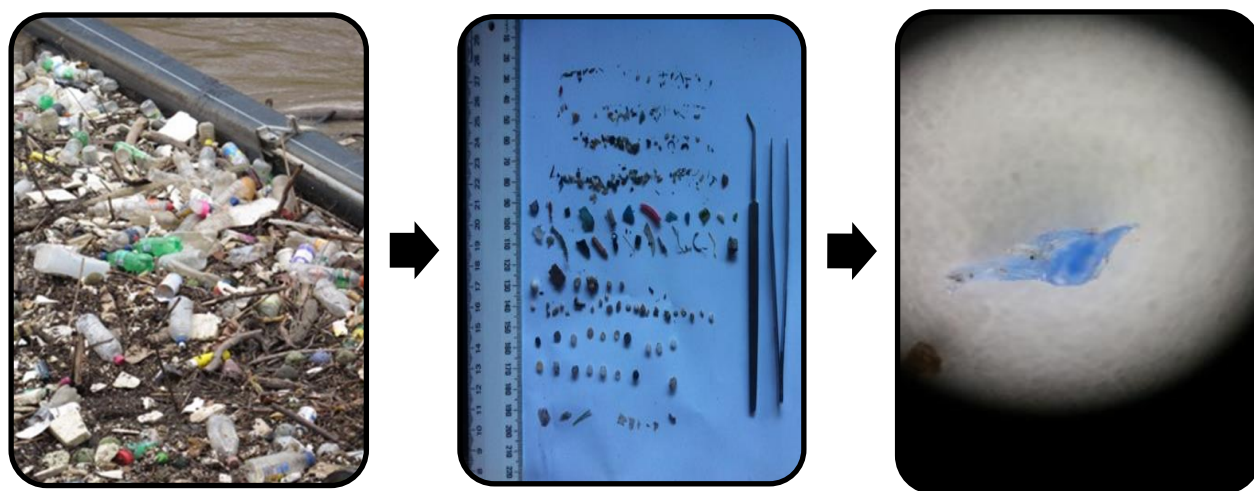


Microplastics in the Maribyrnong and Yarra Rivers, Melbourne, Australia



Report by Port Phillip EcoCentre, July 2017

**Funded by the Victorian Government Litter Hotspots
program**



Executive Summary

The potential for marine debris to cause harm is recognised by scientists as a global problem. Given the consequences of microplastics on marine ecosystems and human health, an Australia Senate enquiry into the threats of marine plastic was conducted in 2015-2016. It recommended active support for research into the threats posed by microplastic pollution, including research to identify the extent of microplastic pollution.

One component of the ‘Turn off the Tap’ project funded through the State Government’s ‘Litter Hotspots’ program, was to identify the extent of microplastic pollution in the Yarra and Maribyrnong Rivers. Monthly microplastic trawls were conducted in the Yarra and Maribyrnong Rivers between January 2015 and May 2017. A total of 4,650 litter items were removed from the Yarra and 3,167 litter items were removed from the Maribyrnong River. Large variations in monthly collections were noted, however, a monthly average of 158 and 122 litter items were collected from the Yarra and Maribyrnong, respectively. There was no significant difference in total litter counts between the Maribyrnong and Yarra Rivers. Litter composition between rivers was similar except for greater quantities (total count) of polystyrene beads observed in Yarra River samples. In both rivers, microplastics formed the bulk of litter and accounted for 79% and 66% of the total litter count in the Yarra and Maribyrnong, respectively. Hard plastic remnants <2mm in length dominated the microplastics category. This study highlights the pervasiveness of plastic in our waterways and reflects their ubiquitous use, as well as their extreme persistence.

Introduction

Marine debris is broadly defined as any man-made, solid material that enters the oceans through sea-based sources such as vessel-traffic and fisheries as well as land based sources such as storm water drains and river runoff. Wide use of single-use plastics, improper waste management practices, inadequate waste water treatment, and littering have led to tonnes of marine debris entering the ocean on a daily basis. In 2015, Jambeck et al (2015) estimated that around eight million metric tons of our plastic waste enter the oceans from land each year, with much of this litter entering the oceans via rivers (Mani et al., 2015, Jambeck et al., 2015).

Much of the litter that enters our ocean are extremely small pieces of plastic debris resulting from the disposal and breakdown of consumer products and industrial waste. These small plastic pieces range in size from a few microns to five millimeters in diameter and are collectively known as microplastics (Thompson et al., 2004). Two main types of microplastics are found most often in waterways and oceans: pre-production pellets (nurdles) and fragments (Barnes et al., 2009). Nurdles, are spherical or cylindrical in shape, are usually clear or white in colour but it is not uncommon to find black, red, yellow and blue pieces (Cole et al., 2011). Pellets are the pre-fabrication material for a wide range of industrial and consumer plastic products and they enter the aquatic environment mainly through accidental spillage at processing plants but can also be lost during transport (Cole et al., 2011). Fragments on the other hand are known as secondary microplastics, and are derived from the breakdown of larger plastic debris (Cole et al., 2011). They are irregular in shape and vary greatly in color due to their primary design. Once in the ocean, microplastics persist for thousands of years, and have been observed in marine systems worldwide (Cole et al., 2011, Barnes et al., 2009)

Marine debris is becoming an increasingly urgent threat to wildlife in waterways and oceans. Worldwide, at least 690 species have encountered marine debris, many of which are listed as threatened species (Gall and Thompson, 2015). Ingestion of marine debris, including microplastics, can lead to injury (e.g. blocked digestive tracts, and organ rupture) and even death (Lavers et al., 2014). Furthermore, plastics, the most abundant of marine debris items, *adsorb* (attract as an exterior film) organic micro-pollutants or persistent organic pollutants (POPs), which include polychlorinated biphenyls (PCBs), Dichlorodiphenyldichloroethylene (DDE) and nonylphenol (Teuten et al., 2009). The ingestion of these toxic chemicals are known to affect the physiology and behavior of organisms which can ultimately affect population stability.

Furthermore, these chemicals bioaccumulate and biomagnify up the food chain. This increasing concentration of toxic chemicals, in the tissues of organisms at successively higher levels in a food chain has been linked to disease and death in several top predators (Gall and Thompson, 2015).

The potential for marine debris to cause harm has resulted in it being recognised as a global problem and it is listed as one of the greatest threats to marine biodiversity (Gall and Thompson, 2015, Depledge et al., 2013). Increased efforts to identify the extent of marine debris, particularly microplastics, and to evaluate the effects of microplastic pollution on marine fauna have commenced in oceans around the globe (Gall and Thompson, 2015). However, relatively few marine and freshwater systems have been investigated in Australia. This is of grave concern considering coastal and estuarine systems around Australia are some of the most diverse ecosystems in the world. Locally, Port Phillip Bay and surrounding waters are home to over 12,000 species, with 1,300 of those species unique to Port Phillip Bay (Marris, 2015). Studies that quantify the effect and extent of microplastics in these biodiverse waters are necessary to inform policy frameworks that reduce marine debris.

In 2014, under the Victorian Governments Litter Hotspots Fund, the Port Phillip EcoCentre conducted a pilot study over five months to identify the extent of microplastic pollution in the Yarra and Maribyrnong Rivers. The study sought to measure ‘background’ levels of microplastics entering Port Phillip Bay from either river and to document common streams of microplastic pollution. The pilot study provided a solid framework for future research and identified ‘nurdles’, polystyrene beads and fragments of assorted user plastics as common microplastic items (Blake and Charko, 2014). In January 2015 this ‘Turn off the Tap’ project recommenced as a means to continue tracking common streams of microplastic pollution and to identify fluctuations in microplastic loads across seasons. The results of this study are presented below.

Study Method

Study Site

Between January 2015 and May 2017 monthly trawls were conducted in the Maribyrnong and Yarra Rivers. The Yarra River flows 242 km from the Yarra Valley through to the city of Melbourne, emerging at Port Philip Bay. More than one-third of Victoria’s population lives in the Yarra catchment, which spans about 4000 square kilometers (Barua et al., 2013). The catchment includes 40 rivers and creeks including the Maribyrnong River which runs for 160 kilometers from its source on the slopes of Mount Macedon. The sites were selected on the basis of being close to the lower reaches of each river and therefore indicative of the total pollution load of each respective catchment. The Maribyrnong trawls commenced at the ‘Water Canon’ jetty extending from the west bank of Coode Island, 300m upstream from the Yarra. The Yarra trawls commenced at Bolte Bridge, 2.5 km upstream of the Maribyrnong mouth. The black dots on the maps below illustrate the approximate location of where trawls are conducted relative to the respective river catchment, while the satellite image shows the approximate locations of the trawl transects. The length of each trawl varied slightly due to the state of the tide and prevailing wind conditions at the time. As river boating involves changing course to safely navigate around other watercraft that may be encountered, the course of the trawls in each river was not rigidly defined. The key objective for all trawls was to maintain progress into the current at the same boat engine speed (1,000 rpm) for 30 minutes.

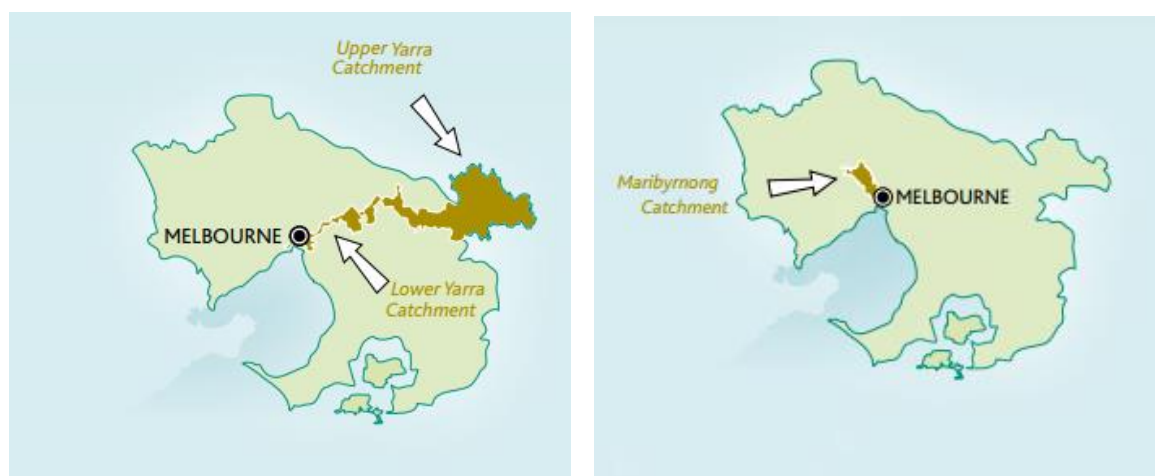


Figure 1. Black dots illustrate the approximate trawl locations within the Maribyrnong and Yarra catchments. Images courtesy of Melbourne Water

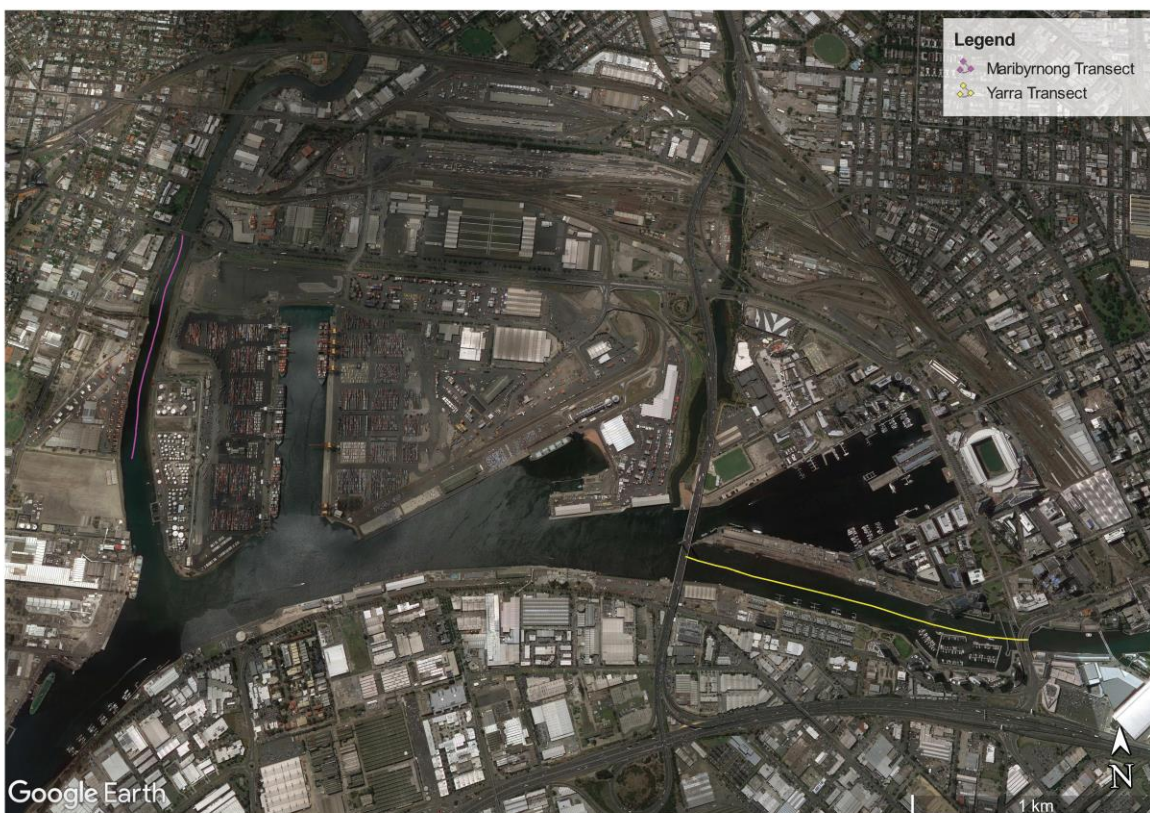


Figure 2. Approximate trawl location transects in the Yarra and Maribyrnong Rivers.

River Trawls

A manta net was deployed from the side of the boat and positioned outside of the wake zone. In each river, all trawls commenced at the same place, traveling upstream for 30 minutes, with the boat motor operated at a constant 1,000 RPM to maintain an appropriate speed to effectively operate the net (Fig. 1).

A manta net designed to collect floatable debris off the water's surface was used in this study. The 'mouth' of the net is 600mm x 200mm, and the net is 3 m long with a 30 x 10 cm² collection net (codend) made of a 0.33 mm mesh size (Fig.2). This manta net is of the same specifications used by 5 Gyres Institute to measure microplastics in international studies. After 30 minutes, the net was retrieved onto the boat, the codend removed and placed in an esky to be dried and sorted.



Figure 3. A. Manta net deployed on side of Yarra Riverkeeper vessel. B. Codend used to capture microplastic samples.

Sample Analysis Method

Dried trawl samples were analysed by separating litter items from the organic matter with the naked eye, using tweezers. Litter items were then sorted by litter type and the diameter measured with a ruler where applicable. Litter categories included: hard plastic pieces <2 mm, hard plastic pieces 2mm-5mm, hard plastic pieces 6-10mm, hard plastic pieces > 10mm, nurdles, polystyrene beads <4mm, polystyrene beads >4mm, plastic caps, plastic straws, soft plastic bags / films, lolly wrappers, cellophane, cigarette butts and ‘other’, which included items twine, rubber and sponge, all found in small quantities.

As per internationally accepted guidelines, plastic pieces smaller than 5 mm in diameter are referred to as microplastics (Thompson et al., 2004). The categories hard plastic pieces <2 mm, hard plastic pieces 2mm-5mm, nurdles, polystyrene beads <4mm and ‘other’ were grouped into the microplastic category. The soft plastic bags/film category was excluded from the microplastics category as the diameter of each soft plastic item was not noted, a shortfall of this study. However, it is worth noting that 400 and 597 soft plastic items were collected from the Yarra and Maribyrnong Rivers, respectively, over the duration of this study. These soft plastics

inevitably breakdown into microplastics and are therefore a key contributor to microplastic loads entering Port Phillip Bay.

Plastic items not visible to the naked eye, including microfibers, were excluded from this study due to logistic and technical constraints.



Figure 4. A. Litter caught in Yarra River boom traps breaks up into millions of microplastics. Photo A courtesy of Heidi Taylor. B. Microplastics collected in the Yarra River as part of the Trawl program. C. Image of <1mm microplastic item sourced in the Yarra River

Trawl Results

The results of the sample analysis show substantial concentrations of litter, especially plastics present in the Yarra and Maribyrnong Rivers. A total of 4,650 litter items were removed from the Yarra and 3,167 litter items were removed from the Maribyrnong River between January 2015 and May 2017. An average of 158 litter items were collected from the Yarra monthly, while an average of 122 litter items were collected from the Maribyrnong River monthly. Hard plastic remnants, polystyrene beads and cellophane were the most common items found in both the Yarra and Maribyrnong (Figs. 4 & 5).

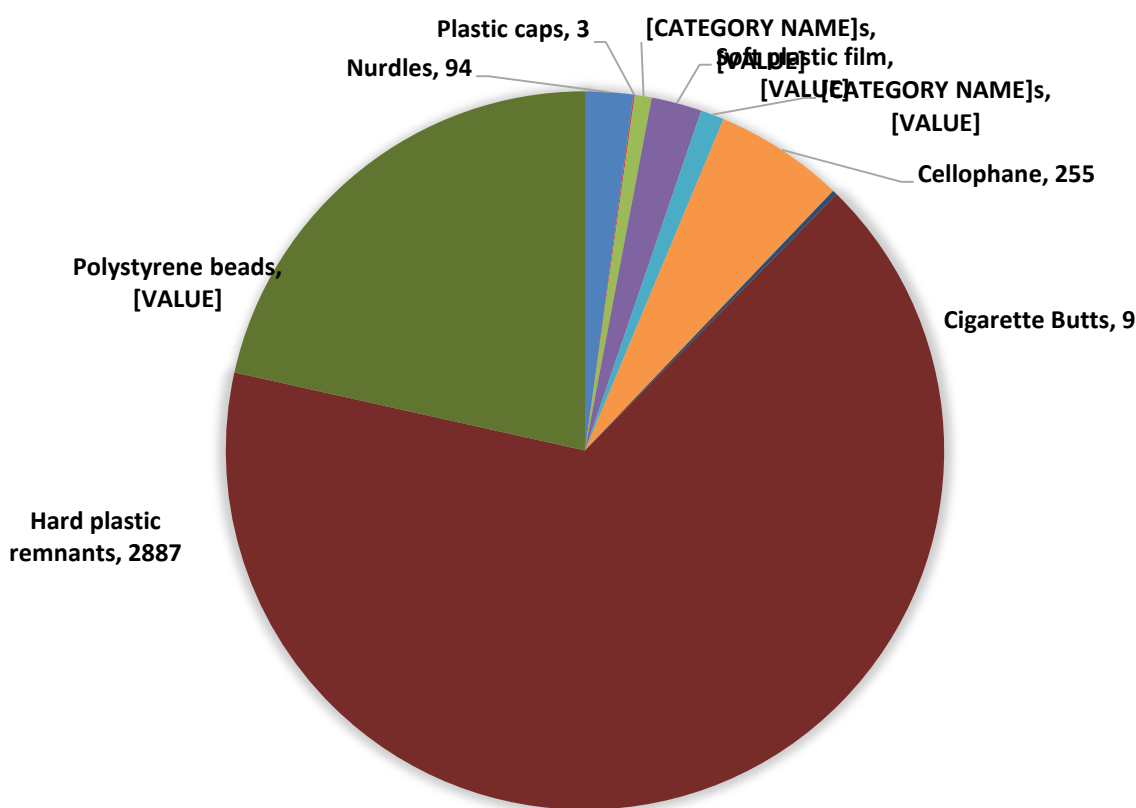


Figure 5. Litter composition in trawl samples obtained from the Yarra River

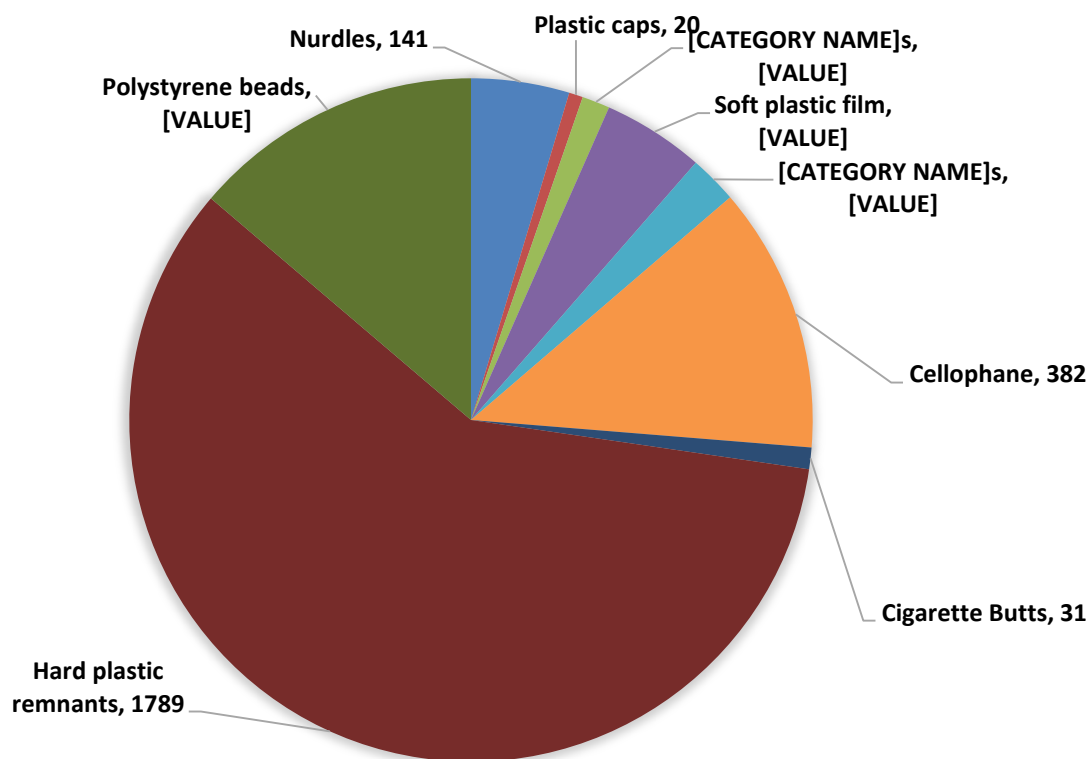


Figure 6. Litter composition in trawl samples obtained from the Maribyrnong River

There was no significant difference in total litter counts between the Maribyrnong and Yarra Rivers ($t = -1.08$, $df = 47$, $p > 0.05$). Samples from the Yarra and Maribyrnong Rivers contained similar quantities (total count) of hard plastic remnants (pieces < 2 mm, hard plastic pieces 2mm-5mm, hard plastic pieces 6-10mm, hard plastic pieces > 10 mm), nurdles, plastics caps, plastic straws, and soft plastic wrappers (Fig.6). However, the Yarra River trawl samples contained significantly greater quantities of polystyrene beads ($t = -2.14$, $df = 40$, $p = 0.038$) (Fig.6). These results indicate that both rivers are largely subjected to similar volumes and types of litter and microplastics but that the Yarra is exposed to greater volumes of polystyrene.

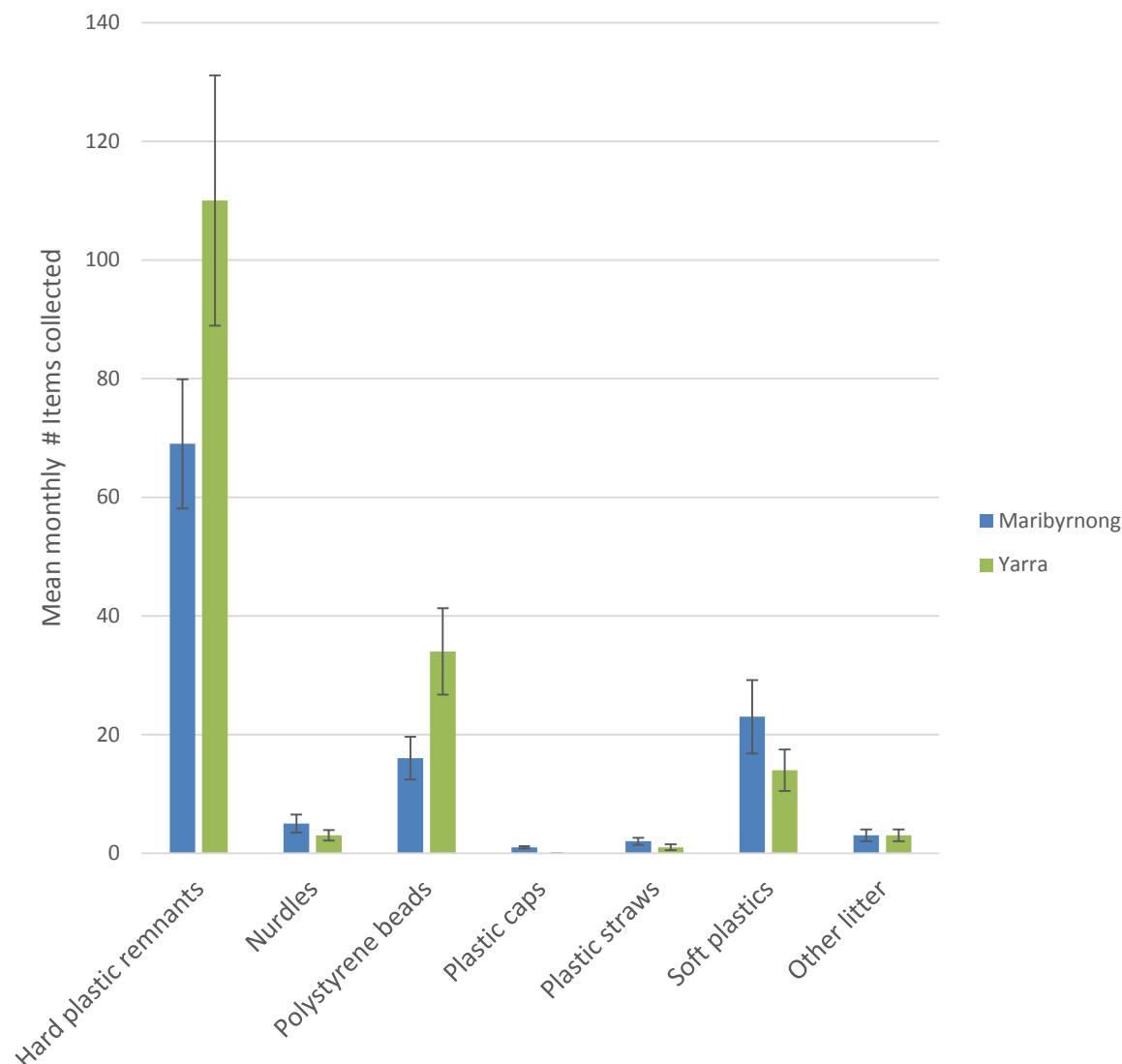


Figure 7. Comparison of mean monthly number (\pm SE) of litter items captured by the manta net in the Maribyrnong and Yarra Rivers between January 2015 and May 2017.

In both rivers, microplastics formed the bulk of litter and accounted for 79% (3,651 pieces) of the total load in the Yarra and 66% (2,083 pieces) of the Maribyrnong load. Hard plastic remnants <2mm in length dominated the microplastics category and accounted for 59% and 60% of microplastics in the Yarra and Maribyrnong, respectively (Fig.7).

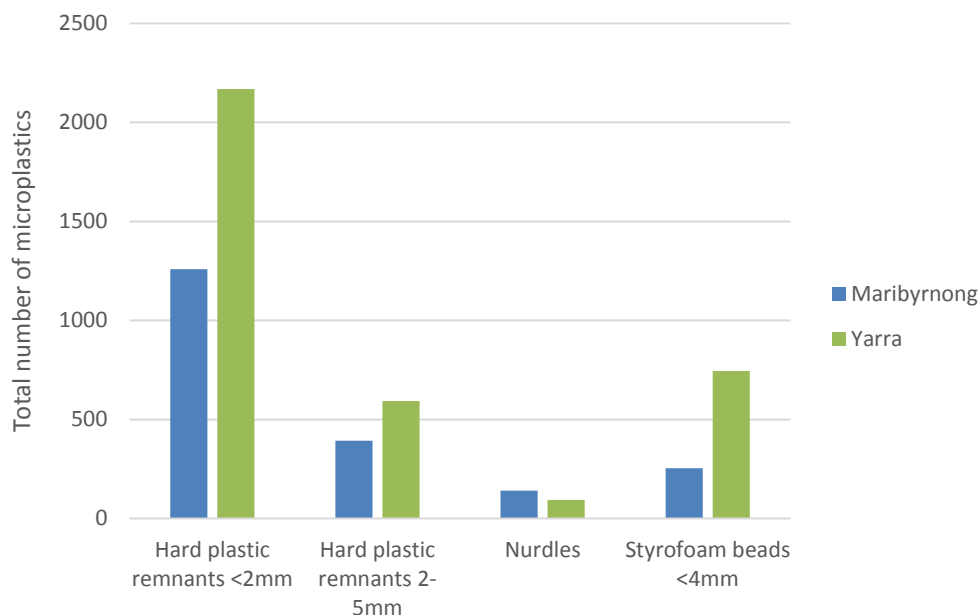


Figure 8. Total number of microplastics captured during river trawls.

Monthly, trawl samples weighed approximately 26 g, most of which was comprised of organic plant matter. On average, litter comprised 3g or 12% of the total sample highlighting the pervasiveness of litter in our waterways. Because the rivers’ widths are more than 160 times wider than the net, the actual volume of litter in both rivers is astounding. For the Yarra, the rough calculation:

$$158 \text{ litter items} \times 48 \text{ half hour sessions/day} \times 365 \text{ days} \times 160 \text{ times net width}$$

suggests that 442,905,600 litter items flow into the Bay annually. This calculation may be an underestimation of litter volume entering Port Phillip Bay annually as it does not take the depth of the river and the fact that less buoyant litter items would pass below the net into account; and, any items not visible to the human eye would not have been recorded in the trawl analysis.

Further, we observed no seasonal variation in the total number of litter items in both the Yarra (F value = 0.929, $df = 3, 24$, $p > 0.05$) and Maribyrnong Rivers (F value = 0.468, $df = 3, 22$, $p > 0.05$). Similarly, river height and rainfall levels did not influence total litter capture.

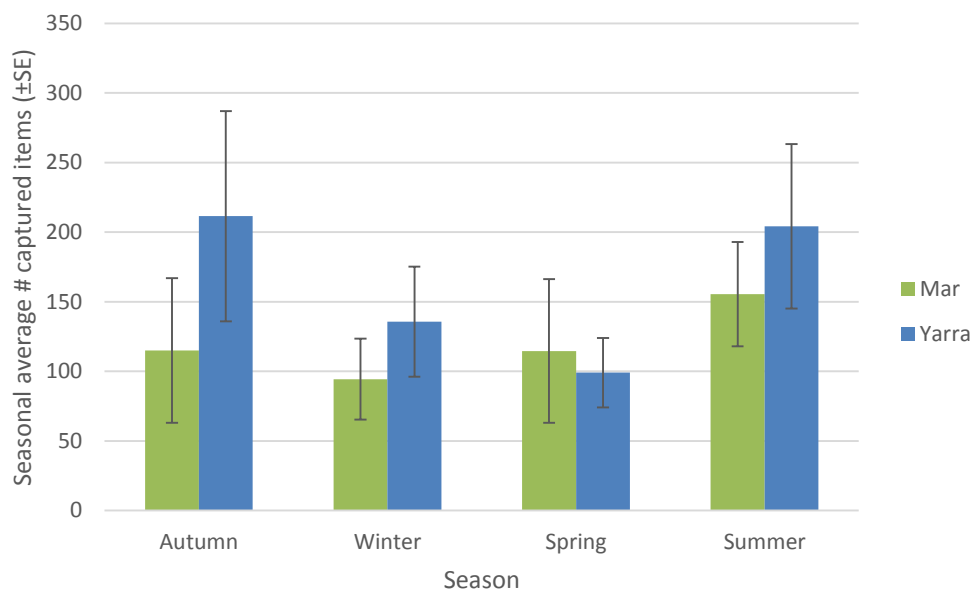


Figure 9. Seasonal variation in the number of captured litter items in the Maribyrnong and Yarra Rivers.

Discussion

Litter quantification and composition in the Yarra and Maribyrnong Rivers

‘Turn off the Tap’ and the preceding pilot project are the first studies to investigate microplastic loads in the Yarra and Maribyrnong Rivers and provide the first estimation of microplastic loads entering Port Phillip Bay on an annual basis. Each of the ‘Turn off the Tap’ trawls (54 trawl samples collected between January 2015 and May 2017) contained microplastics with a total of 7,817 litter items removed from the rivers. An average of 158 and 122 litter items were captured from the Yarra and Maribyrnong Rivers monthly. This study highlights the pervasiveness of plastic in our waterways and reflects their ubiquitous use, as well as their extreme persistence.

Sample analyses revealed that hard plastic remnants less than 10mm in diameter, polystyrene beads and cellophane were the most common items captured. Despite the manta nets selectivity to small, buoyant items, the sample results largely align with local beach clean-up litter audits. Litter audits along the Westgate Park foreshore, and along St Kilda beaches between years 2015 and 2017, revealed foam packaging (polystyrene) and plastic film remnants (bits of plastic bags, wrap, cellophane etc.) are the second and third most dominant litter category, after cigarette butts (amdi.tangaroablue.org). As cigarette butts sink after a relatively short period in water, their abundance in the Yarra and Maribyrnong Rivers does not align with beach clean-up data. It is also worth noting that beach clean-up efforts are typically geared toward the collection of large litter items and small plastic remnants and microplastics are rarely recorded in litter audits (amdi.tangaroablue.org). This may explain the mismatch between trawl and beach clean-up litter findings. Nevertheless, trawl findings provide a fairly good representation of the broader marine debris issue, providing information about the composition and relative abundance of dominant buoyant litter items entering Port Phillip Bay.

Plastic fragments, foam, and film dominate microplastic pollution in many urbanised catchments around the globe. These items were the most abundant litter types collected in trawls in the New York-New Jersey Harbour estuary, USA, one of the most urbanized estuaries on earth. Similarly, fragments, foam and plastic foil dominated microplastic loads along the length of the Rhine River in Europe (Mani et al., 2015). This is not surprising given that worldwide, the packaging industry, the primary material for microplastics in this study, is the third largest after food and energy (Moore and Phillips, 2011). In 2014 alone, 311 million tonnes of plastic was

produced globally (Gourmelon, 2015). Because of plastics’ durability and extremely mobility (it floats, flies, sinks), it eventually enters our waterway either by accident or intentionally (Moore and Phillips, 2011). The large litter items frequently captured in this study including straws, lolly wrappers, and plastic bottle caps eventually deteriorate through physical, biological and chemical processes (Andrady, 2011) into trillions of tiny fragments that enter Port Phillip Bay at an alarming rate.

This study found that the number of litter items captured in the manta net varied substantially from month to month. For example, in September 2016, 10 litter items were captured in the Yarra River trawl compared to 499 items in April 2017. We observed no seasonal variation in the total number of litter items in both the Yarra and Maribyrnong Rivers. Further, contrary to expectations, river height did not influence total litter capture.

Local variables that potentially influence litter capture rate include:

- Trawls coinciding with emptying of the Parks Victoria floating litter traps (potentially releasing microplastics back into the water column during grab bucket transfer of litter from the floating traps to the disposal barge) (Blake and Charko, 2014)
- High volumes of microplastics that have been perched on stream banks above mean high tide are released to the stream by unusually high tides generated by storm surges (Moore and Phillips, 2011)
- Rainfall events occurring several days prior to trawls flushing most pollutants out of the rivers before the trawl being conducted (Moore and Phillips, 2011).
- Wind strength influencing the turbulence of water flow thus influencing the buoyancy of litter items (Kooi et al., 2016).
- Events that lead to the release of large volumes of litter such as sporting events or the accidental spillage of plastic materials at plastic manufactures (Zbyszewski and Corcoran, 2011).

While plastic fragments, foam, and film (aka flexible sheets or soft plastics) appear to dominate global riverine microplastic pollution, their concentration along and between rivers differ

reflecting various sources and sinks (Mani et al., 2015). In this study, the Yarra River trawl samples contained significantly greater quantities of polystyrene beads than the Maribyrnong. The reason for this difference could be related to a multitude of factors including differences in the industrial usage and population density along the rivers (Yonkos et al., 2014). Additionally, the extensive manufacturing, retail and hospitality precincts along the banks of the Yarra may be partly responsible for poor polystyrene management and disposal. Further investigation is required to account for this difference.

Our study found that these urban rivers contain high microplastic concentrations in surface waters. Our estimations showed that the Yarra River alone can transport 12 million microplastic pieces into Port Phillip Bay daily. It is worth noting that items less than 0.5mm were not identified and quantified in this study. Hence, our daily estimates may underestimate the microplastic flow into Port Phillip Bay. Ling et al (2017) noted that plastic filaments, including highly pervasive microfiber pollution) between 0.038 mm and 0.250 mm formed the dominant categories of microplastic in coastal and estuarine sediments around Australia, including Port Phillip Bay (Ling et al., 2017). However, we know little about the downstream movement and deposition of microplastics in rivers. It is unclear what portion of riverine microplastics travel downstream and what portion are deposited to the sediment. Some microplastics are likely transported long distances, as several studies report high concentrations of microplastic in estuaries, with rivers implicated as major microplastic sources to these coastal zones (Yonkos et al., 2014, Lima et al., 2014, Sadri and Thompson, 2014). However, some microplastics are deposited into sediments. In the North Shore Channel for example, microplastic concentrations in sediment were up to 15,000 times higher than surface water samples (Hoellein et al., 2017). Consequently, in order to accurately identify the magnitude of microplastic pollution in Port Phillip Bay it is necessary to better understand microplastic depositional patterns and take into account factors such as hydrology (i.e., storms), geomorphology (i.e., depositional zones), and location within river networks to name a few.

Implications for marine life in the Yarra Estuary and Port Phillip Bay

To date, very few studies have assessed microplastic ingestion/interaction rates for species in Port Phillip Bay. However, worldwide freshwater and marine species at all trophic levels, possessing varied feeding strategies ingest microplastics (Eerkes-Medrano et al., 2015). In lab

Port Phillip EcoCentre, July 2017.

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based studies, ingestion has been associated with: the retention and accumulation of microplastics in organisms including mussels (Browne et al., 2008), lobsters (Murray and Cowie, 2011) and scallops (Brillant and MacDonald, 2000); injury and subsequent disrupted feeding/swimming activity in lugworms (Browne et al., 2013), stress, immune response, altered metabolic function and toxicity in lugworms (Browne et al., 2013), fish and mussels (Rochman et al., 2013), and tumour formation in fish (Rochman et al., 2013) to name a few. Because of the Bay’s potential for high microplastic concentration and because these waters are so biodiverse, high rates of plastic ingestion are likely. Faunal ingestion rates and impacts of marine microplastics at the individual, population, and community levels need to be assessed to prevent further biodiversity loss in the Bay and better understand the human health implications of consuming seafood from the Bay.

Conclusion

The high average monthly quantity of litter in the Yarra and Maribyrnong Rivers highlight the important contribution of these rivers to marine debris mass in Port Phillip Bay. In light of these results, we emphasise the importance of immediate measures to manage plastic pollution, at all stages of its ‘life-cycle’, particularly the early stages where plastic sources are known and can be more easily contained. Policy makers have a key role to play in creating the much needed legislative framework to catalyse a reduction in plastic waste at source before it does the most significant damage, as well as encouraging cleaning up plastic pollution along rivers and coastlines before it does the most significant damage. There is sufficient evidence that microplastics are having an unacceptable impact on the environment. Many scientists have stated that a society should not wait until there is quantified evidence of the degree of damage before acting to reduce marine debris impacts (Lavers and Bond, 2017, Gall and Thompson, 2015). A ‘Precautionary Approach’ needs to be taken. The Grantham Institute ‘Ocean Plastic Pollution Challenge Report’ outline the most promising solutions to reduce the impacts of plastic pollution. These include:

- Managing plastic waste at source, for instance, by raising awareness amongst the public of the harm caused by plastic pollution.

- Developing and expanding the use of plastics that truly degrade in the ocean.
- Managing waste and litter streams better by: ensuring adequate waste management systems are in place; setting up a circular economy for plastic products and waste where possible; boosting recycling etc.
- Using alternative materials to plastic where possible, such as substituting the microbeads in cosmetics for non-plastic alternatives.
- Cleaning up existing plastic pollution, with a focus on waterways, sewerage plants and coastlines.

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