LITTER AND FLOWS

CONNECTING THE YARRA AND BAY

VICTORIA
State Government

Disclaimer

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Figure 1 - Previous
Duck in Merri Creek
Anthony Despotellis

Figure 2
Merri Creek Drain
Anthony Despotellis

Figure 3
Yarra River rocks
Anthony Despotellis

Acknowledgments

Riverkeeper Association proudly acknowledges Victoria's Aboriginal community and their rich culture and pays respect to their Elders past and present. We acknowledge Aboriginal people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely.

This work has been supported by the Victorian Government through Round 1 of the Port Phillip Bay Fund. We acknowledge the critical participation of all stakeholders who engaged with the Yarra Riverkeeper Association particularly our partners in this project including the Department of Environment Land Water and Planning, Parks Victoria, Melbourne Water, Cleanwater Group, the Port Phillip Ecocentre and Neil Blake the Baykeeper.

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We would also like to acknowledge the many schools that participated in the Yarra Riverkeeper education program and who provided in-kind support with litter collection and litter auditing. Finally, we thank the support of the Yarra Riverkeeper Board, Committee members, and community members for assisting with many aspects of this project, most notably Anthony Despotellis, Miriam Sheridan, Ian Wong. Gillian Jervis, Janet Bolitho, Lauri Lidstone, Kate Arnold, Micheal Honnegger, Sebastian Pivet, Christopher Balmford and Karin Traeger.

Executive Summary

Up until recently the main focus of research on plastic pollution has been the marine environment. Thus, there is a relative lack of knowledge on plastic waste occurrence in river water and along riverbanks. Data on their presence, sources, and fate is still scarce. The same is true for their chemical burden and ecological/ physiological effects. This 'Litter and Flows' project was designed to gain a deeper understanding of the pathway of litter into the Yarra and subsequently into Port Phillip Bay. Further, the project aimed to quantify the volume and describe the composition of litter in the Yarra River. Quantitative and qualitative litter data was obtained through: 1). Bandalong litter trap audits, 2). Microplastic trawls in the Yarra and Maribyrnong Rivers, 3). Community/School clean-ups along the Yarra. Over the course of the Litter and Flows project 5,051 participants were involved in the Yarra Riverkeeper litter education program. Approximately 8000 kg of waste was removed from our waterways over the course of the litter and flows project with community contributing approximately $187,000 of in-kind support in clean-up efforts. Each litter audit method delivered different results in terms of litter composition. However, overall, by volume, polystyrene and plastic food packaging were found to be the dominant litter items in the Yarra. The sources and solutions of plastic pollution are discussed in this report.

Figure 4
The Yarra River
Anthony Despotellis

The Yarra Riverkeeper Association

The Yarra Riverkeeper Association was founded in 2004 by a group of passionate community members who were keen to see river protection measures in place. Since then, the organisation has grown to focus on river advocacy, research and education. The Yarra Rivekeeper Framework is built around our motto: ‘Our Yarra, healthy, protected and loved’. Our aims are to protect the Yarra from mouth to source, to revitalise the river and to foster love for the river by current and future generations.

Figure 5
Merri Creek
Anthony Despotellis

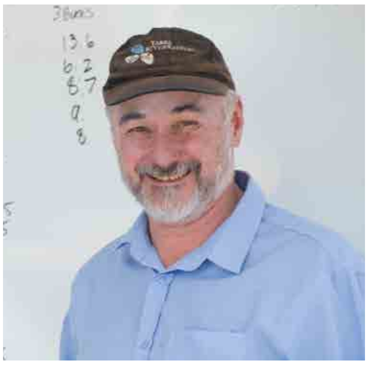
Contents

1.0 Project Leads

Dr Nicole Kowalcyk

Dr Nicole Kowalcyk is the Litter and Flows Project Manager and Education Officer for the Yarra Riverkeeper Association. Her longstanding interest in the marine sciences led her to undertake a PhD program where she focused on the foraging and reproductive ecology of the iconic St Kilda little penguin colony. This research was important to identifying their key foraging locations and prey species and provided insight into foodweb dynamics within Port Phillip Bay. This research also highlighted the threats these seabirds face including the direct impact of pollutants, mainly litter, on their breeding habitat as well as the impact of pollutants on their prey resources.

Since 2017 Nicole has since been working with the Yarra River community to monitor and stem the tide of litter pollution. Nicole uses her research insights to raise awareness about the impacts of littering for habitats and organisms in the Yarra River and Port Phillip Bay.



Andrew Kelly

Andrew Kelly, Vice-President and Yarra Riverkeeper. Andrew has been the Yarra Riverkeeper for the past four years from November 2014. Prior to that he had been on the committee of management of the association for three years. Andrew grew up along the Yarra and has a deep understanding of the river as a connected ecosystem that is the imaginative heart of the city of the Melbourne. He has degrees in archaeology, Australian history and geography. Andrew worked in the publishing industry for 35 years, and after a successful career in corporate publishing he established several award-winning independent imprints. He was vice-president of the Australian Publishers Association and a recipient of the George Robertson award. Andrew is a past president of the Society of Editors (now Editors Vic). He is a member of the Australian Institute of Company Directors.

2.0 Where the Yarra meets Port Phillip Bay

The Birrarung

The Yarra River traverses an enormous range of habitats from pristine forested catchments through a range of agricultural lands and then through dense urban areas. The Yarra flows 242 kilometres from headwaters to sea – from its source on the flanks of Mt Baw Baw in the Yarra Ranges National Park, north-east of Melbourne, through the Yarra Valley and greater Melbourne into Port Phillip Bay at Newport. More than one-third of Victoria's population lives in the Yarra catchment, which spans about 4000 square kilometres. The catchment includes 50 rivers and creeks.

The wildlife living in and around the Yarra River is diverse with one-third of Victoria's animal species found in the Yarra catchment. The river and local surrounds are home to 22 species of fish, 190 bird species, 10 frog species, 16 reptile species and 38 species of mammals. In terms of vegetation, more than 25 unique vegetation communities make their home along the Yarra River, its tributaries, and within the catchment billabongs, wetlands and swamps.

The Yarra River corridor is 22% urbanised, 21% natural vegetation and 57% agricultural (Melbourne Water Corporation, 2018). Historically the Yarra River was treated as a large open sewer and is still suffering. In 2018, the State of the Yarra and its Parklands investigation reported 18 of the 25 environmental health indicators were 'poor'. Only 1 of the overall 36 indicators scored in the 'good' category, which was the indicator for "post settlement colonial heritage" (Victoria, 2018). The three main issues facing the Yarra today are overdevelopment, nature under stress from invasive species and habitat loss, and poor water quality. Water quality has been adversely affected by litter, pollution incidents, sewerage, stormwater quality, and climate change.

The Yarra River estuary extends 22km from Dights Falls, a man-made weir, in Abbotsford to the river mouth at Port Phillip Bay. The Yarra estuary is a salt-wedge estuary, where the heavier salt water from the bay sits under the less dense freshwater on top.The Yarra estuary passes through Melbourne's eastern suburbs and the central business district, which gives the inner urban segment of the river high recreational, ecological, social and economic value. Though, as a result of urban development, a growing city dwelling population and the rivers tributaries, the estuary section of the Yarra is weakening ecologically and polluted with litter (State of the Yarra, 2018). These factors mean that the Yarra estuary is a good site for litter interventions.

The Yarra River discharges into the northern most section of Port Phillip Bay, Hobsons Bay. Port Phillip Bay is the largest marine embayment in Victoria, with an area of approximately 1,930 square kilometres, a coastline of 333 kilometres and a catchment area close to 10,000 square kilometres. Melbourne, with a population in 2018 of 4.9 million people, surrounds much of the Bay. The Yarra River provides most of the freshwater inflow into the Bay and is the largest litter contributor into the Bay.

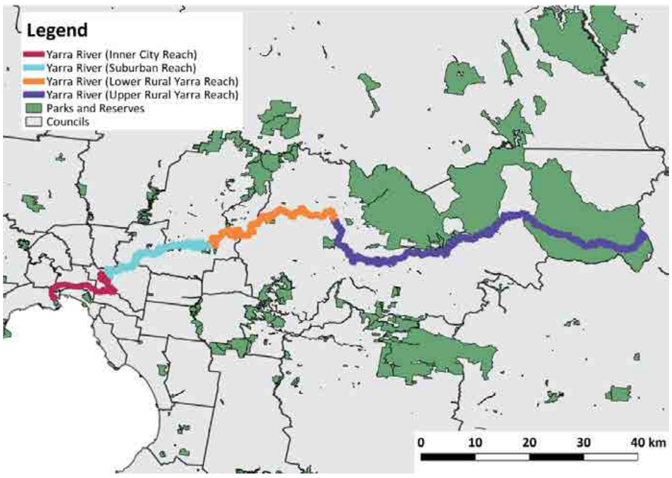


Figure 6
Map of the Yarra River showing the boundaries of each of the four reaches and its entry into Hobsons Bay

3.0 Litter & Flows: Project Background and Rational

Wide use of single-use plastics, improper waste management practices, inadequate wastewater treatment, and littering have led to large volumes of plastic pollution entering the Yarra and Port Phillip Bay. Litter enters our waterways through wind transport, surface runoff and via storm water drains. There is increasing public concern about large amounts of litter in the Yarra River and Port Phillip Bay. This is illustrated in the 'State of the Bays, 2016' and 'State of the Yarra, 2018', developed by the Commissioner for Environment and Sustainability. Litter has been reported to:

- Be unattractive
- Disturb physical habitats
- Degrade water quality
- Attract pests and vermin
- Cause animal illness, injury and death
- Reduce amenity values
- Reduce tourism
- Be costly to clean

Up until recently the main focus of research on plastic pollution has been the marine environment. Thus, there is a relative lack of knowledge on plastic waste occurrence in river water and along riverbanks. Data on their presence, sources, and fate is still scarce. The same is true for their chemical burden and ecological/physiological effects. This 'Litter and Flows' project was designed to gain a deeper understanding of the pathway of litter into the Yarra and subsequently into Port Phillip Bay. Further, the project aimed to quantify the volume and describe the composition of litter in the Yarra River. Quantitative and qualitative litter data was obtained through:

1). Bandalong litter trap audits

2). Microplastic trawls in the Yarra and Maribyrnong Rivers

3). Community/School clean-ups along the Yarra

Litter data was then used in the Yarra Riverkeeper Education Program to raise awareness about the impact of litter on our waterways and to keep the community well informed in how to take practical action to reduce waste. Litter is a problem that affects everyone – and everyone can play a part in making change. An integrated approach to waterway pollution using preventative measures such as education campaigns, containment (e.g. litter traps) and remedial (e.g. river/beach clean-ups) measures are necessary to reduce litter impacts.

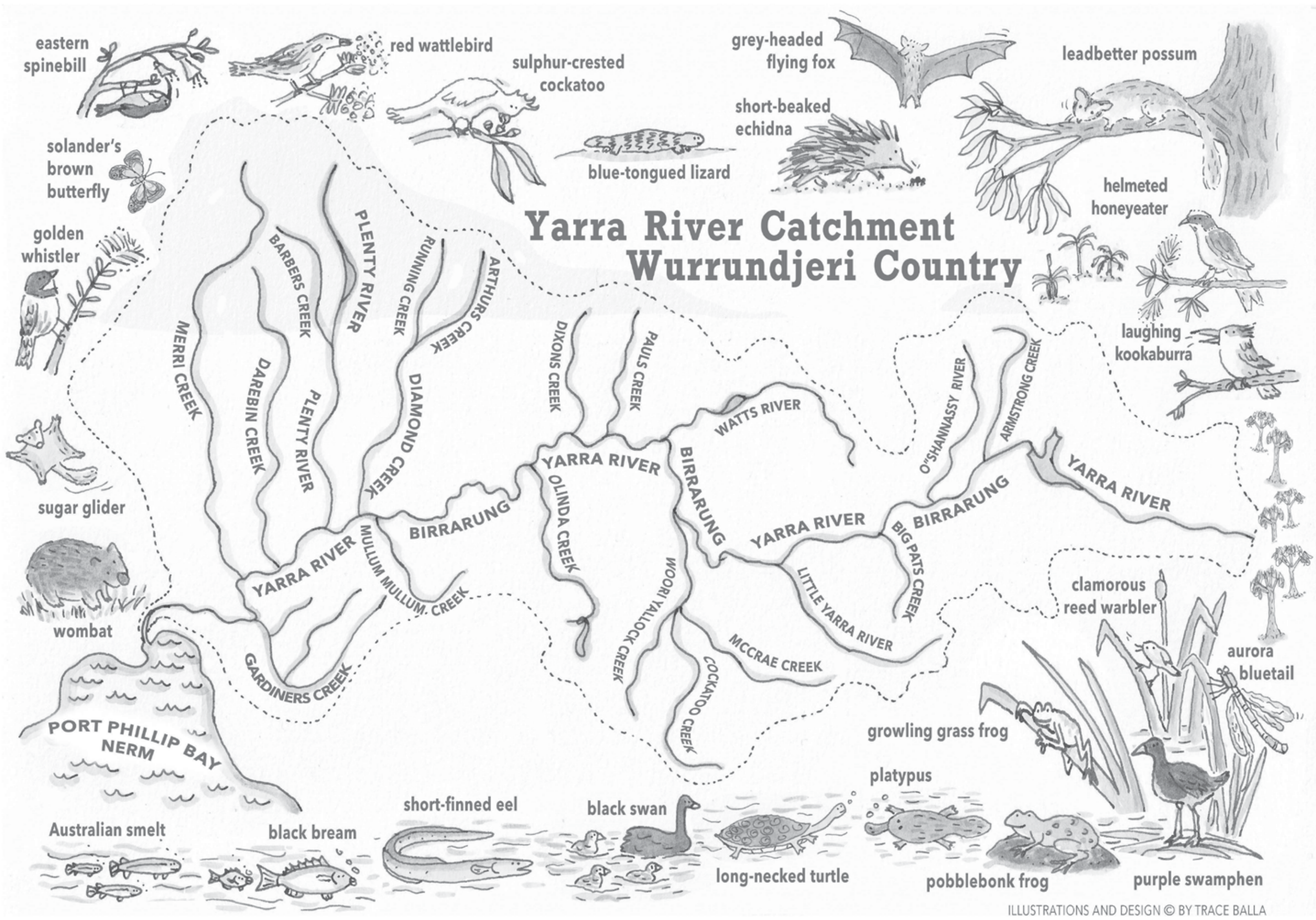


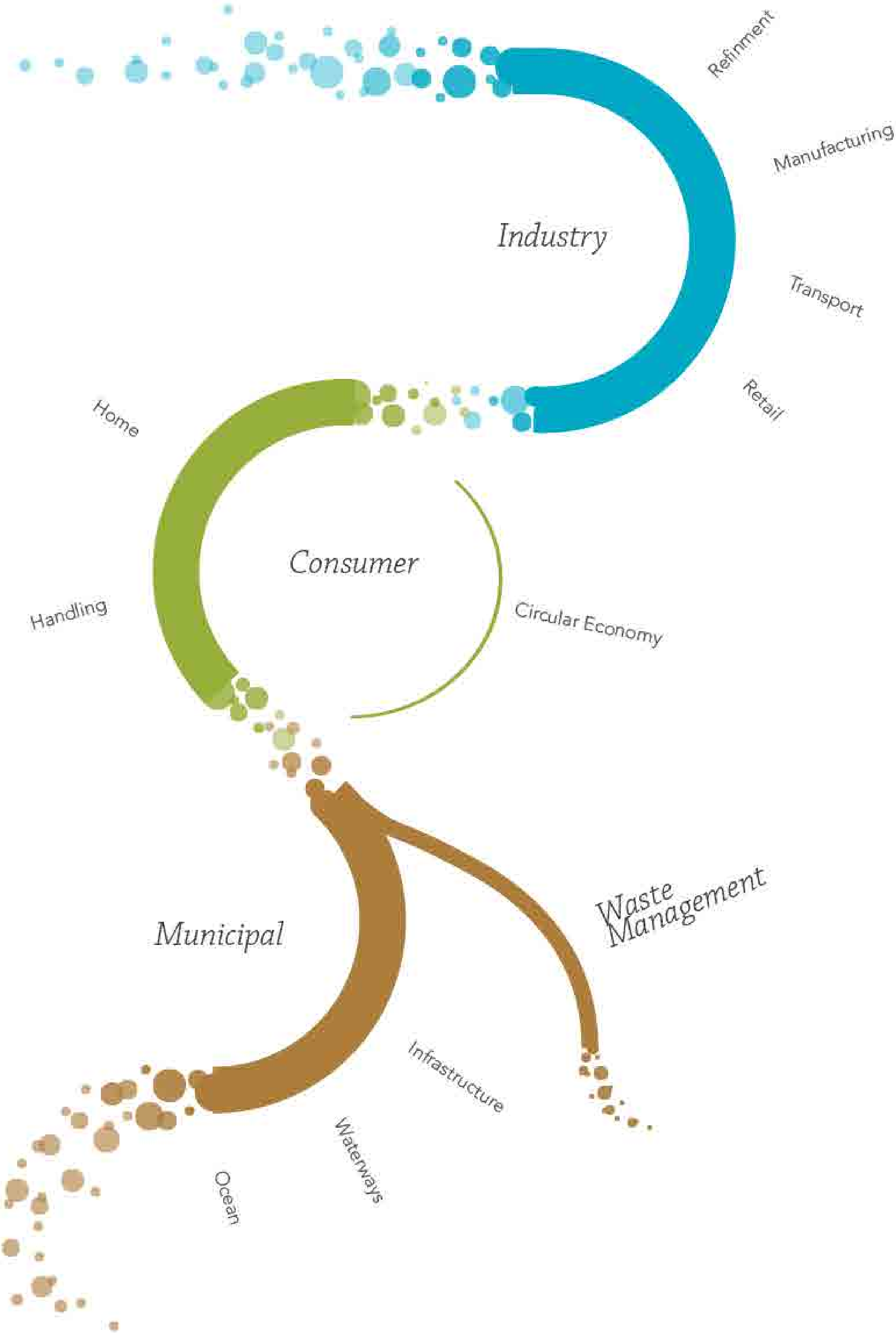
Figure 7
Yarra Riverkeeper Association Brochure designed by Trace Balla highlighting biodiversity along the Yarra River

3.1 The Life Cycle of Plastics

From oil, to hand, to the water

The life cycle of plastics is a complex one. They all begin in the same way, being refined from petrochemicals into various forms, usually tiny pellets, and then are bought by manufacturers before being turned into parts and then products. From here, the plastics enter retail stores and restaurants and are subsequently passed into the hands of consumers. From one specific source, the plastics are now spread all over the world, being consumed in unimaginable amounts. But they eventually reach the end of their "useful" life and are thrown away, either responsibly or irresponsibly. The responsibly disposed of material going into the countries waste management systems, but those carelessly disposed of ends up passing through our infrastructure and into our waterways. From there, only few interventions are in place to capture the litter before it enters the world's oceans.

Figure 8
Journey of Plastics
Anthony Despotellis


Refinment
Manufacturing
Industry
Transport
Retail
Home
Consumer
Handling
Circular Economy
Municipal
Waste Management
Infrastructure
Waterways
Ocean

3.2 *Sources of litter*

Dominant Sources of Litter

According to The Ocean Conservancy, all the litter in our water shares a common origin: "…at a critical decision point, someone, somewhere, mishandled it, either thoughtlessly or deliberately." Most of the litter we find in the Yarra River comes from land-based sources, via storm water drains, or through surface run-off and wind transport. Once introduced into rivers, litter may sink, be deposited on river banks and/or be transported to the marine environment.

Stormwater Drains

Storm water drains service the entire Yarra catchment, which spans approximately 4000km. Litter that has escaped around the catchment, either accidentally (e.g. litter leakage during waste removal and transportation to landfill) or deliberately (e.g. littering) gets swept down stormwater drains.
The draining process occurs in the following order:

Stormwater (and leaked litter) enters house gutters and downpipes, and flows into residential drains

Residential drains connect to council drains along streets and roads

Council drains connect to Melbourne Water's regional drains

Regional drains direct stormwater into the nearest river or creek, or directly to the bay via piped beach outlets

Rivers and creeks flow into Port Phillip Bay or Western Port Bay

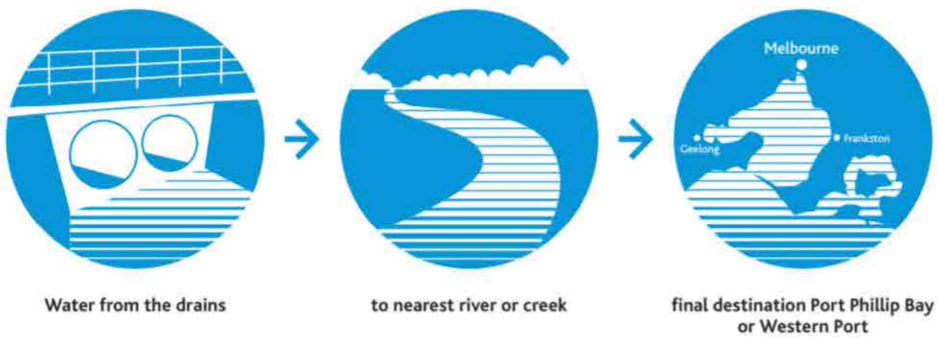
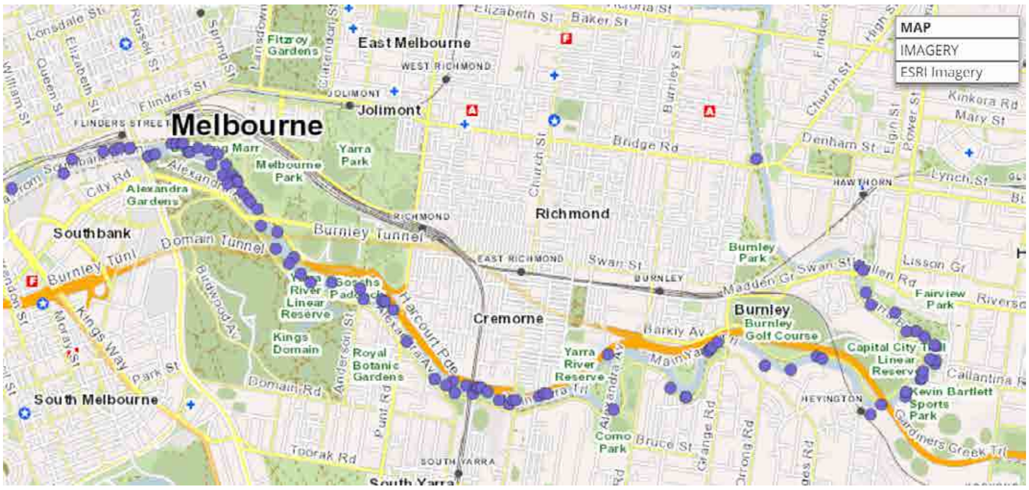


Figure 9
Stormwater drain movement within the Yarra catchment

Figure 10
Prahran main drain flowing
into the Yarra River

Figure 11
Stormwater drain outlets discharging into the Yarra River between Bolte Bridge, Melbourne and Swan Street, Richmond



Thousands of stormwater drains discharge into the Yarra River. The EPA reports that stormwater washes 14,000 tonnes of sediment, 650 tonnes of nutrients such as nitrogen from fertiliser, litter, heavy metals and bacteria into the Yarra River each year. The Yarra Riverkeeper Association identified 92 storm water drains in 10 km of the lower Yarra River, from Bolte Bridge, Melbourne to Swan St Bridge, Richmond. Each storm water drain services a catchment area or varying size, population density and land usage. Consequently, each storm water drain empties a unique assemblage of pollutants into the Yarra River.

Illegal Dumping

Human consumption of waste is enormous which inevitably leads to vast quantities of waste that are not efficiently recovered in the waste management sector. Many items classified as waste are often large, non-recyclable and are often disposed of in an irresponsible manner through illegal dumping. Within Victoria, illegal dumping is defined as the disposal of waste on public or private land or into the water without a license or formal approval. Waste deposited near waterways pollutes rivers through surface run-off and wind transport.

Despite heavy fines for illegal dumping behaviour, many people continue to dump rubbish, particularly along rural roadsides, public parks, roadside rest areas and sometimes along waterways including the Yarra River or creeks and tributaries that feed into the Yarra. Household waste, garden waste, and construction and demolition waste are common categories of waste that are illegally dumped (Sustainability Victoria). Items are illegally dumped to avoid paying disposal costs, transporting material to landfill/transfer station sites as well as a lack of certain waste facilities areas.

Littering along waterways

According to the Environmental Protection Act (1970) 'litter' includes any solid or liquid domestic or commercial waste, refuse, debris or rubbish and, without limiting the generality of the above, includes any waste glass, metal, plastic, paper, fabric, wood, food, soil, sand, concrete or rocks, abandoned vehicles, abandoned vehicle parts and garden remnants and clippings, but does not include any gases, dust or smoke or any waste that is produced or emitted during, or as a result of, any of the normal operations of the mining, building or manufacturing industry or of any primary industry.'

More commonly, littering behaviour is viewed as making a place untidy with rubbish. Negative disposal behaviours have been categorised into numerous categories such as '90%ing' where most items are put in the bin but some are left behind, 'flagrant flinging', throwing or dropping items with no apparent concern, 'foul shooting', a missed throw at a litter bin and 'grinding', grinding items into the ground & leaving them there. A significant proportion of plastics along the river are comprised of food wrappers/containers and plastic cutlery most likely associated with recreational activities along the Yarra River.

Figure 12
Cartoons depicting flagrant flingers, foul shooters, grinders and improvisers by cartoonist Kerry Millard

3.3 Litter Composition in the Yarra

What are Bandalong Litter Traps?
In the suburban and inner-city Yarra reaches, 17 Bandalong litter traps are strategically located along the river to capture litter. The Bandalong Litter Trap is a floating device installed at strategic locations along waterways to collect and retain floating litter and organic debris. Outspread collection booms direct floating litter through a one-way gate into the trap. The system operates silently without any mechanical assistance, capturing and retaining debris ready for removal and disposal (https://www.bandalong.com.au/). Re-entrainment is prevented by a system of counterweights and paddles that close the entry gate when the water flow ceases or there is a change in flow direction due to tide or wind. A polyethylene side skirt beneath the waterline prevents debris escaping under the main floats (https://www.bandalong.com.au/). The first series of traps were first installed in 1996 (3 x 9 meters) followed by the installation of larger traps (3 x 12 meters) in 2015.

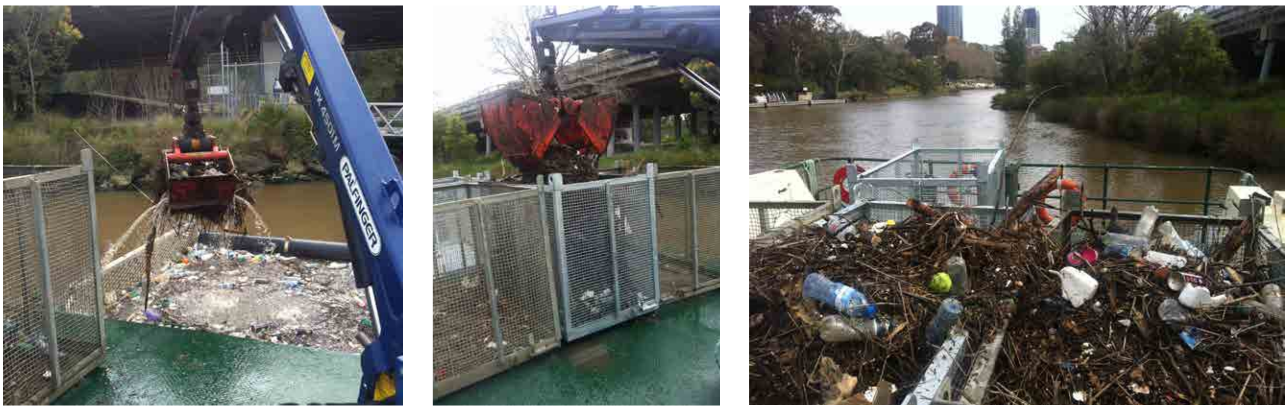


Figure 13
Parks Victoria crane with a bucket grab removing floating litter and debris which is then emptied into wire cages secured to the Pelican vessel

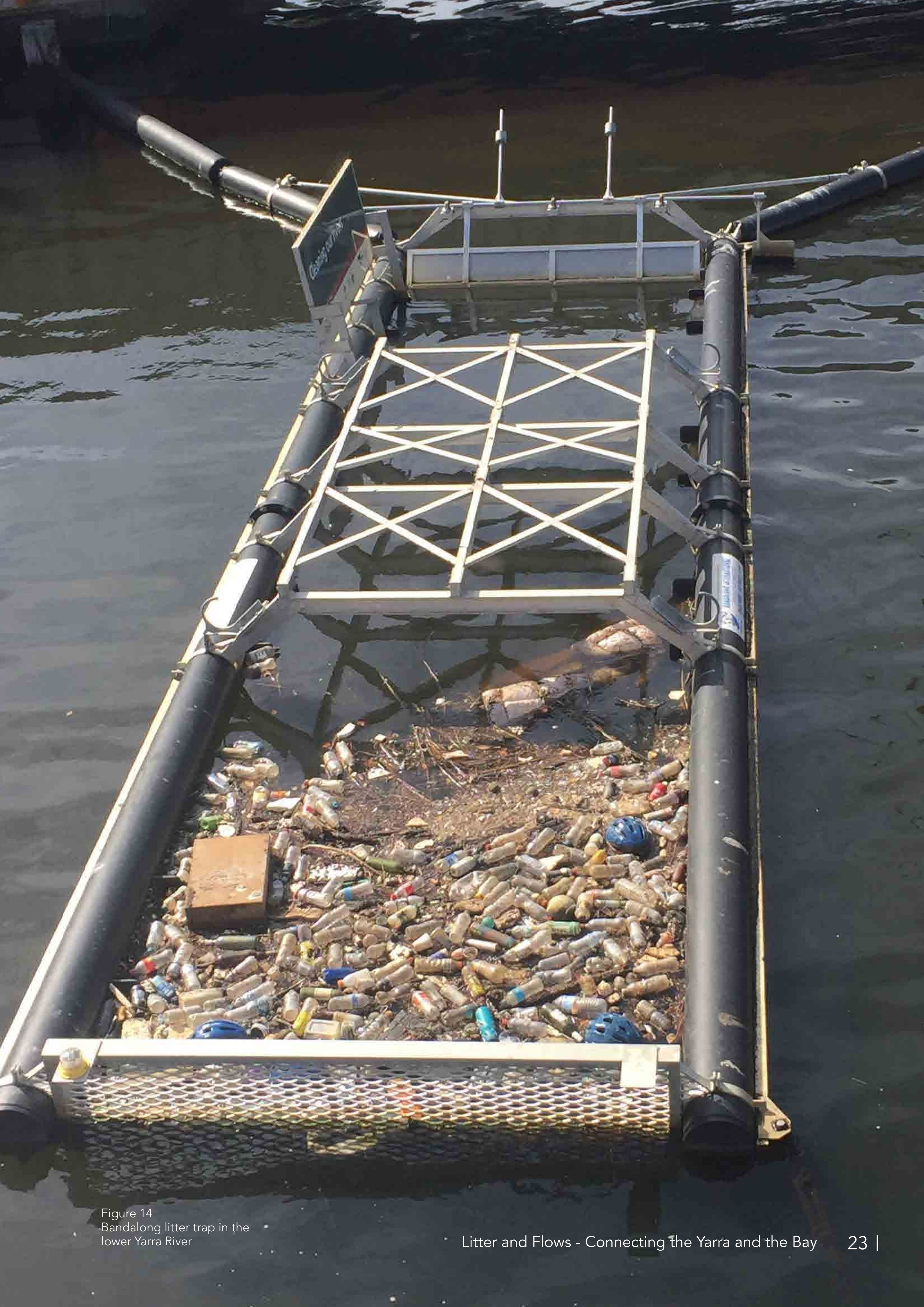


Figure 14
Bandalong litter trap in the lower Yarra River

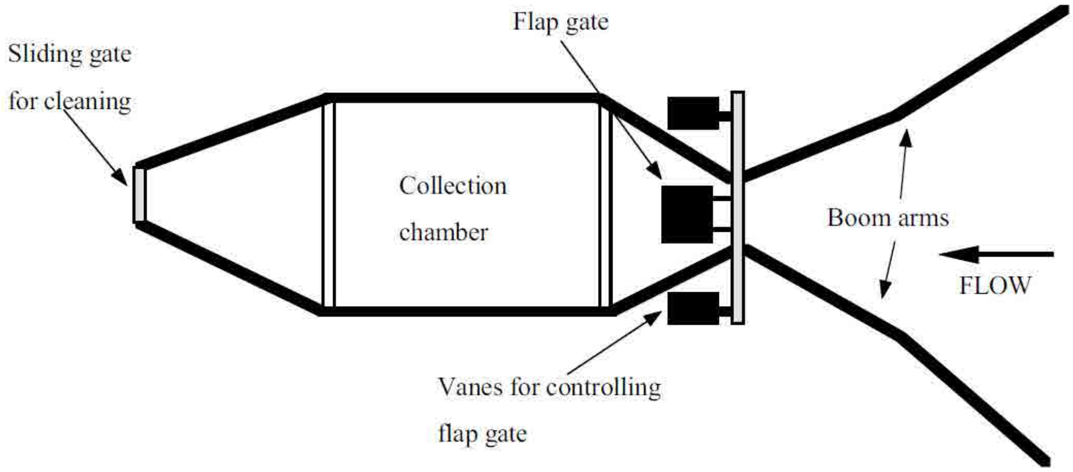


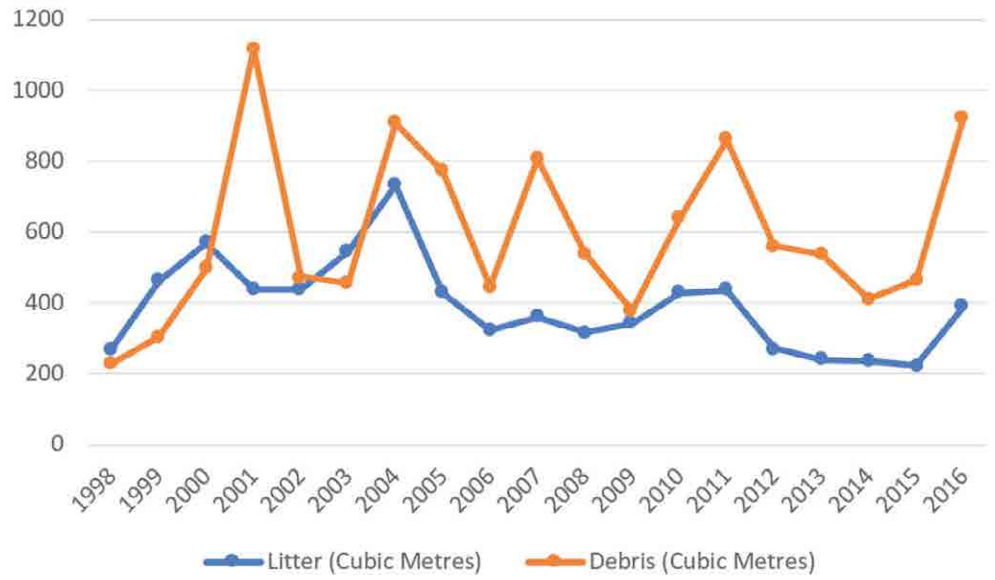
Figure 15
Diagram of a Bandalong litter trap

The traps are maintained by Parks Victoria, who empty the traps on rotation at regular intervals. A crane with a bucket grab removes floating litter and debris and is emptied into wire cages secured to the Pelican vessel.

Parks Victoria keep a record of collected litter and organic debris, measured in cubic metres, for each trap. Collected volumes shift substantially from year to year, depending on the size of traps in place as well as on the number of traps in use.

Between years 2000 and 2017, an average of 1,200 cubic meters of litter and debris are collected by Parks Victoria annually (range 650 – 1,550 cubic metres). Apart from estimating litter versus debris percentages, Parks Victoria do not undertake audits of litter composition within the traps. The aims of the Yarra Riverkeeper Bandalong litter trap audits, therefore, were designed to assess overall litter composition in Bandalong traps as well as to identify differences between the 17 traps in the lower Yarra.

Figure 16
Cubic metres of litter and organic debris collected in Bandalong traps from 1998-2016. Data sourced from Parks Victoria



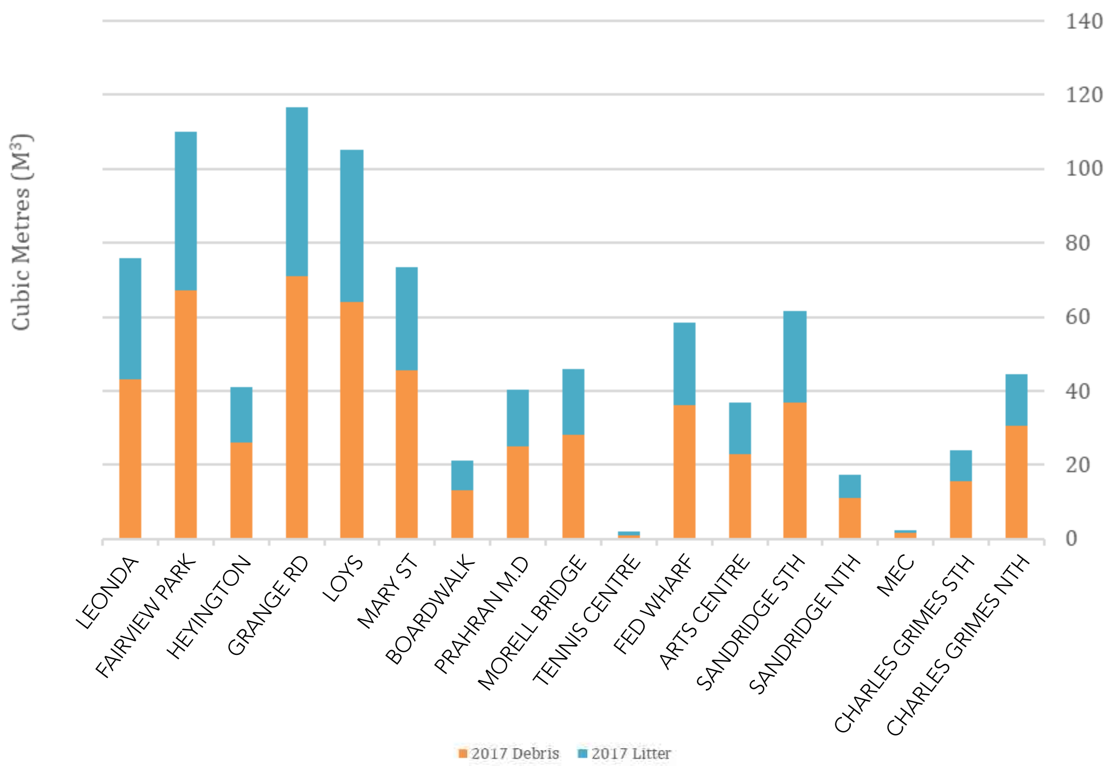


Figure 17
Litter versus debris composition in litter traps in 2017. Data sourced from Parks Victoria

How are the traps audited?

The Yarra Riverkeeper Association conducted 49 Bandalong litter traps audits on three separate dates (27 November 2017, 16 August 2018, 19 February 2019) as part of the Litter and Flows program. The Yarra Riverkeeper vessel approached all 17 litter traps along the lower Yarra. Trap location, fullness (%), and the relative proportion of dominant items (organic material, polystyrene, plastic bottles, metal items, balls, coffee cups, other) were recorded. On one occasion, plastic bottle branding in a single trap was counted.

Trap Composition

Trap fullness and composition varied both within and between traps. Based on the 49 trap audits debris (organic material) dominated trap material comprising on average 59.5% of trap contents (Fig. 13). Polystyrene, in bead and sheet form, and plastic bottles featured heavily in traps comprising on average 18.2% and 13.2% of trap contents, respectively. Balls (predominantly tennis balls) comprised 3.6% of audited material and metal aerosol cans (predominantly spray paint cans) comprised 2% of trap contents. 'Other' items including plastic packaging, glass, and clothing, while coffee cups made up the rest of trap material (3.5%). We did not find major difference in litter composition between traps. Organic material dominated all traps in line with findings by Parks Victoria. Polystyrene and plastic bottles contributed most to litter loads in all 17 traps (Fig. 14). Plastic bottles are a very common item in Bandalong litter traps. During a trap audit at Morell Bridge we encountered 54 bottles, particularly water bottles, with most of these bottles being manufactured by the Coca-Cola Amatil Group.

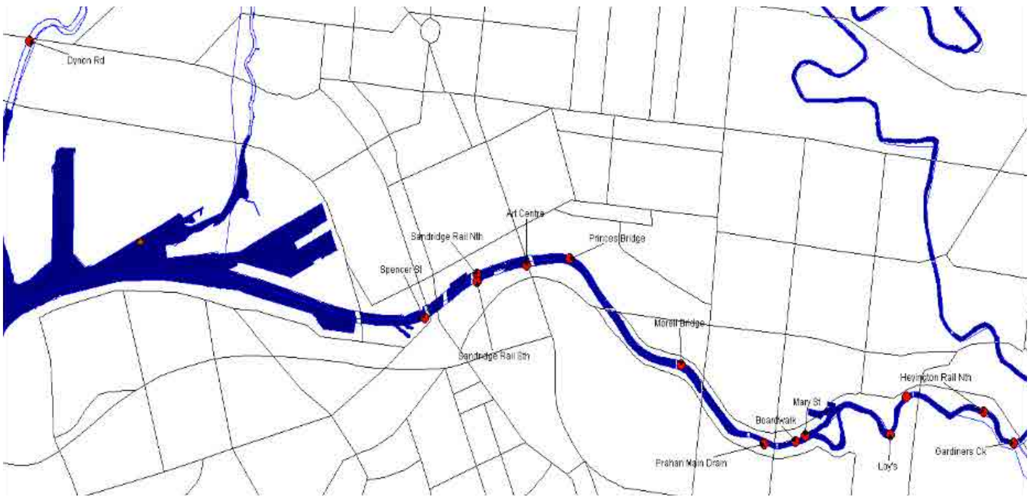
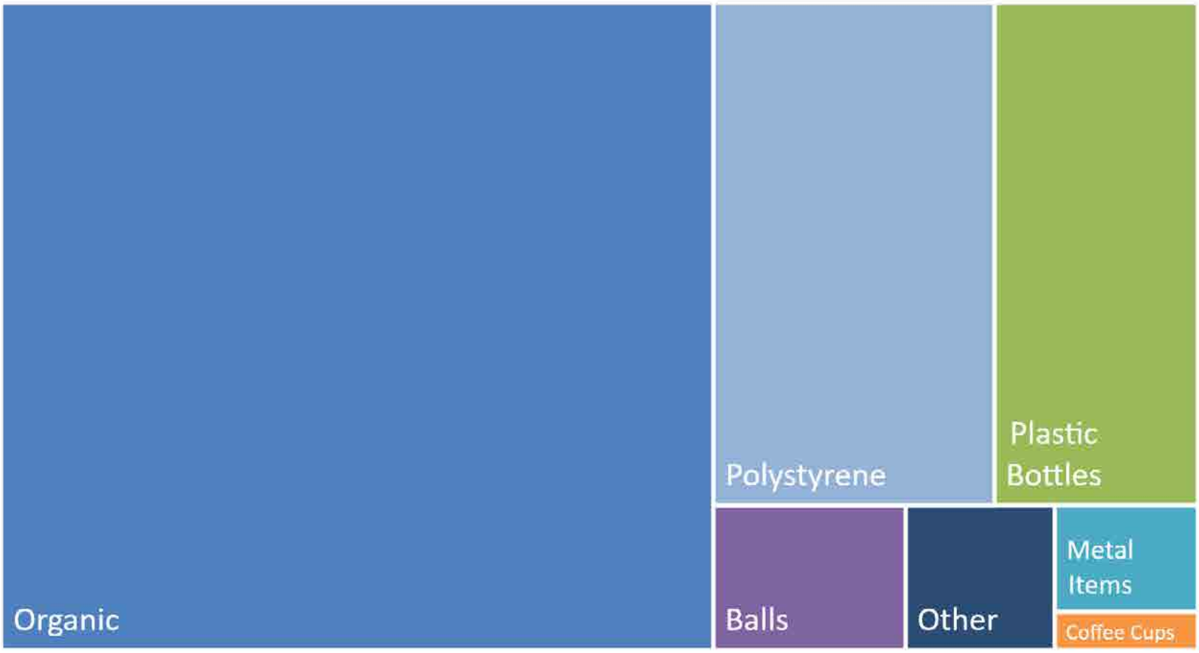


Figure 18
Location of Bandalong Litter traps in the lower Yarra

Figure 19
Average composition of a Bandalong litter trap in the Yarra River (combining all litter traps)



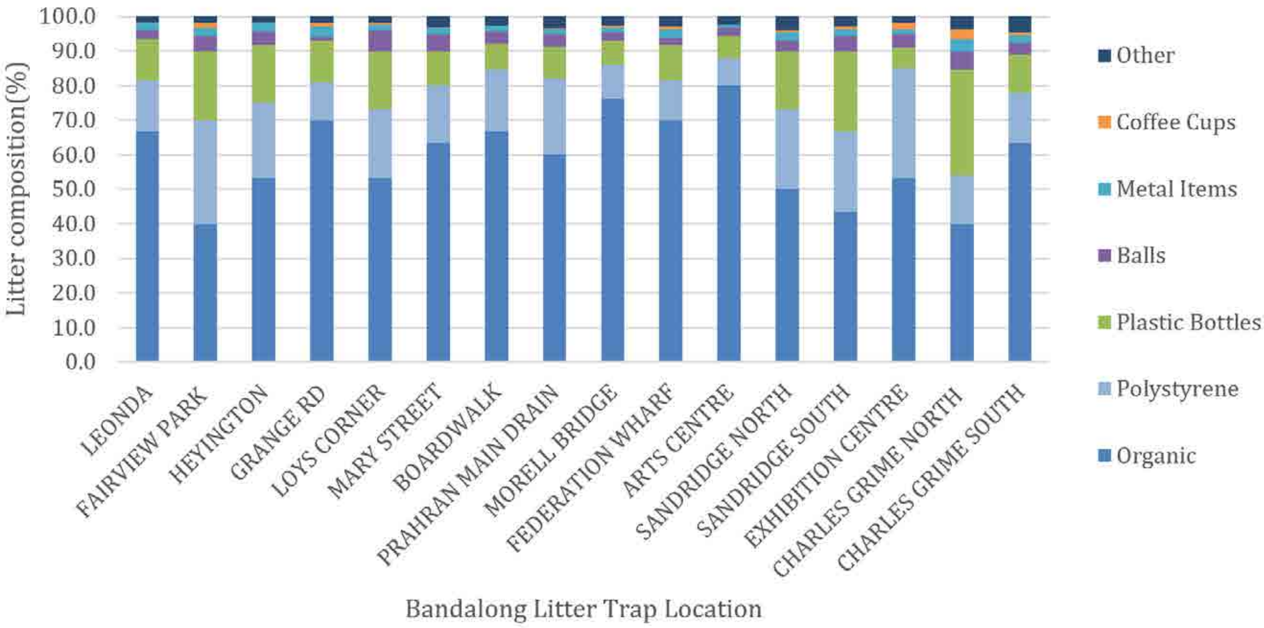


Figure 20
Average Bandalong litter trap composition

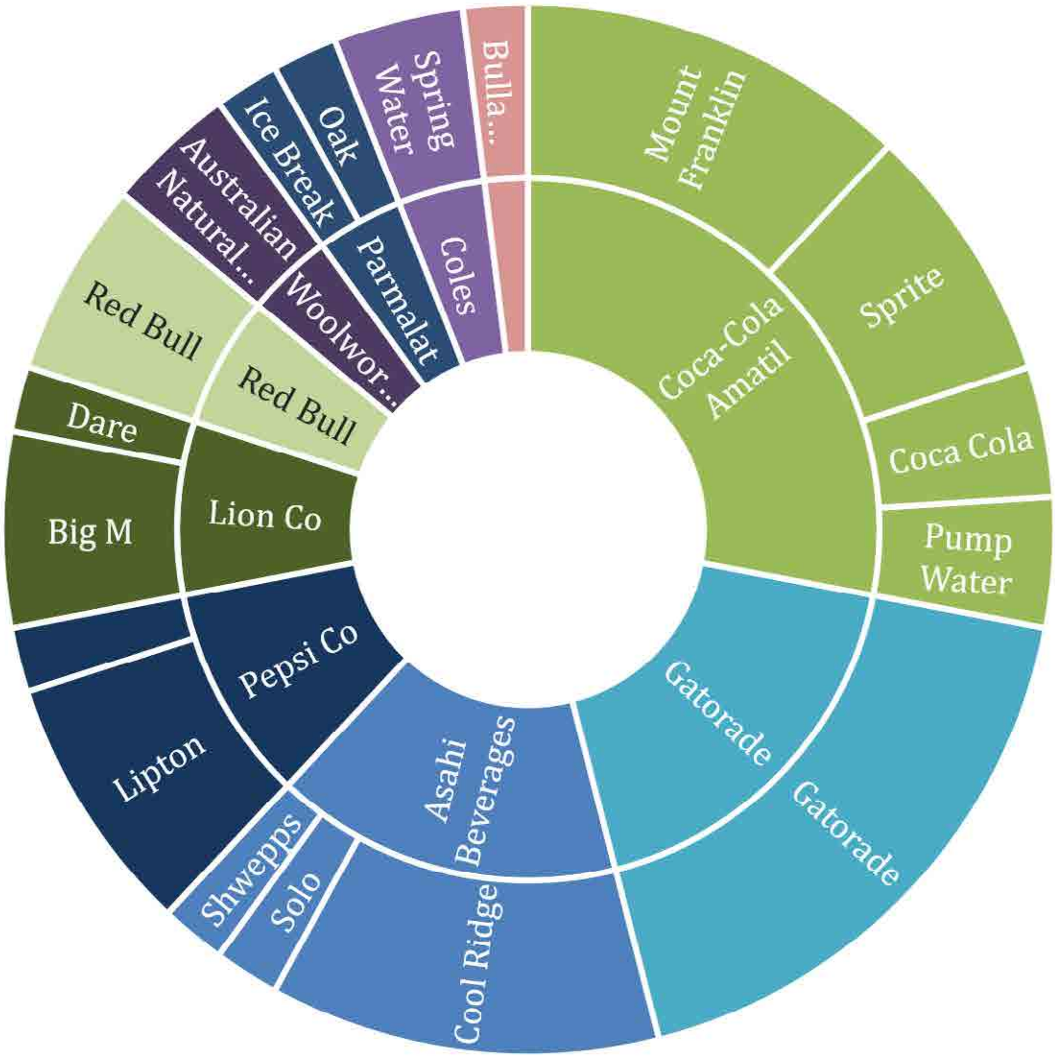


Figure 21
Dominant plastic bottle brands observed in litter traps in the Yarra River

“Polystyrene and plastic bottles contributed most to litter loads in all 17 traps”

Figure 22
Plastic bottle brands observed in litter traps in the Yarra River

3.4 *Microplastics in the Yarra and Maribyrnong Rivers*

The story of microplastics

Much of the litter that enters our rivers consist of extremely small pieces of plastic debris resulting from the disposal and breakup of consumer products and industrial waste. These small plastic pieces range in size from a few microns to five millimetres in diameter and are collectively known as microplastics (Thompson et al., 2004). Two main types of hard microplastics are found most often in waterways and oceans: nurdles and fragments (Barnes et al., 2009). Nurdles 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). They 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). Hard plastic fragments on the other hand are known as secondary microplastics, and are derived from the breakup of larger plastic items (Cole et al., 2011). They are irregular in shape and vary greatly in colour due to their primary design. Once in waterways and oceans, microplastics persist for thousands of years, and have been observed in freshwater and marine systems worldwide (Cole et al., 2011, Barnes et al., 2009).

Up until recently the main focus of research on plastic pollution has been the marine environment. This is of concern considering freshwater and estuarine systems are some of the most diverse ecosystems in the world. Locally, wildlife living in and around the Yarra River is diverse with one-third of Victoria's animal species found in the Yarra catchment. The river and local surrounds are home to 22 species of fish, 190 bird species, 10 frog species, 16 reptile species and 38 species of mammals. Port Phillip Bay supports an increasing recreational angler community and are home to an estimated 10,000 species, with several of those species unique to the Bay (yarraandbay.vic.gov.au). Studies that quantify the effect and extent of microplastics in these biodiverse waters are necessary to inform policy frameworks that reduce marine plastic pollution. Therefore, the aim of these microplastic trawls is to quantify and classify microplastic composition in the Yarra and Maribyrnong Rivers.

Figure 23
Sorted Yarra River microplastic content removed from the manta net.
Anthony Despotellis

Monitoring microplastics study site

Since July 2017, as part of the Litter and Flows program, monthly trawls were conducted in the Maribyrnong and Yarra Rivers, building on data collected since January 2015. The river transects 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, 300 m upstream from the Yarra. The Yarra trawls commenced at Bolte Bridge, 2.5 km upstream of the Maribyrnong mouth. 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, yet trawl speed was kept constant at all times.

River trawls

A manta net designed to collect floating debris off the water's surface 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 and constant speed to operate the net consistently.

The 'mouth' of the manta net measures 600 mm x 200 mm, and the net is 3 m long with a 30 x 10 cm^2 collection net (codend) made of a 0.33 mm mesh size (Fig.3B). After 30 minutes, the net was retrieved onto the boat, the codend removed and placed in a container to be dried and sorted. The manta net is of the same specifications used by 'The 5 Gyres Institute'.

Figure 24
Approximate trawl location transects in the Maribyrnong (Blue) and Yarra (Green) Rivers
Anthony Despotellis

Figure 25
Manta net on the side of the Yarra Riverkeeper vessel
Anthony Despotellis

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 2 mm-5 mm, hard plastic pieces 6-10 mm, hard plastic pieces > 10 mm, nurdles, polystyrene beads <4 mm, polystyrene beads ≥4 mm, plastic bottle caps, plastic straws, soft plastics (film), lolly wrappers, cellophane pieces, cigarette butts and 'other' items, which included twine, rubber and sponges.

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 2 mm-5 mm, nurdles and polystyrene beads <4 mm were grouped into the microplastic category. The soft plastics/film and cellophane categories were 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 585 and 598 soft plastic items (including cellophane) were collected from the Yarra and Maribyrnong Rivers respectively, over the duration of this study. These soft plastics inevitably break up into microplastics and are therefore a key contributor to microplastic loads entering Port Phillip Bay. Plastic items not visible to the naked eye, including microfibres, were excluded from this study due to logistical, technical and funding constraints.

Figure 26 - Left
Codend removed from the manta net revealing trawl contents

Figure 27
Volunteers sorting samples for microplastics
Anthony Despotellis

Sample contents

In both rivers, microplastics formed the bulk of litter and accounted for 77% (4,889 pieces) of the total load in the Yarra and 67% (2,374 pieces) of the Maribyrnong load. Hard plastic remnants <2 mm in length dominated the microplastics category and accounted for 57% and 63% of microplastics in the Yarra and Maribyrnong, respectively (Charko et.,2018). Hard plastic remnants, polystyrene and soft plastics as a whole were the most common items found in both the Yarra and Maribyrnong. Hard plastic remnants made up the bulk of the captured litter items, comprising of 65% of the total capture for the Yarra and 62% of the total items captured in the Maribyrnong. Polystyrene was the second most captured item, with 22% of all items in the Yarra and 13% of items in the Maribyrnong being polystyrene. Lastly, soft plastics (consisting of cellophane, lolly wrappers and unidentifiable soft plastics) made up 9% of total items captured in the Yarra and 17% in the Maribyrnong. A more comprehensive description of analyses and results is obtainable in the report 'Microplastics in the Maribyrnong and Yarra rivers, Victoria, Australia (2018).

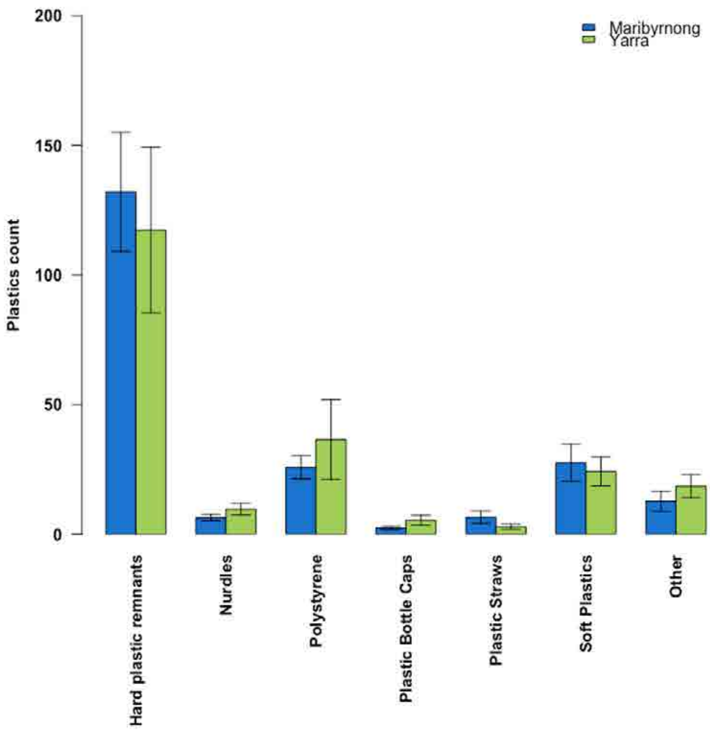


Figure 28
Comparison of mean monthly number (±SE) of litter items captured by the manta net in the Maribyrnong and Yarra Rivers between January 2015 and October 2017.

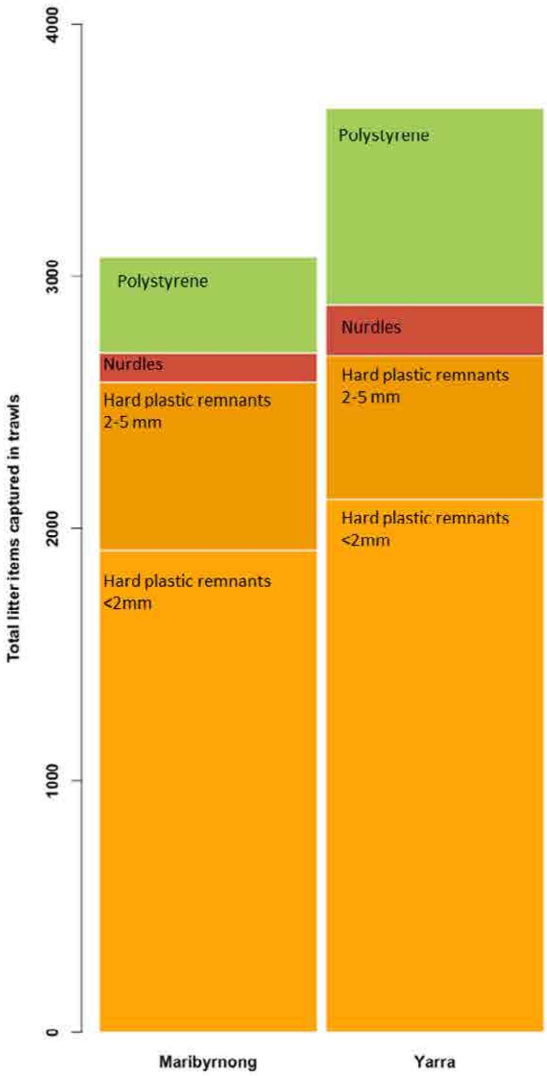


Figure 29 - Above
Total number of microplastics captured during river trawls during January 2015 and October 2017

4.0 School / Community Clean Ups

Community activation and engagement

"Over the course of the Litter and Flows project 5,051 participants were involved in the Yarra Riverkeeper litter education program"

Human behaviour is the sole source of river/marine litter, and changing perceptions and behaviour is key to tackling litter escaping into the natural environment (Pahl et al., 2017). The general public plays an important role in addressing litter through their lifestyles and consumption patterns, waste management practices, and other engagement in the implementation of policies aiming to address the litter issue such as 'ban the bag' and container deposit initiatives.

The Yarra Riverkeeper Association is involved with community clean-ups as well as school incursion/excursions that often conclude in a clean-up of a reserve or parkland close to the Yarra River. Over the course of the Litter and Flows project 5,051 participants were involved in the Yarra Riverkeeper litter education program. Approximately 8000 kg of waste was removed from our waterways over the course of the litter and flows project with community contributing approximately $187,000 of in-kind support in clean-up efforts.

Figure 30
School clean-up around Yarra Bend Park

Clean Up/Presentation Data	Yr 1	Yr 2	Yr 3	Total
Number of community clean-ups	21	22	18	61
Number of participants in clean-ups	801	575	698	2074
Quantity collected waste (kg)	7200	167	487.5	7854.5
Volunteered clean-up/audit hours	2031	1638	2559	6228
In-kind volunteer contribution ($ 30/hr)	$60,930	$49,140	$76,770	$186,840
Presentation Information				
Number of community presentations	35	40	23	98
Number of participants in presentations	1514	781	682	2977
Total number of participants	2315	1356	1380	5051
Number of engaged organisations	41	29	34	104

Table 1
Annual summary statistics for participation in the Yarra Riverkeeper Association 'Litter and Flows' program

Figure 31
Burnley Harbour boat ramp
Anthony Despotellis

4.1 Case Study 1 – Yarra River Blitz

River Clean-ups

"Cleaning our environment is one of the greatest challenges of our time. an educated generation emerges and rolls up its' sleeves" - Blitz Attendee

The Yarra River is the largest contributor of litter into the Bay. Much of the litter entering the Bay is trapped in reed beds in the lower Yarra. These areas are extremely difficult to access. Furthermore, the small size of litter in these areas make litter collection time consuming and expensive. The Yarra River Blitz was designed to remove accumulated waste from reed beds in the lower Yarra and Maribyrnong Rivers using a unique approach which incorporates a boat mounted vacuum system with traditional waterway cleaning techniques. During the Blitz pilot, crew targeted litter in the lower Yarra over 5 days, culminating in a community event on the final day of the Yarra River Blitz. Yarra Riverkeeper members and the community were invited to clean the river on a kayak/canoe or on land and give back to the river.

Over the five days, the Yarra Riverkeeper Association in partnership with Cleanwater Group and Ocean Crusaders trialled the vacuum system and audited vast sums of vacuumed waste. Approximately 5 tonnes of waste were collected during the Blitz with a collection of larger items like 78 O-bikes, 5 shopping trolleys, and 9 milk crates as well as smaller items, most notably polystyrene, plastic bottles and plastic food packaging.

The community event attracted 172 participants who collected a total of 476.5 kg of waste from the reedbeds around Herring Island.

Following the success of the pilot Blitz program the Yarra Riverkeeper Association put in an application to fund 6 additional Blitzes in Round 2 of the Port Philip Bay Grant program. Quantitative data from each of the Blitzes are presented below.

Figure 32
Yarra River Blitz Logo

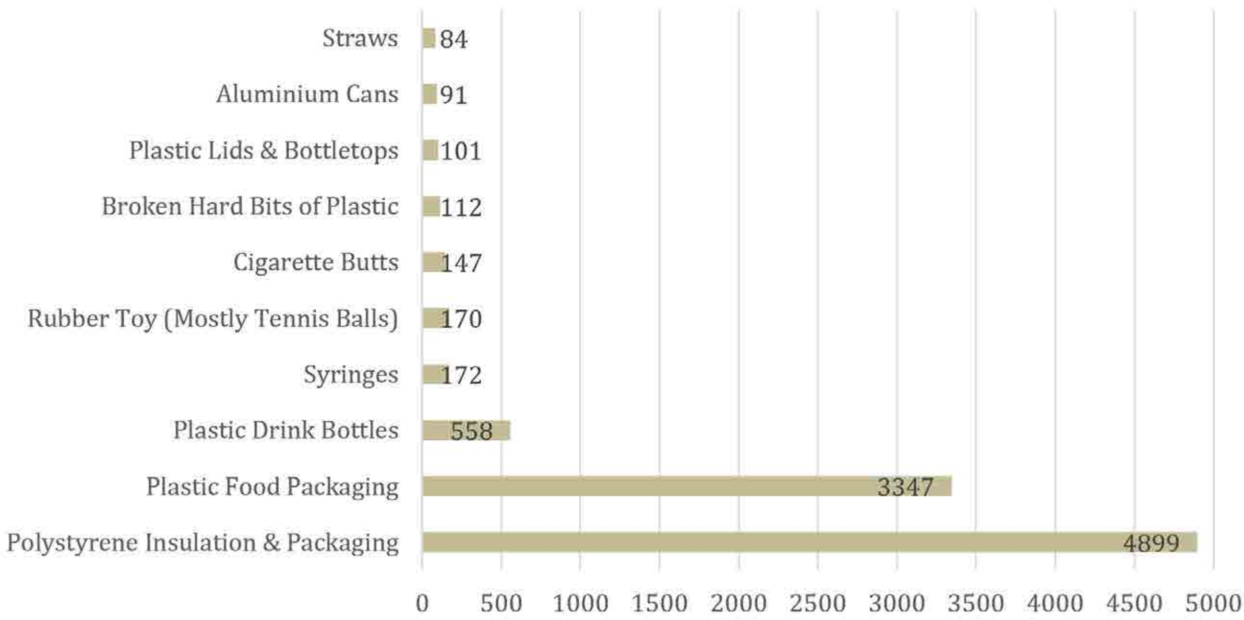


Figure 33
Most common (top 10) items collected from the banks of the lower Yarra River (between Church Street Bridge and Mac-Roberston Bridge), based on a 100kg (20 bags) sample

Blitz Date	Location	Vacuumed Waste (Kg)	Community Collected Waste (Kg)	Cumula-tive Total	Top items collected at community event
16-22 April 2018	Herring Island	5,000	476.5	5,476.5	1.Polystyrene (4899) 2.Plastic food packaging (3347) 3.Plastic drink bottles (558)
16-26 Nov 2018	Herring Island	10,000	267	10,267	1.Polystyrene (qualitative) 2.Plastic food packaging (q) 3.Plastic drink bottles (q)
1-10 March 2019	Footscray City Rowing Club	4,500	282	4,782	1.Polystyrene (222) 2.Plastic food packaging (221) 3.Plastic drink bottles (197)
21-28 May 2019	Melbourne University Boat Club	5,000	126	5,126	1.Plastic drink bottles (605) 2.Plastic food packaging (545) 3.Cigarette butts (441)
19-27 Aug 2019	Richmond Rowing Club	4,000	163	4,163	1.Cigarette butts (1400) 2.Polystyrene (1061) 3.Plastic food packaging (976)
18-25 Nov 2019	Footscray City Rowing Club	4,000	94	4,094	1.Cigarette butts (1200) 2.Plastic bags (832) 3.Polystyrene (784)
28 Jan – 4 Feb	Richmond Rowing Club	TBC	TBC	TBC	
Total		32,500	1408.5	33,908.5	1.Polystyrene (6966) 2.Plastic food packaging (5089) 3.Cigarette butts (1841) 4.Plastic drink bottles (1360)

Table 2
Annual summary statistics for participation in the Yarra Riverkeeper Association 'Litter and Flows' program

4.2 Case Study 2 – Korowa Anglican Girls School Urban Challenge Program

"Furthermore, the breadth of variety in the trash we'd found was, frankly, baffling. We'd even discovered a fully intact vacuum cleaner!"

Written by Yr 9 Urban Challenge Program Student Chyann Fann

Recently as part of our Urban Challenge program, groups of Year 9 Korowa Anglican Girls' students participated in the Yarra Riverkeeper program, where we were tasked to sort and tally the collected trash from the Yarra. The day began with a tour of the reedbeds on the banks of the Yarra. The amount of microplastics strewn across the reeds were astounding - it was almost as if it had snowed, with the lining of garish white Styrofoam beads amongst the healthy brown reeds. However, the surprises didn't end there. Our next assignment was to sort and audit the waste gathered from the Yarra. The waste had been placed in approximately 20 full industrial-sized bags; the amount accumulated was blatant proof that this problem had persisted for far too long. What struck me most was the sheer amount - because you'd never see this amount of waste floating in the Yarra. It just goes to show the immense work of others who maintain the Yarra. In the end, working hard as a group for the better part of the morning and afternoon, we managed to sort four big bags of waste. Plastics seemed to make up the bulk of waste - my friend and I counted over 1100 pieces. Furthermore, the breadth of variety in the trash we'd found was, frankly, baffling. We'd even discovered a fully intact vacuum cleaner! As I reflect on the week, giving back to the community, and to the Yarra which had sustained us for so many years was a heart-warming experience. It opened many eyes in my group to the importance of maintaining our waterways and the vital role we can continue to have as community members.

Figure 34.
Yr 9 students from Korowa Anglican Girls School participating in the Urban Challenge Program

Figure 35
Figure 36
Korowa students assisting with auditing litter collected during the Yarra River Blitz

Figure 37
a) Korowa students assisting with auditing litter collected during the Yarra River Blitz
b) Spray cans collected

4.3 Case Study 3 - Sauce Reduction Campaign

"During the Yarra River Blitz Pilot, 276 soy sauce fish were retrieved from the banks of the Yarra River over a few days"

A Source Reduction Plan (SRP) is a waste reduction effort that aims to minimise waste and prevent pollution. While other waste reduction initiatives may focus on what happens to waste after it has been used, SRPs focus their attention upstream; stopping waste before it happens by targeting the areas where waste is created. Typically, individuals and communities engage with all likely stakeholders to create a strategy that stops those common items from ever entering the environment in the first place. Popular SRPs target common litter items including plastic straws, coffee cups, plastic bags, and single use plastic bottles.

In previous clean-up operations, the Yara Riverkeeper Association identified high numbers of small plastic soy fish along the Yarra River banks. During the Yarra River Blitz Pilot, 276 soy sauce fish were retrieved from the banks of the Yarra River over a few days. In partnership with Sealife Aquarium and RMIT, the Yarra Riverkeepers developed the Soy Fish Sauce Reduction Campaign.

The Soy Fish Sauce Reduction Plan was designed to reduce soy sauce from entering the Yarra River. Yarra Riverkeeper staff and volunteers observed the behaviours of both providers and consumers to create a targeted response to deal with the litter issue. The aims of the Yarra Riverkeeper Association and RMIT students were to:

Map the locations of soy sauce dealers in the City of Melbourne

Develop an audit form and identify, record and analyse poor soy sauce disposal behaviours

Quantify soy fish litter around stores within proximity to stormwater drains that empty directly into the Yarra River

Approach store managers and work together to implement a Source Reduction Plan. SRP involved liaising with sushi vendors, seeking their commitment to providing lower waste alternatives to soy sauce fish. These alternatives included providing easily accessible soy sauce bottles and only offering soy fish upon customer request.

Monitor changes in behaviours and litter volume at selected stores following the implementation of the SRP

Figure 38
Soy fish litter collected at the Yarra River Blitz pilot event

Street audits were conducted between Elizabet and Swanston Street, Melbourne. Both streets have storm water drains that enter directly into the Yarra River. Five sushi retailers were audited. Lids and soy fish within 5-meter proximity of the retailer were counted. Lid counts significantly outweighed fish counts and were most prevalent along storm water drain grates. It is worth pointing out that street sweeper trucks operate within the city of Melbourne, twice a day, cleaning footpaths and streets. It is therefore not surprising that most soy litter was most prevalent near drains, areas typically inaccessible to cleaning trucks. Furthermore, the frequent street sweeping schedules limit our ability to monitor the volume of soy sauce litter and our survey results underestimate the extent of soy fish littering behaviour.

The soy sauce SRP has reduced plastic litter, at the source, potentially preventing thousands of soy fish from making their way into the Yarra River and Port Phillip Bay. The SRP survey activities, brochures and social media posts have raised awareness about the impact of our consumption and litter disposal behaviours on the health of our waterways.

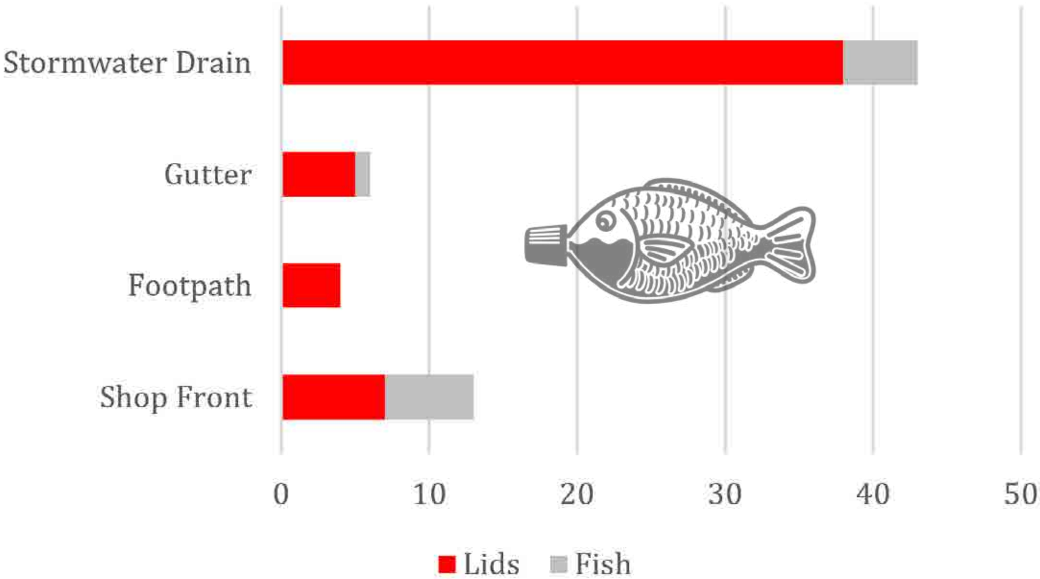


Figure 39
a). Soy sauce litter survey area
b). Sushi lids and fish counted over 1 hour in proximity to five sushi retailers in the City of Melbourne

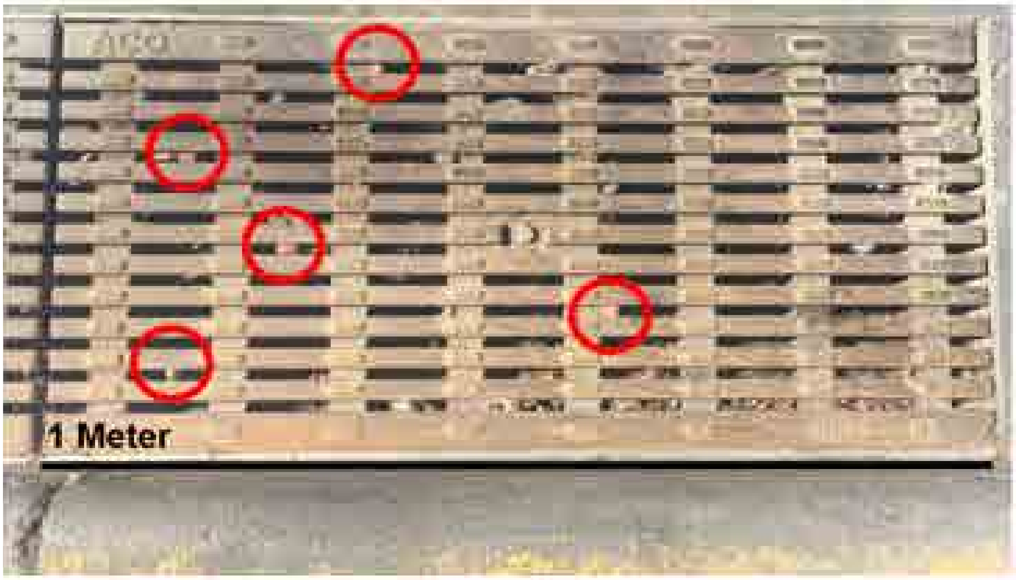


Figure 40
a). Soy fish lids stuck in storm water drain grates
b). Soy fish lids in soil

Figure 41
Infographic presented to retail managers for them to better understand the feat of soy fish

REFUSE OR RECYCLE

plastic soy fish

Thousands of plastic soy fish litter the streets of Melbourne, with many of them entering the Yarra. From there they:

Pollute other water bodies, like Port Phillip Bay

Harm marine wildlife and ecosystems

Stick around for centuries

REFUSE plastic soy fish. Use in-store bottles, or keep soy sauce at your home or workplace.

OR

RECYCLE plastic soy fish by putting them in the correct bin.

YARRA RIVERKEEPER

@YarraRiverkeeper

@yarrariverkeeper

@TheYarraRiver

Figure 42
Poster developed to raise awareness about soy fish pollution and suggested preventative behavioural shifts

5.0 Overview of Findings

One of the benefits of monitoring litter in river systems is the relatively intact structure of litter items, making them identifiable. This is in contrast with marine litter which is often degraded making it near impossible to track the sources of the litter. The litter and flows project highlighted the main litter types found along and within the Yarra River. Using three litter auditing methods we were able to determine the dominant litter types in the Yarra River. Expanded Polystyrene (EPS) was the most abundant litter item, both in terms of quantity and volume. EPS is low in cost, lightweight, moisture resistant and shock-absorbing. This makes it a great product for the packaging and construction industries. Despite its practical uses it is having an irrefutable negative impact on the riparian ecology along the Yarra River. Easily transported by wind and water and mimicking fish eggs (a food source for a range of species), it is now the highest littered item found on the Yarra River. EPS was found in greatest abundance during community clean-ups, Bandalong litter traps audits and was the dominant litter item identified during Blitz clean-ups. Interestingly, EPS microplastics did not dominante microplastic samples. The reason for this discrepancy is not entirely clear however may be related to the density of polystyrene relative to freshwater.

Movement of plastics in our rivers, both in vertical and horizontal planes, is created through the characteristics of plastic waste as well as local environmental factors (Schwarz et al, 2019). The vertical movement of plastic in water is influenced by the density, surface area of the item and the particle size (Schwarz et al, 2019). The density of a polymer, the building block of plastic, can either be higher or lower than water and will determine whether an item remains, buoyant or sinks (Schwarz et al, 2019). However, environmental factors such as current and wind strength influence the transport and fate of plastic items. Wind has a strong influence on the horizontal transport of plastics, particularly buoyant objects that are raised above the water surface like air filled bottles and containers and expanded polystyrene. Consequently, these items are more likely to be moved horizontally both faster and further and are also more likely to be deposited on riverbanks (Schwarz et al, 2019). This may explain the abundance of expanded polystyrene on riverbanks along the Yarra river.

Community clean-up and Bandalong litter trap audits found packaging, especially food wrappers (mainly polypropylene) and bottles (polyethylene terephthalate with polypropylene labels) to be the next most abundant littered items in the Yarra River. Polypropylene

	Community Clean-ups	Bandalong Traps	Microplastic Trawls
clean up area	Land and water based	water based	water based
typical size of litter items	Macroplastics (> 5 mm)	Macroplastics (> 5 mm)	Microplastics (< 5 mm)
most common litter items	1. Foam insulation and packaging 2. Plastic food packaging 3. Cigarette butts	1. Foam insulation and packaging 2. Plastic bottles 3. Balls	1. Hard plastic remnants 2. Polystyrene 3. Soft plastic remnants
source of litter items	Industrial and domestic litter	Industrial and domestic litter	Industrial and domestic litter

Table 3. Overview of litter audit results

and polyethylene are subject to degradation from exposure to heat and UV radiation from sunlight and are likely contributing to the high quantities of hard plastic fragments and soft plastic remnant microplastics found in trawl samples.

According to our results, plastic pollution in the Yarra River is associated to domestic solid wastes (e.g. food wrappers, plastic bottles, expanded polystyrene). The predominance of food wrappers/ containers is likely due to littering activities, with direct or indirect dumping into the Yarra in addition to runoff and storm water drain discharges. Our research shows that people are the greatest contributor to riverine pollution meaning that to make a real difference, people must be part of the solution. The CSIRO national study 'Understanding debris sources and transport from the coastal margin to the ocean' identified economic wealth and social disadvantage in the population near a specified site as the strongest predictors of litter at a site. Areas with a high proportion of relatively disadvantaged people, with low income and low skilled jobs (and high unemployment rates) had higher litter loads than wealthier, socially advantaged regions. Littering behaviours are especially associated with transitory activities such as parking or shopping and where the area is surrounded by a natural or semi-natural environment such as a creek or grassy area. Roads, industrial areas, retail strips, shopping centres and car parks often contain high litter loads with litter easily transported into stormwater drains via wind and water. This collective research provides opportunity for targeted education and awareness campaigns or other intervention including increased surveillance and enforcement. This research also highlights the need for improved stormwater drain infrastructure with regular storm water drain maintenance.

Although not prevalent in community clean-up and Bandalong litter trap audits, microplastic trawl samples highlighted the contribution of industrial waste, in the form of expanded polystyrene, plastic resin pellets, plastic spherules and flakes, all raw materials that serve as precursors for plastic production to the Yarra River. The prevalence of these items within and along the river are likely severely underestimated as they are difficult to identify and tedious to pick up manually. In Round 2 of the Port Phillip Bay Fund program, the Yarra Riverkeeper Association and Cleanwater Group's deployed a boat mounted vacuum system to target the enormous volume of microplastics, particularly polystyrene beads, along the Yarra's reedbeds and riverbank. Over 30, 000 kg of waste was vacuumed from the Yarra between June 2018 and Feb 2020, most of which was comprised of polystyrene contaminated soil.

Figure 43
Boat mounted vacuum system targets macro and microplastics along the Yarra River's riverbanks and reedbeds during the Yarra River Blitz

6.0 *Impacts of litter for the Yarra River*

Economic impacts of litter

Litter management and prevention is an expensive operation for the government agencies and local councils in Australia, requiring significant manpower and infrastructure investment to respond effectively. However, measuring the full social, health and economic costs of riverine and marine litter is complex due to the wide range of economic, social and environmental impacts, the range of sectors impacted by marine litter and the geographic spread of those affected. Some of the impacts are easier to evaluate in economic terms because they are more direct, such as increased litter cleaning costs. Others are more complex, for example, the less direct and/or more intangible values such as the impacts of ecosystem deterioration or reductions in quality of life (Newman et al, 2017). Even though litter has become an increasingly important issue in policy discussions, there is only a very vague body of knowledge on the costs of the impacts. In an inquiry into the threat of marine plastic pollution in Australia and Australian waters (2016), the Department of Environment stated it was unable to estimate the economic cost of the damage from marine debris on Australia's tourism, fishing and shipping industries. Other Commonwealth agencies including the Great Barrier Reef Marine Park Authority, the Australian Maritime Safety Authority and the Australian Fisheries Management Authority were also unable to provide such estimates. Elsewhere, the World Economic Forum cited a 2014 study by the UNEP which estimated the total natural capital cost of plastics in the consumer goods industry at $75 billion, of which $40 billion was related to plastic packaging. The UNEP study pointed to the significant impact of ocean plastic on maritime natural capital. It was estimated that the annual damage of plastics to marine ecosystems is at least US$13 billion per year. The Asia-Pacific Economic Cooperation (APEC) also estimated that the cost of marine plastic pollution to the tourism, fishing and shipping industries was US$1.3 billion in that region. Despite the lack of economic coverage it is clear that litter management is expensive with many sectors impacted by waste mismanagement including aquaculture, recreational fishing and boating, tourism and emergency rescue services to name a few.

Litter as an environmental hazard

Organism injury and plastic ingestion

Based on the evidence of widespread presence of plastics, it is highly likely that organisms in freshwater ecosystems will encounter macro and microplastic particles. Depending on the particle size and the physiological and behavioural traits of the organism, there is an opportunity for injury and/or ingestion of these items by invertebrates and vertebrates.

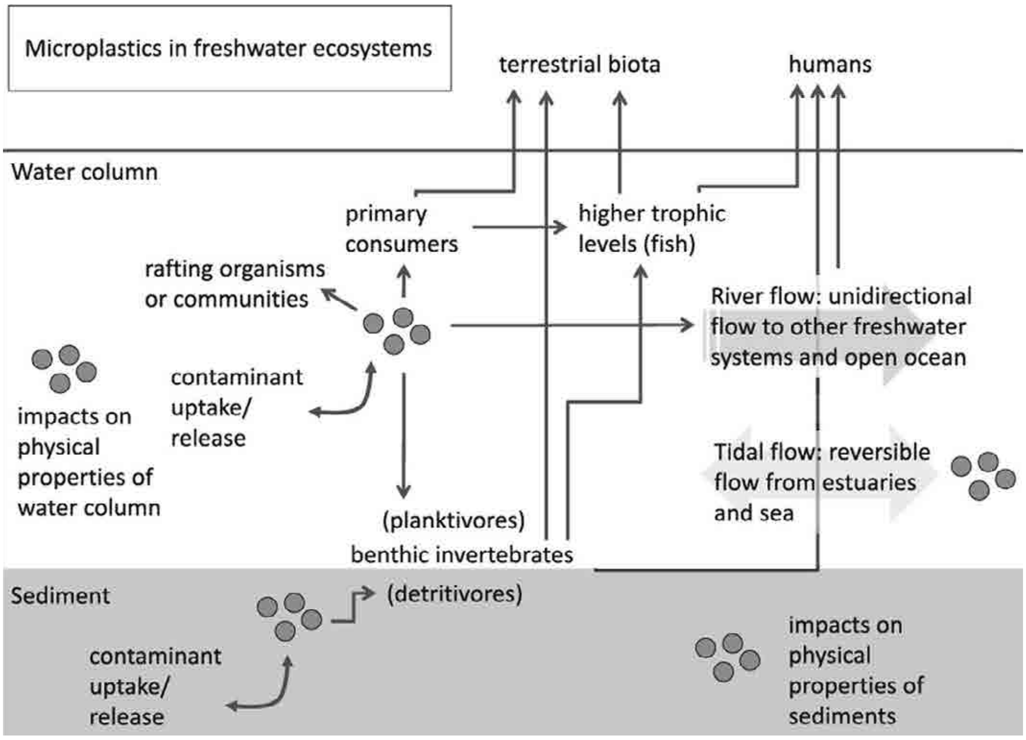
Plastic related injuries are widely documented with fish net entanglement the most common form of injury in marine wildlife. In freshwater systems, wildlife entanglement has been observed in abandoned fishing gear such as nets and lines, plastic bags, packing straps, ropes, clothing gear, and six-pack rings. During surveys on the Yarra River over the course of the Litter and Flows project, staff came across a number of plastic related injuries including a flying fox trapped entangled in fishing line adjacent to the river, a pacific black duck with a hair tie wrapped around it's beak and a seagull chick trapped in the a bandalong litter trap. Entanglement can cause restricted mobility, scoliosis, starvation, smothering and wounding, which in turns leads to infections, amputation of limbs, and death. Entanglement can also reduce the ability to avoid predators.

Plastic ingestion has been widely documented in many marine species. Worldwide, at least 690 marine species have encountered plastic pollution, many of which are listed as threatened species (Gall and Thompson, 2015). Although plastic is largely excreted following ingestion, there is evidence to suggest that microplastics can be retained in the gut over timescales beyond those expected for other ingested matter (Browne et al., 2008). Further, there is evidence that particles can even cross the gut wall and be translocated to other body tissues, with unknown consequences (Browne et al., 2008; Horton et al., 2017). Given the similarity of some phyla that are commonly found in freshwater and marine ecosystems (e.g. nematodes, annelids, molluscs, arthropods), similar findings of ingestion in species in riverine ecosystems are almost inevitable. Since many of these species, likely to take up microplastics, are important to ecosystems, ecosystem processes such as decomposition and nutrient cycling may be affected by microplastic exposure (Horton et al., 2017). Further, there is the potential for food web effects either through effects on keystone species or possibly through the trophic transfer of microplastics themselves (Horton et al., 2017).

Observed toxicological effects of microplastics

Ingestion of microplastic particles by marine invertebrates has been linked with a wide range of sub-lethal effects including reduced reproduction, reduced growth of individuals and reduced fitness. These are generally the result of the physical effects of ingested microplastics including internal damage such as lacerations, inflammatory responses and plastic particles replacing digestible food, causing individuals to reduce feeding hence resulting in lower energy intake, although effects vary between species and plastic

Figure 44
Impact of microplastics in a freshwater system. Source: Eerkes-Medrano et al., 2015.



types (Moore, 2008; Wright et al., 2013). While there are fewer studies conducted to date with freshwater species, the studies that have been conducted generally confirm the potential for microplastics to have detrimental effects on the physiology of species across many ecological niches (Eerkes- Medrano et al., 2015, Horton et al., 2017).

Furthermore, plastics 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). This may be especially significant in freshwater environments, where concentrations of these chemicals are expected to be higher than in marine systems, due to proximity to the use of these chemicals (Dris et al., 2015). Little is known about the effects of these plastic chemicals in freshwater systems. However, Mato et al. (2001) documented 100,000 to1 million times higher concentrations of polychlorinated biphenyls (PCBs) and dichlorodiphenyldichloroethylene (DDE), both classified as toxic chemicals, in polypropylene pieces from the sea than in the surrounding water. The ingestion of these toxic chemicals is known to affect the physiology and behaviour of organisms, which ultimately affects population stability, as shown by reproductive dysfunctions caused by PCBs in orca and dolphin populations in Europe (Jepson, 2016). 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).

Microplastics as a chemical hazard

Plastic materials often contain a wide range of plasticiser chemicals to give them specific physical properties such as elasticity, rigidity, UV stability, flame retardants and colourings. Many of the chemicals associated with plastics have been identified as either toxic or endocrine disruptors including bisphenol-A, phthalates such as di-n-butyl phthalate and di-(2-ethylhexyl) phthalate, polybrominated diphenyl ethers (PBDEs) and metals used as colourings (Lithner et al., 2009; Teuten et al., 2009). Additive chemicals like these are weakly bound, or not bound at all to the polymer molecule and as such these chemicals will leach out of the plastic over time. Such releases can be facilitated in environments where particle dispersal is limited and where plastics will experience UV degradation and high temperatures (Horton et al 2017). The locations where microplastics may accumulate in soil and surface waters are therefore likely to be subject to the possible release of these chemicals from plastics and their subsequent transfer to water, sediment and organisms. Lithner et al. (2009) showed that different plastic items can leach toxic chemicals into water that can cause varying effects on Daphnia magna. Different items made of the same polymer may have varying toxicity effects following leaching, based on the type and quantity of plasticisers added during the manufacture process. This demonstrates that plastic materials can act as a source of complex leachate mixtures to the environment.

It is worth noting the relationship between environmental concentrations and those used in toxicity studies is not fully established. Hence, it is possible that the concentrations used in laboratory tests either over or underrepresent levels of environmental contamination. However, it is still valuable to understand the potential ecological implications of microplastic pollution at these low/high concentrations as a means to understand potential hazards and to assist in developing risk assessments. Further, given that environmental concentrations of microplastics are likely to increase with input and fragmentation of plastics already present in the environment, the future presence of higher concentrations can be expected.

7.0 *Keeping the Yarra Healthy, Protected and Loved: Recommendations*

There is now irrefutable evidence that litter particularly plastics and microplastics have severe negative impacts on the environment. Many governments have now accepted the recommendation from the science community that society should not wait until there is more quantified evidence of the degree of damage before acting to reduce marine plastic pollution impacts (Lavers and Bond, 2017, Gall and Thompson, 2015). In their report 'Marine Plastic Debris and Microplastics' the United Nations stated that there is a moral argument that we should not allow the ocean to become further polluted with plastic waste, and that marine littering should be considered a 'common concern of humankind' (UNEP, 2016).

The large volumes of litter in the Yarra and Maribyrnong Rivers highlight the large contribution of these rivers to plastic pollution in Port Phillip Bay. Hence, immediate measures to manage plastic pollution at all stages of its 'life-cycle' (see figure 2), particularly at the early stages where plastic sources are known and can be more easily contained, need to be addressed.

In consultation with the Port Phillip EcoCentre and drawing on recommendations listed in Charko et al 2018, the Yarra Riverkeeper Association recommend the following:

1 Improve the life-cycle stewardship of plastic

As the bulk of the litter audits and litter samples in this study contained mostly polystyrene and hard plastic remnants, broken up from larger plastic items, it is essential to improve waste management practices of the items that result in these meso and microplastics. This includes the introduction of large-scale infrastructure changes like a container deposit scheme, tackling items such as bottle caps and plastic bottles, before they make their way into the rivers and break up into microplastics. Similarly, while expanded polystyrene is technically "recyclable" there is, to date, no meaningful recycling of Expanded Polystyrene (EPS) or Styrofoam due to high food contamination rates and a very weak market to clean, handle and process the material, despite it being the number one pollutant in our waterways.

Recently, China announced it will not be importing any more recycling from Australia. This has presented the government with a rare opportunity to redesign new waste management and recycling systems with a circular economy structure. Necessity is a great driver of innovation and as such some Victorian plastics manufacturers have already invested in machinery that can process used recyclables (including moderately contaminated plastics) back into nurdles and then into the next life stage of plastic products for sale to the public; all within their own, local manufacturing business. Reshaping the lifecycle of plastic and keeping the processes in-house and local could change the way we value plastic as a resource and reduce the use of new fossil fuels for the manufacturing process.

In addition to ecological benefits, early-stage interventions would reduce the opportunity cost of volunteers spending time manually removing litter from the environment, which is costly (Australian Conservation Foundation, 2011) and relatively ineffective, as it is treating the symptom rather than addressing the cause. One example of a low-cost early intervention is the placement and management of storm water drain pollutant pit traps in key places draining into the river systems.

On an industry level, nurdles can be vastly reduced in the environment by implementing a stewardship best practice product handling manual such as Operation Clean Sweep (opcleansweep.org.au) and making this mandatory for all users and manufacturers of nurdles in Victoria.

2 Implement bans on the use of unnecessary plastic from a higher-level perspective

Internationally, countries like New Zealand and Britain are implementing an increasing number of bans on problematic litter items such as straws and plastic bags. On 1 November 2019, the Victorian State Government joined most other Australian States by announcing the implementation of a ban on plastic bags. The ban applies to ALL retailers – including supermarkets, greengrocers, bakeries, pharmacies, clothes stores, restaurants, cafes, markets, food outlets, and many more. The ban applies to all lightweight plastic shopping bags which have a thickness of 35 microns or less at any part of the bag, including degradable, biodegradable and compostable bags.

Although banning items such as straws and ubiquitous packaging of fruit and vegetables in supermarkets is a start towards preventing these items from getting into the environment, we recommend future bans are implemented on a higher level materials-based approach, rather than by individual end product, to avoid perverse incentives (such as offering thicker plastic bags for a price). This means that rather than product-by-product bans, the government needs to implement higher level regulations that require materials and designs to fulfill a set of sustainability criteria at all stages of their life cycle. Products that do not fulfill these criteria could then be amended or phased out by an agreed date.

Stimulate innovation and alternatives to plastic products 3

Reducing the amount of plastic used by the growing Victorian population is most likely the key to reducing the trend of increasing plastic pollution in the Yarra. The government can play an important role in the transition away from plastic, seeking opportunities to work closely with industry, and stimulate new products designed to replace plastics by investing in innovative ideas and promising start-ups. Similarly, existing plastic manufacturers should be stimulated and supported (e.g. with subsidies or tax breaks) to make the change to alternative forms of packaging and move away from producing plastics. Packaging products like polystyrene, which were particularly problematic in the Yarra and on the increase, need to be replaced by truly environmentally friendly alternatives.

4 Cultivate effective partnerships and take shared responsibility

The problem of plastic pollution is everybody's. It is as much the responsibility of the community and government, as it is the industries. To reduce plastic pollution in the environment, it is critical that conversations and true working partnerships are forged and maintained with a long-term vision of collaboration and tangible outcomes. An example of what this could look like is the Californian Blue Business Council, run by a community organisation and consisting of businesses that recognise their ecological and economic dependence on clean water and work as a network to implement business models that prioritise healthy waterways (bluebizcouncil.org).

5 Increase education and 'plastic literacy' of all plastic users

As part of cultivating shared responsibility of plastic use and disposal, education of plastic product users on responsible plastic use and disposal is essential. The State Government has rightly decided to invest in education by funding education-based projects through the Port Phillip Bay Fund, but social change requires engaging a critical mass of the entire plastic-using population, which is effectively every Victorian. We recommend a multi-pronged approach, including via formal education of all levels (including in design and engineering), mainstream media and community organisations.

Extend stormwater controls and fund gross pollutant traps 6

Pollution form stormwater is the single biggest threat to water quality in the Yarra River. Stormwater drains are the single biggest contributor of litter to the Yarra and therefore to Port Phillip Bay. Current planning controls are inadequate and need to be amended to incorporate appropriate stormwater management measures.

Improve our understanding of the environmental impacts of plastic pollution 7

Both primary and secondary microplastics entering the environment will persist and continue to fragment to smaller particles. These smaller fragments are likely to pose a greater risk to organism health due to their increased likelihood of uptake, increased surface area for interactions with chemicals and greater number of particles per unit of bulk mass. It is important to better understand the likely ecological implications of plastics under realistic exposure conditions (i.e. microplastics of the type and concentrations likely to be encountered by organisms).

Figure 45
Bird with plastic
Anthony Despotellis

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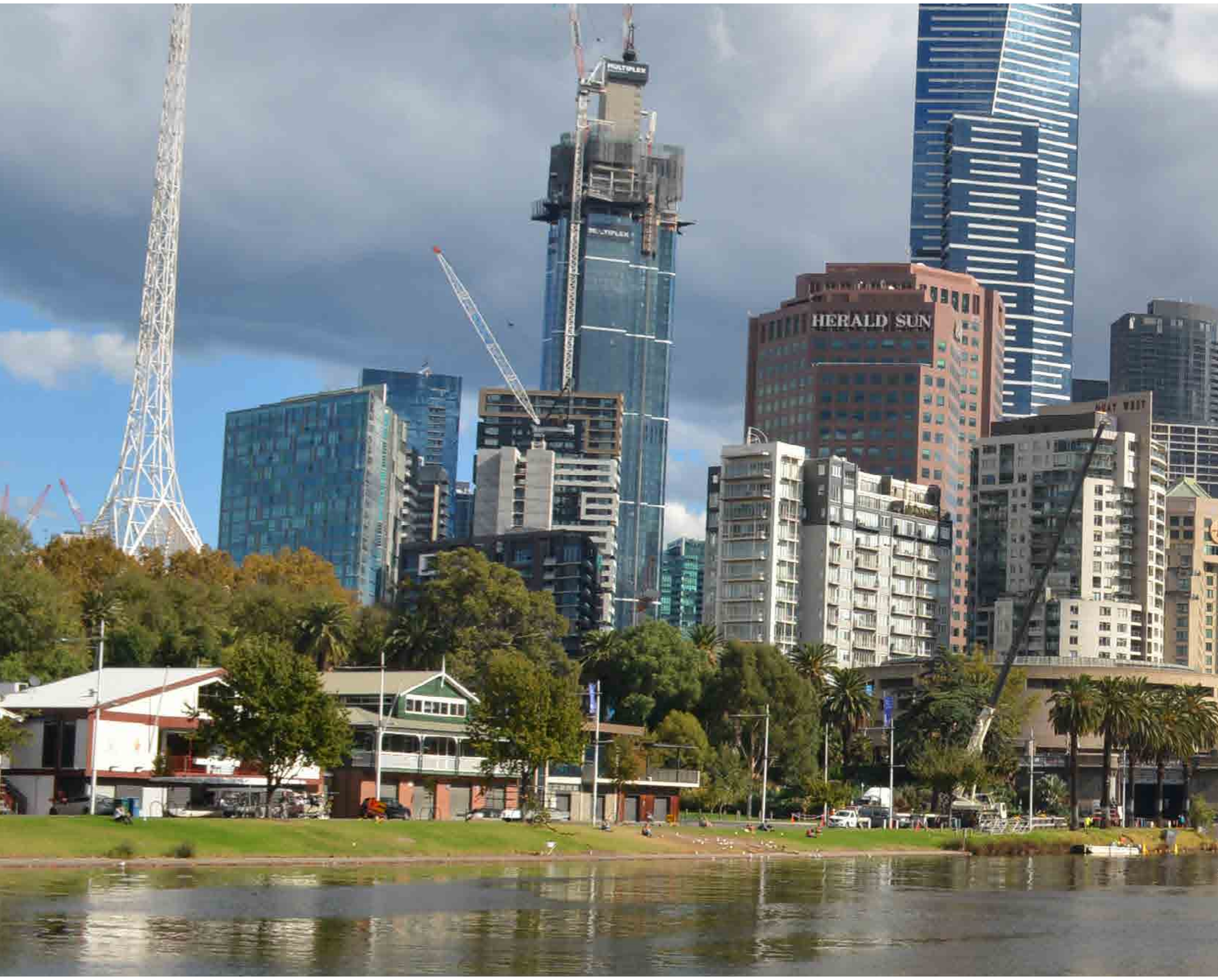

Figure 46
The Yarra River
Anthony Despotellis

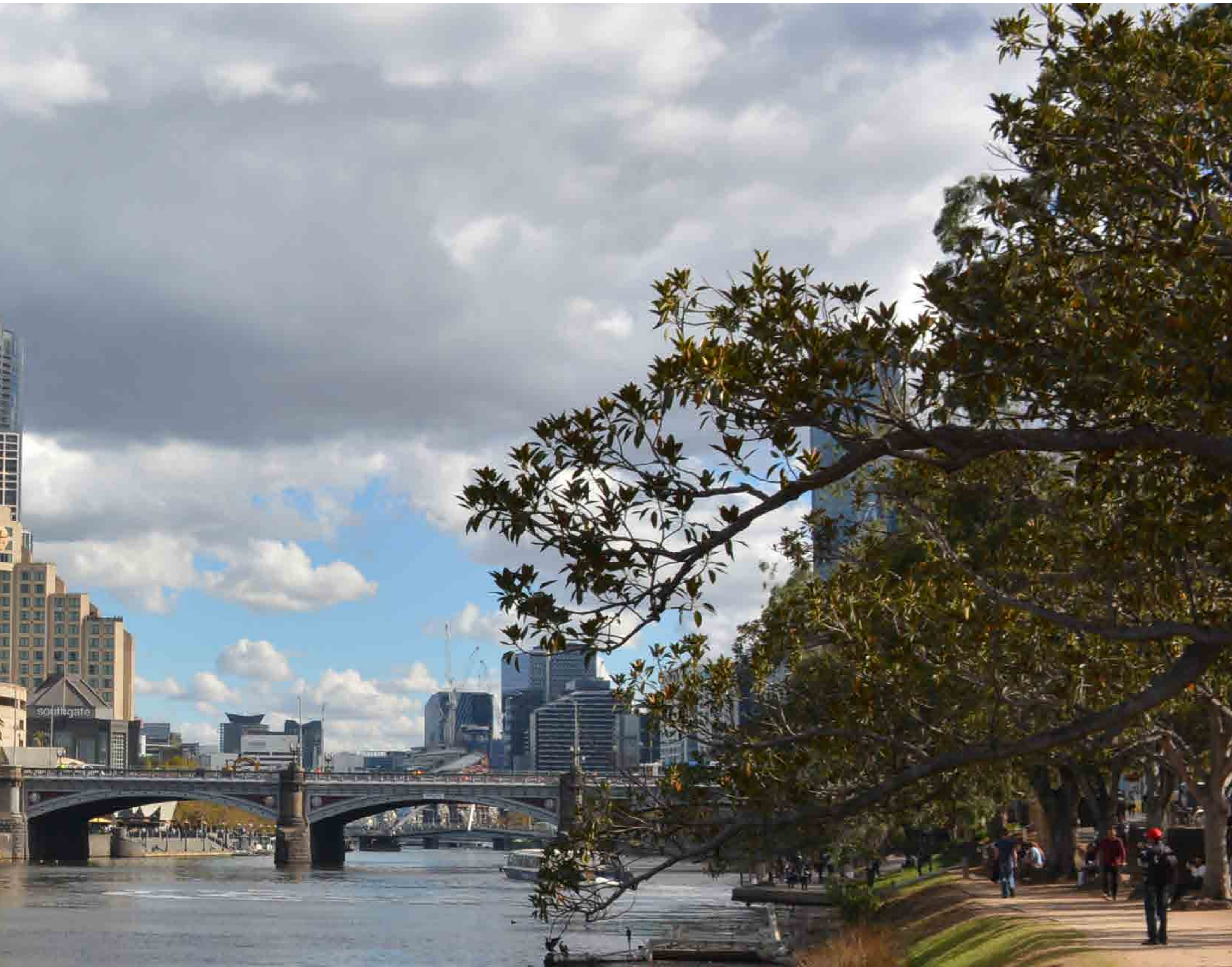

Figure 47 - Next page
The main Yarra trail
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