Developing a System to Monitor Microplastics on Icelandic Shores

An Interactive Qualifying Project Report Submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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Abstract

Microplastics are a growing problem worldwide, and their effects are only starting to be understood. Our goal was to produce a beach monitoring method that can help community groups in Iceland track changes in microplastic pollution. We tested multiple methods from previous studies and combined aspects into one method that is time efficient, simple, and low cost. We also developed an easy to use, consistent verification test. The final method is an ideal way for community scientists to monitor microplastics in beach sand. To keep Iceland's shores clean and marine ecosystems healthy, monitoring microplastics will be the first step in understanding plastic pollution.

Executive Summary

Introduction and Background

Society is heavily reliant on plastic products. There are 300 million tons of plastic produced every year, and nearly half is used once and then thrown away (Dwyer, 2017; Plastic Oceans, n.d.). Once plastics are thrown away, they enter the ocean through boats, rivers, and landfills (National Geographic Society, 2012 a). Currents in the ocean can carry plastic to beaches around the world.

Figure A: Fishing Nets on Beach in Iceland

Iceland is at risk because it is an island nation and the population relies heavily on fish for its diet (The World Factbook, 2018). The fishing industry employs 5% of the workforce in Iceland, and is an important aspect of the Icelandic lifestyle and culture (The World Factbook, 2018). However, a study done in an Icelandic nature reserve found that the fishing industry was the greatest contributor to plastic pollution on the shores (Kienitz, 2013). Fishing nets and gear can end up on the shores and affect tourism, Iceland's largest industry (Figure A) (Fontaine, 2015). To keep beaches attractive and safe for tourists, cities may have to spend time and money cleaning beaches.

Larger pieces of plastic can fragment into microplastics from environmental factors such as sunlight, wind, and currents when in the ocean (Halle et al., 2016). When marine animals ingest microplastics, harmful chemicals work their way up the food chain to humans and other organisms through the process of biomagnification (NOAA, n.d.; Duis & Coors, n.d.). Smaller pieces of plastics can be more harmful to species than larger pieces because smaller pieces absorb and release more chemicals as they break down. BPA, a common chemical found in plastics, mimics hormones in animals and humans (National Geographic Society, 2012 a). Traces of BPA have been found in the breast milk of mothers and urine of children (Mendonca, Hauser, Calafat, Arbuckle, & Duty, 2014). Monitoring microplastics is important in reducing the harmful effects of microplastic pollution.

Scientists have made efforts in developing microplastic monitoring methods; however, more research needs to be done. With microplastic pollution growing on a global scale, scientists can utilize community science, also known as citizen science, to help gather necessary data. By involving community scientists, Iceland can develop a database that can be used to track changes in microplastic pollution on their shores.

Project Goal and Objectives

The goal of this project was to produce a beach monitoring method that can help community groups in Iceland track changes in microplastic pollution. To accomplish this we laid out four objectives.

Objective 1: Determine which methods of gathering samples are applicable to Iceland's beaches.
Objective 2: Determine which methods to pilot test for separating and analyzing microplastics from samples.
Objective 3: Determine the willingness of volunteers and organizations to use a monitoring method.
Objective 4: Identify and communicate the most appropriate method to monitor microplastics for community scientists on Icelandic shores.

Methodology

During our time in Iceland, we evaluated several methods used in previous microplastic studies to gather sediment on three different beaches. We modified these methods because we needed to use quantities that were realistic of community scientists. We were not evaluating the actual concentration and distribution of microplastics during our pilot studies. The first of these modified gathering methods was that of the Baykeeper Beach Litter Audit (Bayas, Buckley, Ford, & Lawes, 2017). We placed a square meter quadrant by the vegetation at the top of the beach, at the high tide line, and at the midpoint between these two quadrants. We only used one transect, rather than three, to save time because we were only evaluating the ease of use for Icelandic beaches. We then gathered the top centimeter of sand with our hands for analysis (Bayas et al., 2017).

The next gathering method we evaluated was based on a master's thesis conducted at the University of Akureyri (Dippo, 2012). We made a square meter quadrant at the high tide line and gathered the top two centimeters of sand. We only used one quadrant for our procedure, and we did not collect the suggested seven and a half liter sample size because we needed to test time efficiency for community scientists (Dippo, 2012).

The last gathering method we tested was based on the procedure of a study performed through Leiden University (Lots, Behrens, Vijver, Horton, & Bosker, 2017). We gathered the top centimeter of sand with our hands at 10 meter intervals on the high tide line. We gathered one handful of sand at each sample site, rather than the 100 gram sample the study recommended (Lots et al., 2017), since we did not have the means to measure these samples and community scientists might not, either.

We also evaluated several methods of analyzing the samples we had collected. First, we placed the collected sand samples in a kitchen sieve and poured water over it until all of the sand had passed through. Any material left in the sieve was placed in a bag for further analysis. We also used hand picking. While sorting through our sample sites, anything that was not sand, rocks, shells or organic matter was placed in a sample bag.

For further analysis, we used ocean water and a saturated salt solution in density separation tests. We placed the sand we had gathered into the salt solutions and stirred until any microplastics rose to the top. In ocean water, the only particles that floated were too small to identify. In the saturated salt solution, we found that nothing from our samples floated. Lastly, since our tests with ocean water and the salt solution did not yield any conclusive results, we tried placing our sand samples in corn syrup and waited for the sample to separate (Figure B).

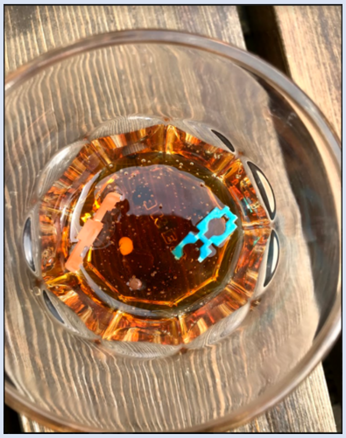

Figure B: Corn Syrup Density Separation Test

We conducted interviews to determine the willingness of volunteers to perform a method to monitor microplastics. We asked questions related to how much time they would be willing to put in and what resources they would be willing to supply. We conducted the interviews at beach cleanups and sent out an electronic survey to environmental organizations, including the Blue Army and SEEDS.

The final method we piloted combined elements from other methods. We called it The Star Method (Figure C) and considered criteria such as ease of use, time commitment, and cost and availability of materials. To begin the Star Method, we located a landmark at the top of the beach. We then placed a stake in line with this landmark at the high tide line. At this stake, we drew a circle with a radius of 1.5 feet and then used our hands to pick out microplastics. After hand picking each circle, we placed these particles in a jar filled half way with corn syrup and waited for any microplastics to float. We counted the particles that floated and recorded the number found at the sample location. We then walked ten paces from the marker towards the rocks or vegetation at the top of the beach and repeated this process. We also did this at ten paces left of the marker, ten paces right of the marker, and ten paces from the marker towards the water.

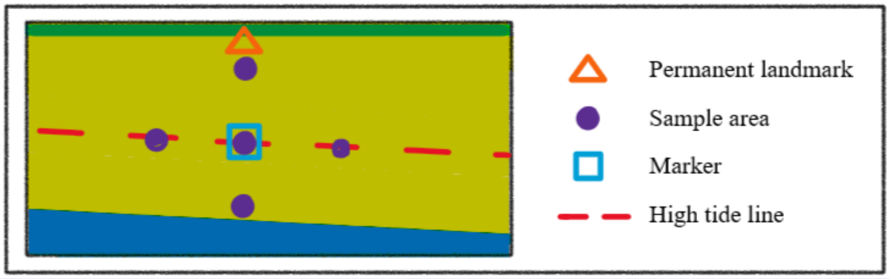

Figure C: Star Method Diagram

Key Findings

Even when using simplified versions of the Baykeeper Beach Litter Audit methodology and the procedure used in master's research at the University of Akureyri, we spent on average 45 minutes conducting these methods. The Baykeeper Beach Litter Audit methodology seemed extraneous because the quadrants were placed very close together due to the location of the high tide line (Bayas et al., 2017). The procedure following the master's thesis conducted at the University of Akureyri was also incompatible with community science because the method resulted in larger volumes of sand to sort through (Dippo, 2012). The modified procedure of the study done at Leiden University was compatible because it took no more than 10 minutes to conduct, but the required materials were not cost effective (Lots et al., 2017).

Identification of microplastics by eye proved to be difficult because they blended in with pebbles and shells. For this reason, we tested methods to separate microplastics from other materials. One method was sieving, but larger pieces of shell or rock were incapable of being sieved from the sample. Picking microplastics by hand was the least time consuming method, but we could not conclude all microplastics were gathered or that the gathered sample was composed only of microplastics. To increase accuracy from hand picking or sieving, we used density separation tests. We found that salt water and ocean water do not have densities high enough for many plastics to float. Corn syrup, however, has a density of 1.4 grams per milliliter, which is higher than most plastics, but lower than rocks (Science Buddies, 2016). Corn syrup was most effective in separating plastics from sand, rocks and shells. Additionally, corn syrup is a low cost, readily available, and feasible analysis to help count microplastics from within collected samples. For this reason, we decided corn syrup would serve as the analysis for the final method.

We conducted interviews to help us develop the Star Method. We received 14 responses from interviews and surveys. Of that number, 13 have participated in beach cleanups and had previous knowledge of microplastics. If a microplastic monitoring protocol was established, seven participants agreed they would participate and five responded unsure or maybe.

The Star Method has a sample site in between the low and high tide lines and three sample sites along the high tide line, because debris most commonly gathered there (Figure D). There is

Figure D: Performing Star Method on Beach in Akranes also an additional sample site above the high tide line. The materials needed for the Star Method were cheap and easy to find, and included an object to mark location, gloves, corn syrup, a spoon, a container to dispose of microplastics, and two glass or metal containers. The Star Method took about 20 minutes for one person to conduct.

Recommendations

After developing the Star Method for community scientists to use in Iceland, we have several recommendations for them to use in the future. Our first recommendation is that community scientists should change the frequency of monitoring beaches based on the concentration of microplastics found. Monitoring using the Star Method should be performed yearly, but if more microplastics are found on a given beach, monitoring should be done more often to better gauge how the concentration is changing in more polluted areas. We created a website that allows community scientists to record their data, access instructional videos, and view a manual. In the future, we would like community scientists to be able to view updated graphics of the data recorded. Future initiatives could improve upon our website to make this possible. These recommendations would help further develop methods of monitoring microplastics for community scientists in Iceland. Our project has potential to create baseline data that can bring awareness to the prevalence of microplastic pollution and the damage it causes not only in the marine environment, but in humans as well.

Acknowledgements

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SEEDS, for giving us valuable information about volunteer work in Iceland, and for taking the Star Method into consideration to perform in years to come.

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All images and figures are from the authors unless stated otherwise.

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Chapter 1: Introduction and Background

The World Economic Forum estimates that the total weight of oceanic plastics will outweigh the weight of fish in the ocean by the year 2050 (Kaplan, 2016). Plastics are composed of lightweight and durable fibers, which are ideal for consumers and producers, but are unable to fully decompose once in the ocean (Johnson, 2017). Instead, plastics break down and become microplastics, which are micro-sized pieces of plastic no more than five millimeters long (Herbort & Schuhen, 2017). Through ingestion, entanglement, or sorption, marine species, birds, and ecosystems are being threatened by the increase in oceanic plastic. With 663 species impacted overall, the overabundance of marine plastics must be addressed in order to keep marine ecosystems healthy (Eriksen, 2014).

As a country surrounded by ocean, Iceland is particularly susceptible to the negative impacts of oceanic plastic pollution. Iceland's economy relies heavily on both the fishing and tourism industries. Tourists are less likely to visit sites as they become visibly polluted, and fisheries will have to spend valuable time cleaning plastic from their equipment. Beach surveying in Iceland concluded that the majority of plastic found was from fisheries and aquaculture (Kienitz, 2013). As pollution increases, Iceland's fishing and tourism industries will be affected, and the extent of the impact will depend on Iceland's ability to mitigate plastic pollution. However, there is little research on methods for monitoring the state of plastic pollution and even less invested in a process for large-scale studies performed by organizations and community scientists.

In this chapter, we discuss the uses of plastic and how it ends up in the ocean. We argue that Iceland's fishing and tourism industries are affected by plastic pollution and discuss organizations that are combating plastic pollution in Iceland. We then demonstrate how plastics break down and how microplastics affect marine life. Finally, we explain the different methods currently used to gather samples on beaches, ways to analyze the samples, and how community scientists can contribute.

1.1 Consumer and Industry Dependency on Plastic Products

Society is heavily reliant on plastic products. The light, durable, and malleable properties of plastic make it a frequently used material that can be found in many aspects of people's lives. Plastics are used in supermarkets, cars, and medicine. The weight of plastics makes supermarket bags easy to carry ("Perfect Plastic", 2015), their durability makes automotive components fuel efficient (Johnson, 2017), and their low cost and disposability makes them safe and optimal for medicinal equipment ("Perfect Plastic", 2015). Figure 1 below illustrates the uses of plastics in the UK, ranging from packaging and furniture to medical uses and footwear. It was found that the majority of plastics were used in packaging, building, and construction (Bose, 2011).

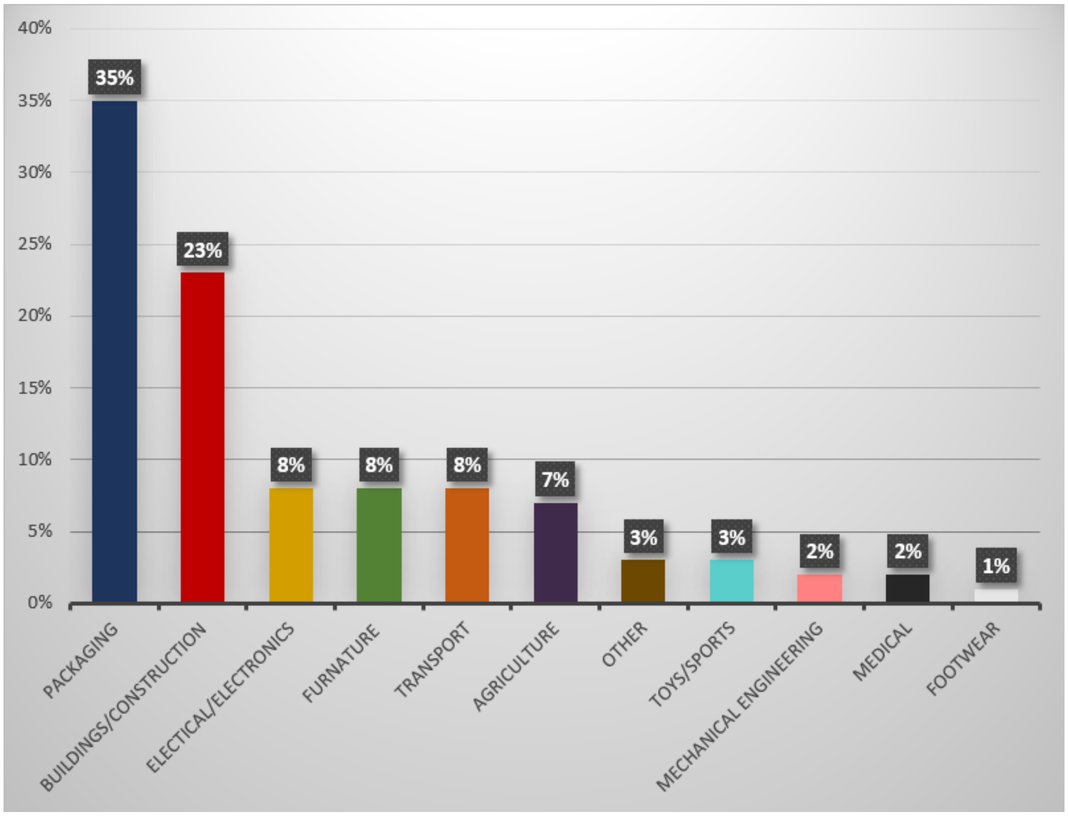

Figure 1: Uses of Plastic in the UK (Bose, 2011)

Due to its convenience, versatility, and low cost, half of the nearly 300 million tons of plastic produced every year is used once and then thrown away (Dwyer, 2017; Plastic Oceans, n.d.). In the United States alone, 500 million plastic straws are only used once and then discarded (Asti, 2016). Plastic bags make up about 90% of all grocery bags, and can be mistaken as food by marine life when found in the ocean (Conway, 2007). While disposable plastics are useful for consumers and industries, they are often not disposed of properly. As a result, the majority of oceanic debris is plastic.

1.2 Sources of Plastic Pollution

An estimated 5-13 million metric tons of plastic enter the ocean per year (Halle, Ladirat, Gendre, Goudouneche, Pusineri, Routaboul, Tenanilleau, Duployer, & Perez, 2016). Plastic can enter the ocean via boats, rivers, and landfills (National Geographic Society, 2012 a). Globally, 80% of marine plastic comes from land, while 20% comes from activities on water (Sue, 2014). The major sources of plastic pollution are land runoff and the intentional dumping or loss of gear from ships (Moret-Ferguson, Lavender Law, Proskurowski, Murphy, Peacock, & Reddy, 2010).

The ocean does not disperse trash equally; it has circular currents that keep the trash constantly flowing in “gyres” (Amaral, n.d.). Gyres are estimated to contain hundreds of thousands of tons of debris, but the majority of the debris is plastic (Clevenger, 2014). There are five major gyres: the North Atlantic, South Atlantic, North Pacific, South Pacific, and Indian Ocean gyres (US Department of Commerce, 2004). It was recently estimated that the North Atlantic gyre, roughly twice the size of Texas, contained 20,328 pieces of mostly micro-sized pieces of plastic per square kilometer (Seleky & Abbing, 2018). These plastic particles and other debris can be carried by ocean currents and distributed across beaches all over the world. Even places that do not contribute to oceanic pollution can be affected because pollution from other sources can be carried to their coastline.

A study done in Hornstrandir, a nature reserve in Iceland, collected debris and found that 95% of the debris was plastic (Kienitz, 2013). The estimated total number of debris on the shores of Hornstrandir was 32,500 items. The study found that beaches gather more debris in certain areas than others due to factors such as currents, wind patterns, or human use of the beach (Kienitz, 2013). Most of the plastic debris found on the shores of Hornstrandir were sorted and traced to fisheries and aquaculture (Figure 2). Debris on Iceland's coastline can be sourced back to many contributors, but the most prevalent source is the fishing industry.

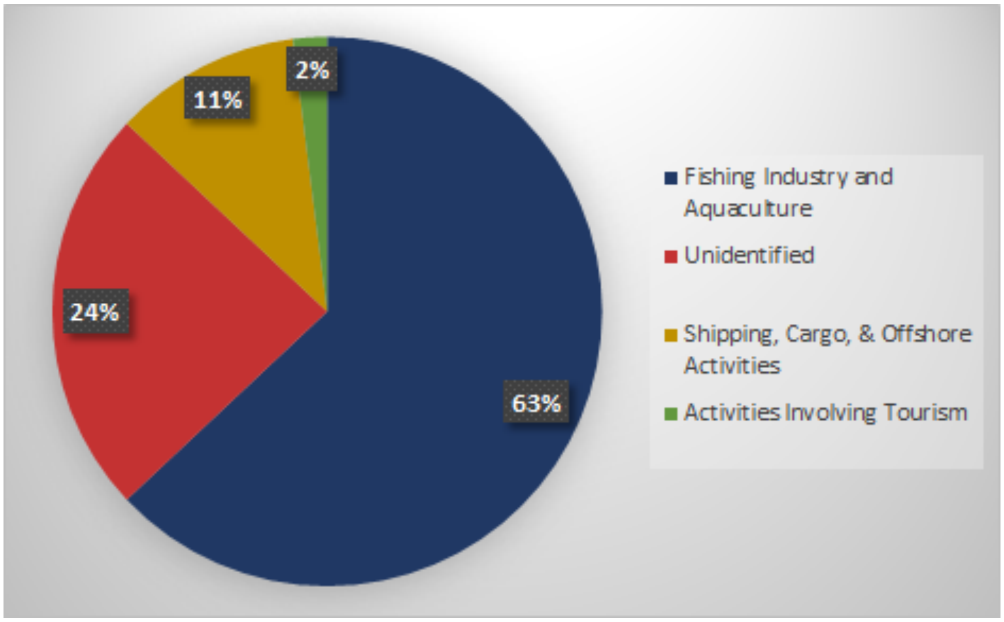

Figure 2: Types of Plastic Debris on Hornstrandir Shores (Kienitz, 2013)

1.3 The Effects of Plastic Pollution on Iceland's Economy

While plastic pollution affects countries on a global scale, Iceland is especially at risk as an island nation. Iceland has a 3,000 mile (about 5,000 kilometer) coastline, and the population relies heavily on fish for its diet (The World Factbook, 2018). The Icelandic fishing industry is responsible for 40% of merchandise export earnings and employs 5% of the total workforce (The World Factbook, 2018). Sigfusson and colleagues (2012) stated "Iceland generates approximately 2% of the global marine catch on average and operates one of the world's more efficient fishing industries," (p. 154). Looking at public data, and interviewing or surveying different industries in Iceland, Sigfusson and colleagues concluded the total contributions (direct, indirect, and induced) of the fishing sector in Iceland was 26% of the GDP in 2010 (2012). Many other sectors in Iceland's economy derived a third to a half of their revenues from the fishing industry alone (Figure 3). The fishing industry in Iceland is essential to maintain quality of life, as employment and revenue are a direct or indirect result of fisheries (Sigfusson, Arnason, & Morrissey, 2012).

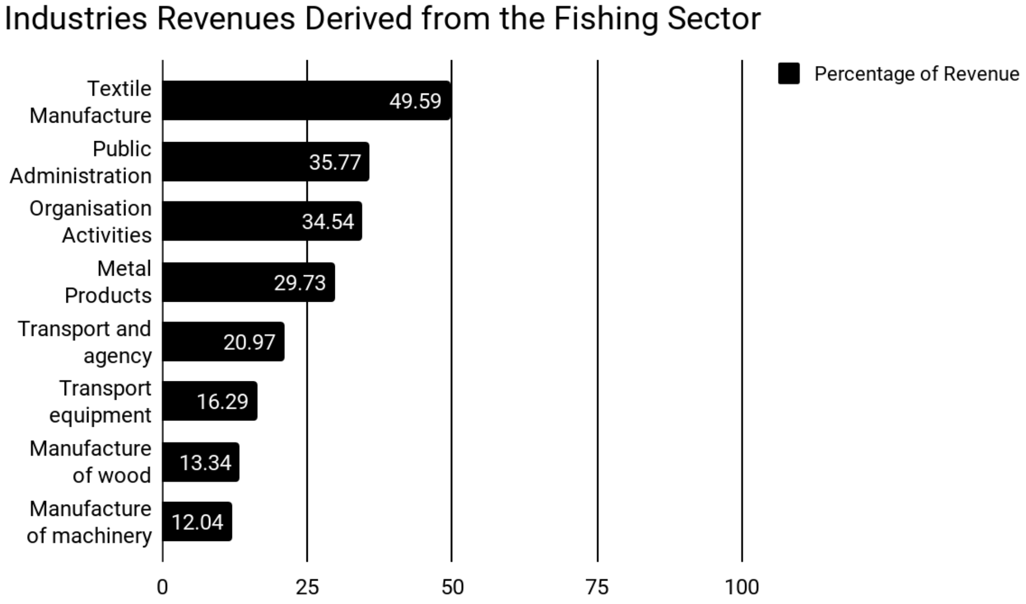

Figure 3: Icelandic Industries Percentage of Revenue Derived from the Fishing Sector in 2010 (Sigfusson et al., 2012)

It is clear that the fishing industry is an integral part of Iceland's culture, but it is also the largest source of plastic pollution on the shores of Hornstrandir, Iceland (Kienitz, 2013). Buoys, ropes, and nets are common equipment lost by fishing vessels at sea (Figure 4). On the shore of the Hornstrandir Nature Reserve, 424 buoys and buoy pieces and 136 pieces of rope and nets were found (Kienitz, 2013). Fishing nets were most commonly sourced to trawling operations. As the fishing industry continues to lose equipment, plastic pollution will continue to increase. However, fisherman will face more repercussions than losing equipment.

Figure 4: Fishing Net on Beach in Suðurnes, Iceland

Fishermen contribute to plastic pollution when they lose equipment, but they are also financially burdened when plastic pollution becomes entangled with their equipment. Propellers, anchors, rudders, or intake pipes can become entangled or blocked when encountering plastics (Newman, Watkins, Farmer, Brink, & Schweitzer, 2015). Fishermen must spend time and money to clean or repair this equipment. Scottish fisheries spent about US$20,000 per year due to marine litter, with two-thirds of this cost going towards time spent cleaning litter from nets (Newman et al., 2015). Based on the data of other countries, Icelandic fisheries are also likely spending resources to combat plastic pollution. The fishing industry will have to find ways to cope with plastic pollution, as well as prevent further pollution. As seen on the shores of Hornstrandir, plastic from the fishing industry can wash ashore, which negatively impacts tourism, the largest industry in Iceland's economy (Fontaine, 2015).

In 2015, Iceland had 1.26 million foreign visitors, and the number is estimated to be 2.5 million by 2019 ("Tourists to thank", 2016). There was a 6% economic growth rate in 2016, and 5% was credited to tourism. In 2010, over 10,000 jobs were created by the tourism sector ("1.35 million tourists", 2015). In the past several years, tourism has been a driving force in Iceland's economic growth. As a result, the amount of trash that has been found, especially around fences and open areas around the Keflavík International Airport and major tourist locations, has increased significantly over the years (Robert, 2017).

Tourism can decrease when attractions become polluted, even though tourists can often contribute to plastic pollution. When assessing economic costs of plastic pollution, some of the key considerations are expenditures to keep tourist attractions clean and the loss of revenue from fewer tourists visiting high pollution sites (Newman et. al., 2015). To keep beaches attractive and safe for tourists, cities may have to spend time and money to keep the beaches clean. The UK spends about US$8,100 per kilometer every year cleaning beaches, and the Netherlands and Belgium spend about US$40,000 per kilometer every year (Mouat, Lozano, & Bateson, 2010). Research shows that tourism numbers drop in response to increasing pollution on the beach. In South Korea, during a period of particularly high marine pollution levels, there were 500,000 fewer visitors than in years prior. An estimated US$27-34 million were lost during that time (Jang, Hong, Lee, J., Lee, M.J., & Shim, 2014). The six most popular beaches in Orange County, California had a 75% reduction in marine litter (Leggett, Scherer, Curry, & Bailey, 2014). In the following three months, the beaches generated US$46 million as a result of their cleanliness and an increased desire of tourists to visit those beaches (Leggett et al., 2014). Based on the worldwide pattern, tourism revenue will likely be reduced in Iceland if beach debris and pollution continue to increase. The magnitude to which tourism in Iceland will be affected will depend on how much debris is on Icelandic shores, as well as the efforts Iceland is willing to take to mitigate the problem.

1.4 Efforts to Mitigate Impact in Iceland

Iceland is already making several efforts to lessen the impact of plastic pollution. In September of 2014, the Environment Agency of Iceland hosted a conference on plastics in the marine environment in Reykjavík. The goals of the conference were to identify existing knowledge of plastic pollution and to determine feasible methods to reduce oceanic plastic pollution (Environment Agency of Iceland, 2014). Additionally, one supermarket chain, Iceland, has become the first major retailer to eliminate plastic packaging from all of its own brand products. A separate supermarket chain also declared that they would become plastic free within five years; the plastic packaging will be replaced with paper and pulp trays, as well as paper bags. Through efforts such as these, Iceland hopes to be plastic free by 2023 (Slawson, 2018).

One Icelandic environmental organization that is working to reduce plastic pollution is The Blue Army (Blái herinn). The Blue Army has organized over 130 beach and underwater cleanups with more than 2,000 volunteers and 54,000 hours of voluntary service over the course of 20 years (Robert, 2017). In 1995, Tómas Knútsson[1], a scuba diving instructor, went scuba diving at the harbor of Reykjanesbær and found many types of debris underwater, ranging from anchors to batteries and oil cans (Robert, 2017). It was then that Tómas established the Blue Army to help mitigate the accumulation of debris. Since then, the Blue Army has removed and recycled 1,400 tons of debris on the coast of Iceland (ESA, 2014; Robert, 2017). Today, the Blue Army continues to devote its time to cleaning up beaches and raising public awareness of beach pollution (Figure 5).

Figure 5: Debris Collected by Blue Army at Beach Cleanup

Another Icelandic environmental organization and non-governmental organization (NGO), Landvernd, was founded in 1969 and is based in Reykjavík (Landvernd, n.d. a). Their objectives include preventing the pollution of Iceland's land, air, and sea; restoring degraded ecosystems in Iceland; promoting sustainability; and promoting the collaboration of Icelanders with people of other countries on environmental issues (Landvernd, n.d. b). They facilitate several projects in Iceland, including Eco-Schools and the Blue Flag Project (Landvernd, n.d. c).

The Blue Flag Project is a voluntary eco-label for private companies that was developed by the Foundation for Environmental Education (FEE) in 1987 and was first introduced to Iceland in 2002. The goal of the project is the sustainable development of beaches, marinas, and

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[1] In Iceland, it is culturally appropriate to refer to people by their first name. We will be addressing people by their first name from this point forward.

boating tourism (Landvernd, n.d. d). Specific Blue Flag criteria can be found in Appendix A. Currently, there are 14 Blue Flag members in Iceland, including the well-known hot spring, the Blue Lagoon. Iceland relies heavily on marine resources, so environmental management through the Blue Flag Project is important for the well-being of the country (Landvernd, n.d. d).

Iceland has been working hard to stay ahead of large plastic pollution washing ashore. Reducing the amount of large plastic debris will help to prevent these pieces from breaking down into microplastics. However, there have not been any large-scale efforts to monitor or mitigate microplastics on the shores of Iceland.

1.5 Formation of Microplastics and Effects on Marine Life and Ecosystems

Because plastic is unable to fully decompose, larger pieces of plastic break down and eventually contribute to the number of oceanic microplastics. Larger pieces of plastic are able to float on the ocean's surface and can fragment from a combination of the shear and tensile stresses experienced by currents, as well as through photodegradation when exposed to sunlight (Halle et al., 2016).

Microplastics that originate from large pieces are classified as secondary microplastics (Figure 6) (NOAA, n.d. b). Plastics manufactured to be small in size are classified as primary microplastics (NOAA, n.d. b). Examples of primary microplastics include microbeads, plastic pellets, and microfibers (Figure 6). Microbeads, which have a spherical shape, are often used as a source of production for products such as skincare, face washes, toothpastes, and makeup (National Geographic Society, 2012 a). Microbeads are often washed directly down drains into the ocean. Plastic pellets are used in factories in order to manufacture large plastics and can be spilled into the ocean during transportation (Leipzig, Ruxton, and Leeson, 2016). Unlike microbeads, microfibers have a threadlike shape and are most often manufactured into clothing. It is estimated that at least 90% of microplastics are fibrous, and up to 700,000 microfibers per load are released into the water when synthetic materials are washed in washing machines (Lots, Behrens, Vijver, Horton, & Bosker, 2017). These fibers then enter the ocean through wastewater systems; they can also enter the ocean through the breakdown of fishing equipment (Lots et al., 2017). Because of their small size, primary and secondary microplastics are hard to remove from the ocean. For this reason, microplastics can remain in the ocean for centuries.

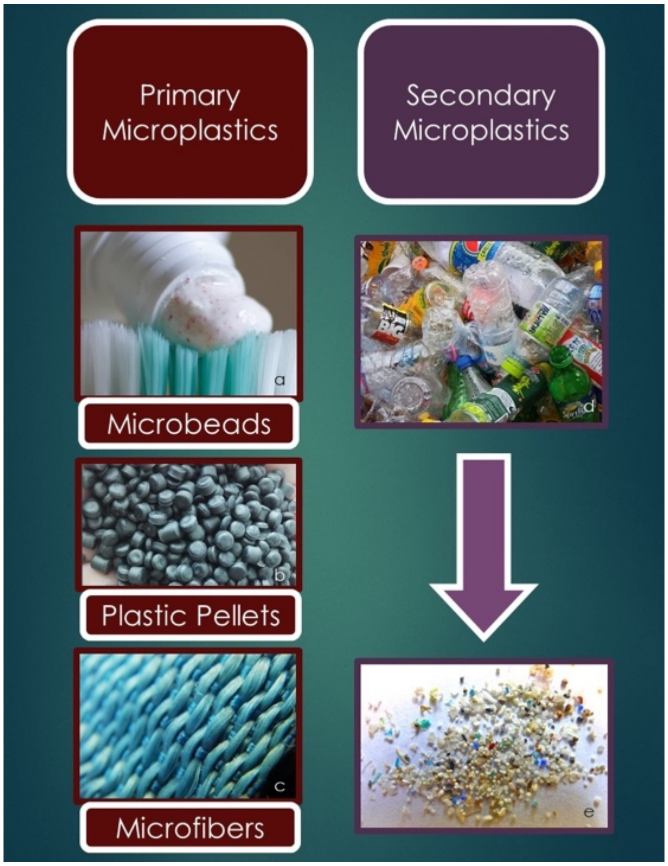

Figure 6: Primary Microplastics versus Secondary Microplastics[2]
Primary microplastics are manufactured to be small, whereas secondary microplastics result from the breakdown of larger pieces of plastic.

The consequences of microplastic pollution can be indicated by the impacts on marine life. Small organisms, such as algae, invertebrates, and fish can attach to a piece of plastic; due to the buoyancy of plastic, the organism and plastic piece can then be carried by the current. The organisms attached to the plastic can then be taken from their native habitats and introduced to non-native regions (Halle et al., 2016). Introducing invasive species can alter habitats, because native species cannot overcome the competition of the invasive species for survival.

Small plastics are also subject to photodegradation and direct leaching, which causes the plastics to release additives. Additives are used to increase desirable properties of plastics as a material, but can cause harm or death when ingested (Moret-Ferguson et. al., 2010). In one study, lugworms, large marine worms that live within the sand, were exposed to polyvinyl chloride (PVC) and common additives in proportions used by industry. These additives included a flame retardant, an antibacterial, and an antifungal (Browne, Niven, Galloway, Rowland, & Thompson, 2013). Worms exposed to the additives displayed tissues that had 950% greater concentrations and intestines with 3,500% greater concentrations of each additive (Browne et.

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[2] All images found were labeled as free to use, share, or modify. a. Microbeads in Toothpaste, Thegreenj, 2008 b. Plastic Pellets, Teemeah, 2016 c. Nylon, Admin, 2016 d. Recycled Bottles, Public Pictures Domain, n. d. e. Microplastics, Flickr, 2012

al., 2013). The results showed a disruption in feeding between 0-65%, depending on the additive. Disruption in feeding can be a result of the organism feeling full from ingesting plastic, but gaining no nutritional value. Additionally, the ability of the lugworms to eliminate harmful bacteria was shown to decrease by greater than 60% when nonylphenol, a type of plastic, was ingested (Browne et. al., 2013). The lugworms also showed a decrease in capability to deal with oxidative stress. While more research needs to be done to investigate how plastics specifically harm other species, we can conclude that the overall ecophysiological processes of organisms can potentially be disrupted when organisms come into contact with plastics and additives.

In Iceland, plastic particles were found inside the intestinal tract of fulmars. Fulmars, a type of seabird, are known to feed only at sea, making them ideal candidates for monitoring plastic ingested from the ocean. Unlike other birds, fulmars do not regurgitate solid particles. For this reason, plastic remaining in the fulmars' stomachs would have been ingested over a period of time before death (Kuhn & Franeker, 2012). A study done in 2011 on 58 fulmars showed that 79% of the Icelandic fulmars had plastic within their stomachs. Icelandic fulmars had a lower percentage of plastic in their stomachs compared to fulmars in countries farther south by 10-20%, but a 40% greater amount than Canadian Arctic fulmars (Kuhn & Franeker, 2012). With the presence of plastic found in birds, other species, including humans, are susceptible to the negative effects of ingesting plastic through the process of biomagnification.

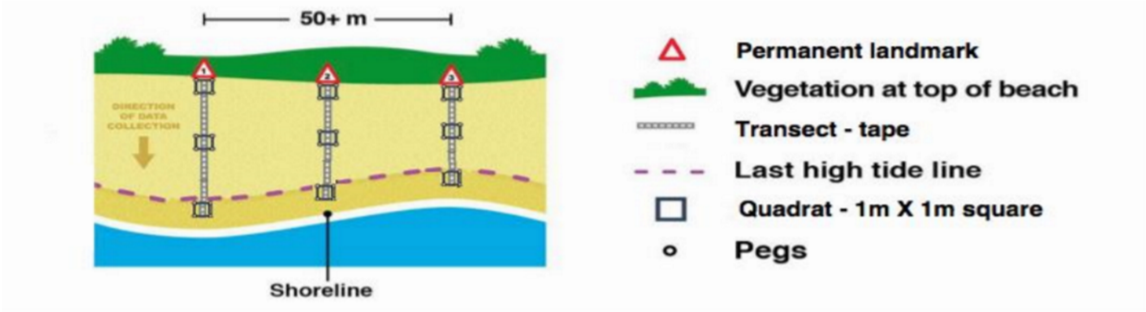
Biomagnification occurs when chemicals and toxins become more concentrated as they travel up the food chain (NOAA, n.d. a; Duis & Coors, n.d.). Plastics already contain chemicals, but as they break down into smaller pieces, they absorb more chemicals from the surrounding environment (NOAA, n.d. a; Duis & Coors, n.d.). Smaller pieces of plastic are therefore potentially more harmful to species than larger pieces. For example, bisphenol A (BPA) is commonly found in plastic and mimics the function of natural hormones in animals and humans. A study done in 2014 discovered that of 27 new mothers, 73% of their breast milk samples contained traces of BPA (Mendonca, Hauser, Calafat, Arbuckle, & Duty, 2014). The mimicking of hormones can also interfere with animals' reproductive systems, causing them to produce fewer healthy offspring (National Geographic Society, 2012 a). Algae and plants, along with fish, can absorb chemicals like BPA through the water. Predators such as sharks, dolphins, and even humans accumulate these chemicals when they eat fish or other organisms lower on the food chain (National Geographic Society, 2012 a). The chemicals from the microplastics become more concentrated because the toxins can be absorbed from the plastics and stored in the tissues and organs of species (Clevenger, 2014). In this case, top predators are the most affected by biomagnification (NOAA, n.d. a), and are thus at greatest risk of disease. With ecosystems being affected, monitoring microplastic pollution will be important in fully understanding the global effects.

1.6 Monitoring Microplastic Pollution and Community Involvement

With 5.3 billion pieces of plastic floating on the surface of the ocean today (Plastic Soup, n.d.), monitoring microplastics and estimating the increasing rate of microplastic pollution can be vital for finding removal or prevention solutions, as well as raising concern and awareness with the public. Monitoring pollution can provide concrete data on how microplastic pollution is changing while also gaining the attention of the public.

1.6.1 Field Sampling Methods

There are multiple ways to gather samples of sediment in order to monitor the accumulation of microplastics on beaches. One method was developed during the Baykeeper Beach Litter Audit in Melbourne, Australia. This method consists of quadrants that are marked in the sand at different tidal zones along the beach (Figure 7) (Bayas, Buckley, Ford, & Lawes, 2017). In a method performed for a master's thesis at the University of Akureyri, quadrants are drawn in the sand and placed at a certain distance along the high tide line (Dippo, 2012). A group of scientists from Leiden University also used a method that studied samples of sand gathered from the high tide line (Lots et al., 2017). Lastly, a group of scientists associated with Clemson University studied samples gathered between the low and high tide lines (Whitmire, Van Bloem, & Toline, 2018). More information on these methods can be found in Appendix B. These several methods could be useful for different landscapes, but the differences between them could cause issue for the comparison of results. To quantify the number of microplastics within each sample, further analysis of the sediment is necessary.



Shoreline graphic and legend by Michael Beasley

Figure 7: Baykeeper Beach Litter Audit Diagram (Bayas et al., 2017)

1.6.2 Collection and Analysis of Microplastic Pollution on Shores

There are multiple methods of distinguishing microplastics from sediment on beaches. One apparatus made in the UK, the Sediment-Microplastic Isolation (SMI) unit, uses density floatation to separate microplastics from marine sediment (Coppock, Cole, Lindeque, Quierós, & Galloway, 2017). Coppock and colleagues tested three different salt solutions (NaCl, NaI, and $ZnCl_2$) to decide which solution effectively separates different types of microplastics based on the density of the plastic (2017). In addition, one organization named Sea Turtles Forever developed a simple and low cost filtration system to sift microplastics from the sand. The product is a mesh screen made from a polymer material that emits an electrostatic charge to catch microplastics as small as 50 micrometers in size (North Shore Productions, 2016). Another study monitoring microplastics on US beaches dried and sieved samples of sediment, which were then observed under a microscope for further analysis (Whitmire et al., 2018). Distinguishing microplastics from the sediment on beaches can be difficult or inaccurate to do by eye. For this reason, having other methods to separate the microplastics from the sediment is important (Ryan, Moore, van Franeker, & Moloney, 2009).

1.6.2 Participation of Community Scientists

Collaborations between the public and scientists "expand opportunities for scientific data collection and provide access to scientific information for community members" (Cornell University, 2018). Community science, also known as citizen science, allows the public to engage in the process of solving problems. Tasks that community scientists can participate in include asking questions, collecting data, and analyzing data (Environmental Protection Agency, 2016). Community scientists also provide the scientific community with necessary hours of labor and data collection that scientists often cannot perform by themselves (Lots et al., 2017).

The public can propose their own ideas to professional scientists, who can then help them with developing their desired program. Professional scientists can develop community science programs in order to collect more data without additional cost, since most community scientists are unpaid. Scientists can also work with groups that are already inadvertently collecting data, such as bird watchers (National Geographic Society, 2012 b). Recently, the number of community science groups has risen due to the availability of the internet and accessibility of smartphones. The GPS capability of smartphones, as well as developing capabilities, makes community science even more accessible to the public (National Geographic Society, 2012 b). Because microplastic pollution is noticeable worldwide, data collection performed by community scientists will be valuable for scientists globally if they are unable to collect all necessary data on their own.

In our project we tested previous monitoring methods and developed a beach monitoring method that can be conducted by community scientists in Iceland. By doing so, we hope to raise awareness and encourage public involvement in monitoring microplastics.

Chapter 2: Methodology

The goal of this project was to produce a beach monitoring method that can help community groups in Iceland track increases in microplastic pollution. To accomplish this we laid out four objectives.

Objective 1: Determine which methods of gathering samples are applicable to Iceland's beaches.
Objective 2: Determine which methods to pilot test for separating and analyzing microplastics from samples.
Objective 3: Determine the willingness of volunteers and organizations to use a monitoring method.
Objective 4: Identify and communicate the most appropriate method to monitor microplastics for community scientists on Icelandic shores.

In this chapter we state each of our objectives and the methods we used to accomplish them. We describe different methods we tested to gather sand samples and to separate microplastics from the sand. We also discuss the interviews we conducted to help determine a protocol appropriate for community scientists to perform. Finally, we identify a monitoring method for recommended use in Iceland.

2.1 Objective 1: Determine which methods of gathering samples are applicable to Iceland's beaches

For this objective, we specifically tested the methods for collecting sand samples. We did not separate the microplastics from the sand. We modified several methods used by other studies to produce fewer sample sites and sizes because we attempted to evaluate the procedures, rather than the distribution of microplastics on the beaches. We evaluated all of the methods to gather sediment on three different beaches located in Akranes, Iceland over a two week period (Appendix C). The first method was that of the Baykeeper Beach Litter Audit methodology (Bayas et al., 2017). We placed a quadrant one square meter in size at the vegetation at the top of the beach, at the high tide line, and at the midpoint between these two quadrants (Figure 8). We only used one transect located on one section of the beach to save time because we were only evaluating the method's ease of use and relevance for Icelandic beaches. To collect sand, we gathered the top centimeter of sand with our hands for analysis.

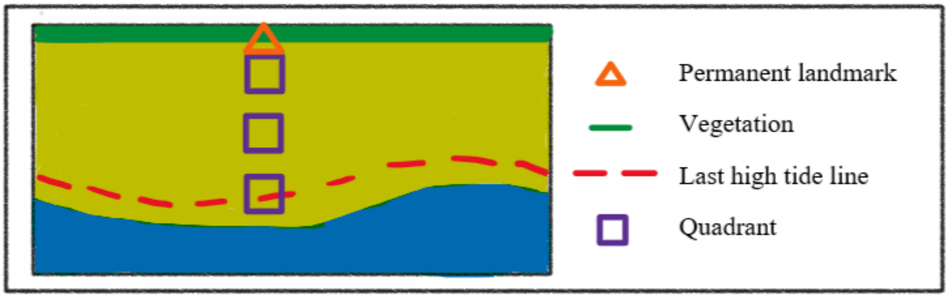


Figure 8: Modified Baykeeper Beach Litter Audit Gathering Method

The second method we tested was based on the procedure used by a study done for the University of Akureyri (Dippo, 2012). We placed a quadrant one square meter in size at the high tide line and then gathered the top two centimeters of sand in the quadrant (Figure 9). We only used one quadrant instead of multiple, and we did not collect the sample size of seven and a half liters as the study suggested. We limited the sample size so as to be time efficient in testing this method multiple times on three beaches (Dippo, 2012).

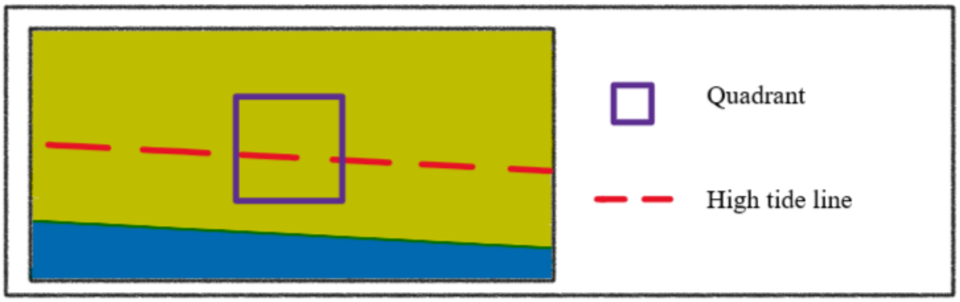


Figure 9: Modified University of Akureyri Gathering Method

Another method we tested was based on the procedure used by a study done through Leiden University (Lots et al., 2017). We placed three stakes 10 meters apart at the high tide line and gathered the top centimeter of sand with our hands (Figure 10). We gathered one handful of sand at each sample site, rather than the 100 gram sample the study recommended (Lots et al., 2017), since we did not have the means to measure out the 100 gram samples.

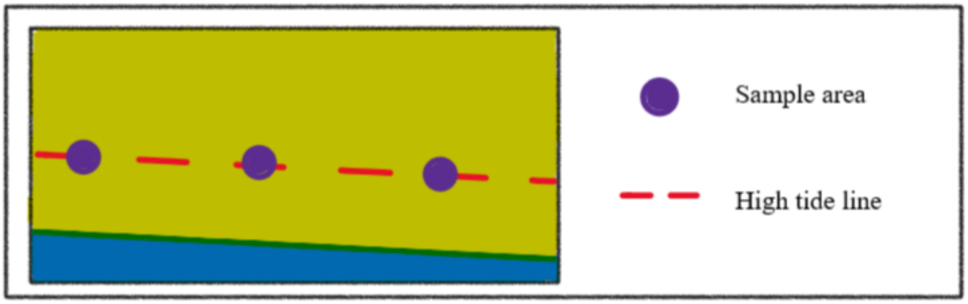


Figure 10: Modified Leiden University Gathering Method

2.2 Objective 2: Determine which methods to pilot test for separating and analyzing microplastics from samples

For our second objective, we separated and analyzed the samples we gathered from our first objective. The separation methods we used included sieving the sand, hand picking microplastics from the sand, and three types of density separation. We tested these separating methods to examine if any small particles collected were microplastics, rather than rocks, sand, shells, or organic matter, and then counted the number of microplastics collected from a specific sample site.

In order to sieve, sand was taken and placed in a kitchen sieve. We then took a bucket of ocean water and poured it slowly and carefully into the sieve until all of the sand passed through (Figure 11). The excess material left on the sieve was placed in a bag for further analysis. This process was continued until either all of the quadrants had been sifted through or the sample bag was filled.

Figure 11: Sieving for Microplastics on Beach in Akranes

We also separated microplastics from the sand using our hands. Each sample site was specifically examined and anything that was not sand, rocks, shells, or organic matter was placed into a plastic bag (Appendix D). Any particles that were difficult to identify or looked unusual were also placed in the plastic bag for further analysis (Figure 12).

Figure 12: Separating Microplastics by Hand

For further analysis, density separation was used to more accurately identify and separate microplastics from the sand. We filled a bucket with ocean water and placed sand inside following the protocol performed for the University of Akureyri (Dippo, 2012). After the contents settled, any microplastics floating on the top of the bucket were scooped out and counted. We also filled a pot with approximately one liter of water and placed it on a stove. We then heated up the water and dissolved salt until we created a saturated solution. Finally, we placed several sand samples we had collected from the beaches in the salt solution. We found that none of the particles in our sand samples floated, as they were all denser than the salt solution we created. As a result, we used corn syrup to test our samples because this liquid is denser than most plastics (Figure 13).

Figure 13: Corn Syrup Density Separation Test

2.3 Objective 3: Determine the willingness of volunteers and organizations to use the method

In order to determine which microplastic monitoring method was the most appropriate for use by community scientists on Icelandic shores, we interviewed Icelandic environmental organizations concerned with plastic pollution. We spoke to the director of the Blue Army, Tómas (Appendix E), as well as eight volunteers at World Cleanup Day to learn what motivates them to clean the beaches and determine if they would incorporate microplastic monitoring into their beach cleanup projects. We asked questions related to how much time they would be willing to put in, as well as what resources they would be willing to supply to monitor microplastics. Full interview questions can be found in Appendix F. We also sent out the same questions in an electronic survey by email to the volunteers and staff of other environmental organizations, such as SEEDS, the Environment Agency of Iceland, the Environment and Natural Resources program at University of Iceland, Landvernd, and Go Green Tours to obtain a larger quantity of answers. We asked these groups to answer the survey themselves and post it on their Facebook pages.

During our time with Tómas, we contacted the CEO of Landvernd, Rannveig Magnúsdóttir. Rannveig gave us the contact information of the Eco-Schools project manager, Katrín Magnúsdóttir. We interviewed Katrín about the possibility of the Eco-Schools participating in microplastic monitoring and she told us there is interest in beach cleanups and activities amongst Eco-School students (Appendix G). For example, there were Eco-School students present at World Cleanup Day. Katrín was willing to ask teachers if there was any interest in microplastic monitoring projects for their classes, and took a copy of our Star Method manual and videos to give to interested teachers.

2.4 Objective 4: Identify and communicate the most appropriate method to monitor microplastics for Iceland's shores and volunteers

For the final step in our project, we tested a method of our own design using aspects of previously evaluated methods. We named this method the Star Method, due to the shape the sample areas make (Figure 14). To design the procedure, we placed three sample sites along the high tide line, following the studies done for Leiden University and the University of Akureyri (Lots et al., 2017; Dippo, 2012). We also placed one sample site above the high tide line because the Baykeeper Beach Litter Audit methodology also had sample sites above the high tide line (Bayas et al., 2017). Finally, following the study performed with Clemson University and the US National Park Service, our last sample site was between the high and low tide lines (2018). We chose sample sites at these locations relative to the high tide line to allow for variety in mapping distribution. We also used the method of hand picking from the surface of the quadrant, because the Baykeeper Beach Litter Audit methodology followed this same method, and it was the simplest to use (Bayas et al., 2017).

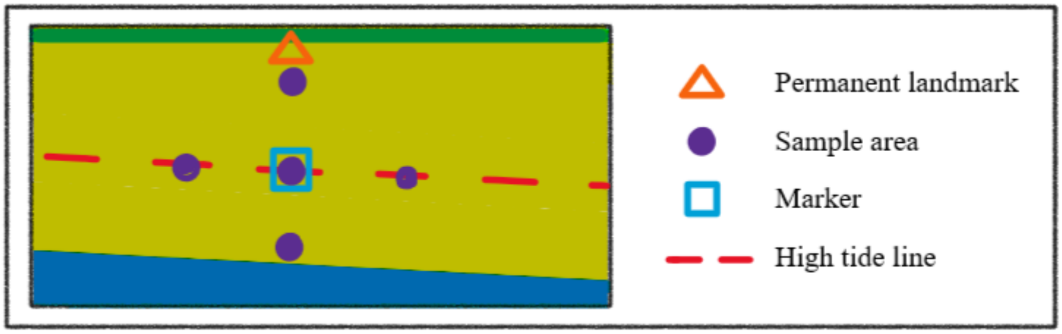


Figure 14: Star Method Diagram

To begin the Star Method, we found a landmark at the top of the beach which, in our case, was a lamppost on the street. We then placed a stake at the high tide line and drew a circle around the stake with a radius of 1.5 feet (0.5 meters). Within the circle, we used our hands to pick out microplastics or unidentifiable particles that resembled microplastics from the top first centimeter of sand (Figure 15). We placed these particles and microplastics in a glass jar (Figure 15). We then walked ten paces from the marker towards the vegetation or rocks at the top of the beach and repeated the same process. We repeated this process ten paces left of the marker, ten paces right of the marker, and ten paces from the marker towards the water. We decided that ten paces would be the standard distance from the central marker because paces do not require a tape measure and this distance seemed appropriate based on previous microplastic monitoring methods (Dippo, 2012; Lots et al., 2017). To analyze the collected samples, we filled a cup half way with corn syrup and poured the contents of the sample collected on the beach into the cup. After waiting for the sand and rocks to sink to the bottom of the glass, we removed the floating pieces from the corn syrup and counted them.

Figure 15: Performing the Star Method on Beach in Akranes

In order for community scientists and Eco-School volunteers to fully understand the procedure, we recorded videos of the Star Method and corn syrup procedure. We went through the procedure step by step to ensure consistency amongst the different groups using the method and ensure that users had a thorough understanding of the method. We also created a brief video on microplastics' harmful effects to help inform the general public on why their work is important. These materials can be found on the website we developed, which will be discussed in Chapter 4.

Chapter 3: Results and Discussion

This chapter discusses the results from sampling and analyzing methods to monitor microplastics. We argue that different gathering and separating methods each have their own advantages and disadvantages. We then analyze interviews done with volunteers of environmental organizations. We use these results to provide insight into what microplastic monitoring system would be most suitable for community scientists, accounting for ease of use and accuracy.

3.1 Gathering Sediment Samples

Despite using a simplified version of the Baykeeper Beach Litter Audit methodology (Bayas et al., 2017), we still found it to be long and tedious. While we became more efficient at following the protocol after each use, the method still typically took about 45 minutes to conduct (Figure 16). Additionally, of the three beaches on which we conducted our research, two of them did not have vegetation at the top of the beach, but rocks instead (Appendix C). It was important to conduct this method at low tide, so the water did not interfere with our sample sites. We also noticed that after a few weeks of surveying beaches, the high tide levels increased, so the beaches were mostly covered in water. This meant that we had to place our quadrants very close to one another. Using this method, we found few microplastics on the three beaches. For this reason, this method seemed extraneous because it seemed implausible for finding a pattern of distribution.

Figure 16: Performing the Modified Baykeeper Beach Litter Audit

The second method, based on the study done for the University of Akureyri (Dippo, 2012), was also not suitable on its own for community scientists. The two centimeter depth created a larger volume of sand to sort through, which caused this procedure to take the longest amount of time (Dippo, 2012). On beaches with more debris to sort through, the procedure would take up to an hour. On beaches with less debris, it still took approximately 45 minutes to complete the method.

Our abridged version of the procedure conducted through Leiden University (Lots et al., 2017) was the quickest, taking no more than 10 minutes to conduct. Measuring the 10 meter increments and placing the stakes occupied the majority of the 10 minutes, while looking through a handful of sand at each stake proved to be easy. Despite this smaller sample size, we were still able to find what we believed to be microplastics.

Gathering Methods	**Time under 30 minutes**	**Easy to Use**	**Priced below 1500 ISK**	**Effective**
Modified Baykeeper Beach Litter Audit				
Modified University of Akureyri Method		✓		✓
Modified Leiden University Method	✓	✓		✓
Analyzing Methods	**Time under 30 minutes**	**Easy to Use**	**Price below 1500 ISK**	**Effective**
Sieving			✓	
Hands	✓	✓	✓	✓
Salt Water	✓	✓	✓	
Ocean Water	✓	✓	✓	
Star Method and Corn Syrup	✓	✓	✓	✓

Figure 17: Comparison of Piloted Methods

As shown in Figure 17 above and expanded upon in Appendix H, we used four different criteria to conclude which gathering method was the most appropriate for community scientists to use on Iceland's beaches. The four criteria used were the time it took to complete the method, how easy the method was to use, if the materials needed for the method cost less than approximately US$13.00 (1,500 ISK), and how effective the method was in monitoring microplastics. The modified method of the Baykeeper Beach Litter Audit did not meet any of the criteria because it was long and extraneous, the materials cost more than US$13.00 (1,500 ISK), and the method was not effective in gathering samples. The modified version of the method done for the University of Akureyri was easy to use because there was only one quadrant to sift through and it was effective in gathering samples for analysis. However, it took longer than 30 minutes and the materials that were needed cost more than US$13.00 (1,500 ISK). Finally, the modified method done through Leiden University did not take long to complete, was easy to use, and was also effective in gathering samples, but did not cost less than US$13.00 (1,500 ISK).

3.2 Separating Microplastics from Sediment

While some microplastics could be identified by eye, it was difficult to conclude that the particles we found in the sand were not small pebbles or pieces of shells. Therefore, we used several separating and analysis methods to quantify microplastics from sand samples. Of the five separating methods that we tested to separate microplastics from the sand, sieving took the longest. The sieve we used was relatively small, so we could only test small volumes of sand at a time. This meant that gathering sand using quadrants took about 45 minutes to complete. On all three beaches on which we conducted the methods, the sand was very wet and did not dry throughout the day (Appendix C). For this reason, we gathered ocean water using a bucket and poured it over the sieve until all of the sand was filtered into a second bucket. Depending on the beach, the effectiveness of the sieve changed. On beaches primarily made up of rocks and shells, the sieve was difficult to use because the larger pebbles and shells would not filter through the sieve and our sample bag would be filled primarily with larger objects. On beaches with fine sand, the sieve was easier to use because the sand passed through and we were left with a more concentrated sample size (Figure 18).

Figure 18: Sieving on Shelly, Pebbly, and Sandy Beaches

Using our hands to collect microplastics from the quadrants on the beaches was the least time consuming, but was not the most accurate method by itself. One reason hand picking was not accurate was because we could not ensure that we collected all the microplastics in a given area or that the pieces we picked up were microplastics. Distinguishing microplastics from rocks and shells proved to be difficult. On pebbly beaches, using our hands was the best way to collect only the pieces that we believed to be microplastics (Figure 19). On shelly beaches, it was more difficult to distinguish microplastics, as the shells were multicolored and any pieces of plastic tended to blend in with the sand. On beaches with fine sand, it was more difficult to hand pick microplastics because the sand would stick to our gloves and to small particles we found. We used a microplastic identification chart to help us pick microplastics out of the shells, sand, or rocks (Appendix D). However, while we had an idea of what microplastics should look like, it was difficult to be sure that what we found was plastic, rather than rocks or shells. To check our accuracy, we used various density tests on the samples collected by hand.

Figure 19: Hand Picking Microplastics on Pebbly Beaches

When performing the salt water density separation test for microplastics, we found that this method did not produce the intended results. We found a particle we thought was plastic on the beach that sank slower than rocks in pure water. However, when we added salt to the water, the piece still did not float. Additionally, when placing sand into the salt water, none of the sediment floated besides organic matter and some particles that were too small to identify. Placing sand in ocean water produced the same results. Upon further research, we found that many common plastics have a density greater than fully saturated salt water or ocean water and, for this reason, would not float in salt or ocean water. For comparison, pure water has a density of about 1.00 gram per milliliter, ocean water has a density of about 1.03 grams per milliliter, and saturated salt water has a density of about 1.22 grams per milliliter, while PVC plastic has a density of about 1.37 grams per milliliter (Figure 20) (Lenntech, 2018). Our conclusion was to try corn syrup as a potential medium for separating rocks from plastic because it has a density of about 1.4 grams per milliliter (Science Buddies, 2016). When testing previously gathered samples in pure and salt water, the collected pieces sank. In corn syrup, however, the pieces floated while the rocks and shells still sank. A full comparison of these separation methods is detailed in Figure 17 and Appendix H. We evaluated the analyzing methods using the same four criteria that we used with the gathering methods. We found that all of the analyzing methods except sieving took less than 30 minutes to perform and were easy to use. The only method that was effective in separating microplastics from the sand was hand picking. Additionally, corn syrup was the only method that was effective in determining if small particles were microplastics.

Figure 20: Comparison of Plastic Density to Corn Syrup and Water
In various water and salt solutions, some plastics, such as PVC, sink whereas others, such as PET, float. In corn syrup, plastics that sink in various water and salt solutions float. Rocks sink in all liquids shown above.

3.3 Determining Appropriateness for Community Scientist Use

To determine what factors were necessary to motivate volunteers to perform the monitoring method we devised, we attended World Cleanup Day in Iceland on September 15, 2018, and shared a Google Survey with environmental organizations. We received 14 responses in total. Of that number, only one person had never participated in a beach cleanup. Also, 13 of the people who took the survey said they know what microplastics are and would be willing to participate in monitoring after beach cleanups. Of the people surveyed, 11 people were willing to spend about US$13.00 (1,500 ISK) on materials and one person was unsure if they would (Figure 21).

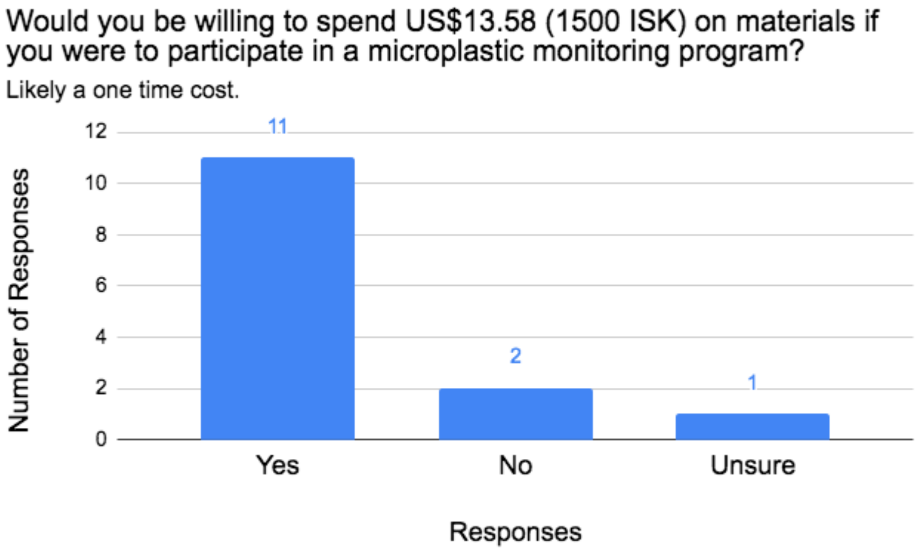


Figure 21: Willingness to Spend US$13.58 on Materials

When asked if they would be willing to monitor microplastics on their own, given an organization had a set protocol to follow, seven responded yes while five responded maybe or unsure (Figure 22). During our in-person interviews, most people were hesitant in agreeing to go out on their own and perform an established monitoring system because they did not seem to know exactly what this would entail. When asked how organizations could motivate people to participate in monitoring microplastics, answers varied from "being a role model in addressing the project" to advertising and giving out free food and spreading awareness about microplastic pollution.

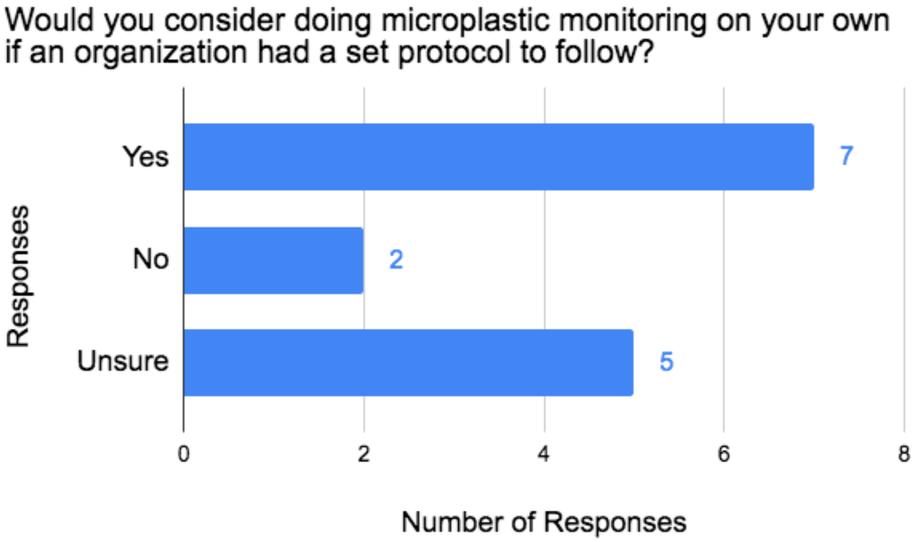


Figure 22: Interest in Individually Conducting Microplastic Monitoring Method

These responses were important in establishing what criteria were necessary in developing an easy-to-use but effective monitoring method for people in Iceland. For example, knowing that people would be willing to go out on their own and also spend about US$13.00 (1,500 ISK) on materials for the monitoring system allowed us to determine what protocol and materials to use when developing our own monitoring method. A full summary of the interview questions and responses can be found in Appendix F.

3.4 Implementing a Monitoring Method for Icelandic Community Scientists

The main criteria we took into consideration when developing a microplastic monitoring method that community scientists would be able to conduct were the ease of use, the time commitment, and the cost and availability of necessary materials. We compared the different methods in full detail in Figure 17 and Appendix H. Based on these findings, we contended that the Star Method would be the best method for volunteers and school children to use in Iceland. The beach areas concentrated with pebbles or shells, usually below the high tide line, were the most promising areas to find microplastics because microplastics and other small debris would easily become stuck when washing ashore. Of the few microplastics we found during our time in Iceland, most of them were located in the pebble or shell filled areas. For this reason, we used a combination of all the methods discussed in section 2.1. By evaluating three sample locations along the high tide line and a sample location below the high tide line, community scientists would be putting effort into searching for microplastics in the most promising locations. Searching in promising locations increased simplicity and time efficiency. Sampling above the high tide line was less promising for finding microplastics, but will prove useful in the future because microplastics might gather there if pollution were to increase. For this reason, we included one sample location above the high tide line.

The Star Method also needs to be consistent and repeatable for community scientists to use on a yearly basis. Community scientists need to locate a permanent land marker on each beach and use that marker in following years to ensure the same sample sites are examined each year. Using sample sites that have a radius of 1.5 feet (0.5 meters) and a set distance between quadrants will allow community scientists to be consistent while using this monitoring method. As long as school programs consistently use a child's pace, and other organizations consistently use adult paces, the beach monitoring should be comparable year to year. Community scientists should also conduct monitoring during low tide, so they can work with the largest area of beach possible. These specifications will allow for community scientists to observe and track changes of microplastic pollution in each observed sample site, as well as any changes in the distribution of microplastics.

Community scientists should find the procedure easy to use, since we found ways to remove materials such as tape measures, GPS, and string by using a permanent land marker, using paces, and approximating the radius of sample sites. The only materials necessary to carry out the Star Method procedure were an object to mark location, gloves, corn syrup, a spoon, a container to dispose of microplastics, and two glass or metal containers. Glass or metal containers were needed to avoid contaminating the sample. The total cost of these materials was less than approximately US$13.00 (1,500 ISK) and would therefore be a reasonable amount to spend according to our surveys and interviews. The Star Method was also time efficient, only taking 20 minutes to complete, and would be faster to conduct when more people are involved. For this reason, organizations, including Eco-Schools, the Blue Army, and SEEDS, would find the Star Method quick and easy to follow because they have many members. Organizations that already participate in beach cleanups could also conduct the Star Method before or after beach cleanup events. Compared to the other gathering and analyzing methods, the Star Method was the best option for community scientists (Figure 17 and Appendix H).

The Star Method included a corn syrup analysis method that allowed for a low cost and feasible procedure that community scientists could use to separate and count microplastics from collected samples. Corn syrup is readily available and can be found in most grocery stores. Corn syrup's availability, cost, and density make it ideal for community scientists to use to separate plastics from sand or rocks (Figure 23). Community scientists will be able to easily and reliably use our procedure. The method may seem tedious on beaches where microplastics are not currently present, but with microplastic pollution increasing, having reliable data could help Iceland get ahead of the problem.

Figure 23: Plastics on Surface and Rocks at Bottom of Corn Syrup

Chapter 4: Recommendations and Conclusion

From our project we have created one instructional video to aid community scientists in using the Star Method. We developed a website[3] for community scientists to record the data found from monitoring, as well as access the instructional video and a written Star Method procedure. A printable template for recording data during beach monitoring is also available (Appendix I). Additionally, we produced an educational video on what microplastics are, how they end up in the ocean, and the negative effects they have on organisms, ecosystems, and food chains. The educational video can be found on the website.

Based on our results from developing a system for community scientists to monitor microplastics on the shores of Iceland, we developed nine recommendations that could be implemented by community scientists or future initiatives.

1. **We recommend that the frequency of monitoring beaches is determined by the concentration of microplastics found.** To start, beaches should be monitored once a year. Beaches with higher numbers of microplastics should be monitored more frequently to create a larger database on how the concentration is changing in more polluted areas. However, we do not have the data to conclude when monitoring frequency should increase or how much it should increase.
2. **We recommend future initiatives further develop our website to record data on microplastic pollution.** While our website provides a public database on microplastic pollution, it only provides community scientists with access to raw data. It would be ideal for future initiatives to create visuals of the data that is collected, such as a map of beaches currently being monitored. In addition, updated graphs and charts on the concentrations and distributions of microplastic pollution based on this data would help community scientists visualize how microplastic pollution is potentially affecting their communities.
3. **We recommend testing liquids other than corn syrup because other liquids have more ideal densities.** We did not have the time or resources to try other liquids, such as zinc chloride, a solution in which most plastics would float (Coppock et al., 2017). Performing density tests with denser liquids would allow for a wider range of microplastics to be collected. However, liquids with densities higher than rocks or shells would be an inaccurate way to separate microplastics because the entire sample would float.
4. **We recommend that other microplastic monitoring methods be tested.** We did not have the time or the resources to test other methods we found, such as the Plastic Eating Device for Rocky Ocean Coasts (P.E.D. R.O.C.), BabyLegs, and Microplastic Filtration System developed by the Sea Turtles Forever Foundation. The P.E.D. R.O.C. was created to catch microplastics on rocky beaches, and is constructed of a mesh that allows plastics and water to flow in and a sieve that filters the water out of the bottom (Liboiron, 2017 a). BabyLegs is a trawl made of children's tights and plastic bottles, and can be dragged through the water in order to filter and collect microplastics (Liboiron, 2017 b). The Microplastic Filtration System, an electrostatically charged screen, was discussed in section 1.6.2 and can be purchased on the Sea Turtles Forever website (North Shore Productions, 2016). These methods have their own advantages and disadvantages; P.E.D. R.O.C. is made specifically

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[3] https://sites.google.com/view/iqpmicroplasticmonitoring/home

for rocky beaches, BabyLegs is more economical, and the Microplastic Filtration System has a high level of accuracy.

5. **We recommend testing easy mechanical alternatives to corn syrup, such as scratch tests.** Since not all community scientists will want to purchase corn syrup, it would be more feasible for them to conduct tests using materials that they most likely already own such as pieces of glass, pins, and tweezers. Community scientists could try to scratch the samples they find with a piece of glass. If it results in a mark on the sample, they can confirm it to be a rock because glass would not leave a mark on a piece of plastic. Likewise, community scientists can also poke the microplastics with a pin or needle. If it does not leave an indent, they can confirm it to be a rock; if it does, it is likely plastic (Dippo, 2012). Also, smaller microplastics are attracted to metal when placed in water. Therefore, tweezers or a piece of metal can be used by community scientists to collect and count smaller microplastics (Calcutt, Nussbaumer, & Sluka, 2018).
6. **We recommend that, based on the desired accuracy of the data, more precise gathering methods be used.** Our project developed a simple and easy-to-use method. For this reason, our method may not be entirely accurate, but will provide preliminary data on microplastics instead. For a higher level of accuracy, the procedure used by the study conducted for the University of Akureyri (Appendix B), for example, can be used instead of the Star Method (Dippo, 2012).
7. **We recommend that community scientists use microscopes to identify any materials that cannot immediately be verified as microplastics.** When we were performing our gathering methods, we had difficulty distinguishing materials that might have been microplastics from sand, shells, or rocks. Using a microscope would allow for a more accurate count of how many microplastics are present in a specific sample site. Community scientists could use microscopes they own or use ones from schools or universities.
8. **We recommend that community scientists monitor the sources of macroplastic pollution in order to understand where oceanic plastics originate.** After participating in a beach cleanup with the Blue Army, we collected 1.6 tons of debris on one Icelandic beach. The Blue Army sorts and sources the debris collected. Because plastic can break down into microplastics in the ocean, understanding where macroplastic pollution originates could help to stop microplastic pollution from growing.
9. **We recommend that community scientists also examine areas bordered by bodies of water other than the ocean, such as riverbanks, for plastic pollution.** By doing this, community scientists can work on tracking the sources of plastic pollution before it reaches the ocean.

Conclusion

While plastics are useful products, we need to respect them (T. Knútsson, personal communication, September 4, 2018). It is a common perception that Iceland is extremely clean, but plastics in the ocean wash onto Icelandic shores even if Iceland is not the source of oceanic plastic pollution. Every day, millions of people around the world throw away their disposable plastic products, and these products often end up in the ocean. While people think that plastic products are left to float in the ocean, they fail to realize that large plastics eventually break down into microplastics and cause damage to organisms, ecosystems, and food chains. Studies have shown that chemicals from microplastics can end up in human breast milk and urine when humans consume products from the ocean, such as fish or sea salt (Mendonca et al., 2014).

Monitoring microplastic pollution provides important data on the concentrations and distributions of microplastics found on shores. Our project provides a method for community scientists to analyze beaches in Iceland and monitor the amount of microplastics, if any, that can be found within a given study site. We researched and tested previously used monitoring methods and tracked the ease of use, the time commitment, and the cost and availability of necessary materials. We were then able to take what we learned from each of these researched methods and develop our own method. The method is easy to use and does not require a laboratory or expensive equipment. Consequently, the method results in a system of data collection that can be performed by anyone. We were able to reach out to SEEDS and the Blue Army; these organizations were valuable resources in developing and distributing the method. The Star Method will go on to benefit residents of Iceland who are in close proximity to beaches, as well as scientists studying microplastics in Iceland. The method will create preliminary data and a better understanding of where and how much of a concern microplastics are in Iceland. In addition to scientists, future Interactive Qualifying Projects (IQPs) and Eco-Schools will be able to develop our methodology over time for distinct beaches. We hope that scientists, Eco-Schools, and future IQP teams will be able to further develop the online database on which community scientists will be able to record their results, so that a public record can be created.

People need to respect plastics. To do so, society needs a closed circulatory process where all plastics are reused or recycled, ensuring no plastics are disposed into the ocean (T. Knútsson, personal communication, September 4, 2018). Plastic pollution entering the ocean started with us, and now needs to end with us.

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Appendix A: Blue Flag Criteria

The Blue Flag Project criteria for beaches includes:

1. Beaches must be free of litter
2. Seaweed and other natural debris cannot be removed from the beach
3. Trash cans must be maintained on each beach
4. Recycling bins must also be available if the community has a recycling facility
5. Sensitive habitats must be monitored
6. Water quality must be sampled (Blue Flag, 2018 a)

The Blue Flag Project criteria for marinas includes:

1. Marinas must offer the Blue Flag to boat owners
2. Sensitive areas must be monitored
3. Hazardous waste containers must be provided
4. Trash cans and recycling bins must be provided
5. Pollution from repair and washing areas must not enter the water
6. Only products with an eco-label may be used for cleaning marina facilities (Blue Flag, 2018 b)

The Blue Flag Project criteria for boating tourism includes:

1. Hazardous waste containers must be provided
2. Trash cans and recycling bins must be provided
3. Use of recyclable and biodegradable materials should be prioritized, with single-use products having lower priority
4. Environmentally friendly paints, paint remover, and detergents should be prioritized
5. Pollutants from repairing and painting boats must not enter the water
6. Environmentally friendly toiletries should be provided (Blue Flag, 2014 c)

Appendix B: Case Studies

Monitoring Microplastics in Port Phillip Bay

A group of WPI students traveled to Australia in 2017 to monitor microplastic pollution on beaches in the Port Phillip Bay area. They used the Baykeeper Beach Litter Audit, which is a technique used to sample and collect microplastics on the beach (Bayas et al., 2017). The first step in this technique is to define the study area. Beaches were analyzed for locations of waterway entries from rivers and creeks into the bay, the pattern of the tidal currents, and the direction of the winds (Bayas et al., 2017).

The second step in the Baykeeper Beach Litter Audit was to set up reference points. Once the beach was classified as an ideal candidate for monitoring plastics, the dimensions of the beach were then analyzed. Transect lines were placed at the widest and narrowest sections of the beach in order to cover different terrains on the beach and areas most exposed to water action. Landmarks were taken as permanent structures at the top of the beach to be used as a reference point for future audits and data comparison (Bayas et al., 2017).

Once the transect lines were established, quadrants were placed at the high tide line, top of the beach, and midpoints of each transect, each one square meter in size. The quadrants were hand picked for inorganic material, which was collected and recorded on a data sheet. In areas where there was not any sand (such as in between rocks and areas of dirt and grass), quadrants were analyzed and observation was used to count microplastics (Bayas et al., 2017).

Microplastics in the Coastal Environment of West Iceland

In a university project taking place in the coastal areas of Iceland, including Reykjavík, researcher Benjamin Dippo wanted to determine whether there was a detectable gradient of decreasing plastic concentrations with increasing distance of urban centers around Reykjavík. The study region included sample sites within urban, semi-rural, and rural coastal settings (Dippo, 2012). There were four sites at each of these locations in which plastic was monitored, and the data collection included both qualitative and quantitative measures. The beach was sectioned off into quadrates and observations for qualitative measurements took into account landscape, wildlife, human activities, and settlement patterns (Dippo, 2012).

According to the sampling design, the beaches needed to be composed of sand. Dippo was able to use an interactive aerial view satellite map to identify the most likely locations of sandy beaches. He then used this map to randomly choose sampling quadrates to create a gradient from urban to rural sites. In the end, there were 24 sampling sites that were visited over a ten day period (Dippo, 2012). Upon viewing these sites on arrival to Iceland, it became apparent that not all of these sites were feasible for testing. Twelve of the twenty-four sampling sites were used, providing a mix of urban and rural areas of study.

Once the sites were established, Dippo used three quadrates, each one square meter in size, to divide up each site. The quadrates were located on the high strandline, also called the wrack line, a line of debris left by high tide that usually contains eel grass, seaweed, kelp, crustacean shells, feathers, plastic, and other sources of litter (Minustide, 2011). Once a quadrate was established, the second quadrate was established by walking 15 paces (about 20 meters) to the right of the first quadrant when facing the ocean along the wrack line, and the third quadrate to the left of the first (Dippo, 2012). A nylon cord was used to isolate the square meter plot and photos were taken of each. Beach sediment was also collected from the quadrates and sieved into size classes. If there were any large natural pieces of debris in the quadrates, such as rocks or sticks, they were brushed clean of sediment and then labeled with site and quadrate number and saved for further classification in a lab. The volume reduced method was used to collect sediment in each quadrate (Dippo, 2012).

As a result of the monitoring and experimentation, Dippo was able to identify and classify the microplastics he found, as well as the amount of other plastic debris. He found that a detectable gradient of decreasing plastic concentrations with increasing distance of urban centers around Reykjavík was not the case. While the closest site to Reykjavik was found to have the highest concentration of plastics, as the sites moved farther away, no detectable decreasing concentration pattern of microplastics was recorded. About 50 kilometers away from the city of Reykjavík, the amount of plastic pollution found on the shores was most affected by ocean currents and immediate offshore activities.

The Analysis of Microplastic Contamination on European Beach Sediment

One study performed through Leiden University examined the sand of 23 beaches in thirteen different countries throughout Europe (Lots et al., 2017). Volunteers collected five samples from each beach. They filled six zip top bags with 100 grams of sand from the high tide line. The samples were taken every 10 meters and used only the top five centimeters of sand. Community scientists also collected samples with a metal spoon. They were also asked to take a picture of the beach and note the GPS location, if possible. The samples were then sent to Leiden University for analysis by scientists.

Once the samples reached the lab, they were dried, sieved, and filtered through a vacuum pump covered with filter paper. These filter papers collected microplastics, which were then analyzed using spectroscopy and stereo-microscopes. They were categorized based on location, abundance, color, material, composition, and length. The study found that the village of Vik in Iceland had surprisingly high concentrations of microplastics, possibly due to plastics being carried to Iceland by the North Atlantic Current (Lots et al., 2017).

Quantification of Microplastics on National Park Beaches

Principal investigators Stefanie Whitmire and Skip Van Bloem and National Park Service technical coordinator Catherine Anna Toline wanted to monitor microplastic pollution in US National Parks for the Marine Debris Program in the National Oceanic and Atmospheric Administration. Thirty-seven coastal sites from 35 National Parks Service units were selected. The sites include the Northeast Region, Great Lakes, West Coast and Pacific Islands, and the Alaska Region (Whitmire et al., 2018). Sediment samples were collected from June to December 2015, but due to weather and remote access in the Alaska region, three locations there were sampled from June to August 2016 (Whitmire et al., 2018). The monitoring was broken down into two methods. The first was the method for gathering sediment samples, and the second method was for analyzing the samples and isolating and quantifying the microplastics.

The method for gathering sediment was done by National Park Service staff or volunteers. Sampling kits were provided for the staff and volunteers included a written procedure with a visual illustration, a metal sampling ring, a metal spoon, premade aluminum foil bags, a beach evaluation, and a box with return postage. The beach evaluation covered several important qualities of the beach such as the location of any large debris, how often cleanups were performed, locations of creeks and rivers (if any), locations of pipes (if any), and sand descriptions. The beach evaluation also covered important weather characteristics at the time of sediment collection, such as the current weather and if there was a storm in the past two weeks (Whitmire et al., 2018). Sampling locations within each site were based on where large marine debris was consistently observed. Samples were collected at low tide along a 50 meter transect parallel with the shore between the high and low tide lines. To keep sample sizes consistent, the metal ring with a 25 centimeter diameter and 1.5 centimeter height (equivalent volume = 736 cm^3) was pressed into the top sand layer until the upper rim of the ring was flush with the sand. Material within the ring was carefully collected to the bottom of the rim using the metal spoon and subsequently transferred into an aluminum foil bag. A total of 10 samples along the 50 meter transect were collected from each site, with at least one meter between each sampling point. The bags were shipped back to the laboratory at the Baruch Institute of Coastal Ecology and Forest Sciences in Georgetown, South Carolina for processing (Whitmire et al., 2018).

In the laboratory, the method for analyzing, isolating and quantifying the microplastics took place. Sediment was dried at 70°C for 48 hours. The sediment was then sifted through a 4.75 millimeter brass mesh sieve and then a 2 millimeter brass mesh sieve to remove larger pieces of debris and organic matter. The amount of microplastics from 2 – 4.75 millimeters were visually counted and recorded in the lab. Since the amount of microplastics seen in the 2 - 4.75 millimeter size range were minimal (less than one piece per sample on average), these items were not considered in the analysis. The sieved samples were stored in glass jars with metal lids until further analysis (Whitmire et al., 2018). Four dried, sieved sand samples from each site were randomly selected for microplastic isolation by density separation. Dried sand (200 grams) was mixed with 250 milliliters of a filtered concentrated saline solution (NaCl 1.27 grams per milliliter) in 500 milliliter glass canning jars. Filtration of the saline solution was necessary to remove microplastic contaminants from the salt. The glass jars were sealed with metal lids and shaken for three minutes. After at least two hours of settling, the supernatant was removed with a metal baster and filtered through a glass filtration system and a sterile gridded 0.45 micrometer nitrocellulose filter. Extreme care was taken to not contaminate the samples by keeping the filtration system covered and washing the transfer apparatus with deionized water multiple times. All washing solutions were filtered through the same glass-fiber filter to minimize any sample loss due to adhesion of microplastics on the wall of any part of the filter apparatus. The microplastic isolation was repeated three times for each sample to ensure recovery. Since organic material was not a problem in the sand samples, no further processing was necessary to remove it during the density separation. A blank consisting of the salt saline solution but with no sand was run concurrently with the four samples to assess potential background contamination from the method or from the lab itself. The microplastic particles were then counted according to color and relative shape (Whitmire et al., 2018). To count and identify the shape of the microplastics, the filters were examined using an EMZ-5 Meiji Binocular Stereoscope. Large pieces of vegetative debris such as seaweed and dry leaves were picked out with tweezers. The abundance of microplastics in a sand sample was expressed as the number of pieces per kilogram of dry sand (Whitmire et al., 2018).

Appendix C: Beaches Used for Method Evaluations

Table 1: Observation Sheet for Beach Analysis

Location, Date, Time	
Surveyed by	
Width (low tide to where vegetation starts) [m]	
Length (estimate~ 100m, 200m, 300m)	
Soil Type	
City Population	
Wildlife	
Uses: Recreation, Sporting, Industry	
Relevant notes	

Langisandur, Akranes:

Table 2: Langisandur Observation Chart

Location, Date, Time	Langisandur Beach Near Krónan, Akranes 64° 19’ 0” N 22° 4’ 8” W 8/28/18 11:15 AM
Surveyed by	All
Width (low tide to where vegetation starts) [m]	35 meters
Length (estimate~ 100m, 200m, 300m)	1,000 meters
Soil Type	Fine, tan sand, shells concentrated in areas, rocks at top of beach
City Population	~5,000, located near residential living and hotels
Wildlife	Crabs, birds, seaweed
Uses: Recreation, Sporting, Industry	Recreation
Relevant notes	Trash in rocks is noticeable Rubber, net, cans, styrofoam, seaglass, caps Majority of debris is fishing supplies Trash getting stuck in rocks (where high tide line is for west side of the beach) East side of beach has lower tide line, and more sand

Langisandur Beach

The methods stated in section 2.1 for evaluation were conducted on Langisandur on September 5, 2018, September 10, 2018, and September 12, 2018. On September 5, sieving was performed with all the methods detailed in section 2.1. On September 10, hand picking was used for all the methods detailed in section 2.1. On September 12, ocean water was tested on the adapted Baykeep Beach Litter Audit methodology detailed in section 2.1.

Vesturgata, Akranes:

Table 3: Black Sand Beach Observation Chart

Location, Date, Time	Black sand beach 9/3/18 2:35 pm 64° 19’ 10” N 22° 5’ 9” W
Surveyed by	All
Width (low tide to where vegetation starts) [m]	19.2 meters
Length (estimate~ 100m, 200m, 300m)	600 meters
Soil Type	Darker, black sand, pebbles, lots of seaweed
City Population	~5,000
Wildlife	Seaweed, birds
Uses: Recreation, Sporting, Industry	Recreation
Relevant notes	Lots of debris- a lot organic or biological Easy for microplastics to be disguised Skaginn 3X is an industrial equipment supplier next to the beach


Black Sand Beach

The methods stated in section 2.1 for evaluation were conducted on the Black Sand Beach on September 6, 2018, and September 10, 2018. On September 6, sieving was performed with all the methods detailed in section 2.1. On September 10, hand picking was performed with all the methods detailed in section 2.1.

Old Akranes Lighthouse, Akranes:

Table 4: Old Akranes Lighthouse Beach Observation Chart

Location, Date, Time	64° 18’ 36” N 22° 5’ 32” W Akranes 8/27/18 10:10 AM
Surveyed by	All
Width (low tide to where vegetation starts) [m]	22 meters
Length (estimate~ 100m, 200m, 300m)	34 meters
Soil Type	Shells, tan sand, fine sand, crushed shells
City Population	~5,000
Wildlife	Jellyfish, seaweed, crabs, birds
Uses: Recreation, Sporting, Industry	Sightseeing (near lighthouse)
Relevant notes	Debris at high tide line Found: plastic, fishing line, net, rubber, wood Would be hard to distinguish microplastic from crushed shells


Old Akranes Lighthouse Beach

The methods stated in section 2.1 for evaluation were conducted on the Old Akranes Lighthouse Beach on September 6, 2018 and September 11, 2018. On September 6, sieving was performed with all the methods detailed in section 2.1. On September 11, hand picking was performed with all the methods detailed in section 2.1.

Appendix D: Identifying Microplastics on Beaches

Common Items Found on Icelandic Beaches

Various Items

Volcanic Rocks

Sea Glass

Microplastics

Nurdles

Small, round, and smooth beads of plastic (Fidra, n.d.)

Secondary Microplastics

Small pieces of plastic that are not smooth or rounded in shape (Fidra, n.d.)

Appendix E: Interview with Tómas Knútsson, the Director of the Blue Army

Our meeting with Tómas was informal. We spent the day visiting a recycling plant in Iceland, participating in a beach cleanup, and having dinner. Throughout the day Tómas told us stories about how he founded the Blue Army and about the issue of plastic pollution within Iceland. Tómas told us about how he did a cleanup on the black sand beach we used for our research. According to him, after the cleanup, he advised Akranes to clean the beach regularly. The town decided to cover any remaining pollution with rocks rather than spend the time and money cleaning up the debris.

The Blue Army does monitor the plastics they find. By weighing the debris collected from cleanups, as well as sorting it to be sourced, Tómas was aware of when a beach had more or less debris on it from year to year.

Tómas also gave us valuable information regarding our own project. After our meeting, we became in contact with Landvernd and signed up to participate in World Cleanup Day. Tómas has not done work with microplastics, but he does occasionally send in sand samples to a lab to be analyzed after beach cleanups. After describing our project, Tómas felt our project has potential to be of value, but he also stated that it is uncertain what people will be interested in doing until you give them a chance to try it out.

Appendix F: Interviews with Volunteers at World Cleanup Day

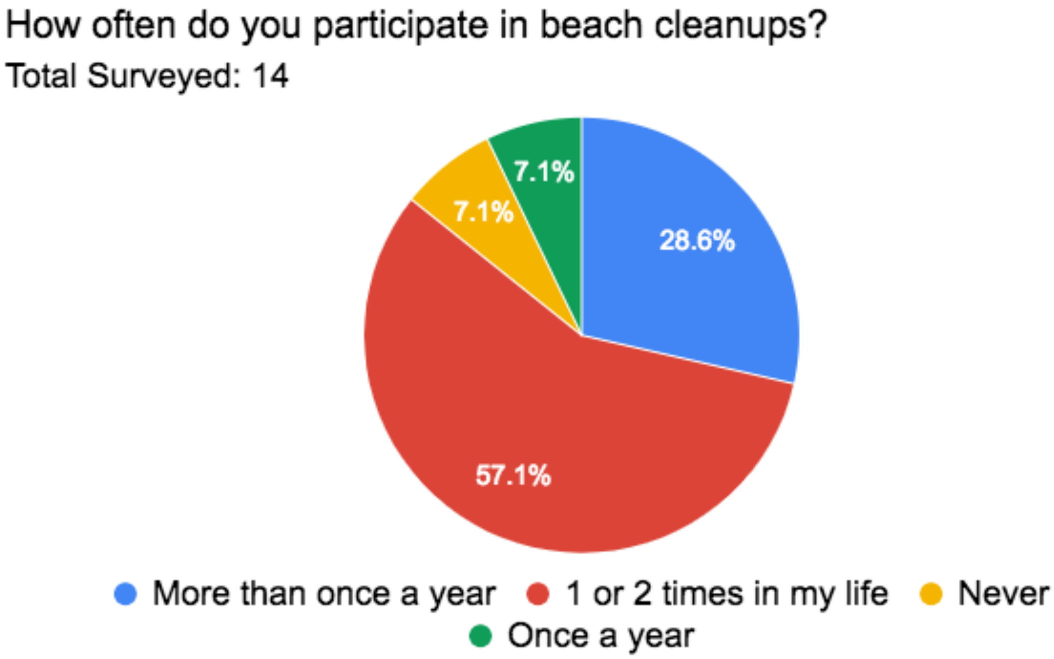
To gauge volunteers interest in microplastic monitoring within Iceland, we attended World Cleanup Day with the Blue Army to interview volunteers. World Cleanup Day was on September 15th, 2018 across 158 countries, with 15 million people participating (World Cleanup Day, n.d.). World Cleanup Day was "the biggest ever civic action against waste" (World Cleanup Day, n.d.). We used the following interview structure when talking to the volunteers:

Hello, my name is ____, I'm one of the WPI (Worcester Polytechnic Institute) students working on a microplastic monitoring system for Iceland to study if there is an increase in plastic particles in the sand. Would you be comfortable answering some questions? It should take about five minutes. Is it okay if we take notes? You will remain anonymous.

1. How often do you participate in beach cleanups?
2. Have you ever heard of microplastics or know what they are?
3. Monitoring microplastics includes counting plastics in a bucket of sand, for example, to see if it changes over the years. To help us gauge interest (or hypothetically if that can be understood) would you be interested in spending an extra hour after beach cleanups to follow a monitoring method for microplastics?
    a. If no: what is your concern?
    b. If yes: continue with these questions
4. Would you consider doing this on your own if an organization had a community science plastics monitoring program?
5. Would you be willing to spend 1,500 ISK on materials if you were to participate in a program to monitor beach plastics?
6. How do you think an organization could get people interested in participating in monitoring microplastics?

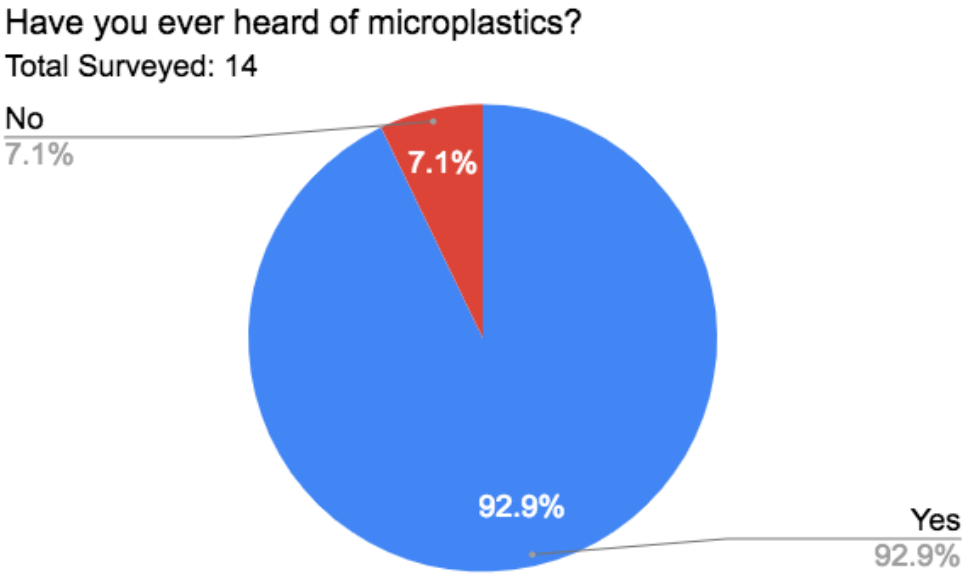
That is all the questions I have. Thank you for your time and hard work.

During one of our interviews, we met a volunteer from SEEDS who gave us Lara Roje's contact information, a SEEDS employee. After calling both Lara and Tómas, we created a Google Survey to share the same questions on the Facebook pages of the Blue Army and SEEDS. The results from both the in person interviews and Google Survey are as follows:



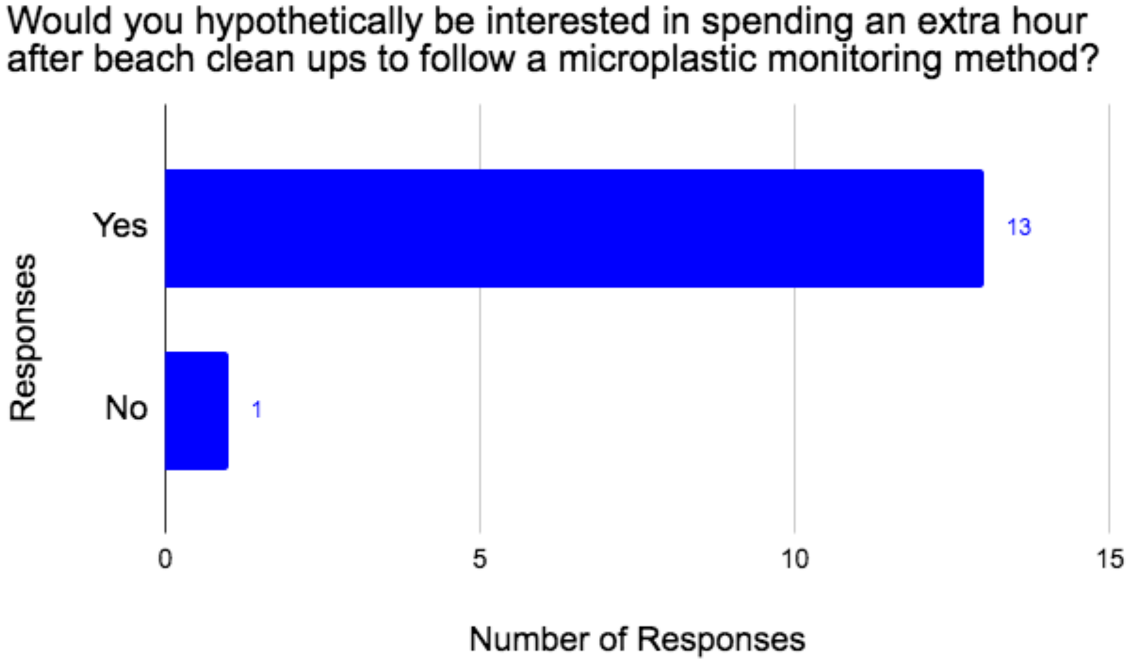
How often do you participate in beach cleanups?

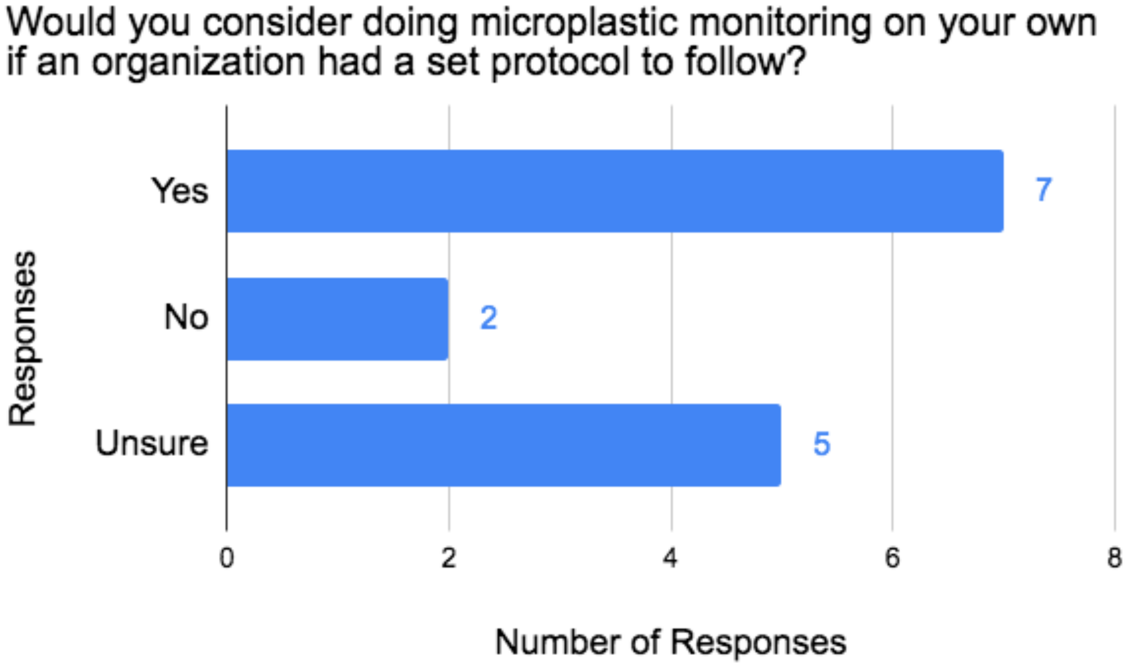
Total Surveyed: 14

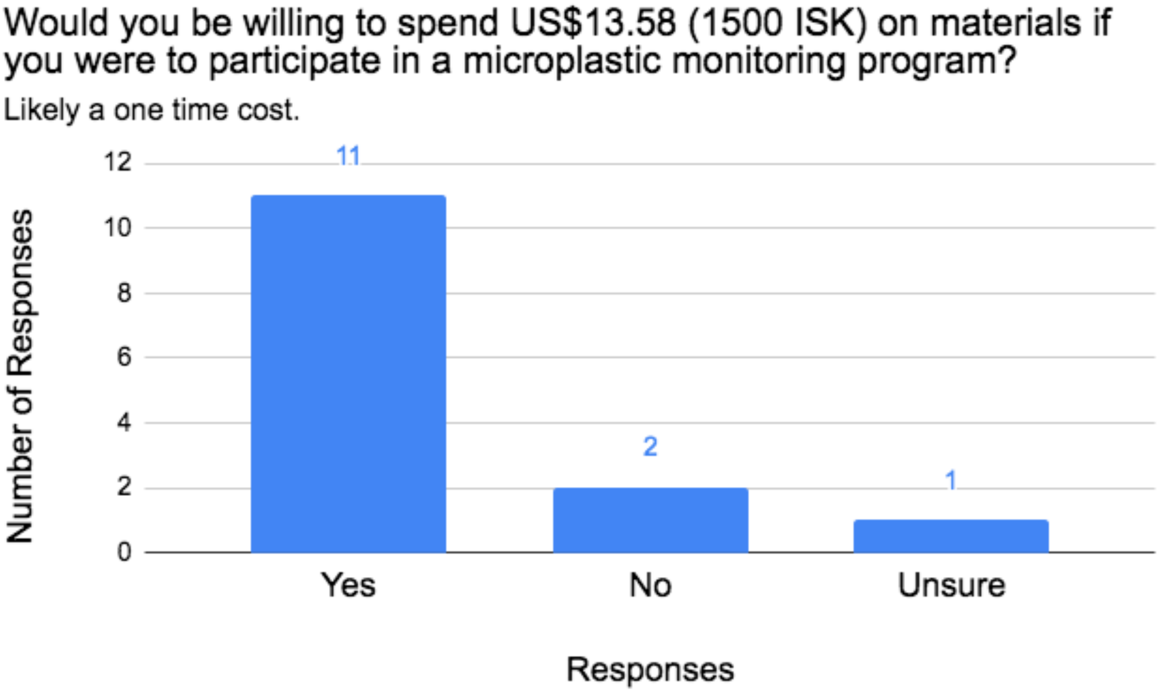


Have you ever heard of microplastics?

Total Surveyed: 14


Would you hypothetically be interested in spending an extra hour after beach clean ups to follow a microplastic monitoring method?
Responses
Yes
13
No
1
0
5
10
15
Number of Responses


Would you consider doing microplastic monitoring on your own if an organization had a set protocol to follow?
Responses
Yes
7
No
2
Unsure
5
0
2
4
6
8
Number of Responses



Would you be willing to spend US$13.58 (1500 ISK) on materials if you were to participate in a microplastic monitoring program?

Likely a one time cost.

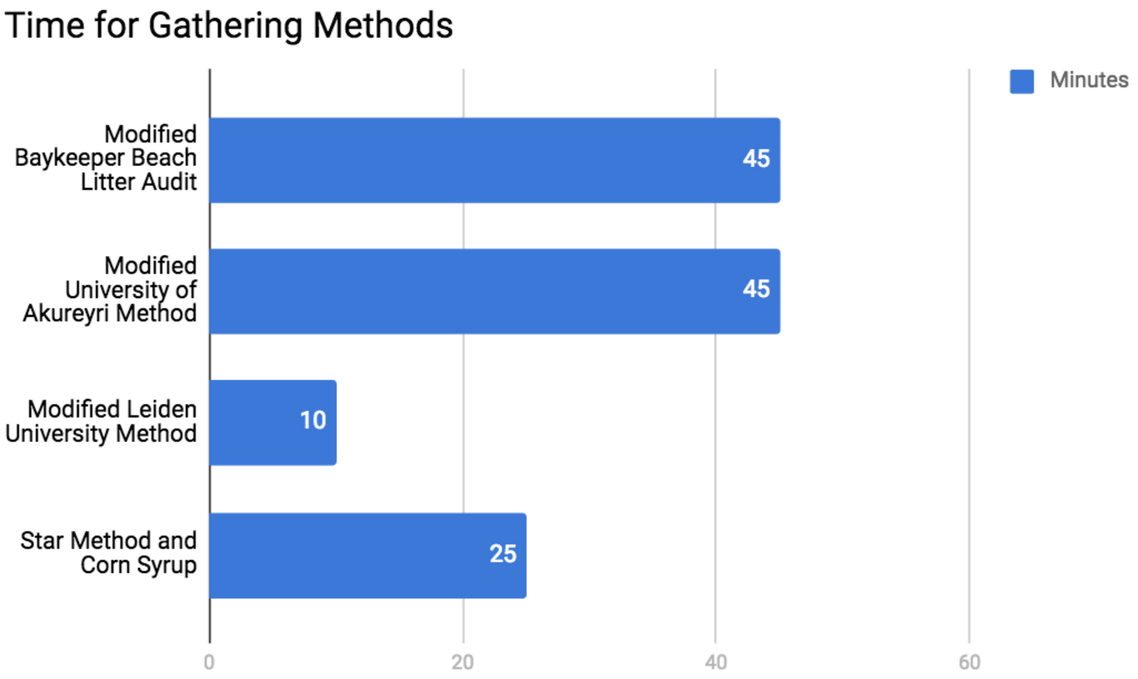
Appendix G: Interview with Eco-School Project Manager, Katrín Magnúsdóttir

After receiving Katrín's email from Rannveig, we exchanged a few emails with Katrín and asked her five questions regarding Eco-Schools and their interest in microplastic monitoring. Our questions are as follows:

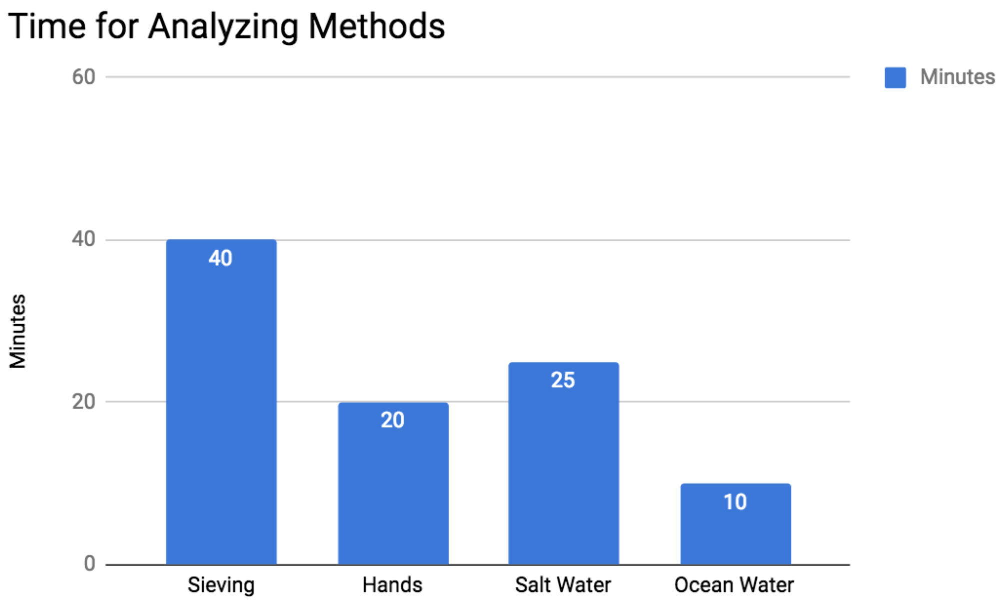
1. Can you tell us about how the Eco-Schools work – or what is the model of the Eco-Schools?
2. Do the students learn about ocean ecosystems or beach pollution?
3. Do the Eco-Schools already take part in or do any cleanup days (beaches, parks or otherwise)?
4. Would teachers have interest in bringing their students to a beach to do microplastic monitoring?
5. Could you get us in contact with any teachers interested? We'd be happy to give them a copy of our final product for their and their students use.

Appendix H: Time and Cost Comparison of Gathering and Analyzing Methods

We used four criteria to compare the different gathering and analyzing methods to conclude which method would be the best for community scientists to use. Two of these criteria were time and cost of materials.



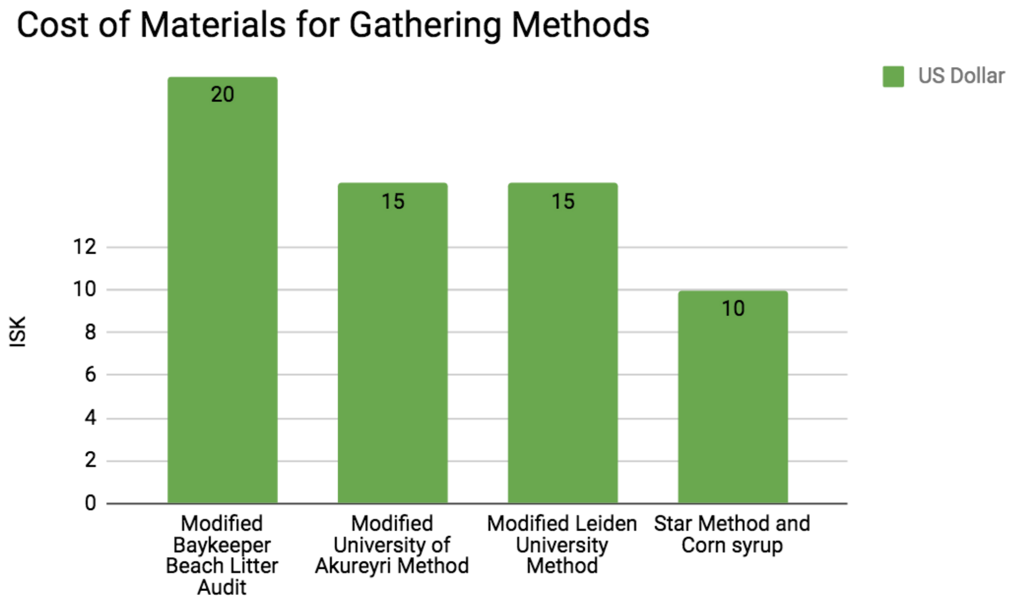
The modified Baykeeper Beach Litter Audit and the procedure done for a master's thesis at the University of Akureyri both took the longest amount of time, about 45 minutes. Even though the Star Method with corn syrup took longer than the modified method performed by Leiden University, it was still significantly shorter than the other two gathering methods.



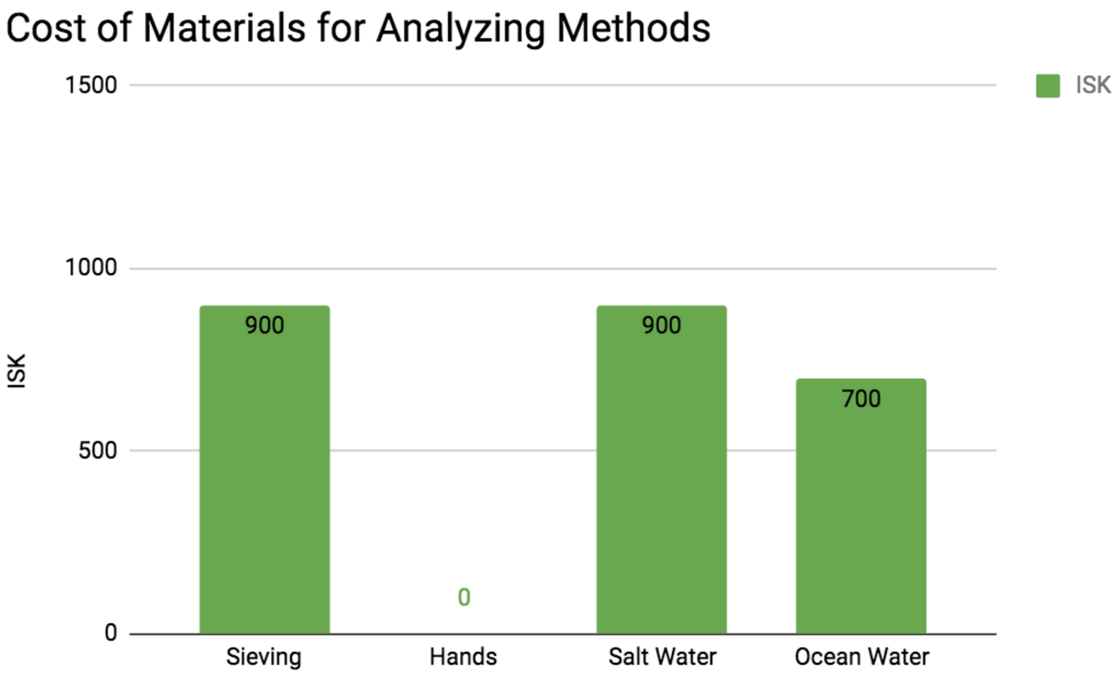
The graph above represents the time it took to complete each analyzing method for three square meter quadrants using the modified version of the Baykeeper Beach Litter Audit.

Of all the analyzing methods, sieving took the longest to complete. Using salt water and our hands took about the same amount of time, and ocean water took the least amount of time. However, using our hands was the most effective way to separate small particles from the sand.

When assessing the most appropriate monitoring method for community scientists to use in Iceland, cost was an important factor because community scientists need to purchase materials to perform the method themselves.



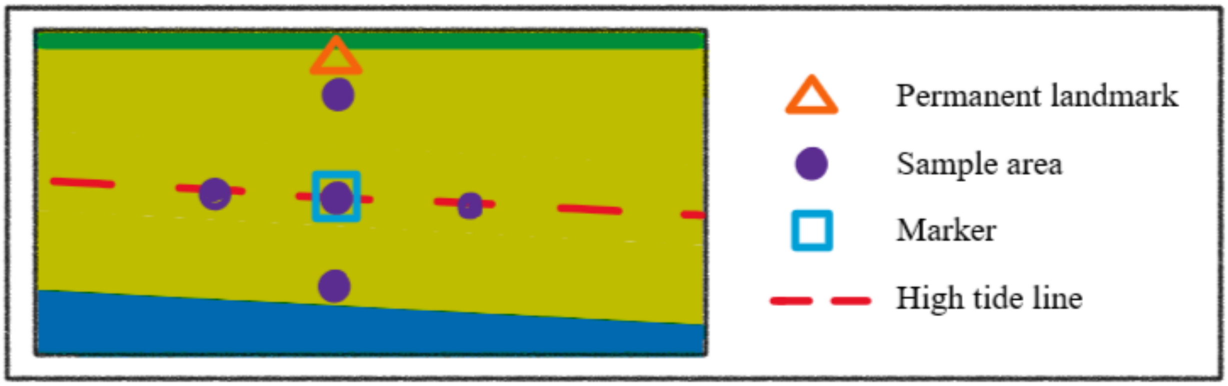
Of the gathering methods we tested, the Star Method was the only method that we spent a one-time cost less than US$13.00. Some of the materials that contribute to the cost of the other gathering methods are gloves, stakes, and a tape measure. The Star Method only requires the purchase of gloves and corn syrup. We reused jars for our containers to conduct the Star Method.



All the materials needed for the analyzing methods cost under US$13.00. Since it costs nothing to hand pick microplastics, and it is time efficient, we chose hand picking as the gathering method for the Star Method.

Appendix I: The Star Method Manual

The Star Method Manual



For this procedure, you will need:

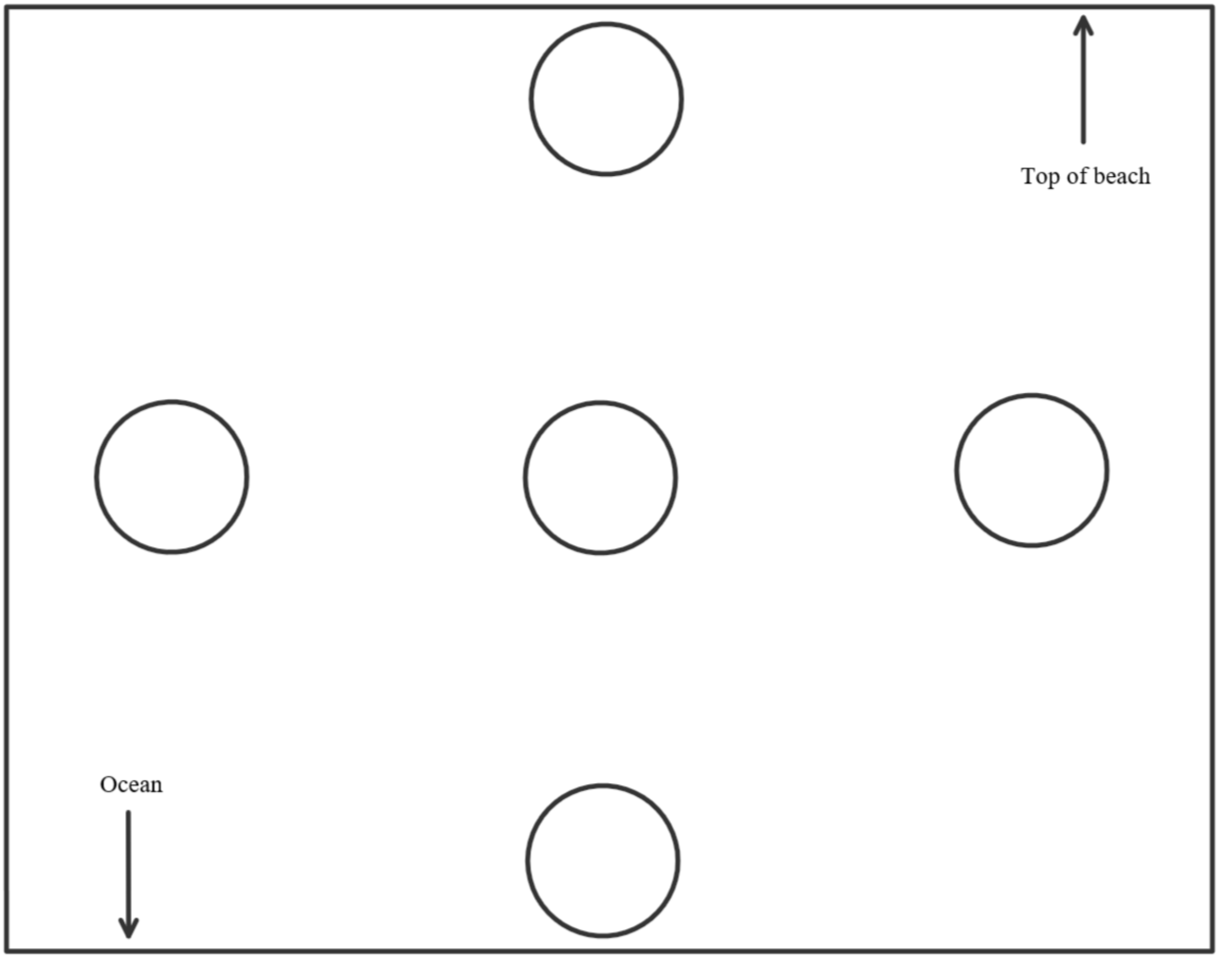
- An object to mark location (bag, reusable water bottle, jacket, rock, etc.)
- Gloves
- Corn syrup
- Container to dispose of microplastics
- Two glass or metal containers
- Spoon

Procedure:

1. Before you go to the beach, gather your materials. Bring gloves, two glass or metal containers, another container for disposal, a spoon, and an object to mark location.
2. Following the diagram above, find a permanent landmark at the top of the beach. You should be able to line up your marker with this landmark. Place this marker at the high tide line.
3. Draw a circle around this marker with a half meter (1.5 feet) radius.
4. Use your hands to pick out microplastics or unidentifiable particles from the top first centimeter of sand. Place these in an empty glass or metal container.
5. After the circle has been looked through, place the particles found in a container filled with corn syrup. Wait for the sand or rocks to fall to the bottom of the container, and then remove the floating pieces from the corn syrup with the spoon and count them.
6. Record the number of floating particles in the blank diagram below. Make sure the number recorded corresponds with the circle from which you collected the samples.
7. Place the particles in the container for disposal.
8. Walk ten paces from the marker towards the vegetation or rocks at the top of the beach and repeat steps three through seven.
9. Walk ten paces left of the marker and repeat steps three through seven.
10. Walk ten paces right of the marker and repeat steps three through seven.
11. Walk ten paces towards the water and repeat steps three through seven.

Star Method Data Collection Sheet

Date:_________________ Location:_________________



In each circle, record the number of floating particles you collected. Make sure the number recorded corresponds with the circle in which you collected the sample.

Once you have recorded your data here, you can upload it at:
https://sites.google.com/view/iqpmicroplasticmonitoring/recording-data

A video explaining the star method can be found at:
https://sites.google.com/view/iqpmicroplasticmonitoring/the-star-method-manual