A PUMP-BASED METHOD TO SAMPLE MIDWATER MICROPLASTIC POLLUTION

B-TERM
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ABSTRACT

Microplastics, plastic pieces less than 5mm in diameter, are a threat to marine ecosystems. The Port Phillip EcoCentre quantifies surface level microplastics entering Port Phillip Bay in order to advocate for policy to mitigate microplastic pollution in Australia. We worked with this organization to develop a method to collect microplastics at greater depths, between 0.2 to 2 meters below the water's surface. We designed and tested a portable pump and created a how-to video and an instructional manual for its use. We also created an animation to show the consequences of microplastics and the importance of our project to the public.

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MICROPLASTICS: TINY POLLUTANTS, GREAT CONSEQUENCES

Plastic pollution is a major threat to marine ecosystems. Worldwide, the use of single-use plastic, combined with frequent littering, negligent waste management practices, and inadequate wastewater treatment lead to unwanted plastic in rivers and oceans (Charko, Kowalczyk, Johnstone, Seymore, & Quekal, 2018). Cauwenberghe et al. (2013) reported that plastic has only been around for 60 years but has since contaminated most marine habitats (Figure 1).

Figure 1. A Manta Ray Swims through Plastic Pollution in Indonesian Waters (Gaworecki, 2018).

Microplastics are particularly problematic, as they are less than 5mm in diameter (smaller than a pea) and are easily mistaken by marine organisms as food. Once swallowed, microplastics accumulate in and block an organism's digestive tract, causing starvation (Rezania et al., 2018) or possible organ rupture (Lavers, Bond, & Hutton, 2014). Additionally, microplastics have toxicological effects on marine organisms—microplastics can adsorb persistent organic pollutants and metals, and thus when an organism consumes microplastics they also are ingesting toxins (Mai, Bao, Shi, Wong, & Zeng, 2018). After an organism ingests microplastics, these microplastics become a threat to the health of animals higher in the food chain; humans and other predators who eat organisms containing microplastics may suffer the same physical and toxicological complications mentioned above (Rezania et al., 2018).

Our project addressed microplastic pollution in and around Port Phillip Bay, a bay located in the southeastern Australian state of Victoria. The Victorian Government reports that the Bay is home to nearly 10,000 species of aquatic life, with several of these species being exclusively found in the Bay (2018). Given that the large metropolitan area of Melbourne surrounds the Bay, and that there are so many endemic species, consideration of microplastic pollution in the Bay is warranted.

We worked with the Port Phillip EcoCentre (hereinafter referred to as the 'EcoCentre'), an environmental hub in Melbourne that performs research to quantify the effects and abundance of microplastics in the Bay (Charko et al., 2018). Through sampling research, the EcoCentre aims to make evidence-based recommendations to policy makers in order to reduce microplastic pollution. This research is vital, because an Australian Senate Inquiry into the threat of marine plastic pollution concluded that "further research is required to identify effective mitigation and prevention strategies to stop plastic debris from entering the marine environment" (Urquhart, 2016, p. 62).

The EcoCentre has shown that about 1.4 billion litter items reach Port Phillip Bay each year; 79% of these items are microplastics

Recent trawling studies by the EcoCentre reveal that about 1.4 billion litter items reach Port Phillip Bay each year from the Yarra and Maribyrnong Rivers, and that 79% of these litter items are microplastics (Blake & Charko, 2019). However, the EcoCentre's method of trawling is only efficient at analyzing microplastics located in the top 20 cm of the rivers. Therefore, their results are likely an underestimation, as some plastics sink below the surface if they are of a higher density, or if they take on pollutants or other attachments in the ocean (Mai et al., 2018).

The goal of our project was to develop a means to quantify microplastic pollution at various depths, between 0.2 to 2 meters below the surface of the waterways that flow into Port Phillip Bay. To reach this goal, we set the following objectives:

1. To become familiar with microplastic pollution and work being done to address it
2. To identify appropriate methods for collecting microplastics at various depths
3. To design and build a suitable portable microplastic sampling method
4. To create instructional materials for our sampling method to be used in the future

Figure 2. Our Objectives.

BACKGROUND ON MICROPLASTIC POLLUTION & SAMPLING STRATEGIES

In this chapter we will discuss the causes and effects of microplastic pollution. Then, we will describe the geography of Port Phillip Bay and its surrounding catchments. We will introduce the Port Phillip EcoCentre, noting the work they have completed in measuring microplastics coming into the Bay. Finally, we will review sampling methods used to collect and measure microplastics in other parts of the world, and how these methods could be adapted to align with research being done by the Port Phillip EcoCentre.

Microplastics: What Are They and How Are They Harmful?

Environmental experts across the world agree that plastic pollution is a major threat to our planet. Annually, millions of metric tons of plastic are produced, and after these plastic products have served their purpose they do not go away. Most plastics are resistant to biodegradation, and so they persist in the environment (Thompson et al., 2004). As more plastic is produced everyday, the plastic pollution problem will continue to worsen with no end in sight.

Recent studies have begun to draw attention to a new facet of plastic pollution—microplastics. Microplastics are plastic particles less than 5 mm in diameter. There are two categories of microplastics: primary and secondary. Primary microplastics are circular or cylindrical plastic particles that are the pre-fabrication material for many commercial and industrial plastic products (Mai et al., 2018). These plastics are called nurdles or pellets, and end up in waterways due to spillage at industrial production sites (Rezania et al., 2018). Secondary microplastics are particulates that have broken off of larger plastic debris (Cole, Lindeque, Halsband, & Galloway, 2011). Plastic debris can fragment from physical, biological, or chemical processes, such as UV degradation (Mai et al., 2018).

Microplastics are especially prevalent in oceans, lakes, and rivers because the marine environment is the "main sink" for plastic waste (Imhof, Ivleva, Schmid, Niessner, & Laforsch, 2013). Recent studies have found that even remote environments like the Arctic deep sea are accumulating microplastic pollution (Bergmann & Klages, 2012). When plastics first enter marine ecosystems, they tend to be very buoyant and light, thus easily transportable by currents and winds (Imhof et al., 2013; Cauwenberghe, Vanreusel, Mees, & Janssen, 2013). Research done by Adventure Scientists, a nonprofit organization engaging citizen scientists in environmental research, not only shows the prevalence of microplastic pollution, but also the magnitude at which currents and wind spread microplastics (2017). Their map of microplastic pollution (Figure 3) shows that ocean currents between South America and Africa and to the west of the United States carry a high density of microplastic pollution.

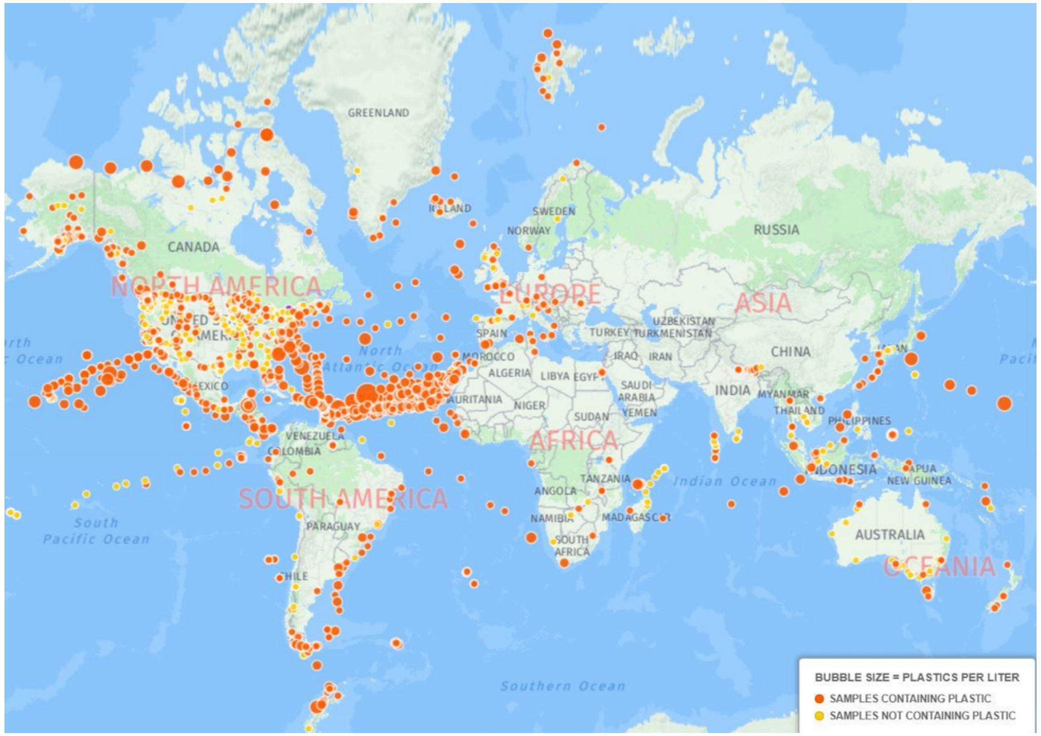

Figure 3. Presence of Plastic Pollution in Sample Areas Across the Globe (Adventure Scientists, 2017).

Since microplastics are less than 5mm in diameter, they can easily be mistaken as food by marine organisms and can harm marine life (Charko et al., 2018). Once swallowed, microplastics accumulate in and block an organism's digestive tract, resulting in starvation (Rezania et al., 2018) or possible organ rupture (Lavers et al., 2014). Additionally, microplastics adsorb persistent organic pollutants (POPs) and metals, which worsens the toxicological effects they have on a marine organism once ingested (Mai et al., 2018). A subtype of POPs is polychlorinated biphenyls (PCBs). These pollutants have been reported to cause reproductive dysfunctions in orca and dolphin populations in Europe (Jepson et al., 2016).

After an organism ingests microplastics, these microplastics become a threat to the health of the animals higher in the food chain; humans and other predators who eat organisms containing microplastics may suffer the same physical and toxicological complications mentioned above (Rezania et al., 2018). A preliminary study done for the United European Gastroenterology Week in Vienna, Austria investigated the occurrence of microplastic in human stool samples (Schwabl et al., 2018). The study found that in samples from eight healthy adults, each living in different parts of the world, microplastics were present in every sample. The report acknowledged that since the study was only preliminary and tested eight adults, the findings are not conclusive. However, statistician Daniela Dunkler says that it is reasonable to estimate more than half of the population has microplastics in their stools (Duncombe, 2018). Exact side effects of microplastics in human gastrointestinal tracts are undefined, but one can infer that, just as with marine organisms, aggregation of microplastics in a human's digestive tract will eventually cause harm. To address this lack of knowledge, researchers are now investigating what direct effects, if any, microplastics have on human health.

Collection Sites around Port Phillip Bay

Port Phillip Bay (Figure 4) is located in southeastern Australia in the state of Victoria. Water flows into the Bay from drainage basins, which are also known as "water catchment areas." Surface water coming from rain runoff, snowmelt, and streams which all flow into a shared outlet are considered to be part of a water catchment area. The government agency Yarra and Bay reported in 2018 that there are 21 natural drainage basins that drain into the Port Phillip Bay. The main rivers in the drainage basins are the Yarra, Maribyrnong, Werribee, Patterson, and Little Rivers. Also, in the drainage basins are three creeks: the Kananook, Mordialloc, and Kororoit creeks. The total area of these waterways and their catchments is over 9,790 km^2 (Yarra and Bay, 2018). In our study, we collected microplastic samples at sites along the Yarra and within the Bay itself. To provide geographical context for our project, we review the conditions of the Bay and the Yarra below.

Figure 4. Port Phillip Bay (Google Maps, 2019).

Port Phillip Bay

The Port Phillip Bay covers 1,950 km^2 and is located at the southern end of Victoria, feeding into the Bass Strait, (Yarra and Bay, 2018). Yarra and Bay reported in 2018 that the Bay is on average 13 meters deep with sandy seafloor, seagrass beds, and rocky reefs. The Port Phillip Bay is home to the Port of Melbourne—the home of 15,000 jobs and the location of 82 million dollars in annual exports and imports. The Bay also generates 10 million dollars in commercial fishing with its 10,000 different species of marine plants and animals (Yarra and Bay, 2018). The Bay's shore is home to over 3.2 million people, which makes it the most populated catchment in Australia. A noteworthy feature of Port Phillip Bay is the narrow mouth which connects it to the ocean. The mouth is only 3.5 km wide, which means that the plastic found in the Bay comes almost completely from its surrounding water catchments (Healey, Sorensen, Bergstrom, & Duquette, 2017). Further, plastics that reach the Bay from the surrounding water catchments are not likely to leave the Bay, also due to its narrow mouth.

The Yarra Catchment

The Yarra River is 242 km in length and runs east to west from Mt. Baw Baw and then down through Melbourne and into Port Phillip Bay (Melbourne Water, 2009). The Yarra water catchment is over 4,000 km^2 (Melbourne Water, 2009), and its location appears in Figure 5.

The Upper Yarra Catchment consists of freshwater rivers and creeks. One part of the Yarra River runs through Yarra National Park and has been closed off from the public since 1890. This preservation of the river is necessary because approximately 70% of Melbourne's drinking water comes from this length of the river annually (Yarra and Bay, 2018). The waterways in the National Park are highly valued and enjoyed for their beauty by both locals and visitors (Melbourne Water, 2017).

The southern reaches of the Yarra exhibit lower water quality (Melbourne Water, 2009b), likely due to a higher population density living in the area. Melbourne Water, a Victorian government owned statutory authority, reported in 2009 that more than one-third of the population of Victoria live in the Yarra catchment. Additionally, Yarra and Bay reported in 2018 that most of the land in the middle and lower section of the river has eroded, giving the river its muddy color. The land around the river has been cleared for agriculture, urban, and industrial development, which contributes to river erosion.

The Middle Yarra Catchment is comprised of the Yarra River, seven creeks, and a significant wetland area which is highly valued for its beauty and indigenous species. However, the balance between urbanization and agriculture in this area is delicate (Melbourne Water, 2017). The Middle Yarra Catchment transitions to the Lower Yarra Catchment at the Dights Falls, at which point the Yarra River then flows 17 km before reaching the Port Phillip Bay, going through Melbourne (Yarra and Bay, 2017). At the Dights Falls, the Yarra River turns from a freshwater river to an estuary, which is a tidal mouth of a large river (Melbourne Water, 2009). There are many wetlands in the lower catchment including both natural and stormwater treatment wetlands.

Despite locals valuing these waterways, the urbanization of this area has greatly altered them. Some alterations include straightening, channeling, and installing concrete lining in the waterways, which reduces the water quality, water flow, oxygen levels, and natural vegetation growth (Yarra and Bay, 2018). The greatest source of urbanization and development in the Yarra Catchment is the city of Melbourne. The size of the greater Melbourne area is 9992.5 km^2 and the estimated population that lives within it is 4.96 million (City of Melbourne, 2018).

Figure 5. The Yarra Catchment (Charko et al., 2018).

The EcoCentre: Driving Policy Changes to Mitigate Microplastic Pollution

The EcoCentre describes itself as a small not-for-profit organization that aims to "inspire, educate, and demonstrate sustainable practice to reconnect people to the natural world" (2018, p.2).

The EcoCentre itself is an environmental hub in St Kilda, an idea launched by the City of Port Phillip in 1998 (Port Phillip EcoCentre, 2019). According to the EcoCentre's website, the building was originally the St Kilda Botanic Gardens' old Park-Keeper's house, with a one-star energy efficiency rating. By 2003, the building had been retrofitted to a five-star energy level, and today it has six stars.

Through partnering with over 200 community groups, government agencies, schools, and research institutions, and by running seminars, hosting excursions, teaching in schools, and conducting research, the EcoCentre forms a vast network of knowledge and experience (Port Phillip EcoCentre, 2018, p.3). The work done with each collaborator produces different types of knowledge, as reported in a WPI Interactive Qualifying Project, "Identifying Knowledge Flow to Develop a Strategic Plan" (Stark, Wilson, Savoie, & Li, 2018). These outcomes include:

- Event/project cooperation
- Consulting
- Publicity
- Sustainability networking
- Political advocacy and development
- Scientific research

Through collaborative projects, the EcoCentre makes a significant contribution to the state of Victoria. From 2017 to 2018, the EcoCentre made submissions on ten local, state and federal plans, policies and strategies concerning biodiversity, waterway health, waste management, climate change and more (Port Phillip EcoCentre, 2018, p.3). Our Interactive Qualifying Project is designed to aid one of the EcoCentre's existing projects: Clean Bay Blueprint.

Clean Bay Blueprint Overview

Clean Bay Blueprint is a current project run by the EcoCentre which aims to quantify the amount of litter flowing into the Bay from Yarra and Maribyrong Rivers. This project is funded by the Victorian Government's Port Phillip Bay Fund, a fund created to improve the health of the Bay and its surrounding catchments. Energy, Environment and Climate Change Minister Lily D'Ambrosio stated that the projects supported by the fund "will protect the rich and unique environment of the Bay—one of our city's most important ecosystems" (Atkinson, 2017). The Port Phillip Bay Fund totals AU$3.57 million, so the EcoCentre came into public light when it received a grant of AU$600,000 for two of its projects (Atkinson, 2017). Clean Bay Blueprint was allocated AU$287,000 in funding to be used over the three years (Charko et al., 2018). Clean Bay Blueprint has, to date, accomplished the following:

- Developed a 'litter audit' method (Bayas, Ford, Lawes, & Buckley, 2017)
- Trained citizen scientists to perform quarterly litter audits at six beaches and various streets in catchments around Port Phillip Bay (Port Phillip EcoCentre, 2018, p.11)
- Undertaken monthly boat trawls of microplastic pollution that reveal increasing litter loads entering Port Phillip Bay (Charko et al., 2018)

In 2018, the EcoCentre published a report summarizing its methods and initial results from Clean Bay Blueprint. According to the report, the EcoCentre began monthly microplastic trawls in January 2015 under a previous project called "Turn Off the Tap," also funded by the Victorian Government. The methodology used was replicated in the Clean Bay Blueprint trawling.

The EcoCentre performs its monthly trawls along specific lengths of the Yarra and Maribyrnong Rivers (Figure 6). The two transects are purposefully close to where each river feeds into the Bay, as the trawls done there should reveal the total amount of litter flowing into the Bay. The researchers always start each trawl at a defined location and travel upstream for 30 minutes. However, the course of the boat along the river is not consistent for every trawl month-to-month, as boating inherently involves changing course to avoid other watercraft.

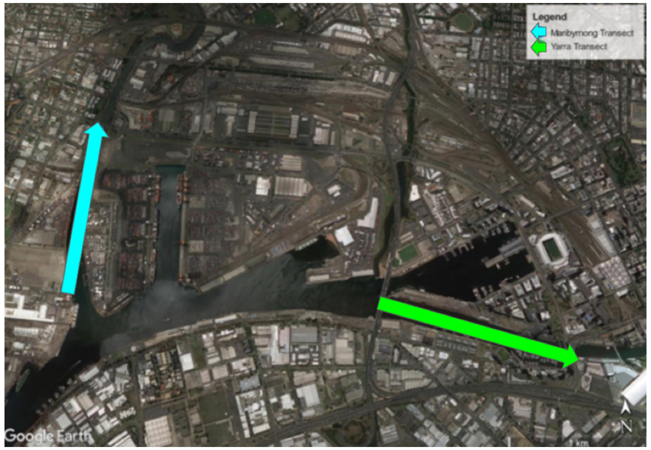

Figure 6. Approximate Trawling Transects Used by the EcoCentre (adapted from Charko et al., 2018).

The EcoCentre utilizes a manta net, which is a collection net designed for surface-level collection of microplastics (Figure 7). Microplastics accumulate in the codend, a mesh sock, located at the end of the net. The manta net is positioned on the side of a boat, outside of the boat's wake. During the trawl the boat motor speed is kept constant at 1,000 rpm. This constant speed ensures that the net is under consistent and appropriate conditions. The manta net that the EcoCentre employs has the following specifications:

- Mouth: 600 mm x 200 mm
- Length: 3 m
- Codend volume: 30 x 10 cm^2
- Mesh size: 330 µm

Figure 7. Manta Trawl on Side of Yarra Riverkeeper Vessel (Charko et al., 2018).

After the net has skimmed the river surface for 30 minutes, the net is retrieved, and the codend is transferred to a container to be dried. Once dried, samples are sorted into litter items and organic matter. To achieve separation of litter and organic matter, a researcher uses their own visual judgement and tweezers. The litter items are further sorted by diameter and litter type (Table 1).

From its data, the EcoCentre then extrapolates the total amount of litter that flows into the Bay from these rivers each year. To do this statistical analysis, they assume that the Yarra is 160 times wider than the width of the net, and the Maribyrnong is 120 times wider than the net.

Table 1. The EcoCentre's Categories of Litter Items (Charko et al., 2018).

MICROPLASTICS	MACROPLASTICS	NON-PLASTICS
Hard plastic pieces <2mm	Hard plastic pieces 6-10mm	Sponge
Hard plastic pieces 2-5mm	Hard plastic pieces >10mm	Other
Nurdles	Polystyrene beads >4mm	
Polystyrene beads <4mm	Plastic bottle caps	
Soft plastics <5mm	Plastic straws	
Cellophane <5mm	Soft plastics >5mm	
	Cellophane >5mm	
	Twine/fishing line	
	Cigarette butts	

Size reference:

Outcomes from Microplastic Trawling

In the EcoCentre's 2018 report, it stated that the Yarra River carries significantly more plastic than the Maribyrnong, and further that the litter loads in the Yarra seem to be increasing. It also reported that the major type of litter found in both rivers was hard plastic remnants. The EcoCentre postulates that the plastic pollution in the Bay comes from land-based sources, entering the Bay through storm water drains, wastewater treatment plants, and river runoff. Further, it found higher counts of polystyrene, nurdles, and plastic bottle caps in the Yarra River, and hypothesized that these come from the substantial manufacturing, retail, and hospitality precincts along the river. The EcoCentre reported that spikes in litter shown in its data correlated with times that Parks Victoria, a Victoria Government agency, emptied floating litter traps in the Yarra River.

According to its most recent number, the total number of litter items flowing into Port Phillip Bay from these two rivers is around 1.4 billion litter items annually; 79% of these litter items are microplastics (Blake & Charko, 2019). However, those numbers are most likely an underestimation, as the EcoCentre's method only collects surface-level microplastics and yields no data on the load of any microplastics located deeper than 20cm (Charko et al., 2018). Likely, there are microplastics located at deeper depths, as plastic particles that have adsorbed additives or other attachment will sink below the surface (Mai et al., 2018). Our group will address this gap in its data by developing and testing methods to measure microplastic pollution at deeper depths (Blake & Charko, 2019).

Microplastic Sampling Methods

Around the world, researchers use a wide variety of microplastic sampling methods. Based on the location and depth at which they are sampling, researchers customize their microplastic collection devices. Two common collection techniques are manta trawling and pump sampling. Both techniques present unique advantages and disadvantages, as discussed below. One key difference is that trawling collects surface level microplastics, whereas pumps collect microplastics below the surface. These techniques complement each other and have the capacity to produce the most robust data on microplastic pollution (Tamminga et al., 2019).

Manta Trawls

Manta nets (Figure 8) or trawls are tools that collect microplastics samples on the surface of waterways (Mai et al., 2018). The manta net was one of the first devices implemented for microplastic collection in 1980 (Setälä, Magnusson, Lehtiniemi, & Norén, 2016). The widely used mesh size of a manta net is 300 µm; this size is small enough to capture an adequate sample of microplastics, but not too small that it would become frequently clogged with debris (Mai et al., 2018). Advantages of manta nets include their easy usage and comparability to microplastic pollution data collected by similar devices. They are also able to sample large volumes of water, which helps to yield data that is representative of the total microplastic pollution on the surface of the waterway being tested (Prata, Costa, Duarte, & Rocha-Santos, 2019). However, manta nets are expensive, require a boat, make sampling time consuming, and cannot collect microplastics smaller than 300 µm due to the limiting mesh size (Prata et al., 2019).

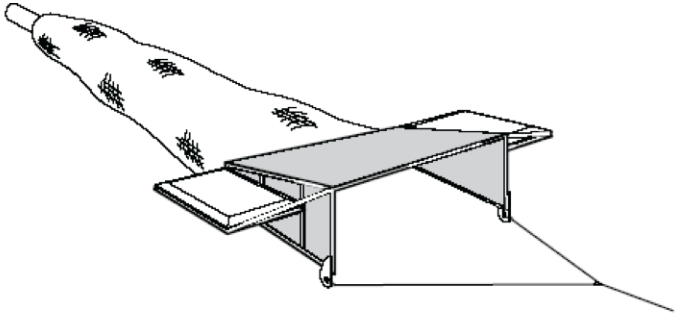

Figure 8. Manta Net (NOAA Fisheries, 2014).

Pumps

Portable pumps are an effective and simple method for microplastic sampling in rivers. Pumps can give a researcher access to shallower water where boats cannot navigate (Desert Research Institute, 2019). Sediment microplastic separation is the typical purpose for using pumps—a pump will push water and sediment up into an elutriation column where the heavy sand and rocks are separated from the microplastic (Ogunola & Palanisami, 2016). However, there are also effective pumps designed for microplastic collection in the water above sediment; specifically, submersible and above-water pumps are used for microplastic collection (Kershaw, Turra, & Galgani, 2019).

Both types of pumps must be operated in a stationary manner, and therefore cannot be towed by a boat. Outi Setälä (2016), a researcher at the Finnish Environment Institute, described the process of using a submersible pump (Figure 9). To operate a submersible pump, the device is lowered to a desired depth and the electrically driven internal flow gauge measures the controlled inlet flow of the pump for a fixed suction power and the sample water passes through the filter at the inlet of the pump. Setälä et al. used either a 100 or 300 µm mesh in their pump and found that “the pump with 100 µm filter gave higher microliter concentrations compared to manta trawl or pump with 300 µm filter” (2016, p. 177).

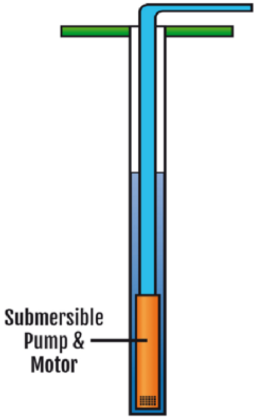

Figure 9. Submersible Pump (Alam, 2016).

The second type of pump, an above-water pump (Figure 10) is comprised of a long tubing lowered to a certain depth in the water, with a pump secured above the surface. Above-water pumps pull the water up from the larger body of water, as compared to the submersible pump, which pushes water up by creating pressure inside the pump, so the water has to flow through it. The function of this pump is the same as the submersible pump because water passes through a filter to capture microplastics. As in a submersible pump, the filter size can easily be changed in an above-water pump.

Figure 10. Above-Water Pump System (Mintenig, Int-Veen, Löder, Primpke, & Gerdts, 2017).

The volume of water sampled in a pump-sampling technique will influence whether the results for microplastic concentration levels are representative or not (Tamminga, Stoewer, & Fischer, 2019). If the concentration of microplastics is less than one particle per 1000 liters (which is often the case for microplastics greater than 300 microns), then a sample volume of greater than 1000 liters is required (Lenz &

Labrenz, 2018). Thus, when using a pump, a researcher should pre-determine their desired sampling volume based on the size range ofplastics being addressed and the expected concentrations of microplastics (Tamminga et al., 2019).

Extracting & Sorting Samples

After a researcher collects a sample of microplastic, using trawling or pumping, the next step is to extract the microplastics from the sample, identify them, and quantify them (Mai et al., 2018). The following is an example of a typical process researchers across the globe undergo to analyze microplastic samples. First, if the sampling device has collected organic matter in addition to plastics, a researcher performs an extraction. To extract the microplastics, first the sample volume is reduced, which can be done by utilizing a net that allows water to pass through during collection or by following bulk sample collection with sieving (Prata et al., 2019). Sieving involves using a metal mesh to isolate microplastics from fine debris, such as sediment.

Next, microplastics are drawn out through density separation; a saturated solution of NaCl, with a density of 1.20 g cm^-3, will cause most plastics to float to the top of the solution, as plastics generally have a density of 0.8-1.6 g cm^-3 (Mai et al. 2018). However, this step is only necessary when the sample contains sediment, and this method cannot recover higher-density plastic polymers, such as high-density polyethylene (Prata et al., 2019).

After extraction, purifying the sample by removing organic matter is helpful because purification allows for clearer identification of plastics (Mai et al., 2018). A frequently used technique is to add 35% hydrogen peroxide to the sample, which dissolves organic matter (Mai et al., 2018). This step is followed by a drying step, where the sample is typically put in a 60 ˚C oven (Mai et al., 2018). Next, to identify and quantify the microplastics in the sample, researchers often rely on visual inspection (Prata et al., 2019). Larger microplastics are easily identifiable and sorted out, but a microscope is necessary to observe smaller particles (Mai et al., 2018). Although visual sorting is simple, it lacks accuracy. Chemical characterization of microplastics though Fourier transform infrared spectroscopy or Raman spectroscopy can identify the exact type of plastic, if the particle ends up being plastic (Prata et al., 2019). Lenz et al. assessed the accuracy of visual inspection in 2015 and found that, for particles less than 100 μm in size, the success rate of visual inspection was less than 80%. Consequently, researchers should subject 10% of the microplastics they collect in a sample that are 100-5000 μm and all of the particles that are 20-100 μm to spectroscopic methods, in order to verify their identity as plastics (Prata et al., 2019).

Adapting a Method for the EcoCentre's Purposes

In proposing a method for midwater microplastic sampling of rivers, our group reviewed literature to find out the qualities of effective sampling methods. One significant consideration when sampling is that the “quantity and quality of microplastics recovered are highly dependent on sampling location and depth” (Prata et al., 2019). Before sampling, one should assess locations. Water currents and wind could direct plastics to a certain location within a river, for example. Also, most microplastics can be found at the top of waterways, so the method should include surface sampling. However, if the goal of sampling is to assess the total load of microplastics, one should design a method that is capable of analyzing microplastics at various depths. Methods that result in sampling larger areas, such as manta trawls, produce more representative data (Li, Liu, & Chen, 2018). However, bigger samples can also mean large sampling times, and in some cases, researchers might prefer rapid and less laborious sampling methods (Prata et al., 2019).

When collecting microplastics there is always risk that a sample will become contaminated with microplastics that are not actually from the waterways in which the sampling took place. For example, manta net sampling can contain contamination from the boat used for the trawl and the tow ropes attached to the net (Prata et al., 2019). Pump systems that are made of plastic could also contribute microplastics, contaminating the sample (Prata et al., 2019). Devices that avoid the use of plastic polymers in their design are optimal (Lenz & Labrenz, 2018).

One final consideration is that when using nets to collect microplastics, the mesh size greatly influences the concentration of microplastics found (Prata et al., 2019). For example, Prata et al. reported that in one study, “a nylon net (100 μm) revealed concentrations almost a hundred times higher than a manta net (333 μm), 0.1 and 0.00135 MP L^–1 respectively” (p. 152).

The main goal and deliverable for our project is to design a suitable, portable method to sample microplastics at depths varying from 0.2 to 2 meters. Through talking with Neil Blake, April Seymore, and Fam Charko of the EcoCentre, we learned what qualities they considered to be essential in a microplastic collection method (Figure 11).

- Produces accurate data
- Is replicable by others
- Allows for comparison to previous data collected
- Is portable, convenient, and inexpensive
- Is integrable into their current methods

Figure 11. The EcoCentre's Desired Qualities for a Microplastic Collection Method.

In order to obtain data that is comparable to the EcoCentre’s data, we had to use the same size mesh, 330 μm, in our device. Also, our method had to be able to measure the number of litter items flowing into the Bay over time, to be consistent with how the EcoCentre currently reports data.

Next, the EcoCentre visually sorts its collected samples, as previously described, so our method did not have to consider cross-contamination. Any cross-contamination collected in the sample would be smaller than could be seen with the naked eye, and therefore not included in the results. Earlier, we discussed that in scientific literature, researchers often include extraction and purification steps in their microplastics sample analysis. However, the EcoCentre’s method of sample analysis does not include these steps. Since the EcoCentre has been analyzing its samples for five years in the same way, we decided to follow the same method because, if we changed the analysis method, we would not be able to compare our results to its previous results. Finally, portability will allow our method to be used by anglers or other citizens who might measure microplastics in other locations. In the next section we will explain the methods we used in order to design a midwater microplastic sampling method that addressed the EcoCentre’s needs.

RESEARCHING & DESIGNING THE MCWAP (MICROPLASTIC COLLECTOR WITH A PUMP)

The aim of our project was to aid the EcoCentre in achieving its goal of driving policy changes to mitigate microplastic pollution in Port Phillip Bay. Specifically, this project determined a way to measure microplastic pollution below the surface of the waterways flowing into the Bay. Here, we will detail the methods we used to accomplish each of our objectives (Figure 12). We also report on the results of our work.

Objective 1: Understanding Microplastic Pollution and its Prevalence in Port Phillip Bay

In the previous section, we outlined what microplastics are, why they are a problem, and how they act in waterways. We also summarized the EcoCentre's most recent publication, which reports on microplastic pollution in the Bay.

We also interviewed Neil Blake, the Port Phillip Baykeeper, and Fam Charko, a marine biologist at the EcoCentre, about their experiences with microplastics in the Bay and their views of the most effective way to address microplastic pollution moving forward. Our interview instruments are presented in SM-A.[1] Through our discussions, we learned that when the EcoCentre first began research on microplastics, the public was virtually unaware of microplastics' existence. However, since that time, microplastic research and knowledge has expanded exponentially. Charko and Blake also noted that the most

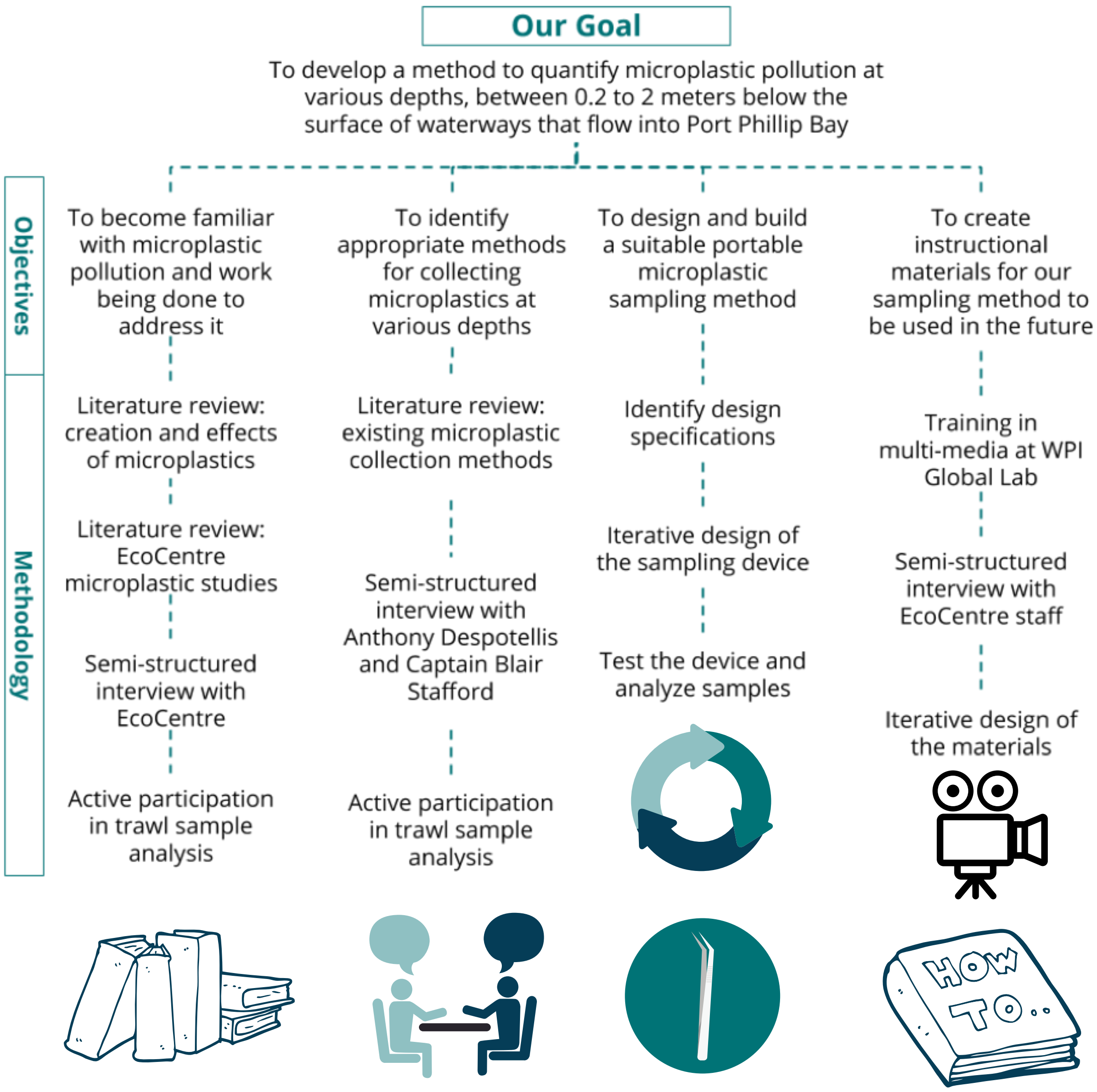

Figure 12. Our Goal, Objectives, and Corresponding Methods

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[1] Supplemental Materials ("SM") for this project may be found at wp.wpi.edu/melbourne/projects/, using the search bar to locate the project report materials.

important qualities of a microplastic collection method are accuracy, replicability, practicality, and comparability to previously collected data.

To deepen our understanding of microplastics and the EcoCentre's microplastic research, we also actively participated in the analysis of one of the EcoCentre's trawl samples (Figure 13). This analysis entailed visually sorting plastic items from organic items using tweezers. The trawl sample analysis methodology is detailed in SM-B. This analysis gave us an opportunity to work closely with microplastics. We experienced firsthand the careful concentration and considerable time necessary to sort microplastics. For just one trawl sample, our team of four spent a combined 72 hours to complete the analysis.

We also learned that, in order to maintain consistency, trained EcoCentre personnel check each of the volunteers' work and verify that each litter item has been sorted into the correct category. This experience informed us that we should also seek to ensure consistency in a similar way in our sampling method. Finally, performing trawl sample analysis showed our group the significance of our project, as we were astounded to see how a single surface trawl collected hundreds of microplastics.

Figure 13. A. Our Team Performing Trawl Sample Analysis. B. An Example Trawl Sample Analysis Sheet.

Objective 2: Identifying Appropriate Methods for Microplastic Sampling at Depth

Research teams around the world are measuring microplastic pollution in waterways. We performed a literature review of these sampling methods in order to fully understand the process of collecting microplastics. We learned that the most common microplastic collection methods are manta nets and pumps (submersible and above-water), as is discussed in the Background. While manta nets can only sample microplastics on the surface, pumps can be used to obtain microplastics from varying depths, and so we determined that our device should incorporate a pump.

With this choice in mind, we performed semi-structured interviews with individuals who have experience with and knowledge of microplastic pollution in Victoria. Their information on local water conditions and potential sites for microplastic sampling informed where and how we tested our pump. Anthony Despotellis, a design student in his fourth year at RMIT, designed a passive microplastic collection device that can be placed in unpredictable conditions, such as a river where the current changes directions. From Despotellis, we learned of three spots along the Yarra where we might find a high concentration of microplastics: Dight Falls, the Main Yarra Trail, and the Docklands (Figure 14). Also, he pointed out some design decisions for our pump that we had not considered:

- Diameter of the hose
- Rigidity of the hose
- Ways to keep the inlet at a certain depth (flotation devices or clips)
- Anticipation of variable organic material concentration in midwater

Next, we interviewed Captain Blair Stafford, a Sea Shepherd Captain and the Australian Ambassador of the 5Gyres Institute, a nonprofit that focuses on addressing plastic pollution (5Gyres, 2019). Captain Stafford is an expert on the Bay and has experience collecting microplastics with a manta net. After discussing our pump design with him, he brought up that we will have to test how long our pump can run before it must be cleaned. He suggested that with the amount of silt in the Yarra River, we may end up having to dedicate significant time cleaning the filter and should research ways to mitigate this problem. He also suggested several sites where we could find microplastics: Merri Creek, the Yarra River near the Abbotsford Convent, and St Kilda Pier (Figure 14).

Figure 14. Potential Sampling Sites.

Finally, in actively participating in the EcoCentre's trawl sample analysis, we learned what a sample containing microplastics should look like. Also, we experienced how easily one can lose microplastics just by moving or breathing near them. This information influenced our filtration system design, as we focused on ensuring that no microplastics could escape our device. We also recognized that we would have to develop specific methodologies to prevent the user from losing microplastics in steps between sample collection and sample analysis. Finally, the trawl sample analysis helped us later on when trialing our device, as we could quickly look at our device filter and know if its contents included microplastics or not.

Objective 3: Designing & Building a Suitable Portable Sampling Method

After talking with Blake and Charko, we first identified our design specifications (Figure 15).

1. Able to collect microplastics at various depths
   between 0.2 to 2 meters deep
2. Inexpensive
   less than our budget of AU$1267
3. Portable
   can be suspended off of a boat or bridge
   can be brought to a creek
   can fit inside a 35L backpack
   is under 16kg
4. Compatible with fresh or saltwater
5. Easy to use
   steps for usage can be broken down so that a nontechnical person can follow them
6. Eco-friendly
   avoids plastic use when possible
   device is durable
7. Efficient sampling
   flow rate is a minimum of 5 liters per minute

Figure 15. Design Specifications of our Microplastic Collection Device.

Next, we used iterative design to develop and build our sampling device. Iterative design is a cyclic process composed of prototyping, testing, analyzing, and refining, with feedback built in at various points. The benefits of iterative design are that the process helps to minimize costly late-stage design alterations while generating a product better suited to the user by including the user in the design process (Wachter et al., 2003). The steps we took in our iterative design process appear in Figure 16.

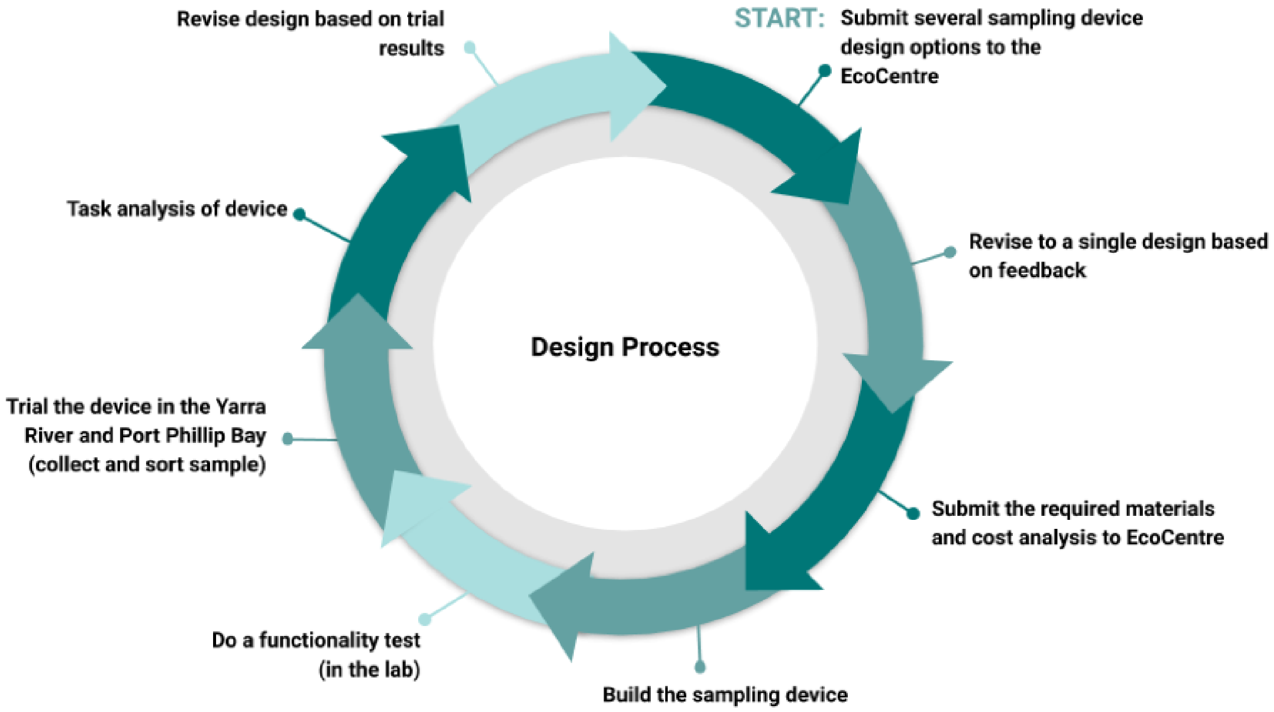


Figure 16. Iterative Design Process of Building the Sampling Device.

Initial Design Features

In designing our device, we first had to decide what type of pump we were going to use: submersible or above-water. We researched submersible pumps and found several designs online (My Projects Labs, 2018), but decided against a custom build, as it would take substantial time to assemble and troubleshoot. Rather, purchasing an already-built pump would ensure high quality and good suction and allow us to choose from pumps that already had ideal flow rates, as documented by manufacturers.

Two main factors were considered when deciding on a pump at the local hardware store: flowrate and saltwater compatibility. We identified two which were able to pump about 3,000 L/hr and purchased the Ozito 800W Swimming Pool Pump, a saltwater certified 19,000 L/hr pump. When we purchased the Ozito 800W Swimming Pool Pump, we thought it met all of our design specifications, including portability. However, after testing it at the EcoCentre and talking with the manufacturer, we realized that a portable 240V battery would not supply enough power to the pump. Thus, this pump was not portable, as it could only be used proximal to a wall outlet.

We had already set up boat trips to test a prototype of our device in the field, so we decided to reach out to the captains of those boats to see what kind of power supply they each had. We learned that the most common outlet on the boats was a 12V outlet. We determined a 12V bilge pump, a pump designed to remove bilge water from inside a boat, would best suit our needs as it can be powered by the boats and portable battery banks. We then selected an Ozito 12V Pressure Pump (Figure 17), which had a lower flow rate than the swimming pool pump (only 600 L/hr), but it was more portable. The specifications for the pump appear in Figure 17.

Specifications	
Length	355mm
Width	110mm
Height	130mm
Weight	1.8kg
Price	AU$109

Figure 17. Ozito 12V Pressure Pump.

The 12V Ozito pump can be plugged into a 12V cigarette lighter outlet, which most boats and cars have. If using the device elsewhere, there are two power options. The EcoCentre had a pre-built solar panel kit with a 12V battery and a cigarette lighter outlet attached. This battery was very small and could only fully power the pump for about five minutes, however. The second powering option we identified was a car battery. We purchased a general car battery (12V, 40 ampere hours) and the Projecta 12V Portable Power Station (Figure 18). This power station not only allowed us to safely house the battery, but it also included a cigarette lighter outlet, which our pump required.

Specifications	
Length	220mm
Width	360mm
Height	300mm
Weight	12kg
Voltage	12V
Amperage	40Ah
Price	AU$167

Figure 18. Power Station and Battery.

We also purchased a flow meter, a crucial design feature, as it allowed us to measure the volume of water that passes through the hose. The amount of microplastics collected by the pump can be divided by the number of cubic meters of water sampled to determine the concentration of microplastics. We found other researchers used a Gardena Water Smart Flow Meter as the flow meter in their sampling method (Talvitie, Mikola, Setala, Heinonen, & Koistinen, 2017). We found that the Holman Flow Meter Counter (Figure 19) was less expensive than the Gardena meter but did the same job. A disadvantage was that it was uncertified for saltwater use. We contacted the manufacturer who speculated that dried salt would build up on the spinning impeller, which measures flow. This buildup overtime could lead to inaccurate results. We researched other saltwater certified flow meters, but they were very expensive, so we used the Holman Flow Meter Counter. However, we made sure to include a step in our methodology during which the meter is rinsed with fresh water.

Specifications	
Length	115mm
Width	40mm
Height	45mm
Weight	0.0076kg
Price	AU$19.80

Figure 19. Holman Flow Meter Counter.

We next wanted to add a filter system to our design, using the same 330 µm mesh the EcoCentre uses when manta net trawling. However, this proved more challenging than expected. The filter had to be attached to the inlet tube, so that filter could stop debris from entering and damaging the pump. However, for the pump to be able to pull water it needs to create a vacuum by using pressure in the tubing and in all equipment between the inlet and pump. To guarantee optimal vacuum pressure, we needed to have an airtight seal, but we experienced difficulty achieving this seal when adding the mesh into the filter. In our initial designs we lost a lot of suction power when we incorporated the mesh to the point where the pump could only pump if it was at the same level as the water.

Through research we found a new method to attach the mesh into the filter opening using epoxy. We cut a circular piece of mesh and epoxied it into a PVC fitting (Figure 20). This gives the filter enough surface area to hold the litter it captures, but also provides a good seal for the pump. In initial trial runs, we had no issues with suction loss from this design.

Specifications	
Length	350mm
Width	60mm
Height	60mm
Weight	0.2226kg
Mesh Size	330µm
Price	AU$40.28

**Figure 20. A. Entire Filter System.
B. 330 Micron Mesh Fitted into PVC Coupling.**

As suggested by Despotellis, we wanted a way to stabilize the inlet hose in the water so that it was not pushed by currents. We bought three galvanized steel rods and several hose clamps for this purpose. These rods could be attached end-to-end, allowing users to adjust height as necessary. We purchased galvanized steel rods rather than normal steel ones, as the layer of zinc coating the galvanized steel prevents the steel from rusting as easily. We would have preferred to purchase sea-grade aluminum rods, since this material is the most resistant to corrosion from seawater. However, we did not have this material available to us. Finally, to attach the metal rods to the inlet hose we used the hose clamps.

Field Testing & Revisions

With the device now including a pump, filter, flow meter, and stabilizing rod, we tested its functionality in the field. As Despotellis suggested, we first used the device off one of the docks located in the Docklands in Melbourne. We found that our device was functional and could pump water up from at least 2.5 meters. Next, we wanted to use our device off the side of a boat to see how different conditions could affect device usage. Dr. Nikki Kowalczyk, project manager of the Yarra Riverkeeper Association, took us out on the Yarra Riverkeeper vessel to a litter trap located next to Webb Bridge, as there were likely microplastics there near the trap (Figure 21). Our goal was to demonstrate that our device was functional, not to collect a sample for analysis. We verified that our device could not only pull debris up the inlet but also capture it in the filter. After pumping 50 liters, we found that the filter collected small debris, illustrating that our design was functional (Figure 22). During this test, we also learned the best order in which one should detach the hoses after pumping. This information was later included in our instructional materials.

Figure 21. Yarra River Litter Trap Beneath the Webb Bridge.

Figure 22. Sample Collected at the Yarra River Litter Trap.

Our next step was to design a feature to indicate at what depth the pump is operating so that the user would be able to do so consistently. We screwed hex couplers onto the stabilizing rods at 0.25-meter intervals and used epoxy to secure them. With the couplers on the rods, the user can lower the hose and stabilizing rods and be able to tell the exact length of the hose that is in the water.

We found in our initial test in the field that keeping the inlet stable was difficult for one person to do (Figure 23). Thus, to make the hose freestanding and keep it at a desired depth, we had to design a stabilizing base—a piece of plywood with a large hole drilled in it and three pieces of hardware to hold the inlet steady (Figure 24). The operator still needed to keep a hand on the inlet and fixture to make sure they did not fall in, but this was easier to maneuver than operating with no base. Also, since the inlet was then resting on a platform, the inlet was kept steady at the desired depth.

Figure 23. Spencer Holding the Inlet Off the Yarra Riverkeeper Vessel.

Figure 24. Stabilizing Base for the Inlet.

The last feature we added to the device was a tripod to hold the filter system upright (Figure 25). During sampling, the filter had to remain vertical so that water flowed directly down onto the mesh. If the filter was tilted at all, there was a risk that water carrying litter would flow back out of the filter. In our field test, we simply held the filter upright, but to make sampling easier, we created a structure to make the filter freestanding. We attached the filter to the tripod using elastic bands, however large hose clamps would also work.

Figure 25. Tripod Fixture to Hold the Filter Upright.

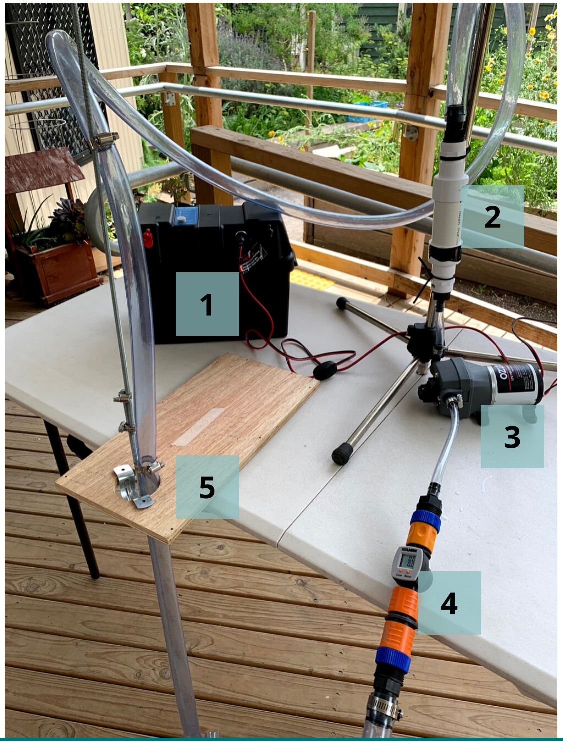
Task Analysis

One key step in our iterative design was task analysis, involving observation of what tasks are performed when a user interacts with a system (Kirwan, 2001). Through this type of detailed observation, a designer will gain a better understanding of how the "human element" can most effectively be integrated into a system with regard to safety and productivity (Kirwan, 2001). In our case, the system was the use (set up, operation, maintenance) of our sampling device prototype. A task analysis showed us what the user did with the pump, problems they encountered, questions they developed, and knowledge they needed. We performed task analysis by observing each other using the device. As mentioned, through this analysis we were able to identify stabilizing features that made device usage easier. The instrument for this task analysis appears in SM-C.

The Finished McWap

Our final device design (Figure 26) met all of our design specifications, except that it could have been made more eco-friendly. Working within our seven-week term and with what parts were readily available, we chose to use PVC to enclose our filter. However, PVC is plastic and in cutting the PVC we actually created microplastics. A better material to enclose the filter would have been a sea-grade aluminum pipe. Also, rather than using our nylon 330 micron mesh, we would have preferred to order a custom 330 micron metal sieve.

The entire system weighs 21.3kgs (9.3kgs without battery), can fit in a 35L backpack (excluding battery), cost about AU$561.34, and pumps water at around 7L/min—depending on how far the water surface is from the system. The device is portable and can be powered by any car or boat with a 12V cigarette lighter plug. If a car or boat is not accessible, the battery station can power the system for approximately 8 hours if it is fully charged. A complete list of parts of the McWap, how to assemble them, and how to use the device can be found in in SM-D.



Parts	
1	Battery station
2	Filter and tripod
3	Pump
4	Flow meter
5	Inlet tube and mount

Figure 26. The Finished McWap.

Trialing the McWap

We collected several samples at various depths in the Bay and the Yarra with the McWap. To sort the samples we collected, we used the same sample analysis method we had previously practiced when sorting the EcoCentre's trawl samples (SM-B). The results of our sample analysis are presented in Table 2. The results show that there were microplastics at depth in the Yarra River as well as Port Phillip Bay.

Table 2. Test Sites, Parameters, and Results of Visual-Manual Categorization.

LOCATION	DATE	TIME PUMPED (MINUTES:SECONDS)	VOLUME (LITERS)	DEPTH (METERS)	MICRO-PLASTICS	CATEGORIES	CONCENTRATION (MICROPLASTICS PER M^3)
St. Kilda Pier (extends into Port Phillip Bay)	15-11-2019	34:34.24	242.2	1.00	2	1 hard plastic <2mm, 1 cellophane <5mm	8.26
The Main Yarra Trail near the McConchie Reserve	22-11-2019	48:38.29	250.0	1.00	4	4 hard plastics <2mm	16.00
The Main Yarra Trail near the McConchie Reserve	22-11-2019	52:53.26	250.0	1.75	4	2 hard plastics <2mm, 1 soft plastic <5mm, 1 cellophane <5mm	16.00
The Docklands	06-12-2019	52:39.95	250.0	2.00	3	1 hard plastic <2mm, 1 hard plastic 2-5mm, 1 cellophane <5mm	12.00

Objective 4: Creating Instructional Materials for Device Use

While our team was still in Worcester, we were not sure what form our instructional materials would take, but we imagined we might be creating a how-to video or animation, which would require software. We consulted with WPI's Global Lab and learned about several free online animation programs: 2Dimensions and Animaker. After looking into those two options, we found a third: Powtoon. This online software included pre-made characters and objects which fit the style of the video we wanted to make. We also attended a workshop on transmedia storytelling taught by Leslie Dodson of the Global Lab. This workshop encouraged our group to think about how we could use a compilation of photos, videos, and physical objects to effectively communicate our project to public audiences as well as explain why and how to conduct the sampling to future volunteers.

Charko indicated the EcoCentre would benefit most from a how-to video as well as a written manual with more in depth instructional information. The how-to video would be valuable, since a user would be able to observe the entire assembly process and pause when necessary. However, if a user did not have strong enough internet to stream a video then they could instead follow the written manual. Additionally, the manual would be preferable to people who learn best by reading instructions rather than receiving them orally.

Charko was interested in our idea of creating an informative animation. The animation would be made for a general audience and include background information on microplastic pollution. Also, the animation could discuss the EcoCentre's past work on microplastic pollution and how the McWap will bolster this research.

We employed iterative design (Figure 27) to create the instructional materials to ensure that users would be able to properly perform the sampling method. We included user testing whereby we observed a volunteer attempting to use the final sampling device with our preliminary instructional materials. We used the task analysis instrument exhibited in SM-C. After conducting this user test, we were able to see how one of our intended users actually interacted with our instructional materials, how accurately they completed the steps of the instructions, and what problems arose when attempting to follow the instructions.

We did our user tests with Charko and Professor Lorraine Higgins, separately. In both tests they were able to successfully assemble and use the McWap. However, in certain parts of the assembly, such as putting together the power station, we identified points of confusion, and revised our instructional materials accordingly. This user test also proved that our device was relatively easy to use, since it was assembled and used by people who do not have engineering backgrounds.

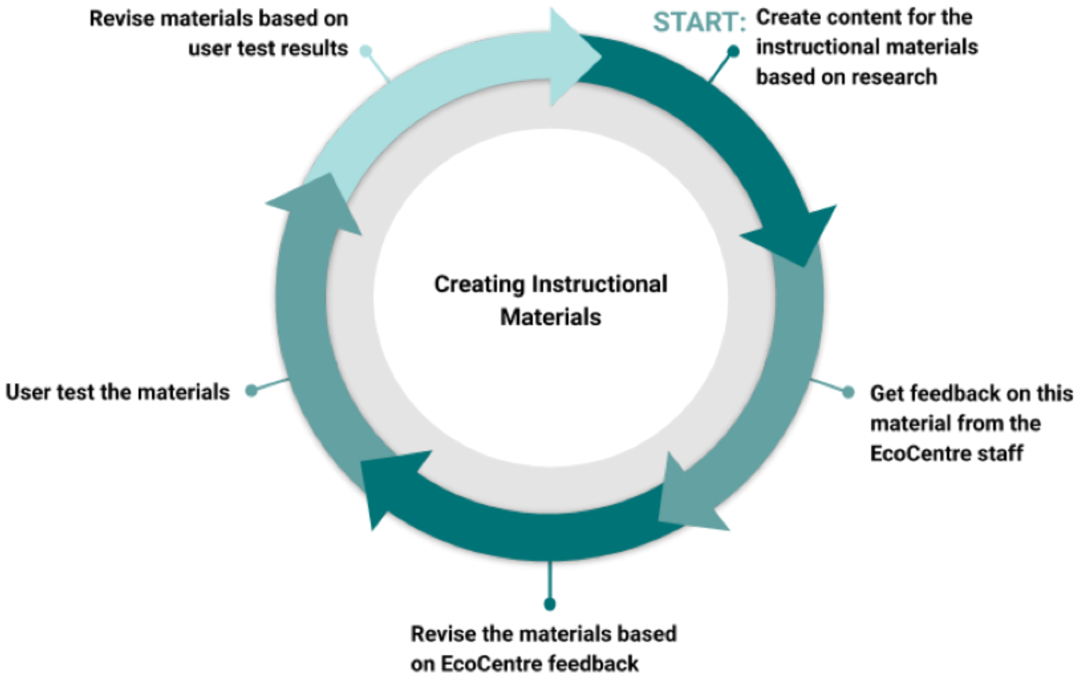
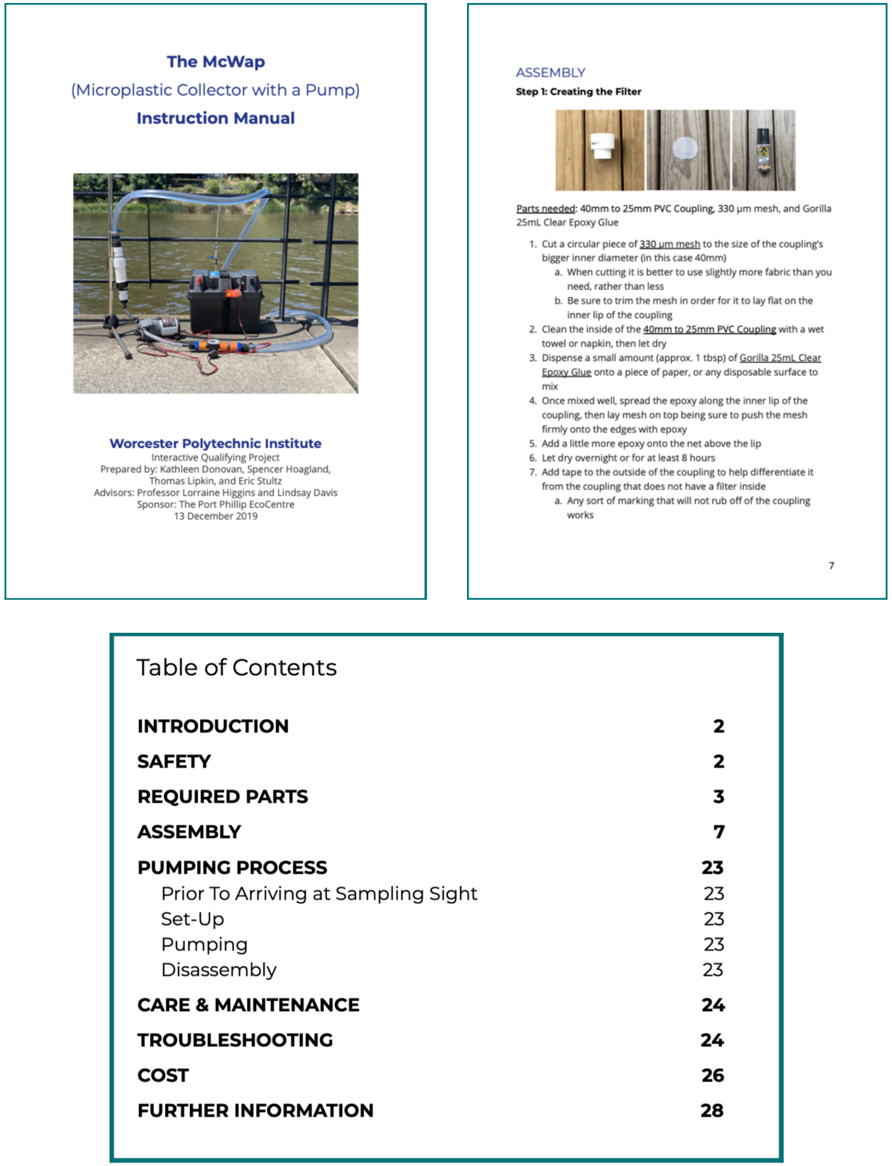


Figure 27. Iterative Design Process to Create Instructional Materials.

Our final instruction manual (Figure 28) appears in SM-D. Our how-to video (Figure 29) and informative video (Figure 30) can both be found at wp.wpi.edu/melbourne/projects/, using the search bar to locate the project report materials.



The McWap
(Microplastic Collector with a Pump)
Instruction Manual

Worcester Polytechnic Institute
Interactive Qualifying Project
Prepared by: Kathleen Donovan, Spencer Hoagland,
Thomas Lipkin, and Eric Stultz
Advisors: Professor Lorraine Higgins and Lindsay Davis
Sponsor: The Port Phillip EcoCentre
13 December 2019

ASSEMBLY

Step 1: Creating the Filter

Parts needed: 40mm to 25mm PVC Coupling, 330 μm mesh, and Gorilla 25mL Clear Epoxy Glue

1. Cut a circular piece of 330 μm mesh to the size of the coupling's bigger inner diameter (in this case 40mm)
    a. When cutting it is better to use slightly more fabric than you need, rather than less
    b. Be sure to trim the mesh in order for it to lay flat on the inner lip of the coupling
2. Clean the inside of the 40mm to 25mm PVC Coupling with a wet towel or napkin, then let dry
3. Dispense a small amount (approx. 1 tbsp) of Gorilla 25mL Clear Epoxy Glue onto a piece of paper, or any disposable surface to mix
4. Once mixed well, spread the epoxy along the inner lip of the coupling, then lay mesh on top being sure to push the mesh firmly onto the edges with epoxy
5. Add a little more epoxy onto the net above the lip
6. Let dry overnight or for at least 8 hours
7. Add tape to the outside of the coupling to help differentiate it from the coupling that does not have a filter inside
    a. Any sort of marking that will not rub off of the coupling works

7

Table of Contents

Figure 28. Instruction Manual Cover Page, Excerpt, and Table of Contents.

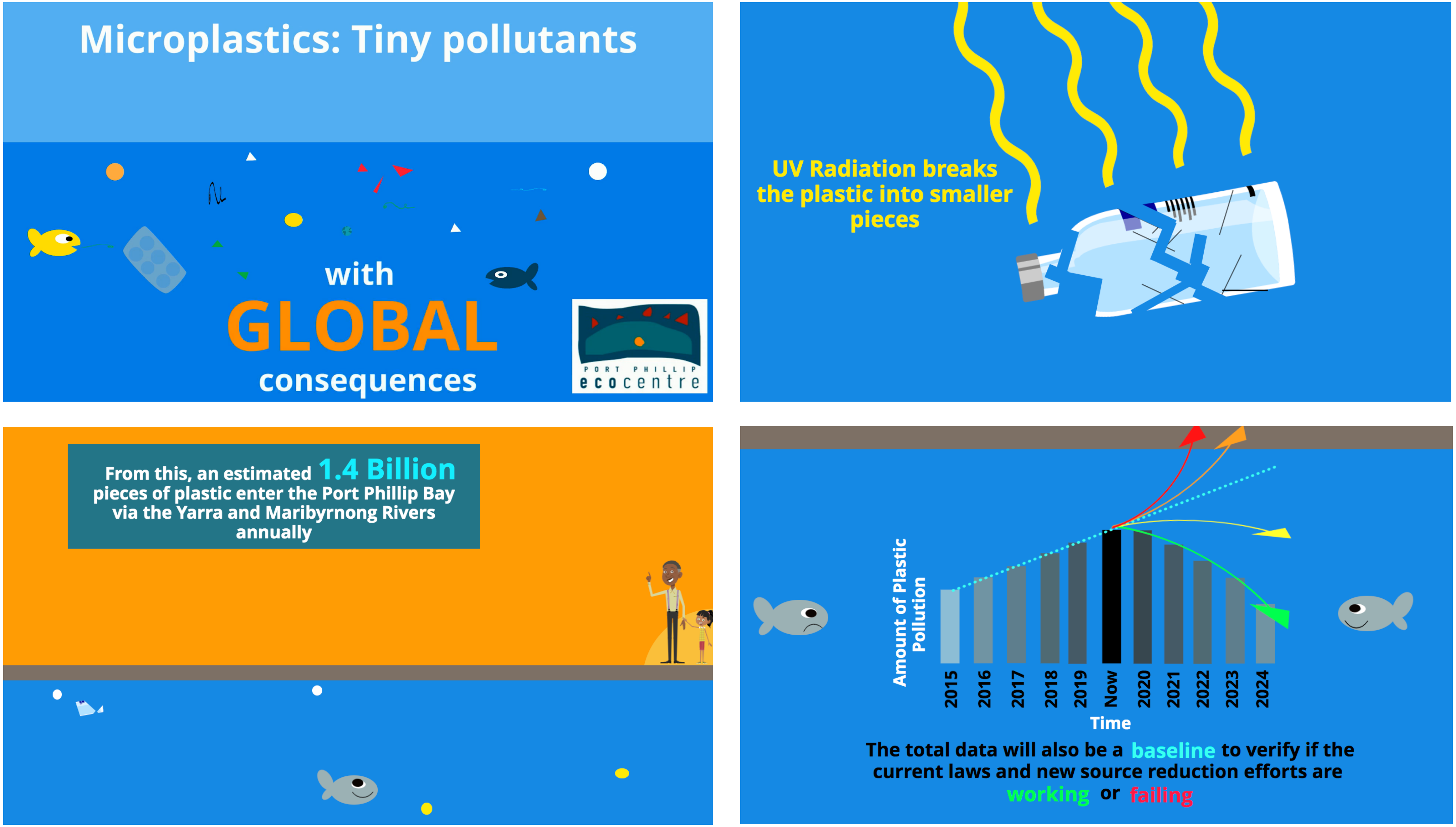
Instructional Video For McWAP
Port Phillip EcoCentre

Materials You Will Need:

1	330-Micron Mesh in 40mm dia Circle	1	Black Electrical Tape
2	40mm to 25mm PVC Coupling	1	Teflon Tape
1	40mm x 11cm PVC Pipe	2	Threaded 25mm dia Male Quick Disconnect
2	25mm PVC Threaded Fitting	1	Female to Female Quick Disconnect
2	25mm x 3m Tube	1	Holman Flow Meter
1	13mm x .13m Tube	1	Ozito 12V Pressure Pump
1	13mm x .25m Tube	2	Battery Terminal Adapters
1	Pipe Saddle Bracket	1	Projecta 12V Automatic Battery Charger
2	25mm Barbed Threaded Fitting	1	12V Power Battery Station
2	13mm Barbed Threaded Fitting	1	12V Exide Endurance 40 CMF Battery
4	11mm-16mm dia Hose Clamps (STEEL 316)	1	Tripod
4	17mm-32mm dia Hose Clamps (STEEL 316)	1	Solar Panel Apparatus (optional power source)
4	22mm-32mm dia Easy Hose Clamps	1	Wood Plywood with 7cm Hole
4	16mm-27mm dia Easy Hose Clamps	1	Gorilla Clear Epoxy
8	7.9375mm x 2.3cm Nuts	2	Elastic Bands
3+	91.44 cm x 7.9375 mm dia Zinc Plated Threaded Steel Rod		

Take Off The Protective Caps & Keep Track of Positive & Negative
DO NOT TOUCH BOTH TERMINALS AT THE SAME TIME

Figure 29. Stills from the How-To Video.



Microplastics: Tiny pollutants with GLOBAL consequences

UV Radiation breaks the plastic into smaller pieces

From this, an estimated **1.4 Billion** pieces of plastic enter the Port Phillip Bay via the Yarra and Maribyrnong Rivers annually

The total data will also be a baseline to verify if the current laws and new source reduction efforts are working or failing

Figure 30. Stills from the Animation.

CONCLUSIONS & RECOMMENDATIONS

The Port Phillip EcoCentre currently quantifies surface-level microplastics through monthly trawls of the Yarra and Maribyrnong rivers. The EcoCentre believes the results of its study underestimates the total number of microplastics flowing through these waterways, as there could be microplastics flowing below the surface. To aid the EcoCentre, our project developed a means to quantify midwater microplastic pollution, employing iterative design to do so. Through our research we determined that a pump system would be best suited for collecting microplastics at depth, while also achieving portability. Once we found a suitable pump, flow meter, and filter system, we constructed an initial prototype. We added additional features to the design after field testing. Our final product, the McWap, met all of our design specifications, including that it was portable, inexpensive, and easy to use.

In addition to creating the collection device itself, we sought to create sufficient instructional materials, so that staff of the EcoCentre could use our device independently in the future. We developed an instruction manual and how-to video to show device assembly and usage. We also discussed common problems that might occur during device use.

Finally, since our device addresses a major issue, microplastic pollution, we wanted to communicate our project to the public. We decided that the optimal way to tell our story was through video animation. The final three minute long video explains how microplastics are created and how the McWap could be used to quantify and eventually combat microplastic pollution.

With the pump and instructional materials complete, we have several recommendations for the EcoCentre as it moves forward with microplastic research using the McWap.

1. As it currently does with microplastic trawling, the EcoCentre should plan to use the McWap on a monthly basis or on some other regular interval. The McWap collects significantly smaller samples than surface trawls, so sample analysis can be done quicker. Routine collection of data will allow the EcoCentre to monitor how the concentration and types of microplastics in and around Port Phillip Bay change over time.

2. The EcoCentre should perform research in order to select appropriate sampling sites for the McWap as well as the depths at which they will sample at each site. An optimal site would be one where there is an expected high concentration of microplastics. Also, the McWap performs optimally when sampling no higher than 1.5 meters above the water.

3. The EcoCentre should keep the volume of water pumped during each sampling consistent to ensure that its data is meaningful. Based on the literature, we found that 1000 liters would be an adequate volume when using a 300 micron mesh size (Lenz & Labrenz, 2018). However, based on our trials with the McWap, pumping 1000 liters would take about 3 hours and 20 minutes. We believe the significance of our device is that it can be used to show that the EcoCentre's previous trawling numbers were an underestimation by proving that there are microplastics below the surface of the waterways where the EcoCentre has sampled. Our team found microplastics in the Yarra River and at the St Kilda Pier after only pumping 250 liters, so we believe that the EcoCentre could collect valuable data if they consistently pumped 250 liters at various depths.

4. The EcoCentre should check the hose clamps of the device the day before any planned sampling. The hose clamps go through wear and tear, as they are taken on and off the device with each use and are sometimes exposed to saltwater. Thus, these parts need to be checked in case they need to be replaced before going out into the field.

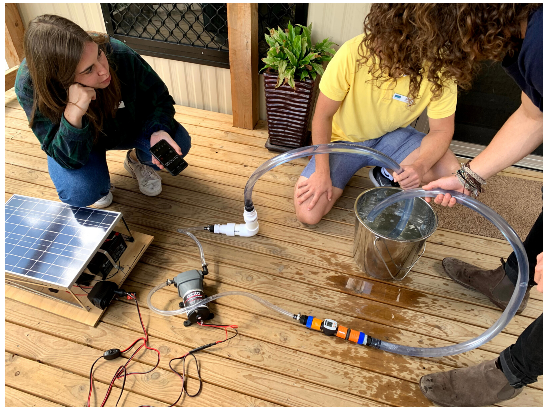
5. After discussions with Dr. Randall Lee of EPA Victoria, we suggest looking into replacing the 330 micron nylon mesh with a metal sieve. This change would make the filter more durable and easier to clean, since the sieve could be removed. There are various manufacturers that specialize in metal sieves that can be found online. Dr. Lee also suggested the addition of a 5mm pre filter at the inlet to prevent large debris from clogging the 330 micron filter.

6. To make a comparison between midwater and surface-level microplastic concentration, our device needs to be adapted to be able to sample at the surface. To do this, a simple floatation device could be made and fashioned to the inlet. The floatation device would rise and fall according to the water level, holding the inlet tube at the surface.

A shortcoming of our project was that we were developing and building a device in less than seven weeks. With this short timeframe, we could only use parts that were readily available to us. Parts of our device, such as the plastic tubing and PVC pipe, could be replaced with metal parts. Metal parts would be more eco-friendly, however, the plastic components are still suitable and durable for saltwater. In future studies, a team should allow for ample time to find and order specialized parts to create a more streamlined and eco-friendly design.

Through the use of our device and implementation of our recommendations, we hope that the EcoCentre will be able to collect meaningful data regarding the concentration of microplastics in the midwater in and around Port Phillip Bay. This data can stop microplastics from ever entering the waterways, since concrete numbers can be used to advocate for policy changes that address microplastic pollution.

Author contributions to this project are outlined in SM-E.



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