Global Plastic Leakage Baseline Data Summary Report, Mombasa, Kenya

Report for fieldwork conducted April 2019

CSIRO Marine Debris Team* in collaboration from the Kenya Marine and Fisheries Research Institute (KMFRI) and associated participants, with support from United Nations Environment (UNE).

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Foreword

Plastic volume in the ocean is increasing rapidly, affecting wildlife, economies and potentially human health. Recent model projections suggest that somewhere between four and twelve million tons of plastic flow into the world's oceans each year, with much of this waste coming from urban centres (Jambeck et al. 2015). However, to date there has been very little data collected to empirically document the existence and extent of these plumes and to validate the model estimates.

Through this collaborative field-based project, CSIRO is developing the first global, empirical baseline estimate of mismanaged waste entering the coastal and marine environments near major urban centres in countries around the world. The project aims to identify links between land-based waste management and pollution entering the marine environment. The data collected is helping to clarify the magnitude of this pollution to the public, to industry and to policy makers. Learnings from the project can serve as a basis for decision making, and to support social pressure for investment in infrastructure and regulation for improved waste management. We hope the results can also be applied to engage with industry, the retail sector, government and consumers alike regarding best-practices. We also aim to improve waste management and increase the value of plastic to reduce poverty and create alternative livelihoods that are socially, culturally, economically, and environmentally appropriate and sustainable.

We are carrying out this research in countries all over the world, and thus far have surveyed major metropolitan centres in numerous countries in the Asia Pacific region, as well as South America and Africa. In Mombasa, Kenya, CSIRO, United Nations Environment, Kenya Marine and Fisheries Research Institute staff and numerous participants joined together to help achieve this goal.

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1   Introduction

Increasingly considered a tragedy of the commons of the 21st century (Vince and Hardesty 2016), plastic pollution is a wicked problem (Landon-Lane 2018; McIntyre 2020). Trash knows no geopolitical borders, moving with people, rivers, through the landscape and ultimately, if not managed properly, it can be lost into the global ocean. We know that mismanaged waste results in negative social, economic and ecological outcomes. There is substantial value in collecting data to help improve our understanding of the sources and drivers of why, when, where, and how waste is lost to the environment. Furthermore, knowing how waste moves through the environment, the impact our waste has on people, communities, wildlife and economies, and how we can implement policies to result in better outcomes can arm us with the knowledge to make better decisions. Data collected properly and consistently affords us a metric, a tangible means of measuring change through time and space. This is fundamentally important to understand how effective new actions, activities and legislative measures are in terms of reducing waste entering the environment.

In late 2016, CSIRO was successful in securing funds to embark on a world first project which aims to quantify how much waste is leaking to the environment, where it is entering the environment, and to identify interventions that may be successful in stemming the flow of plastic pollution from land to the sea. The primary objective of the project is to use field sampling and mathematical modelling to document the distribution of plastic in the ocean, on the coast and in the nearshore environment generated by major urban centres and surrounding areas that have been identified as having significant waste mis-management losses into the coastal/marine environment. We initially targeted 6-8 major metropolitan areas in different countries around the world, with a focus in South East Asia. We are focusing on this part of the world because it has been identified as a region of high waste losses to the environment (Jambeck et al. 2015). Furthermore, recent work has suggested that many of the world's major polluting rivers are located in Asia (Lebreton et al. 2017). Rivers are increasingly recognized as critical conduits to plastic waste entering the oceans (Wagner et al. 2019), further highlighting the need for research such as this where empirical data is used to ground-truth predictions and inform model-based estimates of waste in the environment. However, this does not mean that we want to overlook other critical countries and regions of the world where mismanaged waste is also a significant issue. In fact, with the growing population numbers and change in accepting waste from overseas across countries in Asia, ensuring representation from countries across Africa and the Americas is critical.

Understanding the transport of plastics from land into coastal and marine systems is critical for modelling the distribution and trends of plastic in the ocean, estimating its impact on regional economies near sources, and clarifying the magnitude of this pollution to the public, to industry, and to policy-makers. With a robust, comparable baseline of information, we not only are poised to evaluate policy effectiveness and change through on-ground activities at local, national and international scales, but we are starting to see these changes happen. However, this does not mean that we want to overlook other critical countries and regions of the world where mismanaged waste is also a significant issue. In fact, with the growing population numbers and

change in accepting waste from overseas across countries in Asia, ensuring representation from countries across Africa and the Americas is critical.

A further objective of the global plastics leakage project is to increase the capacity and skillset for on-ground partners in multiple countries, helping to build the breadth and depth of skills to monitor coastal and ocean health beyond the life of this project. The more people are armed with knowledge and skills across jurisdictions, the better equipped individuals, communities and governments will be to make the decisions needed to ensure the best outcomes possible to ensure growth, health, wealth and well-being and ensure sustainability and a reduction in waste leaking to the environment.

We hope that the results from this work will serve as an international baseline against which progress can be gauged through time and space. Ideally, governments from all levels, from local or municipal to state and national will be able to use the information from this work to inform or underpin policies and decisions that will ultimately lead to a reduction in waste entering the environment. We also hope that the results can provide opportunities to engage with industry regarding best-practices and product identification for major brands which are frequently lost into the environment.

1.1   A Partnership in Action

In April 2019, CSIRO staff with support from United Nations Environment (UNE), the West Indian Ocean Marine Science Association (WIOMSA), and the Kenya Marine and Fisheries Research Institute, worked with Kenyans from seven counties, and a participant each from Ghana, Nigeria and South Africa to quantify the amount of debris coming from land in the metropolitan and surrounding regional areas of Mombasa, Kenya, and arriving at the coast. The Mombasa region was selected in collaboration with our partners because it represented an urban region of significance within the country and encompassed one of the largest cities in the country. Furthermore, the region was identified as an area that could be sampled within a reasonable time frame (~ 2 weeks). Furthermore, the region or watershed also has a river system which could transport debris to the sea, and hence was deemed appropriate in the context of the overall global project. Our ultimate goal was to develop a baseline measurement of debris along an approximately 200 km stretch of coastline and the surrounding riverine and inland areas of Mombasa. To this aim, we conducted field surveys that included coastal, inland, river-side, and trawl debris surveys following a statistically robust and user-friendly sampling methodology. With a few days of training, the crew was ready to tackle the challenge.
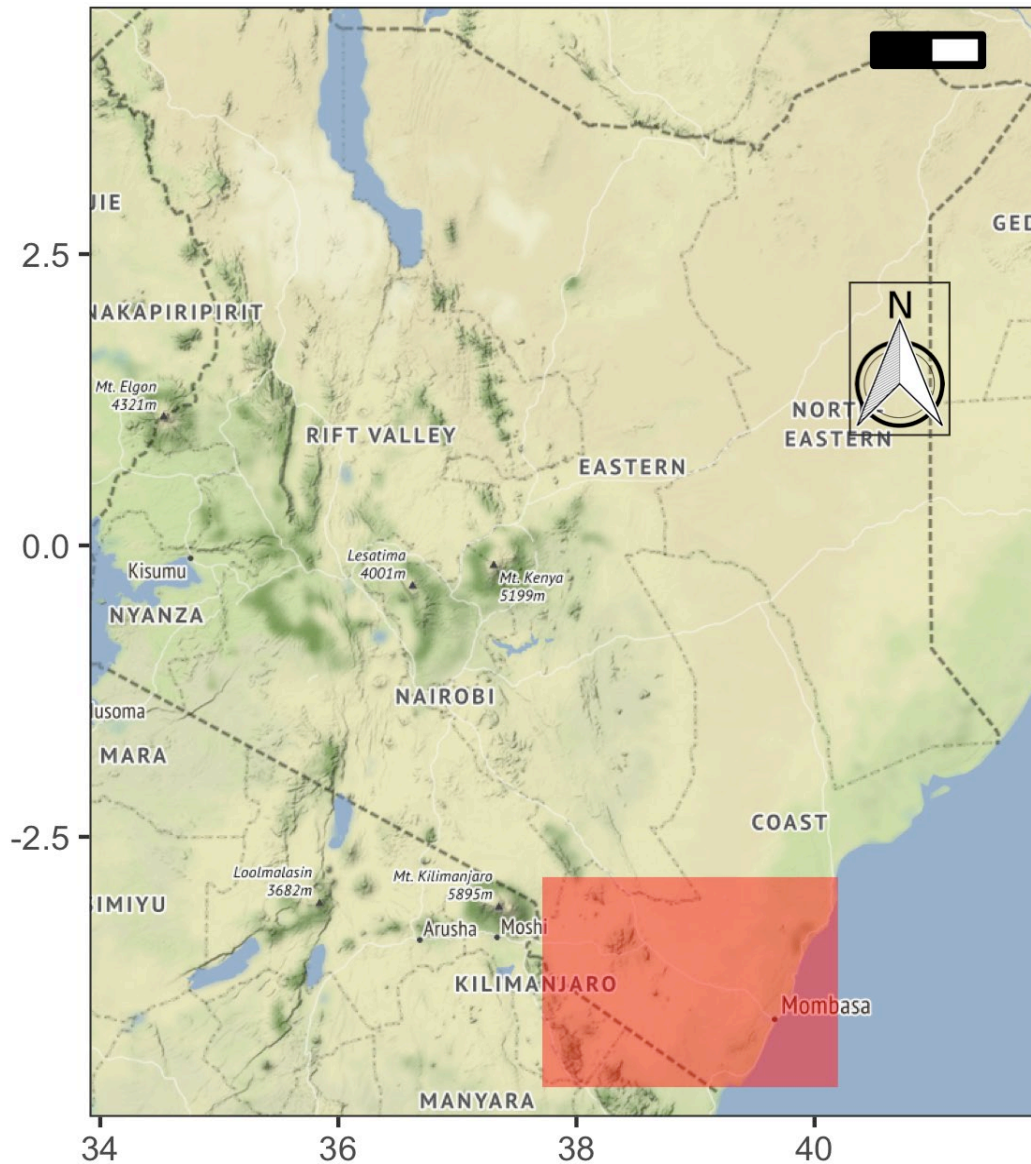
Figure 1. Location of study area.

1.2   Site Selection and Study Area

Our target area included the metropolitan and regional areas surrounding Mombasa. We selected a region roughly 250 km long from the Tanzanian boarder to the town of Marereni north of Malindi. The inland and river sites surveyed extended inland past Voi in the west. The study area was constricted by the Tsavo National Park in the west and included Kwale, Mombasa, Taita Taveta and Kilifi counties.

Survey locations were provided by CSIRO to partners in Kenya, so they could be assessed for suitability and any alterations needed could be made prior to arrival to conduct fieldwork. Sites were selected based on a suite of criteria and were intended to sample across the range of a variety of covariates, including population density, land use type, road and transportation networks. We aimed to strike a balance between sites that were representative across the watershed region we were surveying and ensuring travel times between sites were not so long as to make field work impractical. While all the sites were selected in advance, occasionally chosen

site locations could not be accessed in the field. This could be due to a range of reasons, including that the points fell on private land or were unsafe to access. In these instances, surveyors chose the nearest location that was accessible to and in a similar environment as the originally designated site.

During the first four days, participants and trainers worked together to ensure all participants received consistent, intensive training on how to collect, record, report, and make decisions regarding debris items, site selection characteristics, and other key factors required for consistency in data collection for four different survey methods (coastal, inland, river, and trawl). Following the training period, we divided into a number of teams to carry out fieldwork safely and securely across the chosen study region. Over a 9-day period, the group successfully completed surveys at a total of 98 sites (Figure 2). These included 2 river sites and 2 inland sites that were surveyed as part of the training process, at sites selected haphazardly near the training centre.
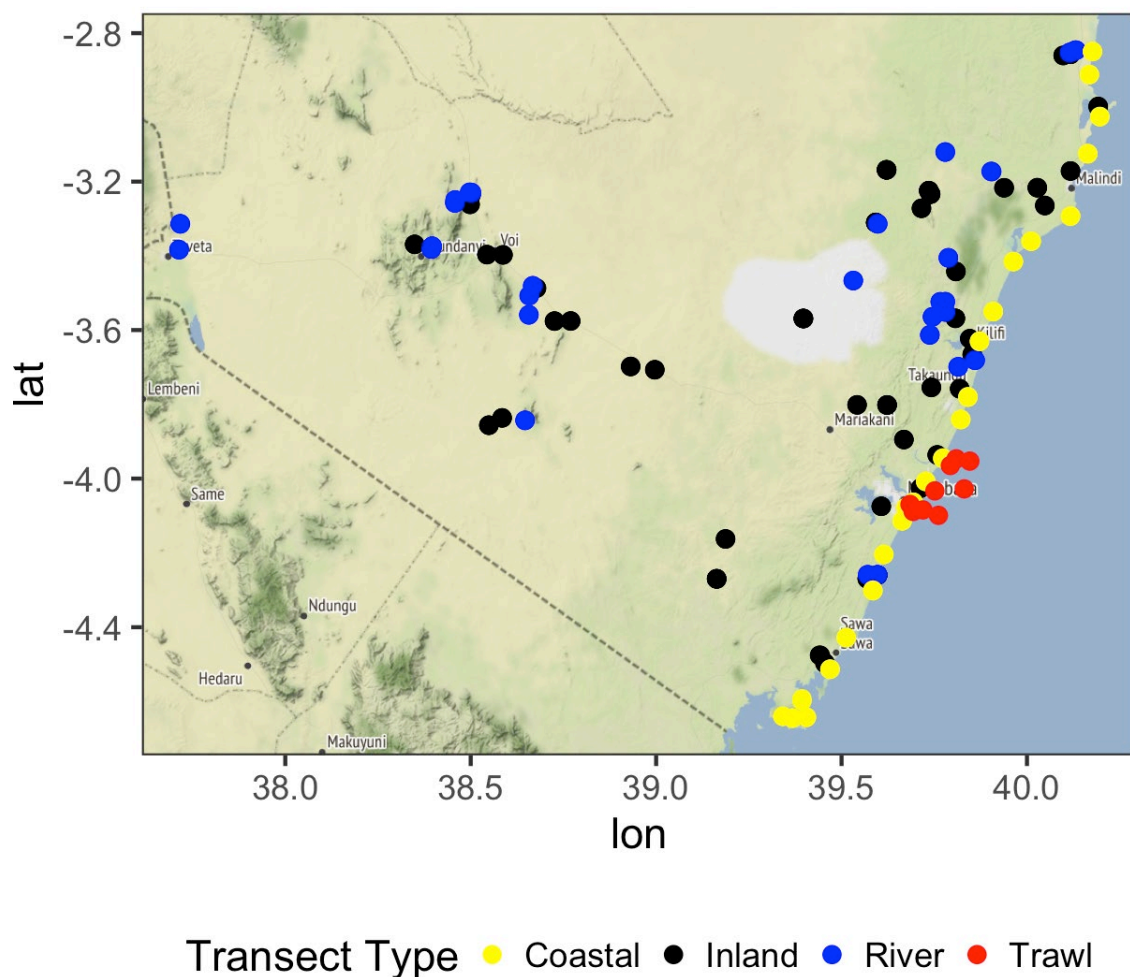

Figure 2. Location of completed surveys along the selected region of coastal Kenya. The yellow points are coastal sites, the black points are inland sites, the blue points are river sites, and the red points are where trawl sampling occurred.

1.2.1 Coastal sites

Coastal sites are defined as those sites that occur directly up to the ocean's edge. They could encompass any of a number of substrates and were not limited to sandy beaches. Coastal sites were selected between Marereni in the north and Venga near the Tanzanian boarder towards the south, at approximately 10 km intervals along the coastline. At one site we were unable to carry out surveys due to restricted access, and slight adjustments had to be made at a couple of other coastal sites due to accessibility.

1.2.2 Inland sites

To select inland survey sites, we placed a 5 km grid over the study region and selected the centre of each 5 km x 5 km cell. We then used globally available Geographic Information System (GIS) spatial layers to quantify several factors that have been shown in our previous work to be associated with the amount of debris or litter observed (covariates). Covariates included the local population density, land use type, distance to the nearest road, distance to the coast, distance to the nearest river and distance to the nearest railway station. We also used two different proxies for socio-economic status, night lights within 1 km radius of the site, and a measurement of the total monetary value of the built environment (both rural and urban), calculated by the United Nations as part of a global exposure dataset aimed at disaster risk management (UNDDR, 2015).

We carried out a stratified random sampling design to select sites that covered, as much as possible, the full spectrum of these important covariates.

1.2.3 River sites

We used a global GIS data layer of rivers (https://hydrosheds.org/), and subset the layer to select sites every 10 km along the river features, starting at the coast. From this set of points, for ease of access, we selected sites that were less than 2 km from the road and no more than 6 km from another inland site.

1.2.4 Trawl Surveys

We are also interested to understand the 'urban plume' of floating plastic around major urban centres. To measure the amount of floating or positively buoyant debris in the nearshore environment, we conducted surface trawl sampling at nine stations emanating from the mouth of the Mombasa harbour running parallel to the shore heading north to Mtwaoa Creek and circling back towards the harbour. We conducted three tows (each was ~ 10 minutes long) at each station and recorded all the anthropogenic debris collected in the net.

2 Methods

The initial few days the team was together were spent explaining the goals of the project and training participants in the survey methods. All participants learned to search, record data, and lay out transects for river, inland coastal, and trawl surveys. Furthermore, participants were provided an electronic copy of CSIRO's survey methods handbook for reference, and a hard copy of the handbook was available for each vehicle transporting participants.

Debris was measured at each land-based site type (river, coastal and inland) using a consistent survey method. Once a site was chosen, a Site Information Sheet was completed before any surveys took place (Figure 3). This information sheet collected information about the site's aspect, accessibility, apparent cleanliness, number of people present, etc as well as weather conditions, time of day, and details of the survey recorder.

At each site, a minimum of three and a maximum of six transects were carried out. For river and coastal surveys, transect lengths varied depending on site characteristics such as the width of the beach (distance from the waterline to the backshore vegetation) and riverbank height. There was no fixed length for these two survey types, the length of the transect was dependent upon the local environment, and each transect was 2 m wide. For inland surveys, survey length was fixed. Each inland transect was either 12.5 m long x 2 m wide, or 25 m x 1 m wide.

Transects were laid out with a metre tape. For coastal and river transects, the transect always began at the water's edge and ran perpendicular until reaching two metres into the backshore vegetation. For inland transects, the starting point was that which was closest to the GPS location identifying the site. The transect was also divided into ten equal distance intervals that encompassed the full length of the transect. For example, an 18 m long transect would have ten 1.8 m intervals or segments. Typically, two people walked the transect (each surveying a 1 m wide swath) while a third person recorded the debris category for every item found, and whether it was a whole item or a fragment. This information allows us to understand whether the items are likely to have been recently littered or are slightly older and more degraded. Observers were each provided with a string that was one metre wide to ensure only items within the survey width were recorded. This prevents errors that can occur if observers include items that may fall just outside the one metre wide transect zone.

Each item observed was recorded in a debris category (See Appendix A). The size class was also recorded for the first item found in each distance interval (and if no item occurs in that distance interval a 0 or dash (-) was recorded). The purpose of recording this size information is to gain an indication of the sizes of items across the each transect. We are striking the balance between time required and important information to collect. We acknowledge it would be too time consuming and labour intensive to record the size of every single item (particularly since we can sometimes report hundreds or even thousands of items on an individual transect).

Trawl surveys were conducted along two lines emanating from the mouth of the emanating from the mouth of the Mombasa harbour running parallel to the shore heading north to Mtwaoa Creek and circling back towards the harbour. Three tows were conducted at each station, using a

neuston net with mesh size of 330 µm and a mouth opening size of 0.6 m x 0.3 m. Each tow lasted approximately 15 minutes. The vessel moved at slow speed (no more than 2-3 knots) to ensure the trawl net did not skip or jump. Sea state and wind conditions must be mild for proper sampling. After returning to the lab, a visual search was conducted to count and categorise all plastics found in the sample net. For each sample, an observer removed all organic material and then searched for 15-20 minutes to locate any non-organic material. This process was repeated 3 times (with at least 2 different observers) to ensure observer fatigue does not reduce detection of small sized plastic items. The minimum size of plastic able to be caught by the net was 330 µm, and the maximum size was anything that could fit within the sixty centimetre mouth of the net.

For an in-depth description of the methodology used for each of the survey types please refer to the CSIRO handbook (Schuyler et al. 2018).

Figure 3. Site Information sheet used to collect data for every survey location.

2.1 Analysis

To design effective interventions and prevent mismanaged waste from entering the sea, it is important to understand what is driving the distribution of debris. Based on previous work, we investigated several different factors that could influence debris distribution. At each survey site, we collected information on the local conditions, including the number of visible humans, the slope of the land, the height of the vegetation, the percent of the transect that was bare ground, and the substrate colour (see Schuyler et al. 2018 for example data sheets).

We also integrated information from globally available GIS layers, including the local population density, land use type, distance to the nearest road, distance to the coast, distance to the nearest river and distance to the nearest railway station. We also used proxies for socio-economic status, including night lights within 1 km radius of the site. Additionally, we included a measurement of the total monetary value of the built environment (both rural and urban), calculated by the United Nations as part of a global exposure dataset aimed at disaster risk management (UNDDR, 2015). We put these covariates into a statistical model, designed to determine which factors are most strongly correlated with debris amounts in the survey sites. We used the R program mgcv and MuMin packages (Wood, 2011; R Core Team, 2018; Bartoń, 2018) to find the model with the lowest AIC value, which explains the most amount of the variability in the data. More than one model was within two AIC points of the best model, which means they are essentially equivalent models. In order to incorporate information from all relevant models, we used model averaging to get the best-fit model.

For coastal analyses, we used an offset of lineal metres for the model, to reflect that the measure of interest was the amount of debris along the lineal coast, while for inland analyses, we used the offset of the area of each transect. We examined residuals of the models to look for indications of non-linear patterns in explanatory variables. We ran comparative models using some variables as categorical, or continuous smoothed variables to identify better fit.

To be able to directly compare the covariates and determine which best predicts the observed debris amounts, we calculated the effect size. Terms with a positive effect size have a positive correlation with the amount of debris, while terms with a negative effect size are negatively correlated with the amount of debris. In other words, the higher the value of the covariate, the lower the amount of debris. The higher the absolute value of the effect size, whether positive or negative, the more that particular covariate explains the variability in the debris found (see Figure 10 and Figure 14).

3   Results and Discussion

A total of 14,367 debris items were detected and recorded across the 98 sites surveyed.

The ten most abundant fragment debris items included unknown hard plastic, food wrappers, soft plastic, string/ribbon, glass and bottle caps/lids (Figure 4). The most common fragment item was unknown/other hard plastic with 51.5% of all fragment items found, followed by food wrapper/label at 7.4%.

The ten most abundant whole debris items found in the surveys included bottle caps/lids, beverage bottles, earbuds, straws and food wrappers (Figure 5). The most common whole item was Bottle cap/lid, with 35.3% of all whole items found, followed by Lollipop stick/earbud at 19.5%.

In terms of debris density, coastal surveys had the highest debris density with 2.73 items found per m^2 (Figure 6). Overall, coastal debris density was 5.6 times that observed at river sites, and 4.6 times that observed at inland sites.
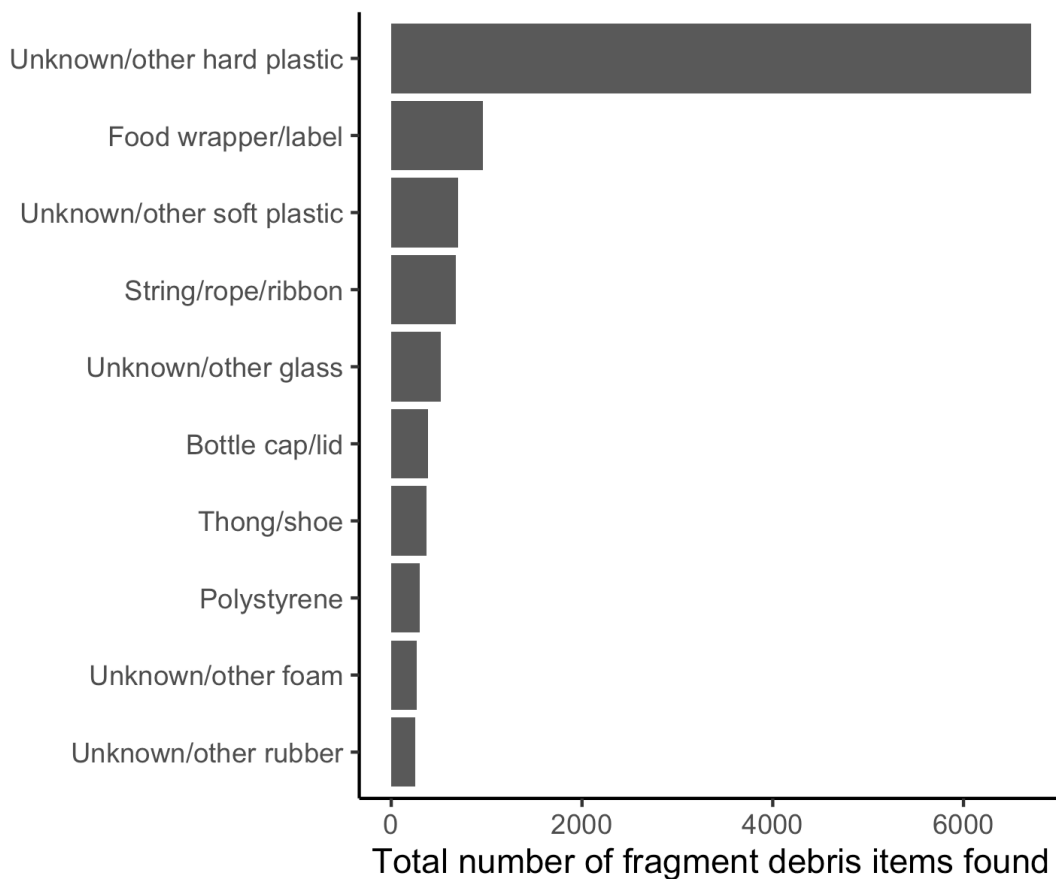
Figure 4. The ten most abundant debris items (fragments) found across the coastal, inland, and river surveys combined.
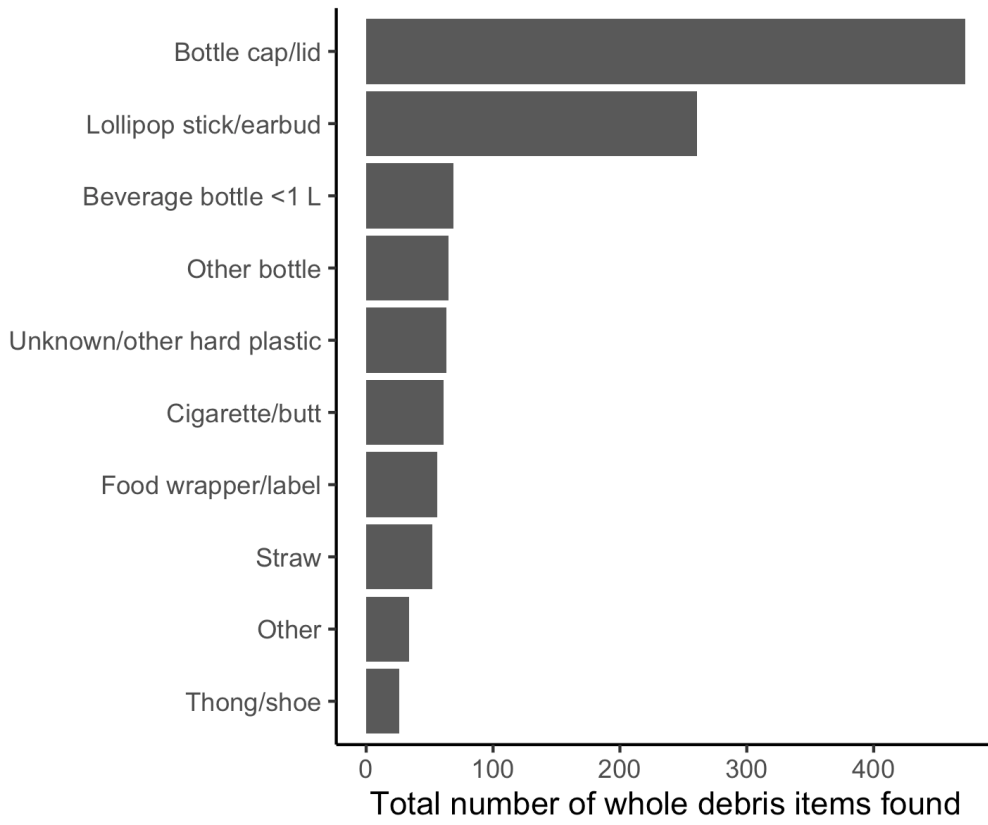
Figure 5. The ten most abundant debris items (whole) found across the coastal, inland, and river surveys combined.
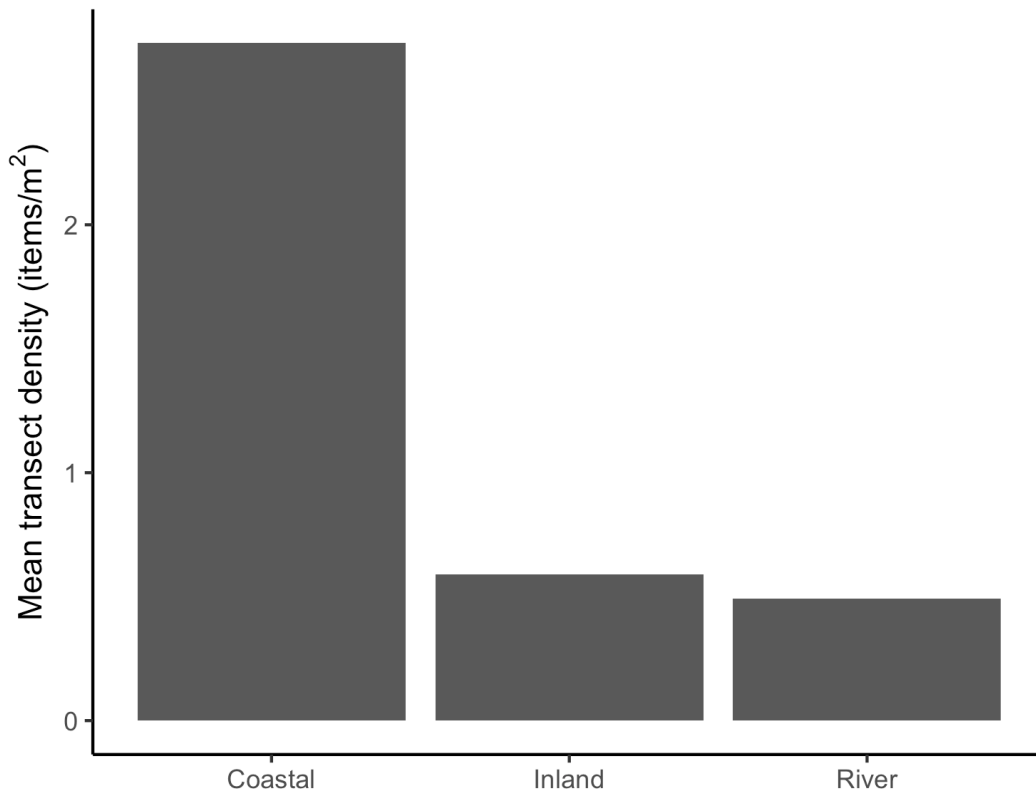
Figure 6. The mean density of debris found from transects based on all coastal, inland and river surveys.

3.1 Coastal Surveys

3.1.1   Results

A total of 73 transects were completed at 24 coastal sites. Figure 7 and Figure 8 show the team conducting coastal surveys at two different coastal transect sites. Overall, 10,846 items were recorded. On average, across all transects, 74.29 items of debris per lineal metre of coastline were recorded.

Unknown/other hard plastic was the most common *fragment* type found with 5785 pieces or 59.19% of the total fragment items recorded. String/rope/ribbon was the second most recorded item with 614 items recorded and Food wrapper/label was the third most common, with 506 pieces recorded.

Bottle cap/lid was the most common *whole* item found with 431 pieces or 40.2% of the total whole items recorded. Lollipop stick/earbud was the second most recorded item with 247 items recorded and Other bottle was the third most common, with 54 pieces recorded.

A size class was estimated for 845 debris items with size class 4 being the most common found (size class 4 objects are larger than 4 cm x 4 cm, but smaller than 8 cm x 8 cm). For further information refer to the size class chart in the [Marine Debris Survey Handbook] (https://research.csiro.au/marinedebris/resources/). Of all items recorded, 19% were 16 cm^2 or smaller.

Figure 7. Team members conducting a coastal debris survey in challenging terrain.

Figure 8 Team members conducting a coastal debris survey at a sandy beach (on a windy day).

There was substantial variation in the number of debris items observed across the coastal surveys (in the unit of log number of items per lineal metre) (Figure 9). The highest number of items found on a coastal survey was at site KMC20 located at -3.294, 40.117 between Kilifi and Malinda. Of the 2279 items recorded at this site, 1841 of them were classified as H10_F: Pipe/PVC whole.
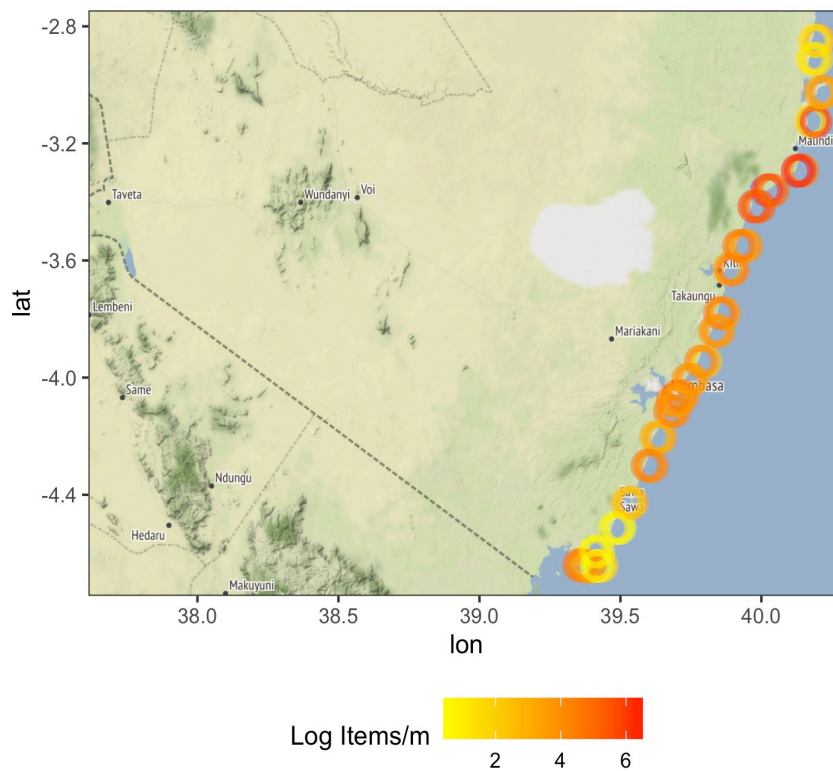
Figure 9. The log number of items per lineal metre for coastal sites near Mombasa, Kenya.

In Mombasa data, after running the GAM, four coastal models were functionally equivalent, based on AIC values. These models were averaged to get the best final model. In the best final model, four terms were statistically significant. While the remaining terms were not statistically significant at p = 0.05 level, they did explain some of the variability in the model, and thus were left in the model. The terms with the highest effect size were wind direction in relation to the shore, with highest densities of rubbish when there was wind, higher densities with increasing rural value, and higher densities of rubbish for areas backed by villages than those with croplands.
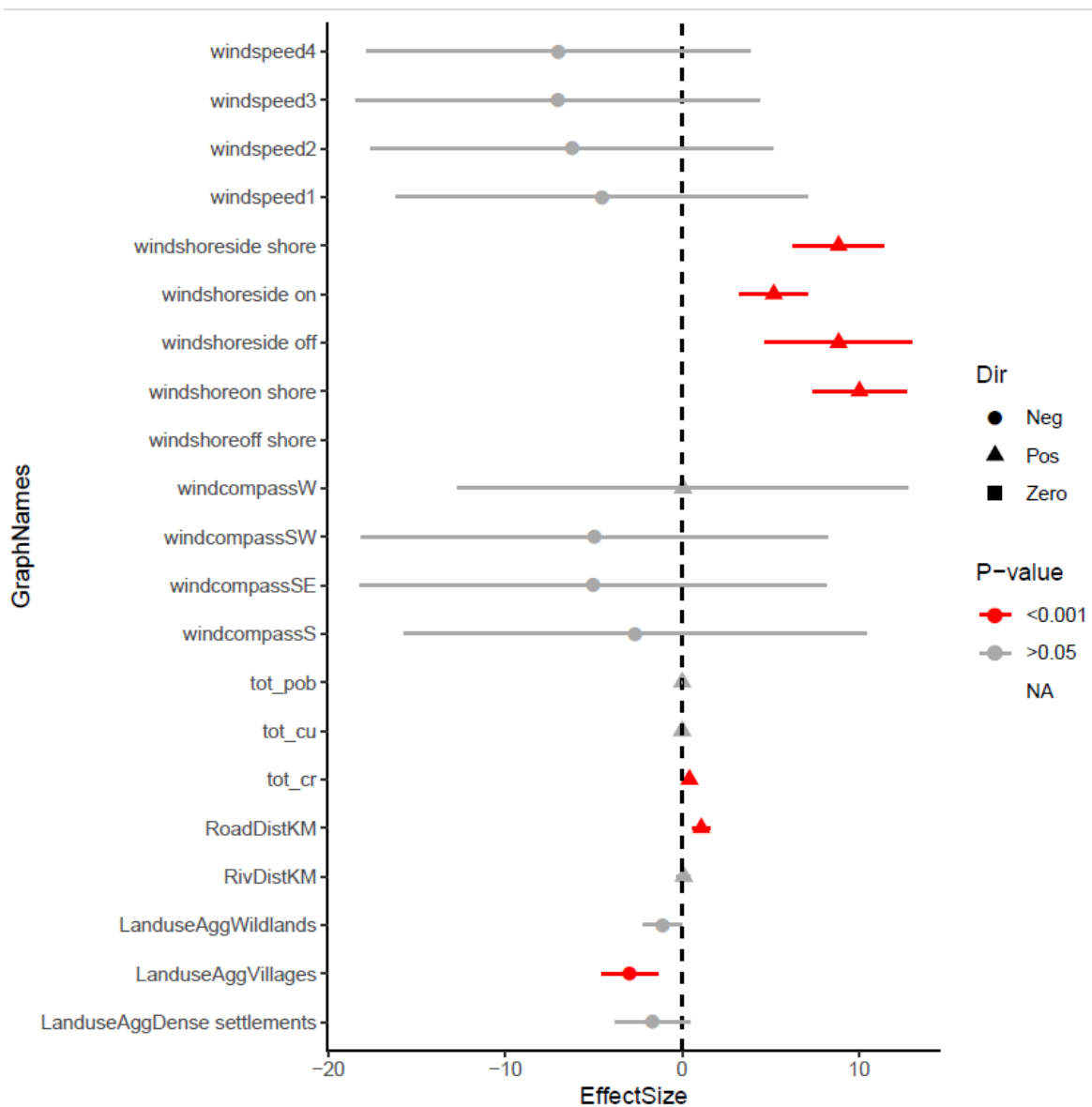
Figure 10. Model average effect size plot for coastal transects. Colour represents the p-value significance level, and the lines are the standard error for each term. Triangles denote a positive coefficient for a given factor, whereas circles denote a negative coefficient. The effect size is calculated as the median value of the factor times its coefficient. Reference variables for categorical variables were: windshore is compared to when there is no wind, windcompass is compared to winds from the East, and Landuse is compared to areas backed by Croplands.

3.2 Inland Surveys

The team completed 159 transects at 44 inland sites across a range of site types including car parks, natural vegetation and agricultural landscapes (Figure 11) and roadways which in one case was interrupted cows (Figure 12). A total of 2347 items were recorded; equivalent to an average of 0.59 pieces of debris for every square metre of land surveyed.

Unknown/other hard plastic was the most common *fragment* type found with 376 pieces or 17.42% of the total fragment items recorded. Unknown/other soft plastic was the second most recorded item with 315 items recorded and food wrapper/label was the third most common, with 302 pieces recorded.

Cigarette/butt was the most common *whole* item found with 35 pieces or 18.52% of the total whole items recorded. Bottle cap/lid was the second most recorded item with 34 items recorded and unknown/other hard plastic was the third most common, with 20 pieces recorded.

A size class was estimated for 763 debris items with size class 4 being the most common found (size class 4 objects are larger than 4 cm x 4 cm, but smaller than 8 cm x 8 cm). For further information refer to the size class chart in the Marine Debris Survey Handbook. Of all items recorded, 21% were 16 cm^2 or smaller.

Figure 11. Transect method of debris survey at an inland survey site.

Figure 12. Transect at an inland survey site (interrupted by cows).

There was substantial heterogeneity in the number of debris items observed across the inland surveys (in the unit of log number of items per square metre) (Figure 13). The highest number of items found on an inland survey was at site KMIT02 located at -4.27, 39.569 to the north of Mombasa. Of the 449 items recorded at this site, 87 of them were classified as S2_F: food wrapper/label fragments.
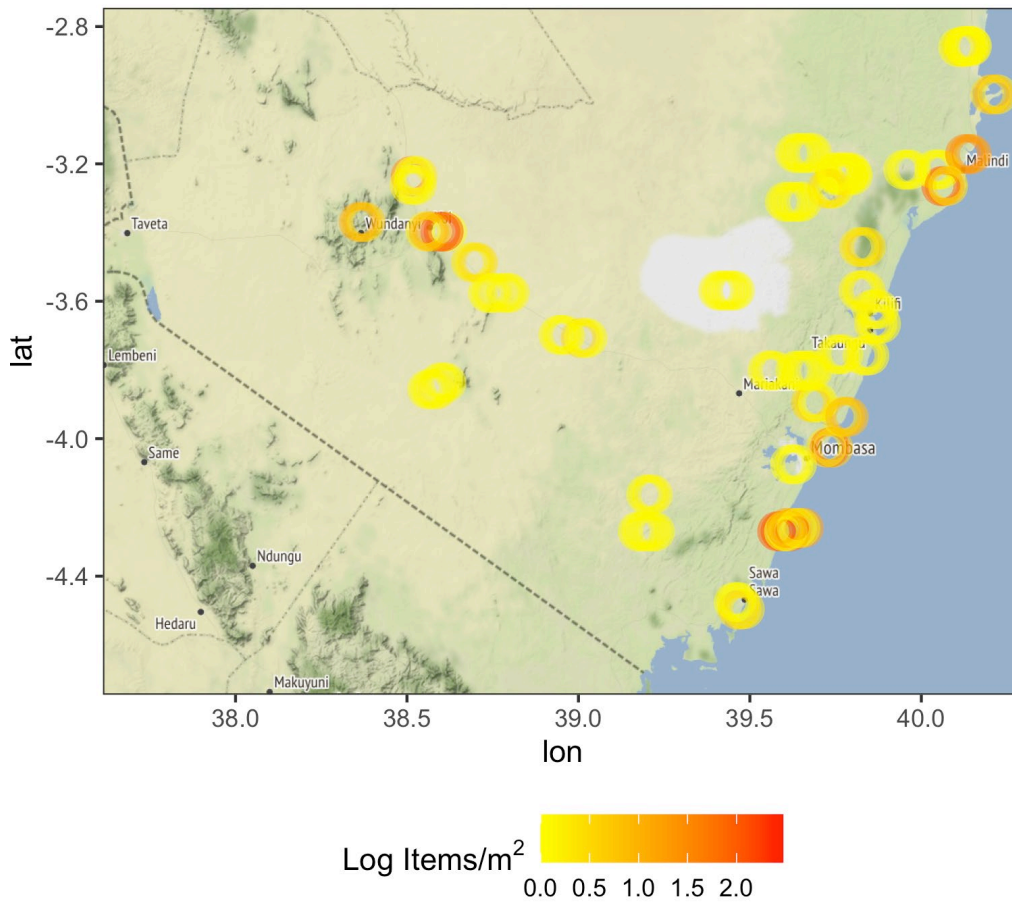
Figure 13. The log number of items per square metre for inland sites in Mombasa, Kenya.

In Mombasa and surrounds, after running the GAM, ten inland models were functionally equivalent, based on AIC values. These models were averaged to get the best final model. In the best final model, four terms were statistically significant. While the remaining terms were not statistically significant at a p = 0.05 level, they did explain some of the variability in the model, and thus were left in the model. The terms with the highest effect size were Land use and distance to coast. Croplands had a significantly lower amount of debris than urban areas; other land uses were not significantly different from urban. The further the distance from the coast, the more debris was found on transects.
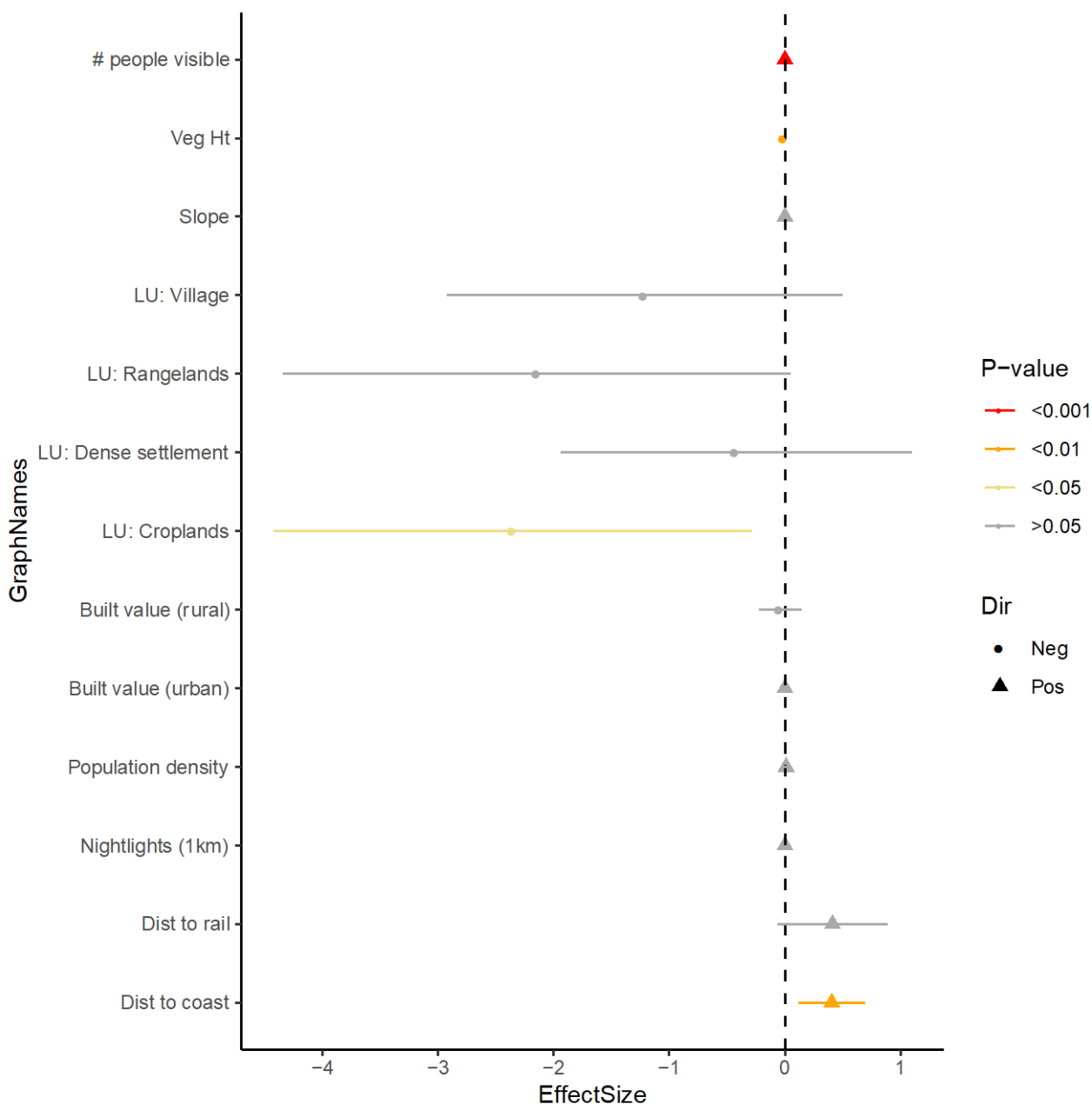
Figure 14. Model average effect size plot for inland surveys. Colour represents the p-value significance level, and the lines are the standard error for each term. Triangles denote a positive coefficient for a given factor, whereas circles denote a negative coefficient. The effect size is calculated as the median value of the factor times its coefficient. The reference term for Landuse is "Urban", meaning that all terms are compared to the urban landuse.

3.3 River Surveys

A total of 93 river transects were conducted at 30 river sites. Some river sites had fully flowing rivers while other sites were on the banks of dry rivers (Figure 15). A total of 1174 items were recorded; an equivalent of 7.38 pieces of debris for every lineal metre of river bank surveyed (on average).

Unknown/other hard plastic was the most common *fragment* type found with 545 pieces or 49.73% of the total fragment items recorded. Food wrapper/label was the second most recorded item with 150 items recorded and unknown/other soft plastic was the third most common, with 99 pieces recorded.

Unknown/other hard plastic was the most common *whole* item found with 10 pieces or 12.82% of the total whole items recorded. Food wrapper/label was the second most recorded item with 10 items recorded and beverage bottle <1 L was the third most common, with 7 pieces recorded.

A size class was estimated for 363 debris items with size class 4 being the most common found (size class 4 objects are larger than 4 cm x 4 cm, but smaller than 8 cm x 8 cm). For further information refer to the size class chart in the Marine Debris Survey Handbook. Of all items recorded, 11% were less than 16 cm^2.

Figure 15. An example of a river transect site where the team conducted debris surveys.

There was substantial variability in the number of debris items observed across the river surveys (in the unit of log number of items per lineal metre) (Figure 16). The highest number of items found on a river survey was at site KMRT01 located at -4.259, 39.596 on a small river at the northern end of Diani beach near Congo River Beach. Of the 664 items recorded at this site, 533 of them were classified as H10_F: Pipe/PVC whole.
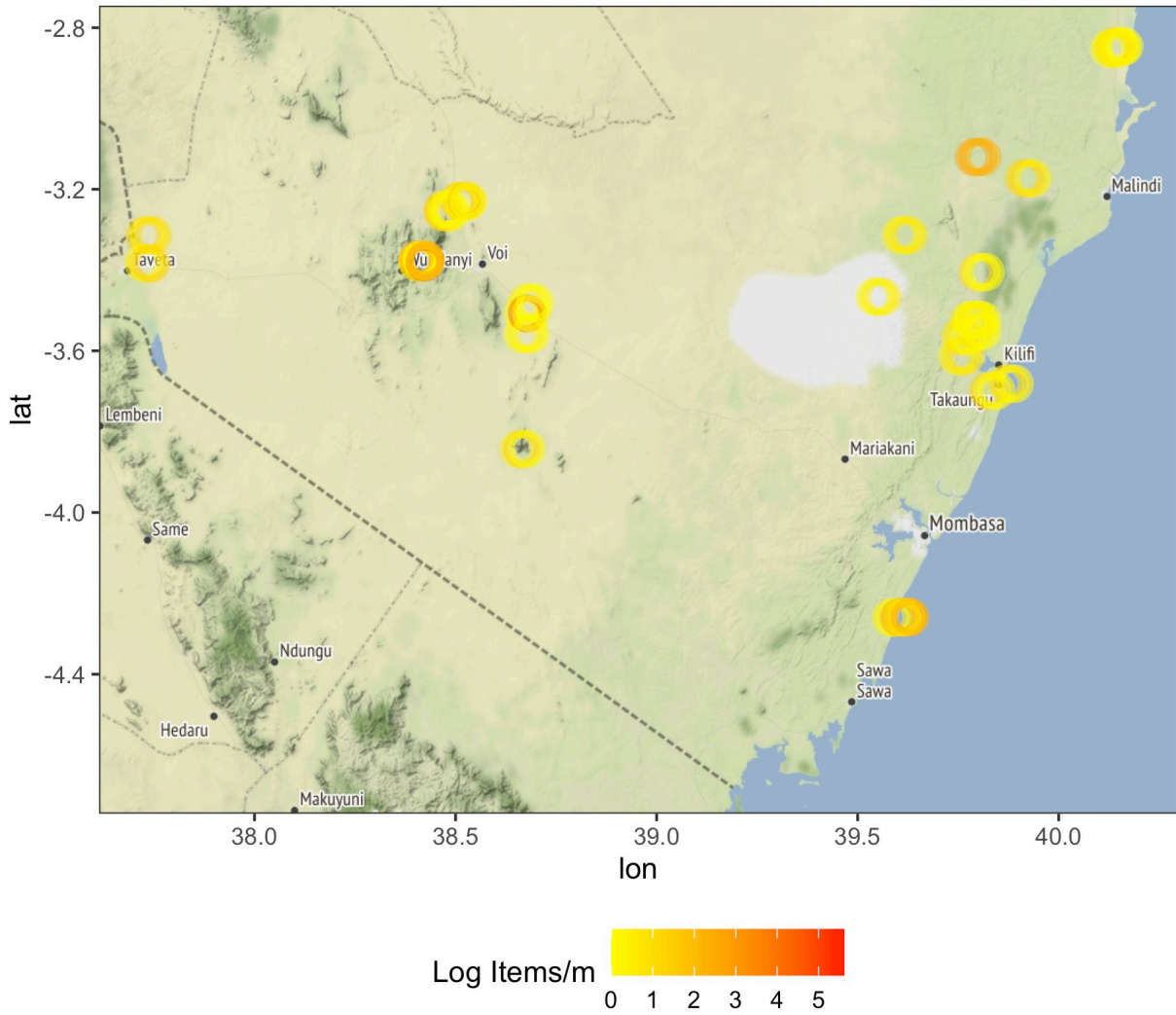
Figure 16. The log number of items per lineal metre for river sites in and around Mombasa, Kenya.

3.4 Trawl Surveys

Figure 17. Trawl surveys with the manta net.

A total of 27 tows were conducted at 9 sites, emanating from the mouth of the Mombasa harbour running parallel to the shore heading north to Mtwaoa Creek and circling back towards the harbour (Figure 18). The mean density of the debris found across all tows was 11899.58 items per square kilometre. Overall, the most common type of debris found was hard plastic, with a total of 153 items, or 46.5% of all items found.
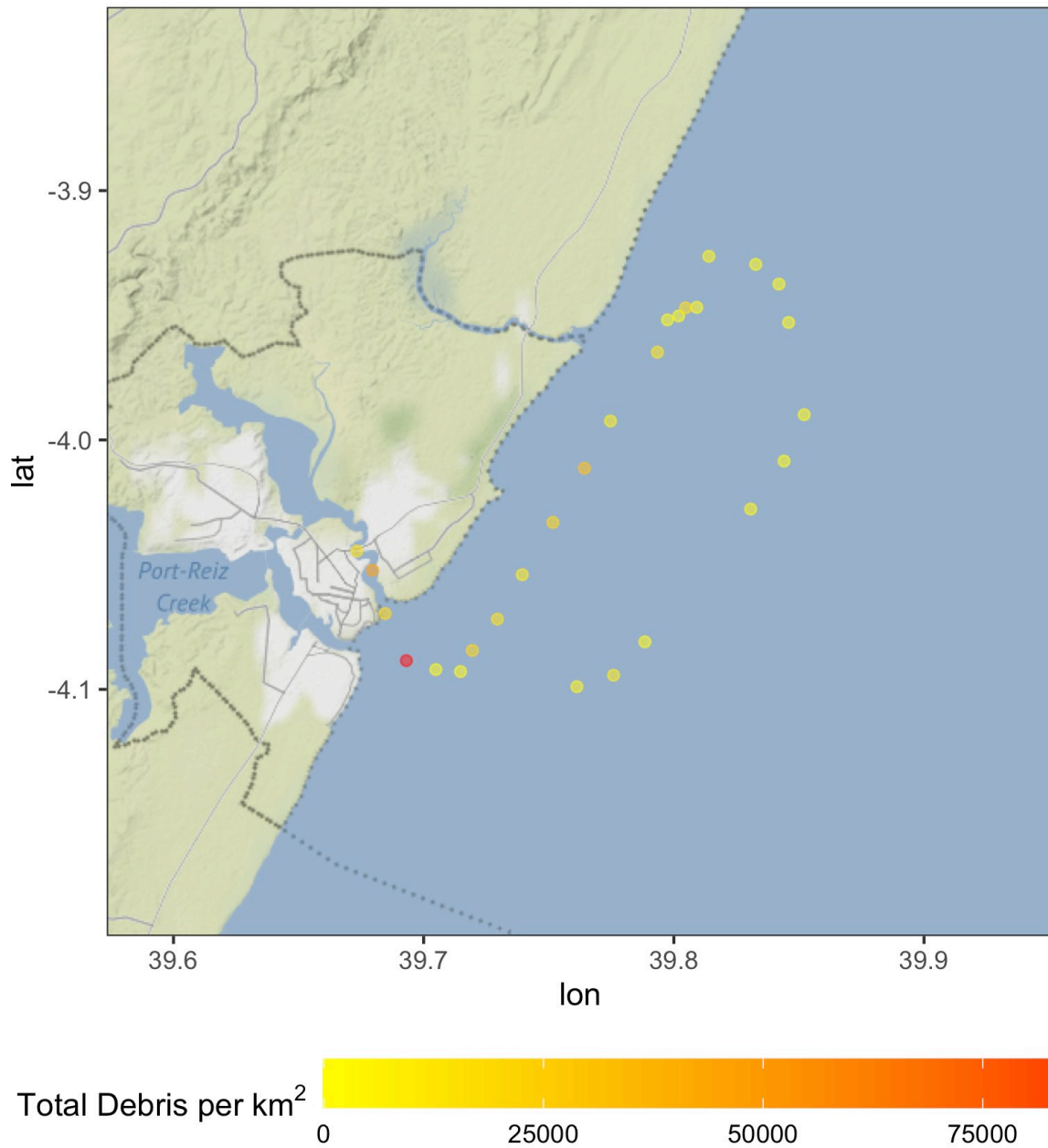
Figure 18. The total number of items per square kilometre for trawl sites near Mombasa, Kenya.

4   Summary

Surveying the Mombasa region of Kenya was a tremendous undertaking, which required substantial coordination, field effort by a large number of participants and patience and good humour by all. A total of 352 transects (including 73 coastal transects, 159 inland transects, 27 trawls and 93 river transects) were conducted. To our knowledge, the data collected provides the first comprehensive baseline look at plastics and other anthropogenic debris on land, along rivers and at the coastal interface for such a large portion of Kenya. While we acknowledge these data provide a 'snapshot' in time, this information can be used as a baseline against which change and seasonal differences in debris deposition and movement can be compared. Such information provides an important first step that can be used to inform policy and decision making. Furthermore, as new policies or practices are implemented, the data can be used to quantify the changes that may come with such policies, practices or awareness-raising campaigns. We also hope to use these data in conjunction with statistical models to produce figures that highlight the litter plume of this particular urban and nearby area.

Furthermore, the data collected here contributes to a world first, statistically robust, global baseline study of how much waste is lost to the coastal and marine environment. By using the same methodology and building capacity for individuals in multiple countries around the world, we are better able to make large scale predictions about not only local, but also national, regional and global debris losses into the environment. Additionally, we can look at differences we identify in types and amounts of debris across coastal, inland and riverine areas between countries to identify the drivers that may be similar or different amongst surveyed regions.

It appears that the density of debris on the Mombasa coastline is around seven times higher than the loads estimated along the Australian coastline, based on surveys conducted around the entire continent (10.2 items/m; Hardesty et al. 2016) and the United States (based on data collected along the west coast of the US (16.5 items/m; Hardesty et al. 2017). Debris recorded on the Kenya coastline was ten times that recorded for the Seychelles, and similarly high (ten times) that recorded the shore of Lake Victoria in Kenya. Using this dataset and others collected from around the world, ultimately we will be able to estimate the amount of waste, most of which is plastic, from these plumes that is lost to the open ocean or redeposited back to land. We are also able to discern regional differences that may occur. For instance, the most common debris item found in Kenya was hard plastics compared to Seychelles which was glass. With a robust, comparable baseline of information gathered in multiple major metropolitan centres around the world, we will have the data in hand to evaluate policy effectiveness and change through on-ground activities at local, national and international scales.

Presuming a similar distribution of debris across the entire 1420 km of Kenyan coastline, this would equate to an estimated total debris load of over 105 million items along the entire Kenyan coastline. We acknowledge that this is an estimate, given the variability in annual weather patterns, coastal topography, population density, and other factors, but it provides a useful baseline to understand the relative magnitude of the problem, based on the very best available data.

Understanding the transport of plastics from land into marine systems is critical for modelling the distribution and trends of plastic in the ocean and estimating its impact on regional economies. This project will clarify the magnitude of this pollution to the public, to industry, and to policy-makers.

Appendix A

An example of the debris survey items list showing all debris categories
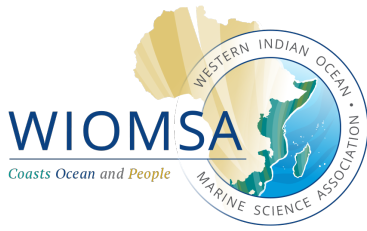
Site ID Code: _____   **ITEMS LIST**

Date: _____ ☐ **No debris found**   **Transect No.** _____ of ___   **Subsampled? Y   N**

	ITEMS	ID	Fragment	Whole		ITEMS Cont.	ID	Fragment	Whole
Hard Plastic	Pipe/PVC	H1			**Foam**	Food container	D1		
	Beverage bottle <1 L	H2				Cup/plates/bowls	D2		
	Other bottle	H3				Polystyrene	D4		
	Bottle cap/lid	H4				Unknown/other	D5		
	Food container	H5			**Paper**	Cigarette/butt	P1		
	Utensil/plate/bowl	H6				Paper/cardboard	P2		
	Bucket/Crate	H7				Magazine/newspaper	P3		
	Lighter	H8				Bag	P4		
	Lollipop stick/earbud	H9				Box	P5		
	Unknown/other hard	H10				Food container/box	P6		
Soft Plastic	Thin film carry bag	S1				Food wrapper/bag	P7		
	Food wrapper/label	S2				Beverage container	P8		
	Sheeting	S3				Cups	P9		
	Cup/lid	S4				Plates/bowls	P10		
	Straw	S5				Unknown/other	P11		
	Unknown/other soft	S6			**Fishing**	Net	F1		
	Other plastic bag	S7				Fishing line	F2		
Plastic Straps	String/rope/ribbon	BP1				Fishing Lures	F3		
	Packing strap	BP2				Buoys/floats	F4		
	Cable ties	BP3				Glow stick	F5		
	Unknown/other strap	BP4				Fishhook/sinker	F6		
Metal	Pipe	M1				Unknown/other	F7		
	Wire	M2			**Miscellaneous**	Battery	Z1		
	Aerosol	M3				Brick/cement	Z2		
	Beverage can	M4				Carpet	Z3		
	Food can/tin	M5				Ceramic	Z4		
	Lid/cap	M6				E Waste	Z5		
	Food wrapper	M7				Furniture	Z6		
	Aluminium foil	M8				Appliances	Z7		
	Bucket/drum	M9				Large car parts	Z9		
	Unknown/other hard	M10				Large boat parts	Z10		
	Unknown/other soft	M11				Bag/box dom. waste	Z11		
Glass	Beverage bottle	G1				Nurdles	Z12		
	Jar	G2			**Other**		O1		
	Light globe/tube	G3					O2		
	Unknown/other glass	G4					O3		
Rubber	Thong/shoe	R1					O4		
	Tyre	R2					O5		
	Balloon	R3					O6		
	Rubber band	R4							
	Unknown/other	R5							
Cloth	String/rope/strap	C1							
	Clothing/towel	C2							
	Wipes/cloths	C3							
	Insulation/stuffing	C4							
	Unknown/other	C5							
Timber	Wood/timber	T1							
	Utensil/food stick	T2							
	Bottle cork	T3							
	Pallet	T4							
	Unknown/other	T5							

Size class (and sub-sampling intervals)

Interval start (m)	Dist on tran	ID (F/W)	Size class
1 0 -			
2			
3			
4			
5			
6			
7			
8			
9			
10 - (end)			

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