SCIENTIFIC REPORT

COMMUNITY SCIENTISTS HELP IDENTIFY LOCAL PRIORITIES FOR MICROPLASTICS: A PILOT STUDY ON VANCOUVER ISLAND, BRITISH COLUMBIA, CANADA

Authors: Iselle Flores Ruiz, Sean Yang, Ethan Edson, Dean Wenham, Anna Posacka

July 17, 2022

This project was undertaken with the financial support of:
Ce projet a été réalisé avec l'appui financier de :

Environment and Climate Change Canada | Environnement et Changement climatique Canada

OCEAN DIAGNOSTICS

SCIENTIFIC REPORT

COMMUNITY SCIENTISTS HELP IDENTIFY LOCAL PRIORITIES FOR MICROPLASTICS: A PILOT STUDY ON VANCOUVER ISLAND, BRITISH COLUMBIA, CANADA

Authors: Iselle Flores Ruiz, Sean Yang, Ethan Edson, Dean Wenham, Anna Posacka

July 17, 2022

TABLE OF CONTENTS

ACKNOWLEDGMENTS

This study would not have been possible without the generous support of our volunteers who collected samples, tested procedures and contributed valuable input into the design of our tools and protocols. We would also like to thank Dr. Peter Dietsh, Donald Gordon, The University of British Columbia's Oceans Leaders program and Ocean Legacy Foundation for helpful discussions on the problem of polystyrene pollution in coastal British Columbia. Identification of microplastic polymers was completed with the help of open-source spectroscopy libraries from Open Specy, SLoPP and SLoPP-E. This project was carried out with the support of Environment and Climate Change Canada.

SUMMARY

Microplastic pollution is a rapidly growing problem, but there are still many data gaps on microplastics in our environment. In partnership with Environment and Climate Change Canada, a pilot study involving 51 volunteers was conducted to improve knowledge on microplastic debris on coastal shorelines and to develop tools for standardized particle analysis by community science programs. Over six months, volunteers collected monthly samples of visible microplastics (0.5-5 mm) in surficial sand at 10 different beaches across the Greater Victoria Region, British Columbia, Canada. The beaches varied in morphology, hydrological conditions, public use, marina activity and the presence of municipal stormwater sewers. Microplastics collected by the volunteers were enumerated and physically characterized using a novel imaging technology, the Saturna Imaging System, with a subset processed with Raman spectroscopy to identify material polymer and inform on putative sources. A total of 2,426 particles was recorded throughout the study, of which the majority were foam (81.4%), while lines (6.5%), films (1.8%), pellets (1.8%) and fragments (8.5%) were significantly less abundant.

Microplastic densities ranged from 0-801particles per m^2, and showed abundance hotspots at specific sites, particularly those surrounded by marinas. Polystyrene dominated particle chemical composition (85%), and its prevalence in our study is consistent with the experience and historical data of communities cleaning up shorelines across coastal British Columbia. This study demonstrates how a standardized long-term community surveillance program can help identify key microplastic litter types and heavily polluted sites to target for intervention. It also provides the most detailed scientific dataset on shoreline microplastics in British Columbia, Canada and a benchmark for future local monitoring. We developed a practical toolkit and resources, including an open-access database to monitor microplastics from sandy shorelines by community scientists and to engage the public in science. The toolkit will be available in the fall of 2022 to a cohort of schools and beach cleanup organizations to expand the microplastic monitoring program across Canada. This initiative will contribute to a better understanding of microplastic patterns in coastal ecosystems, engage communities in research and action and contribute to the UN Sustainable Development Goals.

INTRODUCTION

In the last 70 years, the increasing growth in worldwide plastic production and mismanagement have led to a staggering accumulation of plastic waste in the environment. This problem is projected to worsen in the coming years if no action is taken, with a rise of global plastic waste from 150 million metric tons in 2016 to 646 million metric tons by 2040 (Lau 2021). Scientists have documented hundreds of marine species adversely affected by marine plastics, with entanglement, starvation and injuries as some examples (United Nations Environment Programme 2021). In the environment, plastic litter fragments into progressively smaller particles due to sunlight, mechanical action and biological activity. As a result, plastic materials have become highly prevalent in the global environment and even harder to capture, trace and remove. These pieces, defined as synthetic particles between 5 mm to 1 μm in length, are called microplastics, and they can also include purposefully manufactured particles, such as nurdles and microbeads, and particles released from textiles, tires and paint.

Scientific reports on the ingestion and transfer of microplastics within the aquatic and terrestrial food webs (Besseling et al., 2019; de Sá et al., 2018; Wright et al., 2013) and their potential to affect human health are rapidly increasing (e.g., Campanale et al. 2020). The documented effects vary by species and can be distinguished into physical and chemical effects. Microplastics can cause inflammation, tissue injury and malnutrition (Wright et al. 2013) and expose organisms to potentially harmful chemicals, such as flame retardants, plasticizers or dyes (Fries et al. 2013; Rochman et al. 2019). However, because microplastics vary greatly in their sizes, shapes, morphologies and chemistries, determining how these particles affect the ecosystem and humans is challenging and remains a continued area of scientific inquiry.

Microplastics (MPs) are present in environmental samples and wildlife across Canada, but more research is needed to better understand their sources, transport and fate. In British Columbia, microplastics have been documented in coastal seawater (Desforges et al. 2014), a wastewater treatment plant (Gies et al. 2018), commercial shellfish (Covernton et al. 2019) and critical food web species, including zooplankton (Desforges et al. 2015), herring (Mahara et al. 2022) and Chinook salmon (Collicut et al. 2019). These studies highlight microplastics as a prevalent contaminant on the coast of British Columbia, with plastic fibers being a dominant type of the smaller microplastics (less than 0.5 mm). Data generated by local volunteer beach clean-up groups provides additional insights into the state of plastic micro-debris pollution in this area. For instance, between 2018-2021 the Great Canadian Shoreline Cleanup recorded "plastic fragments and foam," which included the visible microplastics (particles smaller than 2.5 cm), as the second most abundant litter type on its Dirty Dozen list (GCSC, 2018-2020). Microplastic particles have not been monitored regularly with scientific protocols on the beaches of B.C. and across Canada, making our understanding on their abundance, composition and behaviour in these ecosystems limited. Given the evidence that small MPs can be potentially ingested by sand-dwelling organisms, such as crabs, polychaetes and bivalves (Van Cauwenberghe and Janssen, 2014; Horn et al., 2020; Knutsen et al., 2020), monitoring these systems is a priority.

Microplastics are difficult to quantify and characterize due to their complexity, variability in the environment and widespread occurrence. Mapping the distribution and patterns in microplastics at scale using standardized datasets represents a major hurdle in advancing strategies to limit plastic pollution. Engaging members of the public in data collection through a practice called “citizen science” or “community science” offers an opportunity to drastically accelerate environmental research and monitoring. The practice has become an increasingly important resource for scientists and policy makers in recent years, while promoting environmental engagement, behaviour change and community action to improve the quality of the environment (Rambonnet et al. 2019; Zettler et al. 2017). It has also been identified as a key instrument to measure progress towards the United Nation’s Sustainable Development Goals (SDGs) (Fritz et al. 2019). However, collection of quality data by the public for scientific and/or decision-making purposes can be a challenge, due to issues such as data accuracy, completeness and consistency. This is particularly the case for microplastics which vary greatly in their characteristics and where visual and manual methods to sort, count and describe the particles represent the primary tools available for volunteer-based projects.

The goal of this project was to develop and test easy-to-use procedures and technologies that can be employed by communities to monitor microplastics on sandy shorelines. We designed and led a pilot study based on Vancouver Island, B.C., Canada to evaluate scientific protocols to collect visible microplastics (0.5-5 mm) by local volunteers for subsequent analysis using a novel imaging technology, the Saturna Imaging System. Saturna is a portable device designed to capture standardized images of collected particles, which are then rapidly enumerated and characterized in terms of size, morphology and colour using an artificial intelligence algorithm. Therefore, the use of the Saturna Imaging System in microplastics monitoring can greatly improve the quality and throughput of data collection by community scientists.

The study, conducted in collaboration with Environment and Climate Change Canada, involved 51 volunteers who collected monthly microplastic samples from 10 different shorelines in the Greater Victoria Region of Vancouver Island between April and November in 2021. It generated the most extensive dataset on shoreline microplastics in British Columbia and a Community Science Microplastic Beach Toolkit consisting of the field procedures, the Saturna Imaging System, an open-access data portal for data sharing and visualization and science-based educational resources to support STEM learning, advocacy and community-based solution building for plastics. Using the Toolkit, microplastics surveys will be expanded via collaborations with beach-cleanup organizations and colleges in Canada and the Pacific Northwest coast in the fall of 2022. The long-term program goal is to establish an international network of communities collecting data on visible microplastics on beaches with standardized tools. This initiative will contribute to a better understanding of microplastic patterns in coastal ecosystems, engage communities in research and action and contribute to the UN Sustainable Development Goals.

This report describes the key findings from a community-based pilot study on microplastics on Vancouver Island, B.C. Our study demonstrates how a standardized long-term community surveillance program can help identify the most relevant shoreline microplastic litter and heavily polluted sites to target for intervention.

METHODS

Study Area

Vancouver Island is located in British Columbia, Canada. It is surrounded on the west by the Pacific Ocean and on the north, south and east by the Salish Sea (Johnstone Strait, Juan de Fuca Strait, Haro Strait and Georgia Strait). The study focused on sandy beaches in the southernmost region of the Island that is bordered by the Salish Sea — one of the world's most biologically diverse ecosystems that is home to the iconic and endangered southern resident killer whales and Chinook salmon. Here, oceanographic processes such as freshwater inflows and wind-driven surface currents exchange biota, sediments and nutrients throughout the larger ecosystem. Ten different sites with varying levels of public use, commercial and boating activity, beach hydrology and presence of municipal storm drains were selected for the study and are described in Table 1.

Community Scientist Volunteer Recruitment and Coordination

A few strategies were used to recruit volunteers, including social media posts, published blogs, newsletter announcements and direct emails to local chapters of beach cleanup groups, such as Surfrider Foundation Vancouver Island Chapter. Volunteers were divided into volunteer coordinators and general volunteers; volunteer coordinators were selected based on 1) experience or background in marine or environmental sciences, 2) ability to follow scientific procedures and collect data in the field and 3) access to a car. Volunteer coordinators were mostly trained in person by a member of Ocean Diagnostics' science team. This training was followed by a video conference call in which volunteer coordinators were invited to ask questions and clarify doubts pertaining to the written protocol and/or to sampling. Volunteer coordinators then trained their respective sampling groups.

Volunteers involved in the assessment of our AI particle colour and type predictor models were recruited by existing volunteers. They were personally trained and coordinated by the laboratory analyst.

Field Procedure

To assess microplastic pollution in the Greater Victoria Region, 51 community scientist volunteers sampled the selected sandy beaches on a monthly basis between April and November in 2021 (Table 1). The volunteers received sampling kits consisting of three four-gallon metal buckets with lids, one sampling pump, one stainless steel sieve (0.5 mm mesh), one stainless steel hand trowel, one 100 m measuring tape, two metal pegs, one 15 cm metal ruler for beach quadrat sampling, 0.5 x 0.5 m quadrats (200 cm twine attached to four metal stakes to create a square quadrat), one pair of metal tweezers, one plastic squirt bottle, one printed protocol and one printed sample data sheet. Volunteers sampled four quadrats at the same transect perpendicular to the water edge per station every month. The transect began at the back of the beach and ended at the water's edge. The quadrats were located at the following positions: 1 m from start of the transect (quadrat 1), in the middle of the strandline (quadrat 3), halfway between quadrat 1 and 3 (quadrat 2), and halfway between quadrat 3 and the end of the transect (quadrat 4).

Volunteers filtered seawater into four-gallon metal buckets using a modified bike pump connected to a filter housing and 74 μm stainless steel filter (47 mm diameter, McMaster-Carr). Before sampling each quadrat, a 50 cm by 50 cm twine square with steel pegs was used to delimit the area to be sampled. Volunteers collected sand down to 5 cm depth from the quadrat using metal gardening hand trowels and transferred it into the bucket containing pre-filtered seawater. Sand was added to the bucket until its level was nearly as high as the level of filtered seawater. Moving away from the quadrat sampled, the water was then carefully poured through a 0.5 mm mesh stainless steel sieve. Community scientists subsequently picked out all particles from the sieve using metal forceps and filtered seawater in a plastic squirt bottle. The samples with particles containing plastics and other debris were stored in aluminum tins and transported to Ocean Diagnostics' lab for further analysis.

Site number	Site name	Site coordinates	Beach morphology	Number of marina(s) within 1 km radius of site	Prescence of stormwater drains at site according to CRD?
1	Sidney, North Saanich Yacht Club (SNSY)	48.675˚N 123.41˚W	Enclosed	7	No
2	Robert's Bay	48.66˚N 123.40˚W	Enclosed	2	Yes
3	Kayak Launch Amherst	48.66˚N 123.39 ˚ W	Semi-enclosed	1	Yes
4	Lochside Waterfront Park	48.64˚N 123.40˚W	Open	0	Yes
5	Cordova Bay 1, Gloria Beach	48.52˚N 123.37˚W	Open	0	No
6	Cordova Bay 2	48.52˚N 123.36˚W	Open	0	No
7	Cadboro Bay	48.46˚N 123.29˚W	Enclosed	1	Yes
8	Cadboro-Gyro Park	48.46˚N 123.29˚W	Enclosed	1	No
9	Willows Beach	48.44˚N 123.30˚W	Semi-enclosed	0	No
10	Songhees Point	48.43˚N 123.38˚W	Open	5	Yes

Table 1. Characteristics and locations of beaches targeted in the study.

Lab Procedure

At the lab, samples were inspected and plastic particles sorted for imaging and chemical analysis. The overview of sample processing and analysis workflow is presented in Figure 1. Particle preparation involved passing the debris through a stack of stainless-steel sieves (mesh sizes: 4000, 2000, 500, 250 and 125 μm) and cleaning each collection of particles with tap water. Following the guidelines provided in Lusher et al. (2020), when cleaned, the particles were individually assessed to separate microplastics based on their type and morphology. If the particle was identified as a microplastic, both by visual and textural evaluation, the particle was isolated for further physical analysis. If it did not pass at least one of the criteria above, the particle was then subjected to a third assessment involving particle density. Suspected particles were suspended in 0.58 M NaCl solution in a glass beaker. If the particle did not sink to the bottom of the beaker, it was isolated for further physical analysis. When all suspected particles in a sample were isolated back into their original tins, they were dried inside a laminar flow hood for at least four hours.

Dry particles were orderly placed onto the Saturna Imaging System prototype device for subsequent characterization. The metrics captured by the software included maximum width (mm), surface area (mm^2), convex surface area (mm^2), perimeter (mm), convex perimeter (mm), bounding box length (mm), bounding box width (mm), aspect ratio (bounding box width × bounding box length^{-1}), roundness, convexity, solidity, HSV (hue, saturation, value), BRG (blue, red, green), LAB (light, A channel and B channel), colour AI prediction with confidence interval and particle type AI prediction with confidence interval (see Appendix B for more details). When all particles in a quadrat had been measured using the Saturna Imaging System, a unique number identifier was used to label them. Then, the particles were isolated and placed inside individual well plates.

Based on the definition used for visible microplastics in this study, only particles measured to have a maximum width between 0.5 and 5 mm were selected for data analysis and further spectroscopy analysis.

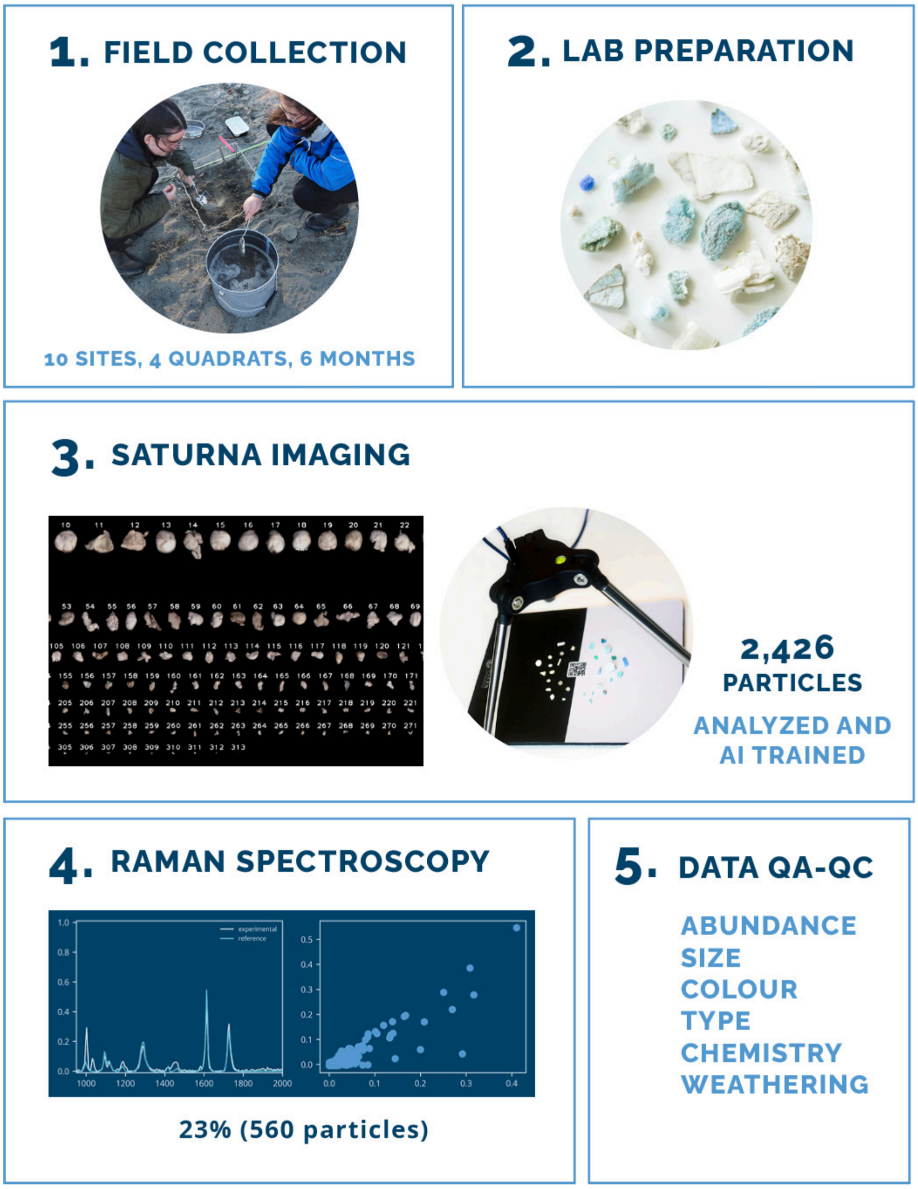

Figure 1. An overview of the data gathering process adopted in the study.

Raman Spectroscopy

Chemical analysis was carried out on a subset of the collected microplastic samples. The model of Kedzierski et al (2019) was used to calculate the amount of microplastics to subsample for each site and month to obtain statistically representative information on microplastic polymer composition with an error rate <10%. When all subsamples were calculated, particles within a specific month and station were indexed. Then, a random number generator was used to select the particles for spectroscopy analysis.

Single-point spectroscopy analysis was carried out using an in-house optical spectroscopy system consisting of a BH200M microscope (AmScope) coupled with a WP-785-R-SR-LMMFC-S laser (Wasatch Photonics, NC, USA). The optical setup can capture a brightfield image of the particle as well as the single point Raman spectrum. The Raman spectral acquisition was collected using either a 5x or 20x magnification objective depending on the particle size. The typical laser power setting was between 20-40% with an integration time between 200-400 ms. In some cases, a diminishing/distorted vibrational response was observed due to particle weathering and its hindrance on chemical identification. In most cases, peak broadening was observed and gathering sufficient spectral information was possible. However, in more severe cases, no vibrational response was observed above the background and particles were classified as unknown.

All subsequent post-processing of the Raman spectrum was done in Python 3.9 using an in-house algorithm. Each collected spectrum was first smoothed using a Savitzky-Golay filter with a window length of 15 and second polynomial order. The asymmetric least squares (ALS) approach outlined by Eilers and Boelens (2005) was chosen for the spectral baseline correction, and the spectrum was vector normalized within the spectral range of interest between 600 cm-1 to 1700 cm-1. Measured spectra were compared to the reference spectra of open-source libraries [OpenSpecy (Cowger et al., 2020), SLoPP and SLoPP-E (Munno et al. 2020)] using Ocean Diagnostics' software by a first derivative Pearson correlation approach.

Statistical Analysis

General Linear Models (GLMs) were developed to explore which beach characteristics might explain the patterns in microplastics contamination on the beaches in the Greater Victoria Region. The models were constructed in Python 3.9 using the statsmodels module. GLMs are based on an assumed relationship between the mean of the response variable and the explanatory variables. As microplastic data is represented by counts, and often shows non-normal and linear distribution in environmental samples, Poisson distribution was assumed in the construction of the models (Consul and Famoye 1992). The models were used to explore whether abundance of microplastics on beaches over the course of the study was influenced by 1) presence of marinas, 2) presence of stormwater drains and 3) beach morphology (open vs closed). Poisson link function was used to fit the data as follows:

$$log(\hat{\mu}_i) = \beta_0 + \beta_1 x_{i,1} + \beta_2 x_{i,2} + \ldots + \beta_k x_{i,k} i = 1, \ldots, 10$$

Data Quality Assurance and Control

Several measures were employed to control for and evaluate the quality of the data collected in this study. The recruited volunteers were trained on the use of the field protocol and assisted in the field as required. A standardized site sheet was provided with each sampling kit to record site metadata and notes on the sampling event (Appendix C). All materials needed for the collection of samples, such as sieves and storage containers, were pre-labelled by Ocean Diagnostics' scientists and distributed prior to sampling surveys. Feedback by the volunteers on the protocol use was collected using in-person interviews.

All particles were assigned a unique number identifier as part of the Saturna Imaging System standard analysis. To assess the accuracy of the AI colour and type predictions, each particle was visually categorized and assessed by the trained volunteers, as described in Section 4, and compared against the AI outputs. When the software did not correctly identify the particle type or colour, visual determination was used for further analysis.

The Pearson correlation coefficient, r, is used directly as the Hit Quality Index (HQI). An HQI threshold of 0.85 was established for the automated spectral matching analysis. A calculated HQI above 0.85 indicates matching successfully with no further manual examination required. A HQI below 0.85 indicates a requirement for analyst review of the matching. In most cases, severely weathered particles that failed the automated matching routine were matched using an alternative approach (i.e., physical examination) to identify their polymer type. We have assumed that all physically-identified white foam particles were part of the styrene polymer class.

FINDINGS

Community Science Microplastics Protocol and Technology Development

To date, most community science projects have focused on macroplastics which are more easily observed and sampled by volunteers compared to microplastics. Therefore, limited information exists on ideal protocols and best practices for sampling and analyzing microplastics by the volunteers. However, several scientists have highlighted the importance of having standardized, pre-tested simple protocols and sample data sheets suitable for your audience (Nel et al. 2020; Zettler et al. 2017; Rambonnet et al. 2019; Uhrin et al. 2019). According to Zettler et al. (2017), adding images or having videos detailing the sampling process can be a great asset. Indeed, this study observed that providing the volunteers with a simple step-by-step protocol is most effective in collecting reproducible data. Additional steps to improve a protocol would be to ensure that the protocol and any additional visual examples do not leave room for alternative interpretations. Furthermore, in-person training, as well as an introductory lesson into the issue of interest, could aid in ensuring all volunteers understand the protocol before sampling.

One of the challenges to efficiently collecting microplastic data is their great diversity in sizes, colours and morphology. These characteristics are typically of interest since they have ecological relevance (e.g., what species could ingest the particles is influenced by size) and can inform on microplastic sources and pollution prevention strategies (e.g., nurdles are indicative of industrial spills). Traditionally, data collection in shoreline samples has depended on visual assessments and manual measurements, particle by particle. This not only creates a challenge to sample analysis through-put and retention of volunteers, but also provides a source of potential errors through difficulty in standardization. To overcome this issue, we developed a camera device and software, the Saturna Imaging System, for rapid characterization of microplastics that can be easily deployed by the volunteers. It is a portable device that produces highly standardized images of particles that are numbered (Figure 2) and catalogued in a CSV file (not shown). In doing so, a wealth of size dimension data is generated that can help improve models to better understand the behaviour, sources, and retention of microplastics on shorelines. Also developed throughout the course of the project is an open-access database to host the data collected by the volunteers. By integrating the device with the data portal, the volunteers can instantaneously analyse and upload the data, thus further improving the efficiency and user experience. The optimized procedures, the Saturna Imaging System and the data portal will be made available in the fall of 2022 to a cohort of schools and beach-cleanup organizations for expansion of the microplastic shoreline program across Canada.

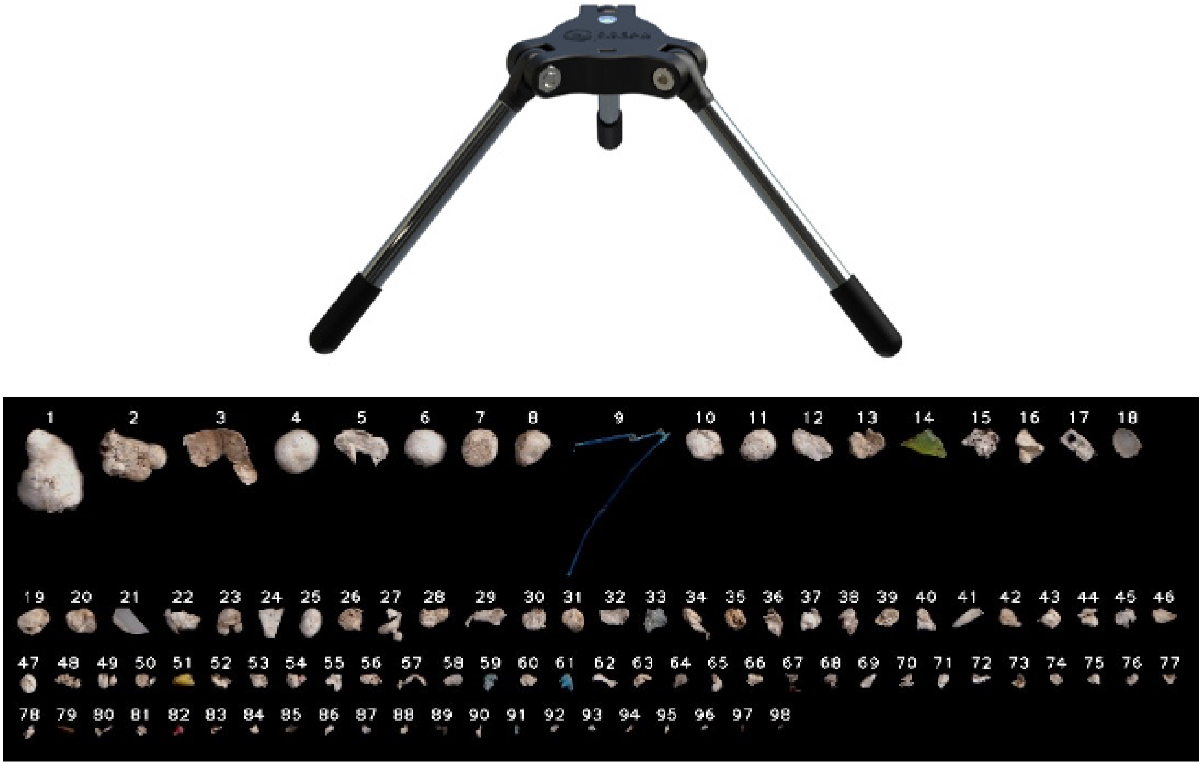

Figure 2. The Saturna Imaging System (top) and the data output (bottom).

Microplastic Trends on Vancouver Island Beaches

A total of 2,426 microplastics were extracted from beach samples collected by the volunteers in this study. The abundances ranged from 0–801 particles m^{-2} throughout the sampling period, and the sites with the highest levels of recorded microplastics were Site 1 (Sidney, North Saanich Yacht Club (NSYC), 801 particles m^{-2}), Site 2 (Roberts Bay Sanctuary, 169 particles m^{-2}) and Site 7 (Cadboro Bay, 253 particles m^{-2}, Table 2). Most of the sampled particles consisted of foam (81.4%), followed by fragment (8.5%), line (6.5%), film (1.8%) and pellet categories (1.8%) (Figure 3a). Spectroscopy analysis on a subset of 560 particles confirmed that the most abundant polymers were polystyrene (85%), followed by polyvinyl chloride (5%), polyethylene (3%) and polypropylene (3%) with a few particles being unidentifiable due to heavily weathered spectral signatures (1.9%) (Figure 3b).

Microplastic abundances varied up to 800-fold within each site and, in some instances (e.g., Sites 1, 2, 6, and 9), the highest levels of microplastics were represented by a single event. This highlights the importance of long-term site monitoring to fully understand which locations are most vulnerable to microplastic accumulation and to establish baseline levels. Foam, which was confirmed as polystyrene using a combination of spectroscopy and texture/physical analysis, typically dominated microplastic abundances at most of the sites (Table 2, Figure 3a). The exceptions were Robert's Bay, where lines were the dominant type of microplastic sampled by the volunteers, and Willows Beach which was dominated by fragments (Table 2).

The highest abundances of polystyrene were recorded on beaches characterized by marina and high public activity, such as the North Saanich Yacht Club, Cadboro Bay, Kayak Launch Amherst and Songhees Point (Figures 3a, and 3c). The GLM models indicated that the presence of marinas was positively correlated with microplastic abundances in our six-month study (Table 4). This could point to unique sources of polystyrene on the sites surrounded by marinas, such as public/commercial use, mismanagement of materials containing polystyrene and/or boating activity, since polystyrene is a frequently employed as a floatation device material (Camins et al. 2022). However, most of the polystyrene microplastics in this study consisted of round pieces resembling expanded polystyrene more commonly used in marine applications, as opposed to extruded polystyrene used in food packaging. Beach morphology also played a significant role, whereby the model indicated that lower abundances of microplastics were associated with open beaches. This may suggest the low retention of microplastics on these types of beaches, and our future modelling studies will further explore this hypothesis. Interestingly, we found that the sites with stormwater drains were associated with low microplastic densities (Tables 1 and 3).

The particles ranged from 0.5 to 5 mm in maximum size (Ferret diameter, defined as the longest distance between any two points along the selection boundary) with the median per site ranging from 1 to 4.5 mm (Figure 4). Microplastic sizes were generally similar across the sites, except for Willows Beach which had the smallest particles of all sites. Within each site, patterns of microplastic sizes varied considerably with some sites accumulating larger particles over time and others having smaller particles over time (Appendix Fig. 4A). These findings reveal the complex behaviour of microplastic debris on shorelines. Our future research exploring the relationship between hydrological conditions and debris size will provide further insight into the fate of microplastics in these systems.

When in the environment, microplastics are subject to various conditions such as sunlight and colonization by microorganisms. This represents a significant challenge in quantifying their sources and distributions as the attributes that help to distinguish them from natural particles can be lost. Spectroscopy is a common analytical tool to assess the chemical identity of plastic polymers in environmental samples, which combined with physical characteristics can inform on potential sources of plastic pollution. The technique measures the unique fingerprints created by the interaction of light with the surface of the particle. In our study, 50% of the foam particles rendered fingerprints indicative to strongly aged particles (weathered) that were difficult to assign to a polymer category (e.g., Figure 5), but their texture and white colour suggested polystyrene foam (Figures 2 and A1).

This finding indicates that many of the particles found on the local beaches did not originate from a recent event and might have been transported from other places. In contrast, a significant portion of foam showed good spectral signatures (e.g., Figure 6), suggesting a relatively new source of polystyrene deposited on the beaches. With the help of community scientists, we have established an extensive library of Raman spectra of beach microplastics that could help advance capability to identify microplastics in the environment, which will be shared in the upcoming scientific publication. Further, the study underscores the need to characterize and document the changes in spectral signatures of plastic polymers under controlled environmental conditions for use in microplastic monitoring. For instance, without availability of this data, foam particles smaller than 0.5 mm would have been completely missed in a scientific assessment because particles below this size are difficult to evaluate based on their texture (Lusher et al. 2020).

Site number	Site name	Foam	Line	Pellet	Film	Fragment	Metric	Value
1	Sidney, North Saanich Yacht Club	18.5	0	0	0	2.5	Median	22.5
		(0-772)	(0-1)	(0-2)	(0-22)	(0-5)	Range	(0-801)
		945	**1**	**2**	**23**	**15**	**Total**	**986**
2	Robert's Bay (Bird Sanctuary)	*1.5*	*0*	*0*	*0.5*	*3.5*	Median	*8.5*
		(0-20)	(0-145)	(0-0)	(0-6)	(0-9)	Range	(0-169)
		26	**146**	**0**	**8**	**21**	**Total**	**201**
3	Kayak Launch Amherst	*13.5*	*0*	*0*	*0*	*1.5*	Median	*18*
		(0-83)	(0-0)	(0-1)	(0-1)	(0-7)	Range	(0-87)
		186	**0**	**1**	**1**	**14**	**Total**	**202**
4	Lochside Waterfront Park	*7*	*0*	*0*	*0*	*0.5*	Median	*10*
		(1-33)	(0-0)	(0-0)	(0-1)	(0-4)	Range	(1-33)
		69	**0**	**0**	**1**	**7**	**Total**	**77**
5	Cordova Bay 1, Gloria Beach	*1*	*0*	*0*	*0*	*0*	Median	*2*
		(0-19)	(0-0)	(0-0)	(0-0)	(0-3)	Range	(0-22)
		24	**0**	**0**	**0**	**5**	**Total**	**30**
6	Cordova Bay 2	*0*	*0*	*0*	*0*	*0*	Median	*0*
		(0-10)	(0-0)	(0-0)	(0-0)	(0-1)	Range	(0-10)
		10	**0**	**0**	**0**	**1**	**Total**	**11**
7	Cadboro Bay	*87*	*1*	*0*	*0*	*18*	Median	*110.5*
		(6-220	(0-4)	(0-5)	(0-1)	(1-29)	Range	(10-253)
		517	**7**	**6**	**2**	**96**	**Total**	**628**
8	Cadboro-Gyro Park	*6.5*	*0*	*0*	*0*	*6*	Median	*16.5*
		(2-42	(0-1)	(0-1)	(0-5)	(1-22)	Range	(7-43)
		76	**2**	**1**	**6**	**44**	**Total**	**130**
9	Willows Beach	*0*	*0*	*0*	*0*	*0*	Median	*0.5*
		(0-1)	(0-1)	(0-0)	(0-0)	(0-26)	Range	(0-26)
		1	**1**	**0**	**0**	**27**	**Total**	**29**
10	Songhees Point	*18.5*	*0*	*0*	*0*	*0.5*	Median	*22*
		(0-42)	(0-0)	(0-0)	(0-3)	(0-6)	Range	(0-47)
		119	**0**	**0**	**3**	**9**	**Total**	**131**

Figure 2. Table 2. Median (italics, particles m^{-2}), range (parenthesis, particles m^{-2}) and total abundance (bold, particles m^{-2}) for each microplastic type identified throughout the sampling season at the 10 different stations.

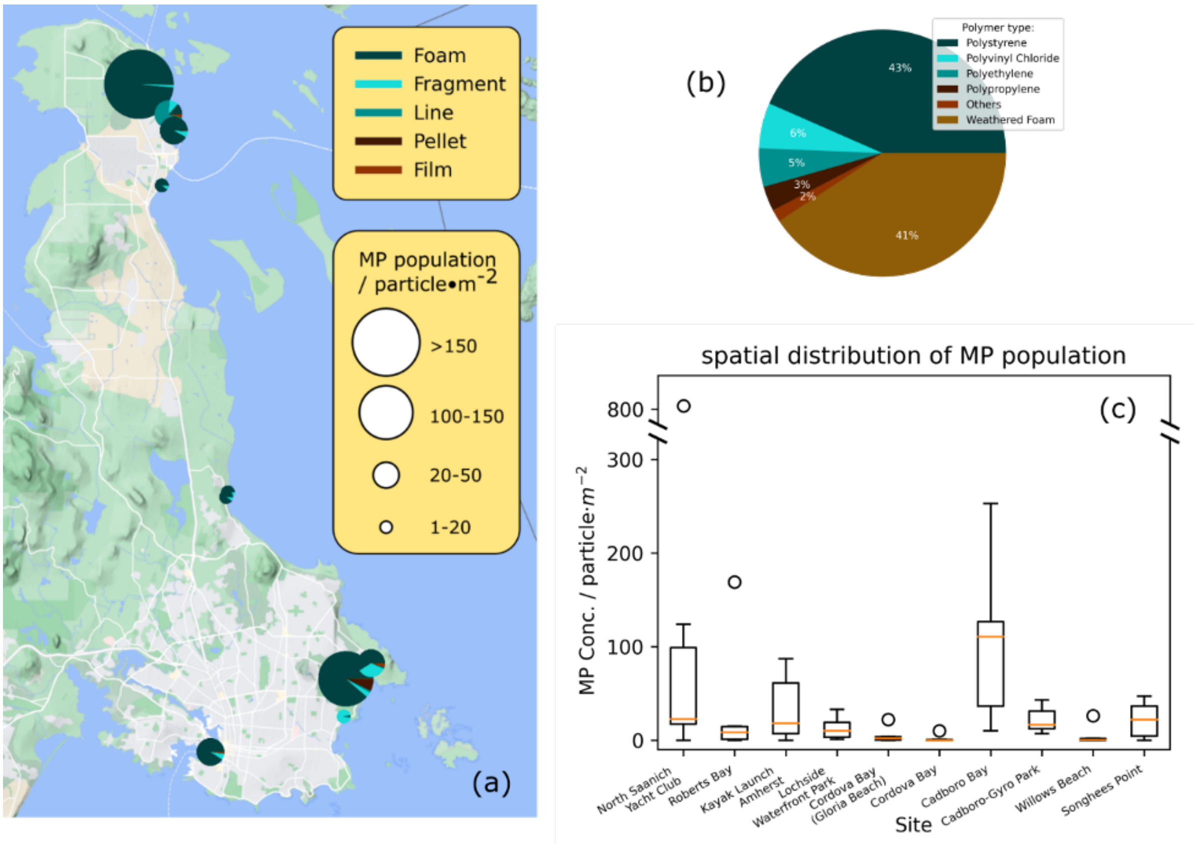

Figure 3. The patterns of microplastic abundance on beaches within the Greater Victoria Region. The map shows the average microplastic concentrations m^{-2} of the beach (a), the pie chart shows the composition of polymers (b) and the box plots document the spread and medians of particle densities m^{-2} at each location (c).

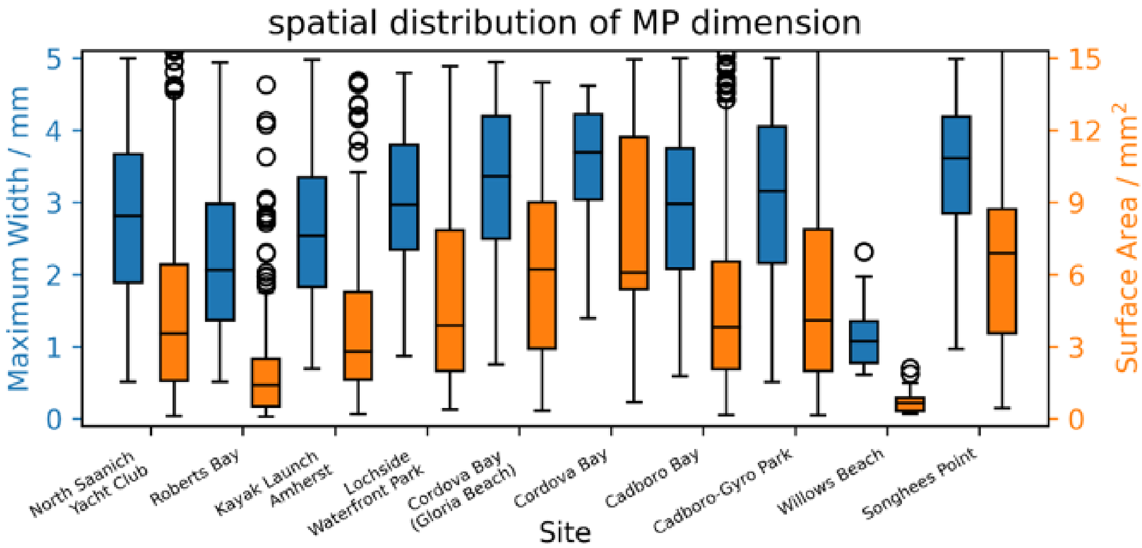

Figure 4. The sizes of microplastics collected from the beach samples at different study sites. The box plots represent a median maximum width (mm) of pooled particles from the six-month monitoring as measured by the Saturna Imaging System.

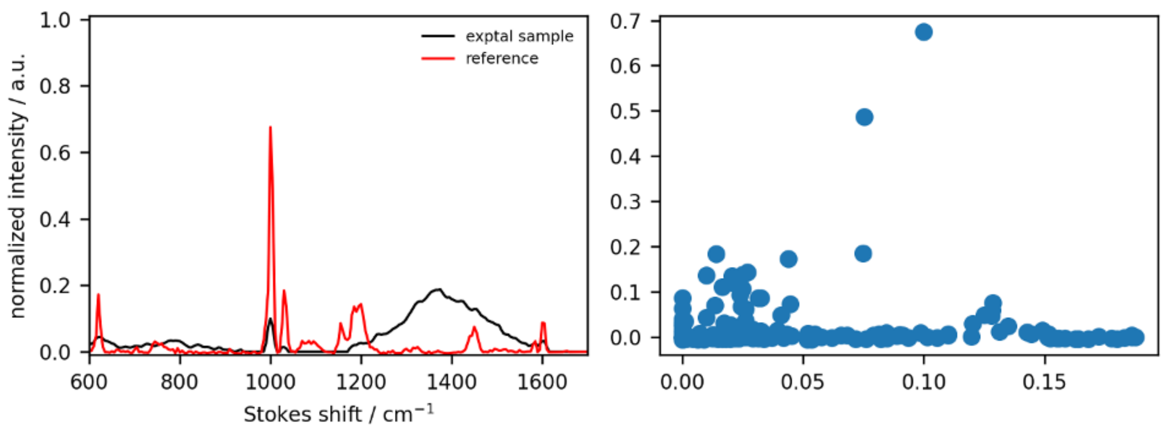

Figure 5. Spectral matching result of a microplastic particle collected at Kayak Launch Amherst site in June 2021 that is identified as polystyrene by physical analysis. Spectroscopy analysis yielded an unsatisfactory result due to severe particle weathering. (Left) Experimental Raman spectrum of the microplastic particle plotted in black and reference polystyrene spectrum plotted in red. (Right) Scatter plot of the normalized intensity of the experimental spectrum and reference polystyrene spectrum.

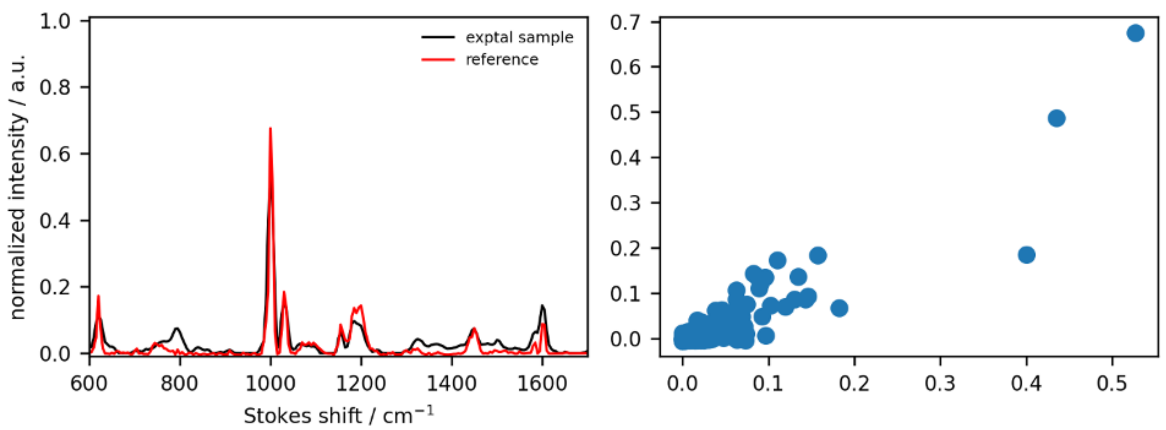

Figure 6. Spectral matching result of a microplastic particle collected at Cadboro Bay in September 2021 that is identified as polystyrene by both physical and spectroscopy analysis. (Left) Experimental Raman spectrum of the microplastic particle plotted in black and reference polystyrene spectrum plotted in red. (Right) Scatter plot of the normalized intensity of the experimental spectrum and reference polystyrene spectrum.

Polystyrene as the Source of Local Microplastic Pollution

The prevalence of polystyrene in our study area is consistent with the experience and data generated by local communities and eNGOs, such as the Great Canadian Shoreline Cleanup, Ocean Legacy Foundation, the BC Marine Debris Removal Initiative and the Lasqueti Shoreline Debris Initiative. These groups regularly find and attempt to remove staggering amounts of polystyrene washing up on local shorelines in the form of pieces and large blocks. For instance, between 2020 and 2021, BC Marine Debris Removal Initiative removed 327 tonnes of plastic waste from British Columbia beaches of which majority were foam polystyrene (SSTOA 2020 and 2022).

Foamed polystyrene is a lightweight insulating thermoplastic that has a variety of uses, including food ware, packaging, construction materials, and marine sectors. It can be either expanded (EPS) or extruded (XPS). While its buoyancy, resistance to degradation and low costs make polystyrene a popular choice in many applications, it represents an environmentally costly and problematic material. Polystyrene easily breaks up into pieces when released into the environment, especially on shorelines which are dynamic environments subject to mechanical action caused by waves, wind and currents (Kwon et al. 2015, Turner 2020). As a result, polystyrene can disperse and be easily transported over vast distances and represents one of the most common types of shoreline litter found worldwide (Turner 2020). Numerous marine species have been shown to accidentally ingest these particles, being potentially exposed to harmful chemicals. These may include chemicals used in the synthesis of polystyrene (e.g., benzoyl peroxide, azobisisobutyronitrile, emulsifiers, flame retardants and hexabromocyclododecane) which have been found throughout the world and known to accumulate in the food chain (Hwang et al. 2020). Further, styrene oligomers, which are constituents of polystyrene, are classified as possibly carcinogenic to humans by World Health Organization (WHO, 2022). These chemicals are widespread and persistent in the ocean, particularly in sand samples on beaches (Kwon et al. 2015).

As polystyrene waste is extremely difficult to retrieve and manage, reducing its presence and impacts will be contingent on source control. Most of the polystyrene particles polluting Victoria Island beaches were in the form of round expanded polystyrene spheres, a kind of material that is commonly used in marine applications, including docks floats, buoys, pontoons and fish boxes (Flora & Fauna International, 2022). These materials may have originated from local marina activities, as suggested by the data in this study, or from other locations in the Salish Sea which harbours fishing, boating and aquaculture activities. The continuous removal of washed-up polystyrene floats and blocks by local clean-up organizations demonstrate that polystyrene use in marine applications is a significant challenge for the Salish Sea ecosystem (Camins et al. 2022). Encapsulation of foam floats in aquaculture is one solution that is being advanced at a federal level (Department of Fisheries and Oceans, Canada, 2022). However, other marine related sources of expanded polystyrene are largely left out of regulations and there is a lack of monitoring of polystyrene in marinas, aquaculture, and other businesses (Lasquetti Debris

Shoreline Initiative, 2022). Local Community Scientists can play an important role in gathering baseline data on polystyrene pollution and through long-term monitoring can help better understand its relative sources and evaluate the effectiveness of regulations and management decisions.

CONCLUSIONS AND RECOMMENDATIONS

Microplastic pollution is a rapidly growing problem. However, the human effort required to conduct robust sampling is often lacking, resulting in data gaps for microplastic sources, impacts and fate. In our pilot study, we have successfully developed tools for standardized particle analysis by community science programs. Fifty-one volunteers from the Greater Victoria Region sampled 10 sandy shorelines of varying characteristics (e.g., morphology, marina presence and stormwater drain presence) monthly for six months. This project has allowed us to establish benchmark datasets on microplastic abundance and composition on sandy shorelines in the study area. It also led to the development and validation of innovative technology for standardized particle enumeration and characterization, the Saturna Imaging System, and the open-access datahub, Mariana, for recording the data; tracking policy change and targeting community action; ocean management; planning and other interventions.

The results of this pilot study underline the need to further investigate trends (both temporal and spatial) in microplastics in the Greater Victoria Region. Our study demonstrates the great potential of sandy beach shoreline monitoring by communities as a tool to inform legislative and management actions while generating benchmark to assess their impacts. We identified best practices for the design and execution of community science monitoring programs and, as a next step, will convene local groups and stakeholders to scale microplastic community surveys using the tools developed in the project.

REFERENCES

Besseling, E., Redondo-Hasselerharm, P., Foekema, E. M., & Koelmans, A. A. (2019). Quantifying ecological risks of aquatic micro- and nanoplastic. *Critical Reviews in Environmental Science and Technology*, 49(1), 32–80. https://doi.org/10.1080/10643389.2018.1531688

Camins, E., Miner, M., & Mussett, K. (2022). The Polystyrene Problem: A Scholarly Report in partnership with the Lasqueti Island Shoreline Debris Initiative. Ocean Leaders. *Marine Styrofoam Pollution on British Columbia's Coasts.* Accessed April 24, 2022: https://www.bcstyropollution.org/_files/ugd/2f4257_ce1882dc21954e859f2631d886f2ffac.pdf

Collicutt, B., Juanes, F., & Dudas, S. E. (2019). Microplastics in juvenile Chinook salmon and their nearshore environments on the east coast of Vancouver Island. *Environmental Pollution*, 244, 135–142. https://doi.org/10.1016/j.envpol.2018.09.137

Covernton, G. A., Pearce, C. M., Gurney-Smith, H. J., Chastain, S. G., Ross, P. S., Dower, J. F., & Dudas, S. E. (2019). Size and shape matter: A preliminary analysis of microplastic sampling technique in seawater studies with implications for ecological risk assessment. *Science of the Total Environment*, 667, 124–132. https://doi.org/10.1016/j.scitotenv.2019.02.346

Consul, P.C., & Famoye, F. (1992) Generalized poisson regression model, *Communications in Statistics - Theory and Methods*, 21:1, 89-109, DOI: 10.1080/03610929208830766

Cowger, W., Gray, A., Christiansen, S. H., DeFrond, H., Deshpande, A. D., Hemabessiere, L., Lee, E., Mill, L., Munno, K., Ossmann, B. E., Pittroff, M., Rochman, C., Sarau, G., Tarby, S., & Primpke, S. (2020). Critical Review of Processing and Classification Techniques for Images and Spectra in Microplastic Research. *Applied Spectroscopy*, 74(9), 989–1010. https://doi.org/10.1177/0003702820929064

de Sá, L. C., Oliveira, M., Ribeiro, F., Rocha, T. L., & Futter, M. N. (2018). Studies of the effects of microplastics on aquatic organisms: What do we know and where should we focus our efforts in the future? In Science of the Total Environment (Vol. 645, pp. 1029–1039). Elsevier B.V. https://doi.org/10.1016/j.scitotenv.2018.07.207

Department of Fisheries and Oceans, Canada. Evaluation of Fisheries and Aquaculture Clean Technology Adoption Program. Retrieved on May 15, 2022. https://www.dfo-mpo.gc.ca/aquaculture/business-entreprises/factap-patppa-eng.htm

Desforges, J. P. W., Galbraith, M., Dangerfield, N., & Ross, P. S. (2014). Widespread distribution of microplastics in subsurface seawater in the NE Pacific Ocean. *Marine Pollution Bulletin*, 79(1–2), 94–99. https://doi.org/10.1016/j.marpolbul.2013.12.035

Desforges, J. P. W., Galbraith, M., & Ross, P. S. (2015). Ingestion of Microplastics by Zooplankton in the Northeast Pacific Ocean. *Archives of Environmental Contamination and Toxicology*, 69(3). https://doi.org/10.1007/s00244-015-0172-5

Eilers, P.H., & Boelens, H. (2005). Baseline Correction with Asymmetric Least Squares Smoothing. *Unpubl. Manuscr.*
Fries, E., Dekiff, J. H., Willmeyer, J., Nuelle, M. T., Ebert, M., & Remy, D. (2013). Identification of polymer types and additives in marine microplastic particles using pyrolysis-GC/MS and scanning electron microscopy. *Environmental Sciences: Processes and Impacts*, 15(10), 1949–1956. https://doi.org/10.1039/c3em00214d

Fritz, S., See, L., Carlson, T., Haklay, M. (Muki), Oliver, J. L., Fraisl, D., Mondardini, R., Brocklehurst, M., Shanley, L. A., Schade, S., Wehn, U., Abrate, T., Anstee, J., Arnold, S., Billot, M., Campbell, J., Espey, J., Gold, M., Hager, G., … West, S. (2019). Citizen science and the United Nations Sustainable Development Goals. *Nature Sustainability*, 2(10), 922–930. https://doi.org/10.1038/s41893-019-0390-3

Gies, E. A., LeNoble, J. L., Noël, M., Etemadifar, A., Bishay, F., Hall, E. R., & Ross, P. S. (2018). Retention of microplastics in a major secondary wastewater treatment plant in Vancouver, Canada. *Marine Pollution Bulletin*, 133, 553–561. https://doi.org/10.1016/j.marpolbul.2018.06.006

Horn, D. A., Granek, E. F., & Steele, C. L. (2020). Effects of environmentally relevant concentrations of microplastic fibers on Pacific mole crab (Emerita analoga) mortality and reproduction. *In Limnology And Oceanography Letters* (Vol. 5, Issue 1, pp. 74–83). John Wiley and Sons Inc. https://doi.org/10.1002/lol2.10137

Hwang, J., Choi, D., Han, S., Jung, S. Y., Choi, J., & Hong, J. (2020). Potential toxicity of polystyrene microplastic particles. *Scientific Reports*, 10(1). https://doi.org/10.1038/s41598-020-64464-9

Kedzierski, M., Villain, J., Falcou-Préfol, M., Kerros, M. E., Henry, M., Pedrotti, M. L., & Bruzaud, S. (2019). Microplastics in Mediterranean Sea: A protocol to robustly assess contamination characteristics. *PLoS ONE*, 14(2). https://doi.org/10.1371/journal.pone.0212088

Knutsen, H., Cyvin, J. B., Totland, C., Lilleeng, Ø., Wade, E. J., Castro, V., Pettersen, A., Laugesen, J., Møskeland, T., & Arp, H. P. H. (2020). Microplastic accumulation by tube-dwelling, suspension feeding polychaetes from the sediment surface: A case study from the Norwegian Continental Shelf. *Marine Environmental Research*, 161. https://doi.org/10.1016/j.marenvres.2020.105073

Kwon, B. G., Koizumi, K., Chung, S. Y., Kodera, Y., Kim, J. O., & Saido, K. (2015). Global styrene oligomers monitoring as new chemical contamination from polystyrene plastic marine pollution. *Journal of Hazardous Materials*, 300, 359–367. https://doi.org/10.1016/j.jhazmat.2015.07.039

Lasqueti Island Shoreline Debris Initiative. Retrieved on May 15, 2022 https://www.bcstyropollution.org/

Lau, W. (2021, March 18). Testimony for The Pew Charitable Trusts by Winnie Lau, Senior Manager. Preventing Ocean Plastics Project. House Committee on Appropriations. Subcommittee on Interior, Environment, and Related Agencies. Accessed April 25, 2022. https://www.pewtrusts.org/-/media/assets/2021/03/testimony-for-house-interior-subcommittee-on-appropriations_pew_ocean-plastics_final.pdf

Lusher, A. L., Bråte, I. L. N., Munno, K., Hurley, R. R., & Welden, N. A. (2020). Is It or Isn't It: The Importance of Visual Classification in Microplastic Characterization. *Applied Spectroscopy*, 74(9), 1139–1153. https://doi.org/10.1177/0003702820930733

Mahara, N., Alava, J., Kowal, M., Grant, E., Boldt, J., Kwong, L., & Hunt, B. (2022). Assessing size-based exposure to microplastic particles and ingestion pathways in zooplankton and herring in a coastal pelagic ecosystem of British Columbia, Canada. *Marine Ecology Progress Series*, 683, 139–155. https://doi.org/10.3354/meps13966

Munno, K., de Frond, H., O'donnell, B., & Rochman, C. M. (2020). Increasing the Accessibility for Characterizing Microplastics: Introducing New Application-Based and Spectral Libraries of Plastic Particles (SLoPP and SLoPP-E). *Analytical Chemistry*, 92(3), 2443–2451. https://doi.org/10.1021/acs.analchem.9b03626

Nel, H. A., Sambrook Smith, G. H., Harmer, R., Sykes, R., Schneidewind, U., Lynch, I., & Krause, S. (2020). Citizen science reveals microplastic hotspots within tidal estuaries and the remote Scilly Islands, United Kingdom. *Marine Pollution Bulletin*, 161. https://doi.org/10.1016/j.marpolbul.2020.111776

Ocean Wise, & World Wildlife Foundation. (2018). 2018 Annual Report Help Keep Our Water Ecosystems Healthy for Everyone. *The Great Canadian Shoreline Cleanup.* https://shorelinecleanup.org/storage/resources/gcsc-2018annualreport-190416.pdf

Ocean Wise, & World Wildlife Foundation. (2019). 2019 Annual Report Help Keep Our Water Ecosystems Healthy for Everyone. *The Great Canadian Shoreline Cleanup.* https://shorelinecleanup.org/storage/resources/gcsc-2019annualreport-en-200512.pdf

Ocean Wise, & World Wildlife Foundation. (2020). 2020 Annual Report Help Keep Our Water Ecosystems Healthy for Everyone. *The Great Canadian Shoreline Cleanup.* https://shorelinecleanup.org/storage/resources/final-gcsc-annualreport2020-en-may10.pdf

Rambonnet, L., Vink, S. C., Land-Zandstra, A. M., & Bosker, T. (2019). Making citizen science count: Best practices and challenges of citizen science projects on plastics in aquatic environments. *Marine Pollution Bulletin,* 145, 271–277. https://doi.org/10.1016/j.marpolbul.2019.05.056

Rochman, C. M., Brookson, C., Bikker, J., Djuric, N., Earn, A., Bucci, K., Athey, S., Huntington, A., McIlwraith, H., Munno, K., Frond, H. de, Kolomijeca, A., Erdle, L., Grbic, J., Bayoumi, M., Borrelle, S. B., Wu, T., Santoro, S., Werbowski, L. M., … Hung, C. (2019). Rethinking microplastics as a diverse contaminant suite. In *Environmental Toxicology and Chemistry* (Vol. 38, Issue 4, pp. 703–711). Wiley Blackwell. https://doi.org/10.1002/etc.4371

SSTOA. (2020). *Marine Debris Removal Initiative 2020 – Coastal Environmental Protection, Employment, and Economic Recovery During the COVID-19 Pandemic.* https://wilderness-tourism.bc.ca/wp-content/uploads/2021/01/SSTOA-MDRI-2020-FINAL-Report-PUBLIC.pdf

SSTOA. *Marine Debris Removal 2021.* Accessed: April 24, 2022. https://wilderness-tourism.bc.ca/shoreline-clean-up/mdri-2021/

Turner, A. (2020). Foamed Polystyrene in the Marine Environment: Sources, Additives, Transport, Behavior, and Impacts. In *Environmental Science and Technology* (Vol. 54, Issue 17, pp. 10411–10420). American Chemical Society. https://doi.org/10.1021/acs.est.0c03221

Uhrin, A. v., Lippiatt, S., Herring, C. E., Dettloff, K., Bimrose, K., & Butler-Minor, C. (2020). Temporal Trends and Potential Drivers of Stranded Marine Debris on Beaches Within Two US National Marine Sanctuaries Using Citizen Science Data. *Frontiers in Environmental Science*, 8(November), 1–19. https://doi.org/10.3389/fenvs.2020.604927

United Nations Environment Programme (2021). Drowning in Plastics – Marine Litter and Plastic Waste Vital Graphics. https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/36964/VITGRAPH.pdf

van Cauwenberghe, L., & Janssen, C. R. (2014). Microplastics in bivalves cultured for human consumption. *Environmental Pollution,* 193, 65–70. https://doi.org/10.1016/j.envpol.2014.06.010

World Health Organization. (2022). Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda, 4th ed + 1st add + 2nd add. World Health Organization. https://apps.who.int/iris/handle/10665/352532. License: CC BY-NC-SA 3.0 IGO

Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: a review. In *Environmental Pollution* (Barking, Essex : 1987) (Vol. 178, pp. 483–492). https://doi.org/10.1016/j.envpol.2013.02.031

Zettler, E. R., Takada, H., Monteleone, B., Mallos, N., Eriksen, M., & Amaral-Zettler, L. A. (2017). Incorporating citizen science to study plastics in the environment. In *Analytical Methods* (Vol. 9, Issue 9, pp. 1392–1403). Royal Society of Chemistry. https://doi.org/10.1039/c6ay02716d

Appendix A. Additional Tables and Figures

Site number	Site name	Beach morphology	Number of marinas	Stormwater at site	Polystyrene abundance (6-month median) (%)	Polystyrene abundance in samples (range) (%)
1	Sidney, North Saanich Yacht Club	Enclosed	7	N	100.00	(0-100)
2	Robert's Bay (Bird Sanctuary)	Enclosed	2	Y	54.42	(0-100)
3	Kayak Launch Amherst	Semi-enclosed*	1	Y	95.65	(0-100)
4	Lochside Waterfront Park	Open	0	Y	100.00	(75-100)
5	Cordova Bay 1, Gloria Beach	Open	0	N	50.00	(0-100)
6	Cordova Bay 2	Open	0	N	0.00	(0-100)
7	Cadboro Bay	Enclosed	1	Y	80.52	57.77-100.00
8	Cadboro-Gyro Park	Enclosed	1	N	76.04	33.33-100.00
9	Willows Beach	Semi-enclosed *	0	N	39.14	0-100
10	Songhees Point	Open	5	Y	52.38	0-100

Table A1. Proportion of the median polystyrene abundance and range in samples for all sites measured over six-month study period.

Site number	Site name	Polystyrene (%)	Polyethylene (%)	Polypropylene (%)	PVC (%)	Other (%)
1	Sidney, North Saanich Yacht Club	93.1	0.0	4.6	2.3	0.0
2	Robert's Bay (Bird Sanctuary)	75.5	0.0	10.0	13.1	1.4
3	Kayak Launch Amherst	96.5	0.0	3.5	0.0	0.0
4	Lochside Waterfront Park	89.7	0.0	0.0	3.4	6.9
5	Cordova Bay 1- Gloria Beach	100.0	0.0	0.0	0.0	0.0
6	Cordova Bay 2	100.0	0.0	0.0	0.0	0.0
7	Cadboro Bay	78.4	8.7	4.1	7.7	1.1
8	Cadboro-Gyro Park	78.0	10.2	0.0	6.8	5.0
9	Willows Beach	80.8	11.5	0.0	3.8	3.9
10	Songhees Point	82.0	0.0	9.0	9.0	0.0

Table A2. Proportion of polymers at each site measured over a six-month study period.

Table A3. Results of the GLM model (Poisson distribution) where the response variable was the average microplastic particles•m^{-2} per month per site (N=53) and the explanatory variables were the beach morphology (open or enclosed), stormwater presence (yes or no) and presence of marinas (yes or no). P-values below 0.01 have been bolded.

Model	Coefficient	Standard Error	p-value
Intercept	2.46	0.1	**<0.01**
Beach morphology	-0.46	0.08	**<0.01**
Stormwater	-0.49	0.04	**<0.01**
Marinas	2.12	0.10	**<0.01**

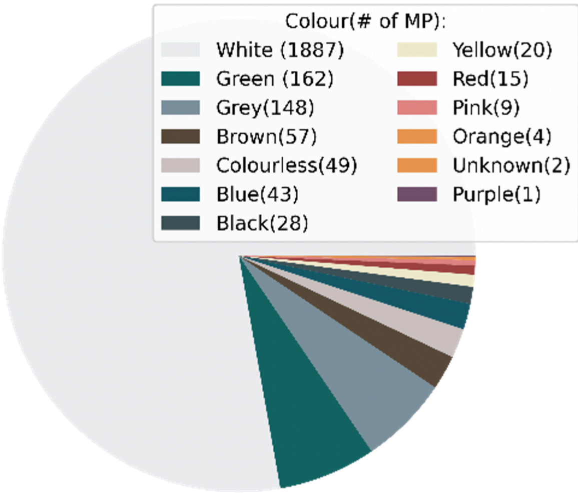

Figure A1. The distribution of particle colors

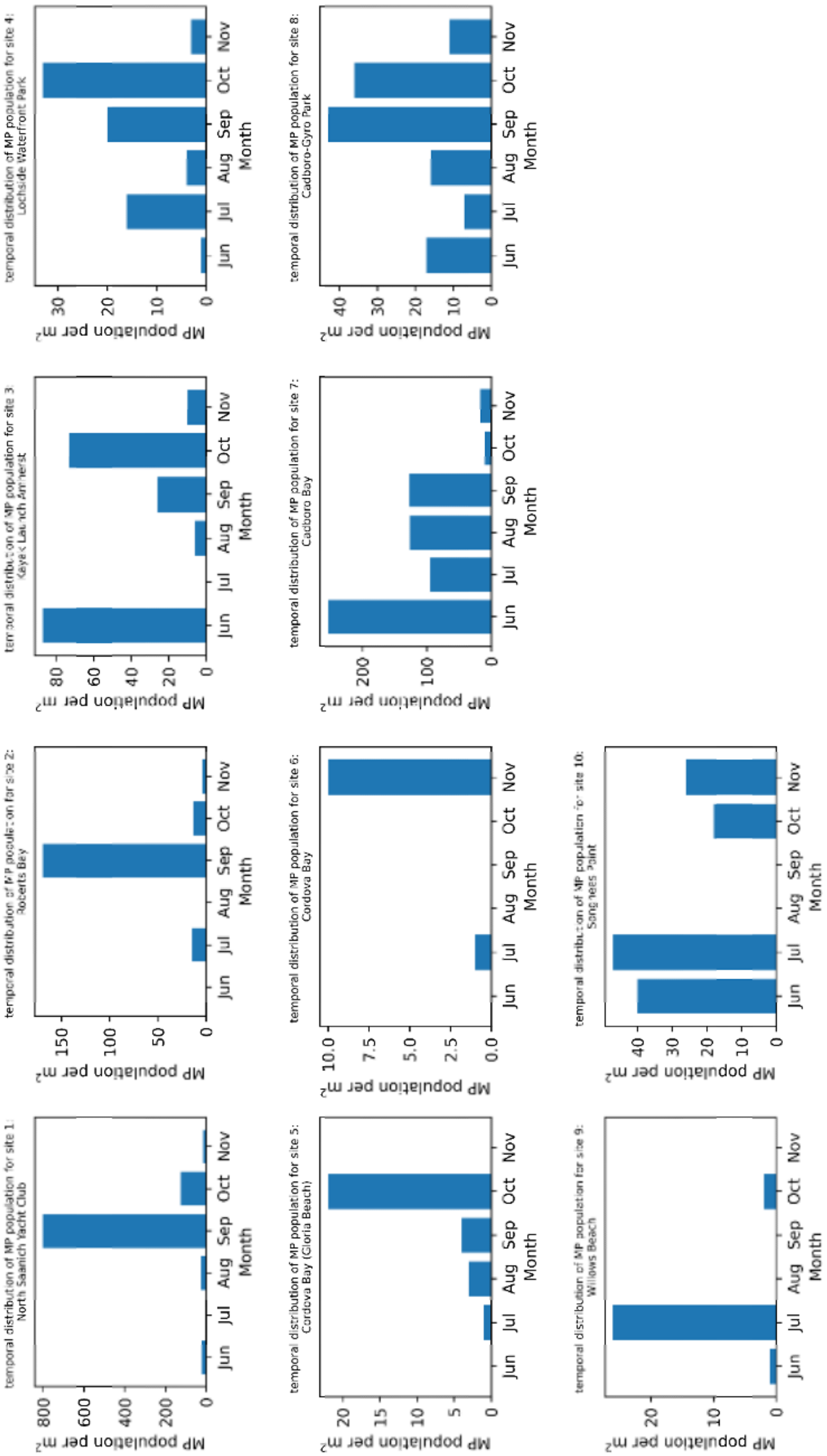

Figure A2. Area-normalized monthly microplastic abundances (particles m^{-2}) at 10 sites monitored by the volunteers.

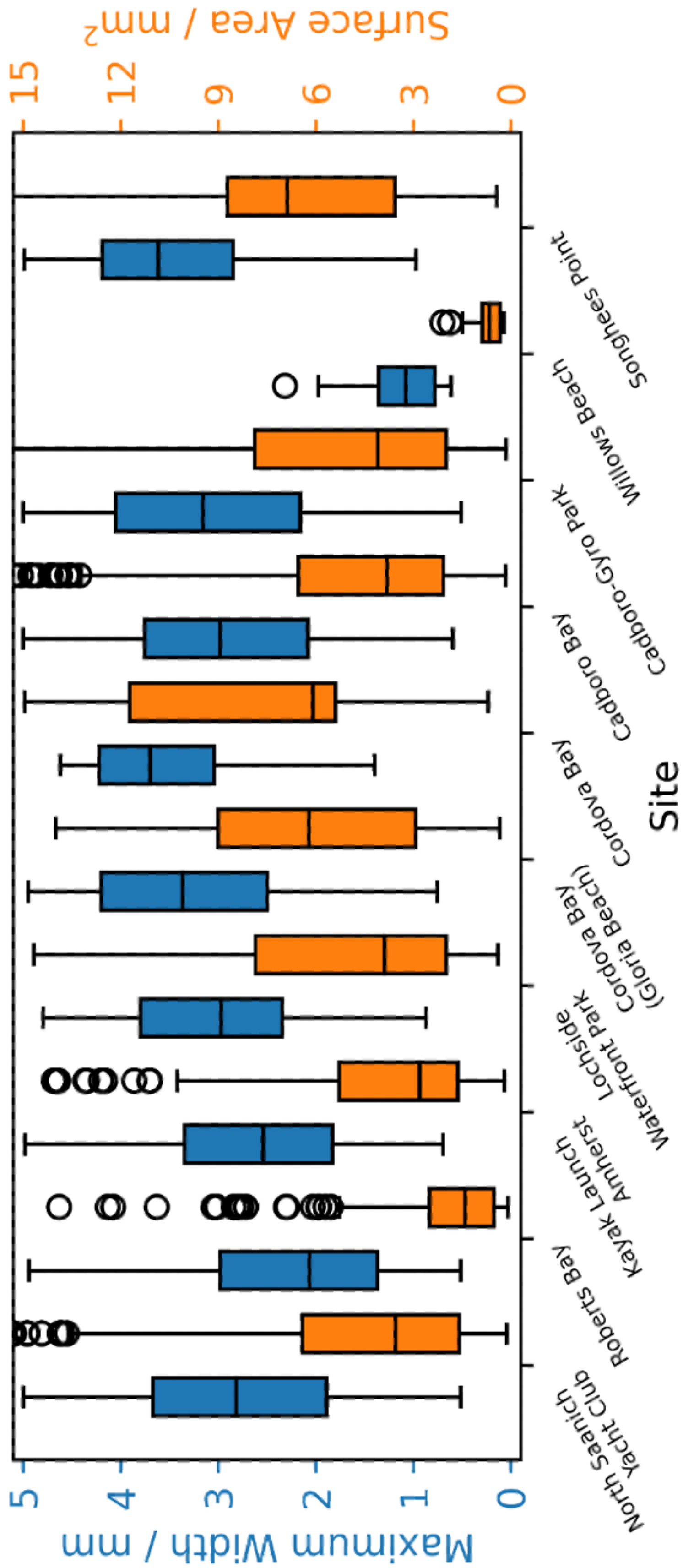

Figure A3. Comparison of particle lengths and surface areas between the sites demonstrates significant variability. Willow's Beach was found to contain the smallest number of microplastics in the study.

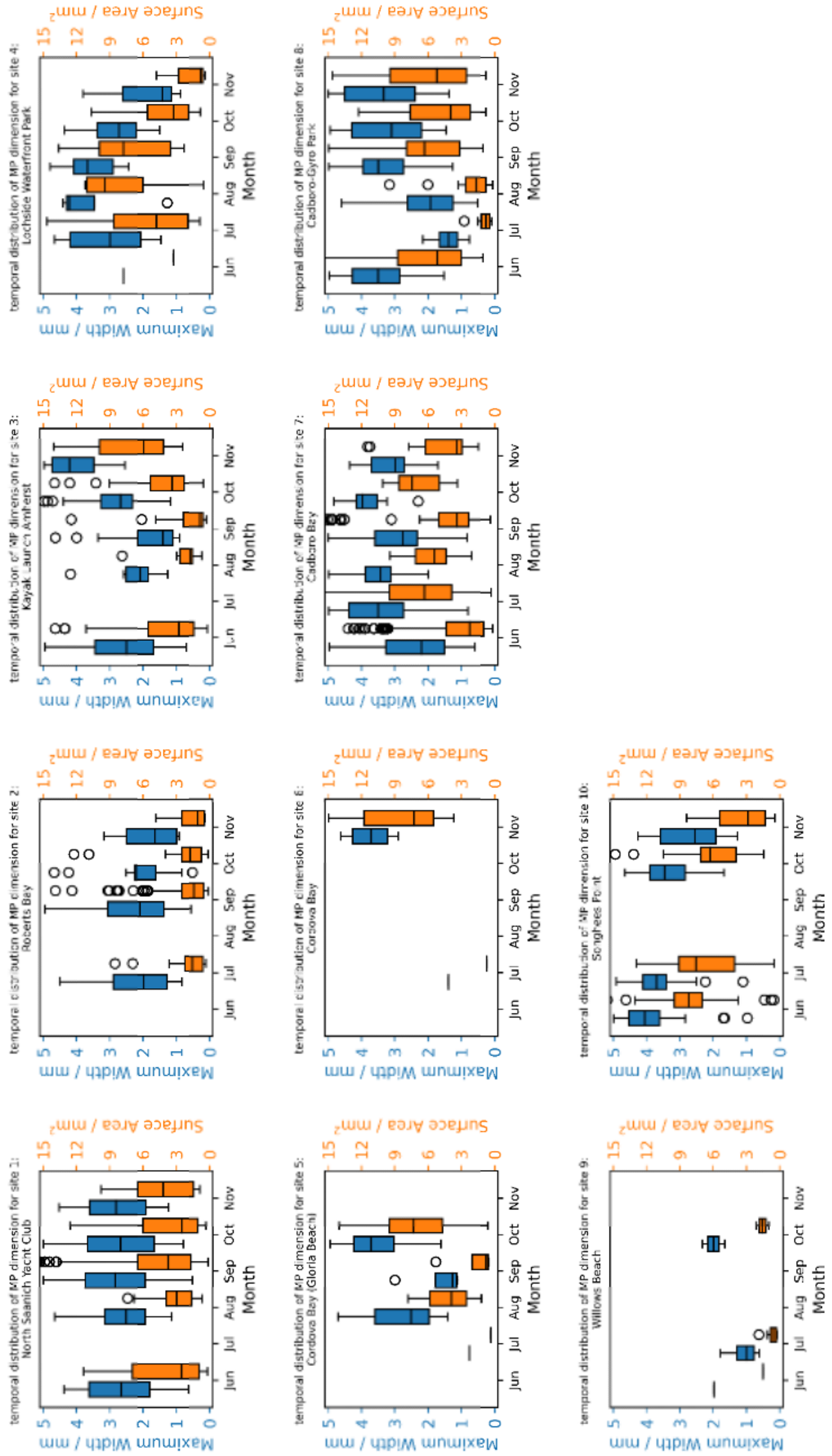

Figure A4. Microplastic width and surface areas differed substantially between and within the sites throughout the study period.

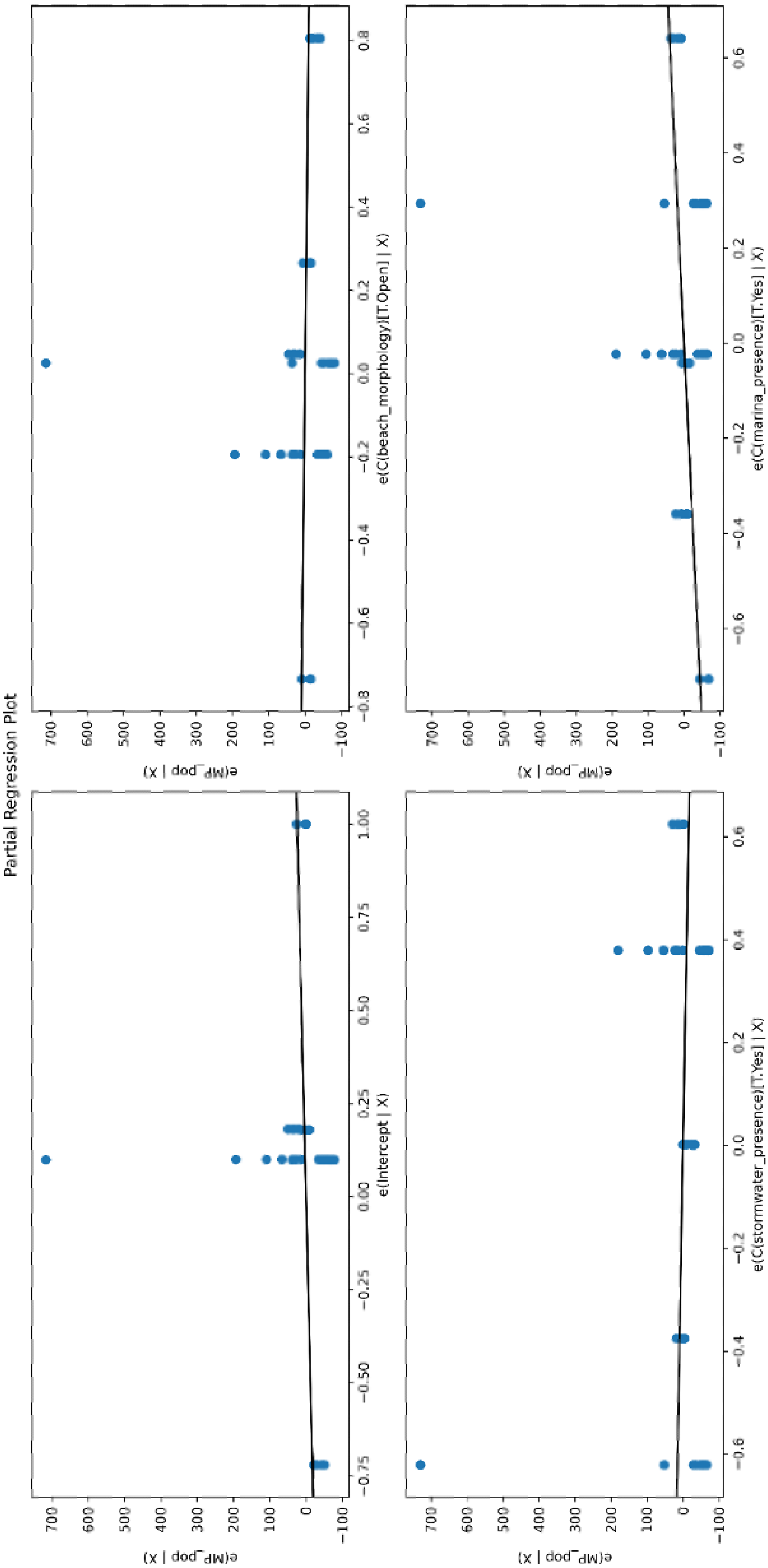

Figure A5. Partial regression of the general linear model for each of the categorical variables.

Appendix B. Definitions of Saturna Imaging System Metrics

Metric	Units	Definition
Maximum width	mm	Maximum distance between two points in a particle
Surface Area	mm^2	2-dimensional area of particle
Convex surface area	mm^2	Area of convex hull
Perimeter	mm	Length of the particle bounding pixels
Convex Perimeter	mm	Length of the bounding pixels of the convex hull
Bounding Box Length	mm	Length of bounding box
Bounding Box Width	mm	Width of bounding box
Aspect ratio	-	Width of bounding box divided by length of bounding box
Roundness	-	Are to perimeter ratio
Convexity	-	Measure of surface roughness
Solidity	-	Measure of boundary/edge irregularity
Hue	-	Numerical scale describing color of an object
Saturation	-	
Value	-	
Blue	-	Combination of proportions of these colors that produce a specific color
Red	-	
Green	-	
Light Channel	-	Another combination of numerical values to represent color
A Channel	-	
B Channel	-	
Color Prediction	-	AI model color result from HSV, BRG, and LAB value analysis
Particle Type Prediction	-	Prediction based on AI model particle training

Definitions of all metrics collected by the Saturna Imaging System.

Appendix C. Community Science Protocol Checklist

Before Going To The Site

- ☐ Sample kit is complete
- ☐ Sample containers have been picked up
- ☐ All sample containers, tins and filter housing(s) are packed and ready to go
- ☐ Have printed sample data sheet
- ☐ Have printed copy of this protocol

Sampling on site

- ☐ Each team member knows their role for the day
- ☐ Record start time
- ☐ Record GPS coordinates for beginning and end of transect
- ☐ Record position of all four quadrats
- ☐ Keep track and record total volume of ocean water filtered
- ☐ Ensure all samples are stored in their corresponding tin or container (Zone 1= Q1, Zone 2= Q2,...)
- ☐ Rinse sieve and buckets between sampling zones
- ☐ Record end time

After Sampling

- ☐ All tools and materials used for sampling have been rinsed with tap water and left to air dry
- ☐ Store all samples in the fridge until delivered to ODI
- ☐ Sample drop off schedule has been communicated and confirmed by ODI
- ☐ Samples have been delivered to ODI

Appendix D. Community Science Data Sheet

Site name and number:	
Sampling date (yyyy/mm/dd):	
High tide at (hh:mm 24hr):	Low tide at (hh:mm 24hr):
Group members: Note taker: Water filterer: Sampler(s):	
Photo documentation available (circle one): Y N	
Site coordinator name:	

	Transect information	Notes
Start time (24 hr):		
Transect length (m): (from top of the beach to the current tide line)		
Transect start GPS coordinates:		
Quadrat 1 (metre mark):		
Quadrat 2 (metre mark):		
Quadrat 3 (metre mark):		
Quadrat 4 (metre mark):		
Transect end GPS coordinates:		
End time (24 hr):		

Total volume of ocean water filtered (L):
Equivalent volume filtered at stormwater outfall (L) (if applicable):
Site observations and beach conditions:
Weather (wind and direction, rain, etc...)