Aligning Citizen Science and Extended Producer Responsibility Policy for Marine Plastic Reduction

by © Lucas Harris

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Abstract

To address plastic pollution in the marine environment, policy interventions need to be focused upstream, at the point of production. Extended producer responsibility (EPR) is a promising upstream strategy to address plastic marine debris, as it shifts the responsibility for waste management of a product or its packaging from local governments to producers. This provides incentives to producers to prevent waste from being generated in the first place (i.e. source reduction), and reduces material going to landfill or leaking into the environment by funding, creating or expanding infrastructure for post-consumer recycling. However, EPR programs are not currently designed to measure this effect of marine plastic pollution prevention. At first glance, citizen science data appears to be a good option to evaluate EPR, since there are a several types of monitoring programs in operation with various pre-existing data sets that track some packaging items. Yet, this information has never been used for this purpose before. This research focuses on British Columbia (BC), the first and only coastal jurisdiction in North America to implement an 100% industry-funded EPR program for packaging and printed paper (PPP) material in 2014. Packaging materials, including food wrappers, plastic and glass drink bottles, bottle caps, plastic grocery bags and plastic lids, all featured in the top ten most frequently found items during marine litter surveys. There are also eight organizations actively conducting citizen science shoreline monitoring activity in BC, making it an ideal candidate for analysing the potential of citizen science data. This research uses both quantitative and qualitative methods. Using various mixed-effect and linear models to analyze pre-existing citizen science data sets, generated with standardized data collection frameworks, demonstrated that there has been no decrease in

packaging debris levels on shorelines after the introduction of EPR in 2014. However, qualitative analysis demonstrated that the characteristics of the citizen science data, structure of the EPR policy in BC and nature of plastic marine debris limit the ability to use the data for this particular purpose. Additionally, citizen science organizations are migrating away from standardized data collection frameworks in order to develop systems that are customized to the specific needs in their community, thereby further limiting data sets that may be used for analysis of EPR. Many of these organizations are choosing to adapt their data collection approaches to align with municipal waste management options available to them. This has led to the creation of a diverse patchwork of information across the province. As a result of this study, it is clear that for upstream policy interventions, such as EPR, to determine if it is affecting packaging pollution levels downstream on shorelines, it needs to develop and implement its own benchmarking and monitoring program, tailored to address its specific requirements of data resolution.

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List of Abbreviations

BC	British Columbia
CCME	Canadian Council of Ministers for the Environment
EPS	Expanded Polystyrene
EPR	Extended Producer Responsibility
GCSC	Great Canadian Shoreline Cleanup
HDPE	High-density Polyethylene
ICI	Industrial, Commercial and Institutional
MOECCS	Ministry of Environment and Climate Change Strategy
MMBC	Multi-Material British Columbia
MSW	Municipal Solid Waste
NOAA	National Oceanic and Atmospheric Administration
NGO	Non-governmental Organization
OFPP	Other Flexible Plastic Packaging
PCB's	Polychlorinated Biphenyls
PPP	Packaging and Paper Products
PET	Polyethylene Terephthalate
PU	Polyurethane
WA	Washington

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Chapter 1 Introduction

Plastic waste generation is overwhelming the planet (Geyer, Jambeck and Law, 2017). This is in a large part due to an increase in plastic production around the world (PlasticsEurope, 2017). In 2016, 335 million tonnes was produced, with a significant amount being used for packaging, the largest single category of material. In Europe, approximately 40 percent of plastic is used to manufacture packaging (PlasticsEurope, 2017), while in Canada, the packaging sector represents 33 percent of plastics demand (Deloitte and Cheminfo, 2019). In terms of plastic marine debris, packaging materials, including food wrappers, plastic drink bottles, bottle caps, plastic grocery bags and plastic lids, have featured as the most frequently found items during marine litter surveys around the world (Hanke, 2016; Chitaka & von Blottnitz, 2019; Paler, Malenab, Maralit, & Nacorda, 2019) and in Canada (Konecny, Fladmark, & De la Puente, 2018).

The Ellen MacArthur Foundation analyzed the global management system of packaging waste in 2013 and found that the flow of material is largely linear, with only two percent circulating back into production systems through recycling (2016). Instead, the majority of material is either managed through landfilling or incineration. What this study points out is that almost one third (32 percent) of packaging waste leaks from waste management systems into the natural environment. To increase the rate of material being recycled and reduce the amount of leakage, a variety of policy interventions have been proposed.

Legislative and non-legislative interventions addressing plastic products and packaging that pollute the marine environment are gaining momentum around the world, with plastic bags representing one of the more popular targets of advocacy and policy interventions (Schnurr et al., 2018). It is a common assumption that once an intervention is introduced, the waste is then reduced and/or managed. In the case of fees on plastic shopping bags, research to support the effectiveness of a fee is often focused on measuring how successful the fee is at influencing consumers to reduce plastic bag use at the point of purchase (Muralidharan and Sheehan 2017; Poortinga, Whitmarsh, and Suffolk, 2013). But as Xanthos and Walker argue, "research related to environmental outcomes is still lacking" and "more research is required to determine whether these reductions are having a positive impact on aquatic or marine environments" (2017, p. 22).

One prominent policy approach that has been suggested to reduce plastic pollution is Extended Producer Responsibility (EPR). EPR shifts the responsibility for waste management of a product or its packaging from local governments to producers (Organisation for Economic Co-operation and Development, 2001). As a result, it sends signals up the supply chain to producers to reduce or redesign materials, so they are more recyclable. EPR is an especially relevant policy response to the increasing amount of plastic marine debris because of how it incentivizes producers to prevent waste from being generated upstream in the first place (i.e. source reduction) and aims to reduce leakage into the environment through funding, creating, and/or expanding infrastructure for post-consumer recycling (Borrelle et al., 2017; Chen, 2015; Cairns, 2009; Tibbetts, 2015; UNEP & NOAA, 2013; Gold et al., 2013). Recently, jurisdictions aimed at addressing plastic marine debris have become interested in the potential of EPR and have included it in various policies and programs.

On December 19, 2018, the European Parliament and the Council of the European Union reached agreement (European Commission, 2018a) on a Directive primarily aimed at reducing the harmful effects of plastic marine debris, with a specific focus on single-use plastic packaging items and fishing gear (European Commission, 2018b). EPR is one of several policy tools outlined in the Directive. In Canada, the federal government, provinces and territories have been focusing on the issue of plastic marine debris through working with the Canadian Council of Ministers of the Environment (CCME) on the Strategy on Zero Plastic Waste (Canadian Council of Ministers of the Environment, 2018). In terms of EPR, the Strategy states "collaboration under the CCME, in particular through continued implementation of existing initiatives such as the Canada-wide Action Plan on Extended Producer Responsibility (2009), serves as a foundation for the transformation ahead" (Canadian Council of Ministers of the Environment, 2018, p. 3). In theory, it is logical to consider EPR as a tool to address plastic marine debris. However, EPR has never been specifically evaluated in terms of its ability to reduce plastic marine debris levels.

In terms of monitoring plastic pollution levels in the marine environment, citizen science plays a major role. Citizen science is a decentralized civic mode of data collection that has become integral in the development of data and information on shoreline plastic marine pollution levels (Hidalgo-Ruz & Thiel, 2015). Performed by people who may not be accredited scientists, citizen science is an approach that broadens the coverage and increases the sampling power of marine debris monitoring that would otherwise not have been addressed due to a lack of resources, time, or geography (Cigliano et al., 2015; van der Velde et al., 2017). The data citizen science creates through shoreline marine debris cleanup and monitoring projects may provide valuable insight into plastic pollution trends generally and, potentially, in relation to the introduction of EPR.

The purpose of this research is to explore how citizen science and EPR policy relate to each other in terms of what they measure, through analyzing EPR policy and citizen-based shoreline survey programs for plastic marine debris accumulation. British Columbia (BC) is the only jurisdiction in North America to recently introduce a 100% industry-funded province-wide EPR program for packaging material in 2014, one of the most common types of plastic marine debris (Ocean Conservancy, 2017; Browne et al., 2010; Konecny, Fladmark & De la Puente, 2018). BC also has numerous organizations conducting science monitoring work. This research intends to qualitatively analyze the relationship between the metrics and categories used by citizen science shoreline cleanup organizations to record pollution data and by government to track the performance of EPR policy for packaging waste, while also quantitatively analyzing citizen science shoreline cleanup data in BC as a case study to see temporal and spatial trends in shoreline packaging waste.

This research provides empirical and theoretical contributions to various disciplines within the social sciences. Through its focus on packaging marine debris flows and the impacts of formal recycling regulation on the efficiency and sustainability of municipal solid waste (MSW) management, this research develops findings applicable to the field of geographies of waste (Moore, 2012; Davies, 2016). And given that it investigates the role of policies as governing instruments and considers the factors that shape their impacts, this research simultaneously exists within the field of policy studies (Fischer, 2003; May & Jochim, 2013). But the main contribution of this research is found within discard studies. The field of discard studies is central to thinking through and countering the familiar aspects of waste (Liboiron, 2014). In particular, discard studies trouble the assumptions, premises and popular mythologies of waste, one of which is that postconsumer recycling reduces waste. It has been reasonably well established in the literature that recycling represents a somewhat problematic response to the problem of waste, and plastic waste in particular (MacBride, 2003; Lepawsky, 2018). Instead, the logical response to problems associated with recycling is to address waste upstream, at the point of generation (Liboiron in Hutton & Hess, 2019).

EPR represents a policy tool that recognizes some of the challenges with conventional recycling and aims to shift pollution prevention actions upstream to the point of production. But it is unclear how effective EPR and other upstream policy approaches to waste management will be, despite discourses that hail EPR as the best solution to waste management (Eriksen, 2017; Chen, 2015). This uncertainty stems from the fact that so few policies actually shift the focus upstream and as such, few studies have been focused on upstream policy intervention effectiveness in reducing plastic waste. In short, a discursive and political commitment to a method of reducing waste is based on ideals and concepts as opposed to empirical evidence, a mainstay focus in discard studies. As previously mentioned, the ones that have been performed have focused primarily on plastic shopping bag bans or levies and reduced use amongst the general public (Poortinga, Whitmarsh, and Suffolk, 2013), but not on environmental outcomes such as marine debris reduction (Xanthos and Walker, 2017). And no studies have looked at EPR and its ability to reduce plastic marine debris on shorelines.

At the same time, discard studies has a truism of its own: that upstream methods of waste management that deal with waste at its inception are superior to those that deal with waste after it has been created (Lepawsky, 2017; MacBride, 2012; Liboiron in Hutton & Hess, 2019). Yet there are few studies that show the effectiveness of this strategy. Therefore, this research provides a rare look at an upstream policy intervention and the considerations needed regarding oversight and evaluation. By doing so, this research tests the assumption that upstream policy is the preferred approach to waste management, while providing critical insight and empirics into how policy needs to be designed and monitored to ensure it is effective.

As previously mentioned, there are numerous examples throughout the literature and in recent policy contributing to the assumption that EPR is an effective tool for reducing plastic marine debris. But in terms of using citizen science data as a metric for policy evaluation, there are a few recent examples that demonstrate this growing assumption. First, recent news items have used citizen science data from California's Coastal Cleanup Day to describe the performance of the State's plastic bag ban that was introduced in 2014, reporting a 72% reduction in shoreline plastic bag debris compared to 2010 data (The Times Editorial Board, 2017; Mercury News & East Bay Times Editorial Boards, 2017; Phillips, 2017). Second, in a recent journal article assessing Great Canadian Shoreline Cleanup (GCSC) data in BC, Konecny, Fladmark, and De la Puente (2018) discuss how this particular data set is spatially and temporally extensive can be used to assess effectiveness of policy changes to reduce pollution. In particular, they suggest how this data can be used to track changes that may result from the City of Vancouver's planned introduction of a ban on the distribution of single-use plastic straws, polystyrene take-out containers and cups in June 2019. Building off these and other examples, this research project tests the assumptions that 1) EPR is an effective tool for reducing plastic marine debris, and that 2) citizen science is an appropriate source of information to measure policy interventions, particularly EPR. Given that EPR is becoming one of the chosen policy options for addressing this issue, albeit un-tested, and citizen science is the main source of information, looking at both these fields together is necessary for understanding their ability to achieve the promises that have been associated with them independently.

To test these assumptions, this research project is structured to answer the following questions. First, how do the metrics and categories used by citizen science groups to record plastic debris collection results at shoreline cleanup events relate to those used by government to track the performance of EPR policy for packaging waste? Since citizen science was never designed to evaluate policy and EPR was never designed to measure its ability to reduce pollution in the marine environment, understanding *how* these two fields relate rather than assuming that they will relate is the first and important step in determining if and how they can be used together toward the goal of policy evaluation. The second question guiding this project is: what type of packaging pollution trends are present in data generated by citizen science shoreline cleanup and monitoring programs? The findings from this analysis provide greater insight into the potential and limitations associated with the citizen science data itself, strengthening the understanding of how it may or may not be used toward the goal of policy evaluation. After a thorough analysis of the data, there are a few minor instances where EPR and citizen science connect. But overall, the categories and metrics they both use are in fact very different, making it difficult to link them together. And while it would seem that EPR would reduce shoreline packaging pollution levels, this doesn't appear to be the case in BC, based on analysis of existing citizen science data using various mixed-effect and linear models. However, while citizen science data is arguably the best information available to evaluate EPR, in this case, there are many limitations for using it for this particular application making it a poor option for policy evaluation.

As jurisdictions around the world grapple with the issue of plastic marine debris and consider various policy interventions, this research will help provide valuable insight into the requirements for policy evaluation. More specifically, this study helps illustrate that the most readily available data on plastic packaging debris levels, citizen science, is not appropriate for evaluating policy interventions, such as EPR. And that to measure the influence of EPR policy on reducing shoreline packaging pollution levels, a monitoring program tailored to EPR policy's unique requirements of data is essential in understanding if it is having a positive effect of shoreline pollution prevention.

To arrive at these conclusions, chapter two first provides an extensive review of relevant literature. By doing so, this situates the research in the field of plastic marine debris, EPR and citizen science and identifies the theoretical contribution it provides. Chapter three then outlines the methods used to perform both the qualitative and quantitative research. Chapter four provides the results from the qualitative research. This focuses on the key findings that surfaced in the data and the observations that support them. Chapter five includes the results from three experiments using citizen science data and a discussion about the characteristics of the data sets. Chapter six then follows with a conclusion, synthesizing the results from both Chapters four and five and providing recommendations for how best to approach evaluation of interventions aimed at reducing plastic pollution in the marine environment.

Chapter 2 Literature Review

2.1 Plastic marine debris

2.1.1 The presence of plastic in the marine environment

Plastic is a common and ubiquitous type of pollution in the marine environment, with an estimated global abundance of at least 5.25 trillion pieces worldwide (Eriksen et al., 2014). While different classification schemes for plastic debris vary across the literature, Worm, Lotze, Jubinville, Wilcox and Jambeck (2017) categorize plastic marine debris as either nanoplastic (<1µm in diameter), microplastic particles (1 µm–5 mm), mesoplastic (5–200 mm) and macroplastic items (>200 mm). Microplastics have been further classified into having "primary" and "secondary" sources (Browne et al., 2011). Primary microplastics are plastics that have been manufactured to be a microscopic size (Browne, Galloway & Thompson, 2007), such as plastic pellets used as the raw material for fabricating larger items (Worm et al., 2017) or materials used in hand and facial cleansers and cosmetics (Fendall & Sewell, 2009). Secondary microplastics are tiny plastic fragments derived from the breakdown of larger meso and macroplastic debris (Cole, Lindeque, Halsband & Galloway, 2011), as a consequence of physical, mechanical and biological degradation that reduces the structural integrity of plastic debris (Browne et al., 2007). Common macroplastic items found in the marine environment at international cleanups include cigarette butts (12%), food wrappers (8%), plastic bottles (8%) and plastic bags (4%) (Ocean Conservancy, 2018).

Microplastics are increasingly found to be the most prevalent form of plastic marine debris. Survey work performed by Browne, Galloway and Thompson (2010) in the United Kingdom demonstrate that the size frequency of plastic debris on shorelines is skewed toward smaller, microplastic pieces of debris, with microscopic fragments accounting for 65% of the abundance of plastic debris. Once debris has entered the ocean, there is the potential for it to travel considerable distances (Andrady, 2011; Maximenko, Hafner, Kamachi & MacFayden, 2018), persist in the marine environment for long periods of time (Worm et al., 2017) and accumulate in habitats far from its point of origin (Lavers & Bond, 2017). With the exception of materials that have been incinerated, it is considered that all of the conventional plastic that has ever been introduced into the environment still remains to date, unmineralized either as entire objects or as fragments (Thompson et al., 2005).

2.1.2 The negative impacts of plastic marine debris

Plastic marine debris is a major perceived threat to marine biodiversity and socio-economic systems. From a socio-economic perspective, plastic pollution presents an aesthetic issue that can impact the tourism industry by making shorelines unattractive (Jang, Hong, Lee, Lee & Shim, 2014; Krelling, Williams & Turra, 2017), while also presenting a hazard for numerous marine industries, as plastic may entangle or damage equipment (Derraick, 2002; Mcilgorm, Campbell, & Rule, 2011). Environmental impacts of plastic pollution include the injury and death of various marine species resulting from entanglement (Stelfox, Hudgins, & Sweet, 2016), ingestion (Provencher et al., 2014; Liboiron et al., 2016) and the transport of invasive species (Barnes, 2002). Plastics and plastic additives, such as phthalates, bisphenol A, brominated flame retardants, have also been identified as a potential hazard for human health (Galloway, 2015; Lusher, Hollman

& Mendoza-Hill, 2017). Although this field of research is still in its infancy, different routes of exposure of various classifications of marine plastic pollution and their potential impact to human populations have been documented. In particular, microplastics are considered to be potentially detrimental to human health due to the fact that they can be ingested by a variety of aquatic organisms, and therefore have the ability to accumulate through the food web (Cole et al., 2011; Thompson, Moore, vom Saal & Swan, 2009; Lusher et al., 2017). While some state that the actual environmental risks of different plastics and their associated chemicals remain largely unknown (Koelmans et al., 2017; Burton, 2017; Wright & Kelly, 2017), others argue that sufficient evidence of negative ecological impacts exists for decision makers to begin mitigating against impacts and preventing future plastic accumulation, to avoid increased risk of irreversible harm (Rochman et al., 2016; Law, 2017).

2.1.3 The cause of plastic marine debris

2.1.3.1 Waste management systems

Plastic marine debris is a result of waste management systems and the pattern of plastic production and consumption (Chen, 2015). If managed effectively at end of life, plastic waste may be recycled, burned in incineration facilities designed to generate energy or buried in landfill (Barnes, Galgani, Thompson & Barlaz, 2009). Ineffective waste management occurs through inadequate disposal systems (e.g. disposal in dumps and/or open and uncontrolled landfills where it is not fully contained) and poorly covered dumpsters and dump trucks, and littering (Jambeck et al., 2015; Sheavly & Register, 2007). Sewage treatment and storm water discharge, and extreme weather events such as floods are considered land-based sources and contribute to plastic pollution in the ocean (Axelsson & van Sebille, 2017). This phenomenon where materials do not follow an intended pathway and 'escape' or are otherwise lost to the system is referred to as 'leakage' (Ellen MacArthur Foundation, 2016). These land-based sources of leakage are considered the dominant input of plastics into oceans (GESAMP, 2016), with rivers serving as a primary pathway from land to sea (Lebreton et al., 2017). Ocean-based sources, primarily from commercial fisheries (LI, Tse, & Fok, 2016), but also from shipping, military, and research vessels, recreational boats, cruise ships and offshore petroleum platforms (Sheavly & Register, 2007), also contribute to plastic marine pollution.

2.1.3.2 Growth of plastic production

Alongside problems with waste management systems, the production of plastic material continues to grow every year. With 335 million tonnes being generated worldwide in 2016 (PlasticsEurope, 2018), this further compounds the problem. In particular, single-use packaging is currently the largest sector for plastic production, accounting for close to 40% of total plastic use in Europe. Geyer, Jambeck and Law (2017) state that the "largest (plastic) market is packaging, an application whose growth was accelerated by a global shift from reusable to single-use containers" (p. 1). Plastic is extensively used to manufacture packaging materials, as it contributes important properties such as ease of forming, heat sealability, barrier, flexibility, impact strength, light weight, reduced package size, and low cost (Selke, 2003).

2.1.3.3 Persistence in the natural environment

The only way to permanently eliminate plastic waste once it is created is by destructive thermal treatment, such as combustion or pyrolysis (Geyer et al., 2017). However, while this may eliminate physical plastic material, incineration can release toxic gases, such as Dioxins, Furans, Mercury and Polychlorinated Biphenyls (PCB's) into the atmosphere (Verma et al., 2016). Once in the environment, plastics persist for a long time. Worm et al. (2017) state that "because of their very high molecular weight and lack of natural analogues, conventional plastics do not easily biodegrade in the marine or terrestrial environment and may just disintegrate physically" (p. 9) Barnes et al. (2009) build on this, stating that this is particularly evident on shorelines where prolonged exposure to ultraviolet light (photodegradation) and abrasion through wave action make plastics increasingly brittle and prone to fragmentation. These characteristics, paired with the continual annual input of plastic debris into the ocean from land-based sources (Jambeck et al., 2015), leads to an estimated continual buildup of 1.15 and 2.41 million tonnes of plastic pollution in the ocean on an annual basis (Lebreton et al., 2017).

2.1.4 Packaging material

Plastic packaging is estimated by the European Commission on the Environment to be the most abundant type of plastic marine debris, as its weight, size and low economic value make it prone to uncontrolled disposal (2017). Research on shoreline pollution levels and types have consistently demonstrated that packaging debris is one of the more common types of debris (Browne et al., 2010; Konecny, Fladmark & De la Puente, 2018). The International Coastal Cleanup conducted at locations around the world in 2013 found that packaging materials, including food wrappers, plastic and glass drink bottles, bottle caps, plastic grocery bags and plastic lids, all featured in the top ten most frequently found items during marine litter surveys; together these items comprised 31% of all items found on a global scale (Ocean Conservancy, 2017).

2.1.5 Mitigation

The characteristics of plastic marine debris present a distinct challenge for mitigation efforts. In particular, the continued growth of plastic consumption and the decentralized nature of plastic marine debris make this type of pollution particularly hard to address through conventional regulatory standards (Portman, 2016). Downstream interventions, such as shoreline cleanup, can provide short-term pollution abatement (Löhr et al., 2017). However, it has been suggested that there are no readily available tools that would be effective at collecting debris from large areas once its adrift and that the most effective mitigation strategies must reduce inputs upstream at the source (Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel—GEF, 2012; Jambeck et al., 2015). In the waste management sector, source reduction is often synonymous with the terms pollution prevention and waste minimization (Letcher & Vallero 2011). The National Recycling Coalition (1996) in the United States defines source reduction as “the reduction of the amount and/or toxicity of waste at or before the point of generation” (p. 2). In addition, they state “source reduction occurs during the design, manufacture, purchase and use of products and materials, and includes strategies that use less material per product, extend the useful life of products and materials and reduce overall waste generation” (p. 2).

Alongside source reduction, improved waste management and increased recycling is argued to help prevent the plastic material that has been produced, from leaking into the marine environment (European Commission on the Environment, 2017b; Gold, Mika, Horowitz, Herzog & Leitner, 2013). In particular, efforts to provide incentives for recycling can increase the volume of material recovered from the waste stream for recycling (Loughlin & Barlaz, 2006). One policy tool that has been identified to increase source reduction and recycling infrastructure simultaneously is EPR.

2.2 Extended Producer Responsibility (EPR)

2.2.1 Policy objectives

EPR is a state/provincial or federal policy approach to waste management where a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle (Mckerlie, Knight & Thorpe, 2006; Organisation for Economic Co-operation and Development, 2001). By shifting the historical public sector tax-supported responsibility for waste management upstream to the producer, the objective of EPR is to motivate producers to incorporate environmental considerations in the design of their products (Canadian Council of Ministers for the Environment, 2009). While other interventions like product bans seek to eliminate a certain material from the marketplace altogether, EPR is designed to reduce consumer waste and manage it more effectively.

Many argue that EPR is an especially relevant policy response to the increasing amount of plastic marine debris because of how it incentivizes producers to prevent waste from being generated in the first place (i.e. source reduction) and aims to reduce leakage into the environment through funding, creating, and/or expanding infrastructure for post-consumer recycling (Borrelle et al., 2017; Chen, 2015; Cairns, 2009; Tibbetts, 2015; UNEP & NOAA, 2013; Gold et al., 2013).

In terms of packaging waste, successful EPR programs and the associated recycling infrastructures, including curbside collection, in Europe, have played a significant role in achieving high recycling and recovery rates, diverting packaging waste away from landfills (Newman et al., 2015). In particular, in the 28 European member states, the recycling rate of packaging material went up from 59.2% in 2007 to 67.2% in 2016 (European Commission, 2019). In BC, recovery of residential packaging and printed paper product increased from an estimated 50% to 57% recovery rate pre-2014 (Glenda Gies and Associates, 2012), to 80%, after the introduction of the EPR program for packaging and printed paper in 2014 (Multi-Material BC, 2015). Referring to the influence of EPR on recycling efficiency, scientist Markus Eriksen (2017) argues that "policy-driven EPR is essential. When a company is responsible for the full life cycle of its product and packaging, innovation for recovery catches on like wildfire" (p. 89). While the increase in recovery is a promising perspective to view pollution prevention, it is unclear how this affects shoreline pollution patterns.

2.2.2 Reporting framework

It is clear that the concept of EPR is an attractive orientation to preventing plastic marine debris but the way in which the policy is structured can make measuring its effectiveness challenging. In Canada, provinces and territories have jurisdiction over regulating waste policy, resulting in EPR programs being introduced at a provincial level

(Canadian Council of Ministers for the Environment, 2009). In BC, when EPR policy for a certain product is introduced, an agency (commonly referred to as a stewardship agency) typically forms and producers of regulated materials may choose to appoint the agency to undertake the duties outlined in the legislation (BC Ministry of Environment and Climate Change Strategy, 2012). These duties include, but are not limited to, preparing a plan, implementing and managing a collection program and reporting on performance.

The reporting paradigm for EPR program performance focuses on material flows within the collection system (Lifset, Atasu & Tojo, 2013). For packaging EPR systems, curbside pickup and depot collection performance is typically measured through a "recovery rate," which compares the total tonnage of producer's material entering the market to the total tonnage collected by formal waste management (recycling and landfilling). For example, in BC, the stewardship agency responsible for managing the packaging and printed paper (PPP) EPR program, Recycle BC, reported 238,062 tonnes of all obligated producer packaging material (e.g. plastic, paper, metal, etc.) entering the BC market and 185,477 tonnes collected by the program in 2016, for a recovery rate of 78% (Recycle BC, 2017a).

Other than recovery rate, the BC *Recycling Regulation* outlines several other required reporting criteria (e.g. accessibility, pollution prevention hierarchy, education, etc.), which are intended to demonstrate continuous improvement of the program (Recycling Regulation, 2004). However, even programs that achieve very high recycling rates still fail to capture a significant portion of potential marine pollution (Gold et al., 2013). The remainder of material is managed through conventional waste management processes (i.e.

landfill) or can leak into the natural environment. Furthermore, monitoring and mitigating the leakage of material from the collection system into the natural environment is not a component of the legislative reporting requirement for EPR programs, which is the case in BC. Instead, the provincial government in BC has claimed that by making producers responsible for life-cycle management and high recovery rates, leakage into the marine environment will be reduced (Pacific Coast Collaborative, 2010). However, this concept and the actual performance of packaging EPR systems in reducing plastic marine debris on shorelines has never been assessed.

2.2.3 Recent developments

Recently, there has been increasing interest in the use of EPR policy to reduce plastic marine debris. On December 19, 2018, the European Parliament and the Council of the European Union reached agreement on the *Proposal for a Directive of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment* (European Commission, 2018a). The Directive was released on May 28, 2018 and is primarily aimed at reducing the harmful effects of plastic marine debris, with a specific focus on single-use plastic packaging items and fishing gear, which the Commission states together represent approximately 70% of marine litter items (by count) found on European beaches (European Commission 2018b). Several policy tools are outlined in the Directive that are intended to prevent and reduce plastic marine debris, including EPR. In particular, As per Article 8, Member States will have to establish EPR schemes by 2021; producers of single-use plastic products including food containers, packets and wrappers, beverage containers, cups for beverages, tobacco products with filters, wet wipes, balloons, and lightweight plastic carrier bags will be expected to cover the costs of collecting waste consisting of those products and its subsequent transport and treatment, including the costs of litter cleanup and awareness raising measures.

In Canada, reducing plastic waste, marine litter and plastic pollution has become a priority for the federal government (Fisheries and Oceans Canada, 2018). Recently, Canada used its 2018 G7 presidency to focus in on the issue of plastic marine debris, spearheading dialogue on national and international initiatives intended to address the problem (Environment and Climate Change Canada, 2018). In terms of domestic policy, the federal government, provinces and territories have been working through the Canadian Council of Ministers of the Environment (CCME) on the Strategy on Zero Plastic Waste*,* which outlines a vision to keep plastics in the economy and out of the environment through solutions to better prevent, reduce, reuse, and clean up plastic waste (Canadian Council of Ministers of the Environment, 2018). One of the major components of the Strategy is to work with companies that make products containing plastics or using plastic packaging to shift responsibility to them for the improvement of plastic-waste collection, management systems, and infrastructure across Canada. In particular, the Strategy states "collaboration under the CCME, in particular through continued implementation of existing initiatives such as the Canada-wide Action Plan on Extended Producer Responsibility (2009), serves as a foundation for the transformation ahead" (Canadian Council of Ministers of the Environment, 2018, p. 3).

These recent developments demonstrate how various levels of government are looking to EPR as a solution to plastic marine debris. What is not clear in these strategies is how agencies intend to monitor the effectiveness of any EPR policy that is introduced in terms of preventing plastic marine debris in the ocean and on shorelines.

2.3 Citizen science

2.3.1 Characteristics

The recent surge in plastic marine debris related policy has identified a gap in monitoring programs capable of assessing the effectiveness of recently applied policy measures (Maes et al., 2018). Professional research can address this gap, but it is costly and resource intensive (Hidalgo-Ruz & Thiel, 2015). Volunteer observations and collections in a growing number of nations are aiding our understanding of the scale and pattern of distribution of plastics in the marine environment (Barnes et al., 2009). In particular, citizen science, a decentralized civic mode of quantitative data collection, has become integral in the development of data and information on shoreline plastic marine pollution levels (Hidalgo-Ruz & Thiel, 2015). Performed by people who may not be accredited scientists, citizen science is an approach to broadening the coverage and increasing the sampling power of marine debris monitoring that would otherwise not have been addressed due to a lack of resources, time, or geography (Cigliano et al., 2015; van der Velde et al., 2017). For plastic marine debris monitoring, citizen science often takes the form of shoreline cleanup projects.

2.3.2 Use and application of data

Shorelines are the most easily accessible areas for studying marine debris and allow for the establishment of many volunteer or commercial marine debris survey study sites (Barnes et al., 2009). The data that is generated through volunteer monitoring efforts is often used to increase awareness about plastic marine debris and inform the development and introduction of plastic pollution prevention policy (Rees & Pond, 1995; Zettler et al., 2017; Cigliano et al., 2015). For example, Zettler et al. (2017) discuss how citizen science shoreline cleanup projects that focus on debris items such as cigarette filters, have used their findings to inform the introduction of "smoke-free" beaches to aid in the reduction of cigarette litter.

2.3.3 Citizen science data and policy evaluation

Recently, citizen science data has been used to assess the efficacy of policy interventions. For example, several recent news items have reported the use of citizen science data from California's Coastal Cleanup Day to assess the performance of the State's plastic bag ban, reporting a 72% reduction in shoreline plastic bag debris compared to 2010 (The Times Editorial Board, 2017; Mercury News & East Bay Times Editorial Boards, 2017; Phillips, 2017). In a recent journal article assessing Great Canadian Shoreline Cleanup (GCSC) data in BC, Konecny, Fladmark, and De la Puente (2018) discuss how this particular data set is spatially and temporally extensive and can be used to assess the effectiveness of policy changes to reduce pollution. In particular, they suggest how this database can be used to track changes that may result from the City of Vancouver's introduction of a ban on the distribution of single-use plastic straws, polystyrene take-out containers and cups in June 2019. The National Oceanic and Atmospheric Administration (NOAA) also state that standardized monitoring frameworks used by citizen scientists can be used to evaluate the effectiveness of policies to mitigate debris, such as recycling incentives or extended producer responsibility (Lippiatt, 2013).

When reflecting on this use of citizen data, it is important to keep in mind the diversity of data sets and policy approaches to addressing plastic marine debris.

While citizen science has been identified as a legitimate source of information, it is often under the assumption that it is part of a formal monitoring program. For example, in monitoring radioactivity in seawater on the coast of North America following the release from the Fukushima Dai-ichi Nuclear Power Plants in 2011, researchers designed a scientifically rigorous experiment and used a network of citizen scientists to perform the labour needed to collect samples at pre-determined locations, within a specific timeline (Smith et al., 2017). The data generated by California's Coastal Cleanup Day and the GCSC may be appropriate to evaluate certain policy, such as product bans, given these organizations large scale and use of standardized method. However, there is often a wide variety of other organizations in a specific jurisdiction conducting citizen science shoreline cleanup and monitoring programs and generating data, with several different methods and with little coordination between them. While it has been discussed that synthesizing the majority of data collected by volunteer groups to interpret patterns at a large scale is problematic given that there are often differences in methodologies between sites and observers and information is often difficult to access (Barnes & Milner, 2005), the diversity of information and data available provide an important lens in the pollution landscape and may be an effective tool when looking at policy effectiveness.

This research project explores the variety of citizen science data sets present in BC and identifies how they may relate to the recent packaging EPR policy that was introduced in the province in 2014. As previously discussed, EPR is an attractive market-based policy tool that has become a major focus for various levels of government looking to address plastic marine debris. Investigating the qualitative and quantitative dimensions of the citizen science data present in the province and the EPR program will help develop an understanding if or how the data may be able to be used to evaluate EPR.

2.4 Theoretical contribution

This research contributes to several fields within the social sciences. Given its focus on the management of waste and evaluation of a particular policy intervention in a specific geographical area, the main contributions for this study can be situated within discard studies, geography of waste and policy studies.

Geographies of waste include examinations of its flows and politics (Millington and Lawhon, 2018). In particular, the study of waste reveals the interconnections between the environment, politics, markets, race and class (Thomson, 2009). Of the various concepts deployed in geographies of waste, Moore (2012) explores several of interest of this research project. Waste as resource provides a view into such phenomena as the impacts of formal recycling on the efficiency and sustainability of municipal solid waste (MSW) management (Moore, 2012). She also offers that waste is often conceptualized as an object to be managed and governed at different scales. In particular, questions regarding the effects of supra-local regulation on MSW management often arise from this view on waste. In terms of the MSW stream, Davies (2016) offers that this type of waste in particular "is increasingly fluid, moving both within and between nation states, traversing administrative and political boundaries and encountering different management conditions" (p. 4). Gregson and Crang (2010) acknowledge these perspectives but argue that "predominantly, social science work identifies waste in terms of waste management, a move which ensures that waste is defined by, and discussed in terms of, `disposal' technologies, or more correctly waste treatments, and their connection to policy" (p. 1026). Instead, they suggest how "the geographies of waste scholarship might move beyond their traditional locus of the municipality, the region and the nation-state" (p. 1031). Ocean shorelines represent one such shift in geography, even while they are tied to legal jurisdictions like municipalities and provinces—indeed, this project investigates whether a provincial-scale intervention has impacts on the unruly geography of ocean shorelines.

Another way this research project contributes to the field of geography of waste is by analyzing available citizen science pollution data, it develops a greater understanding of waste flows beyond the conventional MSW stream by looking at leakage of material from this system. But by looking at EPR specifically, this research changes the focus of waste management policy from traditionally looking at downstream municipal disposal treatment, to an upstream approach to pollution prevention. And by doing so, explores how this form of policy intervention affects waste management and pollution prevention. In other words, this research joins the very upstream with the very downstream.

The effect of policy on waste management is a key component of the field of geography of waste, but the investigation of policies and their effects is also a standalone discipline. Closely related to both public administration and political science, policy studies can be broadly defined as the study of nature, causes and effects of alternative public policies for dealing with specific social problems (Nagel, 1981). Fischer (2003) argues "the increasing complexity of modern technological society dramatically intensifies the information requirements of modern decision-makers" (p. 2). As a result, policy studies combine sophisticated technical knowledge with intricate and often subtle social and political realties (Fischer, 2003). In particular, policy studies scholars investigate the role of policies as governing instruments and consider the factors that shape their impacts (May & Jochim, 2013).

This research project also contributes to the field of policy studies is several ways. Investigating plastic marine debris provides an interesting lens to assess the impacts of local waste regulation. Given that plastic marine debris is a highly decentralized form of pollution, this research challenges norms of introducing centralized interventions to address this issue. Building off this, this research also develops the argument that if centralized interventions are to be introduced, regulators cannot simply expect them to work. Unique considerations need to be made that take into account both the transboundary nature of plastic marine debris and the specific design of the intervention. Furthermore, by analyzing the quantitative and qualitative dimensions of citizen science data, this research assesses the ability to use this type of information to evaluate policy, when its main objective has been to inspire policy.

The main contribution of this research exists within the field of discard studies. Discard studies is central to thinking through and countering the familiar aspects of waste (Liboiron, 2014). In other words, discard studies trouble the assumptions, premises and popular mythologies of waste. By doing so, discard studies highlights the difficulties in analyzing waste, due to the fact that many of its economics, infrastructures and social norms are hidden from plain view. To overcome this, the discipline aims at redefining waste and scaling it up, in attempts to make these systems apparent (Liboiron, 2014). A particular example of this can be seen within the discard studies literature on recycling.

Recycling has often been proposed as a solution to the issue of waste. However, it has been reasonably well established that recycling represents a somewhat problematic response to the problem of waste, and plastic waste in particular. In fact, using waste management data from the United States, Europe, China and 52 other countries, Geyer et al. (2017) demonstrated that global recycling rates are relatively low, with approximately only 9% of all plastics ever produced end up being recycled, while 60% were discarded and are accumulating in landfills or the natural environment. There are several factors that limit recycling as a solution to waste. In her book *Recycling Reconsidered*, Samantha MacBride questions the material efficacy of current plastic recycling systems (in the United States), arguing that the varied status and types of plastics in the market reflects the extreme heterogeneity in the group of materials commonly referred to as "plastic" and importantly leaves almost 60 percent of all plastic wastes unaddressed by prevention or recycling programs (2012, p. 175). The exclusion of a large amount of plastics from recycling programs is partly a result of the narrow focus of these programs on the municipal sector. However, Lepawsky (2018) notes available figures for Canada, the United States, and Europe indicate that MSW amounts to somewhere between 2% and 9% of all waste created, while, approximately 91–98% arises upstream in primary industry, manufacturing, distribution, and retail. And by focusing on MSW or postconsumer waste, Lepawsky argues "we are construing waste as a very particular and partial problem. If we then propose solutions such as individual-, household-, or even municipal-scale recycling, we will be dealing with only a tiny portion of waste" (2018, p. 8). He adds, "no amount of postconsumer recycling will recoup discards arising upstream in resource extraction and manufacturing (2018, p. 130).

To overcome the challenge with conventional recycling programs, the focus of interventions in the supply chain needs to change and look upstream. The Global Alliance for Incinerator Alternatives (GAIA) argues "we must acknowledge that recycling will never be able to absorb the existing and expanding production of plastics, and while efforts to improve recycling are necessary, the primary emphasis must be on large scale reduction of plastic in the marketplace" (2018, p. 4). Liboiron builds on this, arguing "the only mode of attack is to deal with a heavy decrease in the production of plastics, as opposed to dealing with them after they've already been created" (in Hutton & Hess, 2019). In other words, the logical response to the problems associated with recycling downstream is to switch the focus upstream, to the source of waste generation. This call to look upstream has become a mantra in discard studies.

Yet there is little empirical data on upstream interventions. Macbride (2012) argues that "producer-focused policies – that require producers to take responsibility for managing spent products – are particularly appropriate for modern materials in general and for plastics in particular" (p. 176). However, she states that for them to be effective, detailed information on material flows is critical, but often not available. As illustrated in Section 2.2.2, EPR programs, which focus upstream, often have information available on material flows between production, sale and collection for recycling, in order to demonstrate their performance to regulators. However, little to no information exists in regarding the leakage of materials from an EPR program into the natural environment. And without specific information on waste flows into the environment, it is difficult to determine how effective EPR, or other upstream policy approaches, will be at achieving the objective of reducing this type of pollution.

The challenges associated with determining if upstream policies are increasing pollution prevention downstream are so rarely remarked upon because so few policies actually shift focus upstream. As a result, little research has been focused on upstream policy effectiveness. The key contribution of this research is to provide a rare look at an upstream policy intervention and its ability to prevent pollution downstream. By doing so, this research both tests the assumptions that upstream policy is the preferred approach to waste management, while providing critical insight into how such policy needs to be designed and monitored to ensure its effectiveness.

Chapter 3 Methods

3.1 Parallel methods

This study uses a parallel approach to research methods. First, this project qualitatively analyzes how the metrics and categories utilized by citizen science shoreline cleanup programs in BC relate to those used by government and industry to measure EPR policy, where there are points of overlap and how they are different. Second, this project quantitatively analyzes pollution data provided by organizations conducting shoreline cleanup and monitoring programs in BC, to identify temporal and spatial trends in packaging waste levels that may be present.

By using a parallel-method approach to research citizen science and EPR, this study can corroborate findings across quantitative and qualitative data sets and therefore reduce the impact of potential uncertainty that can exist and allow for each research question to be addressed adequately. More specifically, qualitative findings create a more comprehensive understand of the quantitative results and any nuances within the data that would otherwise not be known. For example, interviews with key informants and document analysis on Surfrider Vancouver materials identified that in several cases, shoreline cleanup sample sites were recently cleaned before monitoring work was performed, thereby influencing pollution levels that were encountered by citizen scientists. Without performing the qualitative research, this element of the quantitative data set would not be known. Alternatively, quantitative analysis creates a detailed look at some of the trends that can be drawn from the data, which helps understand how the data collection practices align with the data-based goals and objectives of each organization identified during qualitative research. Overall, the conclusions that are drawn from this research are mutually informed by the results of both the qualitative and quantitative research.

3.2 Qualitative methods

The qualitative research component of this project is designed to address the first research question:

> *How do the metrics used by citizen science groups to record plastic debris collection results at shoreline cleanup events relate to those used by government to track the performance of EPR policy for packaging waste?*

The texts for the qualitative research are:

- BC Recycling Regulation – Schedule 5 “Packaging and Printed Paper”
- Stewardship agency (Recycle BC) stewardship plans
- Stewardship agency (Recycle BC) annual reports
- Shoreline cleanup organization websites and reports
- Peer reviewed literature on citizen science shoreline monitoring
- Interviews with representatives of organizations that conduct shoreline cleanup and monitoring projects in BC, government regulators and industry stakeholders responsible for the implementation of the packaging and printed paper EPR program

Qualitative analysis of these texts focused on:

- The degree and ways packaging waste is defined and categorized (e.g. plastic & paper vs. plastic straws, plastic cups, etc.)

- The rationale and origin of this categorization
- What is missed in these categorizations and what effects will this have on the data that is to be analyzed
- The ability to ensure shoreline clean up objects are local or not and what the presence of foreign debris does to shoreline cleanup data
- How measurement of plastic packaging waste occurs
- Stakeholder perspectives on plastic marine debris and packaging waste

To perform the qualitative analysis, document analysis methods were used in conjunction with semi-structured interviews with key informants.

3.2.1 Interviews

Interviews were conducted with 11 representatives from all the eight organizations conducting shoreline cleanup and monitoring work in BC, staff from the BC Ministry of Environment and Climate Change Strategy and staff from Recycle BC, the stewardship agency operating the packaging and printed paper program in BC (see Table 1). When feasible, interviews were conducted in-person. If an in-person interview was not possible, the interview was conducted over Skype or the telephone. Interviews occurred for approximately 30 minutes on average.

Table 1: Organizations Interviewed in this Research Project

Organization Type	Organization Name	# of Interviewees
Organizations conducting citizen science shoreline cleanup and monitoring work in BC	Great Canadian Shoreline Cleanup	1
	Surfrider Foundation – Vancouver Island Chapter	1
	Surfrider Foundation – Vancouver Chapter	1
	Surfrider Foundation – Pacific Rim Chapter	1
	Living Oceans Society	1
	Ucluelet Aquarium	1
	Ocean Legacy Foundation	1
	Clayoquot Cleanup	1
Government	BC Ministry of Environment and Climate Change Strategy	1
Industry	Recycle BC	2

Key informants for shoreline cleanup organizations were typically representatives in a senior role and/or responsible for managing the shoreline cleanup and monitoring program. The key informant for the BC Ministry of Environment and Climate Change Strategy was the Director (i.e. Statutory Decision Maker) responsible for the Extended Producer Responsibility business unit. The key informants for Recycle BC were the Senior Vice President and the Director of Logistics. While this research does not track the names of each key informant, confidentiality is limited due to association through each organization. Limitations to confidentiality were identified during the informed consent process.

Interviews were semi-structured. A semi-structured interview is a qualitative method of inquiry that combines a pre-determined interview schedule with the opportunity for the interviewer to explore particular themes or responses further (Wengraf, 2001). Unlike a structured questionnaire, a semi-structured interview does not limit respondents to a set of pre-determined answers. Interviews were recorded, reviewed and fully transcribed. Interview transcripts were shared with interviewees to confirm the accuracy of the interview.

3.2.1.1 Ethics

The project is consistent with the guidelines of the *Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans* (TCPS2). Full ethics clearance is granted by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) at Memorial University of Newfoundland. The ICEHR number for ethics clearance is 20190638-AR.

3.2.2 Document analysis

Glenn Bowen (2009) describes document analysis as a systematic procedure for reviewing or evaluating documents—both printed and electronic (computer-based and Internet-transmitted) material. For this research document analysis was used to systematically review and evaluate shoreline cleanup organizations websites and reports, peer-reviewed literature on citizen science shoreline monitoring and relevant policy documents. Document analysis is an applicable method for the qualitative component of this study, given that it is often used to analyze different types of documentation. Document analysis is also appropriate for this study due to the fact that it used in combination with other research methods as a means of triangulation — the combination of methods in the study of the same phenomenon (Bowen, 2009).

For citizen science documentation, analysis was focused on identifying the difference and gaps between the way an organization defines packaging material and how they collect data by analyzing various parts, sentences and keywords present in the texts.

For government and industry policy documents, analysis aimed at identifying the specific categories and metrics used in the EPR program.

3.2.3 Qualitative analysis of interviews and documentation

Analytical activities for the qualitative research will follow the sequence outlined by Berg (2004) to organize and reduce data, in order to uncover patterns. The first stage of analysis begins with developing a number of analytical categories and sub-categories that help sort the themes and the various chunks of raw data (e.g. segments of text from field notes, interview transcripts, document text, etc.). The analytical categories and sub-categories that emerged from the literature, research questions and the interview questions are:

A. Packaging waste/debris measurement

  a. Experiences of measuring plastic marine debris
  b. Experiences of measuring packaging waste/debris
  c. Waste/debris measurement approaches
  d. Foreign and domestic waste/debris measurement

B. Packaging waste/debris categorization

  a. Packaging waste/debris definition and categorization
  b. Purpose and origin of categorization
  c. Problems and revisions of categorization

C. Purpose of the Data

An inductive approach to coding was utilized, where the data is systematically reviewed in order to identify the dimensions and themes that is relevant to the research question. The intention of this coding process was to open inquiry widely. This was accomplished by looking at the data with a consistent and specific set of criteria related to the purpose of the study (i.e. analytical categories above) but also remaining open to multiple or unanticipated results that emerge from the data. The initial coding process was broad, analyzing the data minutely and staying open to many incidents and interactions. This helped ensure extensive theoretical coverage of the data. Interesting and relevant information was noted (e.g. highlighted). Since this research project uses an inductive approach to identifying dimensions and themes in the data, the criteria for selection (coding rules) remained open and the various elements in the data, such as words, themes, characters, paragraphs, items, concepts and semantics were be identified as data points. For example, when reviewing data on waste debris measurement approaches, weight and count were tracked as the main metrics for measurement. However, it was also noted when volume, area, truck weight or the number of super-sacks was also identified as a metric for debris measurement.

The next step in the coding process was to organize the findings. Through the use of "coding frames" (Berg, 2004), codes are analyzed through a multileveled process that requires several successive sortings. The first frame is a general sorting of codes into specific groups. This occurred by organizing all codes in a table with the different organizations (rows) and analytical categories (columns). Next, more intensive sorting occurred within each of the analytical categories, allowing for unique patterns (e.g. (in)consistency, repetition, etc.) to emerge from the data. For example, when looking at the different responses within the analytical category "purpose of the data," the goals to raise awareness and inform policy development were consistent across many of the organizations. Coding was performed using electronic spreadsheets as well as post-it notes. Both tools assisted in identifying the thematic patterns in the data. Once the key findings were identified in the data, data was reviewed again, and notes were made on particular points that support each key finding. The outcomes of this process are expressed in Chapter 4.

3.3 Quantitative methods

The quantitative research component of this project is designed to address the second research question:

> *What type of packaging pollution trends are present in data generated by citizen science shoreline cleanup and monitoring programs?*

The data for the quantitative research are pre-existing shoreline pollution data sets that have been generated by and obtained from citizen science shoreline cleanup organizations operating in BC (see Table 2). There is a wide variety of data sets that have been shared by the different organizations, creating a diversity of analytical opportunities. To determine what type of analysis is possible, the first step was to go through each data set and identify the main features of the data (e.g. timespan, frequency, location, number of pollution and packaging categories used, etc.). The goal then was to identify packaging pollution trends present in the data. This is useful, in determining both results in the data, but also the different statistical opportunities that are possible due to the structure of the data.

After reviewing the main features of the data sets, it became clear that three of the eight data sets either focused exclusively on microplastics (Ucluelet Aquarium) or lacked more than one cleanup record (Clayoquot Cleanup and Ocean Legacy). As a result, it was not possible to use the data from these organizations. Of the remaining five data sets, three allowed for several types of experiments that demonstrate different packaging pollution trends: Great Canadian Shoreline Cleanup (GCSC), Surfrider Vancouver & Vancouver Island Chapters (combined) and Surfrider Vancouver Island Chapter. While these three data sets record several types of packaging material over several years, there are several limitations that are important to note. In particular, neither the GCSC nor Surfrider monitoring programs track the source of the pollution, due to the fact that it is not possible to do so. Also, there are only three categories of packaging materials present in the data that align with the regulatory definition of packaging and/or managed by the Recycle BC EPR program, which is relatively small when considering the large variety of packaging materials found in the waste stream.

Table 2: Organizations in BC Conducting Citizen Science-based Shoreline Cleanup Activities

Citizen Science Shoreline Cleanup Organizations	Years of Data	Packaging?
Living Oceans Society	2012 – present	No
Clayoquot Cleanup	2017	Yes
Great Canadian Shoreline Cleanup	2008 – 2017	Yes
Ucluelet Aquarium	2017 – present	No
Surfrider Foundation – Pacific Rim Chapter	2016 – present	No
Surfrider Foundation – Vancouver Chapter	2013 – 2018	Yes
Surfrider Foundation – Vancouver Island Chapter	2011 – 2016	Yes
Ocean Legacy Foundation	2017	Yes

Each data set that was analyzed first underwent thorough data preparation. Some organizations shared data in electronic spreadsheets, while others stored their data in word documents or online. In order for the data to be analyzed in the R Studio statistical software program, it needed be adequately prepared into comma separated value files

(.csv) that can be imported into R Studio and organized into long-format data frames for analytical purposes. While data preparation was conducted, a 'process journal' was used to record all the steps taken to manipulate the data in way that it could be used for analysis. The process journal provided a detailed description of the elements of the data set (method, time-span, location, consistency, etc.), the steps taken to format the data to a usable format and a summary of the data set, which includes, but is not limited to, the number of records present, the metrics and categories used and changes in the data over time.

3.3.1 Great Canadian Shoreline Cleanup

EPR policy for packaging material in BC was introduced on May 19, 2014 in a majority of municipalities across the province.[1] Shoreline cleanup events frequently occur in these municipalities. To analyze long-term packaging material shoreline deposition trends in relation to the introduction of EPR policy, data from the GCSC can be used. The GCSC data set includes 5,752 records for shoreline cleanup events in BC, from 2008-2017. The GCSC has used a tally method (count) to track between 26 – 59 different material categories over the course of these 10 years. Following the protocol for data exploration developed by Zuur et al. (2010), visual techniques were utilized to determine the characteristics of the data.

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[1] The majority of municipalities in BC chose to participate in the EPR program. However, a few municipalities initially chose not to participate in the program and to continue paying and operating their existing packaging collection and recycling programs on their own. In recent years however, all these municipalities have changed their minds and are now part of the EPR program. For the sake of consistency, this analysis only focuses on sites in municipalities that have been part of the program since it launched on May 19, 2014.

For analytical purposes, a subset of data was generated that eliminated records that lacked material-specific results and included sites with consistent records for three years before and after the introduction of EPR in 2014, for a total of seven years of data (2011-2017). Also, all material categories were removed from the data set that were not aligned with the definition of "packaging" in the BC *Environmental Management Act*, narrowing the categories to three that have been consistently recorded throughout the entire data set: plastic bags, six-pack holders and food wrappers. The remaining data set includes 147 records, across 21 different shoreline cleanup sites.

To test the effect of the introduction of EPR policy for packaging (combined total of plastic bags, food wrappers and six-pack holders) on shoreline packaging debris levels, a linear mixed-effect model was constructed, with the location of the shoreline (site) and the number of cleanup participants (people) as random effects, to account for spatial autocorrelation (site) and differences in cleaning efforts (people). The number of packaging per kilometer was used as response variable, to control for shoreline length. The amount of people, the length of the shoreline (kilometers) and the site can each be expected to have an influence on the collection results, hence their inclusion in the models. Using a mixed-model approach enabled me to determine if there was a difference in packaging debris levels between years, while controlling for other factors.

Models were constructed using the function "lmer" (linear mixed-models) of the "lme4" package in R. All models met the assumptions of residuals homogeneity, normality and independence. To meet these assumptions, the response variable was log-transformed +0.0001. For the sake of presenting the results, I did not supress the pretending variable. To evaluate the influence of the EPR policy on packaging shoreline debris levels after it was introduced, I performed model selection based on Akaike's Information Criterion (AICc; to control for small sample size). Model selection was performed on a set of candidate models. Two models were used: (1) a null model, only including the random effects, and (2) a complete model, including the fixed effect of year and the random effects. It is good practice to look for pretending variable (i.e. uninformative parameters), while performing AIC selection (Leroux, 2019). In our case, since we are only comparing two models, pretending variables were not suppressed, but will be acknowledged. Marginal and conditional goodness-of-fit (R^2) were computed following the procedure of Nakagawa et al. (2013). Summary of the models allowed me to determine the importance of year (proxy for EPR policy) on packaging debris levels.

3.3.2 Surfrider Vancouver & Surfrider Vancouver Island (combined)

Data from the Vancouver and Vancouver Island Chapters of the Surfrider Foundation was also used to analyze packaging material shoreline deposition trends in the Vancouver and Victoria areas, in relation to the introduction of EPR policy in 2014. The Surfrider data sets are created in accordance with the NOAA Shoreline Survey Field Guide (2012). The NOAA Field Guide uses a tally method (count) to track approximately 42 different material categories. The NOAA method controls for length of shoreline by utilizing a 100m transect. It also controls for effort by typically having only a few people perform the monitoring work.

There is a combined total of 81 records from both data sets for shoreline cleanup events at locations in both Vancouver and Victoria from 2011-2017. Following the protocol for data exploration developed by Zuur et al. (2010), visual techniques were utilized to determine the characteristics of the data. For analytical purposes, a subset of data was generated that eliminated records that lacked data before and after the introduction of EPR in 2014. The data set was also limited to sample sites in urban areas, in municipalities that are participating in the EPR program. Furthermore, all material categories were removed from the data set that were not aligned with the definition of "packaging" in the BC *Environmental Management Act*, narrowing the categories to three that have been consistently recorded throughout the entire data set: plastic bags, six-pack holders and food wrappers. The remaining data set includes 37 records, across eight different shoreline cleanup sites (seven in Victoria and one in Vancouver).

To test the effect of the introduction of EPR policy for packaging (combined total of plastic bags, food wrappers and six-pack holders) on shoreline packaging debris levels, I performed an analysis of variance (ANOVA) on a generalized linear model with Poisson distribution, to account for count data. I used "site", "year" and their interaction as covariates. Models were constructed using the function "glm" in R. All models met the assumptions of residual's homogeneity, normality and independence. I also performed a paired t-test, by pairing site before and after the introduction of EPR in 2014. For sites that had more than one cleanup event before or after 2014, the average value was used.

3.3.3 Surfrider Vancouver Island

Shoreline cleanup events frequently occur in urban municipalities that are participating in the Recycle BC EPR program. However, shoreline cleanups also increasingly occur in more remote locations of the province. The Vancouver Island Chapter of the Surfrider Foundation is the only organization that has collected data from sample sites in both urban and remote locations consistently over time. Their data was used to analyze packaging material shoreline deposition trends between urban and remote sample sites.

There is a total of 56 records between 2011-2017 across 13 different sample sites on the south west coast of Vancouver Island, stretching from Cadboro Bay to Port Renfrew. 29 records are from sample sites in remote locations and 27 records are from sample sites in urban areas. Following the protocol for data exploration developed by Zuur et al. (2010), visual techniques were utilized to determine the characteristics of the data. For analytical purposes, all material categories were removed from the data set that were not aligned with the definition of "packaging" in the BC *Environmental Management Act*, narrowing the categories to three that have been consistently recorded throughout the entire data set: plastic bags, six-pack holders and food wrappers.

To test the difference in packaging pollution levels (combined total of plastic bags, food wrappers and six-pack holders) between shoreline "type" (urban or remote), I performed an analysis of variance (ANOVA) on a generalized linear model with Poisson distribution, to account for count data. I used "year", "type" and their interaction as covariates. Models were constructed using the function "glm" in R. All models met the assumptions of residual's homogeneity, normality and independence.

Chapter 4: The Alignment between Citizen Science and EPR

4.1 Introduction

This chapter is intended to address the research question: how do the metrics used by citizen science groups to record plastic debris collection results at shoreline cleanup events relate to those used by government to track the performance of EPR policy for packaging waste? To accomplish this objective, this chapter first identified several key observations pertaining to citizen science shoreline cleanup organizations, the legislative framework for packaging EPR policy and the structure of the Recycle BC program, which are critical to supporting the key findings. Building off these key observations, this chapter then shares the key findings that arose during research.

4.2 Key observations

4.2.1 Citizen science shoreline cleanup projects

While there are no doubt countless individual or small group shoreline cleanup endeavours occurring in BC, the focus of this research was to specifically explore citizen science shoreline monitoring activity by non-governmental organizations (NGOs). Early in the research process it became apparent that shoreline monitoring work was primarily undertaken by several organizations. Through online research, conversations with relevant stakeholders and direct dialogue with study participants, it was determined that eight organizations were primarily conducting and/or coordinating citizen science shoreline cleanup work in BC (see Table 3).

The eight organizations range from large funded national organizations with paid staff, such as the Great Canadian Shoreline Cleanup (GCSC), to small local organizations, operated by volunteers. Some organizations have been operating for more than a decade, while others have recently started shoreline monitoring work. Other than the GCSC that supports community cleanups across the province, all the organizations focus on a specific area within the province. Some organizations focus solely on shorelines located in urban areas, while other focus on remote areas. One organization focuses on both types of shoreline environments. The frequency that each organization performs monitoring work also varies, with some occurring monthly, while others occur annually. See Appendix A for a detailed description of each organization.

Table 3: Citizen Science Shoreline Pollution Monitoring and Data Collection Methods.

Green indicates the current method(s) used. Yellow indicates the past method(s) used.

Citizen Science Shoreline Cleanup Method Matrix									
Organization	Data Collection Method								
	GCSC Data Card (Count)	NOAA Field Guide (Count)	Other Count Method	Total Weight	Total Volume	Area Cleaned	NOAA Micro	Polystyrene Volume	# of super sacks
Living Oceans Society									
Clayoquot Cleanup									
GCSC									
Ucluelet Aquarium									
Surfrider – Pacific Rim Chapter									
Surfrider – Vancouver Chapter									
Surfrider – Vancouver Island Chapter									
Ocean Legacy Foundation									

There is great diversity in the data collection practices, categories and metrics used by the different organizations, which is continually changing and evolving (see Table 3). Many organizations have used standardized data collection approaches in the past, such as the GCSC Data Card (2011, 2016 & 2017) or the NOAA Shoreline Survey Field Guide (2012). The GCSC is the largest cleanup organization in Canada. Developed in coordination with the Ocean Conservancy in the United States, the GCSC Data Card is a count-based method that requires each volunteer to tally the number of debris items they find during a cleanup event. At the end of the event, an organizer combines all the individual data cards and submits the results to the GCSC. The most recent edition of the Data Card has 24 different categories, such as cigarette butt, bottle cap or food wrapper. The NOAA framework is also a count-based method, however, instead of recorded the results from an entire shoreline cleanup, it specifically sub-samples a 100m transect. This framework also requires more site-specific information, such as GPS coordinates, proximity to rivers and substratum type. The NOAA framework has 42 item categories. Both of these standardized approaches track several categories of packaging material that is line with the definition of "packaging" in the BC *Environmental Management Act*, such as food wrappers, plastic bags and six-pack rings. While these frameworks have been used by many of the organizations operating in BC, recently several organizations have decided to stop using them, often replacing them with a unique method tailored to their specific needs. As a result, a diverse patchwork of information and data categories is currently present in BC.

The main variation in citizen science data collection practices is found in how each organization approaches classification of the material they collect and manage. Bowker and Star (1999) define a classification system as "a set of boxes (metaphorical or literal) into which things can be put to then do some kind of work – bureaucratic or knowledge production." They argue that in an abstract, ideal sense, a classification system should have consistent and unique classificatory principles in operation, categories should be mutually exclusive, and the system is complete, providing total coverage of the world it describes. However, they also argue that no real-world classification system that they have looked at meets these "simple" requirements and doubt that any could. Instead, they discuss how there is often tension between locally generated categories and formal bureaucratic ones, where an individual or specific community will use “work-arounds” that allow for the practical use of a formal classification system, which is the case here in BC

4.2.2 Regulatory landscape

The regulatory landscape for packaging and printed paper (PPP) in BC sets the context for how EPR policy is implemented in the province. There are several key elements of the legislation to note that are necessary in understanding how EPR relates to citizen science. PPP material is managed in BC under the auspice of several key pieces of legislation. Enacted in 2004 under authority of the *Environmental Management Act*, the Recycling Regulation (the regulation) sets out a single results-based framework for EPR in BC (BC Ministry of Environment and Climate Change Strategy, 2012). The regulation requires product producers to establish targets and report on performance, such as the amount of product sold versus collected (i.e. recovery rate), the number and distribution of collection facilities, and consistency with the pollution prevention hierarchy.[2]

In 2011, the Province amended the regulation (Schedule 5) to make businesses supplying PPP responsible for collecting and recycling their products (Ministry of Environment 2018). The *Environmental Management Act* defines packaging as “a material, substance or object that is used to protect, contain or transport a commodity or

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[2] A waste management framework that is aimed at the management of the product in adherence to the order of preference in the pollution prevention hierarchy. The first order on the hierarchy is reduce, followed by reuse, recycle, residual management (i.e. landfill) and finally (energy) recovery. This means that pollution prevention is not undertaken at one level unless or until all feasible opportunities for pollution prevention at a higher level have been undertaken.

product, or attached to a commodity or product or its container for the purpose of marketing or communicating information about the commodity or product" (2003). Under the regulation, producers must comply with an approved stewardship plan by May 19, 2014 (The Province of British Columbia, 2014). It is important to note that the industrial, commercial and institutional (ICI) sector of the PPP waste stream is excluded from the regulation. Section 5 (1)(d) of the regulation states "with respect to the packaging and printed paper category, the plan adequately provides for the collection of the product by the producer from residential premises, and from municipal property that is not industrial, commercial or institutional property."

It is also important to note that beverage containers are not part of Schedule 5 of the regulation and part of the Recycle BC program. Instead, beverage containers are covered by Schedule 1 "Beverage Container Product Category" and are managed through a different product stewardship program. Beverage containers, specifically polyethylene terephthalate (PET) plastic water bottles, are very common at cleanup events. In the interest of maintaining focus on a comprehensive piece of legislation that includes more types of packaging in its definition, beverage containers have not been included in this study.

4.2.3 Recycle BC packaging EPR program

While the legislation plays a key role in establishing the results-focused framework for EPR in BC, the industry product stewardship agencies are essential for its implementation. Reviewing some of the key elements of the stewardship program for PPP outlines the specific materials, categories and methods for waste management that are currently occurring in the province and that are proposed for the future. This perspective is also important in understanding how EPR relates to citizen science.

Recycle BC (formerly known as Multi-Material BC) is the not-for-profit organization responsible for the residential packaging and paper product EPR recycling program in BC, servicing over 1.8 million households or over 98% of the province (Recycle BC, 2017b). Originally submitted to the Ministry on Environment in November 2012, the Recycle BC stewardship plan was approved in April 2013 and launched on May 19, 2014.

The Recycle BC Plan defines several classes of PPP it manages in the program, such as transportation packaging, service packaging, etc. (see Appendix A) (MMBC, 2012, p. 2). In terms of plastic packaging, Recycle BC identifies four broad material categories (plastic containers, plastic bags, foam packaging and other flexible plastic packaging) and 27 different individual material types, such as plastic jugs, grocery bags, plastic foam containers and zipper lock pouches (see Appendix B) (Recycle BC, 2017c).

The regulation specifies that the PPP products stewardship program must achieve, or is capable of achieving within a reasonable time, a 75% recovery rate (2004). Surveys conducted in 2011 estimate that there are approximately 200,000 tonnes of PPP material recovered in the residential waste stream annually (Glenda Gies and Associates, 2012). Using data from packaging EPR programs in other Canadian jurisdictions, Recycle BC estimated that between 350,000 to 400,000 tonnes of PPP material supplied into the BC market (MMBC, 2012), which in turn allowed them to calculate an estimated baseline PPP recovery rate in BC between 50% and 57%. Since the Recycle BC program launched in 2014, it has consistently achieved a high recovery target, at or above the requirement set out in the regulation, while the amount of waste being generated (i.e. product sold) has been slowly declining approximately 2% annually (see Table 4).

Table 4: Annual Recovery Rates for All PPP Managed in The Recycle BC EPR Program.

Recycle BC Packaging and Paper Products Annual Recovery Rates				
Year	2014[3]	2015	2016	2017
Product Sold (tonnes)	145,351	243,191	238,062	234,847
Product Collected (tonnes)	116,457	186,509	185,477	174,942
Recovery Rate	80.1%[4]	77%[5]	78%[6]	75%[7]

Collection of PPP from the residential waste stream occurs in three main ways. Material is collection at curbside from single-family dwellings, from multi-family buildings and from depots. Generally speaking, printed paper and plastic and metal containers are collected from curbside and multi-family buildings. Glass containers are sometimes collected this way, depending on the specific community. But it is important to note that flexible plastics, such as plastic bags and food wrappers are exclusively collected through the Recycle BC depot network (Recycle BC, 2017d). Recycle BC state that "this is to ensure that they meet recycling remanufacturers' specifications, and because plastic bags collected at curbsides or through multi-family buildings wrap around machinery and impair the recyclability of containers and other recyclables" (Recycle BC 2015). Furthermore, some materials are not accepted in the program at all due to the current inability to recycle them, such as soft plastic six-pack holders. For these materials,

[3] As per the regulation, the program launched on May 19, 2014, therefore it did not operate for the entire year. As a result, this data reflects 7.5 months of operation.
[4] Multi-Material BC 2015
[5] Multi-Material BC 2016
[6] Recycle BC 2017
[7] Recycle BC 2018b

the Recycle BC website states that “this item should not be included in your recycling. Please put this item in your garbage or reuse it if appropriate” (Recycle BC, 2019).

It is also important to note that the current approved stewardship plan is based on reporting recovery performance for all types of PPP managed in the program (i.e. program level performance). However, the new version of the plan that has been submitted to the Ministry of Environment and Climate Change Strategy (MOECCS) for review and approval also includes a new set of performance measures for specific materials. The two levels of performance metrics that Recycle BC intend to report on are (2018c, p. 21):

1) **Program level performance** which is the recovery performance of the program for the aggregate of all PPP collected;
2) **Material category performance** which is the recovery performance for four separate material categories: Paper, Plastics, Metal and Glass; and
    a) Plastic sub-category specific recovery targets for:
        i) Rigid plastics including PET, HDPE, Polystyrene and Other Plastics such as #5 Polypropylene
        ii) Flexible Plastics including Film and Laminates.

4.3 Key findings

The following four sections outline the key qualitative findings that arose during research. Quotations in the text are drawn from interviews with key informants and have been attributed to their parent organizations and not the specific interviewee, in order to promote interviewee privacy.

4.3.1 Differences in shoreline pollution profiles

If we exclude the Ucluelet Aquarium, given their exclusive focus on microplastics, five of the seven remaining organizations conducting citizen science-based shoreline monitoring have migrated away from the GCSC and NOAA data collection methods (see Table 3). This change may be due to other factors that will be discussed in subsequent sections of this chapter. However, the difference in pollution profile between urban and remote shorelines and the lack of focus on degraded material and microplastics has made the use of the GCSC and NOAA methods ineffective for several of the organizations operating in BC.

Many organizations conducting shoreline monitoring and cleanup work in BC note that the pollution profile between remote and urban shorelines is very pronounced. Surfrider Pacific Rim state that "collecting data for those two different types [of shorelines] is vastly different because the nature of what we're finding is so different" and that "to try to apply the same metrics from one to the other, it just doesn't translate. It's very difficult." Living Oceans Society, which primarily monitors and collects debris on remote shorelines exposed to the open ocean, state "we're finding that our cleanups have quite a different profile from the ones in more southerly or interior waters." The Ocean Legacy Foundation has also encountered a difference in pollution profiles between urban and remote shorelines, noting "it's like night and day. In a lot of ways there's no comparison because the amount of fishing gear and aquaculture gear is staggering when you compare those numbers to almost non-existent numbers in urban centers." For Surfrider Vancouver Island, they note that "on the remote cleanups, it would definitely be less identifiable packaging. It would be more derelict fishing gear and more pieces that have broken down to a point where you couldn't really identify where they're coming from.” Overall, organizations remarked on the high occurrence of derelict fishing gear and low presence of packaging material in remote areas. This low trend of packaging material is evident in the Surfrider Vancouver Island data set (see Chapter 5, Section 5.2.3).

As a result, tracking materials in remote shorelines is difficult for several organizations when using the NOAA and GCSC methods, due to the fact that the categories in the methods are not relevant based on what they are finding. Surfrider Pacific Rim previously collected data by using the GCSC data cards. But after doing that for a “long time,” they found it was not appropriate for the type of debris they were gathering, specifically microplastics. They state that counting debris is “tricky because in a day you're not going to be able to count the amount of microplastics. You're just not. There's way too many and it's way too gnarly.” Living Oceans Society, who also previously used the GCSC Data Card, state that “the Great Canadian Shoreline Cleanup tally sheets were created primarily with near urban cleanups in mind, so the lists of possible items to tick off are governed by what's generally found at those kinds of cleanups.” Due to this, they argue that “the tally sheets [Data Cards] aren't particularly useful for us. We find we're ticking ‘other.’ 500,000 pieces of ‘other’ is not a very meaningful statistic to gather.” The Ocean Legacy Foundation does use the NOAA method at several sample sites. However, they feel that the categories in the method are shaped/determined by the frequency of items being found at urban shorelines. In particular, they state “there is a very large difference between their survey outline and what we're actually finding in the field, in terms of industrial gear.” They continue, stating “because it's probably region specific, they [NOAA] probably came up with these items because it's a frequency from either their research or field experience. And so, when we bring that same model into our own community it's not necessarily reflecting the same composition of packaging or debris.”

Besides the difference between the categories in the NOAA and GCSC methods and the profile of debris typically encountered in remote locations, several groups also find the count-based approach in these methods arduous, due to the the amount of volunteer labour it can take. This is because of either the large volume of material encountered, the degradation of certain items or the high presence of microplastics. As previously mentioned, when discussing counting microplastics, Surfrider Pacific Rim not that it is too much work and hassle to count it all. When reflecting on the total volume of debris that they collected last year (~60 cubic meters), Living Ocean Society state “that is just an enormous volume of material and the volunteers simply won't count it.” Surfrider Vancouver Island note that “over the years of doing beach cleanups, there was less recycling (items) and more garbage.” In other words, they explain that “the separation (of debris) is just too tedious. Things were just too unidentifiable.” As a result, categorization and counting has become increasingly difficult. They add “it wouldn't be easy to separate them into different piles; it is a little bit more confusing. Like, is this actually plastic or is it packaging?” Overall, they argue that “it just seems like things are getting a little bit more gray into how you can categorize them over the years.”

The challenges that these organizations have encountered with the GCSC and NOAA methods have led them to explore alternatives tailored to their unique needs. Instead of a purely count-based approach to data collection, Surfrider Pacific Rim has developed a hybrid approach for their cleanups in and around the Tofino area. While they do record the total weight of cleanup results, they “realize it's not showing the whole picture,” particularly in the case of expanded polystyrene (EPS) foam plastic, which can be very large but weigh comparatively very little. For EPS, they record cubic feet by using large ‘super sacks’ (35” x 35” x 50”) to sort and collect it. Hard plastics and the total cleanup results are measured by weight. And for plastic bottles, fishing gear and cigarette butts, they record count. For the remote shoreline cleanups, they also find that count is not practical. In particular, they state that “for our remote shoreline cleanups, it's a lot more difficult because the volume of what we're getting is so much that you can't count things.” For remote cleanups, they measure EPS, rope and hard plastics by the number of super sacks they fill. They also determine the overall weight of the debris gathered at an event by having the shipping company that transports the debris by truck to a waste manager, to report back the weight when it uses a highway scale. While this system is meeting some of their current needs, they state that “these new categories are still quite tricky,” and that they are “trying to redo our system and make it so that it's just easier and more efficient.”

Instead of using count as their primary metric for data collection, Living Oceans Society has started recording the number of hectares or linear miles of shoreline that they have cleaned. They also record the total weight of the debris they collect since they have consistently been able to obtain that information from the landfill as they drop off material. Ocean Legacy Foundation, which continues to use the NOAA method, state “we've definitely added categories in line with aquaculture gear, fishing gear that we're finding. Even as little as like shotgun shells. We find thousands of shotgun shells. And it's not in the NOAA categories. So, we kind of refine it in terms of the frequency as we find items within our own cleanups. So, we've definitely added quite a few categories just to reflect what we're finding in the field." Surfrider Vancouver Island previously used the NOAA method, which records items that are larger than the size of a quarter. But the organization became concerned that they were finding material that was increasingly fragmented. In particular, they state "we are looking at how to measure more microplastics - because that's what we're finding a lot more of. A lot more nurdles and a lot more other things that are smaller than a quarter, and that wasn't taken into account in the transect data." Overall, many of the organizations monitoring marine debris in BC use a mix of different metrics for different items and locations. This is largely driven because of feasibility.

4.3.2 End of life management categorization

Excluding the Ucluelet Aquarium, the primary objective of all the organizations conducting shoreline monitoring of marine debris pollution levels in BC is removal. But many of the organizations are also interested in managing the material they collect and remove in the most environmentally friendly way possible, which mainly involves recycling. In order to increase efficiency of their overall operations, many have altered their shoreline monitoring data collection practices to align with how they sort material for the waste management options available in their community. When observing the interview data, two main options are apparent: Ocean Legacy Foundation and local waste management service providers.

The Ocean Legacy Foundation processes the material that they and many other groups throughout BC collect. Initially, they were accepting material mixed in super sacks. However, recently they have changed how they accept material, stating “we ask now for an initial sort from cleanups, so we'll ask groups to actually sort in the field their packaging.” They have established three categories of how they accept materials (EPS, PET and mixed hard plastics), which they note “allows us much more ease when it gets to our warehouse.” EPS and PET are very common and can exist as standalone categories. The hard plastics category exists as a catch-all for all the other (non-EPS and non-PET) hard plastics that are collected. They also point out that when the Ocean Legacy Foundation volunteers are in the field, they will go into more detail when sorting, but argue that “asking other groups to do that was a little too complicated and time consuming for people.” Instead, they state “this system of keeping three broad categories has allowed us some ease on our end, as well as more efficiency on everyone else's end.” When specifically discussing operations and efficiency, they note that:

> “As they [super sacks] come in, and if they're sorted, then it's a higher turnover rate for us, so that we don't need the same capacity for our volunteer hours. And then also, we can get rid of the materials right away so that we're not left with a thousand cubic meters of unsorted material and we need you know thousands of volunteer hours to go through it. So, it's just started making sense.”

The Surfrider Pacific Rim chapter is one of the organizations that use Ocean Legacy Foundation as their waste manager. They have recently changed how they categorize the debris they collect so it aligns with how Ocean Legacy Foundation accepts material. Surfrider Pacific Rim state, “the categories have been always somewhat there, with the GCSC and Surfrider [NOAA method], to measure the different types of single-use plastics. But now it depends on the end of life stream, how it's going to get broken down when it goes to Ocean Legacy." Overall, they state "we have to categorize it in a way that's going to work for Ocean Legacy because they are our recycler."

Local waste management options also play a large role in shaping how citizen science groups organize their debris categories. While Surfrider Pacific Rim mentions "probably for most of it [debris], Ocean Legacy will take it and recycle it," they do mention that for some packaging materials, such as plastic bags, six-pack holders and beverage containers, there is a possibility that they might be able to recycle it locally through SonBird Refuse & Recycling, the local packaging collector, contracted through Recycle BC. In this case, they note that "if it's [debris] going to be going to SonBird, that will determine how it will be categorized and then ultimately measured."

Similarly, for Surfrider Vancouver Island, the categories the organizations use to track collected debris at shoreline cleanup events have adapted to local waste management options. The organization previously used the NOAA framework for many years to track results at every monthly cleanup event but has recently stopped using it. Instead, they now sort debris into a few general categories, such as glass, metal, mixed plastic, cigarette butts, beverage containers and total weight. These categories have been established through coordination with the waste management company they work with for every cleanup event, Atlas Junk Removal. Surfrider Vancouver Island state that "a lot of the ways that the categorizing for debris was done in a way that could potentially be put into a recycling bin."

Surfrider Vancouver also recently stopped using the GCSC and NOAA frameworks and developed new categories for analysis that are aligned with local waste management options. When specifically conducting a GCSC cleanup event with a large number of volunteers, they found difficulty in ensuring volunteers followed the data card. In particular, they state “we just didn't have the capacity to count all the little things.” Instead, they have developed a new approach, tailored to their specific needs and interests. They state, “we had to just choose kind of a top spot for six (categories) that we wanted to focus on.” The six categories that they track the count and weight of are: cigarettes, straws, cutlery, plastic bags, wrappers and beverage containers. However, their new unique framework also includes 10 waste management categories for all the materials they collect, tracking the number and weight of the bags they fill of each category, and identifying the available collection facility. These categories are: refundable (beverage containers), non-plastic recyclable packaging, hard plastic, soft plastic, foam plastic, compost, mixed paper, textiles, Other Flexible Plastic Packaging (OFPP) and landfill. For all these different categories, they have three different waste managers: the Ocean Legacy Foundation, the Zero Waste Center and the Metro Vancouver Landfill Depot or Transfer Station.

One category to note that Surfrider Vancouver tracks is OFPP[8] (e.g. multi-laminate food pouches), which is a new category of materials that Recycle BC EPR program is collecting at certain depots in Vancouver (Recycle BC, 2018a). Surfrider Vancouver states “it came from just the fact that we find so many wrappers, that it is a big

[8] Other Flexible Plastic Packaging are types of film and flexible plastics that often include multiple layers of different types of plastic, making it more difficult to recycle. Examples of Other Flexible Plastic Packaging include: stand-up and zipper lock pouches, like pouches for granola, frozen berries, etc.; crinkly wrappers and bags, like coffee bags, or chip bags; flexible packaging with plastic seal, like packaging for fresh pasta or pre-packaged deli meats; non-food protective wrap like bubble wrap or plastic envelopes; and net bags for onions, avocados, lemons, etc.

category to keep track of" and that "we wanted to track that [OFPP], rather than putting it in the landfill category. We'll try to divert it from landfill if possible." What is interesting to note about this category, is that it is a direct result of the Recycle BC program and has led to collection options in communities throughout BC.

As discussed here, for many of the organizations conducting shoreline cleanups in BC, the goal to manage the material they collect in an environmentally friendly way and the requirements placed on them by local waste management service providers has further influenced how they collect their data, pushing them away from the GCSC and NOAA standardized methods. This has led to the situation where each organization in BC has their own unique approach to categorization to meet their waste management goals and/or requirements in their community.

4.3.3 Categorization by polymer

Building off the previous section and how many organizations are adapting their data collection practices to align with available end of life management options, both Recycle BC and many of the citizen science organizations are adapting categorization to focus on specific plastic polymer types. This change is largely a result of the desire to further increase their alignment with recycling options, which typically require plastics sorted by polymer-type. But what is interesting to note is that while both citizen science organizations and Recycle BC are independently changing their categorization, a new unintentional alignment between them has been created.

For Recycle BC, they state "originally it [categorization] came from what the stewards supply into the market place." In other words, their categorization system was based on the different material types their producer members (i.e. stewards) distributed into the consumer market. But they state that "what it has evolved to is much more how we sort it and how the Director of Logistics oversees it being sent to end markets." For example, they note "originally it splits out as: we have film, we have rigid containers, we have cartons. And then it became we had PET and HDPE (high-density polyethylene)." As this internal categorization has changed to align with recycling end markets, so has the performance measures in their proposed stewardship plan (see Section 4.2.3).

While it could be argued that the change of performance metrics in the Recycle BC plan is a result of the influence of recycling end markets, there are likely other factors at play. It is important to note that the performance metrics are used by Recycle BC reports its annual performance to government, its stakeholders and the public in general. The decision to include these performance metrics in the new version of the plan could be based on feedback they received from stakeholders during the consultation process or directly from government representatives, who both may be interested in seeing more detail in regard to collection recovery. In other words, the decision to include polymer-specific categories in their proposed stewardship plan may be a result of more than solely the influence of recycling end markets.

In terms of citizen science organizations, Ocean Legacy Foundation and Surfrider Pacific Rim (who uses Ocean Legacy Foundation as its waste management service provider) have adjusted their categorization of debris to focus on specific polymer type (e.g. EPS, PET and hard plastics). By organizing their categories this way, Ocean Legacy Foundation state that "we have recyclers that we've partnered with that will take materials almost instantly," improving the overall efficiency of their operations. For example, they note “in terms of recycling right away, we've got someone who will take the clean polystyrene instantly.” Having debris categories aligned with recycling end markets allows them to explore different opportunities. For example, Ocean Legacy state “we are trying to develop markets around all the different categories we're collecting. So right now, we have about 25 different categories. And we're working with about five or six different recyclers.” Overall, basing categories on polymer type has facilitated their ability to establish relationships with recycling end markets more efficiently and effectively.

Surfrider Vancouver sort all the material they gather at a shoreline cleanup event into 10 waste management categories. In terms of tracking polymer types, they use a hard plastic category, which is a larger catch-all category and includes resin codes 1, 2, 4 and 5. They also have stand-alone categories for soft plastic, polystyrene (resin code 6) and OFPP.

It is clear that for several of the citizen science organizations operating in BC who are adapting their categorization systems to align with waste management options, are also creating categories based on polymer types further increases the alignment with end markets, ultimately increasing the efficiency of their operations. However, while Recycle BC is changing its performance metrics to also focus on polymer type, its less clear what the driving factors are. Regardless, when you look at both the citizen science organizations and Recycle BC together, it is clear to see how both their categorizations systems are increasingly aligned with one another as a result of operating in the same recycling market. At the same time, this new alignment marks a divergence away from packaging-specific categorization. In other words, as these citizen science groups all demonstrate the use of polymer-based categories similar to Recycle BC, increasing a form of alignment, they have simultaneously stopped using categories that allow them to track specific packaging items that are part of the EPR program.

4.3.4 Overlap between regulation and citizen science

There is currently a small amount of overlap between the Recycle BC EPR program and several of the citizen science organizations in terms of the categories they use to manage and track packaging pollution. However, this relationship is complicated due to a variety of factors regarding the source of packaging materials, Recycle BC waste management practices and the way debris and pollution categories have changed over time.

At first glance, it appears that the categories and metrics used by Recycle BC are not aligned with many of the citizen science organizations. Recycle BC reports its collection performance for all the PPP it manages in its program by tonnage, while many of the citizen science organizations have, or continue to report the collection of specific packaging items by count. However, there are still several instances where overlap and alignment between citizen science and the Recycle BC program arguably occurs. First, the GCSC has consistently tracked the quantity (count) of three plastic packaging items that are directly aligned with the legislative definition of packaging: plastic bags, food wrappers, six-pack rings. While the metrics used by the GCSC are not aligned with how Recycle BC tracks weight, the level of specificity in the GCSC data allow for the measurement of packaging pollution trends. Second, the NOAA framework also includes the same three categories aligned with the legislation as the GCSC. And like the GCSC, the detail present in this method allows for the measurement of packaging specific trends. However, it is important to note that except for the Ocean Legacy Foundation, which periodically use the NOAA framework when performing a remote cleanup, all other cleanup organizations that have used the NOAA framework in the past have since stopped. Third, Other than the GCSC, the only other organization that currently tracks specific plastic packaging material aligned with the legislation and Recycle BC program is Surfrider Vancouver, which include a category for OFPP. This is the only polymer-based category that is directly in-line with the Recycle BC program. In fact, Surfrider Vancouver created this category as a result of the Recycle BC program. In particular, they state “we recently found out about the new category, Other Flexible Plastic Packaging that Recycle BC is piloting with different depots to drop off - so, we're going to take it to the depots.” While these three points of alignment between to the two organizations and their categorization are strong, several existing issues still impact them.

One of the issues with the overlap in terms of the source of the pollution partially stems from the structure of the regulation. As discussed in Section 4.2.2, the regulation is focused on the residential waste stream and municipal property that is not ICI. This division of sectors compromises the possibility to determine if the material has leaked from the EPR program, because of the difficulty in knowing whether the material originated in the residential or ICI waste streams. For example, if a citizen scientist picks up a plastic food wrapper on a shoreline, it is currently impossible to determine if that item leaked from the residential or the ICI waste stream.

The problems associated with the source of debris are also based on the fact that plastic marine debris is also a highly decentralized type of pollution (see Section 1.1.1).

Without separating collected debris by source (foreign or domestic), it is difficult to say how much of the packaging material is from the BC waste stream. This is especially relevant in BC, given that the province borders Washington State (WA), which are both located in the Salish Sea. An intricate network of coastal waterways, the Salish Sea includes the southwestern portion of BC and the Northwest portion of WA. All the major cities in this region are located on the Salish Sea, which include, but not limited to, Vancouver, Victoria, Seattle, Tacoma, Bellingham and Port Angeles. Plastic packaging that enters the Salish Sea, has the potential to travel throughout this body of water and become deposited on a foreign shoreline.

Tracking the source of pollution is very difficult. While some of the citizen science programs with operations on the west coast of Vancouver Island made efforts to track foreign debris related to the 2011 Tōhoku earthquake and tsunami in Japan, many of the organizations do not track the source of pollution. And not knowing whether the debris that is collected has leaked from the residential or ICI waste stream, or from a foreign source, makes it very challenging to use the data for the purpose of evaluating a program in a specific portion of the waste stream in a particular jurisdiction.

The list of materials Recycle BC accepts in its program also impacts the existing overlap. As previously discussed, the legislative definition of packaging applies to several of the categories tracked by citizen science data collection methods: plastic bags, food wrappers and six-pack holders. However, Recycle BC only accepts plastic bags and food wrappers in its program, through depot collection. Six-pack holders are excluded from the program entirely and continue to be managed through municipal garbage collection. This is due to the fact that soft plastic six-pack plastic holders are actually photodegradable.

Federal law in the United States has required the rings to be 100 percent photodegradable since 1989, meaning that, over time, the sunlight will break down the plastic into tiny pieces (Brown, 2010). The photodegradability of this packaging has the ability to negatively impact the quality of recycled material that it is processed with. As a result, it has been excluded from the Recycle BC program.

The way many citizen science organizations have altered their debris categorizations has also impacted any overlap with the Recycle BC program. At first glance, the increasing amount of citizen science organizations that are beginning to categorize debris by polymer type (e.g. PET, EPS, etc.) appears to align well with how Recycle BC is aiming to organize the material categories in the performance measures in its proposed stewardship plan. However, for the most part, cleanup organizations are using these new polymer-based categories to track all items of a certain polymer type, not just packaging. For example, at a shoreline cleanup, there can often be a large amount of polystyrene. This material is used to create foam plastic packaging, but it is also the same material used in a wide variety of commercial marine products, such as dock floats, which tend to dominate polystyrene collection at a cleanup event. Similarly, for PET, this material can be used in the creation of packaging materials accepted in the Recycle BC program, such as clamshell produce containers. However, the most common type of PET materials found on shorelines according to several of the organizations interviewed (e.g. Ocean Legacies Foundation, Living Oceans Society) is plastic water bottles, which are not part of Schedule 5 of the regulation and the Recycle BC program (see Section 4.2.2).

4.4 Conclusion

As highlighted earlier, academic literature and recent examples in the media demonstrate the perceived promise of using citizen science data for evaluation purposes. However, the citizen science data sets in this research project represent a case of the tension that Bowker and Star (1999) discuss between the categories used by local shoreline cleanup projects (e.g. Ocean Legacy) and large expansive standards for tracking shoreline pollution levels (e.g. GCSC Data Card or the NOAA method), where an organization will use "work-arounds" that allow for the practical use of a formal classification system. In particular, many of the citizen science shoreline cleanups in BC have changed and evolved to meet the goals of their organization, migrating away from these standards. This can be seen in the move of some organizations to record data on local waste management categories and polymer type. While this situation has resulted in a rich mosaic of information across the province, the development of new data collection approaches has led to the loss of packaging-specific detail and ultimately has limited the availability of information suitable for evaluating EPR policy.

Arguably, there has been a net reduction in alignment between these two fields as citizen science data collection methods have evolved. And the alignment that does remain is impacted by several factors. In particular, attributing source, either to sector (e.g. ICI) and/or location, such as foreign or domestic, may not be possible at all, or at least not possible in all cases.

Chapter 5 Citizen Science Packaging Pollution Trends

5.1 Introduction

This chapter is intended to address the research question: what type of packaging pollution trends are present in the data generated by citizen science shoreline cleanup and monitoring programs? In particular, this chapter aims to analyze packaging trends in relation to the introduction to EPR policy for packaging in BC in 2014.

In Chapter 4, research demonstrated that there are several qualitative dimensions that present challenges for using citizen science data to evaluate EPR, such as the evolution and diversity of citizen science data collection categories and metrics, regulatory framework, structure of the Recycle BC program and decentralized nature of plastic marine debris. Overall, this showed that the data present in BC exists as a patchwork and in many cases is incomplete, in the context of policy evaluation. But performing several types of linear regression and t-tests on three of the standardized longitudinal data sets in BC and identifying packaging trends with EPR policy in mind, allows me to explore the quantitative dimensions of the data and detect further data-based considerations with using this type of information for policy evaluation.

More specifically, As discussed in Section 2.3.3, there are claims that standardized approaches for data collection like the GCSC and NOAA methods can be used to generate data for evaluating policy interventions, such as EPR. However, there are no studies that use pre-existing data sets to analyze a specific EPR policy that has been introduced in a jurisdiction. Furthermore, while the citizen science data in BC has not been generated as part of a controlled experiment intended to monitor a specific policy, it is an accurate representation of how citizen science data generated with these methods exists in many jurisdictions around the world. As a result, this chapter provides in-depth quantitative analysis of standardized data sets as they are commonly encountered, in relation to a particular policy intervention that has been introduced. And by doing so, this research is able to demonstrate some of challenges and considerations when using citizen science data and evaluating policy aimed at preventing and reducing marine plastic pollution.

The uncertainty in using citizen science data to evaluate EPR are not due to a failure on behalf of the various shoreline cleanups projects. Instead, for this type of analysis, the data needs to be collected in a very specific way - something that citizen science was never designed to do. Bowker and Star (1999) discuss how an individual or specific community will use “work-arounds” that allow for the practical use of a formal classification system. This has been the case in BC, where the classification systems that different citizen science shoreline cleanup projects use in BC have been adapted and designed to respond to local conditions. However, some of citizen science data sets offer a large and/or robust resource of data and information, which may have the potential to be used for policy evaluation purposes. The three data experiments performed in this chapter demonstrate trends that are present in the data, while simultaneously shedding light on some of the challenges encountered when trying to use a data set for a specific purpose it was not design for. In turn, understanding these challenges helps identify what data quality dimensions are necessary for evaluating specific policies, such as EPR.

This chapter first presents the results of the three data experiments, identifying the packaging pollution trends and noting the key considerations of each one. From this, discussion will then focus on the main themes that surfaced during the experiments and the implications for policy evaluation.

5.2 Data experiments - results

5.2.1 Great Canadian Shoreline Cleanup (GCSC)

To analyze packaging material shoreline deposition trends in relation to the introduction of EPR policy, data from the GCSC was used. The GCSC data collection method does not control for location of the cleanup site (site), length of the beach cleaned (kilometers) or the amount of people (people) participating in a cleanup event. However, these factors can each be expected to have an influence on the collection results. To address this, linear mixed-effect models were constructed to evaluate the effect of year on packaging debris level, while taking into account the site, number of people, length of the beach. The AIC selection procedure (Table 5) determined that the null model (only including the random effects) was the most parsimonious. Adding the year effect did not improve the model, meaning that year does not have a significant influence on packaging debris levels (R^2=0.009). In other words, the introduction of EPR in 2014 did not significantly influence packaging pollution levels on shorelines. It can be noted, however, that a higher proportion of the variance in shoreline packaging debris levels was explained by the random effects of site and people (R^2=0.193). This result demonstrates that where the site is located in the province and how many people attend has had more of an influence on collection results, than EPR. I suspect that year is a pretending variable in the model – it adds no explanatory information towards packaging debris level variation.

Table 5: AIC Model Selection Results for GCSC Data

Results demonstrate how year accounts for less than 1% of the variance in the data, while site and people account for 19%.

	Model	K	*AICc*	*Delta AICc*	*LL*	*Marginal* R^2	*Conditional* R^2
NULL	Site + People	4	623.768	0.000	-307.743	0.000	0.193
Year	Year+Site + People	5	624.212	0.444	-306.893	0.009	0.206

I also performed a t-test on pre- and post-2014 packaging debris levels, and an ANOVA that did not control for kilometers, site or people. These analyses were limited and not adequate, compared to the mixed-model approach, but showed that there was no significant difference in packaging debris levels from year to year (see Figure1). These analyses are not preferred since they do not control for kilometers, site or people, but still showed the same result. As a result of all these analyses, we can confidently say there is no significant change in packaging debris levels after the introduction of EPR in 2014.

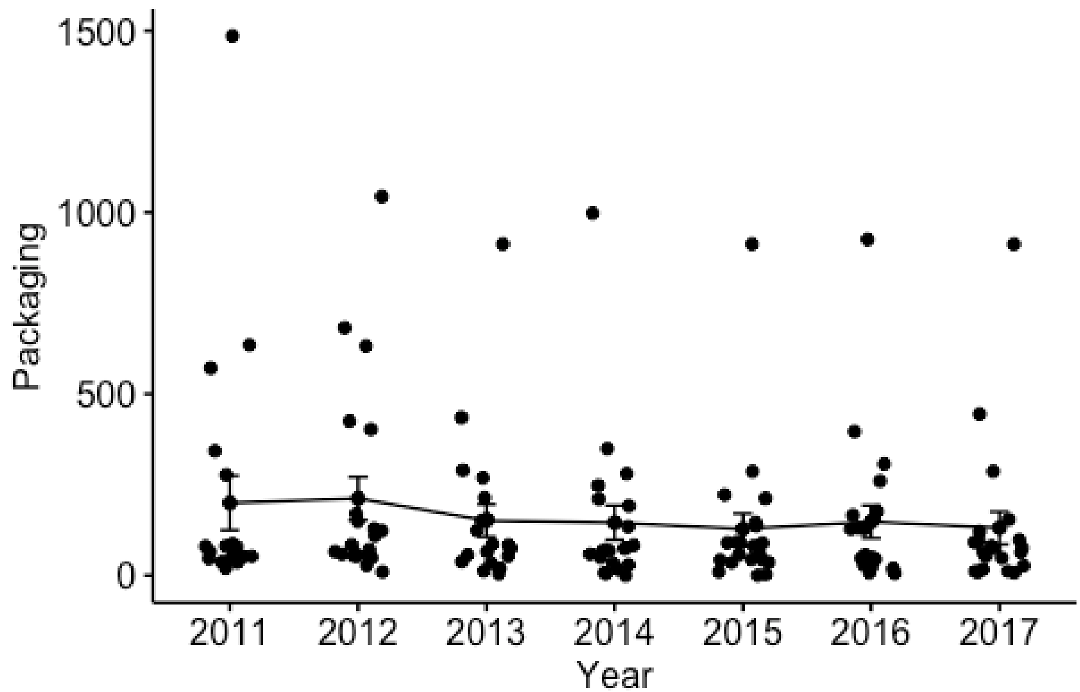

Figure 1: GCSC Mean Packaging Pollution Levels

Plot of GCSC mean packaging pollution levels for three years before and after the introduction of EPR in 2014.

5.2.2 Surfrider Vancouver & Surfrider Vancouver Island

Data from the Vancouver and Vancouver Island Chapters of the Surfrider Foundation was also used to analyze packaging material shoreline deposition trends in the Vancouver and Victoria areas, in relation to the introduction of EPR policy. These data sets were generated with a method developed by the National Oceanic and Atmospheric Administration (NOAA) (2012), which controls for length of shoreline, by utilizing a 100m transect, and for effort, by typically having only a few people perform the monitoring work. The difference in data collection approaches between the Surfrider chapters (NOAA method) and the GCSC data set, allowed me to use a different statistical model and perform an analysis of variance (ANOVA) on a generalized linear model with Poisson distribution, to account for count data. The results of the ANOVA demonstrate that there is a strong interaction of site*year effect, with different trends occurring over time at every site. Some sites show an upward trend in pollution levels, while others show a constant or downward trend (see Table 6 and Figure 3). Nevertheless, there is also a year effect, showing an overall trend in which packaging pollution is increasing over time (see Figure 2 and 3).

Table 6: ANOVA of Surfrider Vancouver and Vancouver Island NOAA Data.

The results demonstrate an upward trend in packaging pollution over time.

	Df	Deviance Resid.	Df	Resid. Dev	Pr(>Chi)
NULL			36	664.91	
Site	7	181.785	29	483.12	<2.2x10^{-16}
Year	1	51.330	28	431.79	7.808x10^{-13}
Site:Year	7	71.746	21	360.04	6.552x10^{-13}

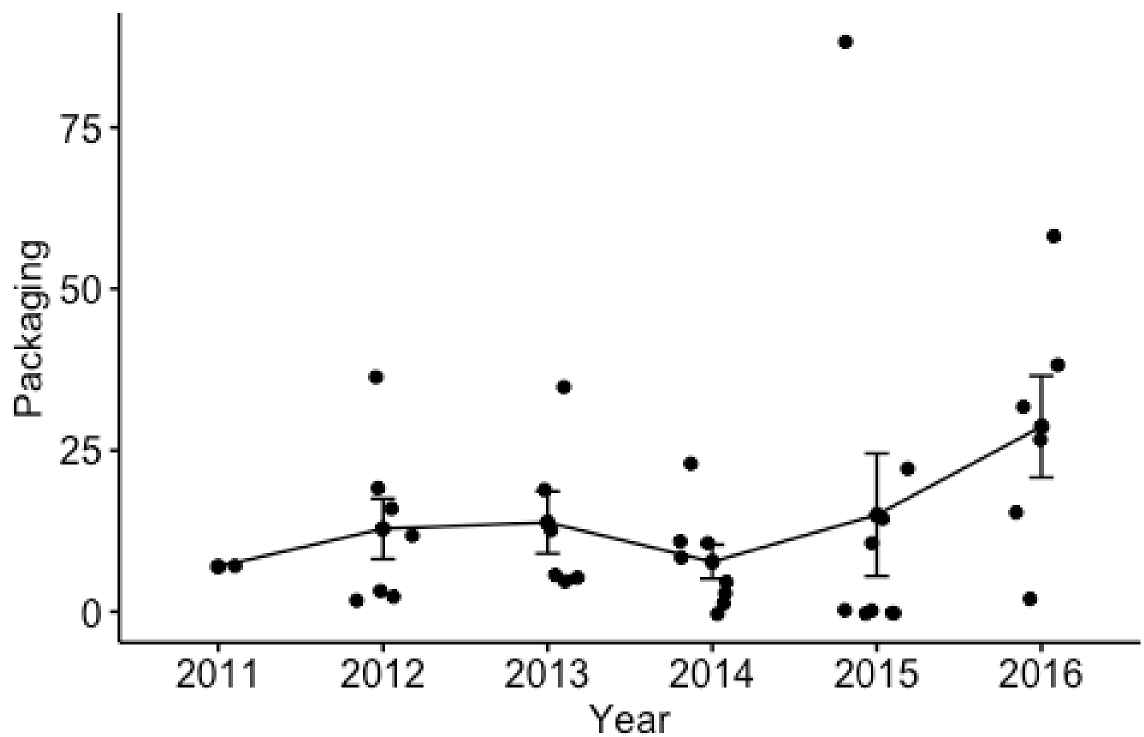

Figure 2: Surfrider Vancouver and Vancouver Island Mean Packaging Pollution Levels

Plot of mean packaging levels for each year in the data set, demonstrating the increase in packaging pollution after 2014.

Since site has a strong effect, I also performed a paired t-test (by site) on packaging pollution levels before (pre) and after (post) the introduction of EPR in 2014. Sites before 2014 had a mean value of 11.1 pieces of packaging, while sites after had a mean value of 19.9 pieces. Each site has its own trend (increase, decrease or constant in packaging pollution) and the difference pre- post- EPR is not statistically significant (p-value 0.1975; see Figure 3).

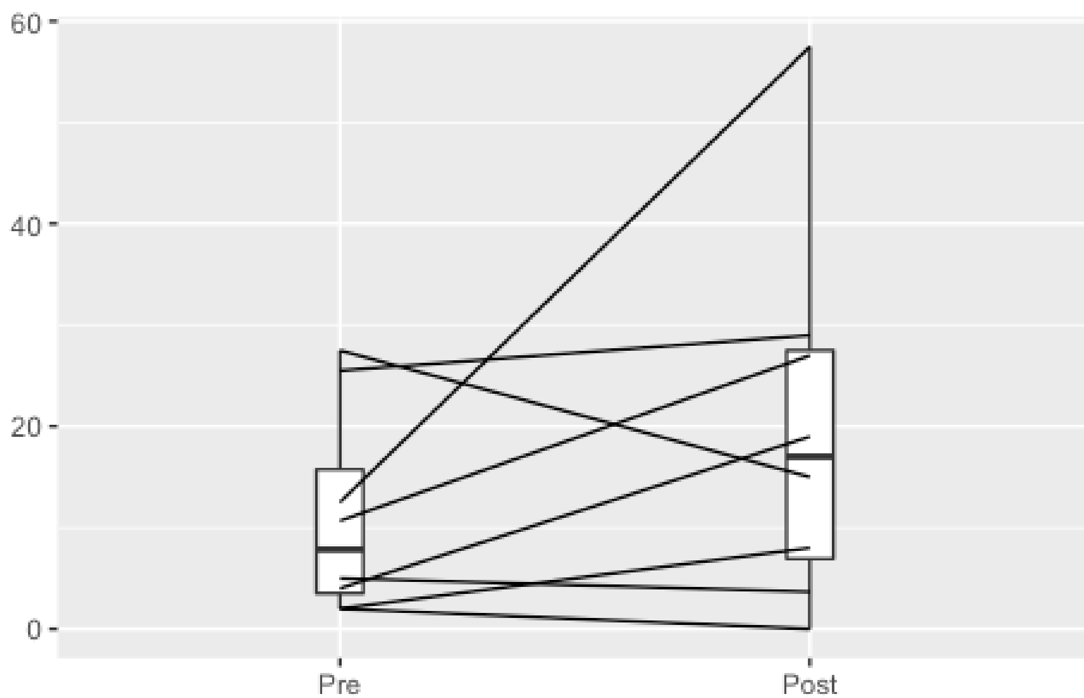

Figure 3: Surfrider Vancouver and Vancouver Island Paired Data

Plot of paired data for sites before (pre) and after (post) the introduction of EPR in 2014. Each line represents a specific site.

This data set has a strong site-specific trend. In particular, the results of the ANOVA demonstrate that packaging pollution levels at each site is very different from the next. The t-test, which accounts for site, does not show any significant difference in pollution levels before or after the introduction of EPR in 2014. This is likely a result of the fact that while the mean packaging levels are higher post EPR, this result is driven by a few sites that have seen their pollution level increase drastically. Using the NOAA method allowed the two Surfrider chapters to develop a good quality records within their data sets. However, the sample size is somewhat limited. Having more records over time would allow me to better define the trend.

5.2.3 Surfrider Vancouver Island

Analysis of the Surfrider Vancouver Island data set is aimed at determining the difference on packaging pollution levels between urban and remote locations. Since this data set uses the same method as the one used in the previous experiment with both Surfrider chapters, I also performed an ANOVA on a generalized linear model with Poisson distribution, to account for count data. However, since this experiment is interested in the difference in pollution patterns between urban and remote locations, I used “year”, shoreline “type” and their interaction as covariates. The results of the ANOVA demonstrate that there is a strong interaction of year*type effect, with shoreline types not reacting the same way over year (see Table 7 and Figure 4). But even across year, the mean packaging number has been consistently lower in remote, when compared to urban.

Overall, the packaging pollution deposition pattern over time between remote and urban shoreline sites has varied. Deposition patterns appear similar in earlier years. But it is evident that remote areas have a constant rate of pollution, while urban sites have seen levels increase over time. This increase in urban area in driven by some extreme values in 2015 and 2016.

Table 7: ANOVA for Surfrider Vancouver Island Data

Results of the ANOVA for Surfrider Vancouver Island data demonstrate that there is a strong interaction of year*type effect, with shoreline types not reacting the same way over year.

	Df	Deviance Resid.	Df	Resid. Dev	Pr(>Chi)
NULL			55	935.08	
Year	1	62.866	54	872.21	$2.212x10^{-15}$
Type	1	186.703	53	685.51	$<2.2x10^{-16}$
Year:Type	1	52.094	52	633.41	$5.292x10^{-13}$

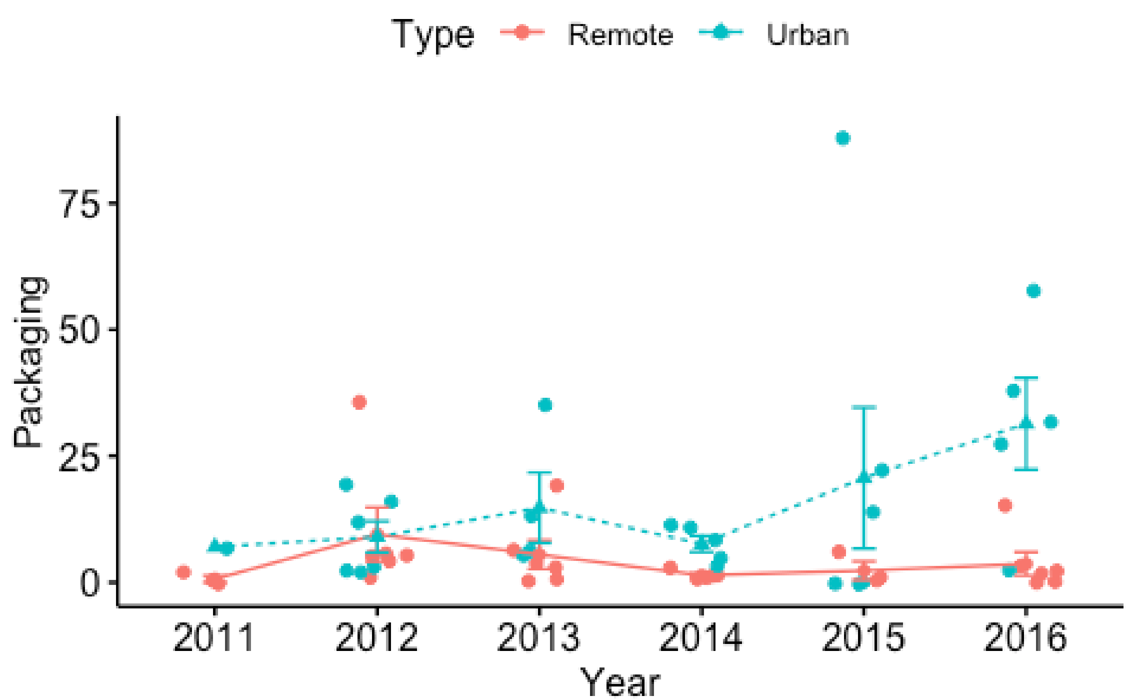

Figure 4: Surfrider Vancouver Island Urban and Remote Mean Pollution Levels

Jitter plot of mean packaging levels (combined total of food wrappers, plastic bags and six-pack holders) in the Surfrider Vancouver Island data set each year, showing results for both urban and remote shoreline site types.

5.3 Discussion

The data sets used in the three experiments all represent longitudinal data, meaning that there are several observations of the same shoreline over a period of time, sometimes occurring over multiple years. Ibrahim and Molenberghs (2009) state “in a longitudinal study, each experimental or observational unit is measured at baseline and repeatedly over time"(p. 1). Hedeker and Gibbons (2006) note that the collection and use of longitudinal data allows researchers to draw causal links between interventions and endpoints. They also note that longitudinal data can be generated as part of rigorously controlled experiments, or from studies that either prospectively collect or, like this project, retrospectively obtain information. One of the main advantages of longitudinal studies over cross-sectional studies, which compare different population groups at a single point in time, is that the repeated measurements from a single subject provide more independent information than a single measurement obtained from a single subject (Hedeker and Gibbons 2006, p. 1).

The GCSC data set is arguably the most effective data set for evaluating the effect of EPR on shoreline pollution levels of packaging in BC, due to the fact that the original data set contains a large amount of records (5,000+) that have recorded data with the same categories and metrics for 10 years. After sub-setting the data to focus solely on packaging pollution levels at sample sites that consistently recorded data every year for three years before and after the introduction of EPR in 2014, 147 records remain over seven years. While the GCSC method does not account for the size of the beach or the amount of people participating, using a linear mixed-effect model with the location of the shoreline (site) and the number of cleanup participants (people) as random effects to account for spatial autocorrelation (site) and differences in cleaning efforts (people), provided an effective approach for analyzing the data. After modelling with this limited data set, I was not able to observe a significant change in packaging debris levels after the introduction of EPR in 2014.

The other two experiments looking at the Surfrider data sets both demonstrated an increase in packaging pollution levels over time, after the introduction of EPR. While using the NOAA method has allowed the two Surfrider chapters to develop good quality records within their data sets, the sample sizes are somewhat limited when compared to the GCSC data set. As a result, it is apparent that the increase in pollution levels after 2014 is driven by a few sites that have seen their pollution level increase drastically. In particular, the increase appears to have occurred at a few urban sites in the Surfrider Vancouver Island data set in 2015 and 2016. With a reduced number of records, having a few high results can have a large influence on the data. Having more records over time would allow me to better define the trend. Tal (2011) argues "a larger sample size means a greater likelihood for detecting an effect when it exists, and a greater accuracy of the measurement can lead to greater likelihood for significant results" (p. 229). While the limited data in both Surfrider data sets show significant results of an increase of packaging pollution levels after 2014, this data set is arguably more appropriate for demonstrating the trend at a few specific beaches and not the province overall.

Theoretically, there are ideal circumstances for monitoring wastes and discards. However, in practice, as is demonstrated with this research, the data that is available is often imperfect, in terms of monitoring a particular policy intervention. The categories and metrics these data sets in this study use provide an opportunity to look at the influence of EPR policy. However, using data sets with small amounts of records and only a few categories of packaging waste, while also being aware of the other limiting factors identified in Chapter 4, make it difficult to accept the results. Overall, the main finding when looking at all these data sets in aggregate is value of having a large sample size. As demonstrated by the GCSC results, having more records allows for a better-defined trend over time, while smaller sample sizes can be susceptible to influences from a few high results.

Chapter 6 Conclusion

It has been well established that post-consumer recycling represents a somewhat problematic response to the problem of waste, and plastic waste in particular. The reasons for this include, but are not limited to, the extreme heterogeneity in the group of materials commonly referred to as “plastic” (MacBride 2012), the limited amount of materials present in the MSW portion of the waste stream relative to the industrial, manufacturing, transportation and retail sectors (Lepawsky, 2018) and the lack of influence that conventional (non-EPR) recycling programs have on reducing waste upstream, during product design (i.e. design for environment) (Lifset & Lindhqvist, 2008). To overcome the challenge with conventional recycling programs, the focus of interventions in the supply chain needs to instead look upstream at the large-scale reduction of plastic production (GAIA, 2018; Liboiron in Hutton & Hess, 2019).

EPR is a promising policy approach to overcome the problems associated with recycling and deal with plastic marine reduction, by influencing source reduction of waste upstream during the product design stage and increasing waste management infrastructure downstream. However, its reporting framework is not currently designed to measure the particular effect of marine plastic reduction. As a result, it is difficult to say if EPR is influencing a reduction in shoreline pollution levels. In fact, as this research has shown, when using limited citizen science data available in BC to evaluate the recent introduction of EPR for packaging material, the results from analyzing the GCSC data show that there has been no change in pollution levels since the policy was introduced in 2014, while the Surfrider data sets demonstrate an increase in plastic packaging pollution levels.

At first glance, citizen science data appears to be a good option to evaluate EPR, since there are several programs in operation and many pre-existing data sets. In particular, the GCSC data set offers a possible option to evaluate EPR, due to the fact that it has consistently tracked several packaging categories aligned with the legislation, the program hosts hundreds of annual cleanups and has been occurring across the province for decades, which has resulted in a large data set. However, the majority of other citizen science data sets available are not appropriate to evaluate EPR in particular, given their lack of packaging-specific categories or limited amount of shoreline cleanup records. The constraints with using these data sets are due to the fact that many of the waste data collection methodologies are inconsistent with one another and with the Recycle BC EPR program, which stems from the challenge of syncing different data sources with one another.

While the GCSC and Surfrider data sets provide sufficient information to perform statistical analysis, the results of both the qualitative and quantitative research have shown that the trends that can be drawn are problematic for several reasons. These reasons stem from the characteristics of the citizen science data, the design of the EPR policy and the nature of plastic marine debris in general. First, other than the GCSC, the data sets from Surfrider and other organizations in BC have a comparatively small sample size, which can reduce the likelihood for detecting an effect when it exists. Second, the citizen science data sets have only three packaging categories that are aligned with the legislative definition of packaging; however, this is a small amount when compared to the 23 categories of plastic packaging material accepted in the Recycle BC program (see Appendix C). Third, the alignment of these three categories is further reduced to two, due to the exclusion of six-pack holders by Recycle BC, due the lack of a technological means for recycling them. Fourth, the exclusive focus of the EPR policy on the residential waste stream and not the institutional, commercial and industrial (ICI) sector, adds a level of difficulty in determining the source of shoreline packaging debris. In other words, it is already very difficult to identify the source of packaging pollution and the citizen science programs in BC do not currently do this. And by separating the waste stream, the regulation has made it essentially impossible to use citizen science data to evaluate EPR, since the data does not determine which portion of the waste stream the material leaked from. And finally, adding to the challenge of identifying the source of debris is the fact that plastic marine debris is a highly decentralized form of pollution. When a piece of debris enters the ocean, it has the potential to travel far distances. This characteristic makes it difficult to know if the pollution levels encountered on shorelines are a result of local waste management or are partially attributed to foreign sources.

It is clear to see that the challenges of using citizen science data for the purposes of policy evaluation are not a failure of citizen science. For the longest time, citizen science has been used to increase awareness about the presence and impacts of plastic marine debris and to leverage the introduction of policy aimed at preventing and reducing pollution. For example, Surfrider Vancouver Island state that the purpose of data collection is for “educating the public, through changing business practices or regulation or policy at a government level.” And for many of the organizations, they have been very successful at accomplishing these goals. In fact, in Canada, awareness and concern regarding plastic pollution is exceptionally high (Denne, 2019). And this has in-turn influenced the federal government to explore the introduction of legislation that bans single-use plastics and hold companies responsible for plastic waste (e.g. EPR) (Office of the Prime Minister, 2019). While this change in awareness and policy is arguably a positive development, it has fundamentally changed the context for citizen science advocacy and data collection. As policy interventions are introduced, they require unique frameworks for evaluation. And many of the citizen science data collection practices that currently exist are not applicable, as is demonstrated here in the case of EPR policy and citizen science in BC. This is because informing and evaluating policy interventions are fundamentally different things. Policy interventions, like EPR, have unique demands of data and require monitoring programs tailored to their specific needs.

A successful data collection approach for evaluating the ability of EPR for packaging material to reduce shoreline plastic pollution levels should address several key factors. First, being able to identify the source of the packaging is critical. However, when analyzing collection results by potential source, it is very difficult to connect a debris item to a specific debris-generating activity (Lippiatt, Opfer, & Arthur, 2013). But addressing the issue of debris source by creating a monitoring program that uses locations that can control for material from different waste streams or from foreign sources is important in isolating the effect of regional EPR policy. It is important to note that the challenge in determining which waste stream packaging debris leaked from would be reduced if the Recycling Regulation in BC addressed both the residential and ICI waste streams. However, controlling for debris from foreign sources in a monitoring program would still be required. Second, most of the available data sets record collection results once a year. Having data collected more frequently (e.g. quarterly, monthly, weekly, daily) would help understand the pollution trends throughout the year and increase the overall resolution of the data (Eriksson, Burton, Fitch, Schulz, & van den Hoff, 2013; EU- TSML, 2013; Lippiatt, Opfer, & Arthur, 2013). For example, monthly data would not only help illustrate trends over time, but perhaps show different seasons throughout the year that have higher levels of pollution. This insight would be valuable in knowing how to improve existing policy. Third, categorization between a monitoring program and the EPR program should be as consistent as possible. In particular, using as many of the 23 categories included in the Recycle BC "list of accepted materials" (Appendix C) as possible in a monitoring program would provide greater insight into pollution patterns of all packaging types, not just a select few. And finally, weight is an attractive metric to track collection results, as it reduces the labour associated with counting each item collected. However, packaging material is becoming increasingly light-weighted to address various needs of the producer (e.g. transportation & production costs) (Morier, 2017; Lifshitz, 2014). As light-weighting occurs, it has the potential to skew collection results, demonstrating a downward trend in pollution levels, when in fact the trend may be a result of the material becoming lighter. Instead, it is recommended that a count-based metric be used to track collection results.

As noted above, adequate data collection to evaluate policy can have substantial requirements, in terms of resources and expertise. For the longest time, citizen scientists have been filling a gap for monitoring work that needed to occur but was not being addressed. And presently, there continues to be promise about the use of citizen science data for policy evaluation, where citizen science is increasingly relied upon to be the accountability measure for various new policy interventions that are introduced. But as this research has demonstrated, using current citizen science data sets provide a limited option for monitoring certain interventions, such as EPR and may produce results that do not accurately represent the pollution trends on the ground. And furthermore, this expectation places a large and inappropriate amount of pressure on these organizations to consistently collect data in a format that may not be aligned with their specific goals and objectives. Instead, now that plastic marine debris has become acknowledged as a serious issue and governments are responding to it with policy, discussion needs to focus on how monitoring will occur. The field of policy studies is clear that effective environmental policy requires that monitoring and enforcement be integrated into policy interventions. As a result, the responsibility to perform policy monitoring and evaluation may lie with the regulator. Or in an EPR regulatory environment, the responsibility may lie with the producers and brand owners who have taken on the responsibility of managing and measuring other components of the waste stream. Or perhaps some type of collaborative approach between government and industry stakeholders may be a more appropriate approach to monitoring. Identifying not just how, but who will do the monitoring work is important when designing actions that will help solve this growing environmental problem.

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Appendices

Appendix A: Citizen Science Organizations in British Columbia

The largest organization operating in BC is the GCSC. A national conservation initiative funded and created by Ocean Wise and the World Wildlife Foundation, the GCSC is recognized as one of the largest direct-action conservation programs in Canada. Launched in 1994, the organization has held over 21,000 cleanup events and collected more than 1.3 million kg of debris across the country (The Great Canadian Shoreline Cleanup: Ocean Wise & WWF 2019). In BC, the organization organizes an average of 530 cleanups annually across the province.

There are three chapters of the Surfrider Foundation actively involved in shoreline cleanup and monitoring work in the province. Each Surfrider chapter operates as its own entity and there is little coordination between them, in terms of the shoreline monitoring and cleanup programs they operate. Surfrider chapters are primarily volunteer-led and have few to no paid staff.

Surfrider Pacific Rim is based in Tofino on the West Coast of Vancouver Island. Tofino is a relatively small municipality, with approximately 2,000 permanent residents. However, Tofino is a very popular tourist destination and receives over 750,000 visitors each year (Anderton, 2015). Surfrider Pacific Rim focuses much of its cleanup activity on shorelines in or closely adjacent to Tofino. While these locations are arguably in an "urban" area, they have much in common with remote shorelines. Tofino is an isolated community at the end of a highway and its beaches are directly exposed to the Pacific Ocean. Surfrider Pacific Rim also undertakes small expeditions to more remote and isolated shorelines on some of the neighbouring islands in Clayoquot Sound, a short trip by boat from Tofino.

Surfrider Vancouver Island is based in Victoria, one of the largest municipalities in the province. They conduct shoreline monitoring and cleanup work at both local urban shorelines in Victoria and at more remote locations along the south west coast of Vancouver Island, either in very small municipalities (e.g. Jordan River, Port Renfrew) or regional park land (Jordan River Regional Park) and provincial park land (Juan de Fuca Provincial Park). They also perform an annual remote beach cleanup expedition to an isolated shoreline, typically on the North West coast of Vancouver Island.

Surfrider Vancouver operates in the greater Vancouver region, performing regular cleanups at popular beaches in Vancouver and its neighbouring municipalities. Vancouver is the largest municipality in the province and all the organizations shoreline monitoring and cleanup work occur at urban locations.

The Living Oceans Society is a marine conservation organization based in the small community of Sointula on Malcolm Island, a small island adjacent to the North East coast of Vancouver Island. Among other programs focused on ocean health and sustainable resource management, it operates the Clear the Coast program on remote shorelines on the North West coast of Vancouver Island, which is focused at performing remote shoreline cleanups. The program engages volunteers to participate in cleanup events primarily in the summer months. The program focuses on marine debris, derelict vessels and ghost fishing gear.

The Ocean Legacy Foundation is a growing organization that both performs remote shoreline cleanups throughout BC and operates a marine debris receiving facility in Vancouver, where they process the debris they collect, as well debris collected by other organizations. For example, the organization collected and processed approximately 250 cubic meters of debris in 2016. But through partnering with 25 organizations, Ocean Legacy estimates that they manage approximately 1000 cubic meters of debris annually. In terms of management, they estimate that 90% of the material they process is either recycle or reused (The Ocean Legacy Foundation, 2018). Cleanup operations and the sorting and processing of debris is all performed by volunteers, with a handful of paid staff.

Clayoquot Cleanup is another organization focused at the removal of debris from remote shoreline environments. Based out of Tofino BC, Clayoquot Cleanup focus its operations at various locations in Clayoquot Sound. The organization has a few paid staff, but primarily uses volunteers to perform its shoreline cleanup and restoration work. Like all other organizations working on marine debris Clayoquot Cleanup is focused primarily at removing debris from the marine environment. Data collection is not a core component of the work that they do. While they do track the total weight of debris they remove, detailed monitoring is infrequently performed by third-party participants and is sometimes shared with the organization. As a result, they had little to contribute to this project, in terms of feedback on debris metrics and categorization practices.

The Ucluelet Aquarium is based in the town of Ucluelet on the West Coast of Vancouver Island, south of Tofino. It has recently started programming for plastic marine debris. However, their citizen science work focuses solely on microplastics. As a result, their data collection practices do not focus on macro-plastic packaging. However, many microplastics are the result of the fragmentation of packaging material into microscopic particles. While the work they are performing is very well organized and necessary, given that the scope of their work is solely on microplastics and differs from the focus of this research project, they have not been included in the results.

Appendix B: Recycle BC Stewardship Plan Packaging Classes

Packaging for purposes of producer obligation and reporting under the PPP Stewardship Plan includes (Multi-Material BC 2012, p. 2):

A. Primary packaging, i.e., packaging that contains the product at the point of sale to the residential consumer;
B. Grouped packaging or secondary packaging that goes to the household[7];
C. Transportation, distribution or tertiary packaging that goes to the household[8];
D. Service packaging designed and intended to be filled at the point of sale and "disposable" items sold, filled or designed and intended to be filled at the point of sale such as: i. Paper or plastic carry-out bags provided at checkout; ii. Bags filled at the shelves with bulk goods, produce, baked goods, etc.; iii. Disposable plates and cups; iv. Take-out and home delivery food service packaging such as pizza boxes, cups, bags, folded cartons, wraps, trays, etc.; v. Flower box/wrap; vi. Food wraps provided by the grocer for meats, fish, cheese, etc.; vii. Prescription bottles filled and provided by pharmacists; viii. Paper envelopes for developed photographs; ix. Gift wrapping/tissue paper added by the retailer; and
E. Packaging components and ancillary elements integrated into packaging, including ancillary elements directly hung or attached to a product and which perform a packaging function unless they are an integral part of the product and all elements are intended to be consumed or disposed of together[9].

Appendix C: Recycle BC Stewardship Plan List of Accepted Materials

Plastic Containers	Plastic jugs with screw tops used for milk, cooking oil, laundry detergent and fabric softener, cleaning solutions, cleaning products, body care products, windshield washer fluid, etc.
	Plastic bottles with screw caps, spray pump, or pull-up tops for food, dish soap, mouthwash, shampoos, conditioners and other personal care products, pills and vitamins, laundry products, etc.
	Plastic jars with wide mouths and screw-top lids for peanut butter, jam, nuts, condiments, vitamins and supplements, personal care products, etc.
	Plastic clamshells with hinged or click-closed tops for baked goods, fruit, produce, eggs, etc.
	Plastic back-bottom trays and clear tops for deli chicken, single-serve meals, prepared foods, baked goods, housewares, and hardware such as screws or picture hangers, etc.
	Plastic tubs and lids for food such as margarine and spreads, dairy products such as yogurt, cottage cheese, sour cream, ice cream, etc.
	Plastic cold drink cups with lids for take-out beverages
	Plastic garden pots and trays for bedding plants, seedlings, vegetable plants, etc.
	Plastic pails less than 25L for laundry detergent, ice cream, pet food, etc.
	Microwavable bowls and cups
	Empty single-use coffee and tea pods; remove lids and do not include lids with recycling
	Rigid plastic packaging for toys, toothbrushes, batteries, etc; remove paper backing and recycle separately
Plastic Bags and Overwrap	Bags for groceries or dry cleaning, bread, newspapers and flyers
	Bags for produce, dry bulk foods and frozen vegetables
	Outer bags and wrap for diapers, feminine hygiene products, paper towels, tissues and soft drink can flats
	Bags for water softener salt and garden products
	Overwrap on mattresses, furniture and electronic equipment
Foam Packaging	Plastic foam containers and trays used for meat and produce
	Foam egg cartons
	Foam clamshells, cups and bowls for take-out food
	Foam cushion packaging to protect electronics, small appliances, etc.
Other Flexible Plastic Packaging	Zipper lock pouches for frozen foods like prawns, berries, vegetables; fresh foods like fruit. deli meat, etc.
	Stand-up pouches for dried fruit and nuts, quinoa, grated cheese, dish detergent pods, etc.

	Bags for potato chips, wrappers for cheese slices and candy bars, cereal bags
	Packaging for dry pasta, pre-packaged deli meats
	Net bags for avocados, onions, citrus fruit
	Padded protective plastic like plastic shipping envelopes, bubble wrap, plastic air packets