing for Litter schemes (Schnell et al., 2017), education and awareness campaigns (Goodman et al., 2019) and retrieval (Goodman et al., 2021).

1.1.2.2 Global Context

Plastic waste generation and mismanagement are largely disproportionate between high-income countries, which account for approximately a third of waste generation, and low-income countries, which only generate approximately five percent of global solid waste (Kaza et al., 2018). Mismanagement of waste in coastal populations tends to be more prominent in low-income countries, with the top five countries for mismanaged waste identified as China, Indonesia, Philippines, Vietnam, and Sri Lanka (Jambeck et al., 2015). However, this study did not address import or export of waste, thereby affecting national estimates. A subsequent study, conducted by Law et al. (2020), found the United States to be a major contributor of plastic marine debris despite a more developed waste management system. Due to the shear amount of plastic waste generated (42 MT), the contributions to environments through littering, as well as exportation of waste to countries with less capacity to properly dispose of materials, results in large amounts of environmental leakage (Law et al., 2020). This research highlights the impact of high plastic usage and thereby the importance of reducing production, as well as implementing responsible, domestic waste processing.

Further, riverine plastics transport remains a key source of ocean plastics debris. It is estimated that 1,656 rivers contribute 80% of global riverine plastic emissions with significant contributions from small- and medium-sized rivers (Meijer et al., 2021). In particular, the greatest riverine emissions were projected for Philippines, India, Malaysia, and China (Meijer et al., 2021). Plastics were found to enter aquatic ecosystems from many emission points, suggesting the importance of global collaboration (Meijer et al., 2021). Some developed nations, such as Canada, have committed to providing provisions to support marine plastics policies in developing nations (Government of Canada, 2020).

The practice of shipping plastic waste from developed to developing countries has been common; however, waste disposal in developing countries often results in a higher environmental cost (Wen et al., 2021). The dynamics of the global plastic waste trade were largely impacted when

China announced a ban on the importation of 24 types of solid wastes, including plastics (Wen et al., 2021). As a result of the China Ban, by 2030 an estimated 111 MT of plastic waste will be displaced through this policy (Brooks et al., 2018). This displacement offers an opportunity for exporting countries to strengthen domestic waste management, as well as reduce plastic consumption and consider alternatives (Rogoff & Ross, 2016; Brooks et al., 2018; Liu et al., 2018; Law et al., 2020; Wen et al., 2021). Further, it could provide a platform to re-envision global plastic trade and create a new, circular plastics economy (WEF, 2016) through establishing a fair-trading system with components such as global extended producer responsibility (EPR) and global standards (Liu et al., 2018; Brooks et al., 2018; Liu et al., 2021).

1.1.2.3 Canadian Context

To mitigate land-based sources of macroplastic debris, improved waste management systems are vital (Karasik et al., 2020). Yet Canada largely lacks sufficient plastic waste management and recycling infrastructure (Walker et al., 2021). Annually, Canadians discard 3 million tonnes of plastic waste, including 15 billion plastic bags and over 20 billion straws (Government of Canada, 2020). This plastic waste is disposed through landfills (86%), incineration (4%), or recycling (9%) (ECCC, 2019c), and an estimated 29,000 tonnes enter the natural environment (Government of Canada, 2020). The 'Dirty Dozen' list produced by the Great Canadian Shoreline Cleanup (GCSC) documents prevalent items found through cleanup efforts, the majority of which are SUPs including food wrappers, plastic bottles, and plastic bags (GCSC, 2020). In 2016, single-use plastic packaging waste accounted for 47% of discarded Canadian plastics (ECCC, 2019c) of which only about 20% can be recycled or reused (Xanthos & Walker, 2017). Canada contains approximately 80 dedicated plastic recycling facilities–primarily in Ontario and Quebec–however, these facilities have limited capacity to recycle complex products, such as plastic mixes, polystyrene containers, and dirty plastics (CCME, 2018).

1.1.2.3.1 Remote/Arctic Considerations

High densities of litter can be found in remote and uninhabited locations (Lavers & Bond, 2017; Mallory et al., 2021); Arctic locations are found to have high concentrations of fishing-related and domestic waste, as well as marine litter transported from distant sources (PAME, 2019). Arctic beach surveys also indicate that large amounts of collected marine debris are plastics (up to 94%) (PAME, 2019). Remote and Arctic communities often do not have access to proper waste disposal and recycling facilities, creating challenges for addressing domestic sources of marine litter (CCME, 2018; ECCC, 2019b; Mallory et al., 2021). Considerations to mitigate these challenges may include: determining viable waste management solutions for these unique communities (that involve local governance and collaboration), as well as increased education and training programs (ECCC, 2019b).

1.1.3 Impacts of Marine Plastics

1.1.3.1 Marine Organism Impacts

Species affected by marine plastics have increased from an estimated 693 species (Gall & Thompson, 2015) to over 3,700 species (Litterbase, 2021). Marine debris now affects 100% of sea turtle species, 43-66% of marine mammal species, and 44-50% of seabirds (Kühn et al., 2015); by 2050, 99% of seabirds are expected to have ingested plastics (Wilcox et al., 2015).

The impact pathways are diverse. Entanglement and ingestion are prevalent threats to marine species, with evidence indicating an increasing trend in plastic litter ingestion and entanglement occurrences (Acampora et al., 2016; Ostle et al., 2019; Litterbase, 2021). These threats are especially concerning for species-at-risk, including the North Atlantic right whale, where 83% showed evidence of entanglement with marine debris (Knowlton et al., 2012; Taylor & Walker, 2017). Plastics also contain various additives and chemicals, such as plasticizers and UV stabilizers (ECCC, 2019b). These chemicals are seen to accumulate on marine debris and some additives may cause endocrine-disruptions or other adverse health impacts to marine organisms (Rochman, 2015; ECCC, 2019b). Further, floating marine debris offers a medium for long-range transportation of invasive species which can result in large ecosystem impacts or biodiversity loss (Werner et al., 2016; Gracia & Rangel-Buitago, 2020). Additionally, large plastic sheets can impact benthic ecosystems through smothering corals, sponges, and plants, limiting gas exchange and photosynthesis (Kühn et al. 2015; Werner et al., 2016). Even in instances where marine plastics do not cause direct mortality, their impacts may result in decreased fitness, subsequently impacting ability to capture food, reproduce, migrate, or escape predation (Galloway et al., 2017; Linnebjerg et al., 2021). Impacts are not only evident on individual levels, but can additionally impact suborganism, organism, population, assemblage, habitat, and ecosystem levels (PAME, 2019). Plastic debris is not the sole stressor on marine environments and may act cumulatively with other prominent stressors to result in larger ecosystem impacts and imbalances (Beaumont et al., 2019).

1.1.3.2 Socio-Economic Impacts

It is estimated that marine litter impacts the livelihoods of over three billion individuals, spanning sectors such as shipping, fishing, and tourism (Abalansa et al., 2020). All global marine ecosystem services are impacted by marine debris to varying extents (Beaumont et al., 2019). Threats to ecosystem services can have adverse impacts on human health and wellbeing linked to heritage, fisheries, charismatic species, and recreation (Beaumont et al., 2019). These impacts are especially prominent in coastal communities who more directly rely on these ecosystem services (Naeem et al., 2016). Currently, the socio-economic impacts of marine litter are not largely incorporated into valuation of marine litter impacts. Beaumont et al. (2019) suggest development of a 'Social Cost of Marine Plastic' to better encompass the social impacts of marine debris and support future provision of marine ecosystem services.

1.1.3.3 Economic Impacts

Marine litter results in economic impacts both through reduction of benefits derived from ecosystem services, increased cost of marine and coastal activities, and loss of plastic material value (Newman et al., 2015; WEF, 2016). Ultimately, marine litter is a result of market failure, where the external cost is borne on society not by the producer (Newman et al., 2015). The main sectors that bear these impacts are: fisheries and aquaculture (through decreased productivity), marine/coastal tourism, shipping, agriculture, and coastal municipalities (Mouat et al., 2010; Beaumont et al., 2019). Exact measurements of economic impacts are challenging due to the wide range of impacts and impacted sectors, as well as large geographic scope (Newman et al., 2015).

Annual economic costs have been conservatively estimated at $3,300-$33,000 per tonne of marine plastic (based on 2011 values; Beaumont et al., 2019). This includes an annual loss of $500-$2,500 billion from marine ecosystem services due to marine debris (Beaumont et al., 2019). Further, at least $13 billion in marine ecosystem damages occur globally each year (CCME, 2018). In particular, plastic packaging contributes to large economic losses, including improper disposal which can clog urban infrastructure and impact the natural environment (UNEP, 2014). The cost associated with discarded plastic packaging, including greenhouse gas emissions from production, is estimated at $40 billion annually (WEF, 2016). In Canada, plastics represent a major loss in the resource chain due to limited recycling capacity and secondary market opportunities. Annually, Canadian plastic waste represents a lost economic opportunity of $8 billion (ECCC, 2019b).

1.2 SUP Mitigation Strategies

A variety of economic, information, and affirmative and prohibitive regulatory instruments exist to prevent SUP use, mitigate SUP environmental impacts, and promote consumer behaviour changes (Chen, 2015; Karasik et al., 2020). The degree of success for instruments depends on factors such as enforcement, sufficiently high fees to incentivize behaviour changes, accessibility of sustainable alternatives, and public support of policies (Karasik et al., 2020).

1.2.1 Disincentive Instruments (Bans, Fees, and Levies)

Prohibitive bans on plastic bags are one of the most common SUP mitigation strategies (Figure 1)—at least 127 countries have adopted legislation to regulate plastic bags (UNEP, 2018). These measures result in an average bag consumption reduction of 64%, however, the range in effectiveness is quite large (33-96%) and depends on a variety of policy factors (Schnurr et al., 2018). Regulatory bans are popular as they require fairly simplistic implementation and monitoring compliance; however, leakage into other, non-banned disposable alterative can occur (Karasik et al., 2020). Further, a long-term 'rebound effect', where effectiveness of instruments diminishes overtime, can also occur as consumers adjust their behaviour (Dikgang et al., 2012). A key factor to instrument efficacy is ensuring fees are high enough to encourage behaviour changes, which may include subsequent fee increases to mitigate rebound effects (Karasik et al., 2020). Additionally, bans or limits on problematic plastics, such as polystyrene and polyvinyl chlorine, can help support industry shifts to more recyclable alternatives (Rochman et al., 2013). Although plastic bag bans are widespread, full bans on other SUPs can also be effective and beneficial, and should be considered for problematic SUPs, such as packaging (Prata et al., 2019; Karasik et al., 2020; Walker et al., 2021). COVID-19 has resulted in unpredicted increases in plastic consumption, as well as reversal or delay of SUP mitigation strategies and decreased public support, highlighting the importance of strengthening SUP reduction policies and developing viable, sustainable alternatives (Prata et al., 2020; Patrício Silva et al., 2020; Kitz et al., 2021).

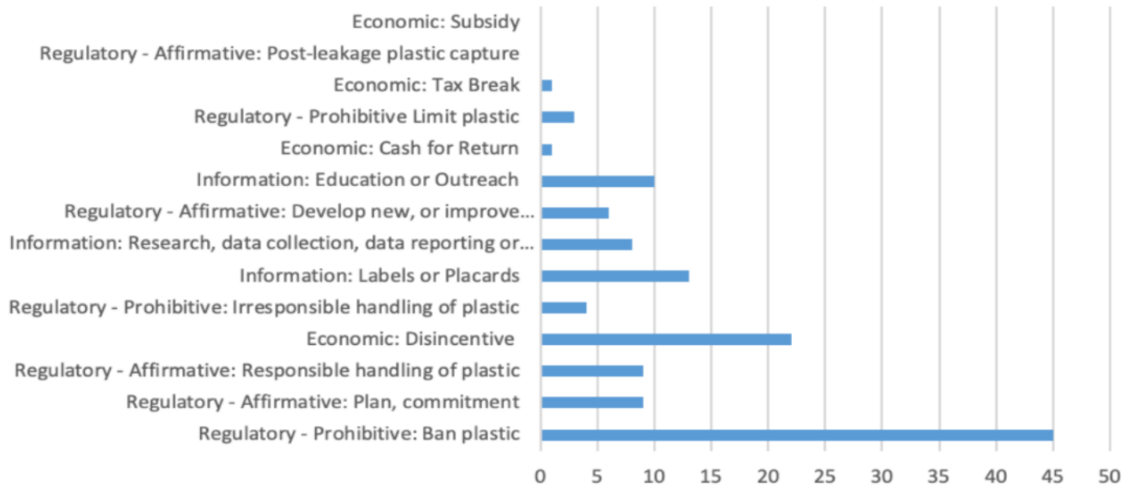

Figure 1: Most Frequent Instruments used in National Plastic Bag Policies (from Karasik et al., 2020).

1.2.2 Cash-for-Return Programs

Cash-for-return programs generally consist of a deposit charged to consumers at item purchase where the deposit is reimbursed upon proper item disposal; this instrument is prevalent for beverage containers (Karasik et al., 2020). The objective of these programs is to incentivize proper disposal and recycling of plastics and have been shown to be consistently effective (Karasik et al., 2020). There is strong evidence that these programs reduce beverage container pollution limiting debris of these items by up to 40%, as compared to regions without such programs (Schuyler et al., 2018). Nova Scotia's beverage cash-for-return program has seen similar effects with direct reduction of beverage litter within the province (Diggle & Walker, 2020).

1.2.3 Extended Producer Responsibility

Extended Producer Responsibility (EPR) is a policy strategy that extends producer responsibility to include end-of-life management, such as product disposal and recycling (Lindhqvist, 2000; Kunz et al., 2018; Diggle & Walker, 2020). Responsibility may include financial and/or logistics accountability, often through supporting waste management and recycling programs (Newman et al., 2015; Prata et al., 2019). The objectives of this model are to incentivize producers to minimize plastic waste, develop more sustainable products, and shift to more recyclable plastics (Kunz et al., 2018; CSSA, 2021; Diggle & Walker, 2021). EPR programs often employ producer-responsibility organizations (PROs) to facilitate payment collection and reallocation to recycling (Newman et al., 2015). Generally, producers pay fees to PROs based on their weight-based production capacities; these fees can then be used to contribute to waste management programs, often run through municipalities (Newman et al., 2015; Diggle & Walker, 2021). Deficits of some EPR programs are that fees do not consider companies that improve product designs or promote circularization, thereby minimizing incentive to develop more sustainable options. This can be amended through programs that reduce fees or provide rebates for producers that employ more sustainable practices (Kunz et al., 2018; Leal Filho et al., 2019; Diggle & Walker, 2021).

EPR programs exist to varying extents in five Canadian provinces: British Columbia, Saskatchewan, Manitoba, Ontario, and Québec (Diggle & Walker, 2021). A full responsibility EPR model is employed in British Columbia, where producers bear the full financial burden of recycling programs (Recycle BC, 2019). Success of EPR can be seen in this instance, as many Recycle BC producers have committed to 100% recyclable packaging by 2025 to improve recycling economics (Recycle BC, 2019). In other provinces, a shared responsibility model is employed, with producers and municipalities contributing to financial and operational components (Diggle & Walker, 2021). Canadian EPR programs tend to only cover residential waste programs, excluding waste generated from institutional, commercial, and industrial sectors (Diggle & Walker, 2021). In 2016, 10.2 MT of waste generated from the residential sector (~13% plastic) and 11.5 MT from the ICI sector (~16% plastic) in Canada (ECCC, 2020b).

Determining implications of EPR programs and producer accountability can be elucidated through litter brand audits. These audits help develop an understanding of brands that disproportionally impact natural environments and create greater producer accountability through EPR programs that target environmental and societal costs of litter (Gaia, 2019). As of yet, no EPR that accounts for societal burdens was found to exist in Canada. Brand audits may also help researchers to determine whether EPR programs influence limiting marine debris from obligate stewards by comparing locations with and without EPR.

Many factors can impact the effectiveness of EPR programs including producer selection criteria, fee determination, and value of secondary markets (Newman et al., 2015). Although EPR programs tend to focus primarily on plastic packaging, such programs may be valuable if extended to other plastic products (Leal Filho et al., 2019; Karasik et al., 2020).

1.2.4 Education/Outreach

Public education and outreach are known to influence consumer behaviours (Prata et al., 2019). When individuals have an improved knowledge of the environment and its threats, consumers are more likely to act in a pro-environmental manner (Glifford & Nilsson, 2014). Further, consumer buying power can exert pressure on producers and is recognized as a driving force of industry change (Garnett 2011; Walker et al., 2021). Consumer awareness and participation in SUP policies is vital; for instance, consumer acceptance and support for waste collection schemes is imperative for successful EPR programs (Newman et al., 2015). Although researchers advocate that education and outreach should be coupled with other policy strategies to increase effectiveness, globally only 11% of national policies include educational components (Karasik et al., 2020). This represents a lost opportunity to build support and awareness for environmental issues, such as SUP use.

Further, consumer behaviour change can be enhanced through citizen science programs (Hardesty et al., 2014). Citizen science programs not only bolster data for researchers, but also act as an outlet to bridge gaps between researchers and the public, as well as promote improved public awareness and support consumer behaviour changes (Schnurr et al., 2018; Ambrose et al., 2019). Consumers have a strong role in the reduction of SUPs through consumer demand for sustainable products, prioritization of recycling, and increasing demand for recycled plastics to support secondary markets (Prata et al., 2019). As such, it is vital that SUP mitigation strategies include public engagement and education campaigns.

1.3 Marine Plastic Policies

Marine plastics are a complex, transboundary issue covered by global, international, national, and regional/local policies that tackle sea- and land-based sources (Linnebjerg et al., 2021). Governance across jurisdictions, however, is often inconsistent resulting in regulatory gaps that allow for evasion of responsibility (Dauvergne, 2018; Linnebjerg et al., 2021). Managing this issue requires coordinated approaches at both global and national scales—it is expected that global policy can only account for 30% of a solution with national and regional policies imperative to adequately address marine plastics (Bondansky, 2010). Since 2000, 28 international policies have been developed to address marine debris, however, these are generally non-binding (Karasik et al., 2020; Table 2). In Canada, marine debris legislation tends to take a more regional focus and until recently, national strategies to address SUP pollution were limited (Karasik et al., 2020; Government of Canada, 2020). Policy is not a sole solution to marine plastics, but a component of the solution that must involve business innovation, government regulation, and behavioural changes (Walker et al., 2021).

Table 2: Major Global Actions for Marine Plastic Pollution (Karasik et al., 2020; Linnebjerg et al., 2021; PPEWG, 2021).

1972	Conventional on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention)
1973/ 1978	International Convention for the Prevention of Pollution from Ships (MARPOL)
1974	United Nations Environment Programme (UNEP) Regional Seas Programme
1979	Convention on Migratory Species
1982	United Nations Convention on the Law of the Sea (UNCLOS)
1989	Basel Convention
1992	Convention on Biological Diversity
1995	UN Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA)
1996	London Protocol
2001	Stockholm Convention on Persistent Organic Pollutants
2005	UN Resolution on Marine Plastic Pollution (Resolution S/60/L.22)
2010	The Strategic Plan for Biodiversity 2011-2020 and the Aichi Targets
2011	Honolulu Strategy-A Global Framework for Prevention and Management of Marine Debris
2012	Global Partnership on Marine Litter (under GPA framework)
2015	UN Sustainable Development Goals
2016	UN Environmental Assembly acknowledge marine plastic as global concern
2017	UN Clean Seas Initiative
2017	UN Resolution on Marine Plastic Pollution
2017	G20 Action Plan on Marine Litter
2018	G7 Ocean Plastics Charter
2019	Basal Convention amended to include plastic waste exports

1.3.1 Major Global Policies & Targets

The first major global policies, International Convention for the Prevention of Pollution from Ships (MARPOL) and London Convention, focused on sea-sourced plastics through prohibiting discard and dumping of waste into marine environments from the shipping industry (Karasik et al., 2020). These two treaties are binding to member states. The transboundary shipment of plastic waste and broad protocols for waste reduction are encompassed under the Basel Convention, which currently has 188 parties and 53 signatories (Secretariat of the Basel Convention, 2019). Primarily, this convention's provisions require environmentally sound import/export of waste and encourages waste management to occur in the country where waste is generated (Raubenheimer & McIlgorm, 2018; Secretariat of the Basel Convention, 2019). The Basel Convention was amended in 2019 to include provisions for global plastic waste trade and to address marine plastic sources (Secretariat of the Basel Convention, 2019).

Another pivotal advancement in global marine plastics policy were the development of conventions that addressed land-based sources of plastic debris. The Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) is a non-binding convention with the objective of preventing, reducing, controlling, and/or eliminating marine debris from land-based activities (Gonclaves & Faure, 2019). The Honolulu Strategy further strengthened these provisions through addressing both land-based and sea-based marine plastics sources, as well as accumulated debris on shorelines, to reduce ecological, health, and economic impacts of marine litter (Löhr et al., 2017; Gonclaves & Faure, 2019). To support the objectives of the Honolulu Strategy, the Global Partnership on Marine Litter (GPML) was commissioned at the Rio+20 Summit (Gonclaves & Faure, 2019; UNEP, 2021). GPML is a voluntary multi-stakeholder working group that brings policy makers, researchers, and private sector together to develop solutions (UNEP, 2021). In 2016, the United Nations (UN) Environmental Assembly acknowledged marine litter as an urgent, global problem (Löhr et al., 2017).

Several global targets to combat marine plastics have also been recognized, notably the United Nations Convention on Biological Diversity Aichi Targets and 2030 Sustainable Development Goals (CBD, 2011; UN, 2015). Within Aichi Target 8, by 2020 pollution (such as marine debris) was to be reduced to levels not detrimental to ecosystem function (CBD, 2011); these targets were largely unmet and unsuccessful (Nature, 2020). Through the 2030 Sustainable Development Goals, Target 14.1 addresses the prevention and reductions of marine pollution, including marine litter, by 2025 (UN, 2015; CCME, 2018; Karasik et al., 2020; Walker, 2021a).

Existing global policies and governance strategies have been largely insufficient to adequately address marine litter (Gold et al., 2013; Dauvergne, 2018). These failures have been attributed to a lack of global binding treaties, and non-specific or measurable targets (Karasik et al., 2020). Researchers have proposed the development of a global treaty that contains binding and measurable targets, robust enforcement mechanisms, and promotes global multi-stakeholder collaboration for development of a circular plastics economy (WEF, 2016; Karasik et al., 2020).

1.3.1.1 G20 Action Plan on Marine Litter

Although not a global convention in scope, the G20 and G7 action plans represent international policies that involve Canada. The G20 Action Plan on Marine Litter encompasses the following recommended actions for member states (MOFA, 2019):

- Promote socio-economic benefits of preventing marine litter.
- Promote waste prevention and resource efficiency (reduce SUPs).
- Promote sustainable waste management.
- Promote effective wastewater treatment and storm water management.
- Raise awareness, promote education and research.
- Support removal and remediation action.
- Strengthen stakeholder engagement.

1.3.1.2 G7 Ocean Plastics Charter

In 2018, Canada committed to the G7 Ocean Plastics Charter which has an overarching goal to recover 100% of all plastics by 2040 (Linnebjerg et al., 2021). Through this charter, participating countries commit to (ECCC, 2018):

- Sustainable design, production, and after-use markets.
    - 100% reusable, recyclable, or, where viable alternatives do not exist, recoverable, plastics by 2030.
    - Reducing the unnecessary use of single-use plastics.
    - Increasing recycled content by at least 50% in plastic products where applicable by 2030.
- Collection, management and other systems and infrastructure.
    - Recycle and reuse at least 55% of plastic packaging by 2030 and recover 100% of all plastics by 2040.
- Sustainable lifestyles and education.
    - Strengthen market-based instruments, promote consumer awareness, labelling standards, and foster knowledge exchange.
- Research, innovation, and new technologies.
- Coastal and shoreline action.
    - Including citizen science, beach cleanups, and ALDFG.

1.3.2 Canadian Policies

Historically, Canadian SUP reduction policies have taken a regional approach through various provincial and municipal plastic bag bans, such as in Nova Scotia and Vancouver (Karasik et al., 2020; Walker et al., 2021). Currently, Canada has 10 federal acts that pertain to marine debris, such as the *Canada Water Act (1985)* and *Canadian Shipping Act (2001)*, which almost exclusively relate to sea-based plastic sources (Linnebjerg et al., 2021). The only current national ban for plastic pollution is *the Microbeads in Toiletries Regulation (2017)* which prohibits microbeads in cosmetic products (ECCC, 2019b). However, Canada has committed to banning six harmful plastic products by the end of 2021 (Government of Canada, 2020).

1.3.2.1 Canada-wide Strategy on Zero Plastic Waste

The Canada-wide Strategy on Zero Plastic Waste (herein referred to as Zero Plastic Strategy) focuses on prevention, collection, and recovery of plastics to support a more circular economy (CCME, 2018; Figure 2). Priority area targets include product design, SUPs, end-use markets, consumer awareness, and global action (CCME, 2018). These shifts are expected to reduce greenhouse gas emissions by 1.8 million tonnes, while also stimulating innovation, increasing competitiveness, and reducing plastic waste entering the environment (ECCC, 2019a; Government of Canada, 2020). The strategy considers various instruments, including EPR, SUP bans, deposit return programs, and education (CCME, 2018). Although there is a Canada-wide Action Plan for EPR that was meant to commit all jurisdictions to EPR programs (CCME, 2009), currently such Canada-wide EPR programs do not exist and are lacking in provinces like Nova Scotia (Diggle & Walker, 2021). Similarly, the Zero Plastic Strategy seeks to develop pan-Canadian targets to ensure consistency across the country and improve producer responsibility (Government of Canada, 2020).

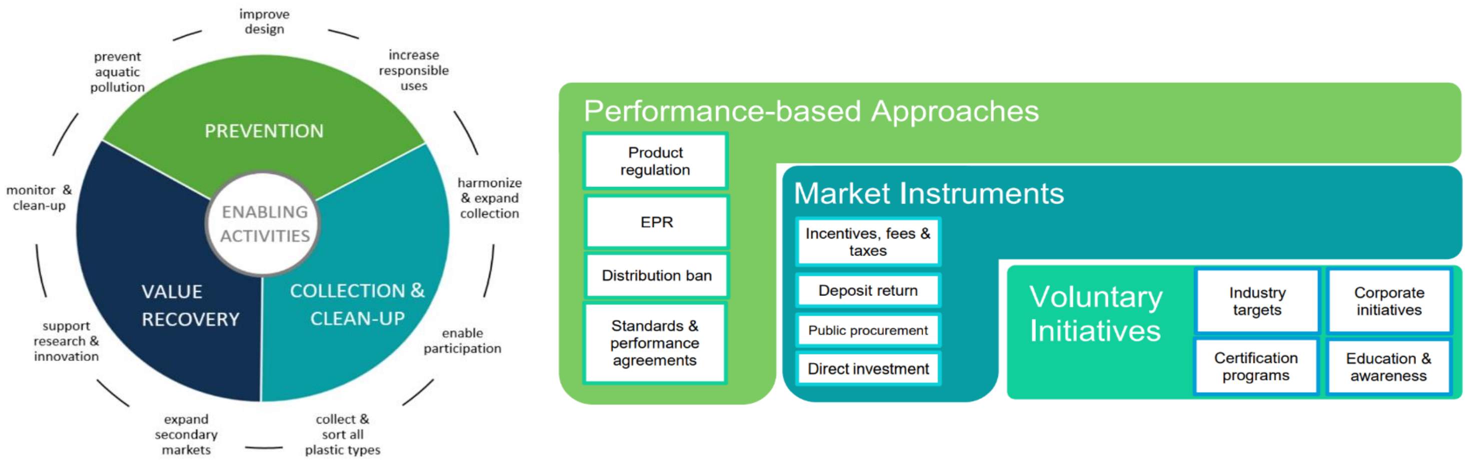

Figure 2: Areas of Action for Canadian Circular Plastic Economy & Potential Instrument Strategies (CCME, 2018).

1.3.2.2 Canada's Plastic Science Agenda

Canada's Plastic Science Agenda identifies research priorities required to adequately understand plastic pollution implications within Canada (Figure 3; ECCC, 2019b; Linnebjerg et al., 2021). Priorities were identified as (ECCC, 2019b):

- Detection, quantification, and characterization of plastics in the environment.
  - Includes: standardizing detection, monitoring, and characterization of sources, pathways, concentrations, and fates of plastics in the environment.
- Impacts on wildlife, human health, and the environment.
- Plastic design and alternatives.
- Sustainable use of plastics.
  - Includes: supporting behaviour changes in industry and consumers.
- Waste diversion and recovery.

Further, a comprehensive Science Assessment of Plastic Pollution was released in October 2020 detailing plastic sources, environmental fates, impacts on environment and human health, transportation of chemicals, and identified critical knowledge gaps (ECCC, 2020c). Knowledge gaps were identified as: lack of standardized methods, poor understanding of microplastics, and lack of monitoring for poorly characterized environments, such as soil (ECCC, 2020c).

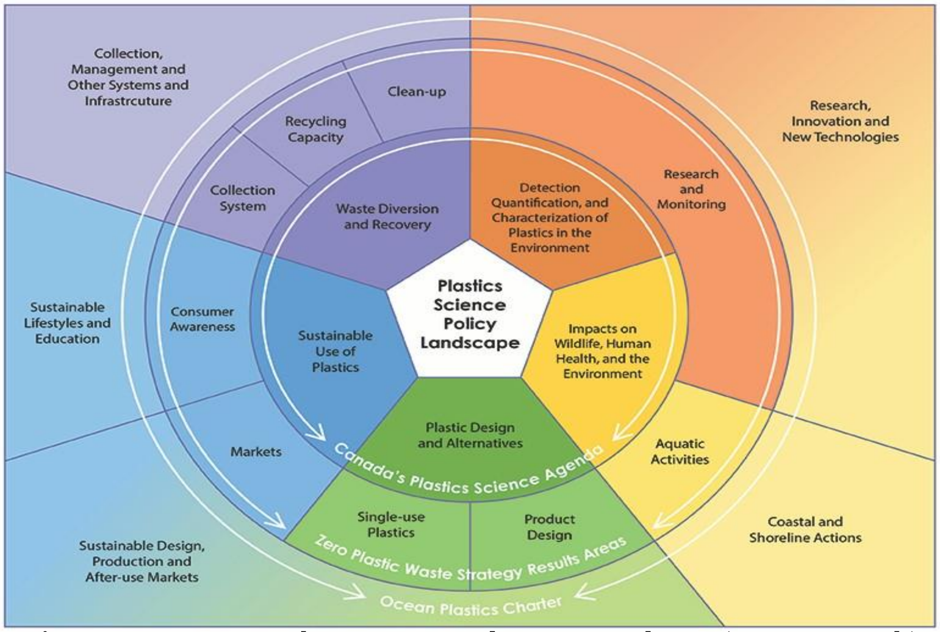

Figure 3: Interaction between Canadian SUP Policies (ECCC, 2019b).

1.3.2.3 Canadian Plastics Pact

The Canadian Plastics Pact is a multi-stakeholder, industry-led initiative to promote a circular plastics economy and combat packaging waste (CPP, 2021). The initiative has four 2025 targets (CPP, 2021):

- Determine plastic packaging that is problematic or unnecessary and eliminate.
- 100% plastic packaging designed to be is reusable, recyclable, or compostable.
- 50% of packaging effectively recycled or composted.
- 30% recycled content across plastic packaging.

Signatories of this Pact include prominent Canadian companies such as Coca-Cola, Kruger, Loblaw Companies Limited, Mondelez, Nestlé, Unilever, and Walmart (CPP, 2021).

1.3.2.4 Proposed SUP Ban

Canada proposed a ban on certain harmful SUPs through adding "plastic manufactured items" under Schedule 1 of the *Canadian Environmental Protection Act (CEPA)* (1999), allowing for increased government regulation (Government of Canada, 2020). On April 23, 2021, 163 plastic items were classified as toxic under CEPA (ECCC, 2019a; Government of Canada, 2021), meeting strong opposition from plastic manufacturers who have since initiated a lawsuit against the federal government (ECCC, 2019a; Government of Canada, 2021; Walker, 2021b). This ban includes six products: plastic checkout bags, stir sticks, six-pack rings, food service ware made from problematic plastics, straws, and cutlery (Government of Canada, 2020; Figure 4). These products were determined through a government review of environmentally problematic products and value-recovery, which included a preliminary list of 28 broad items (ECCC, 2019a). Items were omitted from regulatory measure if they performed an essential function or if no 'viable' alternatives exist to serve the same function (ECCC, 2019a). Management instruments for the remaining materials includes bans, incentives, enhanced recycling requirements, and EPR. Regulations were proposed to come into effect by the end of 2021 (Government of Canada, 2020).

	Management Objective: **Eliminate or reduce from the Canadian market, or restrict use**		***Management Objective:*** **Increase recycling / recovery rate of single-use plastics and packaging**	
	CEPA instruments: *Ban, restrictions in use*	***Instruments:*** *Incentives to encourage reusable products or systems*	***Instruments:*** *Material specifications (for example., recyclable)*	***Instruments:*** *Extended producer responsibility or other collection, recycling requirements*
Environmentally problematic	• Plastic Checkout Bags • Stir sticks • Six-pack rings • Food service ware made from problematic plastics • Straws • Cutlery	• Food service ware	• Hot and cold drink cups and lids	• Beverage bottles and caps • Cigarette filters
Value recovery problematic		• Personal care product bottles • Hot and cold drink cups and lids	• Food wrappers • Other bags (for example., garbage) • Multi-packaging	• Disposable personal care items

Figure 4: Proposed Instruments for Regulating SUPs in Canada (ECCC, 2019a).

1.3.2.5 Canada's Integrated Management Strategy

A number of strategic challenges have been identified, such as lack of end-markets for recycled plastics, low collection rates, insufficient recovery options, and competition between primary and secondary plastics (ECCC, 2019a). To mitigate these identified challenges, an integrated management strategy was proposed which involves elimination of SUPs, enhancing end-markets for recycled materials, improving recovery of plastic products, and innovation of new technologies (ECCC, 2019a). Instruments to implement the integrated approach include establishing performance standards, managing SUPs, adopting a target of greater than 50% recycled content in plastic products by 2030, and ensuring end-of-life responsibility through EPR (ECCC, 2019a). Further, elimination of SUPs in the food industry are expected to be met with barriers, such as sourcing alternatives, costs, knowledge gaps, and food safety regulations (Varkey et al., 2021). The integrated management strategy must seek to work with businesses and citizens to better overcome these projected barriers to both ensure smoother transitions to SUP reduction and develop improved community education on barrier solutions.

1.3.2.6 Public Perceptions

As examined previously, public awareness and support for policies are imperative for success. A recent Canada-wide survey evaluated consumer willingness to reduce SUP waste and to pay premiums for sustainable food packaging alternatives (Walker et al., 2021). In 2019, 93.7% of Canadian respondents indicated motivation to reduce SUPs and 91.1% of respondents felt that SUP food packaging regulations should be strengthen (Walker et al., 2021). For the Atlantic Canada plastic bag ban, 77% of respondents supported the measure, and 75% supported additional legislation measures to reduce SUPs (Molloy, 2020). Both studies support the notion that Canadians largely perceive SUP legislation as important and desirable, indicating a positive political environment for implementation of additional SUP regulations.

2. Research Context

2.1 Regional Context

2.1.1 Vancouver

Vancouver is a coastal metropolis on mainland British Columbia encircled by English Bay and Burrard Inlet to the north and the Fraser River to the south (Vancouver, 2021; Figure 5). Vancouver is shielded from the Pacific Ocean by Vancouver Island located across the Strait of Georgia (Vancouver, 2021). Vancouver is the largest city in British Columbia with a population of 631,486 (c.2016), also making it the eighth largest municipality in Canada (Vancouver, 2021).

In 2014, British Columbia developed the first full EPR program in Canada where obligate stewards are fully responsible for the funding and operation of provincial recycling programs (Recycle BC, 2019; Diggle & Walker, 2020). The Recycle BC EPR program consistently recovers over 75% of packaging and paper products sold annually in British Columbia (Harris et al., 2021), having the highest recycling rate in Canada (69%), while also processing products, such as shopping bags, that generally are not recycled elsewhere in the country (Global News, 2019; Little, 2020). Further, bottle deposit schemes have also existed in British Columbia since 2004 (BC, 2020). Currently, a 10-cent minimum deposit on all beverage containers exists in this region (BC, 2020). Additionally, Vancouver is implementing a phased ban on various SUPs: foam cups/containers (January 2020-ban), straws (April 2020-ban), plastic utensils (August 2020-only available by request), disposable cups (January 2022-fee), and bags (January 2022-ban and fee for alternatives) (Vancouver, 2020). It is worth noting, however, that none of these SUP bans were in place at the time of data collection for this study.

Figure 5: Vancouver. City boundaries depicted in red outline. Developed using ArcGIS.

2.1.2 Toronto

Toronto is located on the northwest shore of Lake Ontario and with a population of 2,956,024 (c.2018), is Canada's largest city (Toronto, 2021; Figure 6). Lake Ontario serves as a collection basin for the Great Lakes and via the Great Lakes-St. Lawrence River System, water from Lake Ontario flows through the St. Lawrence River to the Atlantic Ocean (DFO, 2019).

Ontario has Canada's oldest EPR program (developed in 2005) and currently exists as a shared program between industry and government (Stewardship Ontario, 2018; Diggle & Walker, 2021). However, Ontario's Minister of the Environment has committed to transitioning the Blue Box Program into a full EPR model through the 'Made-in Ontario Environment Plan' by 2023, although some delays in regulation development have already occurred (Ontario, 2019; McGillivray & Rieti, 2021; Ontario, 2021). The current program maintains recycling target of 60% and 94% of Ontario households have access to this recycling program, serving an estimated population of over 13 million individuals (Stewardship Ontario, 2019). Currently, the only bottle deposit program in Ontario operates solely for deposits on alcoholic beverage containers (Ontario, 2016). In terms of SUPs, a voluntary initiative launched through the Ontario Plastic Bag Reduction Task Group in 2007 aiming to reduce plastic bags by 50% over five years; as part of this voluntary initiative, some retailers began imposing bag fees (Sobeys, 2009). In Toronto specifically, a plastic carry-out bag fee was introduced in 2009, however, the program was rescinded in 2012 (Toronto, 2012). Although no formal legislation exists to regulate SUPs in Ontario, *Bill 82 Single-use Plastic Bag Act* was introduced in 2019 with the goal of producing timelines for the reduction and elimination of SUPs (Legislative Assembly of Ontario, 2019); the specific implications of this Bill, and potential SUP regulation strategies, are not clear.

Figure 6: Toronto. City boundaries depicted via red outline. Developed using ArcGIS.

2.1.3 Montréal

Montréal is located in southwestern Québec on Île de Montréal, at the junction of the St. Lawrence and Ottawa Rivers (Linteau, 2019; Figure 7). Montréal is ultimately connected to the ocean through the St. Lawrence River which empties into the Atlantic Ocean (DFO, 2019). With a population of 1,704,694 (c. 2016), Montréal is Canada's second largest city (Linteau, 2019).

Developed in 2005, Québec's EPR program is operated through Éco Entreprises Québec (ÉEQ) (ÉEQ, 2019). Producers finance 100% of the recycling operation: 55% funded by retailers, distributors and first importers; 33% by product manufactures; 8% by providers of general services; and 3% by manufactures of durable goods (ÉEQ, 2019; Diggle & Walker, 2021). ÉEQ collects producer payments and provides them to RECYC-QUÉBEC, who redistribute the funds to municipalities for waste collection (ÉEQ, 2020). The program expects to fully shift control of waste management to companies by 2025, with the ultimate goal of creating a circular economy where 100% of recyclables are recovered (ÉEQ, 2020; ÉEQ, 2021). Further, Québec has a bottle deposit program, run by RECYC-QUÉBEC, that requires deposits on nonrefillable beer and soft drink containers (Container Recycling Institute, 2021). Further, in January 2020, it was announced that the bottle deposit program would expand to include all glass, plastic, and metal beverage containers between 100mL to 2L; this is expected to begin in Fall 2022 (Container Recycling Institute, 2021). In terms of SUP bans, Montréal has prohibited the distribution of certain retail shopping bags since 2018 (Montréal, 2016). These regulations are expected to be strengthened between 2020-2025 to further eliminate other types of SUP bags (Montréal, 2021).

Figure 7: Montréal. City boundaries depicted via red outline. Developed using ArcGIS.

2.1.4 Halifax

Halifax is located on the eastern coast of Canada on the Atlantic Ocean (Halifax, 2021; Figure 8). The Halifax Regional Municipality (HRM) consists of four former municipalities: Dartmouth, Halifax, Halifax County, and Bedford (Halifax, 2021). HRM is the largest metropolitan area east of Montréal, with a population of 403,131 (c.2016) (Statistics Canada, 2016; Discover Halifax, 2021).

Nova Scotia has been committed to lowering provincial disposal rates through the *Environmental Goals and Sustainable Prosperity Act* and overall Nova Scotians send 45% less waste to landfills, as compared to other Canadian provinces (Oakley et al., 2008). However, Nova Scotia does not currently operate an EPR program, and waste management is fully financed and operated by the province without industry support (EPR Canada, 2017; Diggle & Walker, 2020). Since 1996, Nova Scotia has operated a bottle deposit program that includes all beverage containers except for milk containers and is run by the Resource Recovery Fund Board (Oakley et al., 2008; NSE, 2014; Diggle & Walker, 2020). The bottle deposit program has demonstrated a direct connection to reducing beverage litter in the province (Diggle & Walker, 2020). Recently, in October 2020, Nova Scotia banned the distribution and use of SUP checkout bags under *Bill No. 152: Plastic Bags Reduction Act* (NS Legislature, 2019; Nova Scotia, 2020). It is worth noting that the plastic checkout bag ban was not in place at the time of data collection for this study.

Figure 8: Halifax Regional Municipality. City boundaries depicted via red outline including Sable Island (bottom right). Developed using ArcGIS.

2.1.5 Sable Island

Sable Island is located approximated 290 km southeast of Halifax at the edge of the continental shelf in the Atlantic Ocean (Parks Canada, 2021; Figure 9). The island is 42 km long and 1.5 km wide, designated a National Park Reserve in 2013 (Lucas, 1992; Discover Halifax, 2017; Parks Canada, 2021). The only long-term inhabitants of Sable Island are Parks Canada Staff, and occasionally researchers and non-government organizations; otherwise, only day visitation is permitted (Parks Canada, 2021). Sable Island is part of HRM (Discover Halifax, 2017). Due to its remoteness and lack of inhabitants, marine debris is expected to originate from distanced sources, with the waters surrounding the island derived from the inshore branch of the Labrador Current, outflow of the Gulf of St. Lawrence, and slope water from offshore (Lucas, 1992).

Figure 9: Sable Island. Island depicted via red outline. Developed using ArcGIS.

2.2 Management Problem & Objectives

Marine debris remains a pervasive challenge within aquatic ecosystems. This research seeks to further delineate SUP usage across Canada and inform recommendations for improved SUP management. Understanding the prevalent producers responsible for SUPs in Canada, through analysis of brand audit data, will help to inform management approaches to reduce SUPs, thereby mitigating marine debris. Through examining various urban centers, the objective is to determine SUP homo- or heterogeneity across the country, to critically analyze government-proposed reduction measures, such as the federal SUP ban, and provide recommendations. Additionally, through examination of Sable Island, transboundary sources of marine debris may be elucidated. Overall, this research aims to achieve the following objectives:

1. Identify trends and discrepancies between study regions using SUP brand audit and shoreline cleanup data.
2. Compare urban findings to transboundary and global data to elucidate commonalities and identify prevalent polluters.
3. Evaluate the effectiveness of current SUP migration measures, such as regional bans and EPR.
4. Critically analyze proposed federal SUP reduction strategies and provide recommendations for policy improvement.

3. Methodology

3.1 Data Sources

Data used in this study were obtained from three sources: Greenpeace, Great Canadian Shoreline Cleanup, and Sable Island Institute.

3.1.1 Greenpeace Brand Audit

Greenpeace (GP) litter brand audits began in 2018 and use citizen scientists to collect and document litter from greenspaces in urban centres across Canada. In 2019, ~400 individuals participated in collecting data for nine Canadian locations: collection occurred from April to September 2019 (King, 2019). GP partners with local organizations and volunteer members to implement this program (King, 2019). Volunteers were asked to organize cleanup events and collect, sort, categorize, and record litter into the categories of brand, product description (i.e. bottle), number of items collected, product use (i.e. food, smoking material), and type of plastic (i.e. PET). No scientific collection methods, such as transects, appear to be employed. This research used 2019 brand audit data for Vancouver, Toronto, Montréal, and Halifax.

3.1.2 Great Canadian Shoreline Cleanup

The Great Canadian Shoreline Cleanup (GCSC) began in 1994 in British Columbia and has since grown into a national initiative in partnership with WWF-Canada and Ocean Wise — it is one of the largest direct action conservation programs in Canada (GCSC, 2021). GCSC uses a tally/count method for documenting litter similar to the International Coastal Cleanup: this data collection method does not control for length of beach cleaned or number of participants (Harris et al., 2021). Participants are given a data sheet to record litter characteristics including item type (i.e. wrapper, straw), quantity, and weight (GCSC, 2019). Over the course of this initiative, more than 2 million kg of trash have been collected and documented (GCSC, 2021), and GCSC data have been used in various scientific publications (Driedger et al., 2015; Pettipas et al., 2016; Damian & Fraser, 2020; Harris et al., 2021). This study utilized the 2019 GCSC data for Vancouver, Toronto, Montréal, and Halifax. In 2019, 3,012 cleanups were hosted involving 3,937 km of cleaned beaches and 83,815 volunteers (GCSC, 2019).

3.1.3 Sable Island Institute

The Sable Island Institute (SII) collects and documents litter on the shores of Sable Island. In 2019, 17 litter collection surveys were completed (9 on the north beach and 8 on the south beach), approximately every 2-3 weeks between May 17 and October 4 (Z. Lucas, personal communication, April 16, 2021). The south beach is a total of 32 linear kms and north beach is a total of 30 linear kms: the area was searched from the waterline to the upper extent of storm waves (Z. Lucas, personal communication, April 30, 2021). The SII methodology was a more selective brand audit methodology than GP, where only items with complete label information were collected (Z. Lucas, personal communication, October 18, 2021). As a result, items such as cutlery and bottle caps, although present, were not documented through this methodology (Z. Lucas, personal communication, October 18, 2021). Documented categories include: product description (i.e. bottle, package), plastic code, brand and parent company, country of origin, and country of distribution. This study utilized the 2019 brand audit data for Sable Island.

3.2 Data Treatment

Data collected in 2019 were compiled for each study region—every effort was made to group subsidiaries under their parent company. For example, Frito-Lay is a subsidiary of PepsiCo, and for the purposes of this study would be classified as PepsiCo. This approach allows for a more thorough understanding of producer's impact on pollution, which could be obscured if subsidiaries were considered separate entities. Top polluters (based on litter quantity) were visualized using Excel for each region, including separate analysis of the categories: cups and lids, wrappers, plastic bottles, and bottle caps. For this visualization, the top five brands for each category were included, with remaining brands compiled into the 'other' category. The 'unknown' category represents litter in which participants could not identify the brand, often because of environmental degradation. Comparative figures were created using Excel to more directly depict similarities and differences between study locations for both litter type and brand proportions. Statistical significance was tested using the Chi-Square Test of Independence ($\chi^2 = \Sigma \frac{(O-E)^2}{E}$) via R statistical software. Multiple significant tests were conducted between various study locations for litter type and brands (full list of conducted Chi-Square Tests: Appendix I). P-values less than 0.05 were considered significant.

4. Results

Data analysis included comparison of litter types and top brands for each geographic location (Vancouver, Toronto, Montréal, Halifax, and Sable Island). Brands were further analysed for specific litter categories: cups and lids, plastic bottles, bottle caps, and wrappers. The litter category-specific brand data were not always sufficient, and therefore some categories were not presented for certain locations. For each urban location (Vancouver, Toronto, Montréal, and Halifax), litter types were compiled using the GCSC dataset, as it contained larger sample sizes and was more comprehensive than the GP dataset for this variable. Brand audit data for urban locations were compiled from the GP data. For Sable Island, both litter type and brand audit data were obtained from the SII dataset. Statistical analysis using R statistics software were completed for litter type and top brand audit comparisons (see Appendix I for individual p-values).

4.1 Litter Proportions

4.1.1 Vancouver

Litter proportions were obtained from GCSC. This analysis excludes GCSC's 'Tiny Plastic & Foam' and 'Fishing Net/Line' categories to better align with the GP categories and research objectives. Further, 'Other' includes the 'Six-pack', 'Balloons', 'Hygiene', and 'Toys' categories from the original GCSC dataset; this compilation was completed to better align with the GP dataset. Litter categories having the highest count include wrappers (13,700), bottle caps (7,933), and other (6,002). An estimated 5,833 participants were involved in this data collection. Statistical analyses were conducted between Vancouver and other locations. In all instances, p-values were significant ($p<0.05$), indicating that litter category proportions are dependent on geographic location. Litter category proportions for Vancouver are shown in Figure 10.

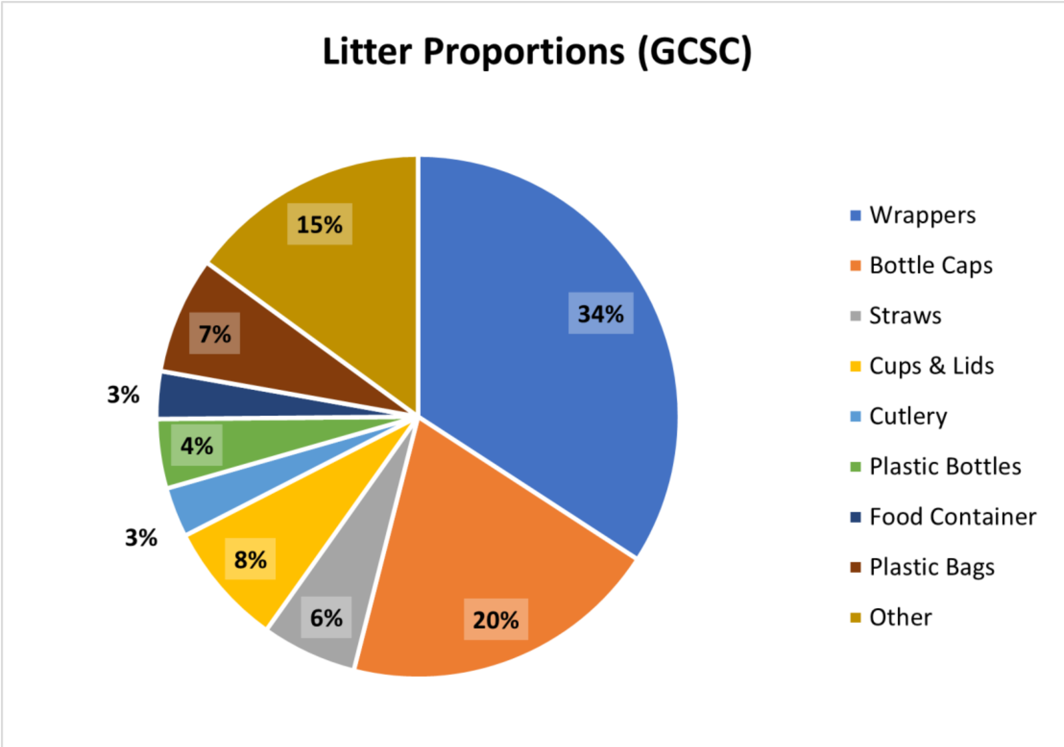

Figure 10: Vancouver Litter Proportions. Depiction of litter category proportions collected by GCSC in 2019 for Vancouver. (n=40,094).

4.1.2 Toronto

Litter proportions were obtained from GCSC. This analysis excludes 'Tiny Plastic & Foam' and 'Fishing Net/Line' categories to better align with the GP categories and research objectives. Further, 'Other' includes the 'Six-pack', 'Balloons', 'Hygiene', and 'Toys' categories from the original GCSC dataset; this compilation was completed to better align with the GP dataset. Litter categories having the highest count include bottle caps (15,703), wrappers (10,802), and other (6,748). An estimated 3,826 participants were involved in this data collection. Statistical analyses were conducted between Toronto and other locations. In all instances, p-values were significant ($p<0.05$), indicating that litter category proportions are dependent on geographic location. Litter category proportions for Toronto are shown in Figure 11.

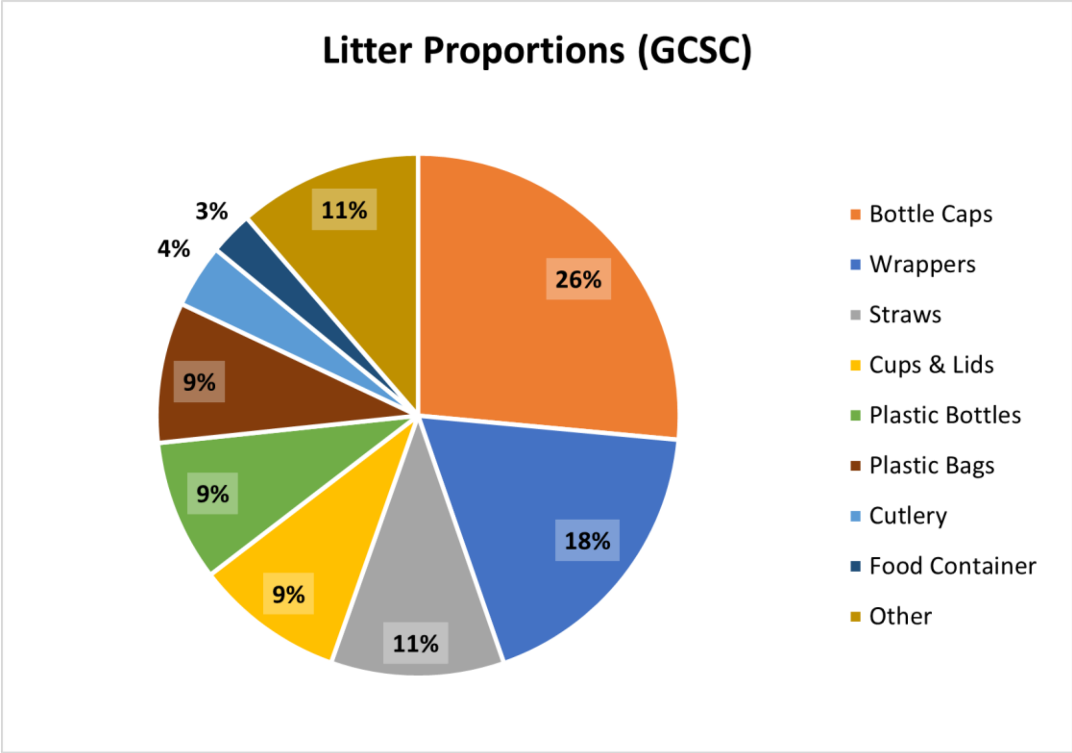

Figure 11: Toronto Litter Proportions. Depiction of litter category proportions collected by GCSC in 2019 for Toronto. (n=59,322).

4.1.3 Montréal

Litter proportions were obtained from GCSC. This analysis excludes 'Tiny Plastic & Foam' and 'Fishing Net/Line' categories to better align with the GP categories and research objectives. Further, 'Other' includes the 'Six-pack', 'Balloons', 'Hygiene', and 'Toys' categories from the original GCSC dataset; this compilation was completed to better align with the GP dataset. Litter categories having the highest count include wrappers (1,022), bottle caps (791), and plastic bottles (679). An estimated 214 participants were involved in this data collection. Statistical analyses were conducted between Montréal and other locations. In all instances, p-values were significant ($p<0.05$), indicating that litter category proportions are dependent on geographic location. Litter category proportions for Montréal are shown in Figure 12.

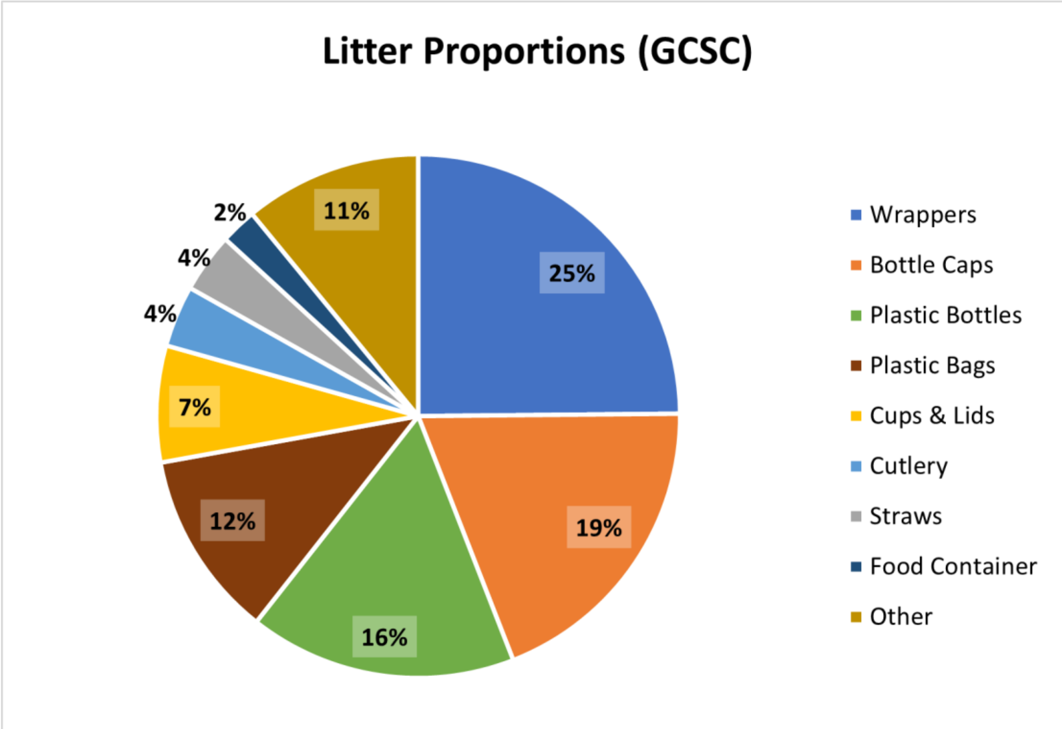

Figure 12: Montréal Litter Proportions. Depiction of litter category proportions collected by GCSC in 2019 for Montréal. (n=4,112).

4.1.4 Halifax

Litter proportions were obtained from GCSC. This analysis excludes 'Tiny Plastic & Foam' and 'Fishing Net/Line' categories to better align with the GP categories and research objectives. Further, 'Other' includes 'Six-pack', 'Balloons', 'Hygiene', and 'Toys' categories from the original GCSC dataset; this compilation was completed to better align with the GP dataset. Litter categories having the highest count include wrappers (1,010), other (858), and bottle caps (563). An estimated 690 participants were involved in this data collection. Statistical analyses were conducted between Halifax and other locations. In all instances, p-values were significant ($p<0.05$), indicating that litter category proportions are dependent on geographic location. Litter category proportions for Halifax are shown in Figure 13.

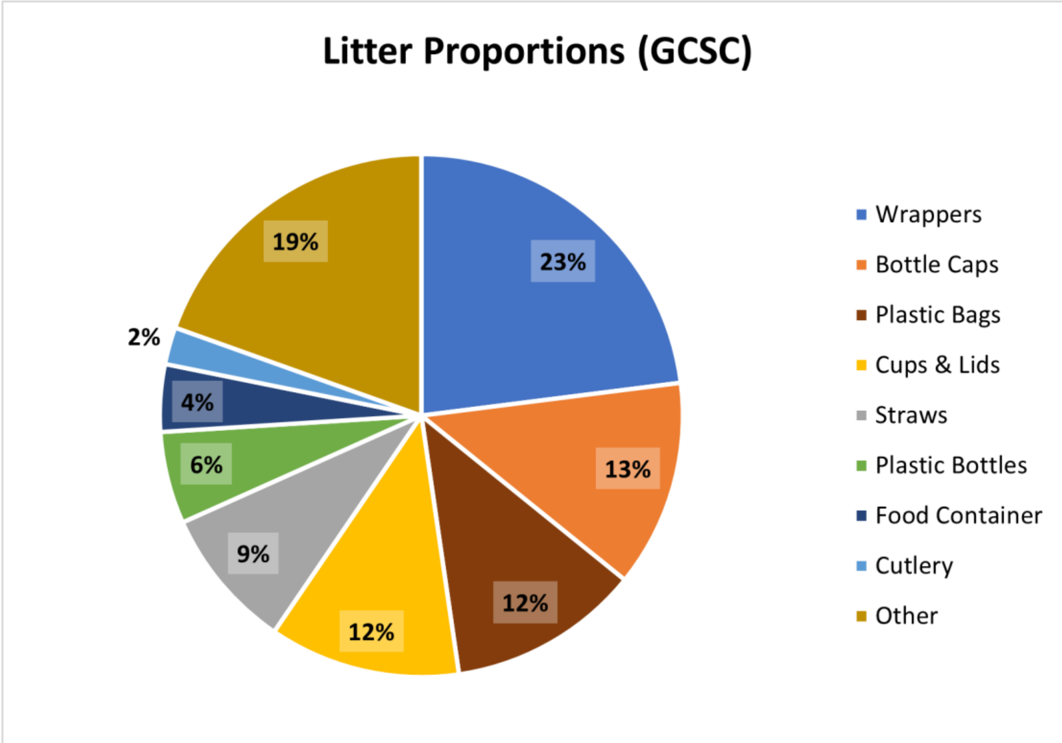

Figure 13: Halifax Litter Proportions. Depiction of litter category proportions collected by GCSC in 2019 for Halifax. (n=4,392).

4.1.5 Sable Island

Litter proportions were obtained from SII. As SII used a brand audit methodology, litter categories are reflective of branded litter, not total litter proportions on Sable Island. Some original SII litter categories were combined to better align with the GCSC and GP datasets: 'Food Containers' includes non-wrapper food packaging, cartons, jugs, k-cups, and tubs/tubes; and 'Other' includes non-food containers (e.g., aerosols, automotive/chemical containers), and plastic labels. Litter categories having the highest count include plastic bottles (262), other (138), and food containers (107). An estimated 1-2 participants were involved in this data collection. Statistical analyses were conducted between Sable Island and other locations. In all instances, p-values were significant ($p<0.05$), indicating that litter category proportions are dependent on geographic location. Litter category proportions for Sable Island are shown in Figure 14.

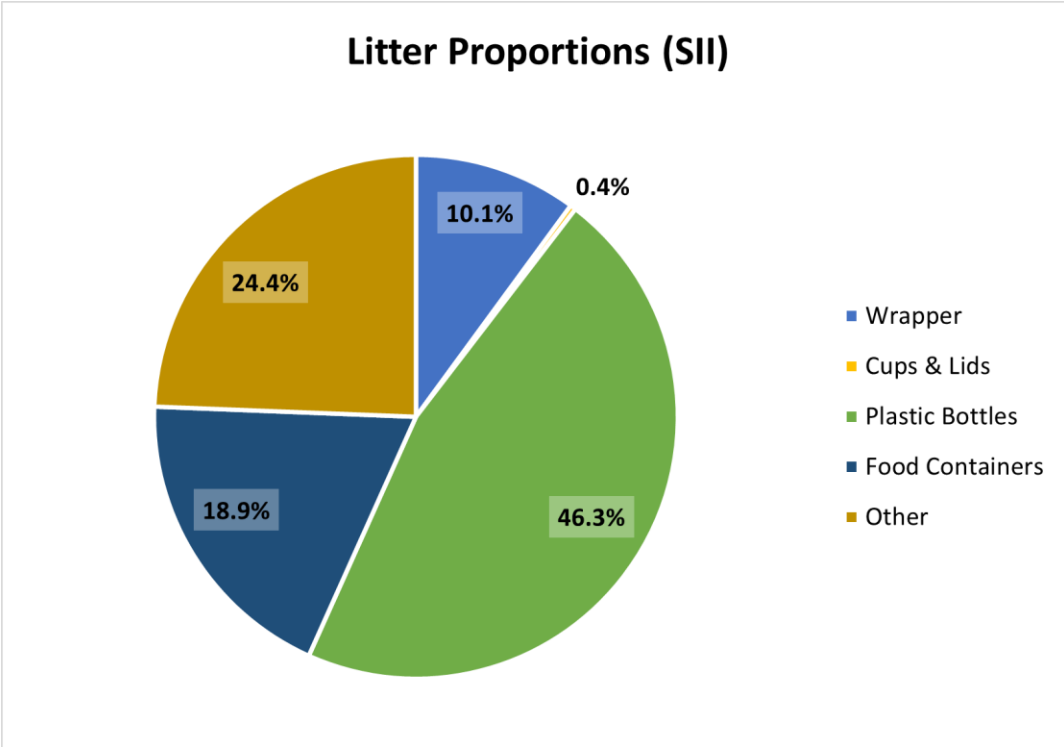

Figure 14: Sable Island Branded Litter Proportions. Depiction of branded litter category proportions collected by SII in 2019 for Sable Island. (n=566).

4.1.6 Cumulative Figure

Litter proportions presented for each region were compiled to allow for better qualitative comparison. Proportions are shown in a stacked bar graph. Statistical analyses of all locations and litter category proportions were conducted. P-values were significant ($p<0.05$), indicating that litter category proportions are dependent on geographic location. Qualitatively, urban locations appear to have more similar distribution of litter types, with Sable Island having larger proportions of plastic bottles and food containers. Cumulative litter category proportions for all locations are shown in Figure 15.

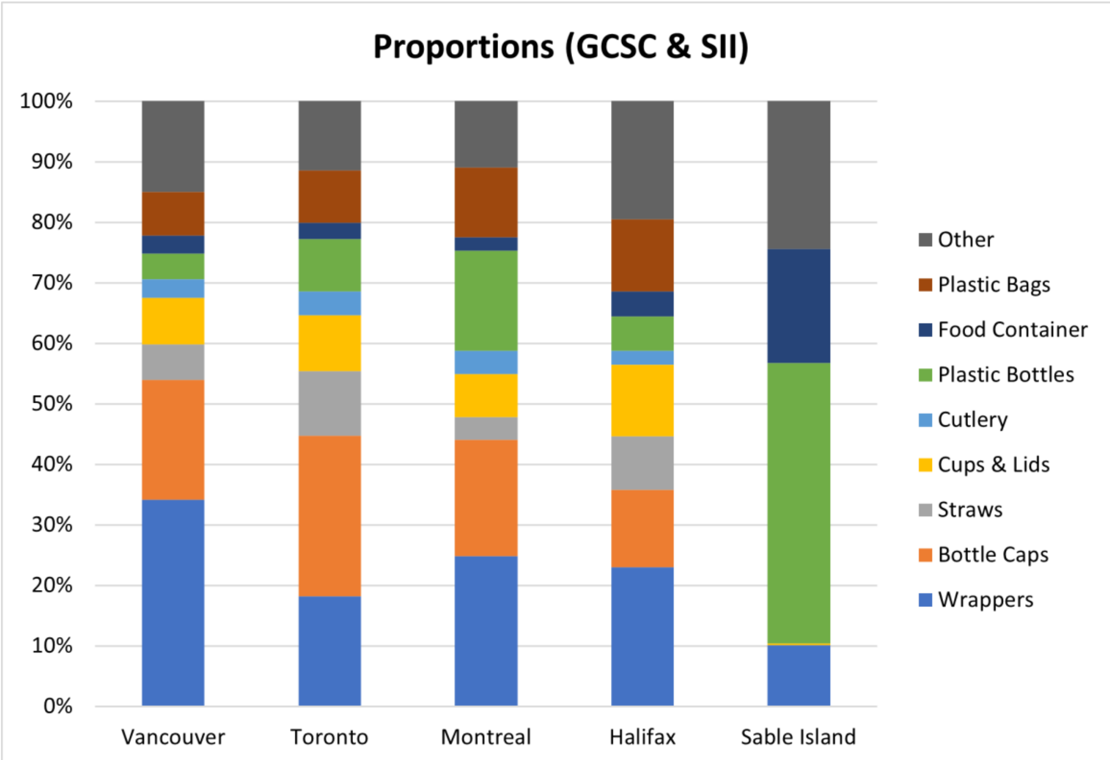

Figure 15: Litter Proportions for all locations. Stacked bar graph shows litter category proportions collected by GCSC and SII in 2019 for all study locations.

4.2 Top Brands

Disclaimer: some sample sizes were low for brand audit data. In some instances, p-value approximations may be inaccurate as expected counts are very small, limiting the power of the approximation. All p-values, with limitations, are outlined in Appendix I.

4.2.1 Vancouver

Top brands were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Frito-Lay classified as PepsiCo). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation. 'Other' encompasses litter that were branded, but not part of the top five brands by quantity. Top brands include Nestlé (144), Starbucks (107), and Coca-Cola (41). An estimated 306 participants were involved in this data collection. Statistical analyses were conducted between Vancouver and other locations. In all instances, p-values were significant, indicating that brand proportions are dependent on geographic location. Top litter brands for Vancouver are shown in Figure 16.

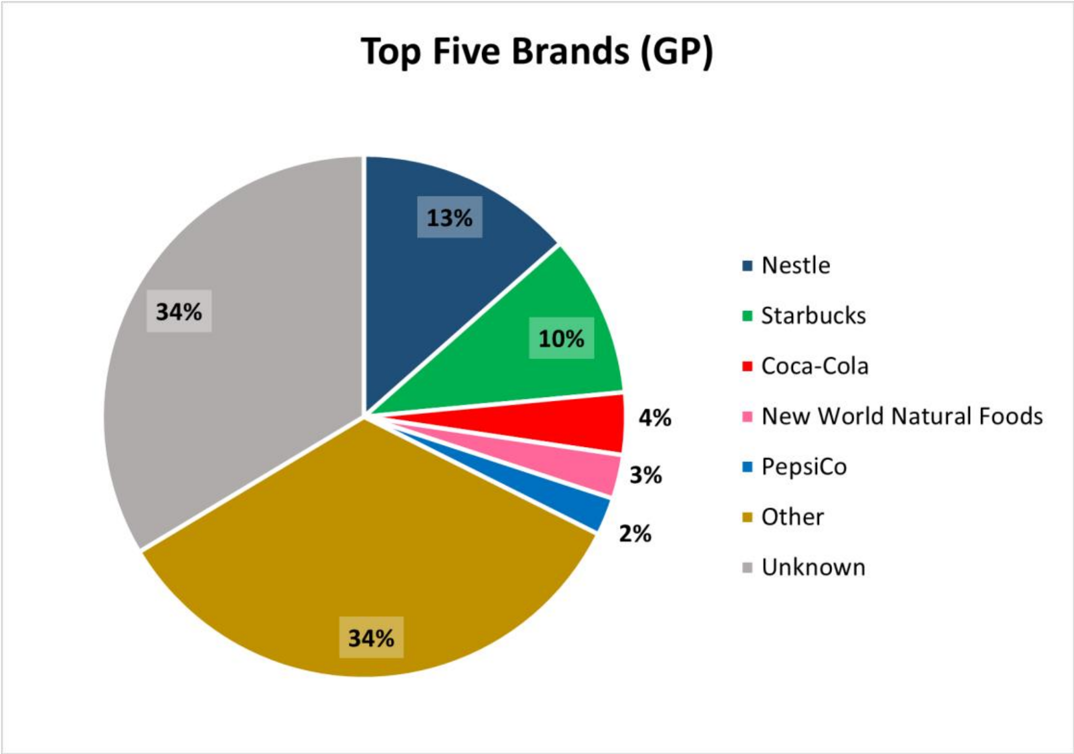

Figure 16: Vancouver Top Five Brands. Depiction of top brands (by quantity) collected by GP in 2019 for Vancouver. (n=1,068).

4.2.2 Toronto

Top brands were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Frito-Lay classified as PepsiCo). ‘Other’ encompasses litter that were branded, but not part of the top five brands by quantity. Top brands include Tim Horton’s (10), Coca-Cola (6), and Nestlé (5). An estimated 14 participants were involved in this data collection. Toronto’s GP sample sizes were small, limiting the ability to calculate reliable statistics or draw representative conclusions. Statistical analyses were conducted between Toronto and other locations. In all instances, p-values were significant, indicating that brand proportions are dependent on geographic location. Top litter brands for Toronto that were clearly identified are shown in Figure 17.

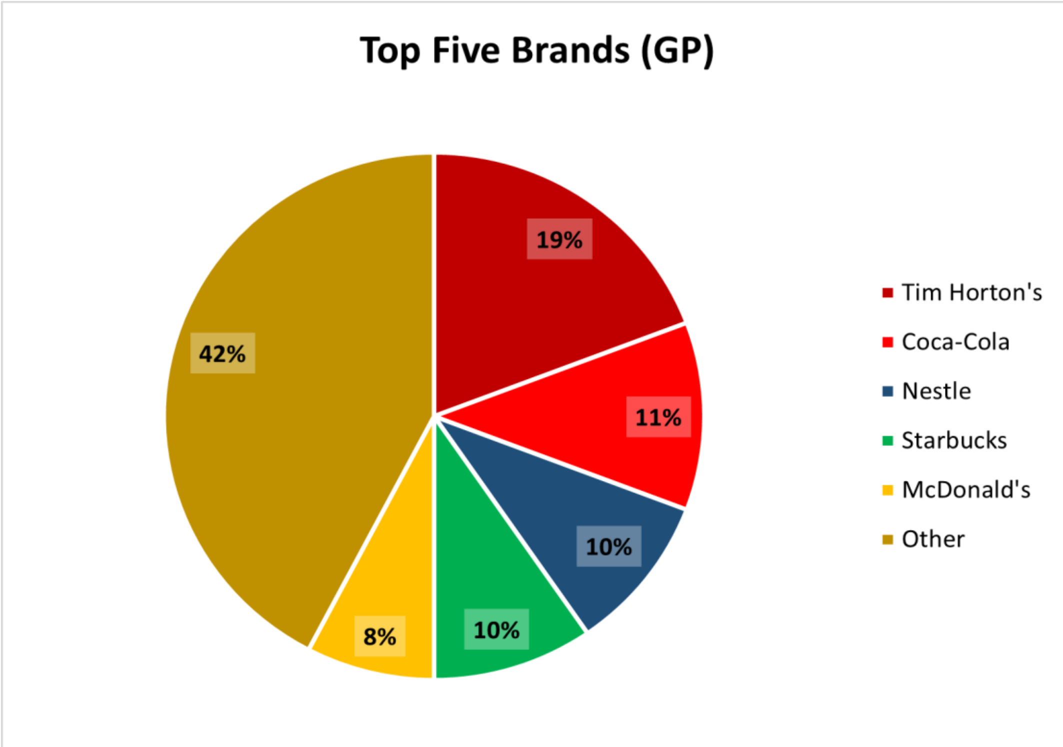

Figure 17: Toronto Top Five Brands. Depiction of top brands (by quantity) collected by GP in 2019 for Toronto. (n=52).

4.2.3 Montréal

Top brands were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Frito-Lay classified as PepsiCo). ‘Unknown’ indicates that the brand information could not be identified, often due to environmental degradation. ‘Other’ encompasses litter that were branded, but not part of the top six brands by quantity. Top brands include Tim Horton’s (89), McDonald’s (39), and Naya (28). An estimated 10 participants were involved in this data collection. Proportion of unknown brands were fairly high for this region (~68%), limiting the ability to fully draw representative conclusions. Statistical analyses were conducted between Montréal and other locations. In all instances, p-values were significant, indicating that brand proportions are dependent on geographic location. Six brands are shown for Montréal’s top brands, as Eska, Nestlé, and PepsiCo all had 20 collected litter items. Top litter brands for Montréal that were clearly identified are shown in Figure 18.

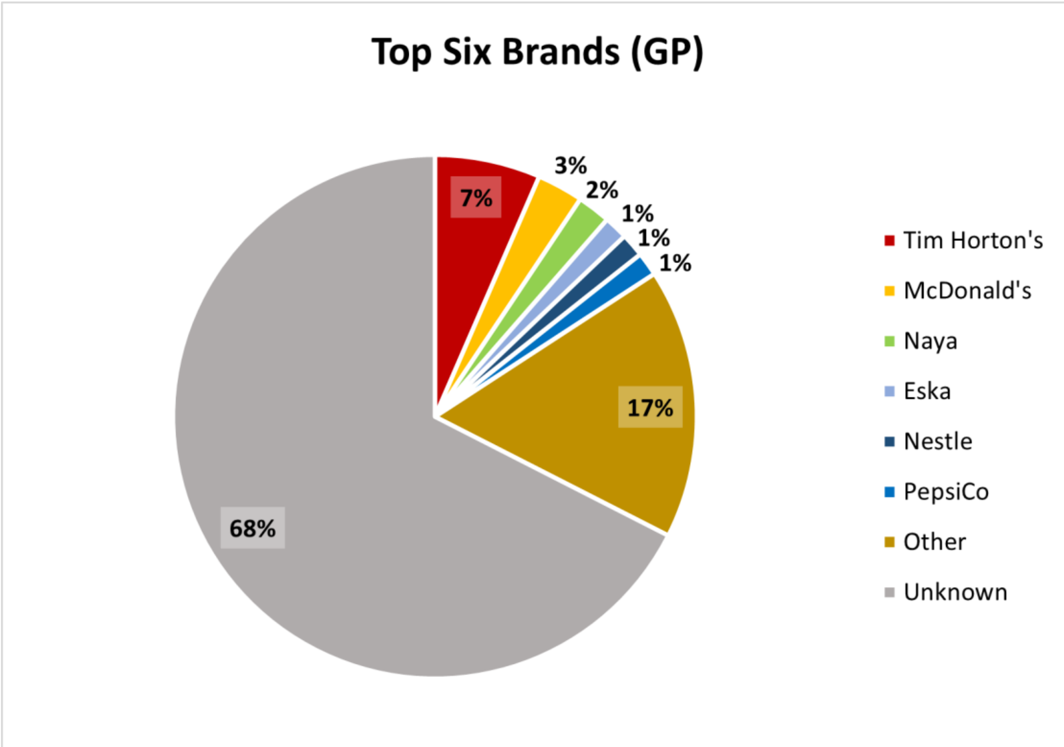

Figure 18: Montréal Top Six Brands. Depiction of top brands (by quantity) collected by GP in 2019 for Montréal. (n=1366).

4.2.4 Halifax

Top brands were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Frito-Lay classified as PepsiCo). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation. 'Other' encompasses litter that were branded, but not part of the top five brands by quantity. Top brands include PepsiCo (11), Tim Horton's (9), and Nestlé (5). An estimated 5-10 participants were involved in this data collection. Proportion of unknown brands were very high for this region (~94%), limiting the ability to fully draw representative conclusions. Statistical analyses were conducted between Halifax and other locations. In all instances, p-values were significant, indicating that brand proportions are dependent on geographic location. Top litter brands for Halifax that were clearly identified are shown in Figure 19.

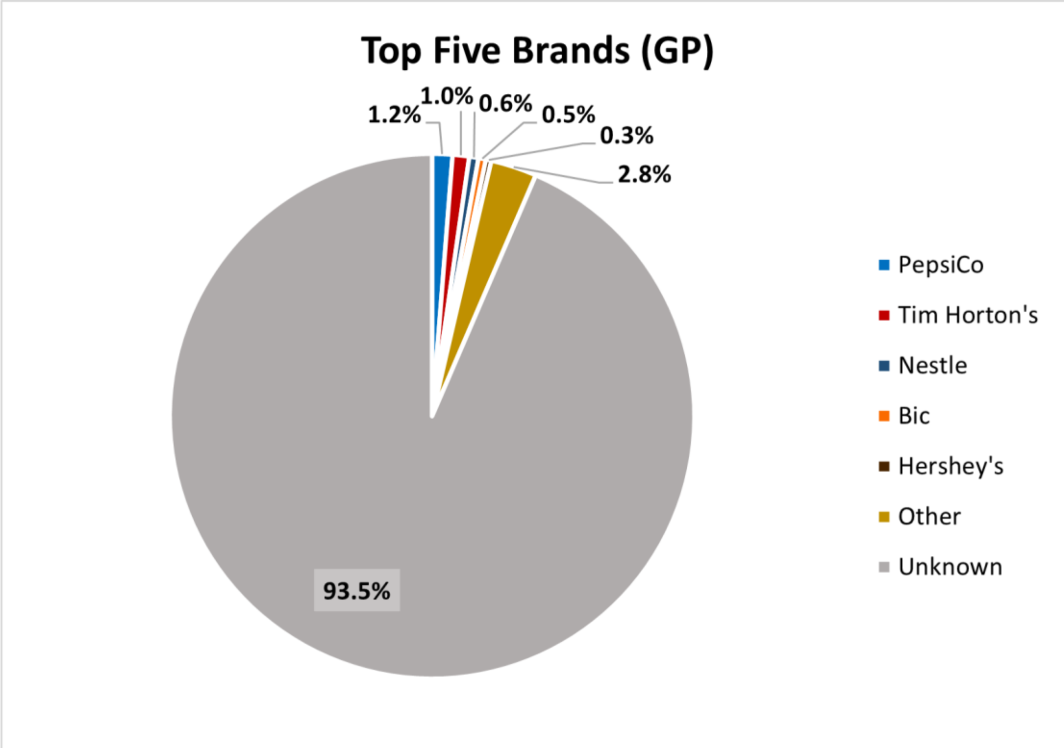

Figure 19: Halifax Top Five Brands. Depiction of top brands (by quantity) collected by GP in 2019 for Halifax. (n=881).

4.2.5 Sable Island

Top brands were obtained from SII. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Frito-Lay classified as PepsiCo). SII brand auditing only collected litter with discernible brand labeling, so no 'Unknown' category is present. 'Other' encompasses litter that were branded, but not part of the top five brands by quantity. Top brands include PepsiCo (85), Sobeys (82), and Coca-Cola (26). An estimated 1-2 participants were involved in this data collection. Statistical analyses were conducted between Sable Island and other locations. In all instances, p-values were significant, indicating that brand proportions are dependent on geographic location. Top litter brands for Sable Island that were clearly identified are shown in Figure 20.

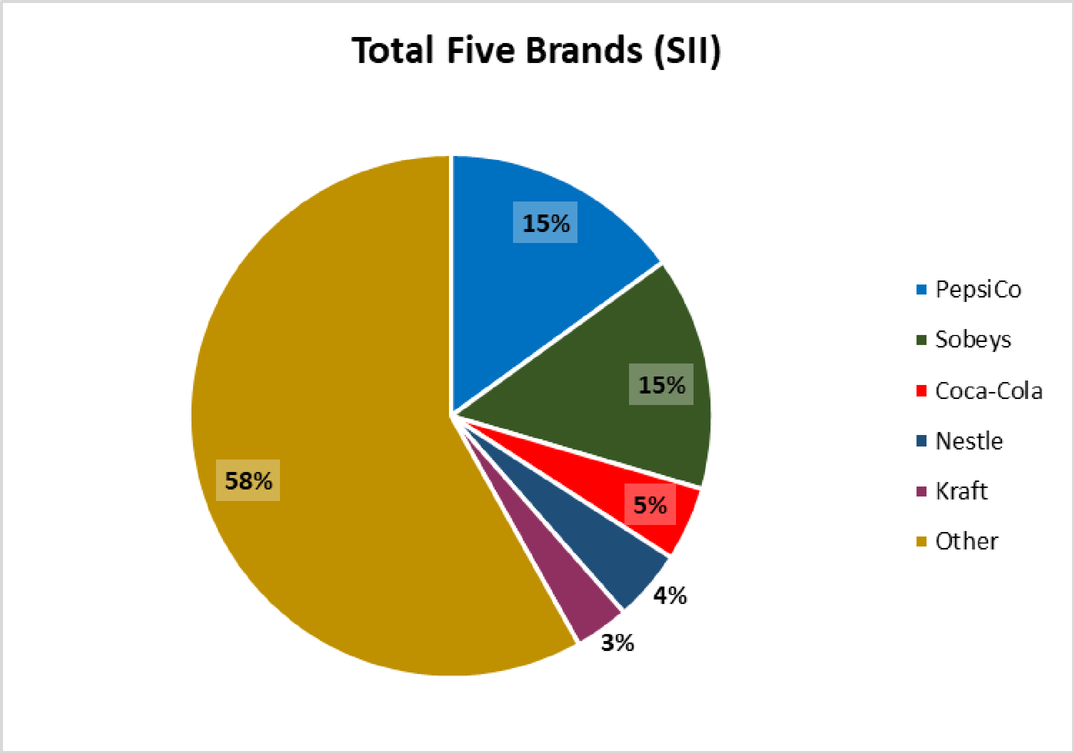

Figure 20: Sable Island Top Five Brands. Depiction of top brands (by quantity) collected by SII in 2019 for Sable Island. (n=566).

4.2.6 Cumulative Figure

Top brands for each region were compiled to allow for better qualitative comparison. Proportions are shown in a stacked bar graph. Statistical analyses of all locations and litter category proportions were conducted. P-values were significant indicating that brand proportions are dependent on geographic location. Nestlé is a top brand in all studied locations. PepsiCo is a top brand in 4 out of 5 studied locations. Coca-Cola, and Tim Horton's are found in 3 out of 5 studied locations. Starbucks, and McDonald's are found in 2 out of 5 studied locations. Unknown and Other categories are excluded to allow for easier comparison between the top litter brands. Cumulative top litter brands for all locations are shown in Figure 21.

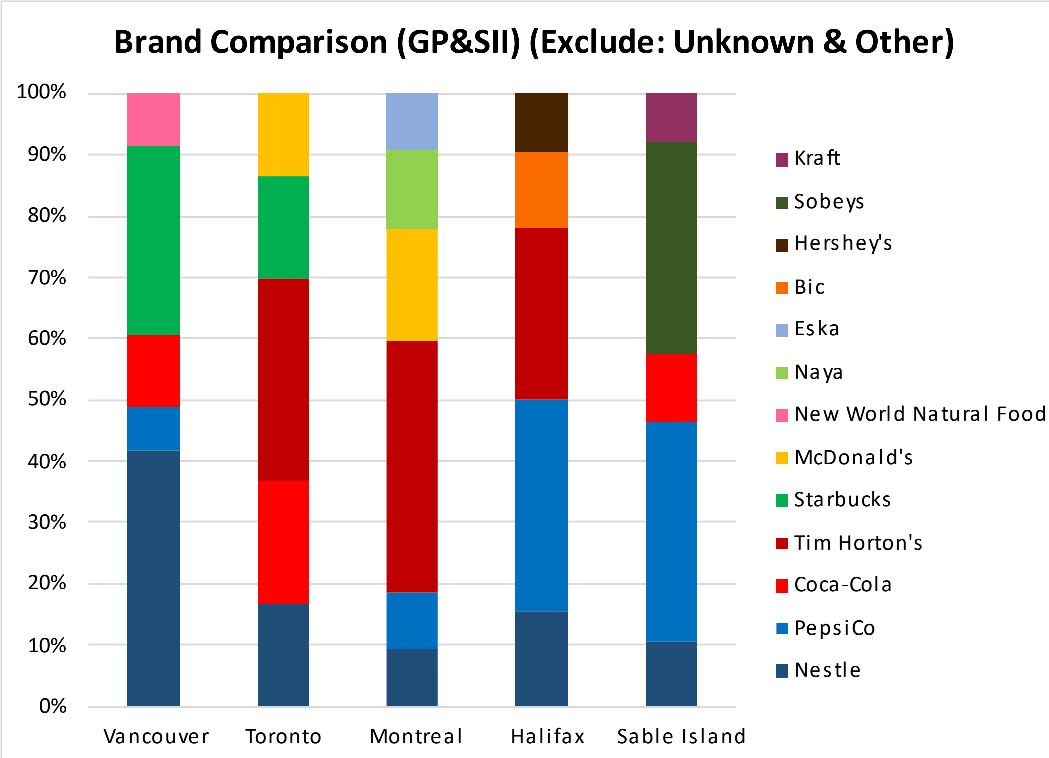

Figure 21: Top litter brands for all locations. Stacked bar graph depicts brand data collected by GP and SII in 2019 for all study locations.

4.3 Top Brands within Selected Litter Types

Brand data were specifically examined for the litter categories: cups and lids, plastic bottles, bottle caps, and wrappers. These categories were chosen as they are all part of the 'Dirty Dozen' for litter collected by GCSC in 2019 (Figure 22). Litter category-specific brand data were not always sufficient, and therefore some categories were not presented for certain locations. Statistical comparisons were not conducted for these categories, as sample sizes were generally small.

1.	Cigarette Butts	686,055
2.	Tiny Plastic or Foam	595,227
3.	Food Wrappers	74,224
4.	Bottle Caps	51,992
5.	Paper Materials	63,371
6.	Plastic Bags	31,164
7.	Beverage Cans	28,192
8.	Plastic Bottles	26,212
9.	Straws	26,157
10.	Other Packaging	22,470
11.	Foam	24,213
12.	Coffee Cups	17,170

Figure 22: The 2019 GCSC Dirty Dozen. Top litter categories (by quantity) collected by the GCSC for 2019 (GCSC, 2019).

4.3.1 Vancouver

4.3.1.1 Branding for Cups and Lids

Top brands for cups and lids were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Kirkland classified as Costco). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation. 'Other' encompasses litter that were branded, but not part of the top brands for cups and lids by quantity. Top brands include Starbucks (29), Solo (13), and Costco (11). An estimated 306 participants were involved in this data collection. Top cup and lid litter brands for Vancouver are shown in Figure 23.

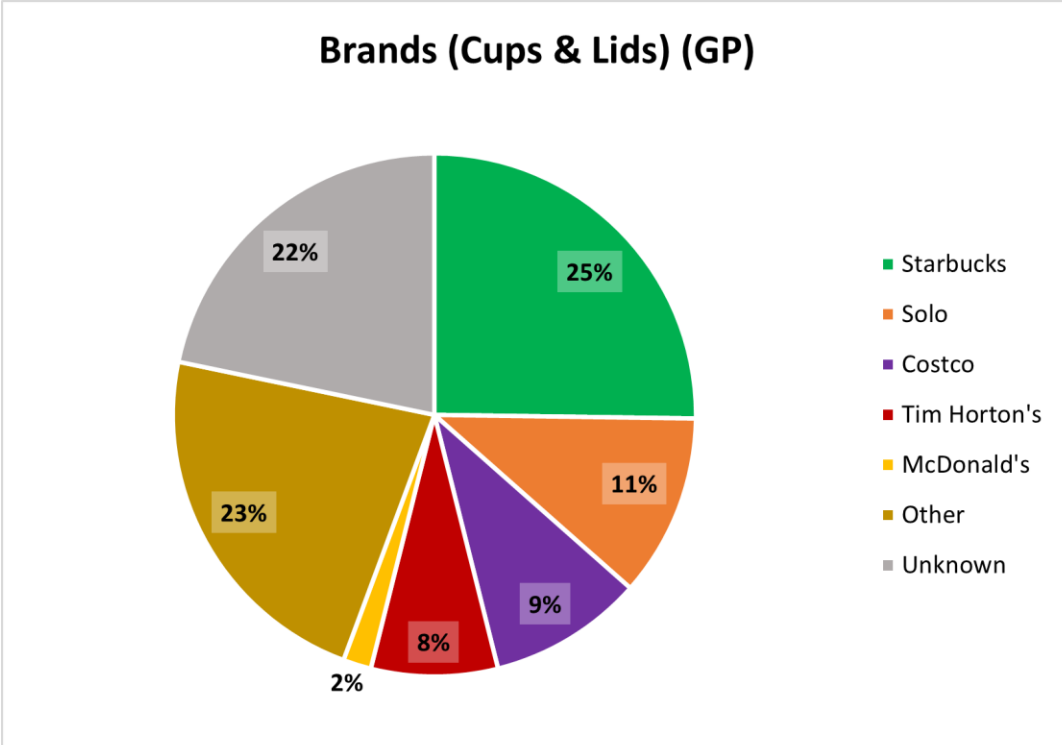

Figure 23: Vancouver Top Cup & Lid Brands. Depiction of top cups & lids brands (by quantity) collected by GP in 2019 for Vancouver. (n=115).

4.3.1.2 Branding for Plastic Bottles

Top brands for plastic bottles were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Powerade classified as Coca-Cola). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation. 'Other' encompasses litter that were branded, but not part of the top brands for plastic bottles by quantity. Top brands include Nestlé (6), Coca-Cola (5), and OKF (5). An estimated 306 participants were involved in this data collection. Top plastic bottle litter brands for Vancouver are shown in Figure 24.

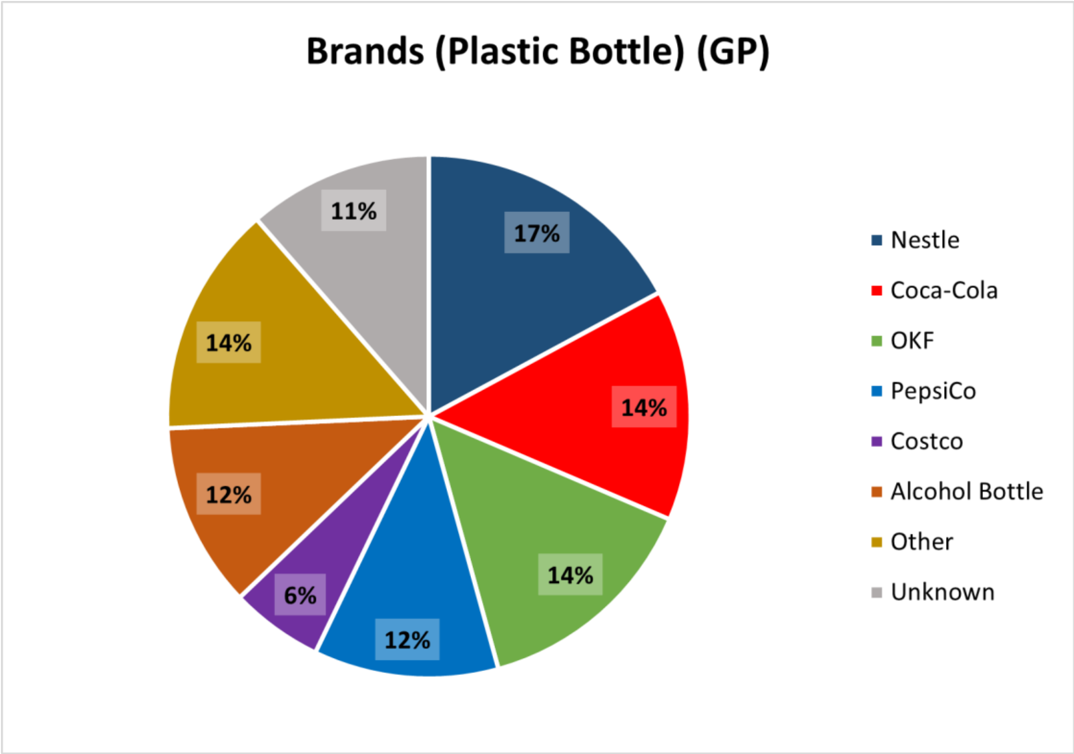

Figure 24: Vancouver Top Plastic Bottle Brands. Depiction of top plastic bottle brands (by quantity) collected by GP in 2019 for Vancouver. (n=35).

4.3.1.3 Branding for Bottle Caps

Top brands for bottle caps were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Powerade classified as Coca-Cola). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation. 'Other' encompasses litter that were branded, but not part of the top brands for bottle caps by quantity. Top brands include Nestlé (111), Coca-Cola (35), Closure Systems International (CSI) (11) and PepsiCo (11). An estimated 306 participants were involved in this data collection. Top bottle cap litter brands for Vancouver are shown in Figure 25.

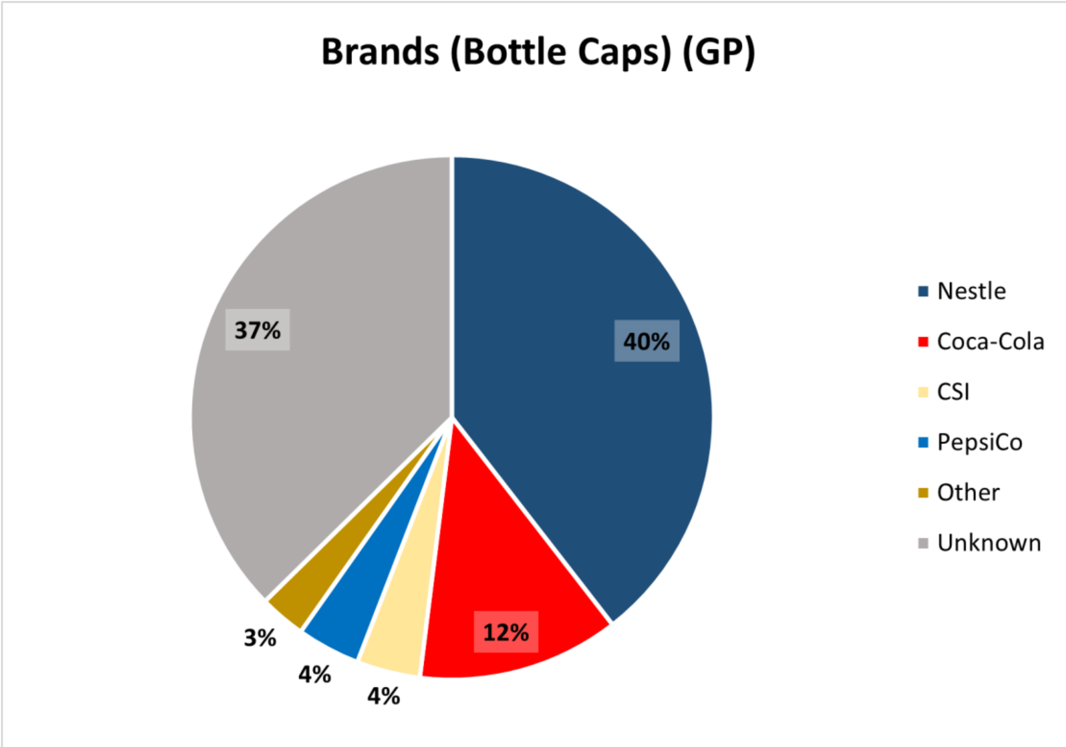

Figure 25: Vancouver Top Bottle Cap Brands. Depiction of top bottle cap brands (by quantity) collected by GP in 2019 for Vancouver. (n=281).

4.3.1.4 Branding for Wrappers

Top brands for wrappers were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Larabar classified as General Mills). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation. 'Other' encompasses litter that were branded, but not part of the top brands for wrappers by quantity. Top brands include New World Natural Foods (29), Nestlé (23), and Werther's (19). An estimated 306 participants were involved in this data collection. Top wrapper litter brands for Vancouver are shown in Figure 26.

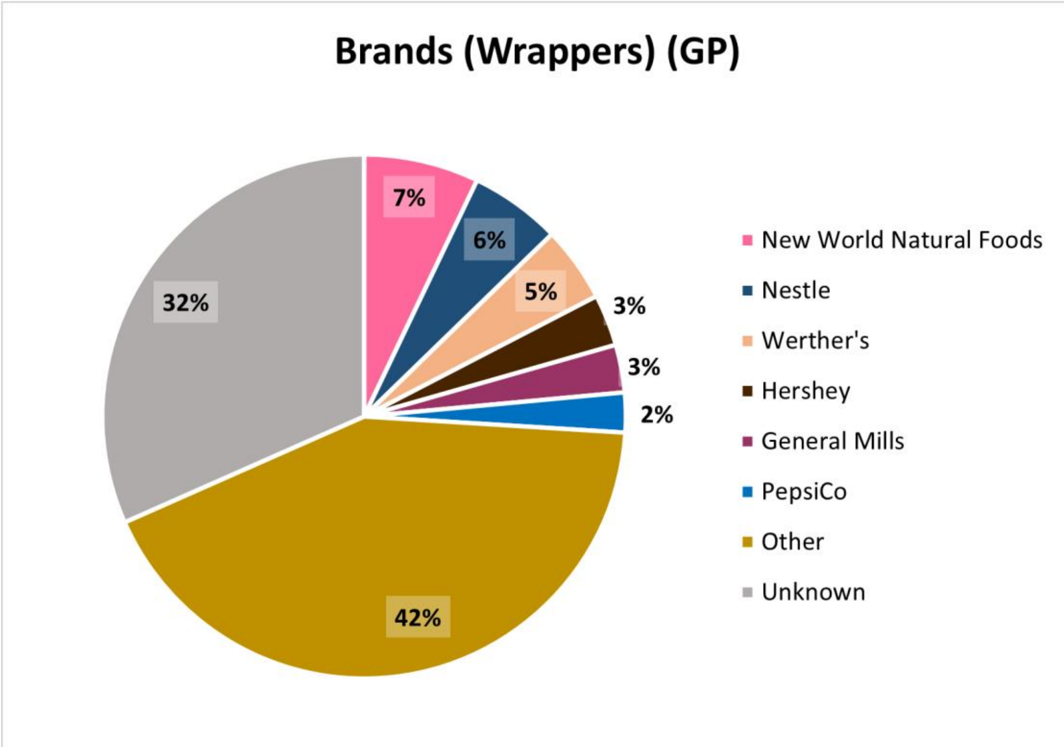

Figure 26: Vancouver Top Wrapper Brands. Depiction of top wrapper brands (by quantity) collected by GP in 2019 for Vancouver. (n=408).

4.3.2 Toronto

The categories of bottle caps (n=0) and wrappers (n=4) did not contain sufficient data for further analysis and are therefore not included below. In general, the sample sizes for the Toronto region are low.

4.3.2.1 Branding for Cups and Lids

Top brands for cups and lids were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Kirkland classified as Costco). Top brands include Tim Horton's (10), Starbucks (5), and McDonald's (4). An estimated 14 participants were involved in this data collection. Top cup and lid litter brands for Toronto are shown in Figure 27.

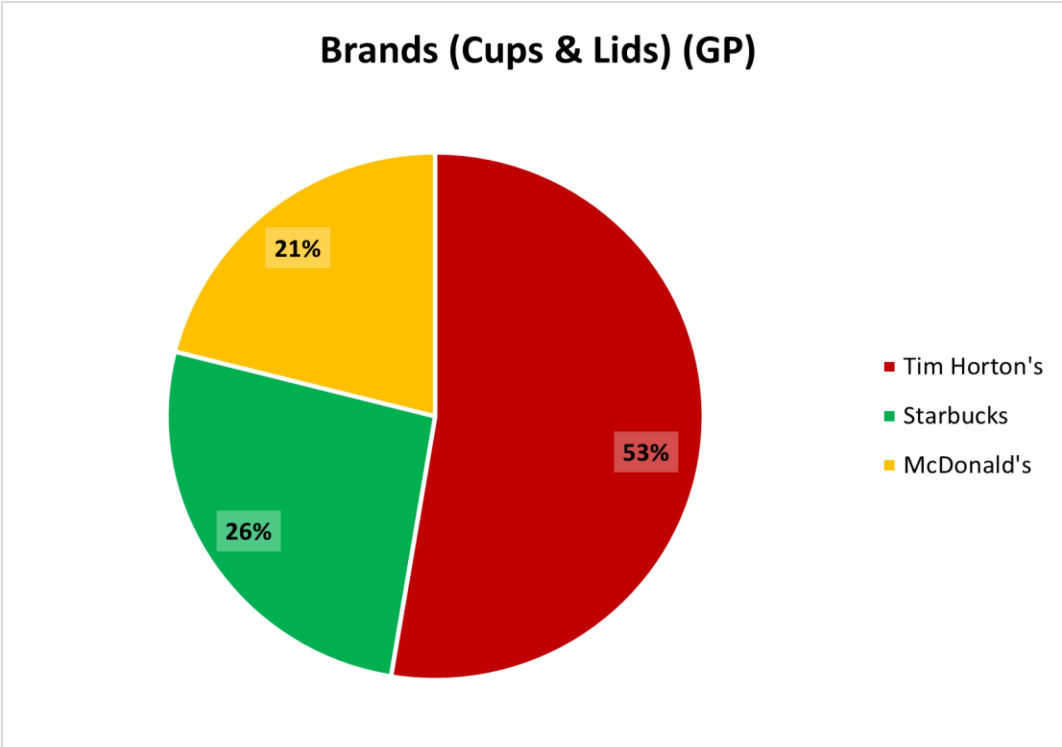

Figure 27: Toronto Top Cup & Lid Brands. Depiction of top cups & lids brands (by quantity) collected by GP in 2019 for Toronto. (n=19).

4.3.2.2 Branding for Plastic Bottles

Top brands for plastic bottles were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Powerade classified as Coca-Cola). 'Other' encompasses litter that were branded, but not part of the top brands for plastic bottles by quantity. Top brands include Coca-Cola (6), Nestlé (5), Eska (2) and Keurig Dr Pepper (2). An estimated 14 participants were involved in this data collection. Top plastic bottle litter brands for Toronto are shown in Figure 28.

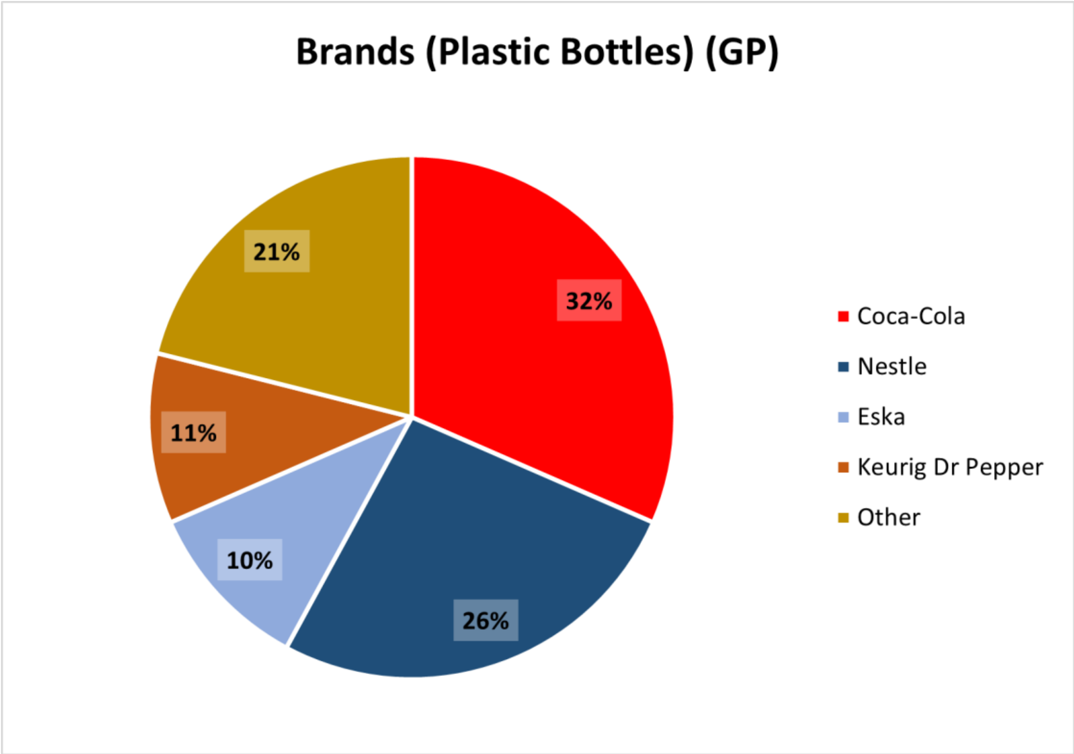

Figure 28: Toronto Top Plastic Bottle Brands. Depiction of top plastic bottle brands (by quantity) collected by GP in 2019 for Toronto. (n=19).

4.3.3 Montréal

4.3.3.1 Branding for Cups and Lids

Top brands for cups and lids were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Kirkland classified as Costco). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation. 'Other' encompasses litter that were branded, but not part of the top brands for cups and lids by quantity. Top brands include Tim Horton's (57), McDonald's (16), and Couche Tard (15). An estimated 10 participants were involved in this data collection. Top cup and lid litter brands for Montréal are shown in Figure 29.

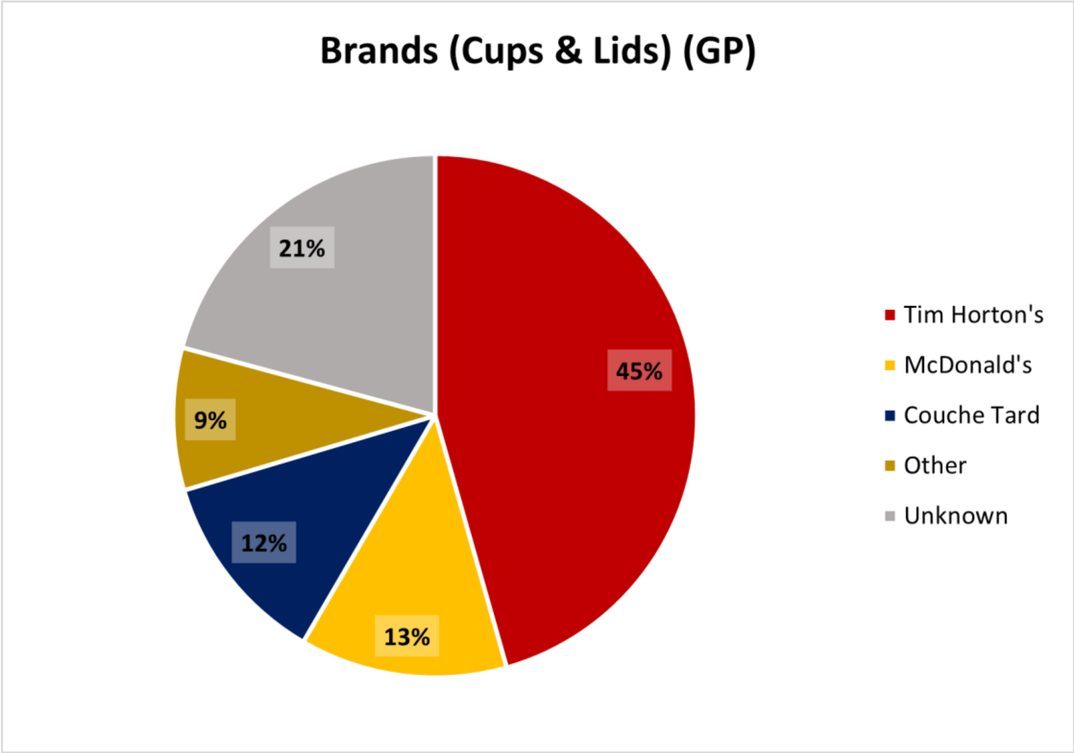

Figure 29: Montréal Top Cup & Lid Brands. Depiction of top cups & lids brands (by quantity) collected by GP in 2019 for Montréal. (n=125).

4.3.3.2 Branding for Plastic Bottles

Top brands for plastic bottles were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Powerade classified as Coca-Cola). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation. 'Other' encompasses litter that were branded, but not part of the top brands for plastic bottles by quantity. Top brands include Naya (12), Eska (9), Nestlé (6), and PepsiCo (6). An estimated 10 participants were involved in this data collection. Top plastic bottle litter brands for Montréal are shown in Figure 30.

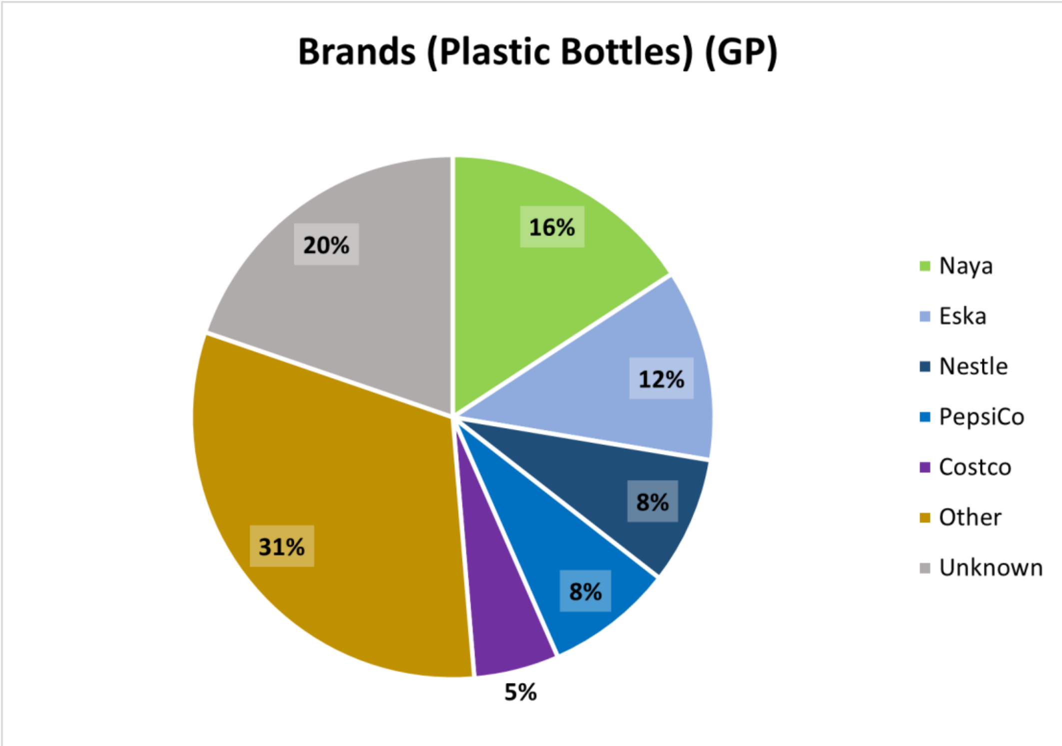

Figure 30: Montréal Top Plastic Bottle Brands. Depiction of top plastic bottle brands (by quantity) collected by GP in 2019 for Montréal. (n=76).

4.3.3.3 Branding for Bottle Caps

Top brands for bottle caps were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Powerade classified as Coca-Cola). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation; Montréal contained high levels of unknown litter in this category (84%). 'Other' encompasses litter that were branded, but not part of the top brands for bottle caps by quantity. Top brands include Naya (11), Eska (5), Lassonde (3) and Nestlé (3). An estimated 10 participants were involved in this data collection. Top bottle cap litter brands for Montréal are shown in Figure 31.

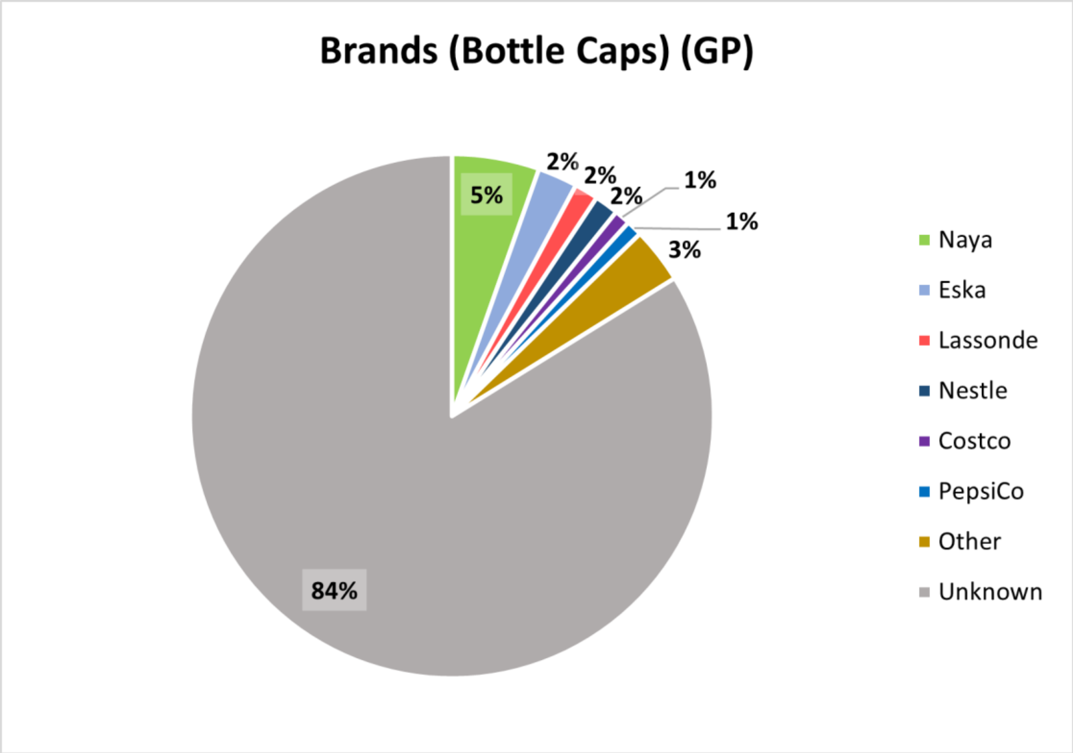

Figure 31: Montréal Top Bottle Cap Brands. Depiction of top bottle cap brands (by quantity) collected by GP in 2019 for Montréal. (n=204).

4.3.3.4 Branding for Wrappers

Top brands for wrappers were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Larabar classified as General Mills). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation. 'Other' encompasses litter that were branded, but not part of the top brands for wrappers by quantity. Top brands include Mars (18), Mondelez (11), Nestlé (11), and PepsiCo (11). An estimated 10 participants were involved in this data collection. Top wrapper litter brands for Montréal are shown in Figure 32.

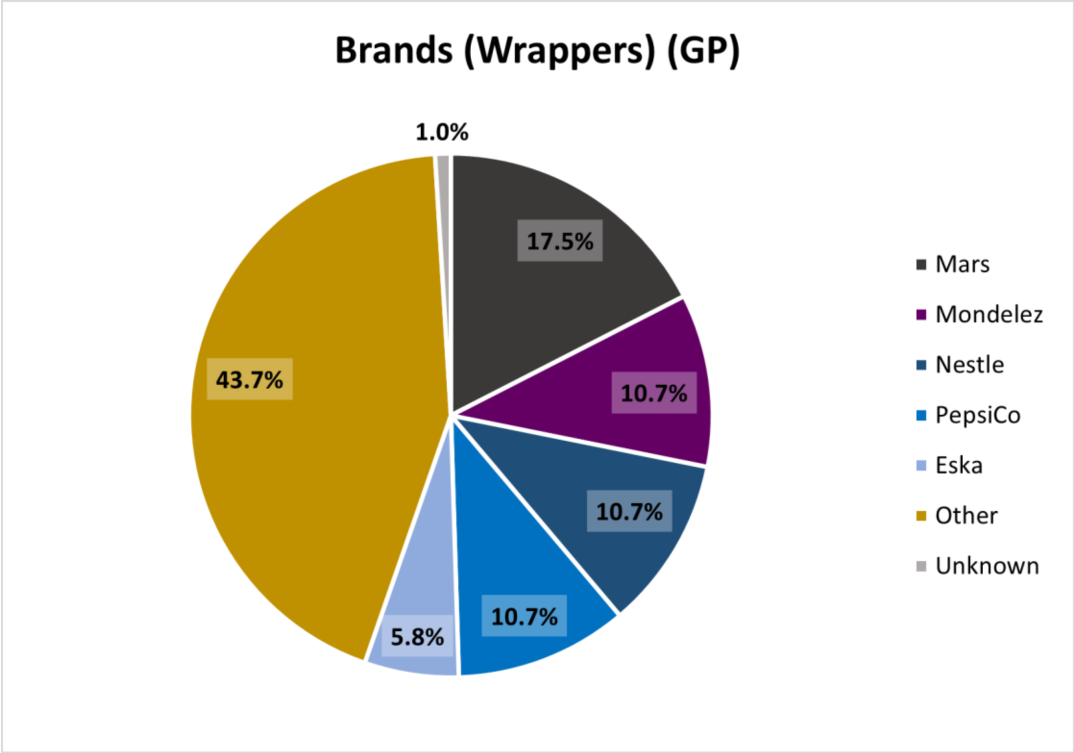

Figure 32: Montréal Top Wrapper Brands. Depiction of top wrapper brands (by quantity) collected by GP in 2019 for Montréal. (n=103).

4.3.4 Halifax

The category of bottle caps did not contain any branded data for further analysis and is therefore not included below. In general, Halifax contains high amounts of unknown litter brands.

4.3.4.1 Branding for Cups and Lids

Top brands for cups and lids were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Kirkland classified as Costco). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation; Halifax contained high levels of unknown litter in this category (79%). Brands with highest cup and lid quantity documented through this collection include Tim Horton's (10), Laura Secord (1), and McDonald's (1). An estimated 5-10 participants were involved in this data collection. Top cup and lid litter brands for Halifax are shown in Figure 33.

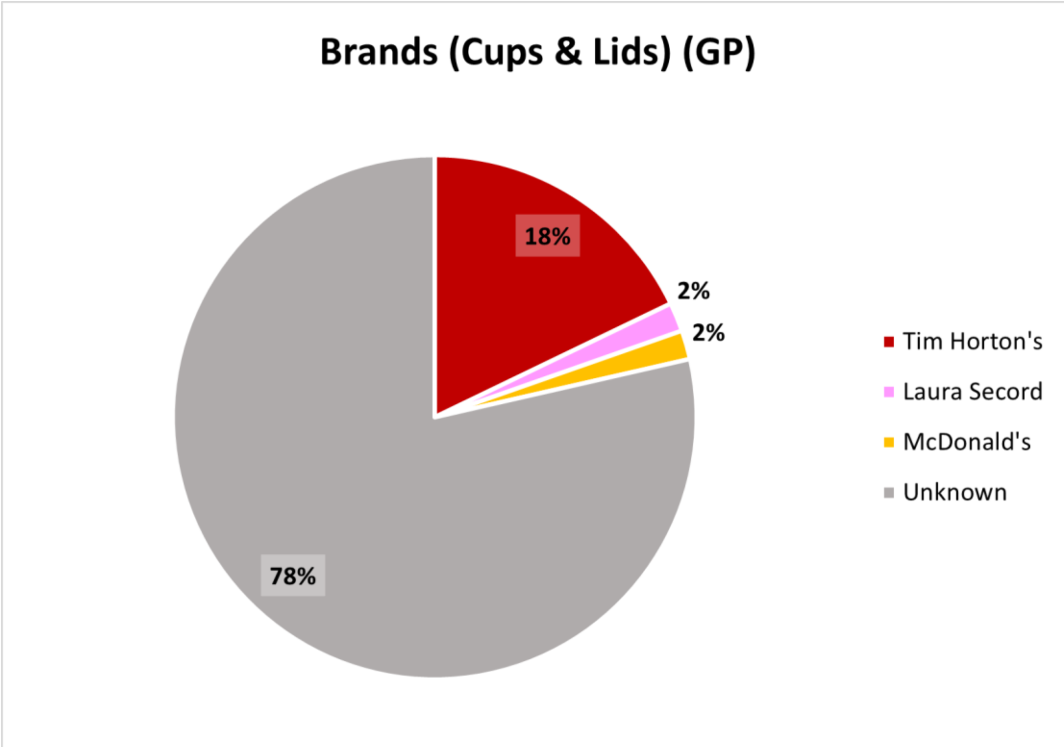

Figure 33: Halifax Top Cup & Lid Brands. Depiction of top cups & lids brands (by quantity) collected by GP in 2019 for Halifax. (n=56).

4.3.4.2 Branding for Plastic Bottles

Top brands for plastic bottles were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Powerade classified as Coca-Cola). 'Unknown' indicates that the brand information could not be identified, often due to environmental degradation; Halifax contained high levels of unknown litter in this category (76%). Brands with highest plastic bottle quantity documented through this collection include PepsiCo (2), ADL (1), Couche Tard (1), and Naya (1). An estimated 5-10 participants were involved in this data collection. Top plastic bottle litter brands for Halifax are shown in Figure 34.

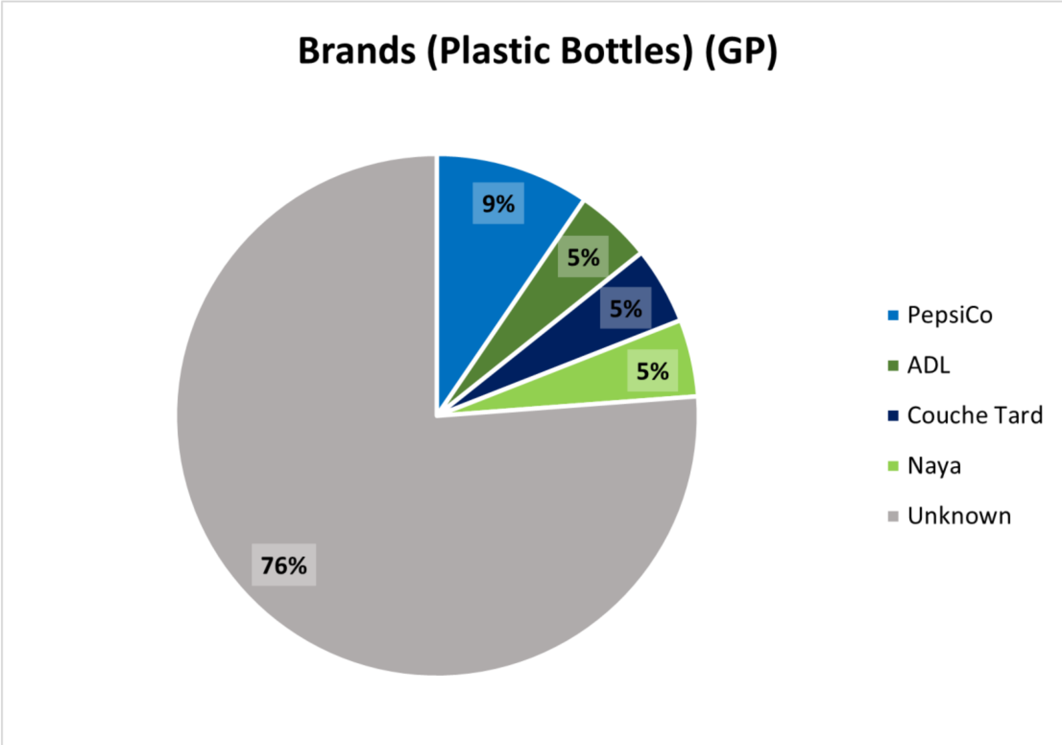

Figure 34: Halifax Top Plastic Bottle Brands. Depiction of top plastic bottle brands (by quantity) collected by GP in 2019 for Halifax. (n=21).

4.3.4.3 Branding for Wrappers

Top brands for wrappers were obtained from the GP dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Larabar classified as General Mills). 'Other' encompasses litter that were branded, but not part of the top brands for wrappers by quantity. Brands with highest wrapper quantity documented through this collection include PepsiCo (7), Nestlé (5), and Hershey's (3). An estimated 5-10 participants were involved in this data collection. Top wrapper litter brands for Halifax are shown in Figure 35.

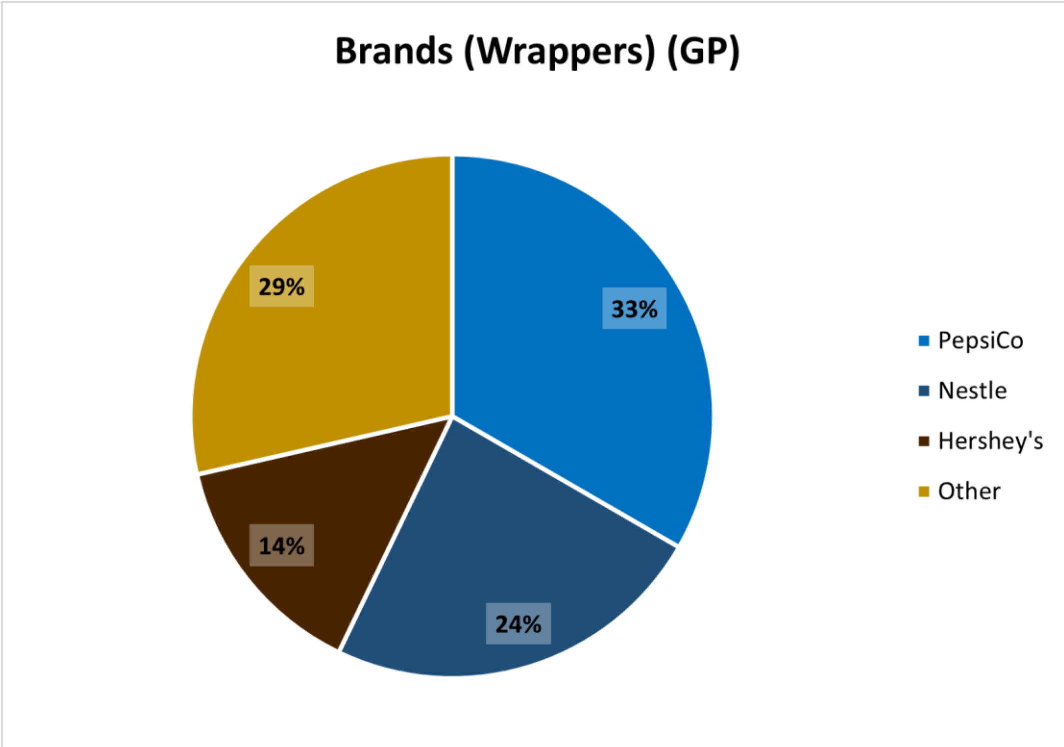

Figure 35: Halifax Top Wrapper Brands. Depiction of top wrapper brands (by quantity) collected by GP in 2019 for Halifax. (n=21).

4.3.5 Sable Island

The categories of bottle caps (n=0) and cups & lids (n=1) did not contain sufficient data for further analysis and are therefore not included below.

4.3.5.1 Branding for Plastic Bottles

Top brands for plastic bottles were obtained from the SII dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Powerade classified as Coca-Cola). SII brand auditing only collected litter with discernible brand labeling, so no 'Unknown' category is present. 'Other' encompasses litter that were branded, but not part of the top brands for plastic bottles by quantity. Top brands include Sobeys (57), PepsiCo (48), and Coca-Cola (18). An estimated 1-2 participants were involved in this data collection. Top plastic bottle litter brands for Sable Island are shown in Figure 36.

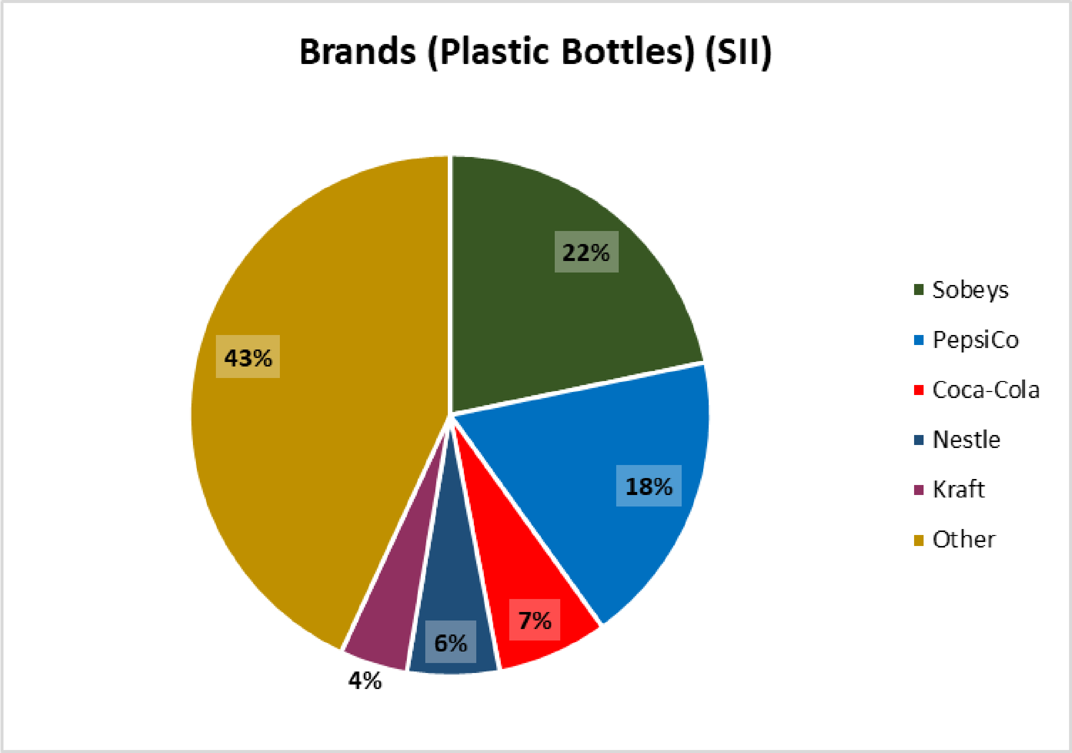

Figure 36: Sable Island Top Plastic Bottle Brands. Depiction of top plastic bottle brands (by quantity) collected by SII in 2019 for Sable Island. (n=262).

4.3.5.2 Branding for Wrappers

Top brands for wrappers were obtained from the SII dataset. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Larabar classified as General Mills). SII brand auditing only collected litter with discernible brand labeling, so no 'Unknown' category is present. 'Other' encompasses litter that were branded, but not part of the top brands for wrappers by quantity. Top brands include PepsiCo (27), Nestlé (7), and Mars (4). An estimated 1-2 participants were involved in this data collection. Top wrapper litter brands for Sable Island are shown in Figure 37.

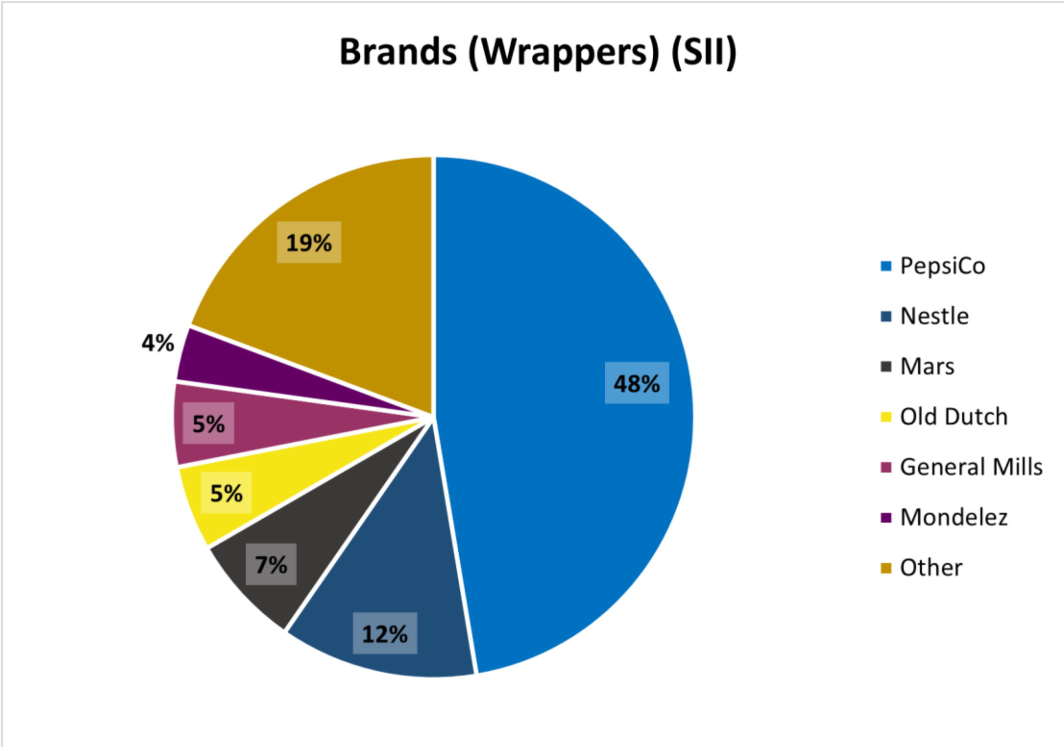

Figure 37: Sable Island Top Wrapper Brands. Depiction of top wrapper brands (by quantity) collected by SII in 2019 for Sable Island. (n=57).

4.4 Presumed Country of Litter Distribution: Sable Island

SII also classified litter based on presumed country of distribution. This classification was accomplished through examination of the languages present on labels and internet search on product's countries of distribution. As such, this is an estimation of litter distribution and potential sources to better inform the transboundary nature of marine litter in this region. Country of distribution were classified into larger regions: Canada, USA, Europe, Central/South America, Middle East, Asia, and Mexico. 'Unknown' represents branded data that did not contain sufficient information to accurately estimate region of distribution—often this is due to presence of information that could reasonably result in distribution classification under multiple regions. Overall, the majority of litter are presumed to be Canadian in origin (74%), with the second highest proportion of known distribution coming from the United States (6.2%). Based on ocean currents in the region, these results align with expected litter origins. These data results support the importance of addressing marine litter nationally in Canada, but also the need for international collaboration on this transboundary marine issue. Presumed countries of distribution for litter on Sable Island are shown in Figure 38.

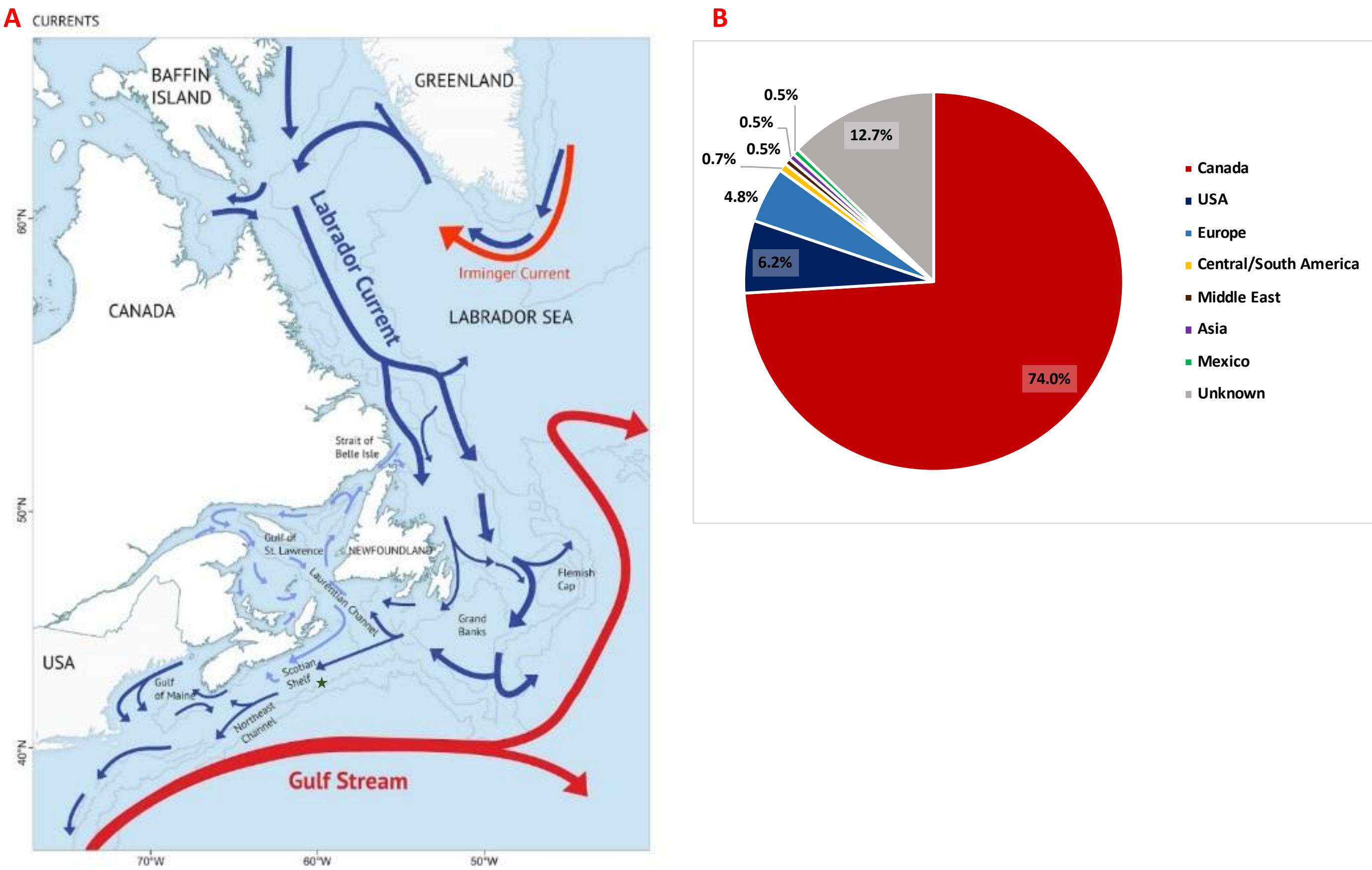

Figure 38: Presumed Litter Country of Distribution. **A**: Major currents in Atlantic Canada include the Labrador Current and Gulf Stream. Approximate location of Sable Island denoted by green star. (DFO, 2018). **B**: Presumed litter region of distribution for Sable Island (n=566).

4.5 Urban *vs.* Transboundary Litter Resin Codes

Litter resin codes (e.g., PET 1) were documented for some of the collected litter. SII documented resin codes for 270 litter items. For urban location comparison, Montréal was chosen as it had the largest resin code dataset available through GP (n=1,230). Resin types included are: PET 1 (Polyethylene Terephthalate), HDPE 2 (High Density Polyethylene), PVC 3 (Polyvinyl Chloride), LDPE 4 (Low Density Polyethylene), PP 5 (Polypropylene), PS 6 (Polystyrene), and Other 7. Overall, Sable Island was seen to have higher proportions of PET 1 and HDPE 2 than the urban location, Montréal. No PVC 3 items were document for branded litter collected on Sable Island. In Montréal, LDPE 4 and Other 7 were found in much higher proportions than Sable Island, perhaps indicating low ocean transportability or high environmental degradation of these plastic types resulting in minimal occurrence on the remote Sable Island. The difference in collection methodologies employed by SII and GP likely contribute to some of the observed litter resin differences, with SII only collecting litter with intact labelling. Global plastic resin proportions for the packaging industry are included in Figure 39 (Yeo et al., 2017).

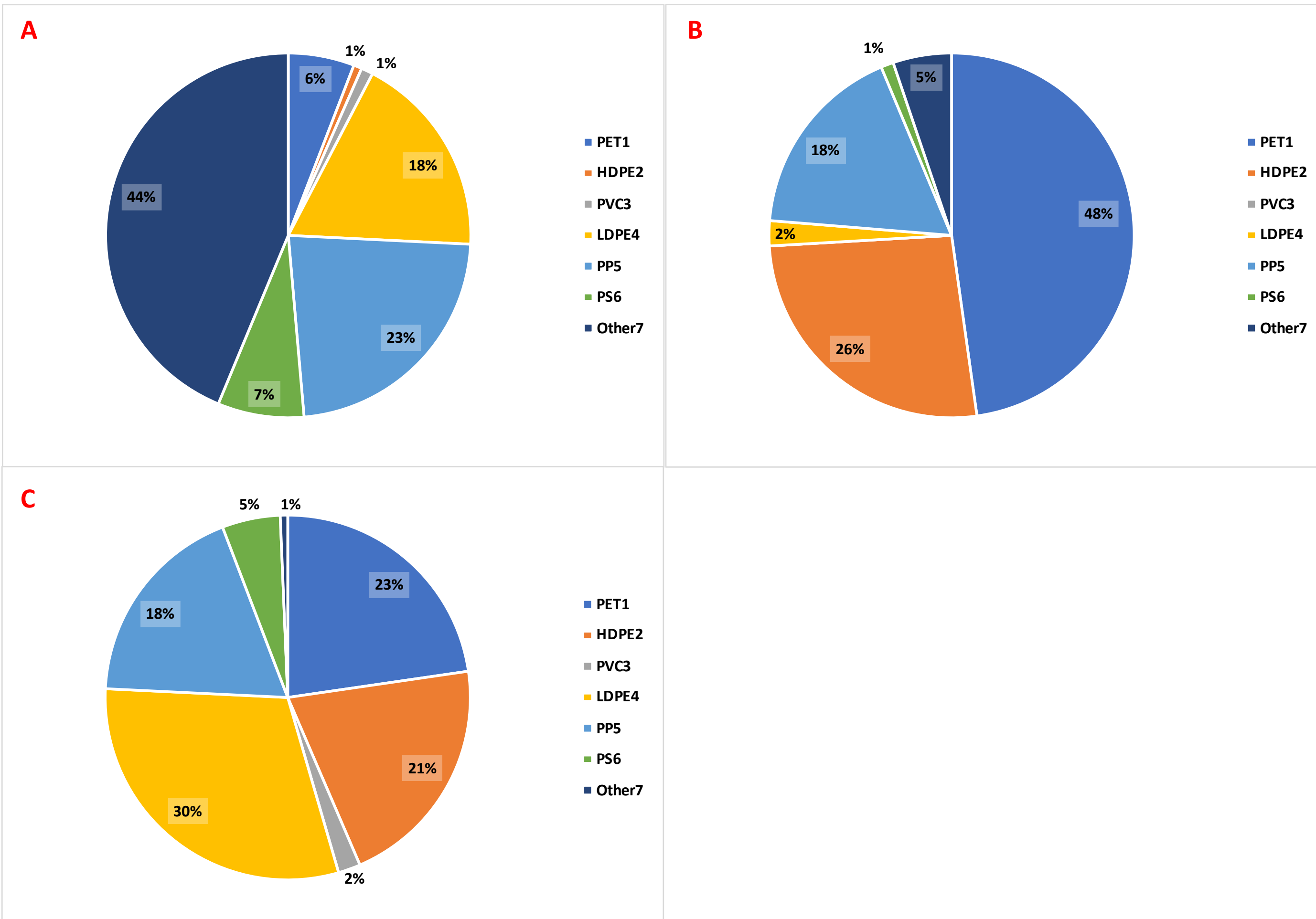

Figure 39: Litter Plastic Resin Codes. **A**: Montréal (n=1,230). **B**: Sable Island (n=270). **C**: Global Packaging Industry from Yeo et al. (2017).

5. Discussion

5.1 Local *vs.* Global

Although plastics are pervasive, higher debris concentrations are expected to accumulate in urban coastal areas (Leite et al., 2014; Driedger et al., 2015). However, remote locations, such as islands, can act as plastic sinks and provide valuable indicators to better understand marine pollution and monitor debris accumulation trends (Walker et al., 1997; Imhof et al., 2017; Andrades et al., 2018; Monteiro et al., 2018; Ambrose et al., 2019; Lavers et al., 2019; Nichols et al., 2021). In particular, Sable Island, due to its restricted access and remote nature, provides an important monitoring site for marine litter in the Scotian Shelf region (Lucas, 1992).

5.1.1 Types of Plastic

Statistically, results indicate that plastic litter type is dependent on geographic location, meaning that studied urban locations also differed significantly from one another. Qualitatively, however, urban locations appeared to demonstrate more similar proportions of litter types compared to Sable Island. In general, Sable Island contained a larger proportions of plastic bottles and food containers. Previous studies have also demonstrated differences in litter types between urban and remote locations (Leite et al., 2014; Jang et al., 2018; Smith et al., 2018; Ryan, 2020), with Leite et al. (2014) demonstrating a significant relationship between distance from urban centre, and density, abundance, and diversity of debris types.

One possible explanation for differences in plastic types found on Sable Island is the different transport mechanisms of plastics and plastic degradation rates in the open ocean. For example, more buoyant plastics with lower densities are expected to be transported to beaches by ocean surface water (Nakashima et al., 2011; Nichols et al., 2021). However, plastics can also undergo cycles of biofouling that increases overall plastic density causing plastic to sink, and defouling which decreases density allowing debris to resurface (Ye & Andrady, 1991; Lobelle & Cunliffe, 2011; Koelmans et al., 2017; Chen et al., 2019; Chamas et al., 2020). Koelmans et al. (2017) developed simulations that demonstrate that 99.8% of plastic has settled below the ocean surface layer, because of density changes and biofouling. Further, degradation in marine environments is reliant on plastic chemical composition, as well as environmental conditions. Polyethylene-based plastics have a chemical backbone that does not readily undergo hydrolysis and is resistant to photo-oxidative degradation (Chamas et al., 2020). HDPE products are generally expected to have a longer half-life (~58 years for HDPE container) in marine environments than LDPE plastics (~3.4 years for LDPE plastic bag) (Chamas et al., 2020). These degradation rates may contribute to the lower levels of LDPE products (2%) found on Sable Island. Further, PET in marine environments is expected to undergo slow rates of hydrolytic cleavage and photo-oxidative degradation (Chamas et al., 2020), perhaps contributing to the higher levels of PET (48%) found on Sable Island compared to both Montréal (6%) and global production rates (20.7%). High proportions of polypropylene and polyethylene-based plastics were similarly found on the remote islands of Andaman and Nicobar Archipelago in India (Krishnakumar et al., 2020), Ookushi Beach in Japan (Nakashima et al., 2011), Vavvaru Island in the Maldives (Imhof et al., 2017), and Trindade Island in Brazil (Andrades et al., 2018), potentially corroborating the capacity for longer range transport and lower degradation of these plastic types.

Large proportions of plastic bottles (46%) were found on Sable Island compared to urban study locations (4-16%). Similar findings have occurred for other remote islands (Nakashima et al., 2011; Smith et al., 2018; Ryan, 2020), where Smith et al. (2018) found remote beaches had four times higher plastic bottle densities compared to accessible beaches. Plastic bottles are generally composed of PET or HDPE (Nakashima et al., 2011; Ryan, 2020), contributing to the higher amounts of these resin types found on Sable Island. Long-range transport of PET bottles requires presence of the bottle cap, whereas HDPE or PP bottles, due to their inherent buoyancy, do not require lids for dispersal (Ryan, 2020). Although presence of bottle caps on collected plastic bottles was not documented through the 2019 brand audit protocols on Sable Island, approximately 95% of PET bottles collected on Sable Island have attached bottle caps (Z. Lucas, personal communication, October 18, 2021), further adding to the plastic types deposited on the remote beaches of Sable Island. Further, PET bottles tend to decrease in abundance with distance from urban areas (Jang et al., 2018; Ryan, 2020), indicating that these litter types likely either come from nearby domestic sources or are dumped from ships (Duhec et al., 2015; Smith et al., 2018).

Some differences in litter types between urban and remote locations in this study may also result from different collection methods employed by GP and SII, particularly the different categories that were used to classify litter. For instance, SII did not include bottle caps in their brand audit litter categories. Further, the current research study only analysed branded plastic litter, thereby excluding most fishing-related debris. This may also limit documentation of quickly degrading plastic products, as products without clearly identifiable branding were not included in this study. As such, this study is likely not reflective of the total proportions of plastic on Sable Island, but instead highlights litter types for branded products.

5.1.2 Brands

Urban and remote study locations demonstrated distinct similarities and differences in litter brands. In terms of similarities, Nestlé was found to be a top brand for all study locations. PepsiCo was a top brand in four of five study locations. Coca-Cola, and Tim Horton's were top brands in three of five study locations, and both Starbucks and McDonald's were found as top brands in two of five study locations. Fast-food brands such as McDonald's, Tim Horton's, and Starbucks were found in low quantities on Sable Island compared to urban study locations, likely due to lower transportability of these litter types. These six prevalent litter brands comprise 45% of known branded litter collected for urban study locations and comprise 39% of branded litter collected in all study locations. Results clearly indicate that these food and beverage companies are disproportionally responsible for plastic litter within Canada. Similar trends are also found from brands audits conducted in other countries. Waste assessments conducted in the Philippines found ten companies comprised 60% of branded waste, including four multinational companies (Nestlé, Unilever, Procter & Gamble, and Coca-Cola) which together accounted for 36% of total collected waste (Gaia, 2019). Further, a litter brand audit for Freedom Island, a UNESCO Ramsar site in the Philippines, found similar trends where six international brands were responsible for ~54% of collected plastic litter, including Nestlé as a top polluter (BFFP, 2017). Finally, brand audits in Great Britain found that the top fifteen brands comprised 41% of collected branded litter, again including many international brands, such as Coca-Cola and McDonald's (KBT, 2020); however, this methodology did not group subsidiaries under parent brands, and therefore this percentage is likely an underestimate. The KBT study also found that higher litter levels tend to occur in urban areas, even when compared to rural locations that are more closely populated, demonstrating differences in litter proportions and quantities based on rurality (KBT, 2020).

However, it is also vital to recognize that these brands do not produce plastic raw materials themselves and that ultimately petroleum companies, which operate further up the supply chain, are also responsible for plastic litter damaging global environments (McIntyre, 2021). In 2019, Exxon Mobil, an American-based oil and gas company, produced the most SUP waste of any public global company—6.5 million tons (McIntyre, 2021). Cumulatively, the top three SUP producers: Exxon Mobil, Dow, and Sinopec, generated 18.5 million tons of SUPs in 2019 (McIntyre, 2021). When analyzing plastic impacts and determining producer responsibility, it is vital the entire plastics supply chain is considered. A holistic assessment of the plastics supply chain, including producers of plastic raw materials, is necessary for comprehensive understanding of plastic litter sources and development of thorough, effective SUP mitigation policies.

Local brands also contributed to plastic litter. For instance, New World Natural Foods, a company local to the Vancouver area, was seen to be a top litter brand in Vancouver. Similarly, Naya and Eska were top litter brands in Montréal, and although they can be found in other locations within Canada, both companies are headquartered in Québec (Eska, 2021; Naya, 2021) and appear to be more prominent water brands in this study region. The importance of local brand contributions to regional litter composition is also seen on Sable Island, where Sobeys was the second highest litter brand by quantity. Although Sobeys can be found throughout Canada, it is headquartered in Nova Scotia (Sobeys, 2021). Importance of local brand contributions to litter have also been demonstrated in other studies (Imhof et al., 2017; Okuku et al., 2020; Okuku et al., 2021). In particular, branded litter collected in Kenya demonstrated that local manufacturers contribute highly to marine litter on all surveyed beaches (Okuku et al., 2020): diversity of local litter contributors was also demonstrated as branded marine litter in Mkomani Beach came from 316 different manufacturers (Okuku et al., 2021).

Together, these results indicate that large, global brands (i.e. Nestlé, Coca-Cola, PepsiCo) strongly contribute to plastic litter, but also that regional, local brands can make large litter contributions. This would suggest that both national and regional strategies should be employed to mitigate plastic litter. Management strategies and recommendations based on these results are presented in Section 6.

No previous studies were found that directly compare plastic litter brand differences between urban and remote locations. Comparison of study results to broader global trends is described below.

5.1.2.1 Global Brand Trends: BreakFreeFromPlastic

Results show some correlation with larger, global brand audits (BFFP, 2019; BFFP, 2020). BreakFreeFromPlastic (BFFP) conducted 484 litter brand audits in 51 countries during their 2019 collection period. The top three brands identified globally: Coca-Cola, Nestlé, and PepsiCo (BFFP, 2019), were also seen to be the top litter brands in this study (Figure 40). Every year that the BFFP brand audit has been conducted (circa 2018), Coca-Cola, PepsiCo, and Nestlé have remained the top three global polluters (BFFP, 2020). These findings suggest that global coordination and accountability are needed to address plastic pollution from global brands that are pervasive throughout many countries and jurisdictions.

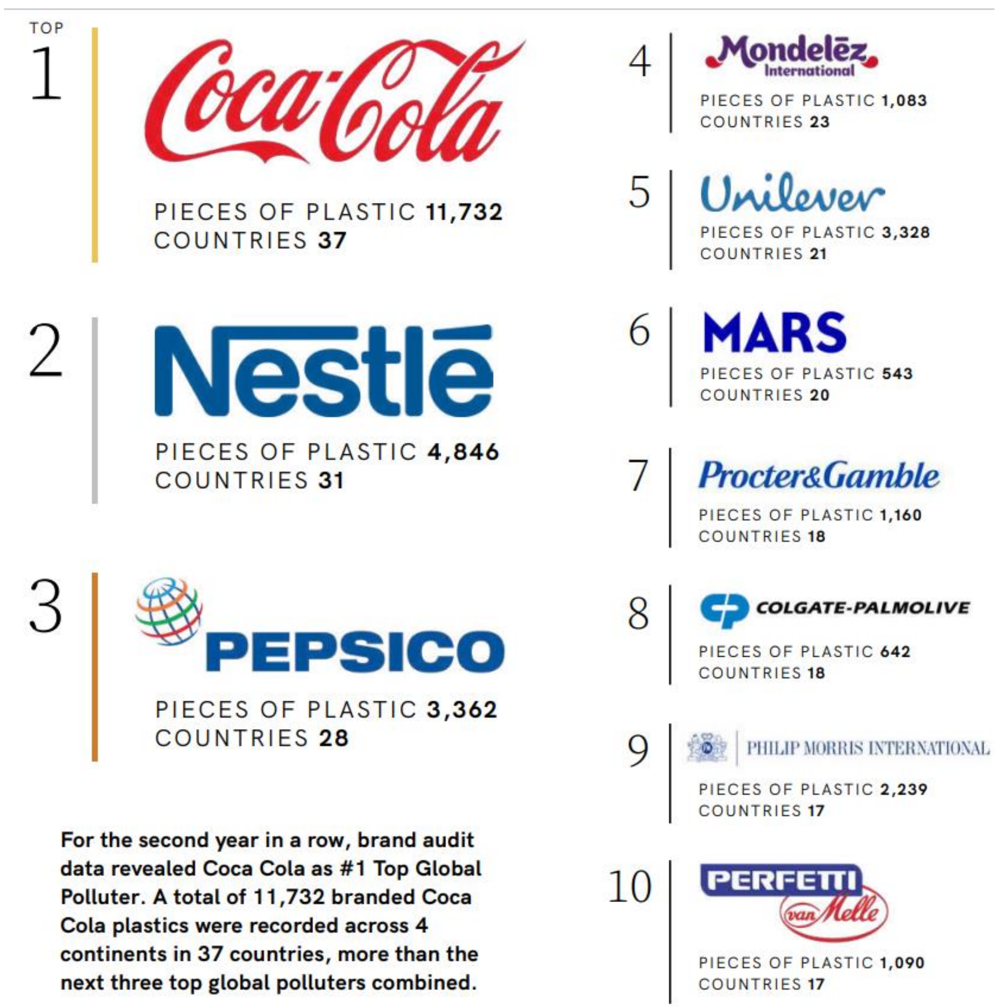

Figure 40: Top Global Plastic Polluters in 2019. BFFP brand audit results from 2019 indicate top litter brands collected globally, as well as number of countries where these brands were collected (BFFP, 2019).

The most common types of plastics collected from the BFFP globally are plastic bags, sachets, and plastic bottles (BFFP, 2019). Other studies conducted globally have noted high proportions of these items, particularly food packaging (Pasternak et al. 2017; Jang et al., 2018;

Okuku et al., 2020; Okuku et al., 2021). Additionally, top litter items from global coastline cleanups conducted during the International Coastal Cleanup in 2019 included wrappers, plastic bottles, and bottle caps (Ocean Conservancy, 2020). These findings mirror the GCSC top plastic products for 2019: wrappers, bottle caps, plastic bags, and plastic bottles (GCSC, 2019). Congruence between Canadian and globally plastic products support the need for globally coordinated efforts to reduce SUPs, including international conventions and treaties.

5.1.3 Litter Origins

Presumed country of distribution was determined for litter on Sable Island. Most plastic litter on Sable Island was presumably from Canadian origins (74%). This was largely anticipated due to the oceanic currents around Sable Island, such as Labrador Current and outflow from the St. Lawrence River, both of which would be expected to transport debris from Canadian origins. Hardesty et al. (2014) similarly found that most coastal debris in Australia originated from domestic sources, and not the high seas. This finding suggests that improved Canadian waste management and regulations for plastic could help mitigate most litter found on this remote island.

Other presumed countries of origin account for 13.3% of collected litter on Sable Island in 2019. Brand audits conducted in Kenya (Okuku et al., 2020; Okuku et al., 2021), Sri Lanka (Jang et al., 2018), and Israel (Pasternak et al., 2017) similarly found that the majority of collected litter originated from domestic sources, but also all documented long-range transport of litter originating from other countries. Transportation of brands that are distributed in other countries could arrive on Sable Island through either oceanic transport or disposal of waste at sea (Lucas, 1992). Although these methods likely account for a minority litter on Sable Island, the importance of global reduction of plastics, as well as compliance with regulations banning at sea waste disposal of plastics (MARPOL Annex V) remain critical for comprehensive mitigation of marine plastics.

5.2 Regional Bans and SUP Reduction Measures

Regional SUP reduction measures for each study location were outlined in the Research Context section. Through the data collected in this study, efficacy of these measures was analyzed. Statistically, litter proportions were seen to be dependent on geographic location; however, the follow section is largely based on qualitative observations. As such, any trends identified through this analysis should be further tested in future studies using more standardized collection methods designed to assess the impact of mitigation measures on plastic litter reduction.

5.2.1 Vancouver

Although EPR was implemented in British Columbia in 2014, the results of this brand audit do not appear to support that EPR has contributed to litter reduction. Vancouver was seen to have the highest proportion of wrappers (34%) compared to other study locations, including Halifax which does not current have an EPR program. These findings are corroborated by Harris et al. (2021) who undertook an examination of shoreline pollution levels in British Columbia pre- and post-EPR. Similarly, their research found that pollution levels were not significantly reduced following introduction of EPR policy. Although this program has been successful in recovering higher rates of packaging since its implementation in 2014 (Harris et al., 2021), perhaps EPR programs do not significantly impact litter quantities, as littering often occur outside of formal waste management pathways. Litter pathways may be more effectively targeted through education programs and anti-dumping campaigns (Hardesty et al., 2014). Further, bottle deposit programs have been in operation in British Columbia since 2004. From this study, Vancouver had the least number of plastic bottles (4%), but a similar amount of bottle caps compared to other urban study areas. These findings likely support the efficacy of the bottle deposit scheme in this region, as plastic bottles attract a refund, whereas bottle caps themselves do not (Hardesty et al., 2014). A similar study in South Australia indicated that a lower proportion of plastic bottles and comparable amount of bottle caps supports that bottle deposit programs are effective in limiting plastic bottle disposal in the environment (Hardesty et al., 2014). Therefore, the results of our study would support efficacy of the bottle deposit program in British Columbia. Finally, as SUP bans in this region were not in effect at the time of litter collection for this study, efficacy of these programs could not be evaluated—this could be an avenue of future research.

5.2.2 Toronto

Ontario has the oldest EPR program in Canada, and interestingly, was found to have the smallest proportion of wrappers (18%) of all urban study locations. These results may support that this EPR program improves recovery of packaging waste and potentially mitigates improper disposal in environments. However, due to the lack of EPR impacts detected in Vancouver and Montréal, further studies specifically measuring Toronto EPR efficacy should be conducted to preclude contribution of extraneous variables. Further, Toronto was the only study region without a bottle deposit program beyond alcoholic beverage containers. From our study, Toronto was seen to have the highest proportion of bottle caps (36%), and second highest proportion of plastic bottles

(9%). All Canadian provinces, except for Ontario and Manitoba, have deposit programs that include non-alcoholic beverage containers (Edwards et al., 2019). In terms of provincial recycling rates for non-refillable containers, Ontario's recycling rate for non-alcoholic containers (45%) is far lower than other provinces (62-86%) (Edwards et al., 2019). Modelling suggests that implementation of a bottle deposit program for non-alcoholic containers in Ontario would be anticipated to reduce beverage container litter by up to 80% (Edwards et al., 2019). As such, implementation of a more extensive bottle deposit program in Ontario is recommended to further support mitigation of plastic bottle litter. Finally, plastic bag litter in Toronto (9%) was seen to be less than Montréal and Halifax (12%), but slightly greater than Vancouver (7%). These results may indicate that the voluntary bag reduction in Ontario has not largely reduced plastic bag waste; however, further studies on this topic would be required. It may be valuable to implement more stringent bans or higher fees to promote reduction in SUP litter (Karasik et al., 2020).

5.2.3 Montréal

Although Montréal has a full EPR program, implications of this SUP strategy were not evident in the study data. In terms of packaging, Montréal had a comparable proportion of wrappers (25%) to Halifax (23%), which does not have an EPR program. Like Vancouver, these results could indicate that EPR does not impact the amount of improperly disposed waste, or that the current study design does not properly capture these impacts. Montréal was found to have the highest proportion of plastic bottles, which was not anticipated due to the operation of bottle deposits in this region since 1984. However, water and dairy bottle deposits are not currently included in Québec's bottle deposit program (Container Recycling Institute, 2021). To determine whether plastic bottle types included in the current deposit program contributed to high litter proportions or if this proportion was composed of non-refundable bottle types, the GP dataset (which indicated ~70% of plastic bottles collected were not eligible for deposit refund) was used to extrapolate the proportion of refundable bottles. Using this method, the proportion of deposit-eligible bottles is expected to only account for approximately 4% of total litter collected. This would demonstrate that Montréal's bottle deposit system is likely successful in mitigating waste of deposit-eligible bottles, as the majority of bottle litter composition appears to be non-deposit bottle types (primarily water bottles). These findings also support that the inclusion of all beverage containers 100 mL to 2 L in this deposit program by Fall 2022 would likely result in reductions to the remaining plastic bottle litter sources. Finally, Montréal was found to have a larger proportion of plastic bags compared to Vancouver and Toronto. Although Montréal prohibited plastic bags in 2018, it is possible that the close timeframe of this study (2019) did not allow for sufficient time to evaluate the impacts of this SUP ban. It is recommended that future studies be conducted to determine whether this particular program has an impact on plastic litter in the region.

5.2.4 Halifax

In terms of wrapper litter, Halifax (23%) was found to have a comparable proportion to Montréal (25%), and differing results for Toronto (18%) and Vancouver (34%). As the only studied location without EPR, these results do not give clear evidence that EPR reduces SUP litter. However, previous research does indicate that EPR implementation could be widely beneficial to Nova Scotia through reducing SUP waste and supporting improved solid waste management (Diggle & Walker, 2021). Further, Halifax was found to have the smallest proportion of bottle caps (13%) and one of the smallest proportions of plastic bottles (6%). These results may indicate that Nova Scotia's bottle deposit program is successful in mitigating plastic bottle litter. These findings are corroborated by past meta-reviews that strongly indicate that cash-for-return instruments reduce beverage container litter (Schuyler et al., 2018; Karasik et al., 2020). Further, previous litter collection studies in Nova Scotia noted a steep decline in deposit-eligible containers following implementation of the province's deposit-return program (Oakley et al., 2008), suggesting the success of bottle-deposit programs in the region. In this study, Halifax had the largest proportion of plastic bags (12%), tied with Montréal (12%). As collection for this study was conducted prior to the Nova Scotia bag ban, it would be valuable to compare this proportion with future litter studies to determine whether the bag ban impacts litter proportions. Finally, Halifax was seen to have much higher proportions of sanitary waste, which is corroborated by previous research findings (Walker et al., 2006). From the GP dataset, tampon applicators were the highest litter type collected in Halifax (~27%), compared to Montréal (0.36%), Toronto (0%) and Vancouver (0%). A similar trend was observed in the larger GCSC dataset: Halifax (6.6%), Vancouver (1.8%), Montréal (1.5%), and Toronto (0.5%). Other litter collections in this region have also found high quantities of sanitary waste, with 381 plastic tampon applications collected on a 150m shoreline in Dartmouth (CBC News, 2018). Halifax accounts for 42% of Nova Scotia's sewage and runoff (Woodford, 2018), and therefore, these results would seem to indicate a deficiency in current wastewater treatment in the region, as well as poor education on the proper disposal methods for sanitary waste, such as tampon applicators.

6. Recommendations

Through Canada's Zero Plastic Waste Strategy, and subsequent Canada-wide Action Plans, a variety of SUP management measures are suggested, including EPR, aquatic waste management, and distributional bans (CCME, 2018; CCME, 2019; CCME, 2020). Based on the findings of the urban brand audits and litter collections analyzed in this study, several suggested management measures are likely insufficient to accomplish strategy goals and overall reduce SUPs in the marine environment. Presented below are recommendations to strengthen current, insufficient Canadian SUP management measures to better align with the goal of reducing SUPs in the environment.

6.1 Distributional Ban

Canada has proposed a distributional ban on six SUP products: plastic checkout bags, stir sticks, six-pack rings, food service ware made from problematic plastics, straws, and cutlery (Government of Canada, 2020). This ban fails to target litter categories that appear to make up most SUP litter found in Canada, such as wrappers and bottle caps (36-54% of litter collected in urban locations via GCSC data). Under proposed Canadian SUP management, only material specifications are used as a strategy for food wrappers (ECCC, 2019a). This management measure fails to address the issue of food wrapper litter in the environment or provide a strategy that could reasonably mitigate environmental impacts. Similarly, only EPR or other collection and recycling requirements are proposed to regulate plastic beverage bottles and caps (ECCC, 2019a).

As EPR programs do not seem to impact environment litter quantities in our study or Harris et al. (2021), it is unlikely that EPR will largely mitigate beverage litter in the environment. In Scotland, marine litter is managed through a multifaceted approach that prioritizes public education to promote behavioural change, employs stringent monitoring and penalties for littering, and regulates that packaging is the minimum amount to maintain safety and hygiene (Marine Scotland, 2014; UNEP, 2016): Canada's SUP mitigation strategy would benefit from inclusion of similar policies. Product design requirements could also help mitigate the high quantities of bottle caps found in the environment. For instance, the European Union's directive 2019/904 only allows sale of containers where "caps and lids remain attached to the container for the products' intended use stage" (EU, 2019, p.10), in order to reduce dispersal of caps into the environment. Canada should consider similar product design requirements, while also enhancing plastic bottles retention through deposit-return scheme programs. Additionally, the proposed SUP ban should encompass a wider variety of SUPs (as many as feasible) to strengthen litter reduction in the environment (Walker & Xanthos, 2018).

Overall, Canada's SUP ban fails to consider the environmental implications of single-use items. Herberz et al. (2020) suggest that single-use items cause harmful emissions, including 'alternative' single-use products derived from renewable resources, such as wood. Instead, bans should holistically promote transition to multi-use products through more general single-use item bans or price premiums for single-use items (Herberz et al., 2020; Karasik et al., 2020). Although perhaps beyond the scope of the Government of Canada's current goals, which focus exclusively on SUPs, future strategies should focus on mitigating single-use products and enhancing incentives for multi-use alternatives.

6.2 EPR

Under the Zero Plastic Strategy, several products are listed under the category 'extended producer responsibility **or** other collection, recycling requirements' (ECCC, 2019a). Due to this ambiguity and lack of detailed action plan, proposed EPR could include beverage bottles and caps, cigarette filters, and disposable personal care items. Alternatively, this category might suggest the use of deposit-return programs for products such as bottles or cigarettes. These ambiguities highlight the need for more clear, actionable government directives to support SUP reduction, as well as improved transparency with the Canadian public. Regardless, the Canadian EPR policy is not sufficient to address improperly disposed waste and subsequent environmental implications.

The proposed Canadian EPR policy for SUPs would benefit from closer alignment with the Polluter Pays Principle (PPP). Although EPR is an extension of the PPP (Raubenheimer & Urho, 2020), in practice the Canadian EPR strategy fails to address the full social and environmental costs of SUP pollution. The PPP is fundamental to a variety of international environmental laws, such as the UN Framework Convention on Climate Change Article 4.1 (UN, 1992). Inferable from its name, the PPP stipulates that polluters should be held responsible for the cost of pollution they produce, including the social and environmental costs (Khan, 2015). Pivotal to the PPP is the link between size of change and societal/environmental damage (Pearce & Turner, 1992). The current Canadian approach to EPR does not indicate that social or environmental costs will be borne by producers, demonstrating a failure to address marine and environmental SUP litter. Monetary valuation of environmental damages could be estimated through cost benefit analysis variations that consider non-marketed environmental goods and services (O'Connor, 1997; Khan, 2015). Further, Canada would benefit from expanding the list of products regulated under EPR. For instance, the EU requires EPR schemes for any SUP product in which no suitable alternative exists, as well as requires that polluters "cover the necessary costs of waste management and cleanup of litter, as well as the costs of awareness raising measures to prevent and reduce such litter" (EU, 2019, p.5). Products covered under this EPR scheme in the EU directive include food containers, packets/wrappers, beverage containers (up to 3L), beverage cups, plastic bags, wet wipes, balloons, and tobacco products (EU, 2019). Clearly, the current Canadian plan for EPR does not adequately address the societal and environmental costs of SUP pollution, and also only covers a small number of products. Therefore, it is recommended that the Canadian EPR strategy better include fundamental PPP objectives by requiring polluters to bear the true costs associated with SUP, as well as extend the list of products proposed under the EPR framework to encompass SUPs that do not have viable alternatives. Any PPP-based policies must consider the entire plastics supply chain, including producers of plastic raw materials, such as petroleum companies.

6.3 Education & Awareness

Under the Zero Plastic Waste Action Plan, the only direct mention of public education and awareness occurs in Phase 2, Action 1: 'Information exchange and awareness' (CCME, 2020). Elements of this action item include provide clear and consistent information to consumers (i.e., open data, product labels); inspire Canadians to make sustainable choices; inform consumers and influencers; and provide guidance to industry (CCME, 2020). None of the current strategies include actionable, clear methods for achieving these overarching goals. Additionally, there are no action items to directly prevent improper waste disposal.

Public education and awareness are essential to promote SUP reduction and prevent marine litter (Pettipas et al., 2016; Hartley et al., 2018; Kerscher, 2019; Napper & Thompson, 2020). Incorporation of effective education, outreach, and awareness can support consumer behaviour change through overcoming information deficits (De Young, 1993; Pettipas et al., 2016; Bartolotta & Hardy, 2018). Education effectiveness can also be enhanced through coupling with positive incentives, such as monetary or social reinforcement (De Young, 1993; Bartolotta & Hardy, 2018).

Canadian SUP reduction measures would benefit from inclusion of actions to enhance both formal and non-formal education, particularly in youth. Inclusion of plastic and ocean education in school curricula can promote ecological thinking, sustainable consumption, and other behaviour changes that support ocean protection (Pettipas et al., 2016; Kerscher, 2019). SUP education should be integrated into various subject areas and undertake a more interdisciplinary approach (Kerscher, 2019) to address the complexity of this issue while also promoting innovation and critical thinking. Beyond the classroom, informal education opportunities, such as educational campaigns and museums, are useful to reach broader audiences (Ham & Krumpe, 1996; Baechler et al., 2021). Effective messaging that links conservation objectives to achievable consumer actions may empower consumer behaviour changes (Ballantyne et al., 2007; Napper & Thompson, 2020; Baechler et al., 2021). For instance, an ocean plastics museum exhibit at the Oregon Coast Aquarium supported consumer awareness and demonstrated an increase in participant desire to address marine plastics (Baechler et al., 2021). It is recommended that formal and informal education target youth, as they represent the next generation of consumers, and also promote larger societal changes through influencing behaviours of their families and close communities (Vaughan et al., 2003; Prata et al., 2019).

The use of product labeling, as recommended by the CCME (2020), can also support improved consumer awareness and positive behavioural changes (Kerscher, 2019; EU, 2019). Consumer labelling on some plastic products in the EU became mandatory on July 3, 2021 (EU, 2019). Goals of the EU labelling program include distinguishing biodegradable and composable plastics, as well as product labelling to inform consumers of plastic content, proper disposal methods, and environmental harm of litter (Kerscher, 2019: EU, 2019). SUPs requiring product labels in the EU are sanitary products (e.g., tampons), wet wipes, tobacco products with plastic filters, and beverage cups (EU, 2019). This type of labelling could be valuable within Canada, especially in regions with high amount of improperly disposed sanitary waste. As Canada does not currently appear to have an approach for labeling SUP product, the approach used in the EU could provide valuable insight to develop this consumer awareness initiative. Finally, as discussed previously, there does not appear to be targeted measures to directly mitigate improper SUP disposal and littering. It is recommended that education programs and anti-littering campaigns be developed (Hardesty et al., 2014). Although education and awareness campaigns can be expensive, an approach similar to the EU where EPR includes producer responsibility to cover costs of awareness raising measures (EU, 2019) can support development of effective education initiatives while decreasing burden on governments.

6.3.1 Citizen Science

Citizen science can include community groups from youth to adults, and involve participation in many stages of research, including data design, collection, and analysis (Hardesty et al., 2014; van der Velde et al., 2017). Beach and environmental cleanups are well-suited to citizen science projects, as litter is often easily identifiable and quantifiable, and collection and documentation can be undertaken with minimal training (Bergmann et al., 2017; Ambrose et al., 2019). For instance, when evaluating volunteer collection efficacy and amount of training, no significant difference was observed between groups that received one or two weeks of training (Hardesty et al., 2014). Employing citizen science programs for marine debris can greatly increase sampling power (Hardesty et al., 2014; Zettler et al., 2017), while providing valuable information for management decisions and contributing to improved understanding of magnitude, sources, and temporal changes of SUP litter (Hardesty et al., 2014; PAME 2019; Ammendolia & Walker, 2022). Beyond supporting research data needs, citizen science can also raise awareness on environmental issues, bridge gaps between the public and scientists, and support interdisciplinary, innovative solutions (Zettler et al., 2017; Schnurr et al., 2018; Napper & Thompson, 2020).

Imperative to successful citizen science is the use of sampling methodologies that are straightforward and can be easily replicated by volunteers with limited training (Hardesty et al, 2014; van der Velde et al., 2017; Zettler et al., 2017). Training can also help to ensure the reproducibility and reliability of collected data, while studies also indicate that with training, data collection conducted by citizen scientists can be as efficient as researchers (Hardesty et al, 2014; van der Velde et al., 2017). Within Canada, there is disparity between the citizen science collection methods employed by NGOs or litter documentation apps, such as the GCSC, GP, and Litterati. It is recommended that standardized methodologies be developed and employed to better allow for data use in scientific literature and promote direct comparison between data collected by different organizations. Currently, GCSC does not document brands in their collection, and GP reporting differs between collection regions in terms of thoroughness of documentation and data gaps. It would be advisable that future citizen science projects employ methodologies that minimize data gaps through clear documentation standards and volunteer training, as well as incorporate brand data. Although some recommendations for standardized data collection have been developed, such as UNEP (2009), many do not include documentation of litter brands (NOAA, 2013; Jambeck & Johnsen, 2015; GESAMP, 2019) (Table 3). Future research projects could further investigate methodologies to best incorporate research data needs, including brand audit data, to better support alignment between citizen science projects and academic research projects.

Table 3: Examples of Citizen Science SUP collection programs. Modified from Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (2019).

Organization	Scientific Goals	Website
Great Canadian Shoreline Cleanup	Macro-litter abundance and composition.	https://www.shorelinecleanup.ca/
Greenpeace Brand Audit	Macro-litter abundance, composition, and brands.	https://www.greenpeace.org/usa/wp-content/uploads/2017/10/Plastics-Toolkit.pdf
BreakFreeFromPlastic Brand Audit	Macro-litter abundance, composition, and brands.	https://www.breakfreefromplastic.org/
Litterati	Macro-litter abundance. Some composition and brand data.	https://litterati.org/
Marine Debris Tracker	Marine litter composition.	https://debristracker.org/
Ocean Conservancy: International Coastal Clean-up & Clean Swell App	Macro-litter abundance and composition.	https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/
International Pellet Watch	Collection of pellets for chemical analysis.	http://pelletwatch.org/

6.4 Coordinated Multi-Level Management Approach

As a transboundary issue, SUPs require coordination on various scales to adequately address marine debris (Gold et al., 2013; Dauvergne, 2018; Walker & McGuinty, 2021). On a global scale, conventions and treaties are necessary to develop minimum global standards, as well as target trans-national and global polluters. National and regional SUP mitigation strategies are also vital to build on global standards to create comprehensive, targeted approaches. These study results support a multi-level management approach, as seen from the diversity of global and local brands found in both urban and remote island litter audits. Further, results from Sable Island would suggest that improved waste management and SUP regulations in Canada could help mitigate most litter found on this remote island. The 13.3% of collected litter from other countries support the importance of global coordination on SUP reduction. The following section outlines recommendations for designing a coordinated multi-level management approach to address SUPs.

6.4.1 Global Scale

The transboundary nature of marine plastics requires global coordination (Walker, 2018; Beaumont et al., 2019; Linnebjerg et al., 2021). Development of a global treaty with binding and measurable targets, robust enforcement mechanisms, and collaboration to promote development of a circular plastic economy is necessary to support global SUP reduction (Gold et al., 2013; Worm et al., 2017; WEF, 2016; Tessnow-von Wysocki & Le Billon, 2019). Such a treaty should be designed to incorporate flexibility to allow for adaptive management and incentivize participation through rewarding compliance and deterring non-compliance (Gold et al., 2013; Tessnow-von Wysocki & Le Billon, 2019). The agreement should also actively consider the entire lifecycle of plastics, including land- and sea-based sources, and provide measures to support a more circular, global plastics economy (Gold et al., 2013; Raubenheimer & Urho, 2020).

Raubenheimer and Urho (2020) have envisioned a global EPR scheme that suggests global minimum design standards. Incorporation of EPR into a global plastics treaty could help to ensure accountability for trans-national companies. Previous treaties and conventions can serve as tools to help develop an effective global, plastics treaty. For instance, the Montréal Protocol is suggested as a model to regulate the global plastics industry through reducing virgin plastic production and regulating additives on a global level (Gold et al., 2013; Raubenheimer & McIlgorm, 2017; Tessnow-von Wysocki & Le Billon, 2019). Further, minimum global standards could be required for international trade of plastic products, helping to mitigate products that complicate waste management or are not recyclable (Worm et al., 2017; Raubenheimer & Urho, 2020).

Marine plastics are transboundary impacting both areas within national jurisdictions and the high seas. It is recommended that international efforts concentrate on developing a binding treaty with measurable targets and strong enforcement, which ensures producer accountability and considers the entire plastics lifecycle.

6.4.2 National & Regional Scales

SUP mitigation policies, such as bottle deposits and EPR, are currently fragmented across Canada, with differing management measures between provinces and municipalities. There is strong evidence to support the use of mitigation measures like cash for return schemes: average proportion of containers in regions with return schemes are 40% lower than areas without such measures (Schuyler et al., 2018; Karasik et al., 2020). Further, the efficacy of EPR and bans are also well-documented (Schnurr et al., 2018; Leal Filho et al., 2019; Prata et al., 2019; Diggle & Walker, 2020; Karasik et al., 2020). All of this evidence supports implementation of national policies to standardize SUP mitigation measures across Canada to ensure minimum, effective mitigation strategies exist across jurisdictions and minimize existing fragmentation (i.e., lack of EPR in Nova Scotia or bottle deposit programs in Ontario).

Solutions, however, also need to consider local conditions and context to be effective (Chen, 2015; Löhr et al., 2017). Hence, regional flexibility within any national policy is also recommended. This will allow regions to target litter types or brands that may disproportionately impact their region, while also considering local community dynamics to develop targeted education and outreach programs. In summary, further action is required at all levels: global, national, and regional to actively and adequately manage transboundary issues, such as marine plastics. A potential distribution of jurisdictional responsibilities is outlined in Figure 41.

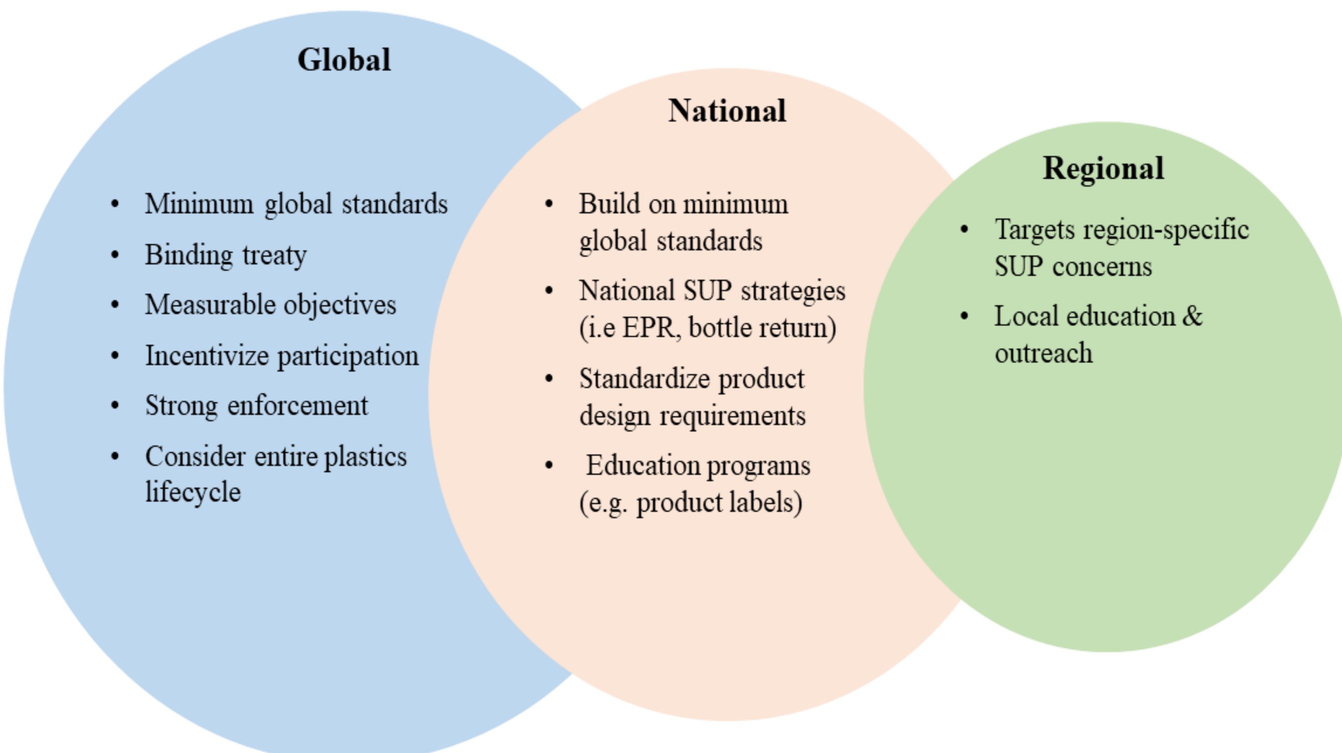

Figure 41: Recommended distribution of responsibilities and actions for each jurisdictional level.

6.5 Summary of Recommendations

- Implementation of national, standardized SUP mitigation policies to minimize fragmentation between jurisdictions.
    - More extensive development of EPR, polluter-pays strategies, bottle deposit programs, SUP bans, and public education.
        - Expand EPR framework to include all SUPs that do not have viable alternatives.
        - Enhance formal and informal SUP education.
    - More accurately reflect the true cost of plastic litter (including societal and environmental costs) in policies.
    - Incorporate regional flexibility to allow for more targeted approaches.
- Develop approaches to directly combat improper disposal of SUPs into the environment.
    - Establish product design requirements that mitigate environmental dispersal (e.g., caps that remain attached to containers, eliminate unnecessary packaging).
    - Consider product labelling or education campaigns to support proper waste disposal.
    - Enhance anti-litter campaigns, litter monitoring/enforcement, and sanctions.
- Establish a global treaty or convention that supports global coordination on SUPs and provides minimum global standards.
    - Ensure treaty is binding with measurable targets and strong enforcement.
    - Include producer accountability for trans-national polluters, and consideration of the entire plastics life cycle.
- Standardize collection methods for citizen science litter cleanups to support alignment between citizen science and academic research projects.

7. Conclusions

7.1 Study Limitations

Certain limitations result from the use of beach cleanup data. Beach cleanups tend to target larger (macro: >2.5cm), intact litter items, thereby underestimating fragmented, smaller (meso: 5 mm to 2.5 cm; and micro: <5mm) plastic debris (Zbyszewski et al. 2014; ECCC, 2020c). Further, certain physical attributes, such as plastic colour, as well as observer experience can bias collection and documentation of plastic debris (Lavers et al., 2016; Mallory et al., 2021)—this could be mitigated through training and thorough collection methods. Finally, high quantities of debris are buried 1-10cm below the beach surface (Lavers & Bond, 2017; Lavers et al., 2019). Therefore, collection methods that focus only on the surface layer will likely underestimate debris quantities (Lavers et al., 2019) and may not accurately reflect true debris proportions.

For this study, sample size and data gaps, as well as inconsistency in collection and documentation methods, limit statistical analysis capabilities. Variations in collection and documentation between organizations also limits compatibility and statistical comparison between datasets. Further, some differences in litter types between urban and remote locations in this study may result from largely different collection methods employed by GP and SII, particularly the different categories that were used to classify litter. Additionally, on Sable Island only intact, branded plastic litter with complete label information were collected, thereby excluding most fishing-related debris. This may also limit documentation of quickly degrading plastic products, as products without clearly identifiable branding were not collected. As such, this study is likely not reflective of the total proportions of plastic on Sable Island, but instead largely highlights litter types for branded products. Finally, this research used pre-existing citizen science data collected for other purposes: this limits the analysis to documented litter categories and is an inherit limitation of using data for purposes other than for which it was collected for (Harris et al., 2021).

7.2 Future Research Directions

Limited studies exist comparing branded plastic litter between urban and remote locations. Future research could expand on this study area by examining other geographic locations to determine trends and add to the scientific literature on branded marine debris. Further, current citizen science collection of debris does not follow standardized collection methods. It is recommended that methodologies be developed that standardize collection while best incorporating both research and citizen science project needs. Additionally, development of monitoring frameworks and collection methodologies is advisable to directly evaluate the efficacy of implemented SUP mitigation measures. Direct design to capture future policy efficacy would mitigation the limitations that stem from using data collected for other purposes, while also ensuring research continuity on SUP policy efficacy, thereby providing necessary information for adaptive management practices. Finally, it is recommended that future research continue to monitor trends in litter type composition and brand prevalence. Brand audits are vital to understand the role of corporations in global plastic waste and reinforcing accountability of producers for the full life cycle of their products (Gaia, 2019). This will allow continuity of this research through examining trends, validating results, and overall providing improved understanding of SUP and marine plastic composition in Canada.

7.3 Conclusion

Plastics are pervasive in modern society, causing a range of ecological, social, and economic impacts. SUPs, designed to be discarded after one use, are a major contributor to global solid waste. A variety of SUP mitigation measures exist, including EPR, disincentive instruments (i.e. bans, fees), cash-for-return schemes, and public education/outreach. Canada has proposed implementation of some SUP mitigation measures, particularly through the federal ban of six SUPs. Using brand audit and cleanup data, this research examined litter types and brand proportions for four urban and one remote location across Canada, in order to provide recommendations to improve Canadian SUP mitigation policy and management. Research found that certain SUP products, namely plastic bottles, and food containers, appear to transit to remote locations in higher proportions. Further, Sable Island litter appears to predominately originate from Canadian sources. Both findings indicate that improved Canadian SUP regulations could also support SUP mitigation on this remote island. Additionally, six brands (Nestlé, Coca-Cola, Tim Horton’s, PepsiCo, Starbucks, and McDonald’s) were found to disproportionally contribute to Canadian SUP litter, comprising 45% of branded litter collected in urban locations, and 39% of branded litter collected at all study locations. Creation of policies based on the polluter-pays principles could help to target prevalent polluters, while also promoting transition to more sustainable product designs.

Overall, the results of this study indicate that current Canadian SUP mitigation measures are likely insufficient to adequately reduce SUP leakage into natural environments. Several recommendations have been suggested to strengthen current Canadian SUP management. First, the development of national, standardized SUP mitigation policies with extensive EPR, polluter-pays strategies, bottle deposit programs, SUP bans, and public education approaches are recommended. It is also imperative that national policies accurately reflect the true cost of plastic litter, including societal and environmental costs, and directly combat improper SUP disposal. Regional flexibility should also be incorporated to allow for targeted, local approaches. Further, the transboundary nature of marine debris supports the establishment of a global treaty. A global SUP treaty should be binding, with measurable targets and strong enforcement to develop minimum global standards and producer accountability for trans-national polluters.

Marine plastics are a pervasive, transboundary issue that requires global coordination and strong SUP mitigation policies. It is critical that governments and jurisdictions recognize the importance of SUP reduction, to support the transition to more sustainable consumerism practices and to protect the environment for future generations.

References

Abalansa, S., El Mahrad, B., Vondolia, G. K., Icely, J., & Newton, A. (2020). The marine plastic litter issue: A social-economic analysis. *Sustainability*, *12*(20), 8677. https://doi.org/10.3390/su12208677

Acampora, H., Lyashevska, O., Van Franeker, J. A., & O'Connor, I. (2016). The use of beached bird surveys for marine plastic litter monitoring in Ireland. *Marine Environmental Research*, *120*, 122–129. https://doi.org/10.1016/j.marenvres.2016.08.002

Ambrose, K. K., Box, C., Boxall, J., Brooks, A., Eriksen, M., Fabres, J., Fylakis, G., & Walker, T. R. (2019). Spatial trends and drivers of marine debris accumulation on shorelines in South Eleuthera, The Bahamas using citizen science. *Marine Pollution Bulletin*, *142*, 145–154. https://doi.org/10.1016/j.marpolbul.2019.03.036

Ammendolia, J., & Walker, T. R. (2022). Citizen science: A way forward in tackling the plastic pollution crisis during and beyond the COVID-19 pandemic. *Science of The Total Environment*, *805*, 149957. https://doi.org/10.1016/j.scitotenv.2021.149957

Andrades, R., Santos, R. G., Joyeux, J.-C., Chelazzi, D., Cincinelli, A., & Giarrizzo, T. (2018). Marine debris in Trindade Island, a remote island of the South Atlantic. *Marine Pollution Bulletin*, *137*, 180–184. https://doi.org/10.1016/j.marpolbul.2018.10.003

Andrady, A. L. (2015). Persistence of plastic litter in the oceans. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine Anthropogenic Litter* (pp. 57–72). Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_3

Baechler, B. R., Granek, E. F., Carlin-Morgan, K. A., Smith, T. E., & Nielsen-Pincus, M. (2021). Aquarium visitor engagement with an ocean plastics exhibit: Effects on self-reported intended single-use plastic reductions and plastic-related environmental stewardship actions. *Journal of Interpretation Research*, *25*(2), 88–117. https://doi.org/10.1177/10925872211021183

Ballantyne, R., Packer, J., Hughes, K., & Dierking, L. (2007). Conservation learning in wildlife tourism settings: Lessons from research in zoos and aquariums. *Environmental Education Research*, *13*(3), 367–383. https://doi.org/10.1080/13504620701430604

Banerjee, T., Srivastava, R. K., & Hung, Y.-T. (2014). *Chapter 17: Plastics Waste Management in India: An Integrated Solid Waste Management Approach*. World Scientific. https://doi.org/10.1142/9789814449175_0017

Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 1985–1998. https://doi.org/10.1098/rstb.2008.0205

Bartolotta, J. F., & Hardy, S. D. (2018). Barriers and benefits to desired behaviors for single use plastic items in northeast Ohio's Lake Erie basin. *Marine Pollution Bulletin*, *127*, 576–585. https://doi.org/10.1016/j.marpolbul.2017.12.037

Beaumont, N. J., Aanesen, M., Austen, M. C., Börger, T., Clark, J. R., Cole, M., Hooper, T., Lindeque, P. K., Pascoe, C., & Wyles, K. J. (2019). Global ecological, social and economic impacts of marine plastic. *Marine Pollution Bulletin*, *142*, 189–195. https://doi.org/10.1016/j.marpolbul.2019.03.022

Bergmann, M., Gutow, L., & Klages, M. (Eds.). (2015). *Marine anthropogenic litter*. Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3

Bergmann, M., Lutz, B., Tekman, M. B., & Gutow, L. (2017). Citizen scientists reveal: Marine litter pollutes Arctic beaches and affects wild life. *Marine Pollution Bulletin*, *125*(1–2), 535–540. https://doi.org/10.1016/j.marpolbul.2017.09.055

Bodansky, D. (2010). The art and craft of international environmental law. *School of Law University of Geogia*. https://digitalcommons.law.uga.edu/fac_artchop/532

Borrelle, S. B., Ringma, J., Law, K. L., Monnahan, C. C., Lebreton, L., McGivern, A., Murphy, E., Jambeck, J., Leonard, G. H., Hilleary, M. A., Eriksen, M., Possingham, H. P., De Frond, H., Gerber, L. R., Polidoro, B., Tahir, A., Bernard, M., Mallos, N., Barnes, M., & Rochman, C. M. (2020). Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. *Science*, *369*(6510), 1515–1518. https://doi.org/10.1126/science.aba3656

BreakFreeFromPlastic (BFFP). (2017). *Green Groups Reveal Top Plastic Polluters Following Massive Beach Cleanup on Freedom Island*. BFFP. https://www.breakfreefromplastic.org/2017/12/17/green-groups-reveal-top-plastic-polluters-following-massive-beach-cleanup-on-freedom-island/

BreakFreeFromPlastics (BFFP). (2019). *Branded: Vol. II Identifying the World's Top Corporate Plastic Polluters*. BFFP. https://www.breakfreefromplastic.org/wp-content/uploads/2020/07/branded-2019.pdf

BreakFreeFromPlastics (BFFP). (2020). *Branded: Vol. III Demanding Corporate Accountability for Plastic Pollution*. BFFP. https://www.breakfreefromplastic.org/wp-content/uploads/2020/12/BFFP-2020-Brand-Audit-Report.pdf

British Columbia (BC). (2020). *Environmental Management Act: B.C. Reg. 449/2004*. Government of British Columbia. https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/449_2004

Brooks, A. L., Wang, S., & Jambeck, J. R. (2018). The Chinese import ban and its impact on global plastic waste trade. *Science Advances*, *4*(6), eaat0131. https://doi.org/10.1126/sciadv.aat0131

Canadian Council of Ministers of the Environment (CCME). (2009). *A Canada-wide strategy for sustainable packaging*. CCME. https://ccme.ca/en/res/sustainable_pkg_strategy_e.pdf

Canadian Council of Ministers of the Environment (CCME). (2018). *Strategy on zero plastic waste*. CCME. https://ccme.ca/en/res/strategyonzeroplasticwaste.pdf

Canadian Council of Ministers of the Environment (CCME). (2019). *Canada-wide action plan on zero plastic waste: Phase 1*. CCME. https://ccme.ca/en/res/1589_ccmecanada-wideactionplanonzeroplasticwaste_en-secured.pdf

Canadian Council of Ministers of the Environment (CCME). (2020). *Canada-wide action plan on zero plastic waste: Phase 2*. CCME. https://ccme.ca/en/res/ccmephase2actionplan_en-external-secured.pdf

Canadian Council of Ministers of the Environment (CCME). (2021). *Best management practices for disposal bans, levies, and incentives for end-of-life plastics*. CCME. https://ccme.ca/en/res/finaldisposalbansbmps-ensecured.pdf

Canadian Plastics Pact (CPP). (2021). *CPP*. https://plasticspact.ca

Canadian Stewardship Services Alliance (CSSA). (2021). *Helping businesses meet their packaging & paper product recycling obligations in Canada: guidebook for stewards*. CSSA. https://www.cssalliance.ca/wp-content/uploads/2021/01/CSSA-Guidebook_May-2021.pdf

CBC News. (2018). *That tampon applicator you just flushed could end up on a beach*. CBC News. https://www.cbc.ca/news/canada/nova-scotia/plastic-tampon-applicators-

1.4914538#:~:text=Halifax%20Water%20spokesperson%20James%20Campbell,or%20people%20on%20commercial%20vessels.

Chamas, A., Moon, H., Zheng, J., Qiu, Y., Tabassum, T., Jang, J. H., Abu-Omar, M., Scott, S. L., & Suh, S. (2020). Degradation rates of plastics in the environment. *ACS Sustainable Chemistry & Engineering*, *8*(9), 3494–3511. https://doi.org/10.1021/acssuschemeng.9b06635

Chen, C.-L. (2015). Regulation and management of marine litter. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine Anthropogenic Litter* (pp. 395–428). Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_15

Chen, X., Xiong, X., Jiang, X., Shi, H., & Wu, C. (2019). Sinking of floating plastic debris caused by biofilm development in a freshwater lake. *Chemosphere*, *222*, 856–864. https://doi.org/10.1016/j.chemosphere.2019.02.015

Container Recycling Institute. (2021). *Bottle bill resource guide: Québec*. https://www.bottlebill.org/index.php/current-and-proposed-laws/canada/quebec

Convention on Biological Diversity (CBD). (2015). *Aichi Biodiversity Targets.* UNEP. https://www.cbd.int/sp/targets/

Cordier, M., & Uehara, T. (2019). How much innovation is needed to protect the ocean from plastic contamination? *Science of The Total Environment*, *670*, 789–799. https://doi.org/10.1016/j.scitotenv.2019.03.258

Damian, M., & Fraser, G. S. (2020). Incorporation of anthropogenic debris into double-crested cormorant nests, Toronto, Ontario. *Journal of Great Lakes Research*, *46*(6), 1761–1766. https://doi.org/10.1016/j.jglr.2020.08.006

Dauvergne, P. (2018). Why is the global governance of plastic failing the oceans? *Global Environmental Change*, *51*, 22–31. https://doi.org/10.1016/j.gloenvcha.2018.05.002

De Young, R. (1993). Changing behavior and making it stick: The conceptualization and management of conservation behavior. *Environment and Behavior*, *25*(3), 485–505. https://doi.org/10.1177/0013916593253003

Deng, Y., Zhang, Y., Lemos, B., & Ren, H. (2017). Tissue accumulation of microplastics in mice and biomarker responses suggest widespread health risks of exposure. *Scientific Reports*, *7*(1), 46687. https://doi.org/10.1038/srep46687

Department of Fisheries & Oceans (DFO). (2018). *Canada's oceans now: Atlantic ecosystems 2018*. Government of Canada. https://waves-vagues.dfo-mpo.gc.ca/Library/40781987.pdf

Department of Fisheries & Oceans (DFO). (2019). *The Great Lakes-St. Lawrence River system*. Government of Canada. https://waterlevels.gc.ca/C&A/glsystem-eng.html

Diggle, A., & Walker, T. R. (2020). Implementation of harmonized Extended Producer Responsibility strategies to incentivize recovery of single-use plastic packaging waste in Canada. *Waste Management*, *110*, 20–23. https://doi.org/10.1016/j.wasman.2020.05.013

Diggle, A., & Walker, T. R. (2021). *Determining Potential Business Impacts of an Extended Producer Responsibility Program for the Printed Paper and Packaging Waste Stream in Nova Scotia*. Divert NS.https://divertns.ca/sites/default/files/researchreportsfiles/2021-09/EPRforPPP_DiggleWalker.pdf

Dikgang, J., Leiman, A., & Visser, M. (2012). Analysis of the plastic-bag levy in South Africa. *Resources, Conservation and Recycling*, *66*, 59–65. https://doi.org/10.1016/j.resconrec.2012.06.009

Discover Halifax. (2017). *11 facts about Sable Island that might surprise you*. https://discoverhalifaxns.com/surprising-sable-island-facts/

Discover Halifax. (2019). *8 reasons to visit Halifax over any other maritime city*. https://new.discoverhalifaxns.com/8-reasons-to-visit-halifax-over-any-other-maritime-city/

Divert NS. (2018). *2017 Waste Audit Report*. Divert NS. https://divertns.ca/assets/files/WasteAudit2017.pdf

Divert NS. (2019). *2018-2019 Annual Report*. Nova Scotia Adopt-A-Highway Program. https://www.nsadoptahighway.ca/wp-content/uploads/2020/01/2019-Annual-Report.pdf

Divert NS. (2020). *2019-2020 Annual Report*. Nova Scotia Adopt-A-Highway Program. https://www.nsadoptahighway.ca/wp-content/uploads/2020/11/2020-Annual-Report.pdf

Driedger, A. G. J., Dürr, H. H., Mitchell, K., & Van Cappellen, P. (2015). Plastic debris in the Laurentian Great Lakes: A review. *Journal of Great Lakes Research*, *41*(1), 9–19. https://doi.org/10.1016/j.jglr.2014.12.020

Duhec, A. V., Jeanne, R. F., Maximenko, N., & Hafner, J. (2015). Composition and potential origin of marine debris stranded in the Western Indian Ocean on remote Alphonse Island, Seychelles. *Marine Pollution Bulletin*, *96*(1–2), 76–86. https://doi.org/10.1016/j.marpolbul.2015.05.042

Éco Entreprises Québec (ÉEQ). (2019). *Gazette Officielle du Québec: O.C. 550-2019*. Gouvernement du Québec. https://www.eeq.ca/wp-content/uploads/Decret_550-2019_VA.pdf

Éco Entreprises Québec (ÉEQ). (2020). *Annual Report: The modernization of curbside recycling 2020*. https://www.eeq.ca/wp-content/uploads/EEQ_RA_2020_VFA.pdf

Éco Entreprises Québec (ÉEQ). (2021). *ÉEQ's mission and values*. https://www.eeq.ca/en/eeq-profile/

Edwards, S., Grushack, S., Elliot, L., Kelly, J., & Card, D. (2019). *Better together: How a deposit return system will complement Ontario's blue box program and enhance the circular economy*. Eunomia Research & Consulting. https://www.reloopplatform.org/wp-content/uploads/2019/06/Ontario-Report-Final-Issued-2.pdf

Environment and Climate Change Canada (ECCC). (2018). *Ocean plastics charter*. Government of Canada. https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/international-commitments/ocean-plastics-charter.html

Environment and Climate Change Canada (ECCC). (2019a). *A proposed integrated management approach to plastic products: Discussion paper*. Government of Canada. https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/plastics-proposed-integrated-management-approach.html

Environment and Climate Change Canada (ECCC). (2019b). *Canada's plastics science agenda*. Government of Canada. https://www.canada.ca/en/environment-climate-change/services/science-technology/canada-science-plastic-agenda.html

Environment and Climate Change Canada (ECCC). (2019c). *Economic study of the Canadian plastic industry, markets and waste*. Government of Canada. http://publications.gc.ca/collections/collection_2019/eccc/En4-366-1-2019-eng.pdf

Environment and Climate Change Canada (ECCC). (2020a). *Canada one-step closer to zero plastic waste by 2030*. Government of Canada. https://www.canada.ca/en/environment-climate-change/news/2020/10/canada-one-step-closer-to-zero-plastic-waste-by-2030.html

Environment and Climate Change Canada (ECCC) (2020b). *National waste characterization report.* Government of Canada. https://publications.gc.ca/collections/collection_2020/eccc/en14/En14-405-2020-eng.pdf

Environment and Climate Change Canada (ECCC). (2020c). *Science assessment of plastic pollution*. Government of Canada. https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/science-assessment-plastic-pollution.html

EPR Canada. (2017). *2016 Extended Producer Responsibility summary report*. EPR Canada. http://www.eprcanada.ca/reports/2016/EPR-Report-Card-2016.pdf

Eska. (2021). *Contact us*. Eska Water. https://www.eskawater.com/contact-us/

Eubeler, J. P., Bernhard, M., & Knepper, T. P. (2010). Environmental biodegradation of synthetic polymers II. Biodegradation of different polymer groups. *TrAC Trends in Analytical Chemistry*, *29*(1), 84–100. https://doi.org/10.1016/j.trac.2009.09.005

European Commission . (2020). *Circular economy action plan: For a cleaner and more competitive Europe*. European Commission. https://data.europa.eu/doi/10.2779/05068

European Union (EU). (2019). *Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment*. Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L:2019:155:FULL&from=EN

Fotopoulou, K. N., & Karapanagioti, H. K. (2017). Degradation of various plastics in the environment. In H. Takada & H. K. Karapanagioti (Eds.), *Hazardous Chemicals Associated with Plastics in the Marine Environment* (Vol. 78, pp. 71–92). Springer International Publishing. https://doi.org/10.1007/698_2017_11

Gaia. (2019). *Plastics exposed: How waste assessments and brand audits are helping Philippine cities fight plastic pollution*. Gaia. https://www.no-burn.org/waba2019/

Galgani, F., Hanke, G., & Maes, T. (2015). Global distribution, composition and abundance of marine litter. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine Anthropogenic Litter* (pp. 29–56). Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_2

Gall, S. C., & Thompson, R. C. (2015). The impact of debris on marine life. *Marine Pollution Bulletin*, *92*(1–2), 170–179. https://doi.org/10.1016/j.marpolbul.2014.12.041

Galloway, T. S., Cole, M., & Lewis, C. (2017). Interactions of microplastic debris throughout the marine ecosystem. *Nature Ecology & Evolution*, *1*(5), 0116. https://doi.org/10.1038/s41559-017-0116

Garnett, T. (2011). Where are the best opportunities for reducing greenhouse gas emissions in the food system (Including the food chain)? *Food Policy*, *36*, S23–S32. https://doi.org/10.1016/j.foodpol.2010.10.050

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

Gifford, R., & Nilsson, A. (2014). Personal and social factors that influence pro-environmental concern and behaviour: A review: personal and social factors that influence pro-environmental behaviour. *International Journal of Psychology*, n/a-n/a. https://doi.org/10.1002/ijop.12034

Gold, M., Mika, K., Horowitz, C., Herzog, M., & Leitner, L. (2013, October 1). *Stemming the tide of plastic marine litter: A global action agenda*. UCLA: Emmett Institute on Climate Change and the Environment. https://escholarship.org/uc/item/6j74k1j3

Goncalves, L., & Faure, M. (2019). International law instruments to address the plastic soup. *William & Mary Environmental Law and Policy Review*, *43*(3), 871.

Goodman, A. J., Brillant, S., Walker, T. R., Bailey, M., & Callaghan, C. (2019). A ghostly issue: Managing abandoned, lost and discarded lobster fishing gear in the Bay of Fundy in Eastern Canada. *Ocean & Coastal Management*, *181*, 104925. https://doi.org/10.1016/j.ocecoaman.2019.104925

Goodman, A. J., McIntyre, J., Smith, A., Fulton, L., Walker, T. R., & Brown, C. J. (2021). Retrieval of abandoned, lost, and discarded fishing gear in Southwest Nova Scotia, Canada: Preliminary environmental and economic impacts to the commercial lobster industry. *Marine Pollution Bulletin*, *171*, 112766. https://doi.org/10.1016/j.marpolbul.2021.112766

Government of Canada. (2020). *Zero plastic waste: Canada's actions*. Government of Canada. https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/zero-plastic-waste/canada-action.html

Government of Canada. (2021). *Canada Gazette, part 2, volume 155, number 10: Order adding a toxic substance to schedule 1 to the Canadian Environmental Protection Act, 1999*. https://canadagazette.gc.ca/rp-pr/p2/2021/2021-05-12/html/sor-dors86-eng.html

Gracia C., A., & Rangel-Buitrago, N. (2020). The invasive species *Perna viridis* on artificial substrates: A baseline assessment for the Colombian Caribbean Sea. *Marine Pollution Bulletin*, *152*, 110926. https://doi.org/10.1016/j.marpolbul.2020.110926

Great Canadian Shoreline Cleanup (GCSC). (2019). *2019 annual report*. GCSC. https://www.shorelinecleanup.ca/storage/resources/gcsc-2019annualreport-en-200512.pdf

Great Canadian Shoreline Cleanup (GCSC). (2020). *Data story maps: 2020 dirty dozen*. GCSC. https://shorelinecleanup.ca/data-story-maps

Great Canadian Shoreline Cleanup (GCSC). (2021). *About us*. GCSC. https://shorelinecleanup.ca/aboutus

Greenpeace. (2019). *Brand audit 2019 results*. Greenpeace. https://www.greenpeace.org/static/planet4-canada-stateless/2019/10/56c941b5-10-08_gp_brandaudit_infographic-en_edited.pdf

Halifax. (2021). *About Halifax: your city*. Halifax Regional Municipality. https://www.halifax.ca/about-halifax/newcomers/your-city

Ham, S. H., & Krumpe, E. E. (1996). Identifying audiences and messages for nonformal environmental education– a theoretical framework for interpreters. *Journal of Interpretation Research*, *1*(1), 11–23. https://doi.org/10.1177/109258729600100103

Hardesty, B. D., Wilcox, C., Lawson, T. J., Lansdell, M., & van der Velde, T. (2014). *Understanding the effects of marine debris on wildlife*. CSIRO. https://apo.org.au/sites/default/files/resource-files/2014-09/apo-nid41318.pdf

Harris, L., Liboiron, M., Charron, L., & Mather, C. (2021). Using citizen science to evaluate extended producer responsibility policy to reduce marine plastic debris shows no reduction in pollution levels. *Marine Policy*, *123*, 104319. https://doi.org/10.1016/j.marpol.2020.104319

Hartley, B. L., Pahl, S., Holland, M., Alampei, I., Veiga, J. M., & Thompson, R. C. (2018). Turning the tide on trash: Empowering European educators and school students to tackle marine litter. *Marine Policy*, *96*, 227–234. https://doi.org/10.1016/j.marpol.2018.02.002

Herberz, T., Barlow, C. Y., & Finkbeiner, M. (2020). Sustainability assessment of a single-use plastics ban. *Sustainability*, *12*(9), 3746. https://doi.org/10.3390/su12093746

Imhof, H. K., Sigl, R., Brauer, E., Feyl, S., Giesemann, P., Klink, S., Leupolz, K., Löder, M. G. J., Löschel, L. A., Missun, J., Muszynski, S., Ramsperger, A. F. R. M., Schrank, I., Speck, S., Steibl, S., Trotter, B., Winter, I., & Laforsch, C. (2017). Spatial and temporal variation of macro-, meso- and microplastic abundance on a remote coral island of the Maldives, Indian Ocean. *Marine Pollution Bulletin*, *116*(1–2), 340–347. https://doi.org/10.1016/j.marpolbul.2017.01.010

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science*, *347*(6223), 768–771. https://doi.org/10.1126/science.1260352

Jambeck, J. R., & Johnsen, K. (2015). Citizen-based litter and marine debris data collection and mapping. *Computing in Science & Engineering*, *17*(4), 20–26. https://doi.org/10.1109/MCSE.2015.67

Jang, Y. C., Ranatunga, R. R. M. K. P., Mok, J. Y., Kim, K. S., Hong, S. Y., Choi, Y. R., & Gunasekara, A. J. M. (2018). Composition and abundance of marine debris stranded on the beaches of Sri Lanka: Results from the first island-wide survey. *Marine Pollution Bulletin*, *128*, 126–131. https://doi.org/10.1016/j.marpolbul.2018.01.018

Jarvis, C., & Robinson, M. (2019). *Canada's recycling industry is on life-support. Here's how to fix it*. Global News. https://globalnews.ca/news/5207352/how-to-fix-canadas-recycling-industry/

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). (2019). *Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean*. UNEP.

https://wedocs.unep.org/bitstream/handle/20.500.11822/30009/plasLit.pdf?sequence=1&isAllowed=y

Karasik, R. T. V., Vegh, T., Diana, Z., Bering, J., Caldas, J., Pickle, A., Rittschof, D., & Virdin, J. (2020). *20 years of government responses to the global plastic pollution problem*. Nicholas Institute for Environmental Policy Solutions, Duke University. https://nicholasinstitute.duke.edu/publications/20-years-government-responses-global-plastic-pollution-problem

Karbalaei, S., Hanachi, P., Rafiee, G., Seifori, P., & Walker, T. R. (2021). Toxicity of polystyrene microplastics on juvenile Oncorhynchus mykiss (Rainbow trout) after individual and combined exposure with chlorpyrifos. *Journal of Hazardous Materials*, 403, 123980. https://doi.org/10.1016/j.jhazmat.2020.123980

Kaza, S., Yao, L. C., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050*. World Bank Group. http://hdl.handle.net/10986/30317

Keep Britain Tidy (KBT). (2020). *Litter composition analysis: summary report*. KBT. https://www.keepbritaintidy.org/sites/default/files/resources/20200330%20KBT%20Litter%20Composition%20Report%20-%20FINAL.pdf

Kerscher, U. (2019). Towards a sustainable future? The EU policies concerning plastics and their didactical potential for primary and secondary teaching. *Discourse and Communication for Sustainable Education*, *10*(1), 47–62. https://doi.org/10.2478/dcse-2019-0005

Ketelsen, M., Janssen, M., & Hamm, U. (2020). Consumers' response to environmentally-friendly food packaging—A systematic review. *Journal of Cleaner Production*, *254*, 120123. https://doi.org/10.1016/j.jclepro.2020.120123

Khan, M. (2015). Polluter-pays-principle: The cardinal instrument for addressing climate change. *Laws*, *4*(3), 638–653. https://doi.org/10.3390/laws4030638

King, S. (2019). *Who tops Canada's plastic polluters list this year?* Greenpeace. https://www.greenpeace.org/canada/en/story/26063/who-tops-canadas-plastic-polluters-list-this-year/

Kitz, R., Walker, T., Charlebois, S., & Music, J. (2021). Food packaging during the COVID-19 pandemic: Consumer perceptions. *International Journal of Consumer Studies*, ijcs.12691. https://doi.org/10.1111/ijcs.12691

Knowlton, A., Hamilton, P., Marx, M., Pettis, H., & Kraus, S. (2012). Monitoring North Atlantic right whale *Eubalaena glacialis* entanglement rates: A 30 yr retrospective. *Marine Ecology Progress Series*, *466*, 293–302. https://doi.org/10.3354/meps09923

Koelmans, A. A., Kooi, M., Law, K. L., & van Sebille, E. (2017). All is not lost: Deriving a top-down mass budget of plastic at sea. *Environmental Research Letters*, *12*(11), 114028. https://doi.org/10.1088/1748-9326/aa9500

Krishnakumar, S., Anbalagan, S., Kasilingam, K., Smrithi, P., Anbazhagi, S., & Srinivasalu, S. (2020). Assessment of plastic debris in remote islands of the Andaman and Nicobar Archipelago, India. *Marine Pollution Bulletin*, *151*, 110841. https://doi.org/10.1016/j.marpolbul.2019.110841

Kühn, S., Bravo Rebolledo, E. L., & van Franeker, J. A. (2015). Deleterious effects of litter on marine life. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine Anthropogenic Litter* (pp. 75–116). Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_4

Kunz, N., Mayers, K., & Van Wassenhove, L. N. (2018). Stakeholder views on extended producer responsibility and the circular economy. *California Management Review*, *60*(3), 45–70. https://doi.org/10.1177/0008125617752694

Lavers, J. L., & Bond, A. L. (2017). Exceptional and rapid accumulation of anthropogenic debris on one of the world's most remote and pristine islands. *Proceedings of the National Academy of Sciences*, *114*(23), 6052–6055. https://doi.org/10.1073/pnas.1619818114

Lavers, J. L., Dicks, L., Dicks, M. R., & Finger, A. (2019). Significant plastic accumulation on the Cocos (Keeling) Islands, Australia. *Scientific Reports*, *9*(1), 7102. https://doi.org/10.1038/s41598-019-43375-4

Lavers, J. L., Oppel, S., & Bond, A. L. (2016). Factors influencing the detection of beach plastic debris. *Marine Environmental Research*, *119*, 245–251. https://doi.org/10.1016/j.marenvres.2016.06.009

Law, K. L., Starr, N., Siegler, T. R., Jambeck, J. R., Mallos, N. J., & Leonard, G. H. (2020). The United States' contribution of plastic waste to land and ocean. *Science Advances*, *6*(44), eabd0288. https://doi.org/10.1126/sciadv.abd0288

Leal Filho, W., Saari, U., Fedoruk, M., Iital, A., Moora, H., Klöga, M., & Voronova, V. (2019). An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. *Journal of Cleaner Production*, *214*, 550–558. https://doi.org/10.1016/j.jclepro.2018.12.256

Lebreton, L. C. M., van der Zwet, J., Damsteeg, J.-W., Slat, B., Andrady, A., & Reisser, J. (2017). River plastic emissions to the world's oceans. *Nature Communications*, *8*(1), 15611. https://doi.org/10.1038/ncomms15611

Lebreton, L., Egger, M., & Slat, B. (2019). A global mass budget for positively buoyant macroplastic debris in the ocean. *Scientific Reports*, *9*(1), 12922. https://doi.org/10.1038/s41598-019-49413-5

Legislative Assembly of Ontario. (2019). *Bill 82, Single-Use Plastics Ban Act, 2019*. https://www.ola.org/en/legislative-business/bills/parliament-42/session-1/bill-82

Leite, A. S., Santos, L. L., Costa, Y., & Hatje, V. (2014). Influence of proximity to an urban center in the pattern of contamination by marine debris. *Marine Pollution Bulletin*, *81*(1), 242–247. https://doi.org/10.1016/j.marpolbul.2014.01.032

Lindhqvist, T. (2000). *Extended Producer Responsibility in cleaner production: Policy principle to promote environmental improvements of product systems* [Doctoral Thesis]. The International Institute for Industrial Environmental Economics, Lund University.

Linnebjerg, J. F., Baak, J. E., Barry, T., Gavrilo, M. V., Mallory, M. L., Merkel, F. R., Price, C., Strand, J., Walker, T. R., & Provencher, J. F. (2021). Review of plastic pollution policies of Arctic countries in relation to seabirds. *FACETS*, *6*(1), 1–25. https://doi.org/10.1139/facets-2020-0052

Linteau, P.-A. (2019). *Montreal*. The Canadian Encyclopedia. https://thecanadianencyclopedia.ca/en/article/montreal?gclid=Cj0KCQjw4v2EBhCtARIsACan3nwYpsPYWSWwFwiMjMiwWArQP9X-Ukb5yweCqMySj4_eVUDEWbAZK-4aAqVUEALw_wcB

Litterati. (2021). *Open Data*. Litterati. https://opendata.litterati.org/

Litterbase. (2021). *Biological Impacts Analysis*. Litterbase. https://litterbase.awi.de/interaction_graph

Little, S. (2020). *B.C. approves cities' single-use plastic bans, extends bottle deposits to milk containers*. Global News. https://globalnews.ca/news/7331695/bc-single-use-plastic-bans/

Liu, Z., Adams, M., & Walker, T. R. (2018). Are exports of recyclables from developed to developing countries waste pollution transfer or part of the global circular economy? *Resources, Conservation and Recycling*, *136*, 22–23. https://doi.org/10.1016/j.resconrec.2018.04.005

Liu, Z., Liu, W., Walker, T. R., Adams, M., & Zhao, J. (2021). How does the global plastic waste trade contribute to environmental benefits: Implication for reductions of greenhouse gas emissions? *Journal of Environmental Management*, *287*, 112283. https://doi.org/10.1016/j.jenvman.2021.112283

Lobelle, D., & Cunliffe, M. (2011). Early microbial biofilm formation on marine plastic debris. *Marine Pollution Bulletin*, *62*(1), 197–200. https://doi.org/10.1016/j.marpolbul.2010.10.053

Löhr, A., Savelli, H., Beunen, R., Kalz, M., Ragas, A., & Van Belleghem, F. (2017). Solutions for global marine litter pollution. *Current Opinion in Environmental Sustainability*, *28*, 90–99. https://doi.org/10.1016/j.cosust.2017.08.009

Lucas, Z. (1992). Monitoring persistent litter in the marine environment on Sable Island, Nova Scotia. *Marine Pollution Bulletin*, *24*(4), 192–199. https://doi.org/10.1016/0025-326X(92)90529-F

Mallory, M. L., Baak, J., Gjerdrum, C., Mallory, O. E., Manley, B., Swan, C., & Provencher, J. F. (2021). Anthropogenic litter in marine waters and coastlines of Arctic Canada and West Greenland. *Science of The Total Environment*, *783*, 146971. https://doi.org/10.1016/j.scitotenv.2021.146971

Marine Scotland. (2014). *A marine litter strategy for Scotland*. Scottish Government. http://www.nls.uk/scotgov/2014/9781784127480.pdf

McGillivray, K., & Rieti, J. (2021). *Ontario's plan to overhaul Blue Box program stalls, leaving sector "on hold"*. CBC News. https://www.cbc.ca/news/canada/toronto/ontario-s-plan-to-overhaul-blue-box-program-stalls-leaving-sector-on-hold-1.6020672

McIntyre, D. A. (2021, November 6). *This company produces the most plastic waste in the world*. 24/7 Wall St. https://247wallst.com/special-report/2021/11/06/this-company-produces-the-most-plastic-waste-in-the-world/

Meijer, L. J. J., van Emmerik, T., van der Ent, R., Schmidt, C., & Lebreton, L. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. *Science Advances*, *7*(18), eaaz5803. https://doi.org/10.1126/sciadv.aaz5803

Ministry of Foreign Affairs of Japan (MOFA). (2017). *G20 action plan on marine litter*. MOFA. https://www.mofa.go.jp/mofaj/files/000272290.pdf

Molloy, S. (2020). *Investigating the Acceptability of Plastic Pollution Legislation in Atlantic Canada: A Case Study on Provincial Plastic Bag Bans* [Master of Resource & Environmental Management Project]. Dalhousie University.

Monteiro, R. C. P., Ivar do Sul, J. A., & Costa, M. F. (2018). Plastic pollution in islands of the Atlantic Ocean. *Environmental Pollution*, *238*, 103–110. https://doi.org/10.1016/j.envpol.2018.01.096

Montréal. (2016). *Ville de Montréal By-Law 16-051*. City of Montréal. http://ville.montreal.qc.ca/sel/sypre-consultation/afficherpdf?idDoc=27530&typeDoc=1

Montréal. (2021). *Plastic bags: Let's do the right thing*. City of Montréal. https://montreal.ca/en/articles/plastic-bags-lets-do-right-thing-3866

Mouat, J., Lozano, R. L., & Bateson, H. (2010). *Economic Impacts of Marine Litter*. KIMO. http://www.kimointernational.org/wp/wp-content/uploads/2017/09/KIMO_Economic-Impacts-of-Marine-Litter.pdf

Naeem, S., Chazdon, R., Duffy, J. E., Prager, C., & Worm, B. (2016). Biodiversity and human well-being: An essential link for sustainable development. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1844), 20162091. https://doi.org/10.1098/rspb.2016.2091

Nakashima, E., Isobe, A., Magome, S., Kako, S., & Deki, N. (2011). Using aerial photography and in situ measurements to estimate the quantity of macro-litter on beaches. *Marine Pollution Bulletin*, *62*(4), 762–769. https://doi.org/10.1016/j.marpolbul.2011.01.006

Napper, I. E., & Thompson, R. C. (2020). Plastic debris in the marine environment: History and future challenges. *Global Challenges*, *4*(6), 1900081. https://doi.org/10.1002/gch2.201900081

National Oceanic and Atmospheric Administration (NOAA). (2013). *Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*. NOAA. https://prod.repository.oceanbestpractices.org/bitstream/handle/11329/1210/Lippiatt%20et%20al%202013.pdf?sequence=1&isAllowed=y

Nature. (2020). The United Nations must get its new biodiversity targets right. *Nature*, *578*(7795), 337–338. https://doi.org/10.1038/d41586-020-00450-5

Naya. (2021). *Contact us*. https://www.naya.com/en/contact-us

Newman, S., Watkins, E., Farmer, A., Brink, P. ten, & Schweitzer, J.-P. (2015). The economics of marine litter. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine Anthropogenic*

Litter (pp. 367–394). Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_14

Nichols, E. C., Lavers, J. L., Archer-Rand, S., & Bond, A. L. (2021). Assessing plastic size distribution and quantity on a remote island in the South Pacific. *Marine Pollution Bulletin*, *167*, 112366. https://doi.org/10.1016/j.marpolbul.2021.112366

Nova Scotia. (2020). *Single-use plastic bag ban*. Government of Nova Scotia. https://novascotia.ca/single-use-plastic-bag-ban/

Nova Scotia Environment (NSE). (2014). *Revising our path forward: A public discussion paper about solid waste regulation in Nova Scotia*. Province of Nova Scotia. https://novascotia.ca/nse/waste/docs/solid-waste-public-discussion.pdf

Nova Scotia Legislature (NS Legislature). (2019). *Bill No.152: An Act to reduce the use of plastic bags and other single-use products*. https://nslegislature.ca/sites/default/files/legc/PDFs/annual%20statutes/2019%20Fall/c025.pdf

Oakley, K., MacLeod, J., Brown, K., Higgins, V., & Smith, H. (2008). *A characterization of Nova Scotian litter-2008 litter survey*. Nova Scotia Youth Conservation Corps & Nova Scotia Environment. https://novascotia.ca/nse/waste/docs/LitterSurvey_2008.pdf

Ocean Conservancy. (2017). *Stemming the Tide: Land-based strategies for a plastic- free ocean*. Ocean Conservancy. https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf

Ocean Conservancy. (2020). *2020 Report*. Ocean Conservancy: International Coastal Cleanup. https://oceanconservancy.org/wp-content/uploads/2020/10/FINAL_2020ICC_Report.pdf

O'Connor, M. (1997). The internalisation of environmental costs: Implementing the Polluter Pays principle in the European Union. *International Journal of Environment and Pollution*, *7*(4), 450–482. https://doi.org/10.1504/IJEP.1997.028314

Okuku, E. O., Kiteresi, L. I., Owato, G., Mwalugha, C., Omire, J., Otieno, K., Mbuche, M., Nelson, A., Gwada, B., & Mulupi, L. (2020). Marine macro-litter composition and distribution along the Kenyan Coast: The first-ever documented study. *Marine Pollution Bulletin*, *159*, 111497. https://doi.org/10.1016/j.marpolbul.2020.111497

Okuku, E. O., Kiteresi, L., Owato, G., Otieno, K., Omire, J., Kombo, M. M., Mwalugha, C., Mbuche, M., Gwada, B., Wanjeri, V., Nelson, A., Chepkemboi, P., Achieng, Q., & Ndwiga, J. (2021). Temporal trends of marine litter in a tropical recreational beach: A case study of Mkomani beach, Kenya. *Marine Pollution Bulletin*, *167*, 112273. https://doi.org/10.1016/j.marpolbul.2021.112273

Ontario. (2016). *O. Reg. 13/07: Ontario deposit return program*. Government of Ontario. https://www.ontario.ca/laws/regulation/070013

Ontario. (2019). *Ontario announces next steps to improve recycling and tackle plastic waste*. Government of Ontario. https://news.ontario.ca/en/release/53338/ontario-announces-next-steps-to-improve-recycling-and-tackle-plastic-waste

Ontario. (2021). *A made-in-Ontario environment plan*. Ministry of the Environment, Conservation and Parks; Government of Ontario. https://www.ontario.ca/page/made-in-ontario-environment-plan#section-6

Ostle, C., Thompson, R. C., Broughton, D., Gregory, L., Wootton, M., & Johns, D. G. (2019). The rise in ocean plastics evidenced from a 60-year time series. *Nature Communications*, *10*(1), 1622. https://doi.org/10.1038/s41467-019-09506-1

Padervand, M., Lichtfouse, E., Robert, D., & Wang, C. (2020). Removal of microplastics from the environment. A review. *Environmental Chemistry Letters*, *18*(3), 807–828. https://doi.org/10.1007/s10311-020-00983-1

Parks Canada. (2021). *Sable Island National Park Reserve*. Government of Canada. https://www.pc.gc.ca/en/pn-np/ns/sable

Pasternak, G., Zviely, D., Ribic, C. A., Ariel, A., & Spanier, E. (2017). Sources, composition and spatial distribution of marine debris along the Mediterranean coast of Israel. *Marine Pollution Bulletin*, *114*(2), 1036–1045. https://doi.org/10.1016/j.marpolbul.2016.11.023

Patrício Silva, A. L., Prata, J. C., Walker, T. R., Campos, D., Duarte, A. C., Soares, A. M. V. M., Barcelò, D., & Rocha-Santos, T. (2020). Rethinking and optimising plastic waste management under COVID-19 pandemic: Policy solutions based on redesign and reduction of single-use plastics and personal protective equipment. *Science of The Total Environment*, *742*, 140565. https://doi.org/10.1016/j.scitotenv.2020.140565

Pearce, D., & Turner, R. K. (1992). Packaging waste and the polluter pays principle: A taxation solution. *Journal of Environmental Planning and Management*, *35*(1), 5–15. https://doi.org/10.1080/09640569208711905

Pettipas, S., Bernier, M., & Walker, T. R. (2016). A Canadian policy framework to mitigate plastic marine pollution. *Marine Policy*, *68*, 117–122. https://doi.org/10.1016/j.marpol.2016.02.025

Piehl, S., Leibner, A., Löder, M. G. J., Dris, R., Bogner, C., & Laforsch, C. (2018). Identification and quantification of macro- and microplastics on an agricultural farmland. *Scientific Reports*, *8*(1), 17950. https://doi.org/10.1038/s41598-018-36172-y

Plastic Pollution Emissions Working Group (PPEWG). (2021). *A History of the International Response to Plastic Pollution*. PPEWG. https://www.plasticpeg.org/history

Prata, J. C., Silva, A. L. P., da Costa, J. P., Mouneyrac, C., Walker, T. R., Duarte, A. C., & Rocha-Santos, T. (2019). Solutions and integrated strategies for the control and mitigation of plastic and microplastic pollution. *International Journal of Environmental Research and Public Health*, *16*(13), 2411. https://doi.org/10.3390/ijerph16132411

Prata, J. C., Silva, A. L. P., Walker, T. R., Duarte, A. C., & Rocha-Santos, T. (2020). Covid-19 pandemic repercussions on the use and management of plastics. *Environmental Science & Technology*, *54*(13), 7760–7765. https://doi.org/10.1021/acs.est.0c02178

Protection of the Arctic Marine Environment (PAME). (2019). *Desktop study on marine litter including microplastics in the Arctic*. PAME. https://pame.is/images/03_Projects/Arctic_Marine_Pollution/Litter/Desktop_study/Desktop_Study_on_marine_litter.pdf

Provencher, J. F., Bond, A. L., Avery-Gomm, S., Borrelle, S. B., Bravo Rebolledo, E. L., Hammer, S., Kühn, S., Lavers, J. L., Mallory, M. L., Trevail, A., & van Franeker, J. A. (2017). Quantifying ingested debris in marine megafauna: A review and recommendations for standardization. *Analytical Methods*, *9*(9), 1454–1469. https://doi.org/10.1039/C6AY02419J

Qu, S., Guo, Y., Ma, Z., Chen, W.-Q., Liu, J., Liu, G., Wang, Y., & Xu, M. (2019). Implications of China’s foreign waste ban on the global circular economy. *Resources, Conservation and Recycling*, *144*, 252–255. https://doi.org/10.1016/j.resconrec.2019.01.004

Raubenheimer, K., & McIlgorm, A. (2017). Is the Montreal Protocol a model that can help solve the global marine plastic debris problem? *Marine Policy*, *81*, 322–329. https://doi.org/10.1016/j.marpol.2017.04.014

Raubenheimer, K., & McIlgorm, A. (2018). Can the Basel and Stockholm Conventions provide a global framework to reduce the impact of marine plastic litter? *Marine Policy*, *96*, 285–290. https://doi.org/10.1016/j.marpol.2018.01.013

Raubenheimer, K., & Urho, N. (2020). Rethinking global governance of plastics – The role of industry. *Marine Policy*, *113*, 103802. https://doi.org/10.1016/j.marpol.2019.103802

Recycle BC. (2019). *Consultation summary for Recycle BC's packaging and paper product Extended Producer Responsibility plan*. Recycle BC. https://recyclebc.ca/wp-content/uploads/2019/07/Consultation-Summary-for-Recycle-BCs-Plan.pdf

Rochman, C. M. (2015). The complex mixture, fate and toxicity of chemicals associated with plastic debris in the marine environment. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine Anthropogenic Litter* (pp. 117–140). Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_5

Rochman, C. M., Browne, M. A., Halpern, B. S., Hentschel, B. T., Hoh, E., Karapanagioti, H. K., Rios-Mendoza, L. M., Takada, H., Teh, S., & Thompson, R. C. (2013). Classify plastic waste as hazardous. *Nature*, *494*(7436), 169–171. https://doi.org/10.1038/494169a

Rochman, C. M., Browne, M. A., Underwood, A. J., van Franeker, J. A., Thompson, R. C., & Amaral-Zettler, L. A. (2016). The ecological impacts of marine debris: Unraveling the demonstrated evidence from what is perceived. *Ecology*, *97*(2), 302–312. https://doi.org/10.1890/14-2070.1

Rogoff, M. J., & Ross, D. E. (2016). The future of recycling in the United States. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, *34*(3), 181–183. https://doi.org/10.1177/0734242X16629599

Ryan, P. G. (2020). Land or sea? What bottles tell us about the origins of beach litter in Kenya. *Waste Management*, *116*, 49–57. https://doi.org/10.1016/j.wasman.2020.07.044

Schmaltz, E., Melvin, E. C., Diana, Z., Gunady, E. F., Rittschof, D., Somarelli, J. A., Virdin, J., & Dunphy-Daly, M. M. (2020). Plastic pollution solutions: Emerging technologies to prevent and collect marine plastic pollution. *Environment International*, *144*, 106067. https://doi.org/10.1016/j.envint.2020.106067

Schnell, A., Klein, N., Gómez Girón, E., & Sousa, J. (2017). *National marine plastic litter policies in EU Member States: An overview*. IUCN. https://portals.iucn.org/library/sites/library/files/documents/2017-052.pdf

Schnurr, R. E. J., Alboiu, V., Chaudhary, M., Corbett, R. A., Quanz, M. E., Sankar, K., Srain, H. S., Thavarajah, V., Xanthos, D., & Walker, T. R. (2018). Reducing marine pollution from single-use plastics (SUPs): A review. *Marine Pollution Bulletin*, *137*, 157–171. https://doi.org/10.1016/j.marpolbul.2018.10.001

Schuyler, Q., Hardesty, B. D., Lawson, T., Opie, K., & Wilcox, C. (2018). Economic incentives reduce plastic inputs to the ocean. *Marine Policy*, *96*, 250–255. https://doi.org/10.1016/j.marpol.2018.02.009

Secretariat of the Basel Convention. (2019). *Basel Convention & Basel Protocol on liability and compensation*. UNEP. http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

Shen, L., & Worrell, E. (2014). Plastic recycling. In *Handbook of Recycling* (pp. 179–190). Elsevier. https://doi.org/10.1016/B978-0-12-396459-5.00013-1

Smith, S. D. A., Banister, K., Fraser, N., & Edgar, R. J. (2018). Tracing the source of marine debris on the beaches of northern New South Wales, Australia: The bottles on beaches program. *Marine Pollution Bulletin*, *126*, 304–307. https://doi.org/10.1016/j.marpolbul.2017.11.022

Sobeys. (2009). *Sobeys Ontario surpasses voluntary provincial plastic bag reduction target*. Cision Canada. https://www.newswire.ca/news-releases/sobeys-ontario-surpasses-voluntary-provincial-plastic-bag-reduction-target-538651602.html

Sobeys. (2021). *Our company and purpose*. https://corporate.sobeys.com/our-purpose/

Statistics Canada. (2016). *Census profile, 2016 census: Halifax, Regional municipality*. Government of Canada. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=1209034&Geo2=CD&Code2=1209&SearchText=Halifax&SearchType=Begins&SearchPR=01&B1=All&TABID=1&type=0

Stewardship Ontario. (2018). *Backgrounder: The blue box program*. Stewardship Ontario. https://stewardshipontario.ca/wp-content/uploads/2013/01/BB-Backgrounder-June-2018-update.pdf

Stewardship Ontario. (2019). *2019 annual report*. Stewardship Ontario. https://stewardshipontario.ca/wp-content/uploads/2020/06/SO_2019_AR.pdf

Talvitie, J., Mikola, A., Koistinen, A., & Setälä, O. (2017). Solutions to microplastic pollution – Removal of microplastics from wastewater effluent with advanced wastewater treatment technologies. *Water Research*, *123*, 401–407. https://doi.org/10.1016/j.watres.2017.07.005

Taylor, S., & Walker, T. R. (2017). North Atlantic right whales in danger. *Science*, *358*(6364), 730.2-731. https://doi.org/10.1126/science.aar2402

Tessnow-von Wysocki, I., & Le Billon, P. (2019). Plastics at sea: Treaty design for a global solution to marine plastic pollution. *Environmental Science & Policy*, *100*, 94–104. https://doi.org/10.1016/j.envsci.2019.06.005

Toronto. (2012). *Plastic retail shopping bags—5 cent charge—Plastic bag ban*. City of Toronto. https://www.toronto.ca/311/knowledgebase/kb/docs/articles/311-toronto/information-and-business-development/plastic-retail-shopping-bags-5-cent-charge-plastic-bag-ban.html

Toronto. (2021). *Toronto at a glance*. City of Toronto. https://www.toronto.ca/city-government/data-research-maps/toronto-at-a-glance/

United Nations (UN). (1992). *United Nations Framework Convention on Climate Change.* UN. https://unfccc.int/resource/docs/convkp/conveng.pdf

United Nations (UN). (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. UN. https://sdgs.un.org/2030agenda

United Nations Environment Programme (UNEP). (2009). *UNEP/IOC guidelines on survey and monitoring of marine litter*. UNEP. https://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y

United Nations Environment Programme (UNEP). (2014). *Valuing plastic: The business case for measuring, managing and disclosing plastic use in the consumer goods industry*. UNEP. https://wedocs.unep.org/bitstream/handle/20.500.11822/9238/-Valuing%20plastic%3a%20the%20business%20case%20for%20measuring%2c%20managi ng%20and%20disclosing%20plastic%20use%20in%20the%20consumer%20goods%20industry-2014Valuing%20plasticsF.pdf?sequence=8&isAllowed=y

United Nations Environment Programme (UNEP). (2016). *Marine litter legislation: A toolkit for policymakers*. UNEP. https://www.eli.org/sites/default/files/eli-pubs/marine-litter-legislation-toolkit-policymakers.pdf

United Nations Environment Programme (UNEP). (2018). *Legal limits on single-use plastics and microplastics*. UNEP. https://www.unep.org/resources/report/legal-limits-single-use-plastics-and-microplastics

United Nations Environment Programme (UNEP). (2021). *Addressing land-based pollution*. UNEP. https://www.unep.org/explore-topics/oceans-seas/what-we-do/addressing-land-based-pollution

van der Velde, T., Milton, D. A., Lawson, T. J., Wilcox, C., Lansdell, M., Davis, G., Perkins, G., & Hardesty, B. D. (2017). Comparison of marine debris data collected by researchers and citizen scientists: Is citizen science data worth the effort? *Biological Conservation*, *208*, 127–138. https://doi.org/10.1016/j.biocon.2016.05.025

Vancouver. (2020). *Single-Use Item Reduction Strategy*. City of Vancouver. https://vancouver.ca/green-vancouver/single-use-items.aspx

Vancouver. (2021). *Geography*. City of Vancouver. https://vancouver.ca/news-calendar/geo.aspx

Varkey, P. S., Walker, T. R., & Saunders, S. J. (2021). Identifying barriers to reducing single-use plastic use in a coastal metropolitan city in Canada. *Ocean & Coastal Management*, *210*, 105663. https://doi.org/10.1016/j.ocecoaman.2021.105663

Vaughan, C., Gack, J., Solorazano, H., & Ray, R. (2003). The effect of environmental education on schoolchildren, their parents, and community members: A study of intergenerational and intercommunity learning. *The Journal of Environmental Education*, *34*(3), 12–21. https://doi.org/10.1080/00958960309603489

Walker, T. R. (2018). Drowning in debris: Solutions for a global pervasive marine pollution problem. *Marine Pollution Bulletin*, *126*, 338. https://doi.org/10.1016/j.marpolbul.2017.11.039

Walker, T. R. (2021a). (Micro)Plastics and the UN sustainable development goals. *Current Opinion in Green and Sustainable Chemistry*, *30*, 100497. https://doi.org/10.1016/j.cogsc.2021.100497

Walker, T. R. (2021b). Plastic industry plan to sue the Canadian federal government for listing plastic as toxic may increase plastic marine pollution. *Marine Pollution Bulletin*, *169*, 112583. https://doi.org/10.1016/j.marpolbul.2021.112583

Walker, T. R., Grant, J., & Archambault, M.-C. (2006). Accumulation of marine debris on an intertidal beach in an urban park (Halifax Harbour, Nova Scotia). *Water Quality Research Journal*, *41*(3), 256–262. https://doi.org/10.2166/wqrj.2006.029

Walker, T. R., & McGuinty, E. (2021). Plastics. In *The Palgrave Handbook of Global Sustainability* (pp. 1–12). Springer International Publishing. https://doi.org/10.1007/978-3-030-38948-2_55-1

Walker, T. R., McGuinty, E., Charlebois, S., & Music, J. (2021). Single-use plastic packaging in the Canadian food industry: Consumer behavior and perceptions. *Humanities and Social Sciences Communications*, *8*(1), 80. https://doi.org/10.1057/s41599-021-00747-4

Walker, T. R., Reid, K., Arnould, J. P. Y., & Croxall, J. P. (1997). Marine debris surveys at Bird Island, South Georgia 1990–1995. *Marine Pollution Bulletin*, *34*(1), 61–65. https://doi.org/10.1016/S0025-326X(96)00053-7

Walker, T. R., & Xanthos, D. (2018). A call for Canada to move toward zero plastic waste by reducing and recycling single-use plastics. *Resources, Conservation and Recycling*, *133*, 99–100. https://doi.org/10.1016/j.resconrec.2018.02.014

Wen, Z., Xie, Y., Chen, M., & Dinga, C. D. (2021). China's plastic import ban increases prospects of environmental impact mitigation of plastic waste trade flow worldwide. *Nature Communications*, *12*(1), 425. https://doi.org/10.1038/s41467-020-20741-9

Werner, S., Budziak, A., van Franeker, J., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., & Vlachogianni, T. (2016). *Harm caused by Marine Litter*. European Commission. https://doi.org/10.2788/690366

Wilcox, C., Van Sebille, E., & Hardesty, B. D. (2015). Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proceedings of the National Academy of Sciences*, *112*(38), 11899–11904. https://doi.org/10.1073/pnas.1502108112

Woodford, Z. (2018). *'A wake-up call': 19 million cubic metres of sewage and runoff flowed into N.S. waters in 2016, data shows*. Toronto Star. https://www.thestar.com/halifax/2018/04/12/enough-of-this-mess-halifax-advocates-call-for-better-infrastructure-notification-of-sewage-overflows.html

World Economic Forum (WEF). (2016). *The new plastics economy rethinking the future of plastics*. WEF. http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf

Worm, B., Lotze, H. K., Jubinville, I., Wilcox, C., & Jambeck, J. (2017). Plastic as a persistent marine pollutant. *Annual Review of Environment and Resources*, *42*(1), 1–26. https://doi.org/10.1146/annurev-environ-102016-060700

Wu, W.-M., Yang, J., & Criddle, C. S. (2017). Microplastics pollution and reduction strategies. *Frontiers of Environmental Science & Engineering*, *11*(1), 6. https://doi.org/10.1007/s11783-017-0897-7

Xanthos, D., & Walker, T. R. (2017). International policies to reduce plastic marine pollution from single-use plastics (Plastic bags and microbeads): A review. *Marine Pollution Bulletin*, *118*(1–2), 17–26. https://doi.org/10.1016/j.marpolbul.2017.02.048

Ye, S., & Andrady, A. L. (1991). Fouling of floating plastic debris under Biscayne Bay exposure conditions. *Marine Pollution Bulletin*, *22*(12), 608–613. https://doi.org/10.1016/0025-326X(91)90249-R

Yeo, J. C. C., Muiruri, J. K., Thitsartarn, W., Li, Z., & He, C. (2018). Recent advances in the development of biodegradable PHB-based toughening materials: Approaches, advantages and applications. *Materials Science and Engineering: C*, *92*, 1092–1116. https://doi.org/10.1016/j.msec.2017.11.006

Zbyszewski, M., Corcoran, P. L., & Hockin, A. (2014). Comparison of the distribution and degradation of plastic debris along shorelines of the Great Lakes, North America. *Journal of Great Lakes Research*, *40*(2), 288–299. https://doi.org/10.1016/j.jglr.2014.02.012

Zettler, E. R., Takada, H., Monteleone, B., Mallos, N., Eriksen, M., & Amaral-Zettler, L. A. (2017). Incorporating citizen science to study plastics in the environment. *Analytical Methods*, *9*(9), 1392–1403. https://doi.org/10.1039/C6AY02716D

Zhu, X. (2021). The plastic cycle – an unknown branch of the carbon cycle. *Frontiers in Marine Science*, *7*, 609243. https://doi.org/10.3389/fmars.2020.609243

Appendix I: Statistical Analysis Summary: Chi-Squared and P-Values (* indicates Chi-squared approximation may be incorrect. Expected counts are very small. The approximation may be poor).

Comparison	Column Categories	Row Categories	Datasets used	X^2	P-Value	Meaning
All locations, all litter types	Vancouver Toronto Montreal Halifax Sable	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC SII	X-squared = 7974.9	p-value <2.2e-16	Litter type is dependent on location.
VTMH (all urban), all litter types	Vancouver Toronto Montreal Halifax	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC	X-squared = 5944.1	p-value <2.2e-16	Litter type is dependent on urban location.
VT, all litter types	Vancouver Toronto	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC	X-squared = 4662.8	p-value <2.2e-16	Litter type is dependent on whether location is Vancouver or Toronto.
VM, all litter types	Vancouver Montreal	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC	X-squared = 1305.8	p-value <2.2e-16	Litter type is dependent on whether location is Vancouver or Montreal.
VH, all litter types	Vancouver Halifax	Wrappers Bottle Caps Straws Cups and Lids Cutlery	GCSC	X-squared = 599.63	p-value <2.2e-16	Litter type is dependent on whether location is Vancouver or Halifax.

		Plastic Bottles Food Containers Plastic Bags Other				
VS, all litter types	Vancouver Sable	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC SII	X-squared = 2846.5	p-value <2.2e-16	Litter type is dependent on whether location is Vancouver or Sable.
TM, all litter types	Toronto Montreal	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC	X-squared = 663.91	p-value <2.2e-16	Litter type is dependent on whether location is Toronto or Montreal.
TH, all litter types	Toronto Halifax	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC	X-squared = 772.41	p-value <2.2e-16	Litter type is dependent on whether location is Toronto or Halifax.
TS, all litter types	Toronto Sable	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC SII	X-squared = 1822.3	p-value <2.2e-16	Litter type is dependent on whether location is Toronto or Sable.
MH, all litter types	Montreal Halifax	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC	X-squared = 563.18	p-value <2.2e-16	Litter type is dependent on whether location is Montreal or Halifax.

MS, all litter types	Montreal Sable	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC SII	X-squared = 915.85	p-value <2.2e-16	Litter type is dependent on whether location is Montreal or Sable.
HS, all litter types	Halifax Sable	Wrappers Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Containers Plastic Bags Other	GCSC SII	X-squared = 1296.5	p-value <2.2e-16	Litter type is dependent on whether location is Halifax or Sable.
All locations, top brands	Vancouver Toronto Montreal Halifax Sable	Nestlé Starbucks Coca-Cola New World Natural Foods PepsiCo Tim Horton's McDonald's Naya Eska Bic Hershey's Sobeys Kraft	GP SII	X-squared = 1082.4	p-value <2.2e-16 *	Litter top brands are dependent on location.
VTMH, top brands	Vancouver Toronto Montreal Halifax	Nestlé Starbucks Coca-Cola New World Natural Foods PepsiCo Tim Horton's McDonald's Naya Eska Bic Hershey's	GP	X-squared = 491.6	p-value <2.2e-16 *	Litter top brands are dependent on urban location.
VT, top brands	Vancouver Toronto	Nestlé Starbucks Coca-Cola New World Natural Foods PepsiCo Tim Horton's McDonald's	GP	X-squared = 71.716	p-value = 1.817e-13 *	Litter top brands are dependent on whether location is Vancouver or Toronto.

VM, top brands	Vancouver Montreal	Nestlé Starbucks Coca-Cola New World Natural Foods PepsiCo Tim Horton's McDonald's Naya Eska	GP	X-squared = 374.22	p-value <2.2e-16	Litter top brands are dependent on whether location is Vancouver or Montreal.
VH, top brands	Vancouver Halifax	Nestlé Starbucks Coca-Cola New World Natural Foods PepsiCo Tim Horton's Bic Hershey's	GP	X-squared = 120.85	p-value <2.2e-16 *	Litter top brands are dependent on whether location is Vancouver or Halifax.
VS, top brands	Vancouver Sable	Nestlé Starbucks Coca-Cola New World Natural Foods PepsiCo Sobeys Kraft	GP SII	X-squared = 340.55	p-value <2.2e-16	Litter top brands are dependent on whether location is Vancouver or Sable.
TM, top brands	Toronto Montreal	Nestlé Starbucks Coca-Cola PepsiCo Tim Horton's McDonald's Naya Eska	GP	X-squared = 53.228	p-value = 3.341e-09 *	Litter top brands are dependent on whether location is Toronto or Montreal.
TH, top brands	Toronto Halifax	Nestlé Starbucks Coca-Cola PepsiCo Tim Horton's McDonald's Bic Hershey's	GP	X-squared = 25.674	p-value = 0.000576 *	Litter top brands are dependent on whether location is Toronto or Halifax.
TS, top brands	Toronto Sable	Nestlé Starbucks Coca-Cola PepsiCo Tim Horton's McDonald's Sobeys Kraft	GP SII	X-squared = 133.55	p-value <2.2e-16 *	Litter top brands are dependent on whether location is Toronto or Sable.

MH, top brands	Montreal Halifax	Nestlé PepsiCo Tim Horton's McDonald's Naya Eska Bic Hershey's	GP	X-squared = 55.219	p-value = 1.349e-09 *	Litter top brands are dependent on whether location is Montreal or Halifax.
MS, top brands	Montreal Sable	Nestlé Coca-Cola PepsiCo Tim Horton's McDonald's Naya Eska Sobeys Kraft	GP SII	X-squared = 284.96	p-value <2.2e-16	Litter top brands are dependent on whether location is Montreal or Sable.
HS, top brands	Halifax Sable	Nestlé Coca-Cola PepsiCo Tim Horton's Bic Hershey's Sobeys Kraft	GP SII	X-squared = 83.009	p-value = 3.348e-15 *	Litter top brands are dependent on whether location is Halifax or Sable.
All, big six brands* *top brand in more than one location	Vancouver Toronto Montreal Halifax Sable	Nestlé Starbucks Coca-Cola PepsiCo Tim Horton's McDonald's	GP SII	X-squared = 582.68	p-value <2.2e-16 *	The Big Six top litter brand proportions are dependent on location.
Urban, big six brands	Vancouver Toronto Montreal Halifax	Nestlé Starbucks Coca-Cola PepsiCo Tim Horton's McDonald's	GP	X-squared = 330.63	p-value <2.2e-16 *	The Big Six top litter brand proportions are dependent on urban location.
All, big four brands* *top brand in three or more locations	Vancouver Toronto Montreal Halifax Sable	Nestlé Coca-Cola PepsiCo Tim Horton's	GP SII	X-squared = 366.83	p-value <2.2e-16 *	The Big Four top litter brand proportions are dependent on location.
Urban, big four brands	Vancouver Toronto Montreal Halifax	Nestlé Coca-Cola PepsiCo Tim Horton's	GP	X-squared = 203.4	p-value <2.2e-16 *	The Big Four top litter brand proportions are dependent on urban location
V, GCSC vs GP litter proportions	Vancouver	Wrapper Bottle Caps Straws	GP GCSC	X-squared = 218.91	p-value <2.2e-16	Litter proportions in Vancouver are dependent on dataset (GP vs GCSC).

		Cups and Lids Cutlery Plastic Bottles Food Container Plastic Bag Other				
T, GCSC vs GP litter proportions	Toronto	Wrapper Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Container Plastic Bag Other Unknown	GP GCSC	X-squared = 9247.7	p-value <2.2e-16 *	Litter proportions in Toronto are dependent on dataset (GP vs GCSC).
M, GCSC vs GP litter proportions	Montreal	Wrapper Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Container Plastic Bag Other	GP GCSC	X-squared = 299.03	p-value <2.2e-16	Litter proportions in Montreal are dependent on dataset (GP vs GCSC).
H, GCSC vs GP litter proportions	Halifax	Wrapper Bottle Caps Straws Cups and Lids Cutlery Plastic Bottles Food Container Plastic Bag Other Unknown	GP GCSC	X-squared = 690.62	p-value <2.2e-16 *	Litter proportions in Halifax are dependent on dataset (GP vs GCSC).
H, GP vs Litterati Top Brands	Halifax	Nestlé PepsiCo Tim Horton's Coca-Cola McDonald's Hershey's KFC Bic	GP Litterati	X-squared = 185.8	p-value <2.2e-16 *	Litter proportions in Halifax are dependent on dataset (GP vs Litterati).

Appendix II: Additional Data Analysis

Halifax: Litterati Brand Audit

Litterati is a citizen science app that allows participants around the world to document litter through geo-tagged photos (Litterati, 2021). Open data for studied regions were collected for 2019 from Litterati: Vancouver (n=0), Toronto (n=10), Montréal (n=1), and Halifax (n=464). Due to small sample sizes, only Halifax was further analyzed for this data source. Open data were only available for September 2019 to December 2019 for this region. Whenever possible, subsidiaries were grouped together under their parent company (e.g., Minute Maid classified as Coca-Cola). Only litter items with documented brand data were used for this analysis and thus no 'Unknown' category is present. 'Other' encompasses litter that were branded, but not part of the top five brands by quantity. Top brands include Tim Horton's (276), McDonald's (97), PepsiCo (16), and KFC (16). An estimated 247 participants were involved in this data collection (based on number of unique coordinates—this number could be smaller as the same participants may document litter from multiple locations). Statistical analyses were conducted between Halifax GP brands and Halifax Litterati brands. P-values were significant ($p<0.05$), indicating that brand proportions are dependent on dataset used. Main differences between these datasets seems to be larger quantities of fast-food litter brands collected by Litterati (>83.8%). This could be exacerbated by the large amount of unknown brand litter from GP dataset or may indicate difference in citizen science collection. Top Litterati litter brands for Halifax are shown in Figure 42.

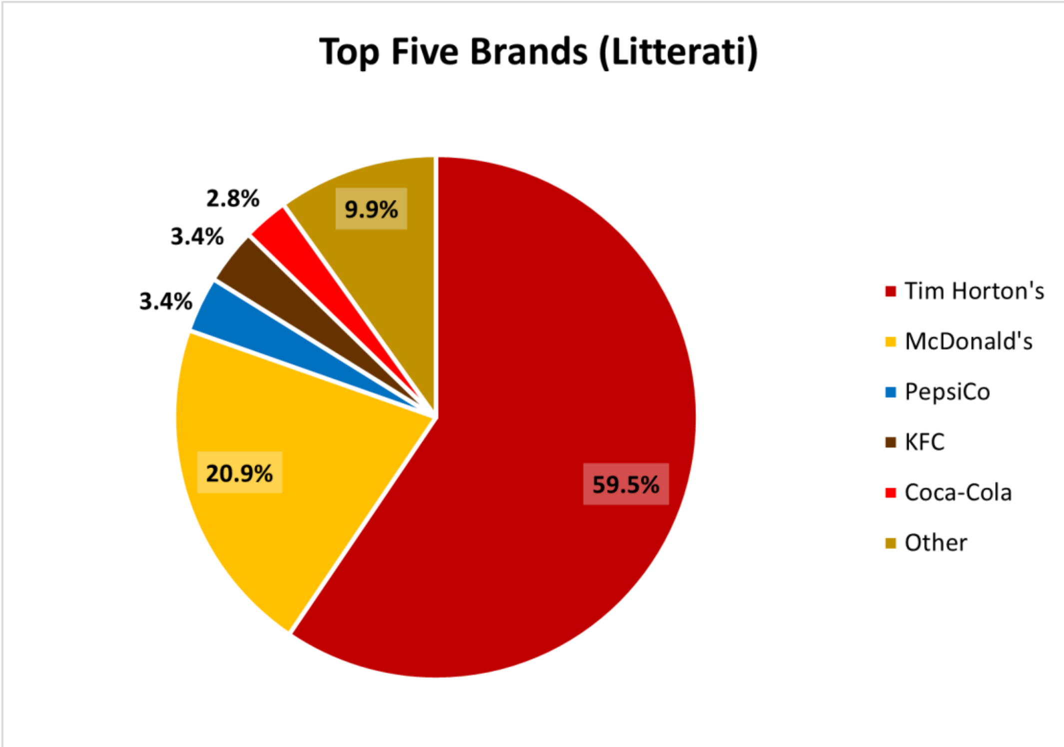

Figure 42: Halifax Top Five Brands via Litterati. Depiction of top brands (by quantity) collected by Litterati from September 2019 to December 2019 for Halifax. (n=464).