A New Survey Method to Determine Plastic Rubbish in Port Phillip Bay,

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Abstract

This is the preliminary report of a daily horizontal sub-tide line survey which has been conducted since the 25th March 2016 on a fixed 35 m long section of an urban beach of Port Phillip Bay, Melbourne, Australia. The purpose of this study is two-fold: (1) to quantify daily rubbish washed in from the bay, and (2) to provide a framework to determine the amount of plastic rubbish present in the bay. The first aspect is done by recording over 12 broad categories such as bottles, bags and food wrappers to identify types of litter plus 3 additional generic categories for other plastic items sorted by size: greater than 50 mm, between 5mm and 50 mm and micro as less than 5 mm. The various ratios of these can help provide insight on the breakdown rate of plastic in the water. The second aspect of this experiment is to enable estimation of the amount of plastic in Port Phillip Bay. By surveying the same 35 m section of beach every 24 hours, as well as recording the on-shore wind vector (direction and strength), the amount of plastic being divulged on this beach section per day is determined for that wind vector. This was then be extrapolated around the bay perimeter for all on-shore wind vectors to estimate how much plastic is being washed ashore every day around Port Phillip Bay. This study provides new insights into the quantity and inter-seasonal variation of plastic items within Port Phillip Bay and can be expanded on with additional sampling areas on other beaches along the bay.

Introduction

Monitoring litter on our beaches has become more necessary as our population grows and our modern “convenient” life style results in increasing usage of disposable plastic items. The potential harm of these items to wildlife is significant. The closer the plastic litter resembles naturally occurring food, the greater is the threat of harm to wildlife, particularly seabirds. It is important to find efficient ways to monitor the amount of plastic in our oceans to be able to quantify potential consequences this pollution has on the marine environment, and ultimately, us. Collecting good quality data is paramount to providing impetus for action to reduce the influx of plastic into our oceans[1].

In the large oceans, plastic litter can travel many thousands of kilometres. Identifying the origin can be difficult, due to weather and currents. Affecting legislation to stem the tide of plastic entering the oceans is hampered by complicated international relations, politics and cultures. These facets can make it very hard to bring the importance of the problem to the source.

Port Phillip Bay in Victoria is a semi-closed large bay that offers a unique opportunity to undertake such a study. It has several river inlets that carry litter into the bay, but with only a narrow outlet to the greater ocean, the majority of litter do not exit to the ocean and remain with the bay, where they often get washed up onto a beach[2].

An experiment was started in March 2016 on an urban beach of Port Phillip Bay to monitor the plastic washed ashore every 24 hours on a fixed 35 m long section of beach. The purpose of and methods used in this experiment are different to other beach litter studies. Many surveys select a fixed sized area on a beach and count litter per square meter and extrapolate that over the whole beach. Other methods use a transect in which a fixed width section of one to two meters wide is surveyed from the water's edge to the top end of the beach. This is done to cover the different zones on a beach. It reaches from the tidal zone at the water's edge, through the beach visitor zone at mid section, up to the wind catchment areas around bushes or fences at the top. These results are then extrapolated over the length of the whole beach.

Fig. 1: Map of Port Phillip Bay[3]

These methods provide information on the type of litter on a beach at any one time. However, they do not provide information on how much litter (type and quantity) is arriving on the beach.

The issue of obtaining accurate litter data is further complicated for urban beaches for two reasons: Firstly, many local councils regularly sweep beaches with cleaning machines that sift the dry sand to remove most of the non sand items. If such cleaning has occurred prior to an audit, then the audit results will underestimate the litter. These machines cannot get down to the tide line, however, as the wet sand clogs their workings. Secondly, people often walk for exercise or walking their dog in the morning and many of these people casually pick up some litter when they see it. This would then also contribute to an under-estimation of true quantitative litter data.

The experiment described in this paper is a horizontal tide line transect, which is performed along the water level up to and including the high tide line. A tide line only survey will not be affected by beach cleaning machines, as those do not clean these areas. The survey is also performed early in the morning and on a stretch of beach with low dog walking activity thereby minimising bias.

Previous studies by the Victoria EPA[3] have shown that most litter entering the bay remains in it. The extrapolations performed in this study are based on a simplified model of the bay as a closed system. Following that, we further assume that any litter that enters Port Phillip Bay from river outlets and other sources gets eventually washed up on the beaches. From surveying the same 35 m section of beach every 24 hours, as well as recording the on-shore wind vector, the amount of plastic being divulged by the bay is determined for that wind vector. These data are then extrapolated around the bay perimeter for all on-shore wind vectors to provide an estimation of total plastic litter within Port Phillip Bay.

Related Work

Melbourne Water[4] performed a litter distribution experiment in 1991. They released 1307 tagged items into the upstream waterways that drained into the bay. The items had a note for the finder so

they could call and report the ID number, as well as when and where the item was recovered. Their study estimated 4-5 million pieces of plastic entering Melbourne waterways per year. This was 23 years ago. The study reported that most of the items recovered were found on northern and bayside beaches. A few items were recovered as far south as Dromana, but none further south. They found that approximately 50% of the litter released into the bayside beach turned up within the first four months. A further 8% was retrieved over the next eight-month period. Some were still retrieved after 21 months.

Fig. 2: Location of Survey Area - North Beach

Experiment Design

The main survey was performed on a northern beach facing south.

The largest inlet to the bay is the Yarra River, which flows through the middle of the Melbourne CBD and is the main contributor of litter into the bay. The close proximity of the surveyed beach to the Yarra River inlet likely over-estimates the bay-wide extrapolation, as northern beaches are likely to receive a higher litter loading than the further away southern shores. To address this bias, a similar but shorter daily survey (carried out over four weeks) was carried out on a beach section on the southern shores. Both, northern and southern beach results were used to extrapolate total litter estimates for Port Phillip Bay. The same method of surveillance was applied at both beach sections.

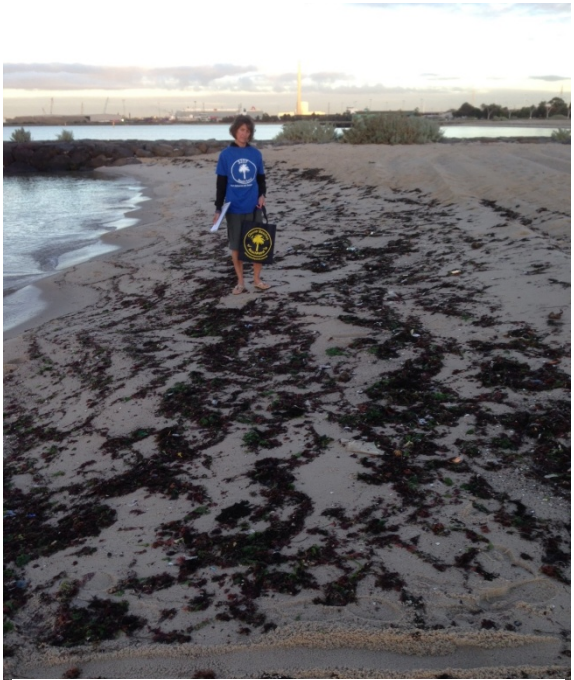

Fig. 3: Section of Northern Beach Surveyed

The north side section is shown with an X on Fig 2. The exact same section of beach with a set length of 35 m was selected for this section.

Litter data for the southern section was collected at a beach at Tootgarook, over a set 50 m section of beach.

The area from the water's edge up to the high tide line was surveyed every morning the number and type of plastic pieces washed upon it were recorded as follows:

- The items picked up were categorised into 15 types. Twelve were specific products and three were generic categories of plastic waste not identifiable to any one product type. The latter three types were listed as *greater than 50 mm, between 5 and 50 mm, or micro being less than 5 mm*. Wave action eventually causes plastic pieces to break up into

smaller and smaller pieces so the ratio of the greater than 50 mm to less than 50 mm is of interest for the bay as it may indicate how long plastic is staying in the water.

- The wind direction and strength every 10 minutes were recorded from a weather website[5] every morning. This was later separated into the on-shore and perpendicular to the shore wind vectors.

Data Calculations

Port Phillip Bay perimeter data

Port Phillip Bay is a bay with an area of 1950 km^2 and a perimeter of 264 km. Using a map of the bay, the coastline was divided into successive straight sections. In all there were 67 sections to span around the bay. For each section, the length was determined from the map scale and its orientation relative to north was tabulated. A minor linear adjustment was made to ensure the total lengths of the sectors added up to the actual coast length of the bay perimeter (264 km). From this, components were calculated for each sector to ascertain the respective North, East, South and West facing directions and the component lengths. Adding up these length components, the total distance of the bay coast facing each of the 4 compass points was determined (Table 1).

Table 1: Length of Bay Shore facing each of the four Compass directions.

South facing beach	86,091 m
North facing beach	87,827 m
East facing beach	77,731 m
West facing beach	84,882 m

Table 1 shows there are not a lot of variations between compass directions in net lengths of each of the beach facing directions.

For the duration of the experiment, the wind speed and direction were in 10 minute intervals were down loaded every morning from the weather website[5]. Seasonal variations in wind are a large factor, hence the need to conduct this experiment for a year to cover multiple month-long term variations in wind vector days.

Wind vector data

Wind vector days (wind-days) were separated into each of the compass directions (Table 2). On-shore winds were deemed the primary winds to blow litter onto a beach. Off-shore winds or parallel-to-shore winds were deemed to not blow litter onto a beach. For example, a south facing beach with a south wind of 20 kph for 24 hours, would be allocated a positive wind-day value of 20. A south facing beach with a north or east or west 20 kph wind vector was assigned a zero value. Table 2 shows wind vector values allocated for each compass direction for the 365 days.

Table 2: Wind-days for the 365 days of the experiment.

Wind-Day Direction	Value, kphDays
North wind vector day	2107
South wind vector day	1143

West wind vector day	866
East wind vector day	321

Table 2 shows that the prominent winds for the experiment are northerly winds. Northerly winds would be expected to blow litter onto the north-facing beaches, which are primarily at the south side of the bay.

Litter data extrapolation

For each beach section surveyed, north and south, the total bits of plastic were tallied over the respective survey period of 365 days for the north beach and 30 days for the south beach.

The items of plastic washed up on the 35 m section of north beach for the full duration of this study are shown in Table 4.

Table 4: Plastic litter (by number and percentage of total) washed up on a 35 m section of a south facing beach in Port Phillip Bay from March 2016 to March 2017 (365 days).

Plastic >50 mm*	Plastic 5mm<x <50 mm	Micro <5 mm	Plastic Bags	Plastic Bait Bags	Straws	Bottle Tops	Bottles /Cans	Bottle Labels	Food Wrappers	Food Containers
37342	38890	18483	1192	110	1434	1152	217	997	14404	771
29.6%	30.8%	14.6%	0.9%	0.1%	1.1%	0.9%	0.2%	0.8%	11.4%	0.6%

Balloons & strings	Butts	Polystyrene Bits	Syringes	Total Pieces
743	2234	8311	20	**126,295**
0.6%	1.8%	6.6%	0.02%	**100%**

In Table 4, the percentages of each category are shown for comparison. The categories of generic plastic >50 mm, plastic between 5 mm and 50 mm, micro plastic <5 mm and food wrappers are the four largest types and combined make up 86% of the count.

The total counts for each beach were then divided by the respective beach length surveyed and the number of on-shore wind days for that beach to arrive at a value of the pieces of plastic per meter per wind day (Table 5).

Table 5: Determining pieces of plaster per meter per wind-day on a beach

Beach Location	Total pieces counted	Beach Length surveyed	On shore wind-days	Pieces/meter/ wind-day
North,	126,295	35	1143 South wind-days	3.2
South, 30 days of data	1452	50	270 North wind-days	0.11

As can be seen in Table 5, the number of plastic items washing ashore on the southern beach is significantly less than that recorded at the northern beach.

Since we have no data from any west or east beach sections, we have assigned the mean value of pieces/meter/wind day of the north (3.2) and south beach (0.11, see Table 5) to the west and east facing beaches: 1.6 pieces of litter per meter per wind day (Table 6).

Finally, we can perform an estimation of the total number of plastic litter pieces washing onto bay shores for each of the four compass directions (Table 6).

Table 6: Estimation of the amount of plastic Items washed ashore over one year.

Beach Facing Direction	Beach Length Facing wind [m]	On shore wind-days	Pieces/meter/ wind-day	Extrapolated Plastic items washed ashore per year
North wind	87,827	2107	0.11	19,798,233
South wind	86,091	1143	3.2	232,734,178
East wind	77,731	866	1.6	90,860,313
West wind	84,882	321	1.6	30,784,939
			Total	374,177,662

Table 6 predicts an astounding 374 million items of plastic being washed up on Port Phillip Bay beaches per year. As mentioned previously this calculation is heavily influenced by the predominance of the northerly wind vector days over the experiment duration.

Broken down into the 15 categories, the model predicts the values for each category (Table 7).

Table 7: Projection of the composition of the plastic items washed ashore over one year.

Plastic>5cm*	Plastic 5mm<x<50 mm	Micro < 5 mm	Plastic Bags	Plastic Bait Bags	Straws	Bottle Tops	Bottles/ Cans
110,631,205	115,220,470	54,760,091	3,531,571	325,900	4,248,551	3,413,062	642,912

Bottle Labels	Food Wrappers	Food Containers	Balloons & strings	Butts	Polystyrene Bits	Syringes
2,953,839	42,675,126	2,284,263	2,201,306	6,618,733	24,623,228	59,255

Discussion

We present an estimation of plastic litter washed up on Port Phillip Beaches over one year, based on the mean pieces of plastic litter recorded on a north beach for 365 days and a south beach (1 month), extrapolated for the entire perimeter of the bay using a calculated value of pieces/m/wind day for each compass direction. The annual wind data from Table 3 shows there are approximately three times more westerly wind days are as easterly wind days. This would indicate more items would be expected to be washed out on the eastern beaches. Figure 4 shows modelling results from the Victoria EPA[7] of the dispersion of plastic items washed out of the Yarra River. As expected, the graphic shows a heavy bias to pieces ending up on the north and eastern shores.

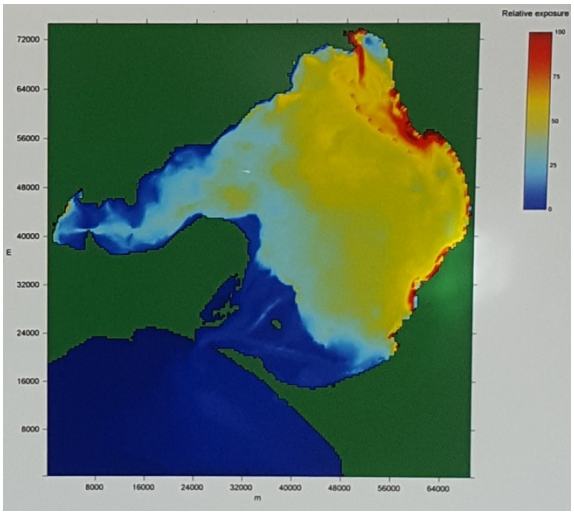

Fig. 4: Predicting Plastics Dispersed from the Yarra River (Source: Victoria EPA[7])

The tide line survey model used in this experiment is limited by the lack of data from east and west beaches, and would benefit from repeating the same full experiment at each of the compass points E, S, and W. This would involve a daily commitment for an extended period of time (> three months). The longer the sampling period, the more accurate the estimated model will become. This, however, requires many hours of work and is possibly beyond the scope of even most very dedicated volunteers. Approximately 600 volunteer hours were involved to perform the daily survey on the northern beach every day for a year.

Plastics break-down

The ratio of > 50 mm pieces over 5 mm to 50 mm pieces of plastic was almost 1:1. Plus another 14.6% of total pieces were micro in size. This would indicate that there is an appreciable amount of

plastic breaking up into smaller pieces in the Bay. The relative smallness of the Bay would imply plastic is not staying in the bay for too long and is therefore breaking up quite fast.

Daily Observations

The maximum number of plastic items picked up in one day off the 35 m north beach section was a staggering 13,908 pieces after a strong southerly wind for two days. Six of the 365 days had zero plastic washed ashore. These were during the winter months where the main winds are offshore winds.

Types of plastic litter

The breakdown of the types of plastic collected show that approx 80% of the items observed are made up of only 4 of the 15 categories. Generic pieces greater than 50 mm, those between 5 mm and 50 mm, micro – less than 5 mm and food/candy wrappers are the predominant items. Items in the greater than 50 mm and between 5mm and 50 mm are typically pieces of clear soft plastic film from food shrink wrap, stretch wrap and bag remnants. Some but not many hard pieces also wash ashore. These include nurdles (plastic resin pellets) and broken up larger fragments.

A question could be asked; why was the plastic drink bottle count so low with the high prevalence of littered drink bottles in Victoria? We suggest a number of reasons for this. Plastic bottles are made from PET, a material that sinks in water. Therefore, if the cap of the bottle is not screwed on, the bottle can fill up and sink to the bottom of the bay. Another reason is that bottles are light-weight and quite large. They catch the wind and easily roll further up the beach out of the tidal zone, an area that was not included in surveys in this study.

Conclusions

The amount of plastic litter washing onto Port Phillip Bay beaches every year is estimated to be over 370 million items annually. The items most commonly encountered were plastic film, plastic bags, plastic wrappers and smaller broken pieces of hard plastic.

The accuracy of the model presented in this study will be further enhanced with sampling points on west and east beaches.

Despite the restrictions of the study, this experiment presents a rough estimation of plastic litter washing out Port Phillip Bay. How much is washing in depends on the break up rate of the plastic once in the Bay. The number reported here is contrary to Australians' general claim of a 'clean country'. However, it reinforces the conclusion of the 2016 Federal Senate inquiry that URGENT action needs to be taken to protect Australian waters from marine plastic pollution. Clearly, more of the same initiatives, such as providing more waste bins, more frequent bin emptying and extra clean-ups are not enough. We advocate stopping the plastic from getting into our waterways in the first place. This requires government intervention with more anti-littering programs to educate the public, financial incentives to reduce littering such as a container deposit scheme, and encourage recycling. It will be necessary to also work with industry to incentivise their reduction of plastic waste and to reduce disposable plastic packaging and the use of disposable plastic items.

About BeachPatrol Australia[8].

BeachPatrol Australia is a volunteer group based in Melbourne Australia. It is made up of over 2000 volunteers concerned about litter on the beaches. Currently the organisation is divided into 21 groups. Each group is responsible for one post code along the bay shores. The groups pick up litter from the beaches in their post code once a month and record basic collection data on the website. Each group's data is recorded as well as a running summation for the groups as a whole.

References

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