A Citizen Science Platform for Long-Term Monitoring of Microplastic Pollution in Port Phillip Bay

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

This project was intended to help the Port Phillip EcoCentre establish a long-term monitoring program to track microplastic pollution in Port Phillip Bay. We trialled, assessed, and designed an implementation plan for the Baykeeper Beach Litter Audit at nine pre-selected sites. We collected preliminary data and developed informational guides, instructional videos, and promotional flyers to recruit and inform citizen scientists. The monitoring program has potential to serve as a tool for management of the bay over the next fifty years.

EXECUTIVE SUMMARY

Project Overview

Eight million tons of plastic enter the marine environment each year, and an estimated 5.25 trillion pieces of plastic have accumulated in the ocean. Plastic consumption continues to increase, and the amount entering the marine environment is an issue because the synthetic polymers that plastics are composed of do not fully degrade. This means that once a plastic enters the environment, its plastic components will perpetually harm the environment. However, plastic debris will not always remain in the form of a plastic bag or water bottle. Once plastic litter makes it to the ocean, it degrades into smaller pieces due to weathering, ultraviolet radiation, and the properties of seawater. Eventually, plastics break down into microplastics, defined as pieces with diameters less than 5 millimeters. Apart from being formed by the breakdown of larger plastics, microplastics also include plastic resin pellets, or nurdles, which are used in plastic manufacturing, microbeads, components of several hygiene products, and microfibers, the synthetic particles that come off of clothing in washing machines. Regardless of their source, microplastics present harm to the marine environment because they contain pollutants and can be easily mistaken for food by marine wildlife due to their small size. When fish ingest microplastics, they absorb their pollutants, and through a process called biomagnification, these pollutants can move up the food chain, putting other animals as well as humans at risk.

Figure 0-1. Nurdles

Microplastic pollution is an emerging global concern; therefore, there is a lack of knowledge and awareness surrounding the topic. Nevertheless, some communities, including the Port Phillip Bay area, have taken initial steps to address microplastic pollution. Port Phillip Bay is located in the southern part of the Australian state of Victoria. The bay is surrounded by four main catchments and multiple sub-catchments, which are home to two-thirds of Victoria's total population. There are several rivers and creeks that run through these catchments and discharge into the bay. These waterways play an important role in providing the Port Phillip Bay area with aesthetic appeal, recreational opportunities, tourism, ecosystem foundations, and wildlife habitat. However, these rivers and creeks also serve as a path for litter to travel from the catchments into the bay. The litter that enters Port Phillip Bay circulates the bay with the clockwise current for an estimated 1.65 years before it is released into the open ocean through Bass Strait.

Neil Blake, the Port Phillip Baykeeper, as part of Waterkeeper Alliance, strives to keep the bay clean by taking action, educating the community, and promoting the cause through a variety of projects. Neil developed the Baykeeper Beach Litter Audit to address microplastic pollution in Port Phillip Bay. It is a systematic method for collecting and recording litter at beaches around the bay. It focuses on microplastics unlike other methods to collect and sample debris from the marine environment. Due to the complexity of the microplastic pollution issue, citizen science is an appropriate approach to get more people involved. Citizen science projects depend on community participation for data collection, and the data is sent to scientists and other experts for analysis.

Project Objectives

The goal was to use the Baykeeper auditing methodology to establish a long-term monitoring program to track microplastic pollution in Port Phillip Bay. This program will be maintained by citizen scientists and will provide a tool for management in the bay for the next 50 years. Our project team, in collaboration with the Port Phillip EcoCentre, developed the following objectives to achieve this goal.

1. Understand the Port Phillip EcoCentre's values and goals.
2. Understand the different perspectives on microplastic pollution in Port Phillip Bay.
3. Trial and assess the Baykeeper Beach Litter Audit and determine implementation protocols at each pre-selected site around the bay.
4. Analyze preliminary data on the distribution of microplastics around the bay.
5. Prepare outreach and instructional materials to ensure consistent implementation by citizen scientists.

Sponsor and Stakeholder Perspectives

It was important to understand the Port Phillip EcoCentre to accustom ourselves with the organization's values. We participated in some of their programs and activities, such as helping to rebuild penguin habitats with corporate volunteers and analyzing samples of microplastics collected in manta nets from the Yarra and Maribyrnong Rivers. These engagement activities helped us realize their vision of "an empowered and engaged community, actively cultivating long-term social and environmental well-being," and the ways in which they pursue it. We also experienced how integral volunteers and citizen scientists are at the EcoCentre.

To understand the different perspectives on microplastic pollution in Port Phillip Bay, we conducted in-person surveys with individuals that visited St. Kilda Beach, including tourists, locals, beach goers, and fishermen. Out of 102 total surveys, 48% of the individuals were not aware of the existence of microplastics. Once we explained to the respondents what microplastics were, only 37% could provide possible sources of microplastic pollution. This lack of awareness within the community reveals an obstacle for the citizen science program because it shows the current lack of understanding of the issue within the community, but it also presents the opportunity for growth in this area.

Implementation Plan

To ultimately develop an implementation plan for long-term monitoring program, we needed to trial and assess the Baykeeper Beach Litter Audit and develop implementation protocols at each of the study sites. These tasks were important for a citizen science project because they helped us set a basis for and create the plan for community members to sustain the long-term monitoring program.

The study area consisted of nine pre-selected sites around the bay (Figure 0-2). This selection was based on the locations of waterway entries from rivers and creeks into the bay, the clockwise movement of the current around the bay, and wind patterns. We validated the suitability of each pre-selected site by determining any factors that might prevent volunteers from performing the audit at the site. This included noting each site's accessibility, such as proximity to car parks, and observing hazards, such as the need to cross bike paths to access the beach. We determined that one pre-selected site, Wader Beach, was not appropriate for implementing the audit due to access difficulties and the danger of tiger snakes in the area.

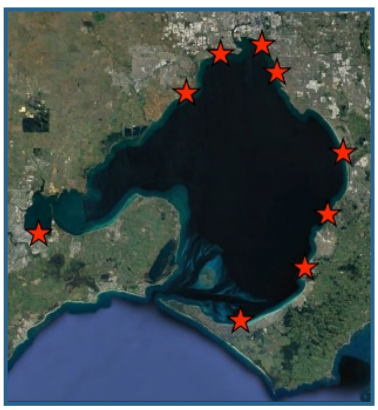


Figure 0-2. Baykeeper Beach Litter Audit Sites

At each validated site, we set up the audit. An overview of the audit setup is displayed in Figure 0-3. The locations of the transect lines at the widest, middle, and

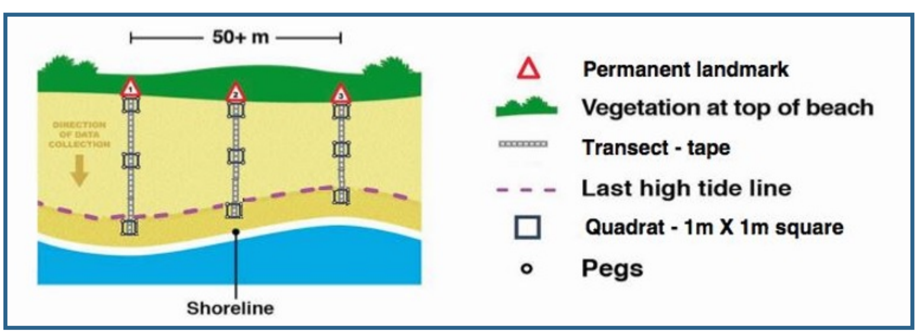


Figure 0-3. Baykeeper Beach Litter Audit Setup

narrowest sections of the beach, must be consistent from study to study to ensure data is comparable. We selected and recorded permanent landmarks at the top of the beach, such as notable signposts or buildings, that will serve as reference points for each transect for all future audits. Along each transect, there are three quadrats, 1 square meter in area, at the top of the beach, the middle, and the last high-tide line. Once the quadrats are located, the top layer of sand in each is surveyed for litter, and all inorganic debris is collected and recorded on the Baykeeper Beach Litter Audit Data Sheet.

To assess the Baykeeper Beach Litter Audit method, we performed a SWOT analysis (Fig 0-4), noting strengths, weaknesses, opportunities, and threats to implementation. One barrier we found in our assessment was deciphering between certain inorganic and organic debris. Nurdles can be commonly confused with small rocks, and seaweed with cellophane. This assessment was important to the citizen science project because it provides guidance for future auditors who will be part of the long-term monitoring program.

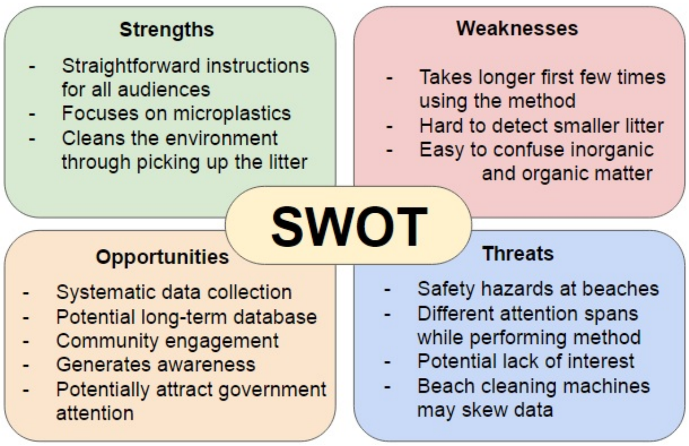
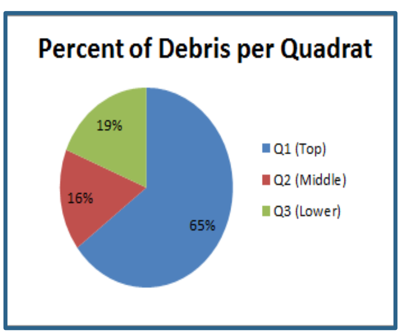


Figure 0-4. SWOT Analysis

Preliminary Data Collection and Analysis

We also collected preliminary data through our initial implementation of the Baykeeper audit. Since this is the first set of data, no conclusions can be drawn, but initial analyses and hypotheses on litter distribution were derived for future references. We collected 516 pieces of litter total, 230 of which were nurdles. We analyzed the distribution of litter per transect (Figure 0-5) and collected a significantly large amount of litter, most of which were nurdles, at Keast Park compared to other sites. This skewed our data but also presented the necessity for continuing audits at this site to observe if trends continue and if so, potentially attract community and



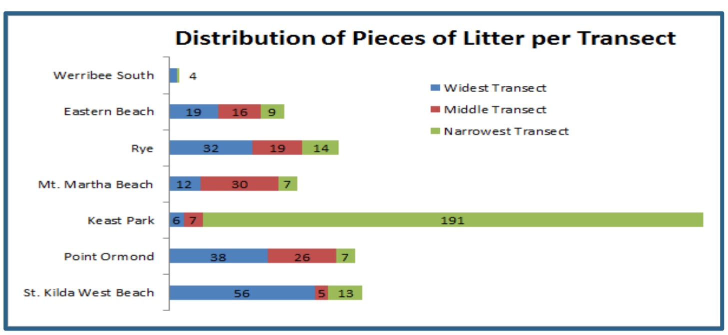


Figure 0-5. Distribution of Litter per Quadrat (left) and per Transect (right)

government attention to the issue. In our initial collection, 65% of all litter was located in the top quadrat. We predict that most litter will continue to be located in the top quadrat for future audits since this area is more exposed to human activity and is usually surrounded by vegetation and/or walkways that enable litter accumulation. These examples prove the importance of a long-term monitoring program for these sites because as more data is collected, different behaviours may become apparent and/or similar patterns may continue.

Outreach and Promotion Materials

Our team developed outreach and promotional materials necessary to establish a long-term monitoring program for citizen scientists. We produced an instructional video demonstrating how to perform the Baykeeper Beach Litter Audit, to provide volunteers with a visual representation of the written instructions. This video will be made accessible to any volunteer who is new to performing the method and will help the data collection be more consistent and reliable. We also developed informational sheets for the audit sites explaining the specifics on each beach so that future auditors could easily retrieve the necessary information to perform the audits. These sheets were a major part of the implementation plan for each audit site that helped set the foundation for a long-term monitoring program for microplastic pollution in the bay. Lastly, we designed a promotional flyer that targets Scout groups in the Port Phillip Bay area. The flyer will be published on the Scout website and magazine and distributed to Scout leaders to recruit citizen scientists for the long-term monitoring program. With cooperation from the Scouts and other citizen scientists, the Baykeeper Beach Litter Audit will be performed on a monthly basis at each audit site.

Our project was successful in helping the EcoCentre establish a citizen science platform for monitoring microplastic pollution in Port Phillip Bay. We trialled the Baykeeper Beach Litter Audit at the preselected audit sites and made hypotheses based on our preliminary data analysis to set the foundation for future data collection and analysis. We designed an implementation plan and video instructions for the method to ensure consistent implementation by citizen scientists. With participation from the Scouts and other community members, this monitoring program will track deposits of microplastics into the bay over time as well as detect patterns in the distribution of microplastics across the bay.

Figure 0-6. Project team performing Baykeeper Audit

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Neil Blake, the Port Phillip Baykeeper, for sharing his vast knowledge with us, putting us in contact with other experts in the field, teaching us about the Baykeeper Beach Litter Audit, and accompanying us in trialling the method at several sites around Port Phillip Bay.

The Port Phillip EcoCentre staff members, for welcoming us into their community, showing us more about the Australian culture, and encouraging us throughout our project.

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AUTHORSHIP

Andrea Bayas: Responsible for writing the Introduction, Background Sections 2 and 3, Methodology Sections 3.1, 3.2, 4, and 5.2, Findings Sections 1, 2, and 3, and Analysis & Discussion Section 1 and 2. She also was responsible for editing all sections she did not write.

Maura Buckley: Responsible for writing the Introduction, Background Sections 1, 3, and 7, Methodology Sections 2, 3.4, 3.5, and 5.1, Findings Sections 1, 2, and 2.1, Analysis & Discussion Section 3 and 4, and Outreach & Education Sections 2 and 3. She also was responsible for editing all sections she did not write.

Cierra Ford: Responsible for writing the Introduction, Background Sections 4, 5, and 6, Methodology Sections 1, 2, 3.3, 3.4, 3.5, and 5.3, Findings Sections 1, 2, and 3, Analysis & Discussion Sections 1 and 2, and Outreach & Education Section 1. She also was responsible for editing all sections she did not write.

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CHAPTER 1: INTRODUCTION

More than 8 million tons of plastic enter the marine environment every year (Besley et al, 2017) and an estimated 5.25 trillion plastic pieces are floating in the sea (Eriksen et al, 2014). This is an issue because the synthetic polymers that plastics are composed of do not fully degrade, and therefore once plastic enters the environment it never leaves. Microplastics, a generally new concern, are pieces of plastic with diameters less than 5mm. They are divided into two categories based on their source: primary and secondary microplastics. Primary microplastics include plastic resin pellets used by factories and plastic manufacturers, microbeads found in several hygiene products, and microfibers contained in articles of clothing. The average U.S. household washes almost 400 loads of laundry per year (Clothes Washer, 2016), and a single fleece jacket can release around 81,000 microfibers in one wash (Rozalia Project, 2014). Secondary microplastics form when larger plastics break down when exposed to oxidation, seawater, and/or ultraviolet radiation. Besides polluting the environment, microplastics are an issue because they are easily ingested by organisms in marine environments and can cause damage to these organisms' digestive and circulatory systems.

Port Phillip Bay is located in the southern part of the Australian state of Victoria. Melbourne, the capital of Victoria, is a major city located on Port Phillip Bay. The bay is surrounded by four major catchments and multiple sub-catchments, which are home to two-thirds of Victoria's population. Stormwater within these catchments flows directly into drains and rivers that discharge into the bay, carrying debris with it. Plastic debris that makes it to the ocean eventually degrades into microplastics. The two main rivers that flow through the catchments around Port Phillip Bay are the Yarra and Maribyrnong Rivers. Each of these rivers dumps over 500,000 plastics per year into the bay (Blake and Charko, 2014). Port Phillip Bay is one of the healthiest bays, and Melbourne is one of the most sustainable cities (The Economist Data Team, 2016), thus there is a sense of responsibility to maintain this high quality to continue to serve as a worldwide example.

Among the many organizations in Victoria that participate in attempts to improve the oceans and beaches is the Port Phillip EcoCentre, a non-profit organization located in St. Kilda, a suburb of Melbourne. The EcoCentre's mission is to empower and engage the community by actively cultivating long-term social and environmental well being. One of their programs, Baykeeper, is part of Waterkeeper Alliance, a global non-profit organization focused on clean water. Waterkeeper Alliance consists of over 300 Waterkeeper Organizations and Affiliates that protect waterways on 6 continents. There are four Waterkeeper Organizations in Victoria: Yarra Riverkeeper, Werribee Riverkeeper, Surry Riverkeeper, and Port Phillip Baykeeper. Neil Blake, who holds the title of Port Phillip Baykeeper, organizes and manages all Waterkeeper activities in the bay area. He works to keep Port Phillip Bay clean of litter by surveying beaches, organizing "Litter Safaris" (where the goal is to clean up beaches and determine litter hotspots), and managing studies to track sources of litter in the surrounding catchments. Through these efforts, the EcoCentre is currently studying and evaluating the situation of microplastics in the bay.

Worldwide, there have been several attempts to address the issue of microplastic pollution in marine environments. Various organizations have manufactured products that are designed to reduce the amount of microplastic pollution in marine environments (A human-scale solution, 2014, Filus, 2009, Ashton, 2013). Other organizations have conducted studies to collect and sample microplastics on beaches and in water bodies to analyze them by location and abundance (Hidalgo-Ruz, et al., 2012, Arthur, 2012, Blake, et al., 2014). However, several complexities arise when addressing microplastic pollution. These include: incomparability of studies, lack of education and participation among the public, and difficulty quantifying plastics by source and location.

The Port Phillip EcoCentre has examined various methodologies to sample and remove litter from the environment and found that they overlook microplastics. Neil Blake designed a beach litter audit methodology that addresses microplastic pollution and is easily replicable. The state of Victoria recently approved this method as a standard technique for collecting data on the distribution of litter around the bay. However, the method's implementation still needs to be validated for each of the preselected audit sites and a framework must be established to guide future audits. Volunteers also need to be recruited so that audits can be performed on a monthly basis and data collection can continue. Ultimately, a long-term monitoring plan to continue the performance of this standardized methodology can help the EcoCentre capture government attention on the seriousness of microplastic pollution

This project was intended to help the Port Phillip EcoCentre establish a long-term monitoring program to track microplastic pollution in Port Phillip Bay. We trialled the Baykeeper litter audit method at preselected audit sites around the bay to assess its validity and evaluate its strengths and weaknesses. Based on our assessment, we developed an implementation plan for each audit site, and then created an instructional video that showed how to perform the audit. Finally, we recruited volunteers and raised awareness about the issue in the community through outreach and education. The monitoring program has the potential to serve as a baseline for management of the bay over the next fifty years.

CHAPTER 2: BACKGROUND

The increase in the amount of plastic (and consequently microplastics) in the oceans over the past few decades negatively affects the environment, including habitats of marine organisms such as molluscs. In this chapter, we will introduce the various impacts of microplastics. Then we will discuss molluscs and how they are affected. We also will give an overview of the Port Phillip Bay Area, and summarize the different methodologies to sample and remove microplastics from the environment. We will discuss some of the legislation in place to mitigate the impacts of microplastics, both worldwide and in Australia. Finally, we will introduce our sponsor, the Port Phillip EcoCentre, and its efforts to engage the community in environmental concerns.

2.1 Microplastics in the Marine Environment

Small particles of plastic from a variety of sources (Browne, et al., 2011) pollute the waters of the world (Andrady, 2011) and affect marine organisms that ingest them (O'Shea, et al., 2014). It has been reported that the annual global demand for plastic is 311 million tons (PEMRG, 2014). It is estimated that of this amount, over 8 million tons of plastic enter the marine environment each year (Besley et al, 2017). As a versatile, lightweight, strong and cost-efficient material, plastic can meet many standards and requirements and is present in many commonly used items. Plastic production and consumption are expected to continue increasing based on current human behavioral trends (Gourmelon, 2015).

Plastics and natural materials are chemically composed of polymers. Polymers are made up of chains of monomers in different shapes and sizes. Natural materials are composed of natural polymers (wood, silk, cotton, etc.), while plastics are composed of synthetic polymers. This means that plastic polymers are made with chemical synthesis, allowing engineers to manipulate their physical and chemical properties. Many commonly used synthetic polymers are not biodegradable (Lower, 2009). When plastics are released into the natural environment, they fragment, as do the polymers they are composed of. The plastic polymer chains may break down an infinite number of times in the environment, but never disappear from the environment all together (Lower, 2009), which means that the harmful properties of the plastic polymers also still exist. Therefore, the amount of plastic polymers in the environment can only increase as plastic consumption continues.

Microplastics are small particles of plastic, sometimes invisible to the naked eye. Scientifically, microplastics are still being understood. One source describes microplastics as pieces of plastic debris “that pass through a 500μm sieve but [are] retained by a 67 μm sieve (~0.06-.5mm in diameter)” (Andrady, 2011). Another source defines a microplastic as having a diameter less than 5mm (Hidalgo-Ruz, et al, 2012), and another as a plastic with a diameter less than 1mm (Browne, et al., 2011). Although there is no standard microplastic size, the international norm is that they are less than 5mm in diameter. Regardless of the size, studies consistently show their ability to pollute the ocean.

2.1.1 Sources of Microplastics

Microplastics enter the ecosystem from a variety of sources. Primary microplastics include plastic resin pellets used in factories that manufacture plastics, microbeads that are found in hygiene products, and microfibers that make up clothing materials.

Most primary microplastics enter the ocean through treated sewage. These primary microplastics come from common household items, including facial cleansers, soaps, and washing machines. One study that tested plastic pollution coming from 18 different city shorelines claimed that washing machines were the main source, followed by cleaning products. Some soaps and facial cleansers contain microbeads, which are a form of microplastic. The study showed the largest proportion of fibers as textiles (Browne, et al., 2011). Research by the Rozalia Project (2014) shows that 81,000 microplastic fibers and textile pieces can come off of a single fleece jacket per wash. From the washing machine, these microfibers enter the sewage system, go through water treatment plants, and depending on the system, the debris that is not separated from the water at these plants ends up in the ocean. This fact is alarming because of how often these items are used. In the U.S. the average household washes almost 400 loads of laundry per year (Clothes Washer, 2016) and people often wash their face with facial cleaners on a daily basis (Fendall, et al., 2009).

Another source of primary microplastics in marine environments is the spillage of plastic pellets from factories. One study collected data on the improper handling of plastic pellets within factories (O’Shea, et al., 2014). The mishandling carries over to the trucks transporting the plastic, which are not required to have a lid (Mallinson, et al, 2013). Pellets fall off the truck and onto the street, and when these streets are driven on and/or rained on, the pellets make their way to stormwater drains, rivers and creeks (O’Shea, et al, 2014), which all eventually discharge into the ocean. Some of these factories documented that they hose their workshops floors down, sending the pellets directly into the drains (Mallinson, et al., 2013).

Secondary microplastics form when larger plastics break down into smaller pieces. Plastic litter follows stormwater runoff when it rains into drains, rivers, or creeks, all of which discharge into the ocean. This plastic litter takes several years to degrade and releases toxic chemicals during the process (Priyanka, et al., 2014).

According to a study published in 2014 by Eriksen and colleagues, there are currently 5.25 trillion plastic pieces weighing 268,940 tonnes floating in the sea. To gather this data, they surveyed the five subtropical gyres (large systems of circulating ocean currents) of the North Pacific, North Atlantic, South Pacific, South Atlantic, and Indian Ocean, as well as coastal regions. These ocean gyres are formed by oceanic surface currents and prevailing winds. They act as shredders, and aided by ultraviolet radiation, the oxidative properties of the atmosphere, and the hydrolytic properties of seawater, they break down large pieces of plastic litter to the point where they become microplastics. Another interesting finding of the study was that the amount of plastics in the southern hemisphere and on the northern one are in the same range, despite the higher influx of plastics into the ocean on the northern hemisphere. This could either indicate that plastic pollution can travel more easily from one oceanic gyre to another than was previously assumed, or there might be significant sources of plastic pollution in the south that are currently unaccounted for, such as currents coming from the Bay of Bengal (Eriksen, et al., 2014). Another hypothesis could be that a major source of microplastic pollution in the South comes from "third world" countries. Some of these countries with limited or no waste management infrastructure and systems, such as garbage collection, affect the rest of the world through this assumed flow between gyres.

2.1.2 Impacts of Microplastics

Due to the size, durability, and persistence of microplastics in the environment, they represent a risk to a range of species that ingest them. Browne and colleagues (2008) used mussels, a bivalve mollusc, to study ingestion, translocation, and accumulation of microplastics in marine wildlife. Initially, the microplastics gathered in the organism's gut, but within three days, the particles moved into the circulatory system, where they stayed for over 48 days even though the mussels had been relocated to clean water (Browne, et al., 2008). There is not much literature with regards to the different factors that influence the physical impacts of microplastics on marine organisms; however, the ones identified are: accumulation (microplastics accumulate in organism's digestive cavities, causing blockage in the digestive system), translocation (microplastics can shift location from the digestive cavities to body tissues and the circulatory system), shape (the negative effects of microplastic ingestions vary with the shape of the particle), and egestion (they can be eaten by other animals or else be affected by the microplastics before being able to egest them).

Other hazardous effects of ingesting these plastics include: inability to secrete gastric enzymes, intestinal obstruction and ulcerations that reduce food consumption, nutrient dilution, reduced growth rates, lowered steroid hormone levels, delayed ovulation and reproductive failure, and absorption of toxins (O'Shea et al, 2014).

Microplastics are, in essence, saturated hydrocarbon units. Their non-polar surfaces allow microplastics to absorb hydrophobic organic pollutants present in seawater, including polychlorinated biphenyls (PCBs), which lead to reproductive failure, dichlorodiphenyltrichloroethanes (DDTs), which can produce thinning in eggshells, polycyclic aromatic hydrocarbons (PAHs), and persistent organic pollutants (POPs) (O'Shea, et al, 2014). Urban or industrial areas produce the majority of these pollutants and release them into the atmosphere. The atmosphere then serves as a pathway for these pollutants to enter water and other terrestrial surfaces (Goia, et al., 2008). The absorption of pollutants makes microplastics even more toxic in marine environments.

The small size of microplastics makes it easy for marine wildlife to deliberately or accidentally ingest them. In addition to impacts on the organism, research suggests that toxins from plastics may move up the food chain through the process of biomagnification. When marine organisms ingest microplastics, the contaminants in the plastic are transferred to the animals' tissues, and can eventually enter humans' systems. A study done by Farrell and Nelson (2013) aimed to analyze the trophic transfer of microplastics using mussels and crabs. The research found that the amount of plastic transferred was small, however, pieces of microplastic were translocated to the haemolymph and tissues of the crab. Humans can also be directly affected from microplastic ingestion by marine organisms. Rochman and colleagues conducted a study to quantify the presence of microplastics in fish and shellfish being sold for human consumption at various markets worldwide (2015). In Indonesia, debris were found in 28% of individual fish and in 55% of all species, and in the U.S., debris were found in 25% of individual fish, in 33% of individual shellfish, and in 67% of all species (Rochman, et al., 2015). This is significant because it documents the presence of microplastics in fish sold directly for human consumption, which raises concerns for human health.

2.2 Impacts of Microplastics on Molluscs

Molluscs are one of the largest invertebrate phylums in the animal kingdom. It is estimated that there are between 50,000 and 120,000 living molluscan species, among which around 30,000 species are found in marine environments, making up 23% of all marine organisms (Gazeau et. al, 2013).

Some common characteristics of molluscs include a soft body, an internal or external shell, and a muscular foot (and/or tentacles). Yet, they are divided into six different categories based on more specific attributes: gastropoda, bivalvia, cephalopoda, polyplacophora, scaphopoda and aplacophora. A classification of mollusc organisms can be seen in Figure 1. Bivalves are the largest subgroup in this phylum (around 15,000 species) (Mollusca, n.d). They are characterized by a body enclosed by two shells connected at a hinge. Some of the most common bivalves are oysters, scallops, mussels, and clams. Gastropods, on the other hand, consist of snails and slugs and are depicted by a soft body and a shell. Cephalopods are exclusively marine animals with a bilateral body symmetry consisting of 8 to 10 feet and/or tentacles. Octopuses, squids, cuttlefish, and nautilus are some of the most known classes within this group. Polyplacophors, also known as chitons, are also marine molluscs that vary in size and consist of flattened oval shaped bodies with a shell formed by eight plates. Scaphopods are characterized by conical and slightly curved shells and are usually found in marine mud and sediments. Finally, aplacophorans lack of a shell and are small, cylindrical, worm-like organisms (Mollusca, n.d).

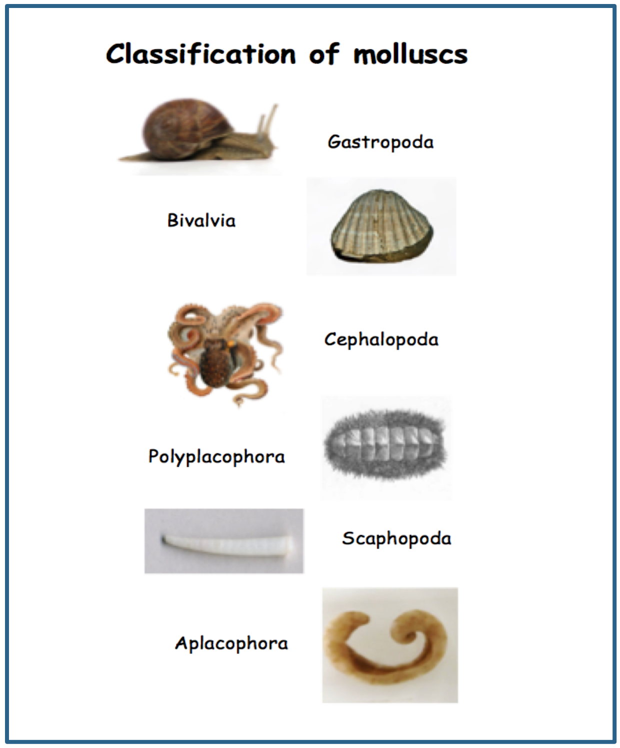

Figure 1. Major mollusc classes

Molluscs play a crucial role in the health of the ecosystem, since they contribute to water purification and the formation of habitat structure for benthic organisms such as mussel and oyster beds. Molluscs are also a food source for other organisms (Gazeau et. al, 2013). Due to their abundance and variety, these animals provide a solid foundation for the marine ecosystem.

Marine molluscs, such as bivalves and monoplacophors feed themselves by filtering particles from water, thus classifying them as filter feeders. This process of filter feeding makes them susceptible to plastic pollution, since sometimes the organisms cannot prevent themselves from ingesting the microplastics. Most bivalves capture and retain 3-4 μm particles with 100% efficiency (Wright et al., 2013). Moreover, due to their inherent feeding strategy, filter feeding molluscs are most likely unable to sort and reject microplastics prior to ingestion (Wright et al., 2013). Consumption of these particles can result in starvation, satiation, or intestinal blockage that could lead to death. Furthermore, the effect on these organisms can result in a greater impact on the rest of the food chain, since microplastics do not decompose once they are consumed, and can be ingested again by other organisms. Therefore, microplastics represent a threat to these animals that may lead to potential consequences in the entire marine ecosystem.

The Marine Research Centre in Finland examined the different types of microplastic ingestion in marine environments by setting up a controlled experiment that exposed various marine organisms to different concentrations of microplastics. The experiment was conducted in aquariums replicating conditions in northern coastal areas of the Baltic Sea. Three different concentrations of polystyrene beads were added to the aquariums, mimicking natural concentrations of plastics in marine environments, and observations were taken on how the organisms interacted with both the environment and plastics. After 24 hours, the water was filtered out, the organisms dissected, and microscopy was used to observe microplastic ingestion. The report noted that "the behavior and feeding mode of an animal played a major role, largely affecting the number of ingested beads" (Lehtiniemi, 2015). The bivalve species ingested significantly more plastic than others. This shows that filter feeders and organisms feeding from the water column instead of sediment may be more at risk of ingestion. This article demonstrates how microplastics can enter the food web starting at krill and invertebrates, how swimming activities help to determine how different marine species are affected by microplastics, and how microplastic ingestion varies based on feeding habits.

Eastern Port Phillip Bay (PPB) has its own blue mussel colony. This industry has been around for 25 years in Port Phillip Bay, with a longline culture of blue mussels as the main activity. (Department of Primary Industries, 2005). O'Shea et al (2014) talks about how these blue mussels consume plastic pellets, which can lead to detrimental effects in the Eastern PPB mussel farms.

2.3 Current Situation of Microplastics in Port Phillip Bay

Located in southern Victoria, Port Phillip is Australia's busiest port and one of the area's most popular recreational destinations. Also known as Port Phillip Bay, Port Phillip is actually a port area made up of over 16 bays (Parks Victoria, 2016). With 1,950 square kilometers, 'The Bay,' as many locals refer to it, supports approximately 300 species of fish, several hundred species of molluscs and crustaceans, as well as numerous species of sponges, cnidarians, seaweeds and polychaetes (DEPI, 2016). Some of the marine ecosystems found in the area include sandy beaches, rocky shores and reefs, mangroves, and sand and seagrass beds. According to Parks Victoria, "Port Phillip is a dynamic and self-sustaining ecosystem which is healthier and cleaner than comparable bays near large cities" (2016). Nevertheless, microplastic pollution represents a potential risk to the port's wellbeing.

Drainage systems facilitate the transfer of microplastics to Port Phillip Bay. There are more than 25,000 kilometers of local stormwater drains in Melbourne that are managed by councils (Melbourne Water, n.a). The process usually follows the path shown below in Figure 2. The water goes from residential drains to council and regional drains that later on flow into rivers and creeks that lead towards the bay.

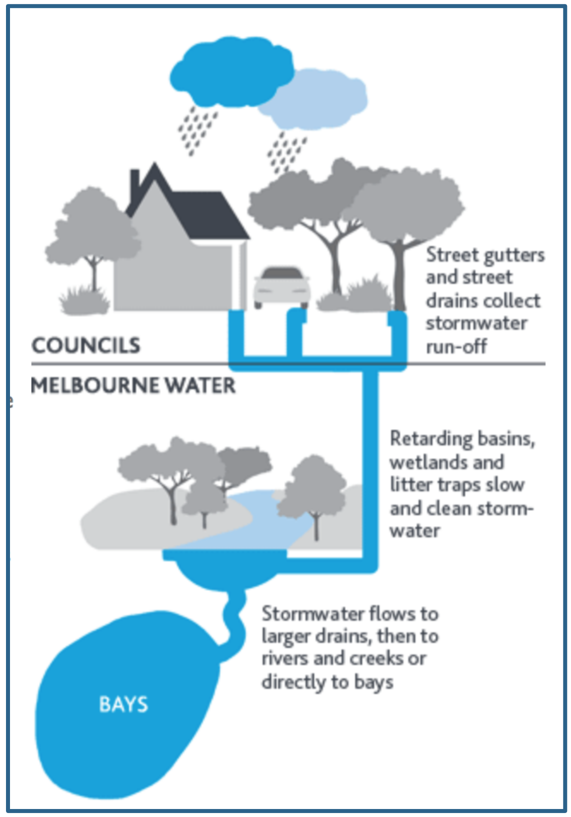

Image supplied courtesy of Melbourne Water

Figure 2. Stormwater path through Melbourne's drainage system (Melbourne Water, n.a)

Unlike the drainage systems, the path of Melbourne's sewage systems include wastewater treatment plants. Microbeads from hygiene products, microfibers in washing machines, and anything else going into a sink, toilet, or washing machine, will enter the sewer. The contaminated water will then pass through the Western or Eastern Treatment Plant in Melbourne, where it is treated (Figure 3). The Western Treatment Plant, which collects 60% of the sewage water in the bay area, discharges into the Port Phillip Bay, whereas the Eastern Treatment Plant collects the other 40% and discharges into Bass Strait (J. Forrester, personal communication, March 23, 2017).

The majority of contaminants will be separated from the water that discharges into the ocean. However, a meta-analysis of 17 different wastewater facilities throughout the United States found that microplastic pollution has been detected in wastewater treatment effluent (Mason, et al., 2016), showing that there is risk also in Melbourne that these small plastics may not be filtered out of the water that enters Port Phillip Bay.

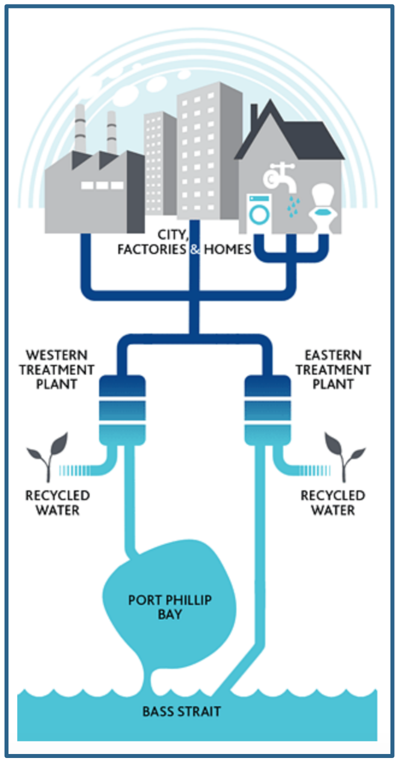

Image supplied courtesy of Melbourne Water

Figure 3. Melbourne's sewage system (Melbourne Water, n.a)

According to the watershed protection program Yarra and Bay, the catchments surrounding Port Phillip Bay cover 9,790 square kilometers in area, and are made up of 21 natural drainage basins (2016). Yarra, Maribyrnong, Werribee, Little Rivers, and Patterson are the rivers that run into the bay. Similarly, Kananook, Mordialloc, Elster and Kororoit are creeks that flow into the bay. These rivers and creeks are a popular destination for residents and tourists, bringing in almost 90 million visitors each year. Furthermore, these waterways are sources of water for drinking, industry and agriculture, and they provide a critical ecosystem service to keep the water clean through the processing of nutrients.

The Yarra River is the greatest contributor to Port Phillip. Its catchment comprises about 4,000 square kilometers and supports industries like agriculture, forestry, recreation, and tourism

(Yarra and Bay, 2016) and is the major source of Melbourne's potable water supply. The mouth of the Yarra River, connecting to Port Phillip Bay, is known as the Yarra plume. The plume was formed by the flow of the river depositing into the bay. A plume becomes widened and influenced because of entrainments of the fluid (water, in the case of the Yarra) moving away from its source. It widens and continuously shapes the mouth of the bay through momentum (*Plume*, 2013). The Yarra Plume has the potential to affect marine wildlife and the communities of Port Phillip Bay (Lucas, 2007).

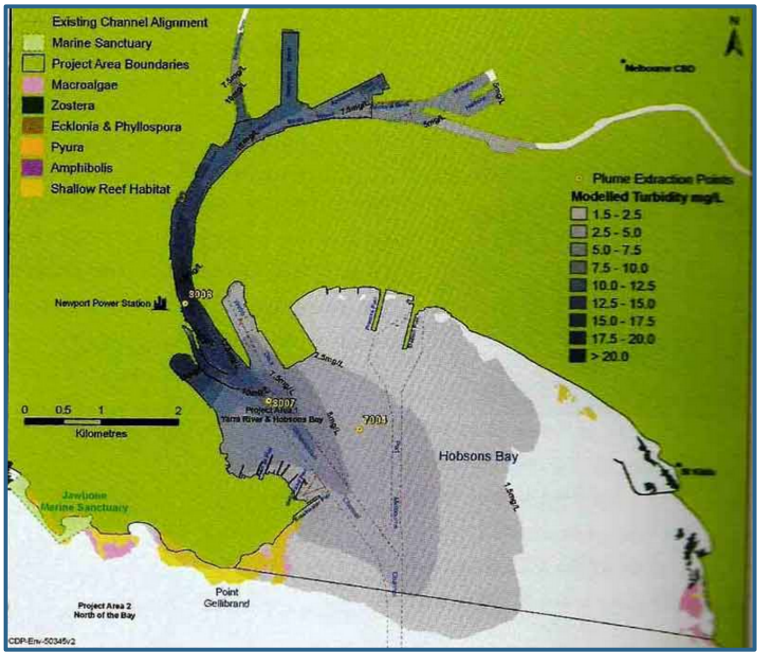

Figure 4. Yarra Plume (Bad Developers).

The commercial fishing and aquaculture industries are valued at $10 million in the bay, according to the Yarra and Bay program (2016). Some of the most demanded sea products include molluscs such as abalones, squids, mussels, and scallops, crustaceans like rock lobster and giant crab, as well as sardines, salmons and snappers.

Melbourne is known throughout the world as one of the most sustainable and liveable cities (The Economist Data Team, 2016). The "Plan Melbourne Metropolitan Planning Strategy" recognizes the city's current and future problems and attempts to plan for a more sustainable future through 2050. It acknowledges that Port Phillip Bay and Western Port are popular recreational destinations for residents and tourists, with around 90 million visits each year. One goal of Plan Melbourne is to improve the quality of the bays and the catchment systems discharging into it (Plan Melbourne, 2014).

The Department of Environment and Primary Industries (DEPI) states that the two greatest threats to Port Phillip's conservation are inflows of nutrients such as nitrogen and marine pest invasions. The ramifications from these two threats negatively impact Victoria's biodiversity and ecological integrity within the marine ecosystem. Moreover, the effects on aquaculture and both commercial and recreational fishing could lead to social and economic consequences in the bay. Microplastic pollution was not mentioned by the DEPI, but it is an emerging concern that is generating attention.

The spilling and pollution of plastic pellets across the Port Phillip Bay area is a direct result of improper handling within factories, according to a report by O'Shea and colleagues (2014). The report states that government managed roads, storm water drains, rivers, and creeks, all of which discharge in Port Phillip Bay, are responsible for the more than 200 pellets per square meter found in local beaches, establishing a direct connection between factory and pellet pollution in this area. Mallinson and colleagues (2013) explain that it is unlikely the pellets in Port Phillip Bay came from the ocean, but rather that they are from deposits from industries along the Yarra River or major stormwater drain outlets. Confirming the origin of plastic pellets is extremely difficult and involves intensive identification processes.

Port Phillip Bay is an enclosed system covering 1930 sq. km., with an opening that extends for barely 3 km and connects it to the Bass Strait. Dr. Randall Lee, a senior specialist in EPA Victoria, estimated that due to the enclosed nature of the bay, pieces of plastics can stay in it up to 1.65 years (Lutman, 2014). Lee ran a simulation, taking into account the predominant currents, which showed that even though some microplastics left the bay, most did not, and circled around it. Unsinkable nurdles with a diameter of 2 mm were considered for the simulation, meaning that it did not take into account those that eventually sunk, and thus can be an underestimate. This study shows how this is a local issue in Port Phillip Bay since the litter present in it comes predominantly from the catchments, and it is isolated from the open ocean gyres.

2.4 Efforts to Address Microplastic Pollution

In January of 2006, the United States established the Marine Debris Act to "help identify, determine sources of, assess, reduce, and prevent marine debris and its adverse impacts on the marine environment" (Marine Debris Act, 2006). Under the Act, a prevention and removal program was created that would use mapping and impact assessments to help monitor marine debris and develop efficient methods for removal. The U.S. government recognizes the importance and threat of marine debris, and the Act serves as a model for legislative action for other countries to address prevention, mitigation, and removal. In Australia, however, there is no current legislation that directly evaluates or regulates microplastic pollution, though there are multiple plans, policies, and other efforts in place to address the issue.

The Victorian Environment Protection Authority (EPA) monitors the marine environment at three fixed monitoring sites in Victoria: Port Phillip Bay, Western Port, and Gippsland Lakes (Monitoring the Environment, 2016). The Victorian EPA collects and analyzes monthly samples to help determine water quality, including measurements of nutrients, clarity, oxygen content, and algae, metals. The Victorian EPA does not have regulations specifying microplastics monitoring, only general pollution of marine environments.

The Australian Department of Environment and Energy created Australia's National Waste Policy, which puts Australia on a track toward improved waste management and resource recovery by 2020. It strives to reduce the amount of waste generated, manage it, and determine proper methods for disposal and reusing (About the National Waste Policy, 2017). Under it, the Minister for the environment posts annual lists of classes of products they are proposing to consider for some form of regulation under the Product Stewardship Act of 2011 (About the National Waste Policy, 2017). This Act plays a legislative role in achieving the National Waste Policy's goals. Product stewardship is an approach to reducing the environmental and other impacts of products by suggesting or mandating that manufacturers, importers, and distributors take responsibility for the products they handle (Product Stewardship Act, 2011). Recently, plastic microbeads have been included on the list for Victoria. In other locations in Australia, leaders have used the Product Stewardship Act to ban microbeads and encourage other legislative actions to protect the environment.

Tangaroa Blue Foundation is a non-profit organization in Australia working toward removing and preventing marine debris. They created the Australian Marine Debris Initiative (AMDI) to help spread their efforts, which brings together volunteers for community clean-ups, finds solutions for preventing marine debris at the source, and works with industries and the government to encourage changes through policy and legislation.

Operation Clean Sweep is a global program that was introduced in Australia to strive toward the United States' industry goal of zero pellet loss. It was adopted in Australia in 2016 with funding from the Victorian Government's Litter Hotspot Program and with support from Tangaroa Blue Foundation and the Plastics and Chemicals Industries Association (Tangaroa Blue Foundation, 2016). Operation Clean Sweep is an industry program the United States developed to help prevent plastic resin pellets from escaping from industries into the environment. The appeal of this program is that it saves companies money through its vision of "zero pellet loss," it avoids fines, and helps protect the ocean (Tangaroa Blue Foundation, 2016). A few industry leaders in Victoria have already adopted the program, including Dow Chemical, Co-Ex Films, and Qenos, but the effort continues to get more participation. Under the program, there are specific guidelines to help plastic industries manage their operations to reduce pellet loss into the environment. The Operation Clean Sweep Australia Program Manual (2012) provides information on how to conduct a site audit, properly set up a work site, design training programs for employees, provides prevention, containment, and clean-up procedures, and other information regarding pellet spills that are helpful to industries handling plastics.

The Boomerang Alliance, managed by the Total Environment Centre, is another Australian non-profit organization focused on plastics in marine environments. The group focuses on raising public awareness, spurring public involvement, and bringing issues to the government level. They created a comprehensive plan, titled the "Threat Abatement Plan: Marine Plastic Pollution" with the ultimate goal of removing 70% of Australian plastic entering the marine environment by 2020 (West, 2016). It will be presented to every State, Territory, and Federal government in Australia to encourage its implementation. The Abatement Plan discusses the process of how plastics reach the ocean, provides estimates of how much plastic resides in Australian marine environments and where it is located, and addresses specific actions that need to be implemented, such as product bans and advance disposal fees. It also describes how microplastics are created and how they absorb pollutants, and then sets recommendations for actions by leadership roles in the country to address the problem (West, 2016). The Boomerang Alliance also led the campaign to Queensland's ban on plastic bags, which occurred in November 2016, following its ban in several other Australian territories.

2.5 Methods for Reducing Microplastic Pollution in Marine Environments

There have been several attempts to reduce the amount of microplastics entering marine environments. These attempts include various products manufactured by different organizations concerned with the health and protection of the ocean. Specifically, this section will discuss an artifact developed by the Rozalia Project organization, as well as a water wheel, and drain filters.

The Rozalia Project is an American organization striving to clean and protect the ocean. Apart from research, the organization has attempted to eliminate one of the sources of plastic pollution in the ocean by developing a mechanism for household washing machines. As mentioned earlier, they claim that over 81,000 microfiber pieces can come off of a single fleece jacket per wash, most of which ends up in the drainage system and eventually the ocean. To address this small portion of the global issue, the Rozalia Project developed "the world's first consumer solution to stop microfiber pollution," called a microfiber catcher (Rozalia Project, 2014). It is a simple and cost-effective solution that prevents plastic microfibers from clothing from escaping through drain water and ending up in the oceans. The Rozalia Project designed this catcher to be put into the washing machine along with laundry, as shown in Figure 5, where it will collect both microfibers and hair in the clothing during the wash.

Image supplied courtesy of Rozalia Project

Figure 5. Rozalia Microfibre Catcher (Rozalia Project, 2014).

Among the different attempts made in the United States to deal with plastic pollution in rivers, an interesting solution was implemented in Baltimore, Maryland. An old water wheel in the Jones Falls River was adapted to pick up trash from the river. The river's current provides power to turn the water wheel, which picks up litter from the water and deposits it into a dumpster. A solar panel array was installed on top of it which powers the wheel whenever there is not enough water current. Once the dumpster is full, a boat tows it away and brings in a new one. The Rozalia Project's actions and development of this mechanism are significant because although they are small changes, they are simple and can be replicated by others in order to make a greater and more global effect.

Another method developed to prevent microplastics and other debris from entering drainage systems and eventually the ocean are drain filters. ENPAC Corporation is an environmental protection company with the ultimate goal of managing pollutants and creating solutions to keep them out of the natural environment. The company created a product called the Storm Sentinel Catch Basin Insert that serves as a filter trap inside of a stormwater catch basin (Filus, 2009). The fabric allows water to penetrate, but traps almost everything else that enters the drain. The Storm Sentinel holds great amounts of sediment and other debris, and must be replaced every few weeks depending on how full it is. It is adjustable to the size of the drain, and has proven to be an effective means for trapping litter and small particles contained in runoff. It can be used on construction sites to keep pollutants in the wastewater from entering local water bodies, and also in catch basins near factories that handle plastic pellets in case of spillage.

A study conducted by the Australian Marine Debris Initiative (AMDI) investigated the local industry's contribution to microplastics in Port Phillip Bay (Ashton, 2013). They took surveys at various sampling sites (including factories, stormwater sites, and coastal areas), took photos, and collected the plastic pellets they found. The surveys found that several sites along the Yarra River, which discharges into Port Phillip Bay, had substantial amounts of plastic pellets littering the area surrounding the properties, including stormwater drains. It was determined that the plastic pellet pollution was a direct result of improper handling techniques (Ashton, 2013). Similar studies AMDI conducted in Perth, Australia, led to the direct involvement of the Department of Environmental Regulation. They determined that certain factories' plastic handling methods were causing plastic pellets to pollute the Swan River, and the Department required cleanups to be performed along with the implementation of mitigation strategies. These strategies included barrier fence and drain filters to prevent pellet spillage (Ashton, 2013). These studies show that monitoring plastic pollution can help instigate the improvement of industrial processes and human behavior that is potentially causing the issue.

2.6 Methodologies for Sampling and Understanding Microplastics

Microplastic pollution is an emerging global concern, and many methods have been developed in an attempt to understand its prevalence. The absence of a standardized methodology is a problem, because studies are incomparable to one another due to their different criteria. Locating microplastic pollution in marine environments involves studying three main environments: the sediment, the water column, and the sea surface (Hidalgo-Ruz, et al., 2012). There are three main sampling methods to collect microplastics for analysis: selective, bulk, and volume-reduced (Hidalgo-Ruz, et al., 2012). Selective sampling involves directly extracting items that are recognizable by eye inspection from the environment; these items are usually found on the surface of sediments. Bulk sampling takes the entire volume of a sample without reducing it during the sample process. It is effective when the items are not big enough to be recognized by simple eye inspection, and since the abundance is small and they are covered by sediment particles, it requires filtering. Volume-reduced sampling is when the volume of bulk is reduced during the sample, preserving only the part of interest. There are also several techniques to process microplastics, including: density separation, filtration, sieving, visual sorting, and separation (Hidalgo-Ruz, et al., 2012). Once processed using one of these methods, microplastics can be characterized by the following criteria: density (which affects degradation rates, surface characteristics, and shapes of microplastic particles), size fractions (sizes vary widely from study to study because there is no universal definition of what classifies as a microplastic), and morphological and physical characterization of microplastics (origin, type, shape, degradation state, and color). All of these factors help identify, quantify, collect, and examine microplastics.

A meta-analysis published by Hidalgo-Ruz and colleagues (2012) analyzed 68 different studies with regards to their methodologies and the criteria used in each. Forty-four of the studies involving sediment samples used seven different criteria. The criteria used in each study varied, thus results were difficult to compare. The authors found less variation in sea surface methods, with Neuston nets being the preferred tool in most cases. This type of net is designed to be dragged by a boat to skim the surface of the water. For water columns, Hidalgo-Ruz and colleagues identified two methods, and found that the majority of studies preferred the use of zooplankton nets.

With respect to the zoning of sediment samples, Besley and colleagues (2017) performed a meta-analysis of sampling methods used by different studies to define areas in the processes that need to be standardized. They found several variations in the sampling and extracting methods over the 22 studies analyzed, including sampling depth, beach zone, number of samples taken per

100-meter stretch, and extraction technique (separating the microplastics from the sediment). After investigating these sampling procedures, they concluded that the location of sampling on the beach - the inter-tidal zone (A), the high-tide zone (B), and the supralittoral zones 1 and 2 (C and D respectively), as seen in Figure 6 - did not influence the outcome of the results, and neither did the sampling depth. However, they recommended sampling from depths between 1 and 5 cm, which is the depth that most studies used, because samples from these depths remain comparable (Besley, et al., 2017). They also advise that a minimum of three repeated extractions are necessary to recover around 80% of the samples. Recognizing the variation across studies, Besley and colleagues developed a standard methodology to collect microplastics, feasible for any country, since it requires little use of sophisticated equipment. For this methodology, they define the size range for microplastics as 5 mm or smaller in diameter. They determine the sample size using a sample size calculator, and then take samples from the top 5 cm of sand using a 5 mm sieve on-site. They collect a minimum of 100 g of wet sand and leave it to dry for 48 hours at 60˚C. After the sand has dried, they extract microplastics using a fully saturated salt solution (358.9 g/L). To accomplish this separation, they dissolve 50 g of sand in 200 mL of the salt solution, stir at 600 rpm for 2 minutes, and then leave it to settle for more than 6 hours. Later, they filter it under a vacuum with pore filters smaller than 1 μm. They repeat the extraction three times.

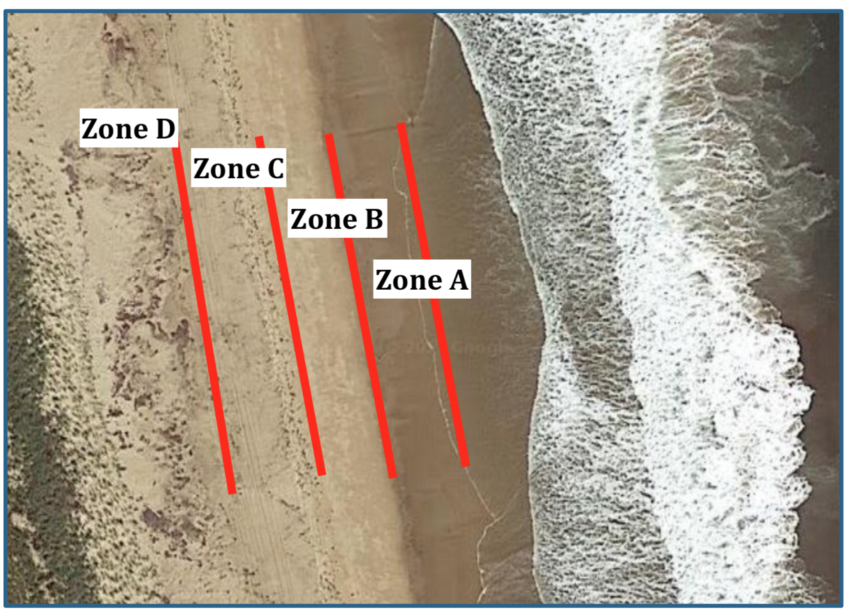

Figure 6. Locations of different beach zones where sampling is done

The predominant method for separating plastics from a sample is chemical separation. As described in the methodology proposed by Besley and colleagues (2017), a solution of NaCl was used in order to chemically separate the plastics from the sample. Most microplastics have a density lower than that of NaCl (1.2 g/cm3). That way, once the solution is applied to the sample, the elements with a density lower than that of NaCl float (the plastics), and those with densities higher (the sand) do not. Many of the 68 methods reviewed by Hidalgo-Ruz and colleagues (2012) used this solution. However, the solution does not extract plastics with a density higher than that of the NaCl solution, such as poly-ethylene, terephthalate, or polyvinylchloride (Claessens, et al., 2013). This presents a problem because these two polymers represent 18% of the European plastic demand, so they could represent a large proportion of the plastics present in the ocean. This issue could be resolved using a high-density chemical, such as NaI, which costs 70 times more than NaCl. In order to reduce such expenses, a process of elutriation was introduced in the extraction procedure. The elutriation column creates an upward water or air flow, separating the lighter materials from the sediment. This significantly reduces the volume of the sediment sample, as well as the volume of NaI needed by 97% (Claessens, et al., 2013).

The National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program is the United States federal government's resource for addressing marine debris. Authorized by Congress under the Marine Debris Act, this program has developed standardized methodologies for monitoring the amount of debris on shores and in surface waters (Arthur, 2012). The program's survey field guide covers two methods of shoreline studies (accumulation and standing-stock), types of data that can be collected with each, directions for how to perform the two studies, and data sheets to fill out during the survey to help assess the situation. The debris size range focused on in the studies covers litter at least 2.5 cm in diameter, whereas microplastics are defined as debris less than 5.0 mm in diameter. Survey techniques for smaller size ranges are less defined and in most cases not addressed, but microplastics are fragments of larger plastic debris, so such methodologies and assessments are still crucial for understanding microplastic mitigation tactics. The Marine Debris Program also addresses the main survey technique for floating debris, which involves boat trawls using Neuston nets to capture and analyze smaller debris sizes. NOAA provides a list of equipment needed, proper and most effective sampling techniques, and equations necessary to analyze the data (Arthur, 2013). The NOAA Marine Debris Program has illustrated the need for monitoring programs in order to compare debris sources, abundance, locations, movements, and impacts, and evaluate the effectiveness of any policies implemented to mitigate the issue (Arthur, 2012). Organizations around the world can model programs after it and replicate their standardized methodologies for assessing this type of pollution.

Ultraviolet or fluorescent light is one technique for examining collected sand samples. For this method, one views samples with a microscope with ultraviolet light. Under this form of light, anthropogenic debris will glow, whereas organic debris will not (Webster, 2016), thus presenting a useful method for detecting and studying microplastics in a sample.

There have also been attempts to sample and understand microplastics by studying their ingestion by marine organisms. An experiment conducted by the Marine Research Centre in Finland, mentioned previously, studied the impacts of microplastics on marine wildlife. In order to determine the amount of microplastics ingested by each organism, they had to dissect the creatures and use microscopy (Lehtiniemi, 2015). Other studies conducted to determine the amount of ingested plastics in marine wildlife have used similar techniques; euthanizing the organisms and then analyzing the stomach contents using microscopes (Peharda, 2012). Because of their small size, evidence of microplastic ingestion is currently limited to laboratory research. No studies have been found that are able to analyze microplastic ingestion with species that are still living.

2.6.1 Monitoring Techniques in Port Phillip Bay

International Pellet Watch (IPW) is a volunteer-based global program that monitors the existence of persistent organic pollutants (POPs) in plastic resin pellets. It attempts to improve the public's understanding of plastic pollution, where the plastic may end up, and how this in turn can affect humans. The IPW sampling technique is classified as "citizen science" because it is based on the actions of citizens; they collect pellet samples, provide information on the collection site, and send in their samples to the IPW. This means that the IPW's reports on the citizens' samples have to be both easy to understand and engaging to encourage further participation. IPW serves as a public database to hold all of the information sent in by citizens throughout the world. After gathering the information, IPW analyzes it and distributes an understanding of the data to the public.

Yeo (2015) used a series of case studies to explore how the IPW program can be used as a means for collecting data and educating the public on POPs and plastic pollution. One case study examined by Tangaroa Blue Foundation sent in several plastic pellet samples from different locations to analyze the abundance of pellets by location and the content of POPs and other pollutants. Higher concentrations of pollutants were found in samples from urban harbors like Port Phillip Bay in Melbourne due to the industrial bases and heavy infrastructure (Yeo, 2015). Tangaroa

Blue Foundation then used IPW data to encourage policies and legislation regarding the handling of pellets and support campaigns on the issue. This study provides an example of how private organizations have used data results posted by the IPW to make a difference.

A study conducted by the Port Phillip EcoCentre in 2014 attempted to determine the amount of microplastics flowing into Port Phillip Bay from the Yarra and Maribyrnong Rivers. Neuston nets were used for trawling items on the surface of the water. The results estimated that these two rivers dumped 586,920 and 501,510 plastics per year into the bay, respectively. These numbers are likely an underestimate, since the calculations were limited to the width of the trawling net (600mm wide), while the width of the rivers are about 160 times that width. Apart from that, the tidal movements, localized currents, and prevailing winds were not considered, nor were other bodies of water that flow into the bay (Blake and Charko, 2014).

That same study focused also on the issue of nurdles, plastic pellets used as raw material in the manufacturing of plastic products, in several beaches in the bay area. The study concentrated on picking up nurdles from the high-tide line or from nurdle hotspots, places where nurdles have been deposited for a long time, brought there by the wind. Nearly 40,000 nurdles were collected during 11 months over 89 sampling sessions (Blake and Charko, 2014). A similar study involving volunteers at the Port Phillip EcoCentre examined nurdles in the bay using the same methodology mentioned above. They compiled their findings, including date, location, search area, and amount of nurdles, in a report. This report explained the variability in nurdles' locations could be due to wave patterns and tidal motion (Maillard, 2013). It provided a Victorian EPA model (Figure 7) which shows the percent of relative exposure to microplastics in different areas of Port Phillip Bay using catchment inflows, rainfall, evaporation, and tides. The report provides a baseline for continuing to collect data on microplastics in Port Phillip Bay by finding the most effective collection techniques.

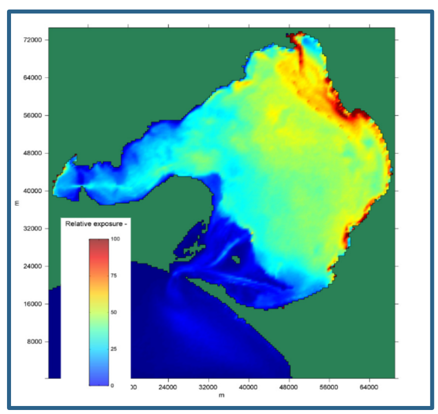

Figure 7. Victorian EPA Model shows estimated concentration of nurdles across Port Phillip Bay (Maillard, et al, 2013)

Another technique to examine sand samples for microplastics is the use of ultraviolet or fluorescent light. A St. Kilda news article discusses the interest of citizen scientists in investigating microplastics in Port Phillip Bay. During an information session held by the EPA Victoria's Citizen

Science team, people viewed sand samples with a microscope under ultraviolet light to study the microplastics. The microplastics "glowed eerily" under this form of light, which helped the public detect them in the samples (Webster, 2016). A study conducted by Shim and colleagues (2016) attempted to analyze microplastic samples by staining them with Nile Red, a fluorescent dye, and then viewing them under a fluorescence microscope. When a sample of sand was viewed using this method, microplastics in the sample would glow under a microscope after NR staining, whereas organic debris, such as plant remnants, sand particles, and crustacean creatures would not show up at all (Shim, et al., 2016). Although it is a complex process, this method is helpful because it provides a scientific technique and model to detect microplastics in samples and study them in Port Phillip Bay.

2.7 About the Port Phillip EcoCentre

The Port Phillip EcoCentre strives to reconnect the local community to the natural world through inspiration, education, and facilitation of practical action. People visit the EcoCentre to engage with community environmental projects, find out about sustainable living practices, attend workshops, and gain meaningful learning experiences. A list with descriptions of several programs run by the EcoCentre can be found in Appendix A.

The Port Phillip EcoCentre runs a Corporate Volunteer Program to engage members of the community in their activities. This program allows companies to fulfill their corporate social responsibility aspirations (Port Phillip EcoCentre, 2016). All proceeds support further marine and ecological research at the EcoCentre. The program called Marine Biologist for a Day involves the above microplastic beach audit method. Members of the EcoCentre staff lead corporate groups in a few types of marine biologist activities, one being performing the beach audit method at St. Kilda Beach. The work done by these volunteers helps the EcoCentre collect data from the litter audits and other surveys performed during the day and provide the local and state government with solid evidence to inform litter reduction strategies (Port Phillip EcoCentre, 2016).

The Port Phillip EcoCentre is also involved with the long-term effort to monitor microplastic pollution. Neil Blake, the Port Phillip Baykeeper, designed the Baykeeper Beach Litter Audit, and it was recently adopted by the State of Victoria. This method to collect microplastics uses selective sampling, which involves picking up litter in the sand along the beach and collecting data on the type and size of each piece. Its methodology is similar to that of other litter monitoring techniques, but it places more focus on the collection of microplastics and smaller debris rather than larger pieces of litter. This method includes a more descriptive breakdown of different categories of litter to include specific forms of microplastics and other debris not accounted for in other methods. It also collects debris solely from the surface of the sand.

Scout groups are also involved with the EcoCentre and the Baykeeper Beach Litter Audit. The Scout Movement is a movement to support the mission of making the world a better place to live in and leaving it in a better condition than how they found it. Scouts are divided into several age groups, all of whom live by these principles. In Australia, Venturers are classified as Scouts 15-18 years old (S. Perkins, personal communication, March 29, 2017). They can work to earn badges in several different skill groups that contribute to their personal growth. There are 150 Scout groups located around Port Phillip Bay (G. Perkins, personal communication, March 29, 2017). The Bayside Brighton Troop is one of the largest troops in this area, with over 220 members. A few of Venturers in this troop are in contact with the Port Phillip EcoCentre to earn badges by volunteering to perform the Baykeeper Beach Litter Audit.

2.7.1 Citizen Science

The Port Phillip EcoCentre bases many of their activities on Citizen Science. Citizen Science projects use volunteers, collaboratively with professionals in the science field, to collect and analyze data relating to the natural world. This type of project is done through five main steps. First the team of professionals must scope out the problem. Next, they design a project and build a community to address the problem. Building the community requires engaging and recruiting its members as volunteers. Then the professionals work alongside the community members to manage the data that was collected and sustain or make improvements to the project (Federal Crowdsourcing and Citizen Science Toolkit, 2016). Citizen Science projects usually include improving the economic livelihood of people and the community. Most of the activities and programs done by the Port Phillip EcoCentre are examples of this practice.

CHAPTER 3. METHODOLOGY

This project was intended to help the Port Phillip EcoCentre establish a long-term monitoring program to track microplastic pollution in Port Phillip Bay. This program will provide a tool for management in the bay for the next 50 years that is supported and maintained by the community. We trialled the Baykeeper Beach Litter Audit at preselected audit sites around the bay to assess its validity and evaluate its strengths and weaknesses. Based on our assessment, we developed an implementation plan for each audit site, and then created an instructional video that showed how to perform the audit. Finally, we recruited volunteers and raised awareness about the issue in the community through outreach and education.

We worked on this project from March 10th, 2017 through May 3rd, 2017. We hope our work with the EcoCentre will influence and educate the surrounding Port Phillip Bay community on the importance of addressing microplastic pollution and encourage them to participate in such efforts.

To establish a long-term monitoring program for microplastic pollution in the bay, our team developed the following objectives:

1. Understand the Port Phillip EcoCentre's values and goals.
2. Understand the different perspectives on microplastic pollution in Port Phillip Bay.
3. Trial and assess the Baykeeper Beach Litter Audit and determine implementation protocols at each pre-selected site around the bay.
4. Analyze preliminary data on the distribution of microplastics around the bay.
5. Prepare outreach and instructional materials to ensure consistent implementation by citizen scientists.

3.1 Understand the EcoCentre's Values and Goals

Our group had to understand the Port Phillip EcoCentre and its values in order to successfully contribute to the organization's efforts. It was important to understand these values so we could exemplify them while representing the EcoCentre within the different communities we worked in.

After acquiring general information about the Port Phillip EcoCentre through our sponsor's original project letter, we opened up personal communication with members of the staff. This communication was the basis for discussing the EcoCentre's values, goals, and thoughts regarding microplastic pollution in the bay.

While on site, along with engaging members of the EcoCentre staff in discussions revolving around previously prepared questions (Appendix C), we also participated in some of the EcoCentre's programs and activities to gain first-hand experience with their working environment. This helped us form a complete perspective on the EcoCentre's purpose within the Port Phillip Bay community.

During our first week in Melbourne, we also presented our background research and proposed our research plan to the EcoCentre. This initiated further discussion with our sponsors, which resulted in new ideas that helped us align our goals with those of our sponsors.

3.2 Understand the Different Perspectives on Microplastic Pollution in Port Phillip Bay

An initial step to address the issue of microplastics was to understand its context in Port Phillip Bay. Apart from our initial conversations with the Port Phillip EcoCentre, we acquired further insight on this topic by interacting with other stakeholders to gain a more complete vision of the problem in the bay. These groups included locals, tourists, beach goers in general, environmental organizations, and experts in the environmental field.

Our team used convenience sampling to take surveys (see Appendix D) of several of these stakeholder groups in the Port Phillip Bay community to gauge their awareness of microplastic pollution. The stakeholders we targeted for our surveys included locals, tourists, fishermen, and beach goers in general. We developed this survey using Google Forms, and then used tablets to obtain the responses. We gathered information on the following topics: demographics, their awareness of microplastics and microplastic pollution, the main sources of microplastic pollution in the bay, and the impacts of microplastic pollution both on the marine environment and on individual stakeholder activities.

We experienced a few limitations and challenges while collecting the survey responses. First, we were surveying along St Kilda Beach, which is a tourist destination, during work hours. This meant a portion of our results were from tourists and unemployed members of the community which presented a limitation in reaching an accurate representation of the entire Port Phillip Bay community. Another possible explanation for skewed survey results was the difficulty in surveying runners and bikers along the beach. Walkers and sunbathers were easier to survey; therefore more results were recorded from people involved in those activities. Another group of people who were difficult to survey were the fishermen. Seven of ten fishermen were not willing to take the survey because they did not want to be disturbed or were busy. It is also important to note that these fishermen were all recreational. Currently, this is the only type of fishing allowed in Port Phillip Bay due to a plan established by the Labor Government in Victoria to completely ban commercial fishing by 2022. Another challenge we faced was communication. Some of the fishermen and tourists we tried to survey spoke little English, so dialog was difficult.

We also interviewed several stakeholder groups to expand our knowledge on the different perspectives on microplastic pollution as well as actions that have been taken to address the issue (Table 1). Interviewing members of the EcoCentre staff led us to other contacts that provided us with more valuable information on our project (in a manner of snowball sampling). We developed interviews to target the individuals and organizations that the EcoCentre directed us to (Appendix E).

Table 1. Interviewee List

Interviewee	**Position**	**Interview Location**
Donna Shiel	Litter Champion - Water and Resource Recovery division	Sustainability Victoria office
John Forrester	Werribee Riverkeeper	Werribee South Beach
Peter Smith	Friends of Williamstown Wetlands Member	Wader Beach
Judith Muir	Owner Operator and Marine Educator at Polperro Dolphin Swims	Rye Beach
Sam and Greg Perkins	Venturer Scout and Scout leader	Port Phillip EcoCentre
Heidi Taylor	CEO of Tangaroa Blue Foundation	Port Phillip EcoCentre

3.3 Trial and Assess the Baykeeper Beach Litter Audit and Determine Implementation Protocols at each Pre-Selected Site around the Bay

The Baykeeper Beach Litter Audit, designed by Neil Blake, the Port Phillip Baykeeper, is a technique to sample and collect microplastics on the beach. It uses selective sampling, which involves picking up litter in the sand along the beach and collecting data on the type and size of each piece. Permanent landmarks are used to keep locations consistent from study to study, and litter is collected in three one square meter quadrats along each transect from these landmarks to cover each beach zone (Figure 8).

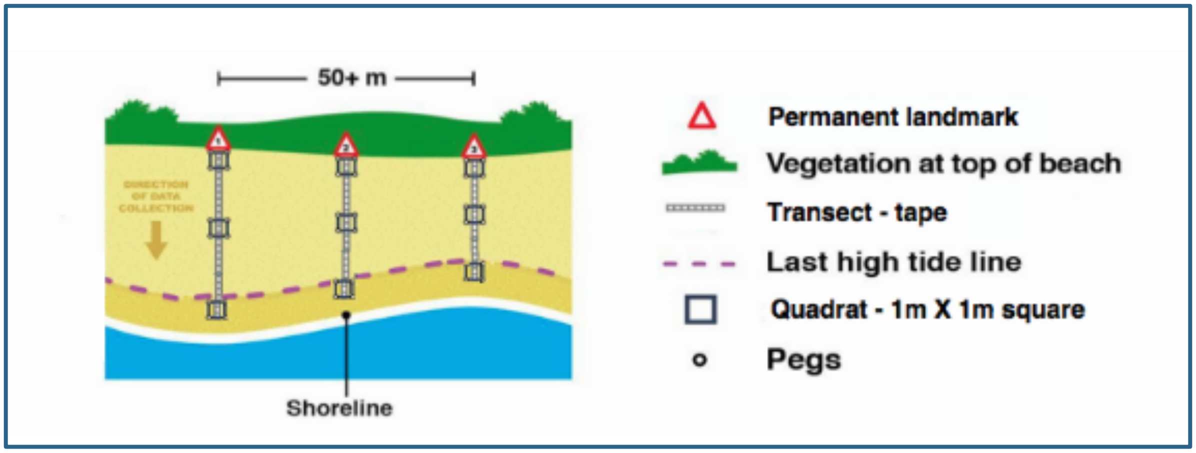

Figure 8. Port Phillip Baykeeper Beach Litter Audit

Before going out in the field to trial the Baykeeper Beach Litter Audit, we took care of the logistics involved. We set up dates with Neil to visit each of the nine different audit sites around the bay, determined transportation, and acquired the necessary equipment. In order to implement, trial, and assess the Baykeeper Beach Litter Audit systematically, we took the following steps:

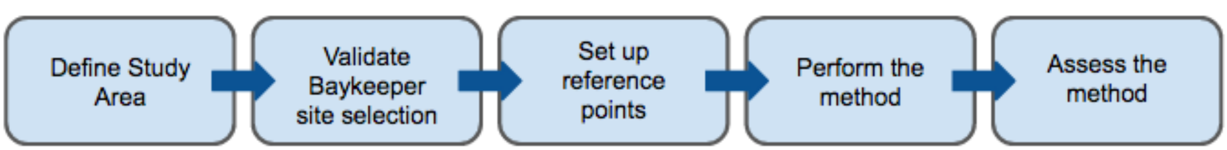

Figure 9. Flowchart for objective 3.3

3.3.1 Define Study Area

Nine beaches around Port Phillip Bay were chosen to perform the Baykeeper Beach Litter Audit (Figure 10). This selection was based on the locations of waterway entries from rivers and creeks into the bay, the pattern of the tidal current, and the direction of the winds. The tidal currents follow a clockwise flow through the bay, and the audit beaches are located to the east of the waterway entries, since they are the most likely to receive the debris coming from these rivers and creeks. There are twice more audit sites on the east side of the bay because of this clockwise current and the predominant southwest winds which push the microplastics to this side.

The first of these nine beaches is St. Kilda West Beach. It is the first beach to receive the sediments and debris from the Yarra Plume, one of the biggest influxes of water into the bay. This made it an important location in that it is the first place in the bay where all the debris coming from the river can settle. Following up the clockwise tidal currents in the bay, Point Ormond is the next audit beach, located just south of Elster Creek and receiving its contents, as well as those from the Yarra Plume that were not deposited on St. Kilda West Beach. The third beach is located in Seaford, near Keast Park, which receives the influx of litter and sediments from the Patterson River. These three beaches are oriented towards the north west. Because of it, the southwest winds will aid the tidal currents in pushing the litter straight towards their shores. The beach at Frankston is further south, near the mouth of the Kananook Creek. Then there is Mt. Martha Beach, near the Balcombe Creek. The final beach on the east side of the bay is Rye. It does not have any body of water coming out, but it was selected for being the southernmost beach in the bay, and to get a representation of the distribution of plastic on that part of the bay. Another reason that Rye Beach was chosen is that during winter, weather patterns change and the predominant winds are north winds, which would be pushing a good amount of litter to the south end of the bay.

Moving west from St. Kilda West Beach is Wader Beach. Wader Beach is located in Williamstown next to the Kororoit Creek and Paisley-Challis drain, which correspond to two waterways that flow into the bay. We decided that Wader beach will no longer be considered as an audit site due to hazards, such as limited access, long vegetation, and tiger snakes. Werribee South Beach is the next beach moving counter clockwise from Wader Beach and the flow of water coming into that part of the bay comes primarily from the Werribee River. Finally, Geelong's Eastern Beach corresponds to the furthest audit side in the west side of the bay. It was chosen because it is a secondary bay within the Port Phillip Bay that could potentially capture litter.

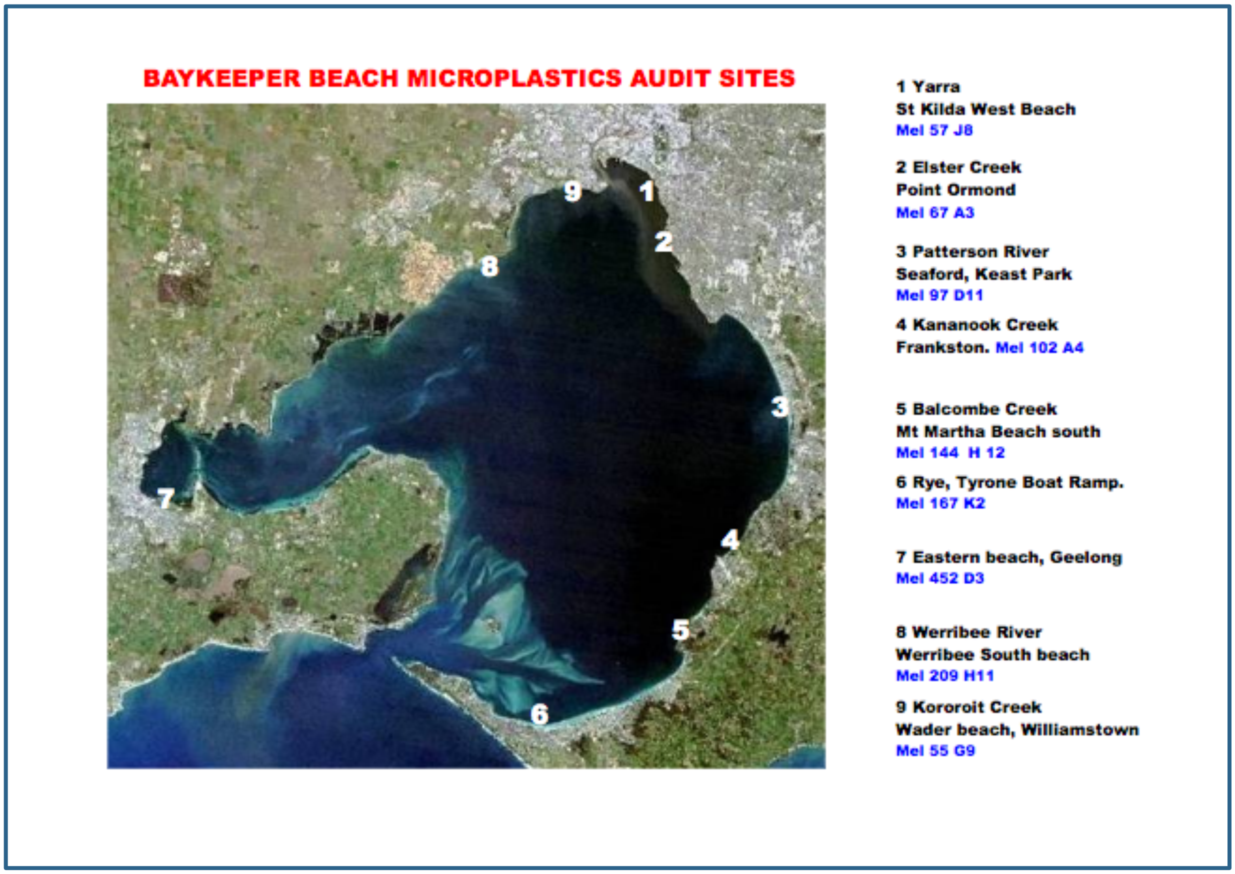

Figure 10. Port Phillip Baykeeper Beach Litter Audit sites

3.3.2 Validate Baykeeper Site Selection

When we visited the nine sites, we had to determine if they were each viable for performing beach litter audits. To do so, we considered the accessibility and hazards for each site. Here, we took into account any factors what would either prevent or challenge our ability to access the audit sites. Additionally, we evaluated the hazards encountered to validate the feasibility for performing the beach litter audit at each site. Hazards and accessibility were critical factors to consider and analyze because they affect the ability of others to conduct future audits.

3.3.3 Set Up Reference Points

Since we were the first group to perform the Baykeeper Beach Litter Audit at each of the sites, our work established a baseline for these audits to continue. We determined the reference points to ensure that the method will be performed consistently so results are comparable from study to study.

To establish the reference points for each site, we first determined the widest and narrowest sections of the beach. The widest section correlated with an area of beach that contained the longest distance from the top of the beach down to the shoreline. The purpose of creating a transect on the widest section is to cover all of the different conditions on the beach, including sand, rocks, and vegetation. The narrowest section of the beach represented a section of beach containing the shortest distance from the top of the beach to the shoreline. The purpose of creating transects on the narrowest section is to survey the area of the beach most exposed to water action. The midsection was located in between the widest and narrowest sections. Transects, lines from the top of the beach to the high-tide line along which recordings are made, will be located within each of these three sections (refer to Figure 8 for transect setup).

Once the beach's widest, narrowest, and middle sections were located, we determined corresponding landmarks to serve as reference points for each transect line. These landmarks were permanent structures located beyond the top of the beach. The transect lines for the widest, middle, and narrowest beach sections would be located in line with the corresponding permanent landmark and follow the path of shortest distance from the top of the beach to the shoreline. These reference points were recorded and will be used for all future audits to ensure data is comparable from study to study.

Once we established transect lines, we took the compass directions that follow their path to the shoreline. These compass directions were recorded and will be used for all future audits until it is determined that the shoreline has significantly changed as well as the path that gives the shortest distance from the top of the beach to the high-tide line. In this case, new compass directions from the permanent landmarks will be determined and recorded.

3.3.4 Perform the Baykeeper Beach Litter Audit

At each of the validated sites, we performed the Baykeeper Beach Litter Audit (Appendix F) with instruction from Neil. The setup to perform this method involved locating the landmarks at three specified transect locations along the beach, taking measurements at each transect, and marking one square meter quadrats at the high-tide line, top of beach, and the midpoint of these for each transect. Performing the method consisted of searching the surface of the sand within each quadrat for inorganic material, collecting, and recording each piece of litter on the Data Sheet (Appendix G).

3.3.5 Assess the Baykeeper Beach Litter Audit

After performing the Baykeeper Beach Litter Audit at the audit sites in Port Phillip Bay, we assessed its implementation. For this, we analyzed our experience at each beach separately by making observations of what worked well and what did not. We also synthesized our assessment of the individual audits to determine key strengths, weaknesses, opportunities, and threats of the method in general. We combined these characteristics into a SWOT analysis after we performed the method at several beaches. While making the SWOT analysis we considered the following:

- Ease of implementation
- Understandability of method
- Ambiguity in interpretations of method
- Impact on the community
- Hindrances on the application of the method
- Factors that could skew our results
- Time to perform

This method is expected to be ongoing, performed on a monthly basis; therefore, it is important to consider all factors that play a role in its application. We considered the above in our analysis because they each have the potential to affect how the methodology is interpreted, implemented, and its ability to be performed successfully. This method not only needs to be performed correctly, but it also needs to be simple and engaging in order to have consistent volunteers willing to perform it.

These considerations also allowed us to validate the use of the Baykeeper Beach Litter Audit for each site. To validate the method, we used our experiences implementing it to determine any parts that needed clarification. We based this on two considerations: first, ensuring that the method would be considered scientifically rigorous enough to provide consistent, valid data and clear, irrefutable conclusions; second, the understandability of the method among different audiences.

These considerations led us to recommend clarifications and modifications to the method in order to ensure its users would collect valid data and to remove any ambiguity in its interpretation.

Our assessment of the Baykeeper Beach Litter Audit was an important part of the initial implementation because it helped us set up the foundation for developing a long-term monitoring system in Port Phillip Bay.

3.4 Analyze Preliminary Data on the Distribution of Microplastics around the Bay

The information we gathered by performing the Baykeeper Beach Litter Audit represented the first data collected, therefore no conclusions could be drawn based on it. Nevertheless, we developed a preliminary data analysis that serves as a baseline to look for specific patterns and behaviours in litter distribution as more data is collected in future audits. For this, we organized the data gathered from the audit sites in tables and then sorted it in different ways to generate hypotheses for future analysis.

3.5 Prepare Outreach and Instructional Materials to Ensure Consistent Implementation by Citizen Scientists

In order to establish a long-term monitoring plan for microplastics and other litter in Port Phillip Bay, we had to develop outreach and instructional materials. These materials were necessary to get Scouts and other community members interested and involved in the Baykeeper Beach Litter Audit and then show them how to perform the method. The materials included an instructional video showing how to perform the method, information sheets to explain the specifics of each site, and a promotional flyer to inform and recruit Scouts to perform the Baykeeper Beach Litter Audit around Port Phillip Bay.

3.5.1 Create Information Sheets for Each Audit Site

In order for other groups to perform the Baykeeper Beach Litter Audit, we developed information sheets with specific information for each audit site (Appendix H). Here, we included accessibility details, hazards and additional comments corresponding to each site. Additionally, we added detailed instructions and images to locate the reference points for each of the three transects. To develop these information sheets we used a template provided by the EcoCentre and modified it in Microsoft Word to get an appealing format that would be easy to read and understand. Then, we filled the sheets with the information collected at each beach and created a table of contents at the beginning to access each beach sites' information. The purpose of this deliverable is to allow anyone interested in performing the audit method to be able to easily retrieve the information from each beach site.

3.5.2 Create an Instructional and Engaging Video Explaining the Beach Litter Audit Method

After trialling and assessing the Baykeeper Beach Litter Audit, we developed a short video containing instructional and engaging footage on how to perform the method. The purpose of this video was to summarize the methodology and show how to replicate it, displayed in ways that are easily understood by anyone viewing them. The target audiences for the video are members of the Port Phillip community, our sponsors at the EcoCentre, volunteers, and anyone else interested in microplastics and their sampling methodologies. In order to complete this video, we collaborated with Neil Blake to learn about the logistics involved with methodology videos targeting the public, because of his background experience with a similar project.

3.5.3 Create Promotional Flyer to Inform and Recruit Scouts to Perform the Beach Litter Audits Monthly at the Preselected Audit Sites around Port Phillip Bay

Venturer Scouts within the 150 groups around Port Phillip Bay were the predetermined target population for performing the Baykeeper Beach Litter Audits on a regular basis. They represent a suitable group to rely on for continuous application of the audits because of their commitment to the environment and their constant engagement in volunteer work to both obtain badges and make the world a better place. The large number of Scout groups around Port Phillip Bay in Victoria also makes them readily available to perform this task.

We designed a promotional flyer to make the scouts aware of the opportunity to engage with the Baykeeper litter audits and partake in efforts to clean the bay. In order to determine contents of the flyer that would appeal to the Scout groups, we first researched the Scout Movement to get a basic idea of Scouts' values and priorities. Then we interviewed a Scout leader and a Venturer Scout from the Bayside Brighton Troop who were already partnered with the Port Phillip EcoCentre due to their interest in performing the beach litter audits. The interview was semi-structured to generate a conversational flow (Appendix I). Through the interview, we obtained further information on Scouts in general, learned about specific Scout activities in the Port Phillip Bay area, and obtained ideas on how to get other Scouts involved. Through this interview, we determined the major components of the flyer in order to best target the Scouts, captivate their interest, and get them to participate.

CHAPTER 4. FINDINGS

This chapter discusses the findings from the following: surveys with beach goers on microplastics awareness, interviews with experts in the field, the implementation and trialling of the Baykeeper litter audit method, and the data collected from performing the method.

These findings served to help the Port Phillip EcoCentre understand different perspectives on microplastic pollution in the bay and the actions being taken by other organizations, along with the impact and progression of the Baykeeper Beach Litter Audit.

4.1 Perspectives on Microplastic Pollution

In order to understand the different perspectives on microplastic pollution in Port Phillip Bay, we conducted both surveys and interviews depending on the stakeholder.

We took convenience samples for our surveys, walking along St. Kilda Beach to find members of the public who were willing to participate. The stakeholders we got perspectives from through surveys included tourists, locals, bikers, swimmers, and other beach goers. The surveys were geared towards gauging general awareness of microplastic pollution in the Port Phillip Bay community.

We also conducted interviews with the specific contacts the EcoCentre provided us with. The interviewees included individuals who were already immersed in the issue of microplastic pollution in some way. The interviews were geared more toward the particular involvement of each individual with microplastics. While conducting interviews, the team listened closely to the stakeholders' answers and took notes to highlight the important responses. These interviews were beneficial to the progression of our project. Each individual interview was summarized and is shown in Appendix J.

4.1.1 Surveys

We successfully recorded 102 surveys and were able to draw certain conclusions based on the results. We collected information related to the surveyees' knowledge of microplastic pollution. Stakeholders' responses are reported below. The pie charts and the coding of responses revealed the need to target and educate the community on the issues of microplastic pollution.

Among the surveyees, 48% did not know what microplastics were when initially asked (Figure 11). However, many of them (including surveyees that initially replied no) had an idea of what they might be. Most were aware of plastic pollution in the bay, and once we explained that plastics break down into microplastics, they reasoned that microplastics are a type of pollution in the bay. This presents a barrier to the citizen science aspect of our project because it shows the current understanding of the issue within the Port Phillip community. In order to get the community involved in the long-term monitoring program, we first will have to spread awareness and expand public knowledge of the topic.

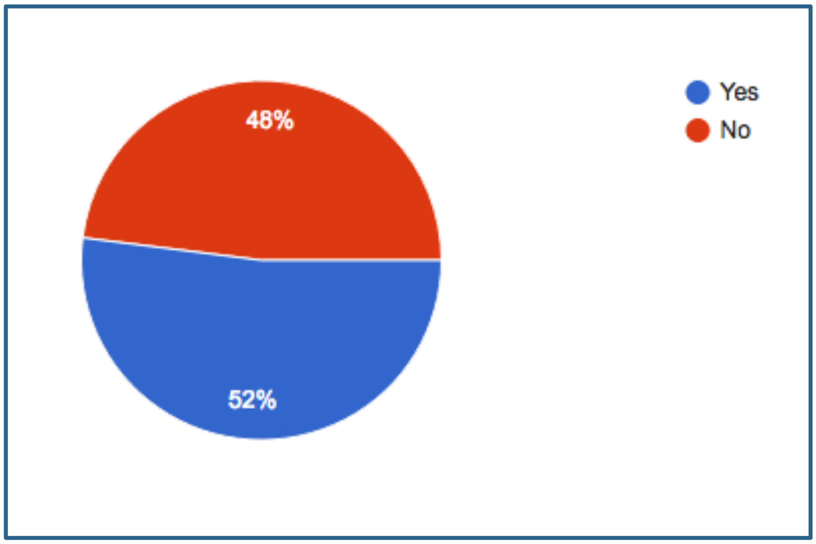

Figure 11. Responses to "Have you heard of microplastics?"

When asked about the sources of microplastics, 37.3% of the surveyees answered that they were aware of what these were (Figure 12). Then, we asked this group to list the sources of microplastics and the majority of them listed broken down plastic and hygiene products. More specifically, 50% of all the mentions involved broken down plastic coming from plastic bottles, plastic bags, plastic toys and/or plastic containers. On the other hand, hygiene products and toiletries such as exfoliators, face scrubs and toothpaste comprised 35% of the mentions. Rubbish was also referenced as a source of microplastic with 10% of mentions. Moreover, an important note from these responses is that only one person (2%) mentioned industry as a source of microplastics. This is relevant because industry is the principal source of nurdles, which from our research and experience so far are one of the most prevalent types of microplastics around Port Phillip Bay. Similarly, only one person (2%) mentioned clothes as a source, which is where microfibers come from. This might also point towards a lack of information and knowledge regarding alternative sources and types of microplastics.

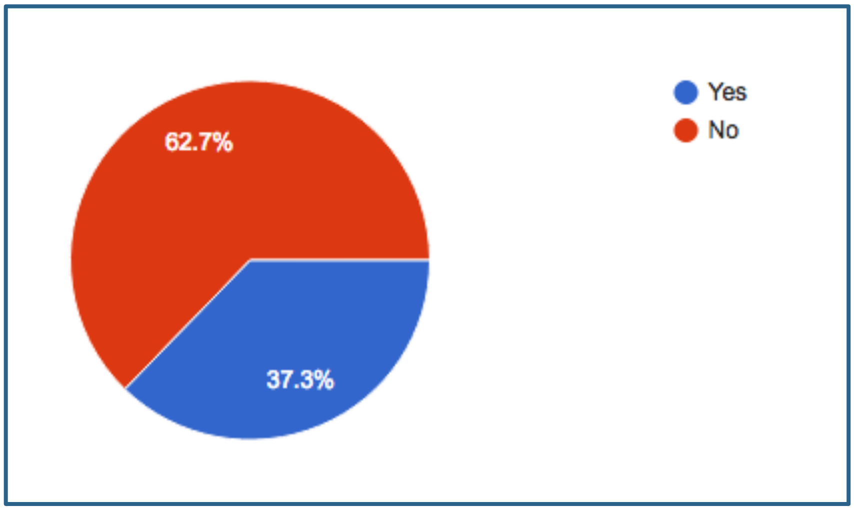

Figure 12. Responses to “Do you know any of the sources of microplastic pollution?”

The next question focused on the effects and consequences of microplastic pollution. Here, the majority of the surveyees listed negative impacts to the marine environment by mentioning the ecosystem, the sea life and certain marine animals. Out of all 58 mentions, 42 were related with the marine environment. Another significant topic, with 8 mentions, involved the toxic build up and biomagnification that can be caused by the size and durability of microplastics. These mentions included microplastics entering the food chain and potentially being consumed by humans. Finally, rubbish accumulation comprised the 8 remaining mentions. Overall, these three major topics correspond to the most visible effects of microplastic pollution.

4.1.2 Interviews

While only 52 percent of the individuals we surveyed knew what microplastics were before taking the survey, the individuals selected for interviews had prior knowledge of microplastic pollution and were involved with it in some way. However, the ways in which the interviewees first became aware of microplastic pollution varied. Donna Shiel from Sustainability Victoria, Judith Muir from Polperro Dolphin Swims, and Heidi Taylor, CEO of Tangaroa Blue Foundation, first learned about microplastics through their exposure to environmental problems due to their occupation. Donna Shiel had many interactions with experts in environmental fields because of her position at Sustainability Victoria, one being the Port Phillip Baykeeper, Neil Blake. Donna already knew about the impacts of litter, but she explained that her conversation with Neil showed her that microplastics were a huge issue in Port Phillip Bay. Donna was also exposed to various social media articles and reports that expanded her knowledge on microplastic pollution. Judith Muir also found out how significant microplastic pollution was in Port Phillip Bay from Neil Blake. He spoke at a conference she attended and sparked her interest in the issue. These two examples show how important word of mouth is in spreading awareness of an issue in a community and getting people interested. Heidi was a scuba dive instructor, and therefore felt a significant connection with the ocean. Through this platform, she was exposed to and concerned about plastics in the ocean. She described an experience when she picked up a plastic water bottle and watched it break into a million smaller pieces in her hand. This shows how strong a visual experience can be to encourage someone to take action on an issue.

Sam Perkins, a Venturer Scout, became aware of microplastics through his involvement in the Scout Movement and his efforts to earn awards for work in the environmental area. He is currently performing beach litter audits with the Baykeeper method to work towards these awards, and he became aware of microplastic pollution through this involvement. John Forrester was also exposed to the issue through his involvement with environmental issues and water quality management as the Werribee Riverkeeper.

Although the interviewees learned about microplastics in different ways, they all became interested in the issue and remain passionate about it because of their personal values. Scouts strive to leave the world in a better state than which they found it, Judith classified herself as a "compulsive picker-upper" who has always valued a clean environment as well as working with an organization that revolves around conservation efforts for dolphins, Heidi is generally concerned with the ocean's well-being, Donna has always considered litter a vast problem, and John applied for the position as a Riverkeeper because of his desire to protect the waterways. They all pursue a similar lifestyle in and outside of work that values the environment, and this is what makes them enthusiastic about addressing microplastic pollution.

The interviewees then described to us the actions they've taken and/or are currently taking to address the issue. Although there is a similar motive of protecting and keeping the environment clean among them all, their efforts regarding microplastics differ. First, Sustainability Victoria is implementing a project that collects microplastics and sand samples from six beaches. These samples will be analyzed through lab work and the data will be presented in reports that the organization will use as evidence to persuade the Victorian Government to fund further research and create policies regarding microplastic pollution. Tangaroa Blue Foundation developed the Australian Marine Debris Initiative, under which they created a litter collection system similar to the Baykeeper Beach Litter Audit. However, the AMDI data sheet does not concentrate on types of microplastics, and has a different breakdown of categories of litter in general. Anyone can participate in AMDI litter collection program and submit their data into the database. Currently, Tangaroa Blue Foundation is working with Sustainability Victoria, the EcoCentre, and scientists to develop a database that includes microplastics.

The Friends of Williamstown Wetlands also partake in beach sampling, but it is more of a beach clean-up style rather than to push legislative action. Judith is simply trying to lead by example when she picks up the litter she sees on beaches. Sam Perkins is working with the Baykeeper Beach Litter Audit to earn a Scout badge, and we aim to use his example to encourage other Scouts to participate in the audit and achieve similar awards.

As shown from the interviews, there are many ways to network in order to spread knowledge on an issue. Networking can be done amongst organizations, as with the Victorian Litter Action Alliance and other programs where organizations meet to discuss and collaborate on projects. Networking can also be done in a different form of professional setting like a conference open to the public, like the one Judith heard Neil Blake speak at, where current projects for the area are shared. It can also be accomplished in a community setting, as when the Scouts tell and teach other Scouts about a project to get them involved, or the Friends of Williamstown Wetlands hold programs for families and community members to engage in environmental projects.

Another theme that we picked up during the interviews was the importance of community initiatives. John Forrester coordinates community involvement in waterway protection in Werribee, such as organizing activities for families to participate in such efforts. The Friends of Williamstown Wetlands is a community group and all of their activities and programs need the participation of the community to be successful. Many Scout activities revolve around the community, and most of their work helps the community in some way, therefore they have a direct impact on the community. Sustainability Victoria is more involved with organizations and the government rather than having direct connections with the community and its members. However, their ultimate goal is to spread awareness of their activities and efforts to their broader stakeholder group (beyond organizations to the actual community members). Tangaroa Blue Foundation is also working to establish a web application for the AMDI litter collection database to target the modern community better.

4.2 Implementation of the Baykeeper Beach Litter Audit at Each Study Site

We travelled to the preselected audit sites (Figure 10) to perform the Baykeeper Beach Litter Audit. At each of these beaches we identified hazards, assessed accessibility, determined reference points, and reflected on our experience with the method. These tasks were important to the citizen science aspect of the project because they helped us establish the plan for members of the public to engage with and participate in the long-term monitoring program.

An important task was identifying reference points to mark the widest, middle, and narrowest sections of the beaches. Several factors influenced our decision of where to locate each transect within each of these sections of beach. Ideally, the narrowest section transect should be located at a walkable distance from the widest section transect to keep auditors engaged. Therefore, we used a range of 100-300 meters between these two transects. Next, reference points were chosen in locations so that the respective transects would not interfere with common footpaths. Finally, the landmarks used for reference points needed to be permanent and easily recognizable by future auditors. To use the reference points we established to implement the audit, volunteers should stand at the top of the beach, in line with or at the permanent landmark (depending on how far beyond the beach it is located), and take the compass direction at this point. The compass direction should ideally create a path of shortest distance from the top of the beach to the shoreline.

With the information recorded in tables 2-9 below, we established the baseline at each site for future audits. The content displayed in the tables represents an analysis of the individual audit sites. After visiting all of the sites, we were able to identify common hazards, complications, best practices, and develop a SWOT analysis for performing the Baykeeper Beach Litter Audit in general.

4.2.1 St. Kilda West Beach

The following table and figures are a compilation of our initial assessment of the Baykeeper Beach Litter Audit implementation at St. Kilda West Beach.

Table 2. St. Kilda West Beach analysis

	Widest Section	Midsection	Narrowest Section
Compass direction	234 SW	234 SW	234 SW
Reference point	Westernmost point of the boardwalk. Align transect with boardwalk post. (Figure 13)	Parking meter above the beach. Align transect with the yellow buoy on the water (Figure 13)	Streetlamp above the beach (Fig 13). Align transect with end of St. Kilda pier walkway
Hazards			
Accessibility comments	• Parking meter required: $5.10 per hour or $12.30 all day		
Additional notes	• There is a great amount of vegetation growing at the top of the beach by the footpath, so this was included in estimating the beach widths • Actual method only looked in the sand, not the vegetation • Quadrat 1 for all transects are areas where beach cleaner did not reach • Quadrat 2 and 3 for all transects are areas where beach cleaner reaches • Distance between widest and narrowest transects: 280 m		

Figure 13. Reference points at St. Kilda West Beach for the widest section (left), midsection (center), and narrowest section (right)

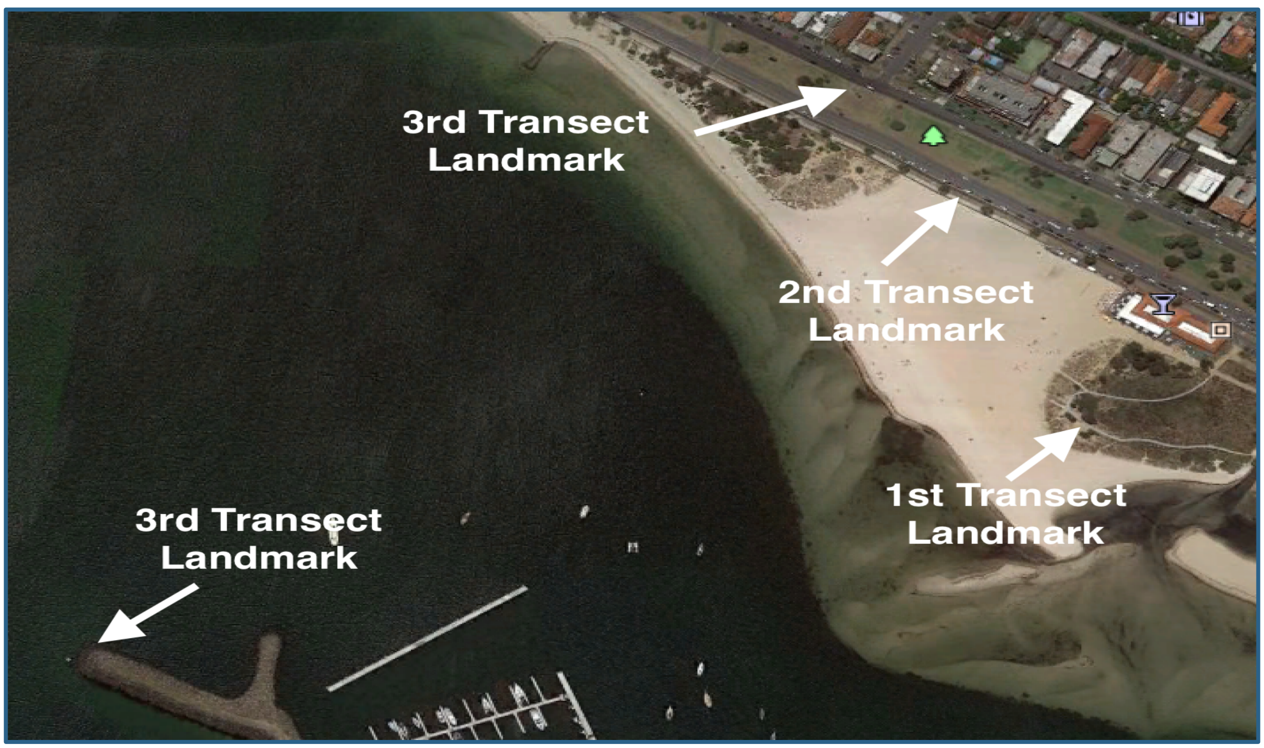

Figure 14. Reference points at St. Kilda West Beach

4.2.2 Point Ormond

The following table and figures are a compilation of our initial assessment of the Baykeeper Beach Litter Audit implementation at Point Ormond.

Table 3. Point Ormond analysis

	Widest Section	Midsection	Narrowest Section
Compass direction	222 SW	222 SW	222 SW
Reference point	Post of the Point Ormond Café. (Figure 15)	Lamp post (Figure 15)	Southernmost ramp of the beach (Figure 15)
Hazards	• Bike path we had to cross from the car park to the beach		
Accessibility comments	• There was a car park at this beach, which required a parking ticket ($5.10AUD per hour)		
Additional notes	• Distance between widest and narrowest transects: 240 m • Seaweed can be mistaken as plastic • Small transparent stones can be mistaken as nurdles		

Figure 15. Reference points at Point Ormond for the widest section (left), midsection (center), and narrowest section (right)

Figure 16. Reference points at Point Ormond

4.2.3 Keast Park

The following table and figures are a compilation of our initial assessment of the Baykeeper Beach Litter Audit implementation at the beach near Keast Park.

Table 4. Keast Park analysis

	Widest Section	Midsection	Narrowest Section
Compass direction	251 SW	251 SW	251 SW
Reference point	Emergency post 114 (Figure 17)	"Fragile Dunes" sign next to the walkway near emergency post 115 (Figure 17)	The 5th treated pine post to the south of the "No Horses" sign. This sign is located right next to the concrete pier. (Figure 17)
Hazards	• Potential for very strong winds		
Accessibility comments	• Car park near next to a walkway leading to the beach. Parking required payment.		
Additional notes	• Distance between widest and narrowest transects: 180 m • The high-tide line for the narrowest section is at a very steep angle • Potential for very strong winds, which will affect data collection		

Figure 17. Reference points at Keast Park for the widest section (left), midsection (center), and narrowest section (right)

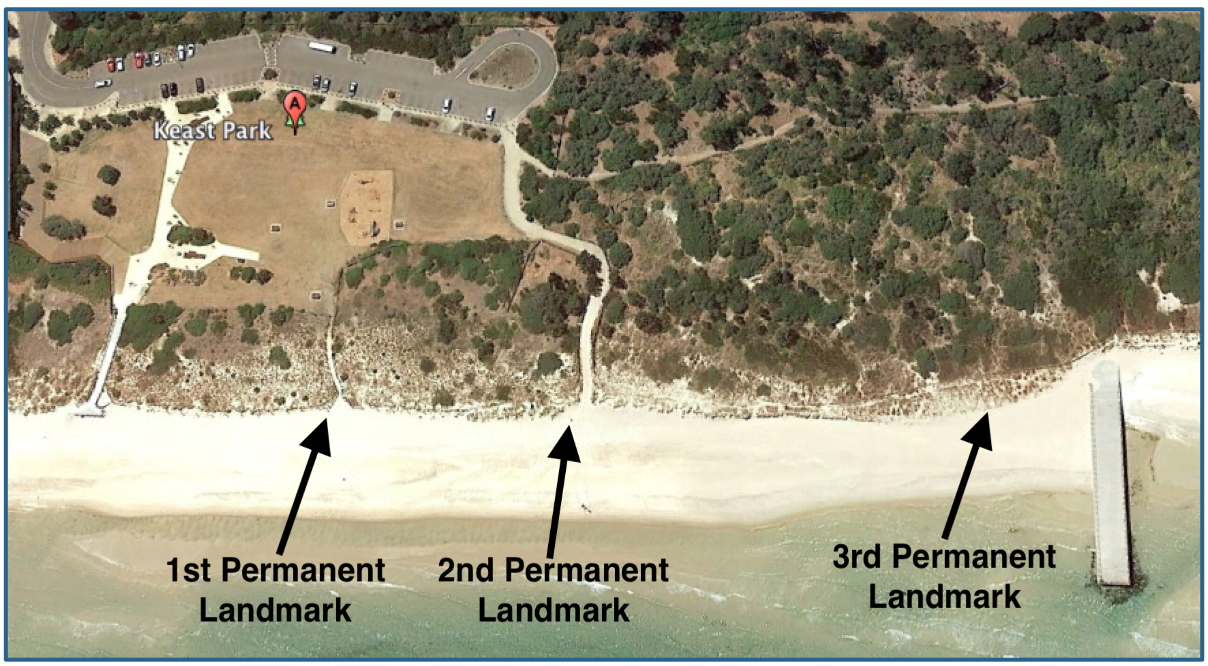

Figure 18. Reference points at Keast Park

4.2.4 Frankston Beach

The following table and figures are a compilation of our initial assessment of the Baykeeper Beach Litter Audit implementation at Frankston Beach. We visited this beach the same day as the one near Keast Park, and noted down the transect layout. However, the wind prevented us from performing the method and getting any data.

Table 5. Frankston Beach analysis

	Widest Section	Midsection	Narrowest Section
Compass direction	293 NW	293 NW	293 NW
Reference point	Emergency post 158 by the entrance near the Australian Volunteer Coast Guard building (Figure 19)	The third post from the walkways by emergency post 159 (Figure 19)	Green and blue sign beyond fence that tells direction of the Pier, Visitor Centre, Playground, Oliver's Lookout and Sweetwater Creek. Post was south of emergency post 160. (Figure 19)
Hazards			
Accessibility comments	• Car park near next to a walkway leading to the beach. Parking required payment.		
Additional notes	• Distance between widest and narrowest transects: 325 m • If confused with transect locations, recall that the widest section is located north of the other transects • The "top of beach" quadrat (Q1) for the narrowest section is located below the vegetation and steep slope, *not* up to the fence. This distance of vegetation was also not considered in our measurement of the distance between Q1 and Q3. However, we still noted the length of this vegetation section because it may change due to erosion: it measured 3.08 m from the fence to where we located Q1 at the end of the vegetation toward the beach		

Figure 19. Reference points at Frankston Beach for the widest section (left), midsection (center), and narrowest section (right)

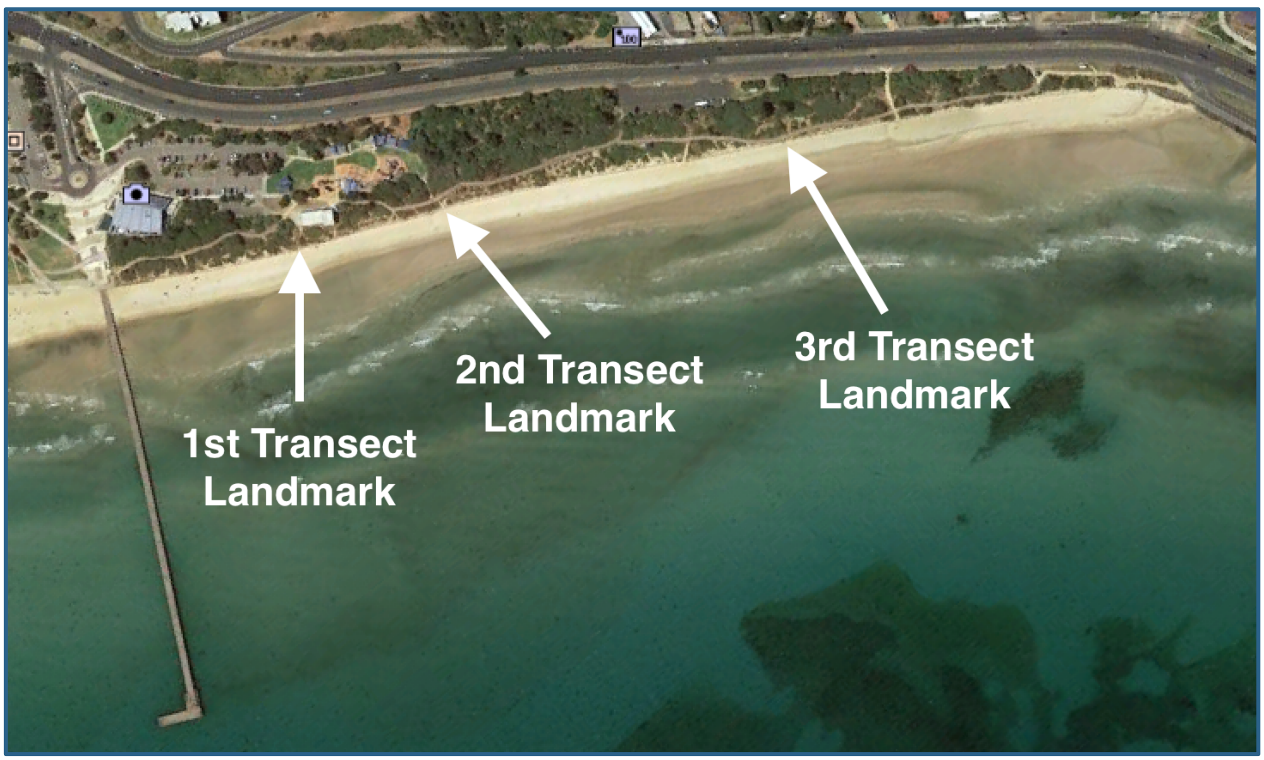

Figure 20. Reference points at Frankston Beach

4.2.5 Mt. Martha Beach

The following table and figures are a compilation of our initial assessment of the Baykeeper Beach Litter Audit implementation at Mt. Martha Beach.

Table 6. Mt. Martha Beach analysis

	Narrowest Section	Midsection	Widest Section
Compass direction	294 NW	294 NW	294 NW
Reference point	Tall gray post with electrical lead behind decaying tree (Figure 21)	Beach box #84, blue and yellow colored (Figure 21)	Beach box #121, red white and blue colored (Figure 21)
Hazards	• Potential for asbestos in pieces of roofing or siding of beach boxes that break off and land in the sand • Potential for being crowded during summer months when people are living in the beach boxes		
Accessibility comments	• Car park right next to beach entrance, no payment necessary to park car there.		
Additional notes	• Distance between the widest and narrowest transects is 274 m • Sand was grainy and looked more like small stones, therefore it was easy to confuse with nurdles		

Figure 21. Reference points at Mt. Martha Beach for the widest section (left), midsection (center), and narrowest section (right)

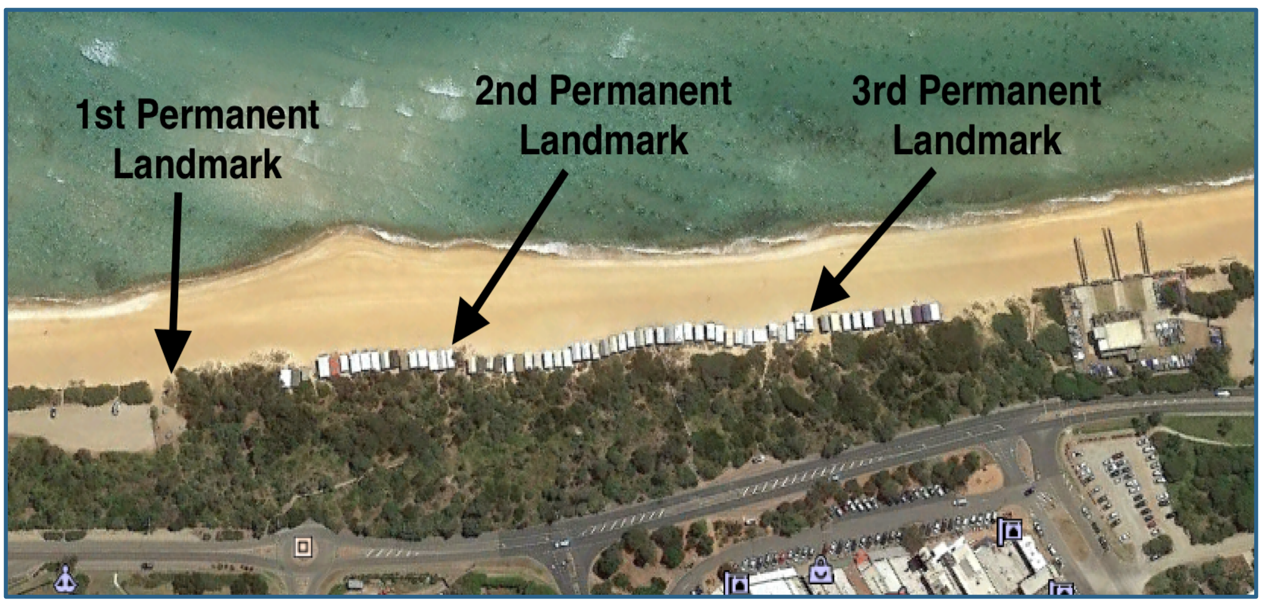

Figure 22. Reference points at Mt. Martha Beach

4.2.6 Rye Beach

The following table and figures are a compilation of our initial assessment of the Baykeeper Beach Litter Audit implementation at Rye Beach.

Table 7. Rye Beach analysis

	Widest Section	Midsection	Narrowest Section
Compass direction	0 N	0 N	0 N
Reference point	Middle of the gated entrance to beach (Figure 23)	Second from the left post of the short wall bordering the beach near the playground (Figure 23)	Sign in the parking lot that reads "Rye Pier 3P Area" (Figure 23)
Hazards			
Accessibility comments	• There is a car park right by the beach, but it required payment.		
Additional notes	• Distance between widest and narrowest transects: 145 m • This beach had mostly cigarette buds and Styrofoam • There was not a lot of debris at the top of the beach, which we assumed was because there is no walkway at the top of the beach for people to drop things along the path, like in other beaches		

Figure 23. Reference points at Rye Beach for the widest section (left), midsection (center), and narrowest section (right)

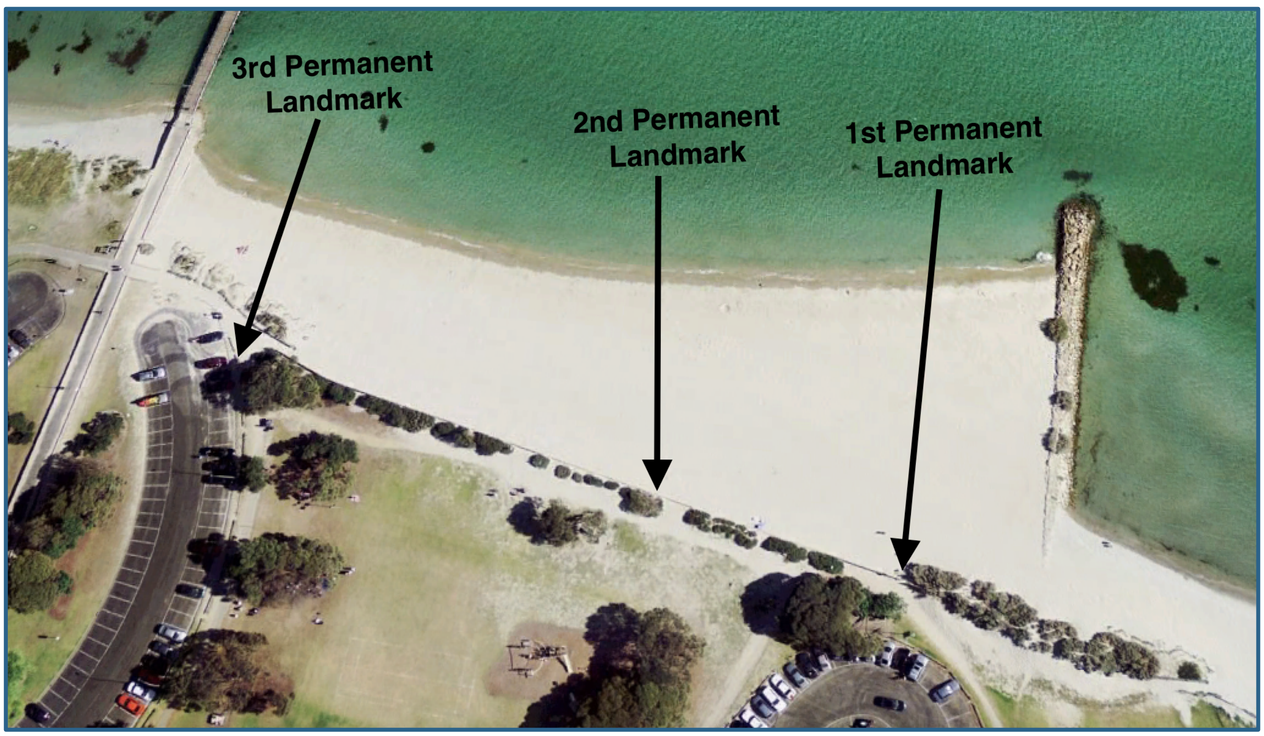

Figure 24. Reference points at Rye Beach

4.2.7 Eastern Beach

The following table and figures are a compilation of our initial assessment of the Baykeeper Beach Litter Audit implementation at Eastern Beach in Geelong.

Table 8. Eastern Beach analysis

	Widest Section	Midsection	Narrowest Section
Compass direction	16 N	16 N	353 N *
Reference point	Palm tree located between two chairs on the sidewalk at the western end of the beach (closest to ferris wheel). Transect should align with the end of the metal fence along the shoreline (Figure 25)	The outside edge of the western post (closest to ferris wheel) of the sign labelled "Eastern Beach" One edge of the quadrat will line up against the outside of the post (Figure 25)	End of blue paint line marking the edge of the sidewalk at the eastern side of the beach (farthest from ferris wheel) (Figure 25)
Hazards	• Volleyball courts, use gloves if rummaging through seaweed (beware of sharp pieces)		
Accessibility comments	• Car park next to beach, payment required		
Additional notes	• Distance between widest and narrowest transects: 265 m (straight), 272 m (path) • A lot of cigarette butts were located along the edge of the sidewalk • In the widest section and midsection, we found that the sand was very compacted in both Q2s (located at the midpoint between the high-tide line and the top of the beach) and that there were no barriers to catch any debris. This compacted sand was also found in all quadrats of the narrowest transect. This factor could mean less debris found due to the lack of barriers to catch it. * For Eastern Beach, we used 353N instead of 16N because there was a large difference between compass directions 16N and the direction of shortest distance to the beach for the narrowest section transect, so we concluded that for Eastern Beach, the compass direction used for the narrowest section transect will be 353N because this better represents the shortest distance to the beach.		

Figure 25. Reference points at Eastern Beach for the widest section (left), midsection (center), and narrowest section (right)

Figure 26. Reference points at Eastern Beach

4.2.8 Werribee South Beach

The following table and figures are a compilation of our initial assessment of the Baykeeper Beach Litter Audit implementation at Werribee South Beach.

Table 9. Werribee South Beach analysis

	Widest Section	Midsection	Narrowest Section
Compass direction	148 SE	148 SE	148 SE
Reference point	Signpost on eastern side of car park. Signpost details: two signs, white sign reading “Market Garden Area” and yellow sign reading “Mud on road” (Figure 27)	Blue lamp post in front of car park (Figure 27)	Door of green building above beach aligned with large tree. Transect direction should align the door with a tree in front of it (circled in Figure 27)
Hazards	• Many sharp shells on beach		
Accessibility comments	• Car park right next to beach, no payment necessary to park car there		
Additional notes	• Distance between widest and narrowest transects: 107 m • Beach is cleaned consistently throughout summer by municipality-owned beach cleaners. Cleanings stop at summer’s end. • Possible reasons for this beach’s cleanliness o No restaurants and shops nearby o No sidewalk/boardwalk at the top of the beach o Beach located in a rural setting rather than urban o Beach was not populated (we only saw two other people there during our visit) • Beach had a steep slope		

Figure 27. Reference points at Werribee South Beach for the widest section (left), midsection (center), and narrowest section (right)

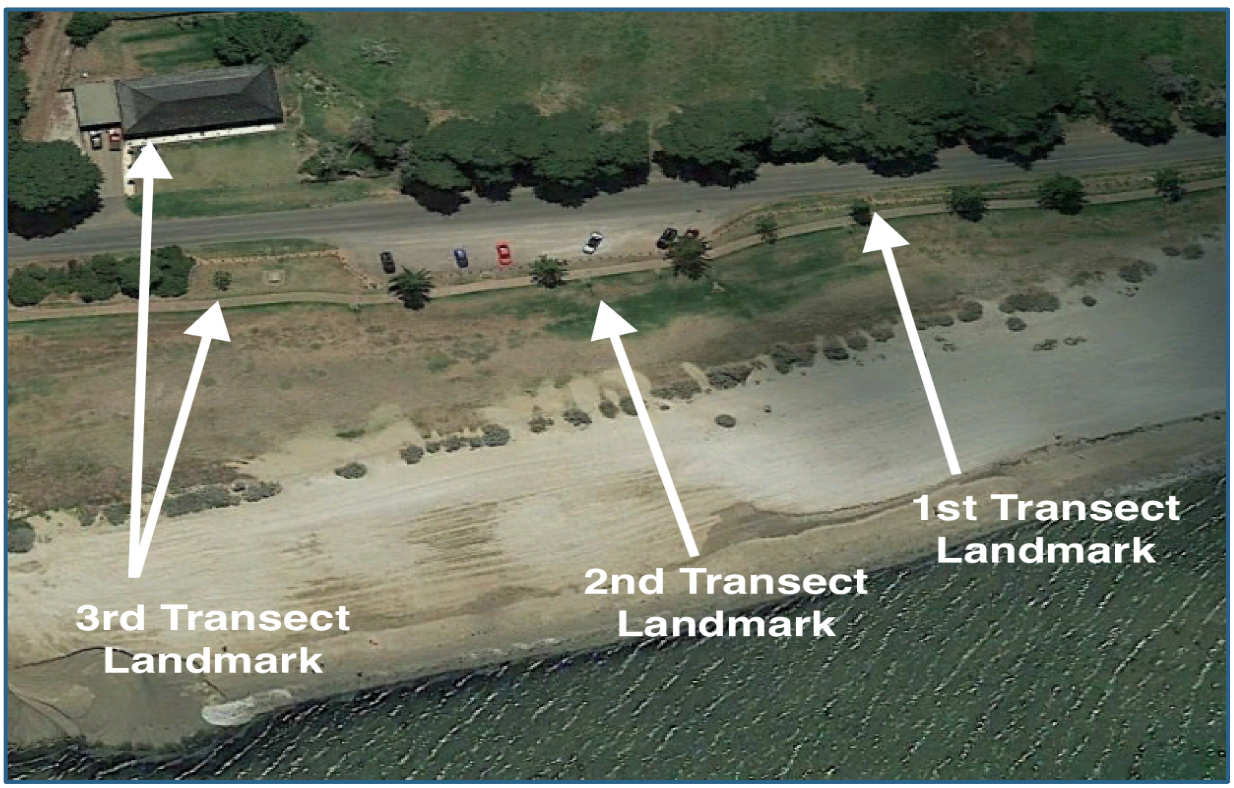

Figure 28. Reference points at Werribee South Beach

4.3 Preliminary Findings on Litter Distribution

We collected a baseline set of data from performing the initial audits at each beach. This data is not a complete representation of what will be found throughout future audits and therefore no final results could be concluded. However, we did develop a basis for future audits to build upon. The data we collected is organized in tabular format and provides a summary of the amount of debris collected in each quadrat at each beach (Appendix K).

Along with this initial data collection, we were able to form some hypotheses about the most common litter types found at each site, which transects and quadrats accumulated the most litter, and how different beaches compared to one another in terms of litter collection. These hypotheses were formed after a single audit at each beach, but they provide a starting point for determining trends as the method is continually performed. Preliminary findings are important to the success of citizen science projects because they provide a foundation for community members to build upon and obtain valuable information from over time.

We took the following steps to analyze the data presented in the tables and make our hypotheses. First, we calculated the total amount of litter collected at each beach. Next, we broke down the totals into different categories for each beach: total litter collected at each quadrat, total litter collected at each transect, and totals of each type of litter collected. Below is a summary of what we found from our initial data collection.

We collected 516 pieces of litter among all 7 beaches. Figure 29 represents the total number of pieces of litter collected per beach. As shown here, the beach we collected the least amount of litter at was Werribee South Beach (4 pieces total). We were informed by John Forrester, the Werribee Riverkeeper, that there had been a beach clean-up two weeks prior to our visit. This was a clean beach because of the lack of litter in comparison with other beaches that had been cleaned by a machine the morning of our visit. We determined the reasons for its cleanliness could be the lack of visitors to the beach (it was mostly empty during our visit) and the lack of shops and restaurants near it to attract visitors or be the source of any litter. There were four beaches where we collected over 70 pieces of litter: Keast Park (204), St. Kilda West Beach (74), Point Ormond (71), and Rye Beach (70). We determined that this could be due to the amount of tourists visiting these beaches, the public activity in the area surrounding them, and the catchments flowing into these beaches.

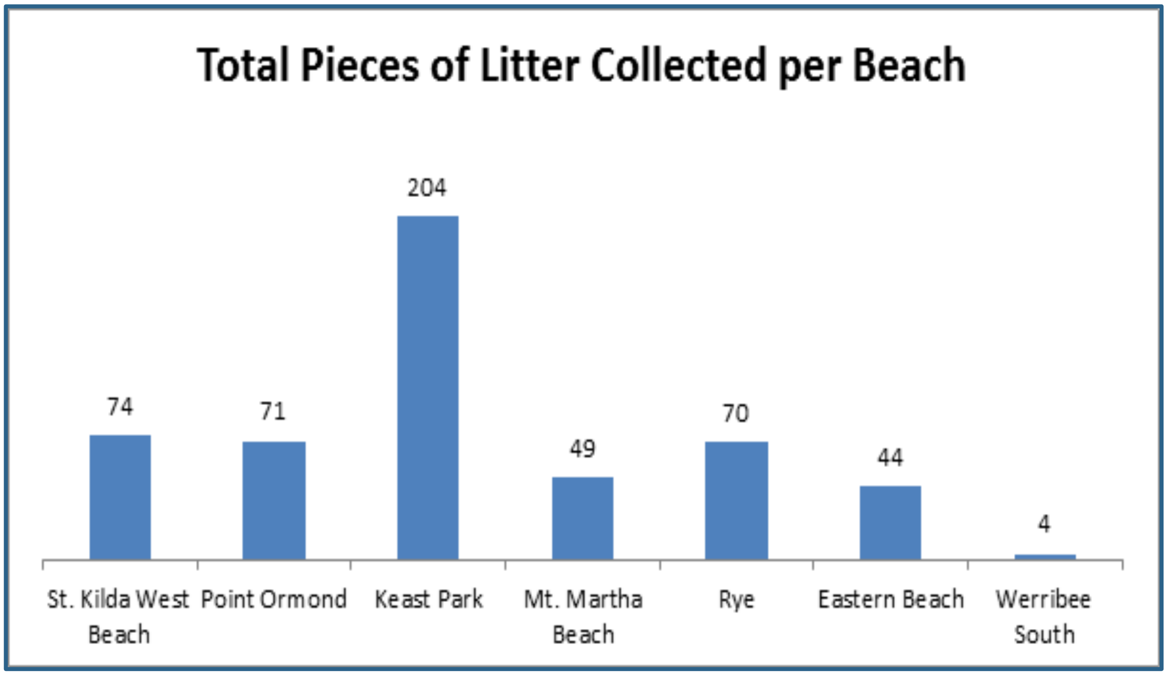

Figure 29. Graph of totals of litter collected per beach

This information is not conclusive of the amount of litter regularly appearing at each beach because this data was collected from a single audit. However, it will be interesting to continue to track the amount of litter at these beaches in search of trends and in order to determine the sites that need to be targeted most for further analysis of where the litter may be coming from

The next element we analysed was the distribution of litter along each of the three transects. Overall we found 166 pieces of litter in the widest transect, 103 in the midsection. and 242 in the narrowest transect. As shown in Figure 30, the trend from our initial data collection was that the most litter was collected along the widest transect among all beaches except for Mt. Martha and Keast Park. Litter in Mt. Martha was mostly collected along the midsection transect. On the other hand, Keast Park presented a large amount of litter in its narrowest transect, with 191 pieces collected, 37% of the total number of pieces. The least amount of litter was collected along the narrowest transect at every beach except for Keast Park and West Beach.

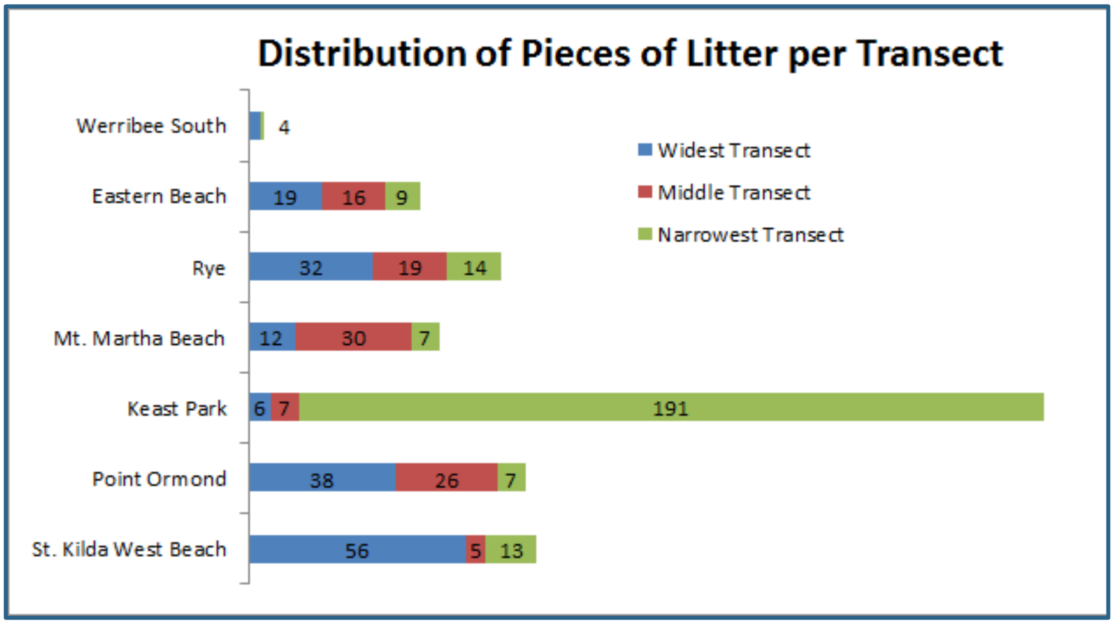

Figure 30. Bar chart showing the distributions of pieces of debris per transect in each beach

We hypothesized that there will be a continued trend in the most number of pieces found in the widest sections as audits are continued at each site, with the exception of Keast Park, where an accumulation of litter in the narrowest transect is expected. The purpose of having a transect on the widest section of the beach is to cover all conditions of the beach, this means that there are more potential areas along it for litter to get caught in the natural barriers it presented. The widest section also captures the most distance of beach for litter to accumulate. In contrast, the narrowest section captures the shortest distance from the top of the beach to the high-tide line, which means that there is less space for litter to accumulate along its transect. The narrowest section is also most exposed to the water, which means that during high tide, the water level will cover a greater portion of the sand along this section than the midsection and widest sections. Therefore, the litter located where the tide reaches will wash out into the ocean with the water. The litter trends by transect will be another pattern to keep track of as audits are continued in order to make viable conclusions as to where litter most likely ends up on a beach.

We also decided to observe the litter trends by quadrat to make hypotheses about litter accumulation at the top of the beach, in the middle of the beach, and along the high-tide line. As shown in Figure 31, most of the litter was collected at the quadrats located at the top of the beach (65%). This was the case at all sites except for Werribee South Beach and Rye Beach. We hypothesized that this will be a continuing trend as audits are continued because the top of the beach is more exposed to human activities and is sometimes surrounded by vegetation and/or walkways that represent a barrier for litter to be accumulated. In other words at the top of the beach, there are sidewalks, garbage bins, restaurants, shops, roads, and people. This means that the actions at the top of the beach along with the wind patterns that day directly affect how much litter accumulates here.

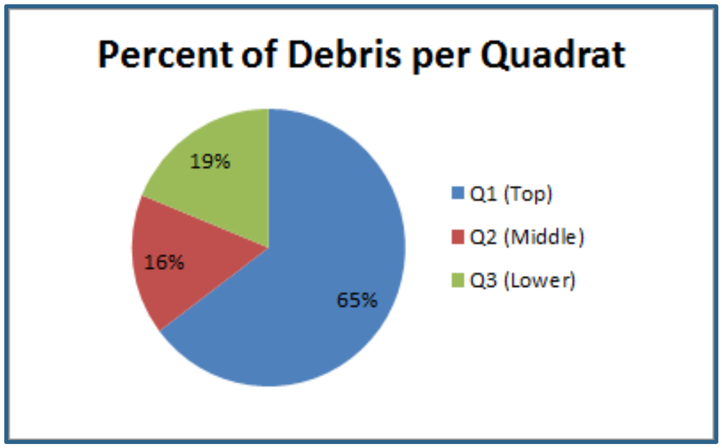

Figure 31. Pie chart showing percent of debris at Q1, Q2, and Q3

We also believe that the data collected from the last high-tide line will not be conclusive until many audits are performed because this location is the most unstable. This is because wind patterns and tides are constantly changing. The litter collected at these quadrats represent the litter that washed up onto the shore with the last high tide, and therefore some days there may be nothing coming in from the water depending on the variables previously mentioned. Similar to observing litter trends at each transect, observing it at each quadrat will be another pattern to keep track of as audits are continued in order to make viable conclusions as to where litter likely ends up on a beach.

As presented in Table 10, the most common type of litter collected at each beach along Port Phillip Bay varied. Nurdles, cigarette butts, broken glass, and pieces of plastic were some of the most common types of litter collected. However, the data in this table could be a misrepresentation because plastic debris was divided into several categories, and the data sheets counted each type of plastic separately. If a total was taken of all plastic litter collected, this value would be greater than many of the other categories for these beaches. Therefore, in order to track the types of litter collected, we recommend taking a total of plastics collected, and then performing a separate analysis of the most common types of plastic collected if this is what the main interest of tracking is.

Table 10. Most common types of litter at each beach

	St. Kilda West Beach	Point Ormond	Mt. Martha	Rye Beach	Eastern Beach	Werribee South Beach
Most common type of litter collected	Nurdles (47)	Broken glass (13)	Nurdles (13)	Nurdles (25)	Cigarette butts (14)	Hard plastics >5mm (2)
Second most common type of litter	Hard plastics <5mm (6)	Cigarette butts (9)	Pieces of painted wood (5)	Cigarette butts (15)	Soft plastics <5mm (6)	Broken glass (1) and soft plastics <5mm (1)

Nurdles were in number the largest type of litter we collected along these beaches. We collected 230 nurdles in total. Table 11 summarizes the number of nurdles collected. The beach in which we found the most is Keast Park, where we collected 125 nurdles from the top quadrat in the narrowest transect, and 138 in total. West Beach also showed a big presence of nurdles with 47 in total and 39 of them being located in the top quarter of the widest transect. Following was Rye, with 25 nurdles, and with 10 of them located in the widest transect's lower quarter. We found 13 nurdles in Mt. Martha, spread throughout all transects and all quadrats. Point Ormond also presented 7 nurdles, all found in the widest transect. On the other hand, Eastern Beach and Werribee South presented no nurdles. From this data there is no correlation among the location of nurdles in transects or quadrats among the beaches, nevertheless, we believe that the collection of nurdles will follow a similar pattern as audits continue to be performed.

Table 11. Distribution of nurdles

	Widest			Midsection			Narrowest			
Beach	Top (Q1)	Middle (Q2)	Lower (Q3)	Top (Q1)	Middle (Q2)	Lower (Q3)	Top (Q1)	Middle (Q2)	Lower (Q3)	Totals
West Beach	39		2		1		1	1	3	47
Point Ormond	2	5								7
Keast Park							125	13		138
Mt. Martha		1	4	1	1	1	1	4		13
Rye		1	10		5	3		2	4	25
Eastern Beach										0
Werribee South										0
Totals	41	7	16	1	7	4	127	20	7	230

Cigarette butts were also a common type of debris found among these beaches. They were mostly found in the top and lower quadrats of all transects. The reason why most of these are located in the top quadrat, 19 out of 47, might be because of smokers dumping cigarette butts as they walk. On the other hand, those found in the lower quadrat, 20, drifted onto the shore with the tide. Point Ormond and Keast Park were the only two beaches in which we found cigarette butts in the middle quadrat, this might be because all other beaches were cleaned on that day or were not frequented by people. Table 12 summarizes the number of cigarette butts collected.

Table 12. Distribution of Cigarette Butts

	Widest			Mid			Narrowest			
Beach	Top (Q1)	Middle (Q2)	Lower (Q3)	Top (Q1)	Middle (Q2)	Lower (Q3)	Top (Q1)	Middle (Q2)	Lower (Q3)	Totals
West Beach	4									4
Point Ormond	1	1		3	2		1	1		9
Keast Park		3					1			4
Mt. Martha									1	1
Rye			10			3			2	15
Eastern Beach	6		1	4					3	14
Werribee South										0
Totals	11	4	11	7	2	3	2	1	6	47

Broken glass was mostly found in Point Ormond's lower quadrats, with 12 out of the 37 pieces we found in total. The total number of fragments among the widest and narrowest was the same (11). Nevertheless, the pattern in the number of pieces collected along the quadrats increased as we approached the sea line (8 pieces in top quadrats, 12 in the middle, and 17 in the lower quadrats). This distribution might be explained by hypothesizing that broken pieces of glass come with the tide, and this is why the majority of them are located in the lower quadrat. Table 13 summarizes the number of broken glass pieces collected.

Table 13. Distribution of broken glass

	Widest			Mid			Narrowest			
Beach	Top (Q1)	Middle (Q2)	Lower (Q3)	Top (Q1)	Middle (Q2)	Lower (Q3)	Top (Q1)	Middle (Q2)	Lower (Q3)	Totals
West Beach				1	2			1		4
Point Ormond	1		7			1			4	13
Keast Park					2	1		4		7
Mt. Martha	1			3						4
Rye					2	2				4
Eastern Beach	1					1	1		1	4
Werribee South		1								1
Totals	3	1	7	4	6	5	1	5	5	37

CHAPTER 5. ANALYSIS AND DISCUSSION

After recording findings for each audit site, we compiled our observations from performing the Baykeeper Beach Litter Audit at each site into a synthesized analysis. In this general analysis of the method, we determined best practices for implementing the method, complications with its implementation, and general hazards. We also analyzed the strengths, weaknesses, opportunities, and threats of the method and developed an in-depth SWOT analysis from these findings. Our overall analysis of the sites and the beach litter audit methodology were a major part of the citizen science aspect of this project. In order to create a long-term monitoring program that depends on the participation of members of the public, there are several measures that need to be taken to ensure that the community members will obtain clear and comparable data.

5.1 Implementation Strategies / Best Practices

In order to keep this method consistent with different practitioners we noticed three elements to consider while performing the beach litter audit method. One of these is to exclusively survey the top of the sand; this means that there should not be any sifting through the sand for any depth. Another is to avoid walking through quadrats, as footprints will compress the sand and potentially bury plastics. Additionally, the time spent surveying should be at least 5 minutes per quadrat or a minimum of one minute per quarter of the quadrat. We used the latter technique because we had four people performing the audit together, and therefore each person spent a minimum of one minute surveying a quarter of the quadrat. Time can be broken up in this manner amongst any number of team members. However, we recommend a maximum of four auditors per quadrat to avoid overcrowding the area. It is important to understand that this is the minimum time to make sure the quadrat is thoroughly surveyed. If there is a considerable amount of litter in the quadrat, more time should be spent on the quadrat until the auditors are sure the quadrat has been completely examined.

5.2 Complications

After performing the Baykeeper Beach Litter Audit at the preselected audit sites, we compiled a list of complications involved with performing the method. One of the major complications during the audits was distinguishing between inorganic and organic debris. To address this complication, we developed a list of commonly confused items and took photos of these items to provide to volunteers in order to remove this confusion. The items we identified as being commonly confused are described and displayed in the images below.

First, we found it can be difficult to distinguish between a nurdle and a small stone or large grain of sand. Figure 32 illustrates images of each to compare them against one another. At first glance, they are similar in appearance, but looking closely, nurdles are cylindrical in shape. This means it is important to pick up objects you may be confused about because with a closer look, the manufactured edges of a nurdle's cylinder are evident.

Figures 32. Nurdles (left) compared to small rocks (right)

Second, a strand of seaweed can be easily confused with a piece of cellophane. Figure 33 shows these two materials side-by-side to clarify between them. When unclear if something is seaweed or plastic, it is important to feel the material. Seaweed will feel slimy and easily tear apart as it is inorganic, but plastic will feel stiffer and will be more difficult to rip apart.

Figures 33. Cellophane (left) compared to strand of seaweed (right) (White Seaweed, n.d)

Another complication with performing the audits is potential crowds at certain beaches and/or on certain days. Some of the audit sites were major tourist destinations or in a heavily populated area. The more populated the site is, the more obstacles there are to avoid during the audit. This may make its implementation difficult because the reference points are fixed, and if the area is too crowded, it may require returning to the site at a different time.

Another complication that was not present during our audits, but future auditors must consider, is high tide. If the beach that the audit is being performed at is experiencing high tide, then the audit cannot be performed because the high-tide line is used as a quadrat. We recommend that the volunteers refer to the high tide chart for the specific beach they are planning to audit, because tides constantly change and affect the ability to perform the audit.

5.3 Common Hazards

Along with identifying hazards at individual audit sites, we determined common hazards with performing the Baykeeper Beach Litter Audit at all of the sites. One common hazard was the sun. Due to the dangers of sunlight, we recommend wearing a long sleeved shirt, pants, a hat, sunglasses, and sunscreen. Another common hazard was wind. Depending on location along Port Phillip Bay or the wind's direction/power on the day of the audit, the wind could present a major hazard to performing the method. High winds blow debris on the beach from location to location and it will rarely settle in one spot depending on how light the piece of debris is. High winds also blow the sand, which presents a hazard to eyes. The Baykeeper Beach Litter Audit involves getting close to the ground to examine the sand, and during high winds the sand will blow into the eyes. Therefore, we made the following recommendation: in case of extreme weather (heat or high winds), do not perform the method but come back at another time. We also recommend checking the wind patterns and recent rainfall prior to going into the field. Figure 34 shows an example of wind patterns retrieved from the BayWind website, which is updated every five minutes. It is important to note that this image is not a representation of the average wind directions in the bay.

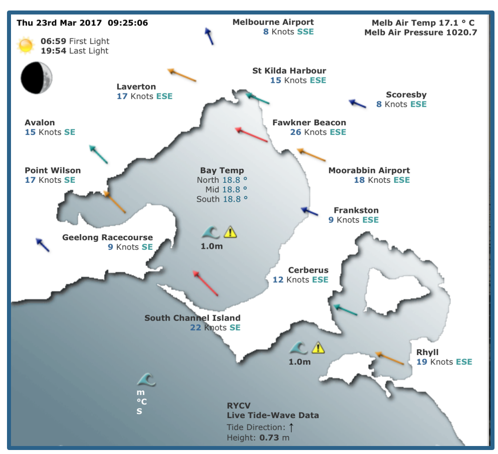

Figure 34. Example of wind patterns (BayWind, 2013)

5.4 SWOT Analysis

After performing the method at several audit sites, we assessed the method by considering its' strengths, weaknesses, opportunities and threats. We developed a SWOT analysis shown in Figure 35 below.

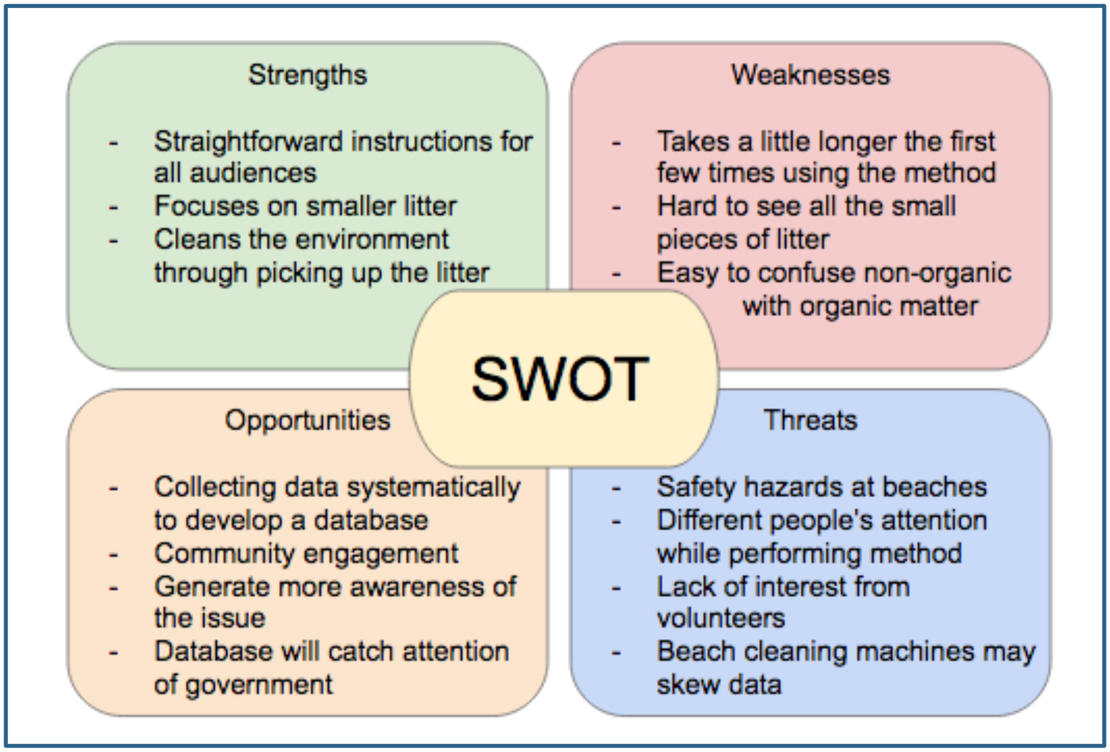

Figure 35. SWOT analysis of Baykeeper Beach Litter Audit

CHAPTER 6. OUTREACH AND EDUCATION

This chapter discusses the deliverables of our project that were necessary to establish a long-term monitoring plan for monitoring microplastics in Port Phillip Bay. These deliverables were all a part of the implementation plan and include: the final version of the Baykeeper Beach Litter Audit, information sheets about each of the audit sites, an instructional video, and a promotional flyer to recruit Scouts. These deliverables were created based on our findings and will serve to help the Port Phillip EcoCentre after the conclusion of our project. They are valuable to citizen science because they serve as the main basis for targeting members of the community to encourage them to participate.

6.1 Implementation Plan

The Baykeeper Beach Litter Audit was established to organize long-term monitoring of microplastics around Port Phillip Bay. Our team developed an implementation plan to initiate the performance of this method and introduce it into the Port Phillip community. The monitoring system entails performing beach litter audits at preselected sites around Port Phillip Bay. These sites will be monitored regularly in order to build a database and track patterns in the data. The monitoring system requires the use of citizen science to be successful. Scouts and other volunteers will be the main citizens involved with the science, but they are essential to both the collection of data on a monthly basis and spreading awareness. The EcoCentre will work alongside the community members to manage the data collected, and help sustain and improve the project. This monitoring program collects and tracks microplastic pollution and other litter found on beaches, and therefore the citizen science aspect is important because the project directly impacts the lives of the people in the communities around Port Phillip Bay. Along with engaging the community, the data collected from this method will be analyzed and used as evidence for the Victorian Government to fund further research on the issue and implement action plans to address the issue.

The final version of the instructions for performing the Baykeeper Beach Litter Audit is shown in Appendix F. The method is to be implemented at each preselected audit site once a month, and data is to be collected on the provided data sheets (Appendix G). Completed data sheets will be sent to the EcoCentre in order to input the information into a database. The method involves picking up litter from 1 square meter quadrats along the high-tide line, the middle of the beach, and the top of the beach (we determined the estimated locations of these quadrats in our initial implementation, see Chapter 4.2).

Our team used a previous version of the method's instructions to perform the method at each audit site. We edited the instructions to make clarifications and remove ambiguity in different interpretations before a final version was distributed. The following clarifications we made in the instructions are described in the following paragraphs.

In "Guide to Audit Setup" number 7, the direction was to "Mark the end of the transect with a peg 0.5m past the last high-tide line." Although this statement was clear, it was unclear where the quadrat would be placed in respect to this temporary landmark at the high-tide line. Therefore, we added the following phrase to the end of this step to make the directions clear: "This is the center of your 1 square meter quadrat." This will ensure that the entire high-tide line quadrat will be placed below the high-tide line, which is important because the purpose of this quadrat is to collect litter that came onto the shore with the last tide.

Next, the image provided in the method that represented the locations of quadrats along the transects was incorrect. As shown in Figure 36, the quadrats located along the high-tide line are in the incorrect location. In this image, the high-tide line runs through the centres of these quadrats. However, as explained above, the center of each quadrat is supposed to be located 0.5 meters below the high-tide line so the entire quadrat lies below the high-tide line. Therefore, our team recreated the figure to represent the correct quadrat locations (Figure 37).

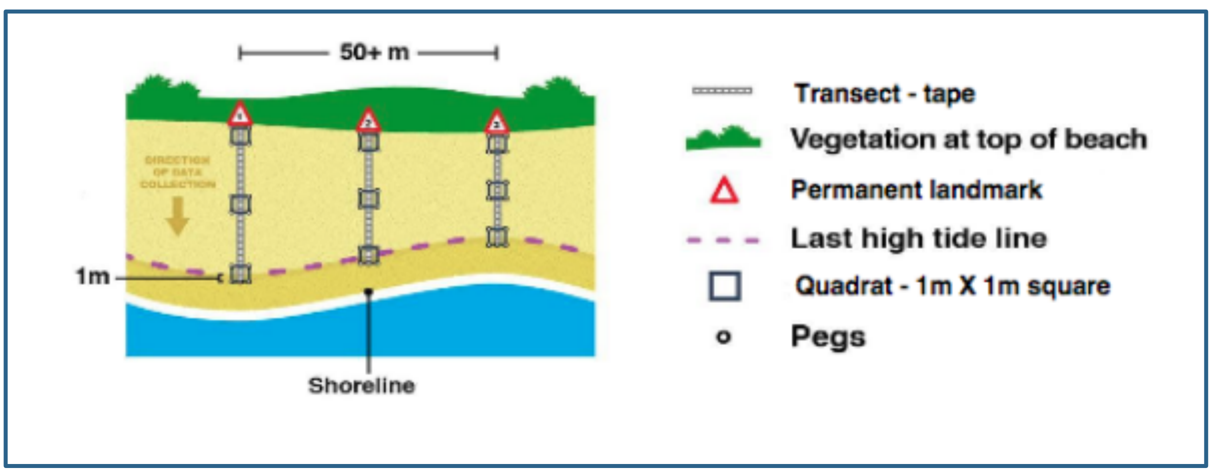

Figure 36. Image of Baykeeper Beach Litter Audit before alteration

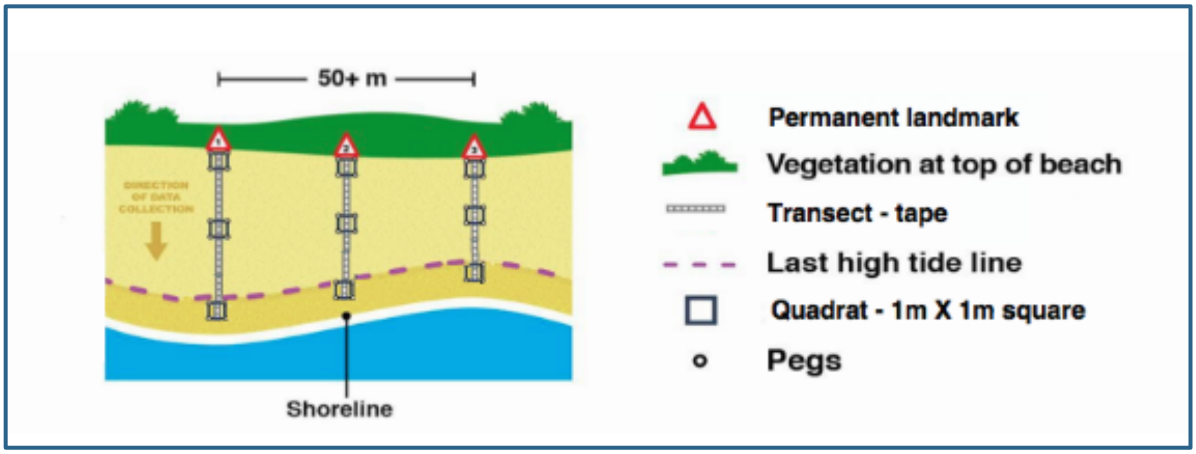

Figure 37. Image of Baykeeper Beach Litter Audit after alteration

6.2 Information Sheets

As shown in Chapter 4.2, we collected information from each audit site during our initial implementation that is essential for a successful long-term monitoring program. We then developed separate informational sheets for each audit site to distribute to Scouts and other volunteers who will perform the Baykeeper method to inform them of each site's hazards, accessibility, and the locations of the reference points we used for each transect to ensure audits are consistent and comparable. The informational sheets for each audit site can be found in Appendix H.

6.3 Instructional Video

The Port Phillip EcoCentre needed a way to clearly communicate how to perform the Baykeeper Beach Litter Audit because until now, the directions were only explained on the data sheet form or demonstrated by Neil Blake. We created a short video with a visual representation of how to perform the method and vocal explanations of each step. To do this, we filmed ourselves performing the method and recorded Neil reciting a script we wrote. We put these together using iMovie and shared this video with the EcoCentre for them to distribute it to the appropriate groups.

6.4 Promotional Flyer for Scouts

We created a flyer to recruit scouts to perform the Baykeeper Beach Litter Audit at each of the sites on a monthly basis (Appendix L). In these flyers, we targeted the scout leaders as our main audience, because they are the ones who find this type of activity for the scouts. We included information on the issue of microplastic pollution in the bay in order to give the scouts and leaders a little background about the activity they would be signing up for. We provided the information on what badges and awards they could win through their participation and referred to our videos to demonstrate how to perform the method. We also gave the contact information of the Baykeeper, Neil Blake and told them to contact him with any inquiries or interest.

CHAPTER 7. RECOMMENDATIONS

After performing the Baykeeper Beach Litter Audit at preselected sites around Port Phillip Bay, we developed a set of recommendations to guide the long-term monitoring effort. The recommendations revolve around data collection and techniques for tracking litter over time in Port Phillip Bay. It is important that the data collected from audits is analyzed in such a way that it clearly illustrates the extent of the issue and microplastic distribution in the bay so the issue can be brought to government attention with specific evidence.

First, we recommend that audits are performed on a monthly basis. This gives enough time between audits for changes in litter to collect naturally along the transects from human activity and/or tidal movement. For instance, if audits are performed daily, litter found in each quadrat will not be comparable to other studies because not enough activity will occur between audits to distribute litter along the beach naturally. By performing audits monthly, a database can be formed quickly and can be easily maintained as long as collections are consistent. This is also a reasonable time frame for Scouts to work with. When we presented this to a Brighton Sea Scout Leader, they believed this was an appropriate amount of hours for Scouts to spend working toward a badge (G. Perkins, personal communication, March 29, 2017).

We recommend taking the following approaches when analyzing the data collected from audits. Charts and tables can be modelled after those we created to display our data with (Figures 29-31 and Tables 10-13). These charts should compare the following in order to accurately analyze the distribution of litter in Port Phillip Bay: the amount of litter collected at each tidal zone (high-tide line, top of beach, and midsection), the amount of litter collected at each transect (widest, narrowest, and midsections of the beach), the total amounts of litter collected at each beach, and the amount of each type of litter collected (types of litter are displayed on the Baykeeper Data Sheet, Appendix G) at each transect, tidal zone, and beach.

If the above approaches are used in data analysis after each audit, the distribution of litter across Port Phillip Bay and across a beach can be tracked over time. This will likely reveal patterns that may be helpful in the future when investigating further into microplastic pollution, such as determining specific sources to target, appropriate legislative action, and other efforts that will be effective in addressing the issue because there is evidence to support claims.

CHAPTER 8. OTHER ACCOMPLISHMENTS

Aside from our project-specific deliverables, we completed several other tasks during our time with the Port Phillip EcoCentre. We participated in a variety of activities and programs while at the EcoCentre, all of which helped us to fully immerse ourselves in their organization.

The first week after our arrival to Melbourne we delivered a presentation to the EcoCentre staff to present ourselves, our university, and the background research on microplastic pollution we did in the previous weeks. This was an opportunity for us to show our knowledge on the issue and listen to the EcoCentre comments on what we did so far.

Also shortly after we arrived we participated in a corporate day. The Port Phillip EcoCentre offers corporate volunteer programs for companies looking to give back to the community. Our team assisted the EcoCentre and the corporate volunteers from Telstra Telecommunications Company with their *Pamper the Penguins* activity. *Pamper the Penguins* is a program designed to help the colony of approximately 1200 Little Penguins, who live at the breakwater at the end of the St Kilda pier, fix their homes and hollows that have begun to be threatened and destroyed by erosion (Pamper the Penguins!). By transporting a mix of beach sand and seaweed from the beach to the breakwater, our team and the volunteers helped improve the penguins' habitat.

An experience that gave us further insight into the complexities of the microplastic issue was helping Dr. Nikki Kowalczyk, the Litter Hotspots Project Manager, in analyzing the samples gathered from the Maribyrnong and the Yarra Rivers. These samples are gathered from boat trawls performed monthly in both rivers, with a Neuston Net, in order to get a constant data that would allow to develop more precise estimates of the amount of debris that is being discharged into the bay.

The samples we analyzed corresponded to the months of January and February. There was a lot of organic components in each of the samples, which made it difficult to recognize all the pieces of plastic. The big ones were easily segregated. Once we separated all the inorganic pieces, we faced a bigger challenge in that the rest was a mixture of very small particles that were very difficult to tell apart between organic or inorganic. It took four hours to go through the four samples between a team of four. We believe that a laboratory analysis, with the use of salty solutions would be convenient to analyze these samples, since it would make the segregation of the debris much faster.

Another activity we took part in was the Friends of Williamstown Wetlands' beach audit method at Wader Beach. We followed the procedure described in section 4.1.2 Interview with the Friends of Williamstown Wetlands in which we collected and classified different types of litter found in the pre established quadrats. Through this involvement we were able to compare this method with the Baykeeper Beach Litter Audit and note major advantages and disadvantages of the latter.

We attended the Port Phillip EcoCentre "Reflection and Learning Day" on April 10, 2017 along with members of the EcoCentre staff and the Committee members. At the beginning of the event, our team presented our research and the progress of our project up to date. There were several other presentations and activities that followed. The purpose of this day was to go over the EcoCentre's three-year Strategic Plan, discuss achievements and challenges with their progress into the plan thus far, and to start looking at options for moving forward to accomplish the plan's objectives. After making our presentation, we participated in the discussions, listened to the other presentations, and observed the meeting in general to gain a better understanding for how the EcoCentre functions, analyzes its progress, and plans for the future.

We joined Neil on the Triple R radio station during our last week working with the EcoCentre. The last Sunday of every month, Neil is a guest on the "Radio Marinara" program with Bron Burton and Dr. Beach. It is the local program about Melbourne's own Marine and Coastal news. We accompanied Neil and were on the air the morning of Sunday, April 30, 2017. We talked with Bron about the work we have completed with the Port Phillip EcoCentre and our plans moving forward. We hope that our discussion, on air, will draw interest to the EcoCentre and the Baykeeper Beach Litter Audit, and potentially reach an audience that are interested in continuing to perform the method on a monthly basis after our departure.

CHAPTER 9. CONCLUSION

This project was intended to help the EcoCentre address microplastic pollution in Port Phillip Bay. We successfully trialled the Baykeeper Beach Litter Audit at each of the preselected audit sites around the bay, collected initial data, and assessed its implementation. Based on our assessment, we developed a citizen science implementation plan for each audit site that sets the foundation for a long-term monitoring program for microplastic pollution in the bay. With participation from the Scouts and other members of the public, this monitoring program will track deposits of microplastics into the bay over time as well as detect patterns in the distribution of microplastics across Port Phillip Bay. We then created an instructional video to demonstrate to the community how to perform the audit and informational sheets with details for each specific audit site. Finally, we promoted the long-term monitoring program and the Baykeeper methodology to recruit volunteers. With cooperation from these volunteers, the Baykeeper Beach Litter Audit will be performed at each site on a monthly basis. Eventually the EcoCentre will build a database that is founded on our initial data collection and built upon through the continuation of the monitoring program. The goal of this program is to serve as a main operation for management in the bay over the next fifty years.

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APPENDIX A: ECOCENTRE PROGRAMS

- Tomorrow's Leaders for Sustainability is a program that helps teach the issues and principles of sustainability to people of all ages. It involves holding education sessions, leading activities, and providing lessons plans for teachers at schools, both primary and secondary.
- The Community Gardens Project revolves around the EcoCentre community garden, located behind the organization's building and home to many Aboriginal plants and vegetables. Several community members tend to this garden, and the produce is shared among them. The garden also features a composting system for the surrounding neighborhood.
- Port Phillip Urban Fresh Food Network (PPUFFN) is part of the Australian City Farms and Community Gardens Network. It is a community-based organization that strives to advocate the benefits of community gardens and oversee the creation and management of community gardens.
- The Speakers Program is a program that allows members of the EcoCentre staff to be hired to hold workshops or speak about environmental and sustainability issues, citizen science, waste management, environmental education, and more. This allows the staff to share their knowledge and expertise with other organizations as well as advocate the EcoCentre and its values at the same time.
- The Litter Hotspots Program is part of the Victorian Government's A Cleaner Yarra and Port Phillip Bay - A Plan of Action. The Port Phillip EcoCentre is involved with this program, and one of the staff members, Dr. Nikki Kowalczyk, is the Litter Hotspots Program manager. This program supports best practice litter prevention projects, and works to increase the public's personal responsibility for litter prevention.
- The Expert in Residence Program is an education program that embeds sustainability and environmental education into a school's curriculum. It allows the EcoCentre to spread their knowledge among younger age groups and influence behavioral changes at an earlier age.

APPENDIX B: ORAL CONSENT OF INTERVIEWS

Hello, we are students working with the Port Phillip EcoCentre.

We are currently working on a project that is intended to help the EcoCentre address microplastic pollution in Port Phillip Bay. First, we will be trial and assess the Baykeeper Beach Litter Audit, and then we will develop an instructional video of the method to encourage community participation.

This interview will last about 30 minutes. We wanted to let you know that your participation in this interview is voluntary, and you do not have to answer anything you do not want to.

We would like to request your permission to take notes during the interview?

We will keep your answers confidential upon request.
Otherwise, can we quote you? If so, do you prefer that we refer to you by name or by organization?

(If applicable) Can we take photos during the interview?

If you have any questions or concerns, please contact us at mpc17-ecocentre@wpi.edu.

APPENDIX C: INTERVIEW SCHEDULE WITH SPONSORS

The conversation with our sponsors at the EcoCentre gauged the organization's values and concerns. The following questions were discussed:

- What is the main goal of the EcoCentre?
- What projects have your organization performed in the past?
- What has led you to focus on the issue of microplastic pollution?
- What is your perspective on microplastic pollution?
- What are your major goals for addressing microplastic pollution?

APPENDIX D: SURVEY SCHEDULE WITH STAKEHOLDERS

This survey is in a Google Form, and will be taken by people at the beach on iPads provided by the EcoCentre. The content is as follows:

Hello, we are students collecting information on the different perspectives on microplastic pollution in Port Phillip Bay.

Your participation in this survey is completely voluntary and you may withdraw at any time. Please know that your answers will remain confidential. No names will appear in the project report or publications. The survey will take less than 4 minutes.

This is a collaborative project with the Port Phillip EcoCentre, and your participation is greatly appreciated. If interested, a copy of our results can be provided at the conclusion of our study. If you have any questions or concerns, please contact us at mpc17-ecocentre@wpi.edu.

Survey Questions

What is your age?

- 10-18
- 19-24
- 25-34
- 35-44
- 45-54
- 55 or more

What is your postcode (N/A if just visiting Australia)?

____

Have you heard of Port Phillip EcoCentre?

- Yes
- No

How often do you visit the beaches in Port Phillip Bay?

- More than once a week
- Once a week
- Once every 2 weeks
- Once a month
- Less than once a month

What do you do at the beaches? (Select all that apply)

- Dining
- Fishing
- Sun bathing
- Swimming
- Tourist
- Walking
- Other

Have you heard of microplastics?

- Yes
- No

Are you aware that microplastics are a type of the pollution in the bay?

- Yes
- No

Do you know any of the sources of microplastic pollution?

- Yes
- No

If "Yes" please list any sources you know of

____

What do you think are the main effects of microplastic pollution?

Are any of your activities impacted by microplastics?

- Yes
- No
- I don’t know

If "Yes," what activities are impacted?

APPENDIX E: INTERVIEW SCHEDULE WITH STAKEHOLDERS

The next interview questions were conducted during interviews with contacts the EcoCentre provided us with. The interviews were semi-structured, so the questions were asked in no particular order but correspond to the flow of conversation.

- How did you become aware of microplastic pollution and what made you become interested in it?
- How do you think this issue is affecting Port Phillip Bay?
- Describe your involvement with microplastic pollution?
- Could you tell us more about your project and/or organization? (values, goals, how it is related to microplastic pollution)
- What is the end goal (or main goals) of your project and/or organization?
- What do you think is the best way to get people involved in efforts to address microplastic pollution?

If interviewee is knowledgeable of the Baykeeper Beach Litter Audit, ask the following questions:

- What value do you find in the Baykeeper Beach Litter Audit and the information gained from it?
    - How do you think the data from these audits can be used?
    - Do you have any suggestions on how to get people involved with these audits?
    - Do you see that there would be any value in getting these data collections from sites within the catchments feeding into the bay?
- Do you recommend other people to contact who have knowledge about microplastic pollution in the bay?

APPENDIX F: GUIDE TO BAYKEEPER BEACH LITTER AUDIT

GUIDE TO BEACH LITTER AUDITS

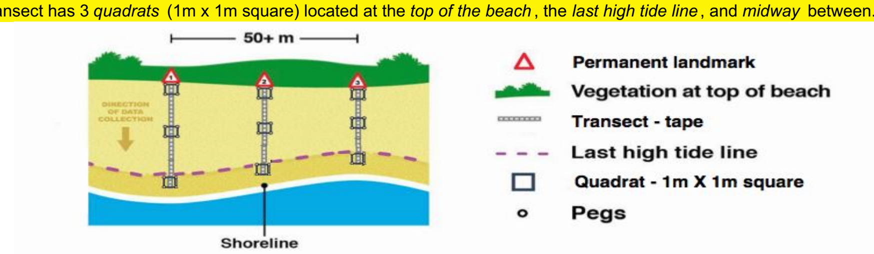
BEFORE YOU START: Have First Aid Kit and gloves on-site. Check entire site to note possible hazards.
Warn all collectors: DON'T PUT YOUR FINGERS WHERE YOU CAN'T SEE THEM.

PURPOSE: Reference sites on beaches are regularly audited to track any increase or decrease of litter items that are known to *threaten wildlife and/or human health, or are the subject of ongoing campaigns,* eg Container Deposit Legislation.
The data will help make a case for legislation, education, infrastructure and enforcement to reduce these items in our waterways.

The data is entered into the Port Phillip Bay Litter Database and the *'Australian Marine Debris Initiative Database'.*

Litter is recorded as collected from 3 transects (lines along which observations/records are made) located at the *Widest, Narrowest* and *Mid sections* of the beach to give a *representative sample* of the whole beach.

Each transect has 3 *quadrats* (1m x 1m square) located at the *top of the beach*, the *last high tide line*, and *midway* between.



Shoreline graphic and legend by Michael Beasley

EQUIPMENT: 50m tape measure, compass, clip board, datasheet, pen, 12 tent pegs, gloves, collection bags or buckets.

GUIDE TO AUDIT SET-UP

1. A permanent structure at the top of the beach serves as the starting point for repeated surveys of the 3 transects.
   Each transect runs from the *permanent landmark* at the top of the beach to 1*m past the last high-tide line*.
2. Describe the *permanent landmark* at the top of the beach in the *"Start landmark"* field at top left side of the datasheet.
3. Run the tape measure across the beach towards the closest point on the shoreline to set the transect direction.
4. At the *start landmark*, use a compass to find the transect direction across the beach. Record the direction on the datasheet.
   Use the same direction for all 3 transects.
5. As you cross the beach look for the last high tide line (usually a trail of seaweed along the beach).
6. Record the distance from top of beach to last high tide at the top left of the datasheet.
7. Mark the end of the transect with a peg 1m past the last high-tide line
8. Leave tape measure in place across the beach and insert pegs 0.5m either side of start and end points.
9. Divide the distance from transect start to finish by 2 in order to calculate the location of the middle quadrat.
10. At the top of the beach, place tent pegs to mark each corner of the 1m X 1m square quadrat (litter data collection zone).
11. Begin litter data collection in quadrat 1 (top of the beach), proceeding to quadrat 2 (middle) and quadrat 3 (high-tide line).

TIPS ON LITTER COLLECTION

TO SAVE TIME: each collector should target a particular item, eg 'cigarette butts' and collect and count 5 of them before telling the Data Recorder as they put the litter into the collection bag.

All litter in audit area quadrats is to be collected, recorded, bagged, and responsibly disposed.

Note: If any litter is collected from outside of the quadrats please don't record it on this datasheet.

TIPS ON DATA RECORDING

A separate datasheet is required for each transect. Be sure to complete all details at the top of datasheet!

Be sure to record the number of items in the correct quadrat column (1,2 or 3).

Blank fields under each MATERIAL TYPE column are for recording *harmful litter items* found that are not listed on the sheet.

If you run out of space in a quadrat column for a particular item, write the name of the item in one of the *blank fields*.

Any additional unlisted items are to be recorded in the appropriate column under NOTES FOR EACH QUADRAT.

To save time and space, record items in groups of 5 as they go in the bag.

Put a comma after each entry so it's clear that *5,5 means 10* (not 55).

Send completed audit to:	**Any queries? Phone Neil Blake 0409 138 565**	
	More information:	
Port Phillip Baykeeper	**Australian Marine Debris Initiative Database**	
Port Phillip EcoCentre	http://www.tangaroablue.org/database.html	
55A Blessington St	**Victorian Litter Action Alliance**	http://www.litter.vic.gov.au/
St Kilda VIC 3182	**CSIRO**	https://blog.csiro.au/tag/marine-debris/
baykeeper@ecocentre.com	**Beach Patrol Australia**	http://www.beachpatrol.com.au/
www.bay-keeper.com		

APPENDIX G: BAYKEEPER BEACH LITTER AUDIT DATA SHEET

PORT PHILLIP BAY CATCHMENTS BEACH LITTER AUDIT TRIAL DATASHEET

Beach name **Date**

Beach transcect (tick): ***Widest*** ***Narrowest*** ***Mid section***

Start landmark **Transect direction (compass reading)**

Distance from start landmark (top of beach) to last high tide line

Start & Finish times

Survey by **Email/phone**

Note: use the blank fields under each MATERIAL TYPE to record harmful items not already listed on the datasheet.

MATERIAL TYPE	Quadrat 1	Quadrat 2	Quadrat 3	Total	MATERIAL TYPE	Quadrat 1	Quadrat 2	Quadrat 3	Total
Plastics					**Plastics (cont.)**				
bags - bait					sauce sachets				
bags - ice					soy sauce (fish)				
bags - shopping (grey)					straws				
bags - shopping (white)					syringes				
bags - shopping					takeaway food tubs (hard)				
bottles - soft drink					takeaway food lids (hard)				
bottles - fruit juice					ties (cable)				
bottles - water					tile spacers				
bottle caps									
bottles - bleach/cleaner					**Polystyrene**				
bubble wrap					beads				
cartons - fruit juice					cups				
cellophane wrap					food boxes / trays				
cigarette lighters					pieces <5mm				
cigarette butts					pieces 5mm +				
cling wrap / film					packaging				
cups / cup lids									
confectionery wraps					**Glass**				
dental floss					broken pieces				
fishing line					bottles - beer				
fishing lures					bottles - beer stubbie				
food packaging (soft)					bottles - wine				
forks, knives, spoons									
lollypop sticks					**Metal**				
nurdles					bottle tops - metal				
pens / markers					cans - aerosol				
pieces - hard <5mm					cans - beer				
pieces - hard 5mm +					cans - soft drink				
pieces - soft <5mm					cans - spirits				
pieces - soft 5mm +					fish hooks				
rope / twine					**Rubber / Elastic**				
6 pack can-holders					balloons				
strapping (scrap)					bands				
strapping (whole)					hair ties				

NOTES FOR EACH QUADRAT - Record any plastic items not listed on datasheet

1. TOP OF BEACH	**2. MID BEACH**	**3. HIGH TIDE**	**OTHER NOTES**

Has the beach been raked or cleaned in the past 24 hours (tick) ***Yes*** ***No*** ***Not sure***

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1

Guide for Performing the Baykeeper Beach Litter Audit

Table of Contents

Background:

The design of the **Port Phillip Baykeeper beach litter audit method commenced in 2014** in response to numerous Australian and international studies that have confirmed the direct environmental impact of marine plastic pollution. It was developed from the need to adopt a consistent data collection method among different organizations. The Baykeeper beach litter audit method is designed primarily to **rigorously document smaller litter items, particularly microplastics, that might otherwise be overlooked by groups conducting 'whole beach' clean-ups.**

Purpose:

This guide is provided for small teams to be able to complete an audit in 2 hours of less. This small time commitment will enable teams to **regularly complete monthly audits over the course of a year and achieve the statistical rigour required to confirm trends in litter volumes and type over time.**

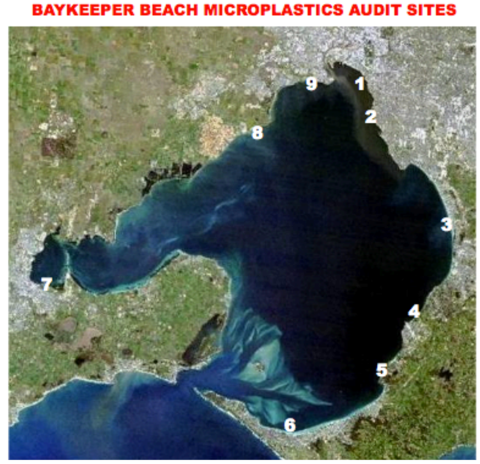
Audit Sites:

Eleven audit locations have been identified at beaches around Port Phillip Bay. Out of these, 8 are associated with **a river or a creek that flows into the Bay from an urban catchment**. The other 3 are located to gather data to provide insights on the **mobility of litter due to tidal currents and seasonal winds**.

Key factors affecting choice of location

The amount of plastics entering the Bay is closely associated with **rainfall events and storm surges**. Most plastics float in the upper water column and are carried on **wind-generated waves** or in the direction of **tidal currents** during calm (low wind) conditions. Due to the combined effects of tides and varying wind directions **some plastic objects may travel widely in the Bay before eventually being cast up on a beach**. Consequently, it is impossible to tell where litter stranded on beaches on any given day may have originally come from. To address this uncertainty, a **'baywide' approach** to consistently document and compare beach litter from several sites over at least **12 months** is required.

BAYKEEPER BEACH MICROPLASTICS AUDIT SITES



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2

Audit Method Design

Need for statistical rigour

Statistical rigour is essential for the data to effectively inform measures to reduce plastic pollution, eg. legislative change, local source reduction plans, and influence community behaviour (choice of products for waste avoidance and responsible disposal).
The key components of statistical rigour are regular data collection, using the same method, at the same place, every month for at least a year (representing all seasonal conditions). To support and add value to the Tangaroa Blue 'whole of beach' audit method the terminology used in the data entry sheet is consistent with Tangaroa Blue's **National Marine Debris Initiative** database.

Snapshot of the 'whole beach' condition

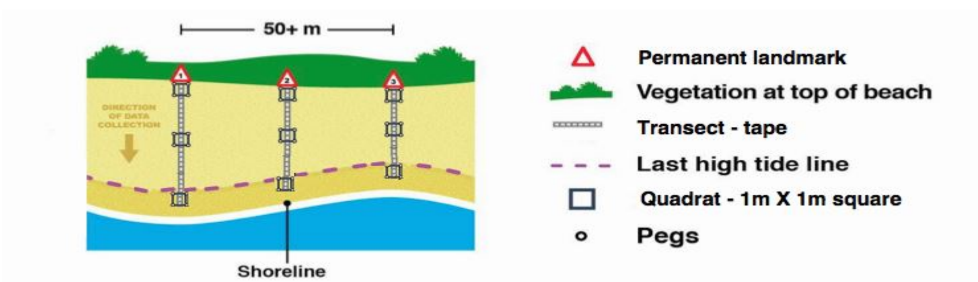
The locations of the three transects that cross the beach ('widest', 'narrowest' and 'middle' sections of beach) provide a representation of the range of conditions created by locally prevailing winds, waves and tidal currents. These prevailing conditions transport sand and debris, including litter. The widest section of beach is where most sand deposition is occurring in the longer term; and the narrowest is where the least is occurring.

Beach width and 'last high tide' line

The width of the beach is formed by conditions prevailing over the longer term, and may vary seasonally due to sand erosion or deposition. However, **the location of the *last high tide line* will vary** from day to day due to prevailing wind conditions at the time of the tide. The reason for locating the quadrat at the last high tide line is that it provides an indication of litter arriving on that day.

Transect and Quadrat Locations

Each transect starts at the 'permanent landmark' at the top of the beach to ensure the transect is in the same place each time you conduct a survey. This is intended to ensure ***statistical rigour*** to systematically represent the prevailing conditions at that section of beach.
As shown above, transects run roughly at a right angle from the top of the beach towards the ***closest point at the waterline***.
Each transect has its own ***permanent landmark***; but the compass directions across the beach are the same for all transects.
The length of each transect ***(distance between each permanent landmark and the last high tide line)*** will generally vary according to the width of beach.



Planning your Audit:

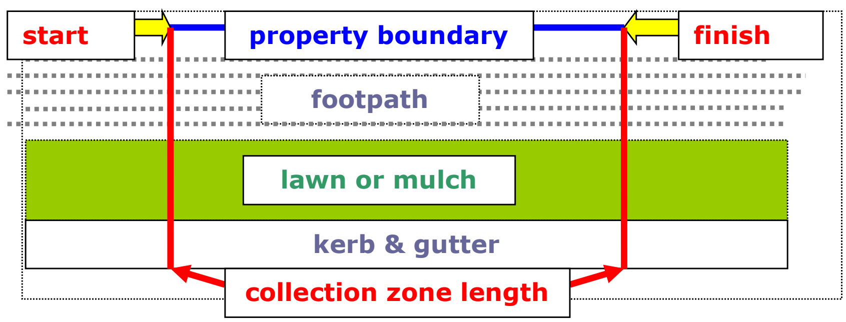
Check the Bureau of Meteorology http://www.bom.gov.au/ for tide times and weather conditions:
- Audits should be ideally conducted 1 hour after high tide
- Audits should not be conducted during strong winds or electrical storms
- Dress for the weather and wear a hat and sunscreen as necessary

Additional Audit Methods
Tracking Beach Litter to Source

Separate datasheets have been created to capture data from **'Streets'** and from **'Creeks and Rivers'** that feed into the Bay. While the beach datasheets can tell us the types of litter entering the Bay, the **'Streets'** and **'Creeks and Rivers'** datasheets will tell us where it's coming from.

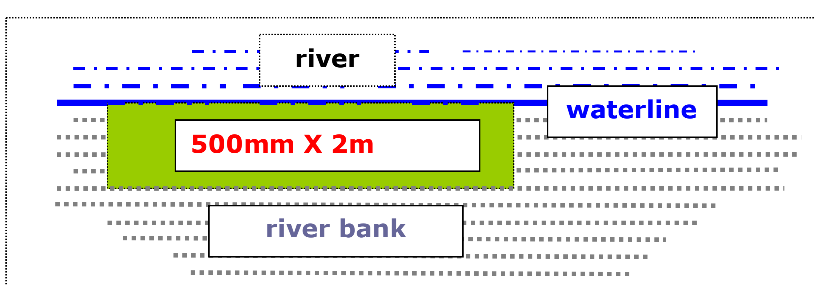
'Street' Audits:

Street audits are conducted noting which of the following land use applies: residential, parkland, commercial (24 hours), commercial (9/5 weekdays), industrial, or public buildings. In the Streets method, litter is collected from 3 zones located at the **footpath, grass and/or mulch beds, and gutter zones** of the street frontage to quantify litter from source to the stormwater system.



'Creeks and Rivers' Audits:

Creeks and Rivers audits are conducted on stream banks, with one quadrat located upstream of a stormwater drain outfall and one quadrat downstream.
Comparing the litter found in quadrats that are upstream of a stormwater outfall with those that are downstream provides clues as to specific items that may be coming from the outfall.



St. Kilda West Beach

Accessibility

- Parking meter required: $5.10 per hour or $12.30 all day

Hazards

- Remember some common hazards include sun, wind, and pedestrians

Additional Notes

- Distance between widest and narrowest transects: 280m

Widest Section
Transect 1

- Align transect with the streetlamp and the end of the St. Kilda pier walkway

Compass direction: 234N

Midsection
Transect 2

- Align transect with the parking meter and the yellow buoy

Compass direction: 234N

Narrowest Section
Transect 3

- Align transect with the black and brown short post on the recycled plastic walkway

Compass direction: 234N

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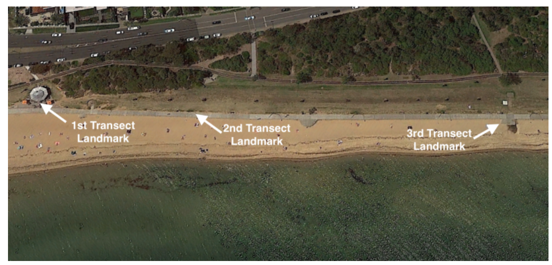
Point Ormond

Accessibility
- Car park next to beach
- Payment required for parking ($5.10 per hour)

Hazards
- Careful with the bike path between the car park and the beach
- Remember some common hazards include sun, wind, and pedestrians

Additional Notes
- Distance between widest and narrowest transects: 240m



Widest Section
Transect 1

- Align transect with the post of the Point Ormond Café building
-

Compass direction: 222N

Midsection
Transect 2

- Align transect with the lamp post

Compass direction: 222N

Narrowest Section
Transect 3

- Align transect with the edge of the ramp closest to the rock wall/pier/dock to the easternmost edge of the beach

Compass direction: 222N

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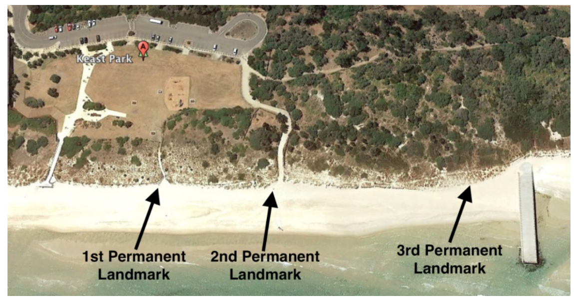
Keast Park

Accessibility
- Car park next to a walkway leading to the beach
- Payment required for parking

Hazards
- Remember some common hazards include sun, wind, and pedestrians

Additional Notes
- Distance between widest and narrowest transects: 180 m



Widest Section
Transect 1

- Align transect with the left edge of the emergency post 114 (looking from the beach)

Compass direction: 251 SW

Midsection
Transect 2

- Align transect with the "Fragile Dunes" sign that is next to the walkway and near the emergency post 115

Compass direction: 251 SW

Narrowest Section
Transect 3

- Align transect with the 5th post to the south of the "No Horses sign"
- This sign is located next to the small concrete pier to the south of the other transects

Compass direction: 251 SW

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Frankston Beach

Accessibility

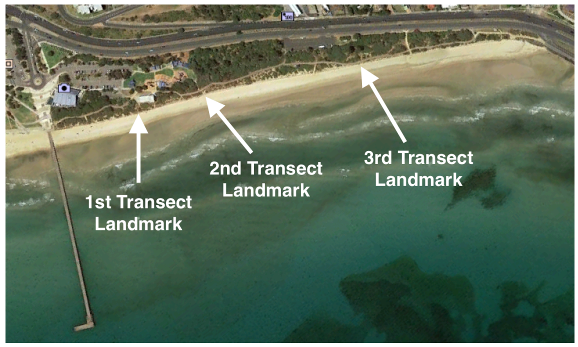
- Car park next to a walkway leading to the beach
- Payment required for parking

Hazards

- Remember some common hazards include sun, wind, and pedestrians

Additional Notes

- Distance between widest and narrowest transects: 325 m



Widest Section

Transect 1

- Align transect with the emergency post 158 right by the entrance by the Australian Volunteer Coast Guard building

Compass direction: 293 NW

Midsection

Transect 2

- Align transect with the third post from the walkways by emergency post 159 and with the large tree located behind it

Compass direction: 293 NW

Narrowest Section

Transect 3

- Align transect with the sign beyond the fence with the direction of the Pier, Visitor Centre and Playground (in blue) and with the direction of Oliver's Lookout and Sweetwater Creek (in green) (it is the post south of the emergency post 160)

Compass direction: 293 NW

Mt. Martha Beach

Accessibility

- Car park next to beach entrance
- No payment required for parking

Hazards

- Potential for asbestos in pieces of roofing or siding of beach boxes that break off
- Remember some common hazards include sun, wind, and pedestrians

Additional Notes

- Distance between widest and narrowest transects: 274 m
- Sand is grainy, easy to confuse with nurdles

Widest Section
Transect 1

- Align transect with the tall gray post with electrical lead behind decaying tree

Compass direction: 294 NW

Midsection
Transect 2

- Align transect with Beach box #84, blue and yellow colored

Compass direction: 294 NW

Narrowest Section
Transect 3

- Align transect with Beach box #121, red, white and blue colored

Compass direction: 294 NW

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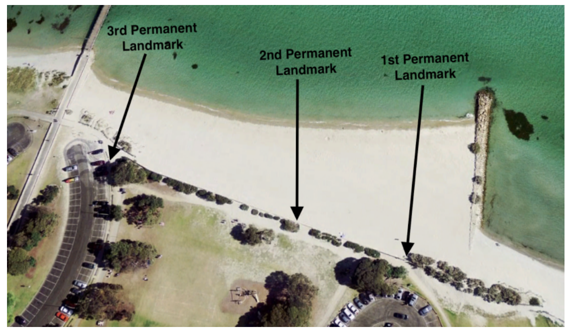
Rye Beach

Accessibility
- Car park next to beach
- Payment required for parking

Hazards
- Remember some common hazards include sun, wind, and pedestrians

Additional Notes
- Distance between widest and narrowest transects: 145 m



Widest Section
Transect 1

- Align transect with the middle of the gate entrance to the beach

Compass direction: 0 N

Midsection
Transect 2

- Align transect with the second from the left post on short wall bordering the beach near the playground

Compass direction: 0 N

Narrowest Section
Transect 3

- Align transect with the sign in the parking lot that reads "Rye Pier 3P Area"

Compass direction: 0 N

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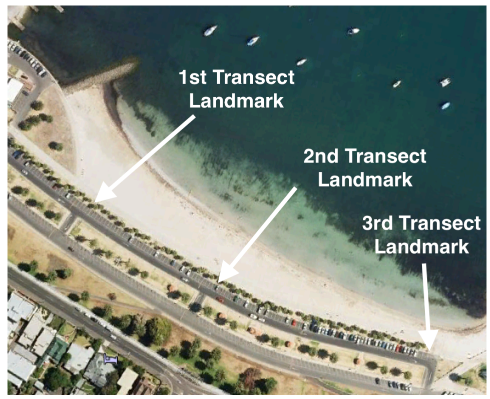
Eastern Beach



Accessibility

- Car park next to beach
- Payment required for parking

Hazards

- Volleyball courts
- Use gloves if rummaging through seaweed (beware of sharp pieces)
- Remember some common hazards include sun, wind, and pedestrians

Additional Notes

- Distance between widest and narrowest transects: 265m straight, 272 path

Widest Section
Transect 1

- Align transect with the palm tree located between the two chairs on the sidewalk at the western end of the beach (closest to ferris wheel).

Compass direction: 16N

Midsection
Transect 2

- Align transect with the outside edge of the post closest to the ferris wheel of the sign labeled "Eastern Beach"

Compass direction: 16N

Narrowest Section
Transect 3

- Align transect with the blue paint line marking the edge of the sidewalk at the eastern side of the beach (farthest from ferris wheel)

Compass direction: 353N

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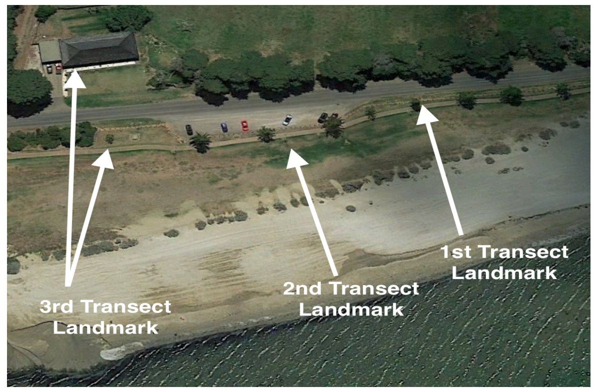
Werribee South Beach



Accessibility

- Car park next to beach
- No payment required for parking

Hazards

- Sharp shells on beach
- Remember some common hazards include sun, wind, and pedestrians

Additional Notes

- Distance between widest and narrowest transects: 107 m

Widest Section
Transect 1

- Align transect with the two signs on the eastern side of the car park: "Market Garden Area" (white) and "Mud on road" (yellow)

Compass direction: 16N

Midsection
Transect 2

- Align transect with the blue lamp post in front of the car park

Compass direction: 16N

Narrowest Section
Transect 3

- Align transect with the door of the green building above beach and the large tree

Compass direction: 353N

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APPENDIX I: INTERVIEW SCHEDULE WITH SCOUT

- Why and when did you become a Scout?
- What are your main values as a Scout?
- What activities in general are Australian Scouts involved in? What activities is your group involved in?
- Can you tell us about earning badges? (the process, requirements)
- What is the purpose of earning badges? How long does it normally take you to earn a badge?
- What badge are you going to earn through your work with the EcoCentre?
- Can you tell us more about what you have to do (requirements) to earn this specific badge?
- Are there other ways to get this specific badge?
- Do you think other Scouts would be interested in getting this badge through this same activity you're involved in at the EcoCentre? Why?
- Outside of earning this badge, what value do you think your work with the EcoCentre has?
- How did you come across the EcoCentre as someone to work with to gain this badge?
- How do you suggest we go about promoting or engaging your fellow scouts on doing this?

APPENDIX J: INTERVIEW SUMMARIES

Interview with Donna Shiel

We interviewed Donna Shiel, Waste and Resource Recovery division of Sustainability Victoria, to better understand the efforts to address microplastic pollution in the Port Phillip Bay area and the government's role in the issue. The goal of this interview was to gather information about Sustainability Victoria, the Victorian Litter Action Alliance, and the Port Phillip Bay microplastics investigation project that Donna is working with.

Donna first provided background about Sustainability Victoria. It is a government state agency made up of three major departments: Waste and Resource Recovery, Energy Efficiency, and Climate Change. Sustainability Victoria works with a range of organizations, including non-profits like the EcoCentre, schools, community groups, and the Victorian government.

Donna described the reasons for her awareness of and interest in microplastics as a combination of interactions and social media that came about because of her position at Sustainability Victoria. As an employee of an environmental government agency, she was more regularly exposed to topics like microplastic pollution. She read about the Microbead Act, where products' barcodes are scanned to see if they contain microbeads or not, and found it an interesting event that showed the importance of microplastics. Through meeting and speaking with Neil Blake, the Port Phillip Baykeeper, she found out that microplastics were a huge issue in Port Phillip Bay. Further interviews on her radio show and with Heidi Taylor from Tangaroa Blue Foundation about plastics and the breakdown of plastics were major influences on Donna's knowledge about the issue and helped give her a better idea of the extent of the issue in her community.

In Donna's role as the Litter Champion within the Waste and Resource Recovery division, she manages a 30-year plan for waste management in Victoria. Part of this plan is Victoria's Litter Report Card, a compilation of data from a variety of sources used to determine the top five key litter issues in the state. Microplastics were found to be one of these five key litter issues, thus Sustainability Victoria began a microplastics investigation project. Sustainability Victoria is working with several organizations on this project: Melbourne Water, which manages water quality and sewage treatment, Environmental Protection Authority (EPA) Victoria, and the Port Phillip EcoCentre. This microplastics project will use the Baykeeper Beach Litter Audit at six pre-selected locations in Port Phillip Bay along with taking sand samples at each. The audit will collect data on the types of visible litter in the surveyed areas, and the sand samples will be analysed through lab work to collect data on the litter not detected by the naked eye. The audits and sampling will be performed one time and the data will be presented in a report that will be used to spread awareness of microplastic pollution and as evidence to the government to fund further sampling and ongoing research in the bay.

Next, Donna described the Victorian Litter Action Alliance. It is a community of practice of 15 organizations who each play a role in different parts of the main goal of improved litter management in the state of Victoria. EPA Victoria and Melbourne Water are both members. VLAA is mainly a networking forum to share information and participate in the development of projects (such as the microplastics investigation project). The VLAA creates an annual business plan to share what each of the 15 organizations are doing and how each can get involved with each other's activities. Donna coordinates this network as the Litter Champion, facilitating the network to improve collaboration within the alliance as well as beyond it. The VLAA strives to spread awareness of the importance of improving litter management in Victoria to their broader stakeholder group.

Interview with the Werribee Riverkeeper

We met John Forrester when we were doing an audit at Werribee South Beach. He is the Werribee Riverkeeper, acts as the official spokesperson of the Werribee River Association, and advocates for its waterways and the environment, as well as coordinates community initiatives. We had a brief conversation with him, in which he pointed out that the Western Treatment Plant of Melbourne, which as stated earlier, collects 60% of the sewage water in the bay area, discharges into the Port Phillip Bay through the Werribee River. This is the waterway coming out just south of Werribee South Beach. When performing the audit, we were surprised at the small amount of plastic found there, but John later told us there had been a beach cleanup two weeks before, were they did find a substantial amount of them right by the river mouth. Just before departing he shared his plans for starting to perform the Baykeeper Beach Litter Audit next summer, and organize the community to do it consistently in order to aid the EcoCentre in its efforts to address the microplastic issue in the bay.

Interview with the Friends of Williamstown Wetlands

We met members of the Friends of Williamstown Wetlands at Wader Beach. This is a community group that was established in order to maintain and enhance the natural areas near Williamstown that had been previously protected by Williamstown Rifle Range. They have several activities that revolve around the environmental scope, among which are the monthly surveys of the beach in search for plastic. However, their litter method is not the same as the Baykeeper method. When researching and setting up their method, they find out that the predominant method consisted of 100 m transects along the beaches, following the shoreline. However, when they trialled it, they realized they needed to go perpendicular to the beach in order to cover the various conditions in the beach.

They run two different methods, one considering a transect and another one considering quadrats. For the transect method they have two different locations on the beach, where they start at pre-selected landmarks and set two temporary landmarks spaced two meters apart across the beach within the "semi-permanent vegetation." From there the transect goes 24 meters towards the beach, and the idea behind it is that it covers more conditions of the beach, such as the semi-permanent vegetation, the seagrass section, and the hard-packed sand. For their quadrat method, they establish three sets of two quadrats across the beach at different locations. The quadrats however, are 16 sq. m., in which the litter is collected and recorded.

Even though the method covers a much larger auditing space than that of the Baykeeper method, it is still completed in an hour. This is because they don't focus on microplastics. The smallest pieces they take in consideration are those smaller than 5 cm, so they disregard nurdles and other types of microplastics.

Finally, they told us that the purpose of their audits was to get a grasp of what is out there. However, they don't exactly know where the litter is coming from. That is why they are going to stop running the method by the end of the year, and focus their efforts on the sources of litter rather than on the beach itself.

After the conversation with the Friends of Williamstown Wetlands we determined that we would not be able to work with them, at least in regards to the data we need, since their focus is on larger pieces of plastic. However, using the Baykeeper method at Wader Beach also has its implications, since there is too much vegetation, which will make it hard to get smaller debris. This interview also served to highlight the differences in the data produced by different methodologies, and showed the importance of producing a standardized method that would allow for further joint efforts.

Interview with Judith Muir

We interviewed Judith Muir, Owner Operator and Marine Educator at Polperro Dolphin Swims, to deepen our understanding of the plastic issues in the marine environment and learn about actions being taken. Judith works at her family owned company, where they tend to and conserve the dolphins, rather than exploit them. *Polperro Dolphin Swims* seeks to promote environmentally responsible behaviour towards Port Phillip Bay's marine environment and its' dolphin and seal populations by embracing an operating philosophy of conservation through education and interpretation (Polperro Dolphin Swims, 2015).

Judith found out about the issue of microplastic pollution through a conference at which Neil Blake, the Port Phillip Baykeeper, spoke. She felt empowered by his message and agreed with what he stood for. Judith told us she believes we must conserve the environment in all ways because it is beautiful, yet fragile. She explained that the ecosystem in the bay is very diverse, as it is home to many different species of marine wildlife, but that it is poor in population, as these species are decreasing in size. Along with her work with the dolphins, Judith categorized herself as a "compulsive picker-upper" (personal communication, March 31, 2017) and is constantly working to take care of the environment. She believes if others see her doing it, they will follow her lead. Judith told us that she knew little about the science and legislative process behind the issue, but knows that her constant efforts are influencing the outcome of the problem.

All the information we gathered during this interview, provided us with a deeper insight on public perspective on microplastic pollution in the bay, along with an awareness of the passion and actions being taken towards preserving the marine environment.

Interview with Heidi Taylor

Heidi Taylor was one of the founders of Tangaroa Blue Foundation in 2004, and is currently the CEO of the organization. Prior to this commitment, she was a scuba dive instructor and felt she had a strong connection with the ocean because of this. She retold her experience when she first became aware of microplastic pollution, when she picked up a plastic water bottle and it broke into a million pieces in her hand. This provided her with a visual of the extent of the issue and how plastic in the ocean can be affected and broken down so easily. She then explained the importance of removing this debris from the ocean as early as possible because the more debris there are, the more expensive and time consuming it is to remove.

Tangaroa Blue Foundation runs a program called the Australian Marine Debris Initiative. This is the national platform where they invite volunteers, non-profit organizations, government agencies, and industry bodies to work on plans and projects revolving around marine debris. The AMDI developed a litter collection system that can be used to track rubbish to where it came from. Heidi explained that there are over 7.8 million pieces of data in the database, and more than 70,000 people have contributed to it since it began. The AMDI website contains further information on this marine debris project and also provides training materials to teach people how to collect data properly and then input it into the database. Then Tangaroa Blue Foundation works with industries to analyze the data and how industries can improve their work habits in order to prevent debris from entering into the marine environment.

However, when Heidi Taylor started running Tangaroa Blue Foundation, there was no general understanding that marine debris was a problem. She described that if you spoke to someone about "marine debris" meant, they thought you were talking about driftwood. And since marine debris in general was not acknowledged as an issue, microplastics were not even close to being on people's radar as pollution.

Currently, Tangaroa Blue Foundation is working with Sustainability Victoria, Neil Blake, and other scientists to determine the best way to include microplastics in the existing AMDI litter collection system. Funding is already secured to expand the database to be able to collect that data. Then Heidi told us about the trial that Sustainability Victoria was implementing with Neil's Baykeeper Beach Litter Audit methodology to collect microplastics. She believes that this trial will be a strong platform for getting people involved. When asked about other ways to get poeple involved in litter audits, Heidi said that the best way to engage volunteers is to use social media. When using this platform, she said it is important to state the goal clearly because people want to know that their time toward the effort is valuable and helping make a difference.

The goal that Heidi informed us of for Tangaroa Blue Foundation is to upgrade the present AMDI database in the next six months to include a section for microplastics.They are also working to develop a web application so people can access the database quicker and easier to input information.

Interview with the Scouts

Since Scouts represent the main target group to continue to perform the beach litter audit method we interviewed two members that have already been involved with it. Sam Perkins is 17 years old and is currently a Venturer Scout; and Greg Perkins is the venturer scouts' leader. They are both part of the Brighton Sea Scouts troop, which corresponds to the oldest and largest scout group in the Bayside area. The interview addressed the badge earning process in the scouts, the work they have been doing with the EcoCentre, and ways of involving other scout groups.

Earning venturer awards such as the Queen Scout award and the Endeavour award is one of the motivations for these scouts to help the EcoCentre with performing the beach litter audit method according to Sam. As Greg explained to us, the hours taken to perform the method count towards the environment component of these two awards, for the Queen award they need 30 hours, while for the Endeavour award they need 70 additional hours (personal communication, 2017). Previously, Greg has involved Sam and the rest of the venturers in activities such as tree planting and working with younger scout branches such as Cubs to fulfil the environment component, nevertheless these activities were not stimulating enough and could not go on for a long period of time. Therefore, this project involving the EcoCentre represents a more engaging activity that will be done on a more regularly basis and will allow the venturers to see the changes in the beach and look for trends in the data of the rubbish they are picking up. As Greg pointed out, the bay is this scout group's "playground", thus these scouts will be willing to engage in ways to learn more about it and protect it.

Currently, Greg and Sam are performing the method once per term, which is approximately once every 3 months. Nevertheless, Neil, the Baykeeper, thinks that collecting data once per month would be more suitable for generating better results. Therefore involving other Scout groups would represent gathering more volunteers to perform the method and possibly be able to get the beach litter audit method done once per month. Greg is already in contact with scout groups in Geelong and Werribee to present the option to participate in the EcoCentre's effort to address microplastic pollution. As he mentioned there are 150 Scout groups around the bay in Victoria and each of them gets $500 per year to contribute to the group's activities, thus Greg believes that this could be a good incentive for other groups to partake in performing the method.

One of the goals of this project is for it to be on an ongoing basis. For this, Greg looks forward getting two or three venturers to get the Endeavour award so that they become the trainers for future scouts willing to participate in the beach litter audit method. This represents a threat now since the venturers currently performing this method might leave and won't be able to train others. Another goal of this project is to get quality data. For this reason Greg thought that the Venturers would be the most suitable group (15-18 years old) since they are more serious and responsible than younger scouts. Similarly, Greg mentions that having more than 7 scouts performing the method is not efficient, since they might get distracted. Therefore he suggest to have 5 or 6 venturers interested and to do the audit on the weekends so that they are more focused.

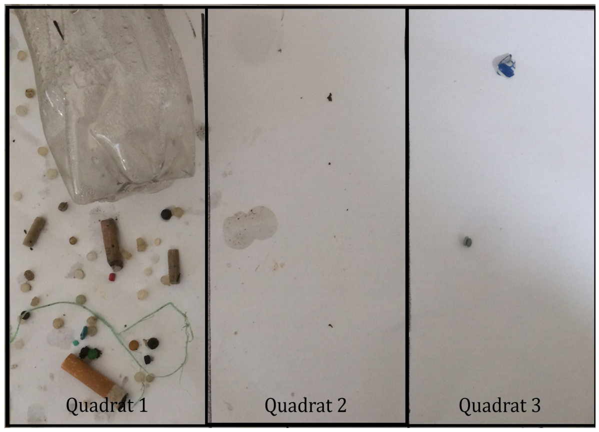
Finally, we asked Greg and Sam about ways of promoting and engaging scouts to perform the beach litter audit method. As a response, they suggested us to write an article in the Scout magazine about the benefits of taking part in the EcoCentre's effort to address microplastic pollution while working towards earning a badge. This magazine comes out every term and is sent out to every venture and leader, thus we might get responses from people interested in taking part. Additionally, they recommended to append our flyer to the links in the Scouts Victoria webpage, since these links show resources for achieving the environment component of the scout awards.

APPENDIX K: DATA

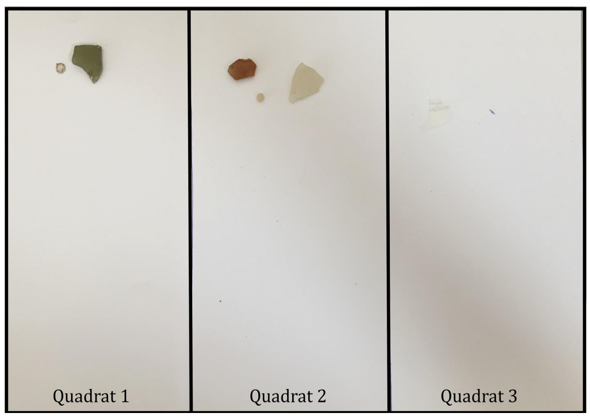
St Kilda West Beach

Date: 22/03/2017									
Location: West Beach									
Transect (compass direction)	Widest (222 SW)			Middle (222 SW)			Narrowest (222 SW)		
Distance from top of beach to last high tide line (m)	53.95			102			10		
	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)
material type									
Plastics									
bags-bait									
bags-shopping									
bottles-soft drink	1								
bottles-fruit juice									
bottle-caps							1		
bottles-bleach/cleaner									
bubble wrap									
cartons-fruit juice									
cellophane wrap									
cigarette lighters									
cigarette butts	4								
cling wrap/film									
cups/lid cups									
confectionary wraps							2		
dental floss									
fishing line									
fishing lures									
forks, knives, spoons									
lollypop sticks									
nurdles	39		2		1		1	1	3
pens / markers									
pieces-hard <5mm	4								2
pieces-hard >5mm	2								

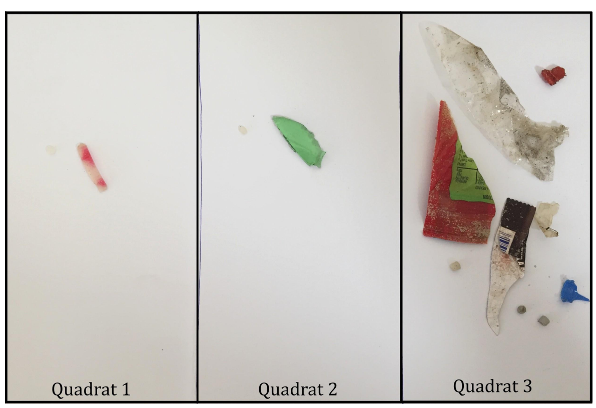
pieces-soft <5mm									
pieces-soft >5mm	1		1						2
rope / twine	1								
6 pack can-holders									
strapping									
sauce sachet									
soy sauce (fish)									
straws									
takeaway containers									
ties (cable)									
tile spacers									
polystyrene									
bead									
cups/lid cups									
food boxes / trays				1					
pieces <5mm	1								
pieces >5mm									
packaging									
glass									
broken pieces				1	2			1	
bottles - beer									
bottles - beer stubbies									
bottles - wine									
metal									
bottle tops - metal									
cans-aerosol									
cans-beer									
cans-soft drink									
cans-spirits									
fish hooks									
syringes									
rubber/elastics									
balloons									
bands									
hair ties									
Other									
List of other items									



Widest Transect



Midsection Transect



Narrowest Transect

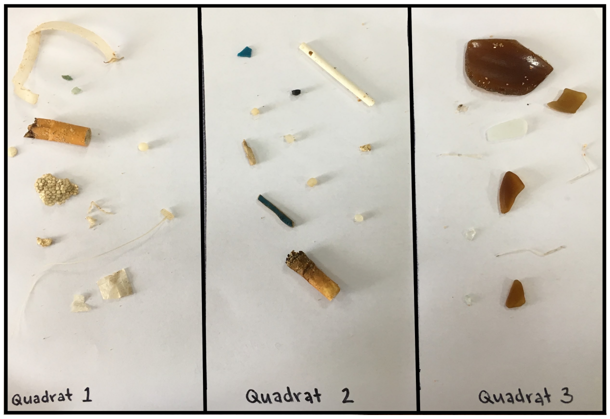
Point Ormond Beach

*Point Ormond was the first beach we performed a trial at and we did not collect any measurements for this site

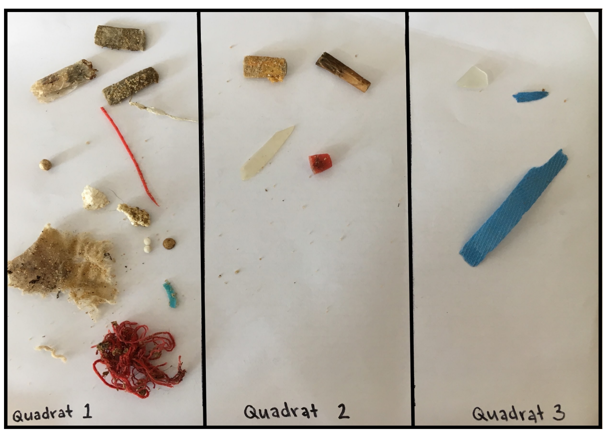
Date: 21/03/2017									
Location: Point Ormond									
Transect (compass direction)	Widest (230 SW)			Middle (222 SW)			Narrowest (212 SW)		
Distance from top of beach to last high tide line (m)	n/a*			n/a*			n/a*		
	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)
material type									
Plastics									
bags-bait									
bags-shopping									
bottles-soft drink									
bottles-fruit juice									
bottle-caps	1			1					
bottles-bleach/cleaner									
bubble wrap									
cartons-fruit juice									
cellophane wrap	2								
cigarette lighters									
cigarette butts	1	1		3	2		1	1	
cling wrap/film									
cups/lid cups									
confectionary wraps									
dental floss									
fishing line				1					
fishing lures									
forks, knives, spoons									
lollypop sticks		1							
nurdles	2	5							
pens / markers									
pieces-hard <5mm	2	1	1	2					
pieces-hard >5mm		1		1		1			
pieces-soft <5mm			1						

pieces-soft >5mm	1	1		2	1	1			
rope / twine				2					
6 pack can-holders									
strapping									
sauce sachet					1				
soy sauce (fish)									
straws							1		
takeaway containers									
ties (cable)									
tile spacers									
polystyrene									
bead	1			3					
cups/lid cups									
food boxes / trays									
pieces <5mm	4	1		2					
pieces >5mm									
packaging									
glass									
broken pieces	1		7			1			4
bottles - beer									
bottles - beer stubbies									
bottles - wine									
metal									
bottle tops - metal									
cans-aerosol									
cans-beer									
cans-soft drink									
cans-spirits									
fish hooks									
syringes									
rubber/elastics									
balloons									
bands									
hair ties									
Other									

List of other items	Clothes price tag, piece of rubber <5mm	rubber fragment >5mm	rubber strand						



Widest Transect



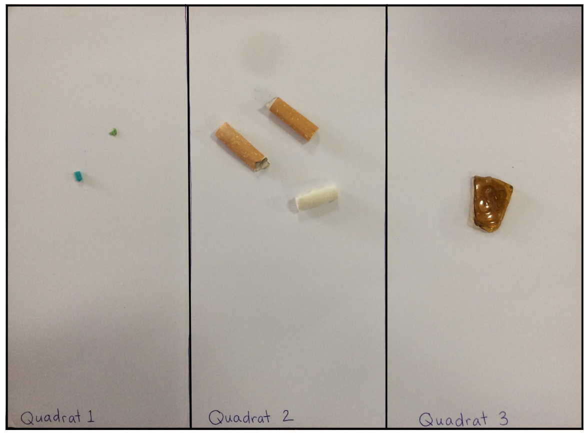
Midsection Transect

Narrowest Transect

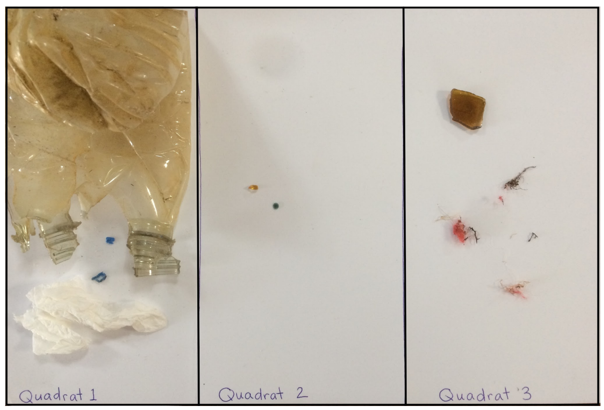
Keast Park

Date: 31/03/17									
Location: Keast Park									
Transect (compass direction)	Widest (251 N)			Middle (251 N)			Narrowest (251 N)		
Distance from top of beach to last high tide line (m)	20.5			21.3			18.3		
	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)
material type									
Plastics									
bags-bait									
bags-shopping									
bottles-soft drink									
bottles-fruit juice									
bottle-caps									
bottles-bleach/cleaner									
bubble wrap									
cartons-fruit juice									
cellophane wrap									
cigarette lighters									
cigarette butts		3					1		
cling wrap/film									
cups/lid cups									
confectionary wraps									
dental floss									
fishing line									
fishing lures									
forks, knives, spoons									
lollypop sticks									
nurdles							125	13	
pens / markers									
pieces-hard <5mm	2	1		1	1		10		
pieces-hard >5mm				1			26	4	
pieces-soft <5mm								3	
pieces-soft >5mm									

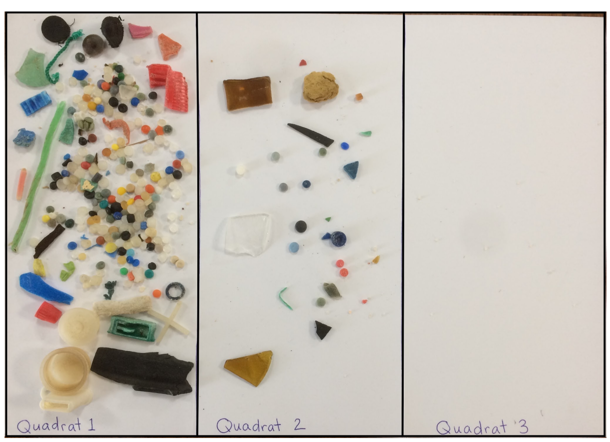
rope / twine						1	1		
6 pack can-holders									
strapping									
sauce sachet									
soy sauce (fish)							1		
straws									
takeaway containers									
ties (cable)									
tile spacers							1		
polystyrene									
bead									
cups/lid cups									
food boxes / trays									
pieces <5mm									
pieces >5mm									
packaging									
glass									
broken pieces					2	1		4	
bottles - beer									
bottles - beer stubbies									
bottles - wine									
metal									
bottle tops - metal									
cans-aerosol									
cans-beer									
cans-soft drink									
cans-spirits									
fish hooks									
syringes									
rubber/elastics									
balloons									
bands									
hair ties							1		
Other									
List of other items								piece of foam	



Widest Transect



Midsection Transect

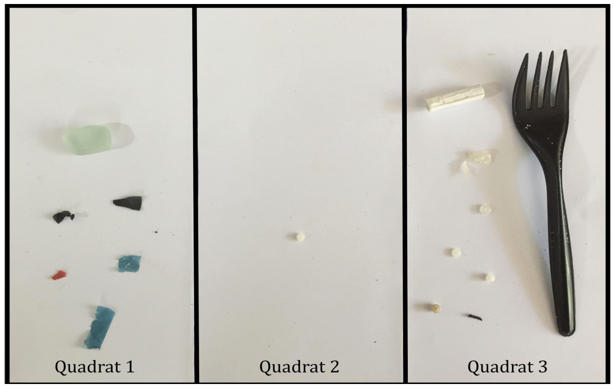


Narrowest Transect

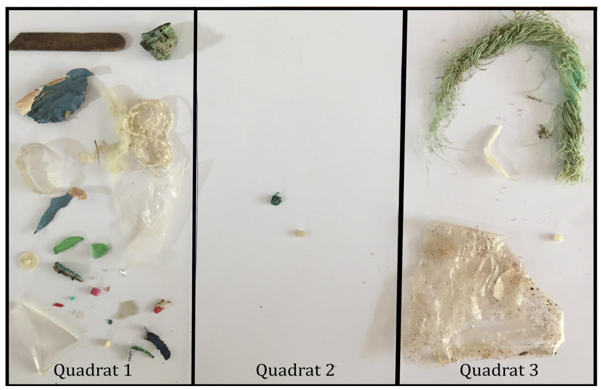
Mt. Martha

Date: 31/03/17									
Location: Mt. Martha									
Transect (compass direction)	Widest (294 NW)			Middle (294 NW)			Narrowest (294 NW)		
Distance from top of beach to last high tide line (m)	31			26.54			22		
	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)
material type									
Plastics									
bags-bait									
bags-shopping									
bottles-soft drink									
bottles-fruit juice									
bottle-caps									
bottles-bleach/cleaner									
bubble wrap									
cartons-fruit juice									
cellophane wrap				1		1			
cigarette lighters									
cigarette butts									1
cling wrap/film									
cups/lid cups									
confectionary wraps				2					
dental floss									
fishing line									
fishing lures									
forks, knives, spoons			1						
lollypop sticks									
nurdles		1	4	1	1	1	1	4	
pens / markers									
pieces-hard <5mm				3	1				
pieces-hard >5mm	2			1				1	
pieces-soft <5mm				1	1				
pieces-soft >5mm	2			1					

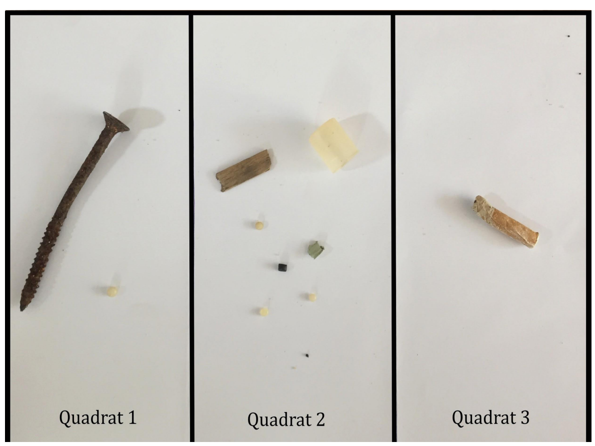
rope / twine				1		1			
6 pack can-holders									
strapping									
sauce sachet									
soy sauce (fish)									
straws						1			
takeaway containers									
ties (cable)									
tile spacers									
polystyrene									
bead				1					
cups/lid cups									
food boxes / trays									
pieces <5mm	1								
pieces >5mm									
packaging									
glass									
broken pieces	1			3					
bottles - beer									
bottles - beer stubbies									
bottles - wine									
metal									
bottle tops - metal									
cans-aerosol									
cans-beer									
cans-soft drink									
cans-spirits									
fish hooks									
syringes									
rubber/elastics									
balloons									
bands									
hair ties									
Other									
List of other items				5 pieces of painted wood, fabric, popsickle stick, button			Large metal nail	Piece of painted wood., popsicle stick	



Widest Transect



Midsection Transect

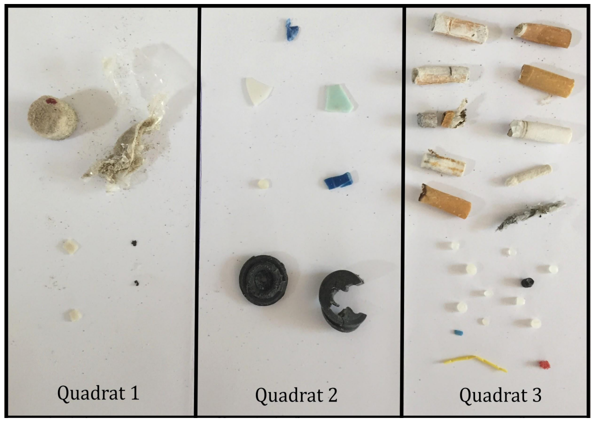


Narrowest Transect

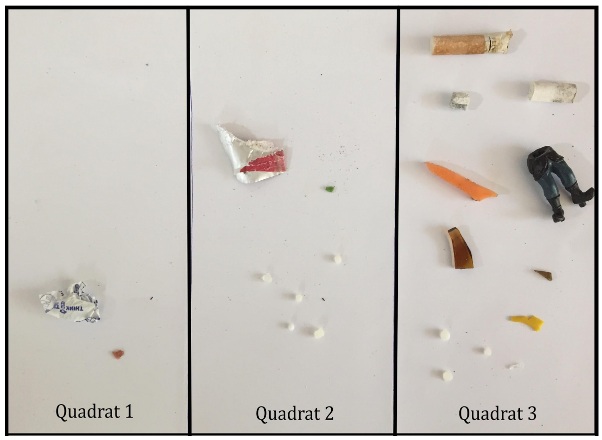
Rye Beach

Date: 31/03/17									
Location: Rye Beach									
Transect (compass direction)	Widest (0 N)			Middle (0 N)			Narrowest (0 N)		
Distance from top of beach to last high tide line (m)	50.8			40.4			15.4		
	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)
material type									
Plastics									
bags-bait									
bags-shopping									
bottles-soft drink									
bottles-fruit juice									
bottle-caps									
bottles-bleach/cleaner									
bubble wrap									
cartons-fruit juice									
cellophane wrap			1						
cigarette lighters									
cigarette butts			10			3			2
cling wrap/film									
cups/lid cups									
confectionary wraps				1					
dental floss									
fishing line									
fishing lures									
forks, knives, spoons									
lollypop sticks									
nurdles		1	10		5	3		2	4
pens / markers									
pieces-hard <5mm	1				1	1			1
pieces-hard >5mm	1	5	1			1		1	1
pieces-soft <5mm									
pieces-soft >5mm	1								

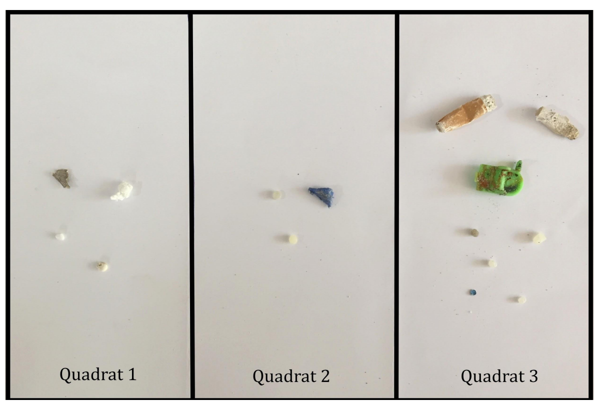
rope / twine									
6 pack can-holders									
strapping									
sauce sachet									
soy sauce (fish)									
straws			1						
takeaway containers									
ties (cable)									
tile spacers									
polystyrene									
bead							2		
cups/lid cups									
food boxes / trays									
pieces <5mm									
pieces >5mm							1		
packaging									
glass									
broken pieces					2	2			
bottles - beer									
bottles - beer stubbies									
bottles - wine									
metal									
bottle tops - metal									
cans-aerosol									
cans-beer									
cans-soft drink									
cans-spirits									
fish hooks									
syringes									
rubber/elastics									
balloons									
bands									
hair ties									
Other									
List of other items	cylinder synthetic material		colorfull pree of spongey foam		magazine piece	plastic toy	shiny paper		



Widest Transect



Midsection Transect



Narrowest Transect

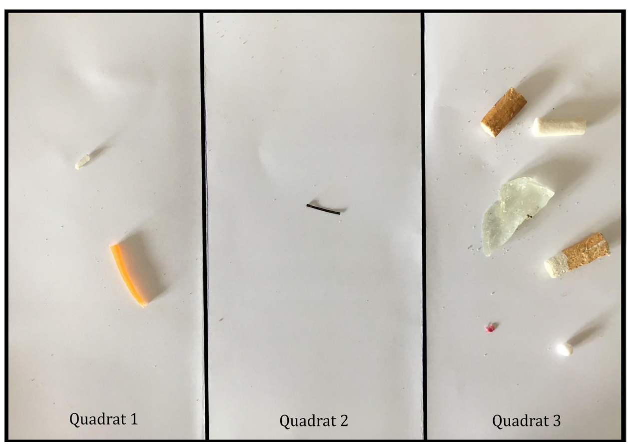
Eastern Beach-Geelong

Date: 23/03/17									
Location: Eastern Beach - Geelong									
Transect (compass direction)	Widest (16 N)			Middle (16 N)			Narrowest (353 N)		
Distance from top of beach to last high tide line (m)	37.2			22			9.5		
	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)
material type									
Plastics									
bags-bait									
bags-shopping									
bottles-soft drink									
bottles-fruit juice									
bottle-caps									
bottles-bleach/cleaner									
bubble wrap									
cartons-fruit juice									
cellophane wrap				1					
cigarette lighters									
cigarette butts	6		1	4					3
cling wrap/film									
cups/lid cups									
confectionary wraps									
dental floss									
fishing line									
fishing lures									
forks, knives, spoons									
lollypop sticks									
nurdles									
pens / markers									
pieces-hard <5mm				3					1
pieces-hard >5mm	1		1				1	2	
pieces-soft <5mm	3		3						
pieces-soft >5mm				2					

rope / twine			1						
6 pack can-holders									
strapping									
sauce sachet									
soy sauce (fish)									
straws									
takeaway containers									
ties (cable)									
tile spacers									
polystyrene									
bead	1			2					
cups/lid cups									
food boxes / trays									
pieces <5mm				1					
pieces >5mm				1					
packaging									
glass									
broken pieces	1					1	1		1
bottles - beer									
bottles - beer stubbies									
bottles - wine									
metal									
bottle tops - metal									
cans-aerosol									
cans-beer									
cans-soft drink									
cans-spirits									
fish hooks									
syringes									
rubber/elastics									
balloons									
bands									
hair ties									
Other									
List of other items	Small fabric, bondage			Fabric, aluminum fragment					

Widest Transect

Midsection Transect

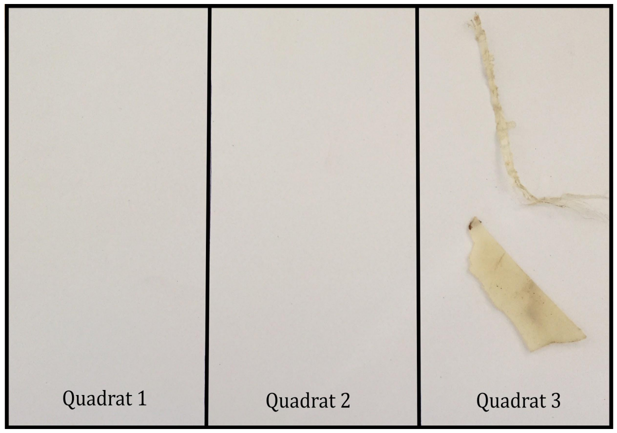


Narrowest Transect

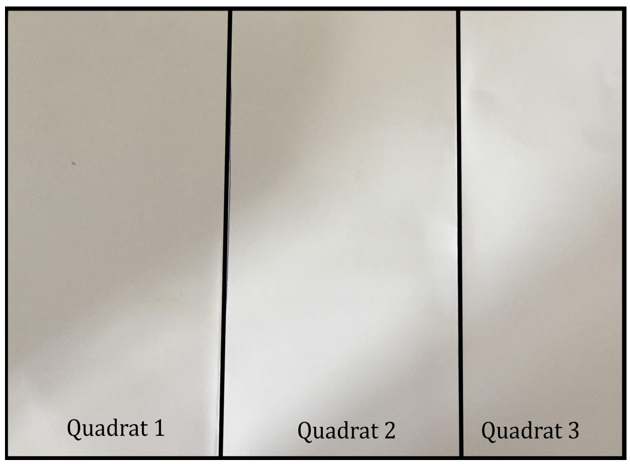
Werribee South Beach

Date: 23/03/17									
Location: Werribee South									
Transect (compass direction)	Widest (148 SE)			Middle (148 SE)			Narrowest (148 SE)		
Distance from top of beach to last high tide line (m)	19.87			10.4			8.13		
	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)	Top (Q1)	Mid (Q2)	Low (Q3)
material type									
Plastics									
bags-bait									
bags-shopping									
bottles-soft drink									
bottles-fruit juice									
bottle-caps									
bottles-bleach/cleaner									
bubble wrap									
cartons-fruit juice									
cellophane wrap									
cigarette lighters									
cigarette butts									
cling wrap/film									
cups/lid cups									
confectionary wraps									
dental floss									
fishing line									
fishing lures									
forks, knives, spoons									
lollypop sticks									
nurdles									
pens / markers									
pieces-hard <5mm									
pieces-hard >5mm			1						1
pieces-soft <5mm									
pieces-soft >5mm			1						

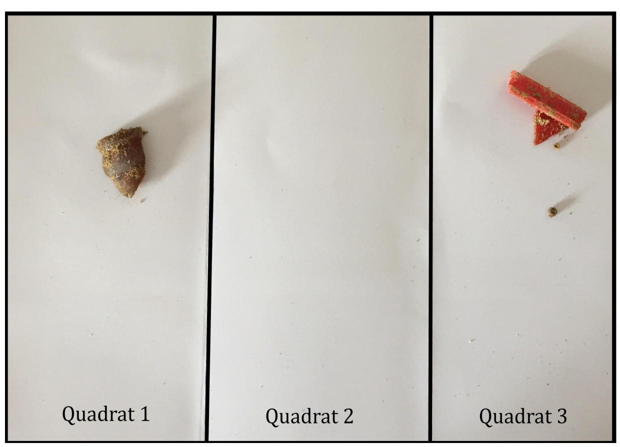
rope / twine									
6 pack can-holders									
strapping									
sauce sachet									
soy sauce (fish)									
straws									
takeaway containers									
ties (cable)									
tile spacers									
polystyrene									
bead									
cups/lid cups									
food boxes / trays									
pieces <5mm									
pieces >5mm									
packaging									
glass									
broken pieces		1							
bottles - beer									
bottles - beer stubbies									
bottles - wine									
metal									
bottle tops - metal									
cans-aerosol									
cans-beer									
cans-soft drink									
cans-spirits									
fish hooks									
syringes									
rubber/elastics									
balloons									
bands									
hair ties									
Other									
List of other items									
				Note: found nothing					



Widest Transect



Midsection Transect



Narrowest Transect

APPENDIX L: PROMOTIONAL FLYER FOR SCOUTS

I WANT YOU TO PROTECT THE BAY

Join in the effort to monitor and combat microplastic pollution in Port Phillip Bay. Microplastic pollution is increasingly harming aquatic wildlife that mistake them for food but they are often missed in litter audits.

The Baykeeper 'Street to Beach' Litter Audits is:

- A systematic method for surveying microplastics on beaches, waterways and streets.
- Designed for a dedicated team to complete each audit in just 2 hours.
- Great for teams and small group of scouts

Monthly data collection will identify the most common plastic pollutants and where they come from. This information will be used to inform local litter reduction strategies and influence government policies. All data collected is entered into the Australian Marine Debris Database. You can contribute to this effort by conducting audits at your local street, waterway, or beach; and eventually training other scouts in the audit methods.

Develop new skills as a Scout, while improving your local environment.

Perform Baykeeper Beach Litter Audits and earn hours toward:

- Environment Badge
- Service Badge
- Venturer Award
- Queen's Scout Award
- Endeavor Award

Don't miss out on this opportunity!

Neil Blake
Port Phillip Baykeeper

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