Spring 2018

Takataka Talk: Waste Presence and Management in Ushongo

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SIT Study Abroad

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Abstract

Increasingly high levels of waste are being generated each year, resulting in millions of tonnes of plastic and other debris ending up in marine and coastal environments. The impacts of the debris on these environments are wide ranging, affecting both environmental health and human wellbeing. Still though, there is a lack of information concerning the presence and effect of garbage in many coastal and marine ecosystems around the globe. This project studied the presence and management of coastal waste along a small portion of the coast of Tanzania, near the village of Ushongo. General distribution, level, and type of garbage along the beach were studied, as well as the impact of different types of human activity along the shore (resort, village, and uninhabited beach) and the level of seaweed. Interviews were also conducted to understand the thoughts, opinions, and concerns of different people residing and working in the Ushongo area. Overall, the study found that human activity type has little influence on garbage and seaweed levels, while seaweed levels have high influence on garbage. Additionally, plastics were found to have elevated levels, and awareness and concern of beach litter was high among members of the village.

Acknowledgements

Thank you to the SIT: Tanzania Wildlife Conservation and Political Ecology directors, staff, and students, for providing the opportunity to pursue this project, and the support necessary to complete it. Thank you to the people of Ushongo for welcoming myself and the other students studying there, and for being so helpful and kind during our stay. Thank you to Adidja, who made the best chapatti I have had in Tanzania, and to Frankie and Valentine for being loving four-legged protectors and companions on my walks. Thank you to my friends and family at home for supporting and encouraging me. And finally, thank you to the beautiful beach and all of the nature in Ushongo for hosting us all.

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Introduction

The presence of plastic and other trash in marine and coastal environments is an issue that has been gaining increased awareness recently. The number of marine species impacted by debris increased 23% between 2012 and 2016 (CBD, 2016), raising the number to a distressing 817 species. There have been several studies conducted on waste management and recycling in urban areas of Tanzania such as Dar es Saalam, and a few studies on marine debris distribution in the Indian Ocean that gather data from off the Tanzanian coast. There has been almost no research found on the basic distribution, concentration, and types of garbage located along different areas of the coast, however. As stated in a CBD report on marine debris, "there are still significant gaps in our knowledge and understanding of debris in the marine environments and how it affects coastal and marine organisms, communities, and ecosystems"(CBD, 2016). This study aims to help address this gap in knowledge through gathering introductory data on the presence and management of waste in the village of Ushongo along the coast of Tanzania.

Background

There are many types of garbage that contribute to issues surrounding waste management and marine/coastal debris. For this study, any reference to garbage, waste, trash, litter, or debris, is in reference to Municipal Solid Waste (MSW). MSW generally refers to everyday garbage from households, commercial, and institutional entities (LaPorte, 2017). Annually, 2.12 billion tonnes of waste are generated, 1.3 billion of which is MSW. In 2012, the World Bank did a breakdown of the global MSW composition (Figure 1). The percentage of organics in MSW was found to increase in 'Low Income' classified countries, such as Tanzania. It was found that in the vaguely defined 'Sub-Saharan Africa' area, 62 million tonnes of waste are generated yearly, with an average of 0.65 kg/capita/day. (Hoornweg and Bhada-Tata, 2012). It was also noted that islands off the coast of Africa and other tropical regions tend to generate higher amounts of waste than mainland locations. Due to insufficient management systems, the presence of waste may appear higher in Low Income countries than Western nations. However, the WB found that all 31 Low Income classified countries generated only 6% of the global waste in 2012.

Regardless of where the waste is generated, there is a global problem with safe and healthy waste disposal. Large amounts of trash end up in unsanitary landfills, or get dumped in the ocean each day. For many years, the ocean was used as a bottomless pit for dumping various types of waste; however, in recent decades, the negative environmental and health impacts of these practices have come more to light and are being addressed in a variety of ways. Starting in the 1970s and continuing since then, numerous international conventions and treaties have been created surrounding proper waste management, movement, and disposal. One such treaty relating to marine and coastal debris was the London Convention, later upgraded to the London Protocol, which put regulations and restrictions on ocean dumping practices. Tanzania is a signer on several other major treaties relating to waste management, including the Basel Convention and Bamako Convention. Tanzania also has two national legislations that seek to improve waste management methods and reduce public littering and ship dumping. These are the 2004 Environmental Management Act, and the 2009 Solid Waste Management Regulations.

Though the World Bank study found plastics to make up only 10% of global MSW, they play an increasingly important role in waste management issues (Hoornweg and Bhada-Tata, 2012). The presence of plastics in marine and coastal ecosystems has been increasing at an incredibly high rate in recent years. The extent of this increase is demonstrated well with the fact that “over the past 75 years, plastic production has increased dramatically from 1.5 million tonnes to 322 million tonnes per year globally” (Coppock et al, 2017). This increase, while a bit shocking in size, is not surprising; plastic is a convenient material to manufacture and use, given that it is “…lightweight, inexpensive, durable, strong, corrosion resistant, and designed to be disposable” (Wessel et al, 2016). 8 million of those 322 million produced tonnes are ending up in the ocean each year as well. And plastic in the ocean is a bit of a double edged sword of damage. On one hand, the lifetime of plastic products is incredibly long, ranging from 10 years for some plastic bags, up to an estimated 600 years for a monofilament fishing line (NOS, 2017). On the other hand, due to the high exposure to powerful UV rays that plastics experience when they're in the ocean versus in a landfill, they degrade much faster. The combined UV exposure and physical damage from waves and natural debris causes the plastic to break down; and not in a decomposition sense, but simply into much smaller pieces of plastic - known as microplastics.

The impacts of both microplastics and larger pieces of debris and garbage found in the ocean and along beaches can be harmful to both wildlife and humans. Entanglement and suffocation of wildlife in trash is a commonly used and straightforward example of the direct damage that garbage can cause. 'Ghostfishing' is a specific type of entanglement, in which animals are caught in old fishing gear. Ingestion of both microplastics and larger debris are also a common form of damage. Ingestion can lead to physical abrasions and blockages in animals, or release toxins that lead to physiological and hormonal deficiencies. Both of these can lead to reductions in fitness or death of the organism that ingested it. In addition, ingestion of harmful plastics or toxins can lead to bioaccumulation up the food web, resulting in health problems for humans or other creatures higher up the web. Because plastics are adept at absorbing toxins, and are often manufactured with their own set of possibly negative chemicals, they can harbor and pass disease to living creatures; and sharp or dangerous pieces of debris can cut unsuspecting beach dwellers or swimmers. Ecologically, debris can get caught in habitats such as coral reefs and destroy them; and travelling ocean debris can act as a vector for the transport of nonnative or invasive species. Indirect issues for humans resulting from this debris includes economic loss (from damaged aesthetics and recreation that sectors like tourism rely on), and navigational issues for vessels at sea that encounter 'plastic islands'. (NOS, 2017) Better understanding the distribution, concentration, and identity of marine and coastal debris around the globe is thus vitally important to both environmental sustainability and to human well being.

Site Description

This study took place along the beachfront of the village Ushongo Mton. Ushongo is located in the Tanga region of Tanzania, about 16 kilometers south of Pangani. The area is split into two villages: the northern Mtoni, and the southern Mabaoni. Surrounding the Mtoni village are five tourist resorts (Emayani's, Mike's Beach Cottages, Drifters Lodge, Tides, and Beach Crab), as well as the Magic Reef Cottages. North of Emayani's is a stretch of uninhabited coastline, intersected by a river than dumps into the ocean. A short sandy ridge separates the beach from other land, which is mainly forested. The area has a high population of local fishermen and boats, but few large-scale ships and vehicles.

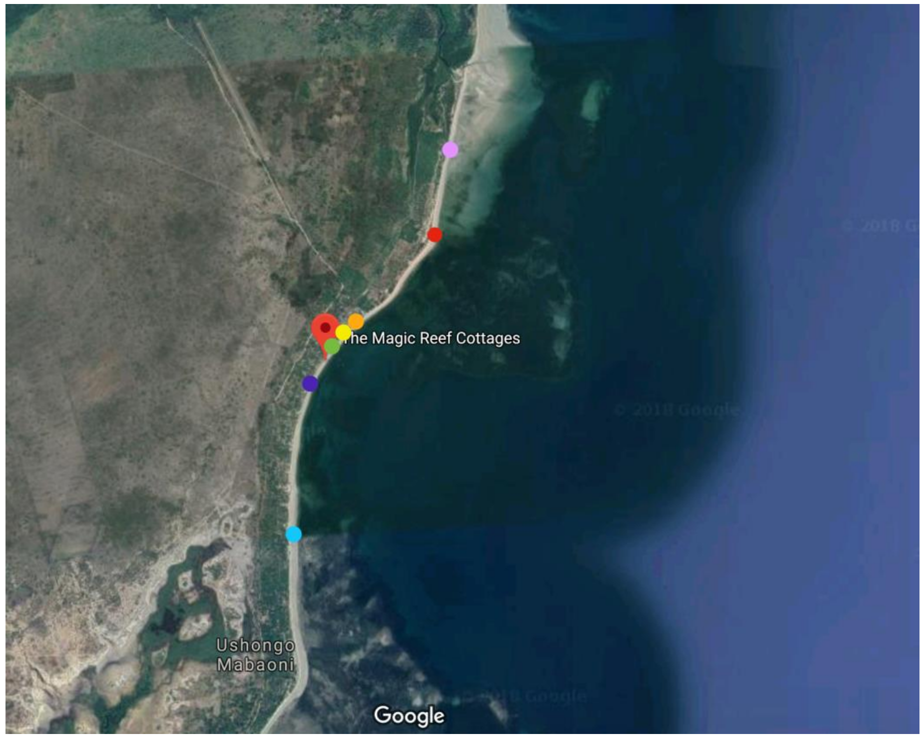


Figure 1: Map of Study Site (Ushongo) Marked sites from North to South: Uninhabited Coastline, Emayani's, Ushongo Mtoni, Drifters Lodge, Mike's Beach Cottages, Tides Resort, Beach Crab

Objectives and Hypotheses

The broad goal of this study is to gain a better understanding of the role that beach litter plays in Ushongo, through an examination of the who, what, when, where, and why of the trash distribution, levels, and types along the coast there. Specifically, this goal will be pursued through a study of the changes in the general distribution and level of trash, as well as the impact that weather, tides, seaweed level, and types of human activity have on trash distribution, levels, and types. In addition, a goal of this project is to speak to a variety of people residing in the Ushongo area about their personal actions, opinions, and concerns surrounding the beach litter.

Based on these aims, there are several hypotheses and predicted results of the study. First, it is hypothesized that measured garbage levels will vary significantly between three different categories of human activity (resort, village, and uninhabited). The village area is predicted to have the highest levels of trash. Second, it is hypothesized that seaweed levels along the shore will vary significantly between three different categories of human activity (resort, village, and uninhabited). The uninhabited area is predicted to have the highest level of seaweed. Third, it is hypothesized that seaweed level will have a significant impact on the level and type of garbage found at all sites. In addition, it is predicted that interviewed village members will have a high awareness of levels and types of garbage along the beach, but varying levels of concern. The main methods of garbage disposal are also predicted to be tossing in the bush or laying in front of the village by the ridge to the beach.

Methods

This project was conducted using both social science methods and physical data collection. Types of information collected fell into three different categories: Daily Survey information, trash data collection, and interviews. Methods for each are described below.

Daily Survey

The first part of my data collection consisted of 'Daily Survey' walks, during which a range of different factors involved in the distribution, levels, and composition of trash along the coast were examined. The survey walks ventured about 30 minutes in the N/E and S/W directions from my place of residence throughout the project (denoted in my data as 'Home'), and included all 5 resorts, the village land, and stretches of uninhabited coastline. In each direction, different stretches of beach were identified based on the type of property they were; such as the specific resort that owned the land, the village beach, or beach located in front of uninhabited areas. The general level of trash was estimated by sight for each of these locations, and recorded in my notebook. Possible identification levels were as follows: None (0), Very Low (VL), Low (L), Medium (M), and High (H) (*See Appendix I)*. In-between levels were also identified; these included 0/VL. VL/L, L/M, and M/H.

In addition to general trash levels, a range of other information was recorded each day. The weather patterns throughout the day and from the previous night were recorded, being especially noted and detailed if there were unusual events (such as intense or extensive storms). Tide times and heights were gathered from the resort Tide's, which had them publicly posted each morning. The tide height is a measurement "...referenced to *Mean Lower Low Water (MLLW).* It is the average of the lower low water height each tidal day observed over the official time segment over which tide observations are taken and reduced to obtain mean value". Weather and tide records were later confirmed by cross-checking with online records for precipitation and tide levels in Pangani during the study period. An estimation of average human activity on the beach was also conducted each day; the number of people seen on the beach and on the shoreline directly behind the beach were recorded, as well as the area of highest human density that day. There was no safeguard for double counting in this, besides my own memory. However, as the specifics of this information will not be used for any calculations, and are merely meant to show the general usage of the beach throughout the day, this is not of much concern.

Trash Data Collection

The main bulk of the project consisted of collecting litter off the beach at 15 different locations for analysis. There were three types of possible collection areas: resort beach, village beach, and uninhabited coastline. All coastline covered in the Daily Survey walks that fit into one of these three categories was broken down into more specific possible collection locations. Five collection blocks were chosen for each category; giving a total of 15 data collection blocks (*Table 1*). The order in which the blocks would be collected from was chosen randomly, through drawing paper slips numbered 1 through 15 from a bowl (*Table 2*). The chosen blocks were 10 meter x 1 meter areas, located at the point of the highest observable tide line. This usually meant the highest discernable line of seaweed along the beach. This location was chosen because of the hope that it would be the most consistent place to collect from between locations.

Resort Beach	Village Beach	Uninhabited Coastline (UC)
A1: Emayani's	A6: $Village_1$ ($Beginning_2$)	A11: UC_1 (Block 3)
A2: Drifter's Lodge	A7: $Village_2$ ($Boats_2$)	A12: UC_2 (Block 4)
A3: Mike's Beach Cottage's	A8: $Village_3$ (End_1)	A13: UC_3 (Block 5)
A4: Tide's	A9: $Village_4$ ($Boats_1$)	A14: UC_4 (Block 6)
A5: Beach Crab	A10: $Villages_5$ ($Beginning_1$)	A15: UC_5 (Block 1)

Table 1: Data Collection Blocks

The different areas the blocks were located in differed greatly in size, the larger of which required another round of randomized selection to determine the exact location of the block within the area. For resorts with smaller properties, such as Mike's Beach Cottage's and Drifter's Lodge, two 10 meter lengths were measured out (with a small gap between them) at each location, and one was chosen at random to be the plot that was collected from. For the resorts with larger properties, the process was a bit more complicated. For Tide's, since the property was broken down into three parts for my Daily Survey's (Beginning, Middle, and End), the first step was to choose which of the three sections the block would be in. Once the Beginning section was randomly chosen, the area was then broken down into multiple 10 meter blocks, each with a small distance between them (about 1 minute of walking time). Then one of these 10 meter blocks was selected as the collection site. Similar patterns followed at Emayani's and Beach Crab, both of which have slightly more extensive property areas. They were broken down into smaller possible blocks with about a 1 minute walking distance between them, and the specific site was chosen at random.

A6	A1	A13	A14	A4	A9	A15	A10	A12	A3	A5	A7	A2	A8	A11

Table 2: Randomly drawn Site Collection Order

For the Village Beach and Uninhabited Coastline blocks, selection was similar to that of the larger resorts. In the village, each section denoted in the Daily Surveys (Beginning, Middle, End, and Boats) was broken into two possible blocks, creating a total of 8 possible blocks. 5 of these blocks were then randomly chosen from paper slips; then the slips were re-drawn in order to determine the order in which those blocks would be collected from. The blocks chosen were numbers 2,1,5,7, and 8. Their order became 2,7,1,8, and 5. The translation of these blocks to locations along the village beach can be seen in Table 3. For the Uninhabited Coastline area, 6 possible blocks were created by measuring 10 meter lengths about 3 minutes walking distance apart from each other. These blocks stretched from 5 minutes past the last Emayani's building until the break in the beach where a river cuts inland. Blocks 1, 3, 4, 5, and 6 were randomly chosen to be collected from; their collection order was 5, 6, 1, 4, and 3. The translation of this order to the labels used for UC areas can be seen on Table 1.

Table 3: Village Blocks

Potential Block Number	**Location along Village Beach**	**Alignment with Village Beach Block Labels**
1	Village Beginning (1)	A10
2	Village Beginning (2)	A6
3	Village Middle (1)	-
4	Village Middle (2)	-
5	Village End (1)	A8
6	Village End (2)	-
7	Boats (1)	A9
8	Boats (2)	A7

Table 3: Village Blocks; The 8 possible village blocks mapped out, their location, and their collection order

Each 10 m x 1 m block is broken down into 40 0.5m x 0.5m plots. Plots were measured in the field by measuring and marking with sticks/plants of the 1 meter sides, and laying the measuring tape along the ground at the middle line. Another plant or nearby branch was then measured and cut to be half a meter long. This was used at individual plots to mark the distance out from the measuring tape that should be collected from. Each plot was also assigned a number, demonstrated in Figure 2. 10 plots were chosen at each location to be collected from. Selection was conducted in the same manner as other randomized choices, by drawing numbered slips from a bowl. Drawing was done in such a way that guaranteed there would be 5 plots chosen between 1 and 20, and 5 chosen between 21 and 40. Plots were chosen before leaving for data collection at a given site.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40

Figure 2: Collection Block Design; In each collection block, 5 plots were randomly selected from the top row, and 5 from the bottom

Collection consisted of searching through the entire area of the plot and gathering all visible pieces of trash. At the start of collection, general notes on the time of day, weather, and other important meta-data were taken. A note was also made for each plot on the surface area coverage of seaweed versus sand in the plot, as well as if there were other impeding factors to collection (such as a crab hole, or a large log or branch). In seaweed covered areas, the entirety of the seaweed was searched through for litter. However, once reaching the sand, only the top layer of sand - a depth of about 5 centimeters - was searched through. No extensive digging occurred to look for more pieces. Any items found partially inside a plot were counted; if an item was partially inside two plots being measured, it was counted for the plot that a larger portion of it was in. If it was unclear if an object was plastic/trash or simply part of a shell or a dead plant, it was taken anyways for further examination. There was no time limit on the collections, and they usually ended up taking about an hour and a half, ranging from a short 40 minute collection to a lengthy 3 hour one. A collection ended when all visible and removable trash had been collected.. Items were stored in 10 aluminum to-go containers with cardboard lids, which were labeled on site to prevent confusion around which plot their contents were from.

Once collection was finished, all collection containers and equipment was carried back to Magic Reef Cottages to be analyzed. Analysis consisted of going through all items found, cleaning them, weighing them, and categorizing them. To clean, if possible, a hand towel was used to wipe away extra sand and organic matter. If necessary, a pan of water was used to rinse, and 6% Hydrogen Peroxide was used to help remove grime and remaining organic debris. Items were then dried completely, and weighed using a kitchen scale. The scales degree of measurement only went down to whole grams; as such, while larger items could be placed directly onto the scale, smaller items required an extra step. Another item (such as a cardboard lid, or a small measuring cup) would be tared on the scale, and then all smaller items would be placed on top and weighed collectively. An overall weight for each plot was recorded, and a photo of all items found in the plot was taken. In addition, pieces were categorized and counted. Categorization was rough, and only as specific as was able to be determined based on sight. Categories included specific items such as bottle caps, plastic bottles, straws, shoes, toothbrushes; there were also more vague ones, such as plastic ribbons, strings/fibers, and unidentified plastics. A complete list of categories and the frequency of items in each can be found in Appendix II.

After weighing and sorting, all items were stored in extra bags and containers and held in a cabinet. At the end of data collection, all items were removed and arranged on the floor by category for a photo. There were too many items to transfer them to Arusha from the coast, so items were left to the current managers at Magic Reef Cottages to dispose of. The plastic and glass bottles found were kept for recycling, and other items were buried in a designated trash pit.

Interviews

Interviews were conducted with three main groups of people: resort staff/owners, tourists, and village members. The original goal of the study was to speak to an equal number of people in each category, but this hope was quickly dashed upon beginning the interviews. Due to it being the off-season for tourism in Ushongo during the time of the study, there were minimal tourists present and few resort staff members at work each day. In all, only 11 resort staff were interviewed (including 3 managers and 1 owner), and 3 tourists that spoke sufficient English were spoken to. Resort staff were interviewed at random times throughout the project period, during stops in at resorts during the Daily Survey walks. Bartenders were spoken to most often, as they were usually one of the only staff members present throughout the majority of the day. Managers were able to be spoken to at three of the five resorts, and the owner was present for interview at only one. Of the tourists interviewed, two were guests at Beach Crab, and one was a guest at Tide's.

Village member interviews were conducted over a period of several afternoons. A local elder Mzonge, who runs the library in Ushongo, was hired as a translator during those days.

Interviewees were chosen at random by the translator. Participants were compensated for their time with 1 kilogram of maize flour, bought for 1200 Tsh a kilogram at one of the local shops. Overall, 35 village members (14 women, 21 men) were interviewed. While the resort staff interviews had a set of questions that were only a basis for more in depth exploration, the village and tourist interviews were meant to be more framed like a survey, so that answers would be more comparable and easy to analyze. The questions asked both to the tourists spoken to and to the village members can be found in Appendix III.

Village Shop/Hotelini Inventory

A list of the products sold at the small shops in the village and the items used at the hotelini's was created. This was done so that the items sold that might possibly become part of the litter on the beach could be compared to the identifiable items found in my Trash Collection. If many of the identifiable items did not appear to originate from the village, it would help support my hypothesis that the majority of the trash is arising not from the village, but from marine debris being washed up. Due to the results of the Trash Collection portion of the project, this method was not able to be fully tested, and Inventory results became additional information not analyzed. Notes were taken on the items sold, and when possible, photos were taken of the shops for later examination and listing.

Village Trash Pit Survey

In addition to the interviews, a survey of the location of trash disposal pits in the village was conducted. The survey was conducted over one afternoon, and consisted of recording the general location, size, and composition of both trash pits and obvious trash burning sites.

Analysis

Daily Survey

A compilation of general waste levels recorded during the Daily Survey walks was created and results were examined. Results were compared with information on weather events and tide levels to study their impact. No statistical tests were performed, as these values were merely estimations and not exact. Spearman's Rho Correlation calculation was run on the weather (precipitation levels) and tidal coefficient throughout the study period to test for the influence weather events have on tide levels.

Trash Collection Data

The impact of seaweed levels on the level and type of trash found on the beach was analyzed through the use of Pearson's Correlation Coefficient calculation. Seaweed percentages in each plot were tested for correlation with the weight of the plots and the number of items found in each plot. In addition, statistical tests were run to test for the correlation of seaweed percentage in each plot with the presence of each of the top five most commonly collected items in the plots. P-values < 0.05 were considered significant.

The impact of the three different areas of human activity (resort, village, and uninhabited coast) on the distribution, level, and type of trash found was analyzed with One-Way ANOVA tests. The differences in plot weight between the three groups, the number of items per plot in each group, and the presence of the top five most collected items in each group were tested. In addition, the difference in plot seaweed percentage in each group was analyzed, to test for the influence of types of human activity on seaweed levels. Again, P-values < 0.05 were considered significant.

Interviews

No statistical analysis was performed on the interview results.

Ethics

All interviewees either read or heard an informed consent form, and signed the form themselves or gave permission to have their name written for them. Interviewees were given opportunity to leave the interview or not answer specific questions whenever they felt uncomfortable, and were given multiple opportunities to ask questions to the researcher and translator. All litter collected was either recycled/reused (plastic and glass bottles), or buried upon the conclusion of the study. All questions and mannerisms in interviews were framed in a way that aimed to help interviewees feel comfortable, safe, and unjudged by any answers they may provide.

Results

Daily Survey: Weather and Tides

In addition to tracking the weather during Daily Surveys, additional information on the precipitation level in the nearby town of Pangani were researched. Both the recorded data and the information concerning Pangani agree, having a majority of days with little to no rain (0-4 mm), with three days of intense storming. The first period occurred on the night of April 7th and the full day of April 8th, resulting in 95 mm of precipitation. The next two days of storming occurred in succession, creating one longer period of rain that began on the night of the 13th and continued through the morning of the 16th, with the majority of the rain falling on the 14th and 15th. Precipitation was 138 mm and 136 mm on those days, respectively.

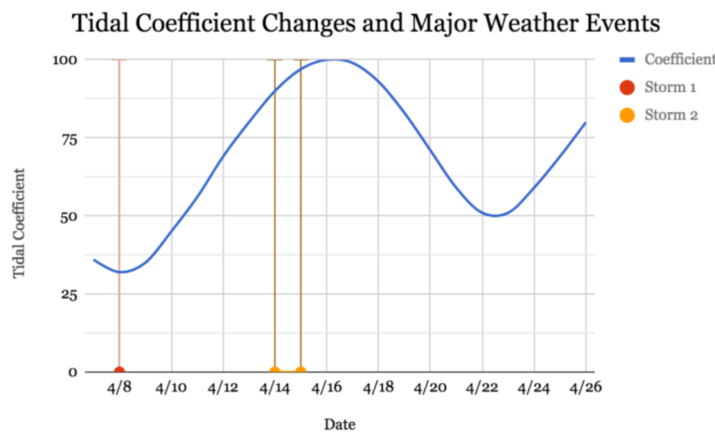


Figure 3: Tidal Coefficient Changes and Major Weather Events; Progression of tidal coefficient throughout study period with major storms marked vertically

There were multiple components to the tide measurements. The height and timing of the tides was recorded, and after data collection was complete, the tidal coefficient during the project period was also researched. The tidal coefficient "... [tells] us the amplitude of the tide forecast (difference in height between the consecutive high tides and low tides in a given area". It is a measure of the intensity of the tide's amplitude on a given day. Figure 3 shows the progression of the tidal coefficient throughout the project period, with the major weather events previously described marked with vertical lines. In both cases, the coefficient increases (indicating a higher amplitude tide) after the storming events. A correlation test was run for the precipitation levels throughout the study period and the changes in tidal coefficient. The results were not significant ($R = 0.065526$, two-tailed p-value = 0.78373). This suggests that the nature of the increases is such that they appear to be more related to a regular cycle of tidal amplitudes rather than the result of the storming.

Another component of the tide measurements was to examine the role tide height plays in depositing and removing litter along the beach. It was demonstrated above in Figure 3 that the amplitude of the tide changed greatly throughout the project period. On the 9th, high tide was only 2.5 meters, with low tide at a nearby 2.1 meters. High tide peaked in height at 4.3 meters on both the 17th and 18th, with low tide reaching its simultaneous low at 0.6 meters on those same days. However, in addition to the naturally fluctuating tidal amplitude, the impact of the tides was influenced by the width of the beach at a given location as well. From halfway through the Uninhabited Coastline area, all the way through the Tide's property, the high tides during the majority of the project period reached all the way up to the ridge that separates the beach from other land. Only in the second half of the Uninhabited Coastline (the half furthest from the village and resorts), and down near Beach Crab and beyond was there a portion of the beach not heavily touched by tides.

Daily Survey: General Garbage Levels

Data from the Daily Surveys on the general garbage level in both the S/W and N/E directions were compiled and arranged to show their changes throughout the project period. All nine garbage level options were converted into a number form, ranging from 0-9 and moving at whole number intervals (None = 0, Very Low/None = 1, Very Low = 2, Very Low/Low = 3, etc). Figure 4 shows the progression of all 10 locations on the South/West side of the survey from April 7th through April 26th. There is no overall trend apparent that would link the progression of the 10 locations. Four of the locations end with the same level they began with, three increase in amount, and three decrease. All locations fluctuate throughout the period, though again there is no clear pattern to these changes. A second graph consisting of the lines for only the locations sampled during Trash Data Collection was created, to gain a better understanding of the relative level of trash on the day of collection and the time surrounding it (*Figure 5*).

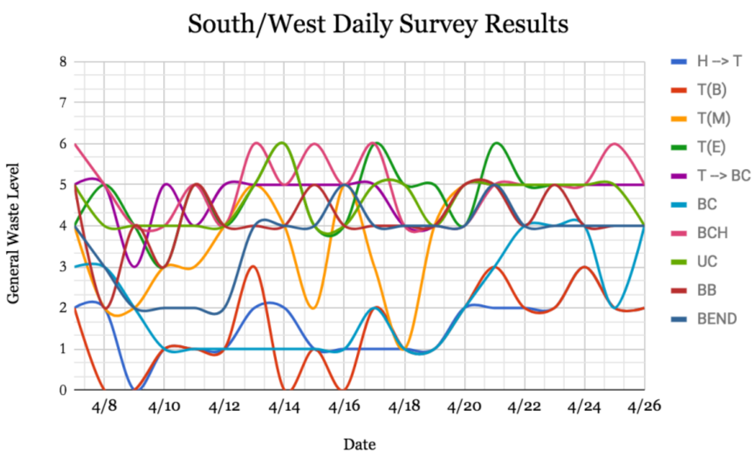


Figure 4: Graph of S/W Daily Survey Results; H = Magic Reef Cottages, T = Tides (Beginning, Middle, End), BC = Beach Crab, BCH = Beach Crab Houses, UC = Uninhabited Coast, BB = Big Building, Bend = Beach Turn to Mabaoni

On the South/West side, only two of the 10 locations were sampled during Trash Data Collection. This is due to the location of Magic Reef Cottages- which the surveys were based around- and to the widespread set up of the resorts and houses on this side of the beach. In Figure 5, the three major weather events during the project period were marked to analyze the impact of weather on the general garbage levels on the beach. The ways in which weather can both directly and indirectly influence the garbage level will be explained in the Discussion section. It can be seen in Figure 5 that after the initial storm on April 8th, the observed levels decreased at both locations (Tides (Beginning) and Beach Crab). Levels at Beach Crab did not appear to be heavily impacted by the storms on the 14th and 15th.

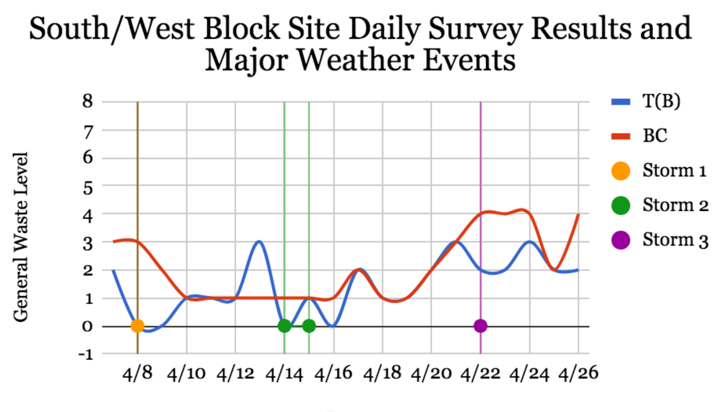


Figure 5: S/W Daily Survey Results at Block Sites; S/W results only at locations where a collection block was located, with major weather events marked

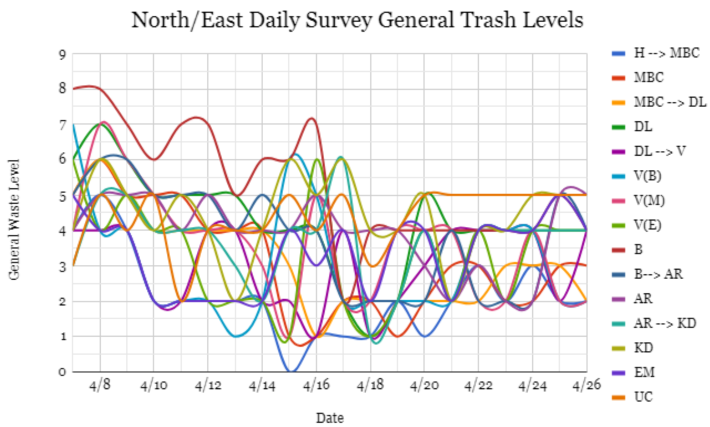


Figure 6: N/E Daily Survey Results; MBC = Mike's Beach Cottages, DL = Drifters Lodge, V = Village (Beginning, Middle, End), B = Boats, AR = Abandoned Resort, KD = Kasa Divers, EM = Emayani's, UC = Uninhabited Coastline

Changes in trash level were also graphed for the North/East side of the Daily Surveys (*Figure 6*). As with the South/West data, the graph of changes at all locations is abundant with data; however the North/East side has a more clear overall trend. Though four locations increased in level by the end, and one had an unchanged level, ten of the fifteen chosen locations had a lower ending level than their beginning amount. This gives an overall decreasing trend, which can be seen by the shape of the graph in Figure 6.

A second graph of only locations within which collection blocks were found was created for the North/East side of the survey as well (*Figure 7)* The three major weather events were inputted. After the April 8th storm, a decrease in general level was seen at four of the seven locations. The storms on the 14th and 15th don't appear to have a clear direct impact on level changes, though there is significant movement to a sharp increase followed by a sharp decrease in several of the locations in the days following those storms.

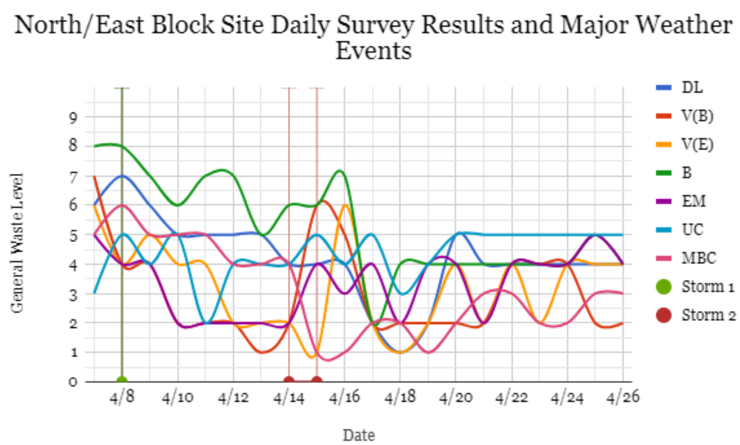
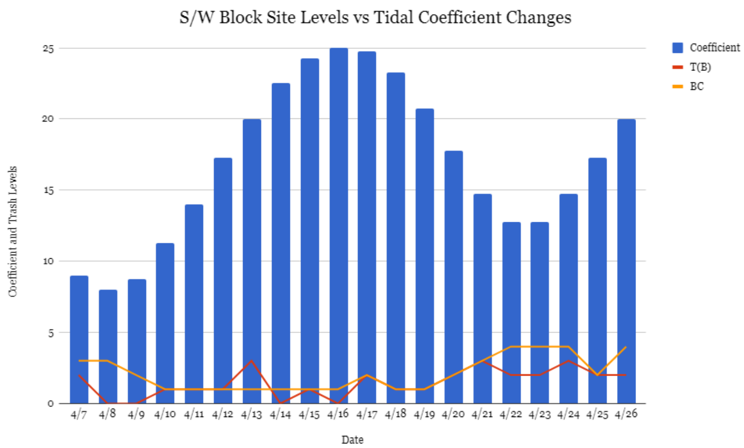
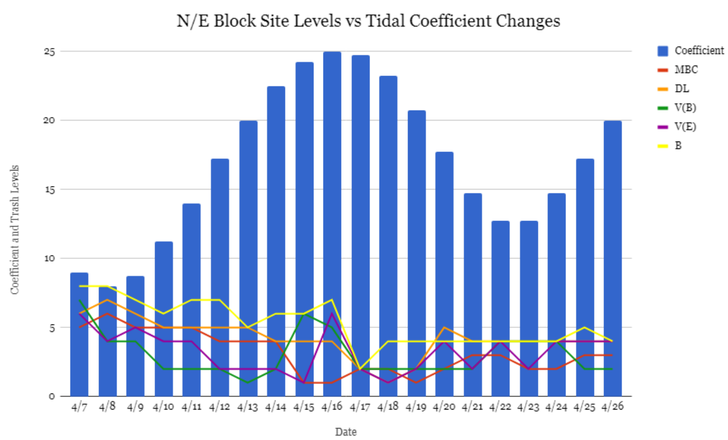


Figure 7: N/E Daily Survey Results at Block Sites; N/E Daily Survey levels at sites where collection blocks were located, with major weather events marked

To look at the possible impact of tidal level changes on the distribution and level of trash along the beach, a comparison was made between the progression of tidal amplitude (measured through tidal coefficient) throughout the study period and the Daily Survey Block Site level changes. The tidal coefficient is a measure of the tidal amplitude, determined through the difference in consecutive high tide and low tide heights at a location. (Tides Tables, 2018). In order to have a comparable graph of this information, tidal coefficient values were scaled down to ¼ their listed value. As this comparison is merely to compare visual changes in the two factors, and not to calculate a relative or specific numerical value for their changes, scaling was not a problem. Figures 8 and 9 show the progression of tidal coefficient changes versus the changes in general trash levels for the South/West and North/East directions, respectively. Once again, no statistical tests for significance were able to be run. On the South/West side, the only possible relationship seen is at 4/21-4/25, where slightly higher general trash levels align with a decreasing coefficient values. On the North/East side, a possible correlation is seen on 4/17, where immediately after a peak in coefficient values, the trash level in several locations decreases sharply. Overall, no significant or substantial relationships between tidal amplitude and general trash level were found.





Figures 8 (top) and 9 (bottom): Daily Survey Result progressions compared to Tidal Coefficient Progression over the study period

In summary, the data gathered on general trash levels suggest that daily levels of trash at all locations along the beach fluctuate day to day, but have relatively stable levels over time. There is a chance they are influenced by the tidal level and the storms along the coast, but evidence to support this was not substantial or clear. Of the block site survey locations, Tide's had the lowest average value (1.45), followed by Beach Crab (2.1). The highest average value was the 'Boats' Village location (5.3), followed by the Uninhabited Coastline (4.35) and Drifter's Lodge (4.25). Based on calculations of standard deviation, the Uninhabited Coastline had the most stable values (STD = 0.88), followed by Tides (0.99). The 'Boats' Village location also had the highest standard deviation (STD = 1.66), meaning it had the most variability in amplitude fluctuations throughout the study period.

Trash Collection Data

All in all, 3777 pieces of trash weighing 3842 grams were collected from 150 0.25m^2 plots over the 20 days of data collection. Items were sorted into 61 different categories, based as specifically as possible on their appearance and material (*Appendix II*). The top five most commonly found items were Unidentified Plastics (2832 pieces), Styrofoam (375 pieces), Plastic Fibers/Strings (153 pieces), Plastic Wrappers (105), and Bottle Caps/Bottle Cap Pieces (81 total pieces, 69 whole bottle caps). Other commonly found items include pieces of small plastic straws, miscellaneous foam pieces, yellow foam/sponges, plastic strips, and rope (made of plastic fibers). Twenty six categories of items identified contain only a single item.

Within the categories of Unidentified Plastics and plastic wrappers, there were several sub-categories of item classification. Unidentified plastics were broken into three groups: large (≥ 3 centimeters long), small (< 3 centimeters and > 1 centimeter long), and microplastic (≤ 1 centimeter long). This is a loose definition of microplastic; some researchers define microplastic only as items less than or equal to 5 millimeters in length, but given the methodological constraints on this study, the definition used for classification was all unidentifiable plastic pieces less than or equal to 1 centimeter long. The remainder of the unidentified plastic was split between 463 small pieces, and 76 large pieces. Plastic wrappers were identified as either water/soda labels or wrappers, candy wrappers, or miscellaneous. The largest portion were miscellaneous wrappers that did not have enough information to be identified, at 83 of the 105 pieces. There were 15 water/soda wrappers, and 7 candy wrappers.

The weight of each plot and the number of items found in each plot were summed to give total weight values and number of items for each of the 15 blocks. Table 4 shows the ranking of all collection block areas by weight. The block with the highest weight was Area 13 - UC_3, which was collected from the fifth potential UC block measured. The total from this block was 867 grams. In contrast, block A8 (Village 'End_1' block) had the lowest weight at 0 grams. The 0 grams was not from a lack of any items in the block, but the result of the accuracy of the scale being used for weight measurements. Table 5 shows the ranking of different areas based on the total number of items in the block. The block with the most items in it was A7 - the '$Boats_2$' village block, with 685 items total. The block with the fewest items was A10 (Village "$Beginning_1$ block), with only 4 items in the whole block.

Table 4 (Left) and 5 (Right): Collection Blocks ranked by total weight and total number of items collected

Collection Block	Total Weight (g)
A13 (UC_3 : Block 5)	867
A9 ($Village_4$: $Boats_1$)	859
A14 (UC_4 : Block 6)	649
A12 (UC_2 : Block 4)	378
A2 (Drifter's Lodge)	291
A11 (UC_1 : Block 3)	218
A1 (Emayani's)	170
A15 (UC_5 : Block 1)	150
A7 ($Village_2$: $Boats_2$)	91
A3 (Mike's Beach Cottage's)	86
A6 ($Village_1$: $Beginning_2$)	59
A10 ($Villages_5$: $Beginning_1$)	17
A5 (Beach Crab)	6
A4 (Tide's)	1
A8 ($Village_3$: End_1)	0

Collection Block	Total Number of Items
A7 ($Village_2$: $Boats_2$)	685
A2 (Drifter's Lodge)	595
A5 (Beach Crab)	571
A1 (Emayani's)	398
A9 ($Village_4$: $Boats_1$)	339
A11 (UC_1 : Block 3)	310
A14 (UC_4 : Block 6)	213
A12 (UC_2 : Block 4)	196
A13 (UC_3 : Block 5)	125
A15 (UC_5 : Block 1)	110
A6 ($Village_1$: $Beginning_2$)	103
A3 (Mike's Beach Cottage's)	100
A4 (Tide's)	26
A8 ($Village_3$: End_1)	22
A10 ($Villages_5$: $Beginning_1$)	4

Impact of Plot Seaweed Percentage

The amount of seaweed in each plot ranged widely across all blocks. Figure 10 shows the frequency of different amounts of seaweed across all 150 plots. 54% of all plots had a surface area less than or equal to 25% covered in seaweed. Only 21.9% of plots had a coverage greater than or equal to 75% seaweed. The correlation between the percentage of seaweed in plots across all blocks was found to have a significant correlation with the weight of the plot (R = 0.3601, p-value < 0.00001). Thus as the amount of seaweed in the plot increases, the total weight of items found in the plot should increase as well. A significant correlation was also found between the percentage of seaweed in a plot and the number of items found (R = 0.5971, p-value < 0.00001). As the percentage of seaweed in a plot increases, so should the number of items found in the plot. Correlation between the seaweed percentage in plots and the presence of each of the top five most common items found was also significant. Unidentified plastic pieces and plastic fibers/strings had moderately positive correlations (R = 0.5404, p-value < 0.00001 and R = 0.5265, p-value < 0.00001 respectively). Styrofoam, plastic wrappers, and bottle caps all had weak but significant associations (R = 0.2708, p-value < 0.000803; R = 0.4149, p-value <0.00001; and R = 02.824, p-value < 0.000463 respectively). Figure 8 shows the presence of the top five items in four categories of seaweed percentage (0-25%, 26-50%, 51-75%, 76-100%). For each item, the highest number of items is found in the highest seaweed percentage group.

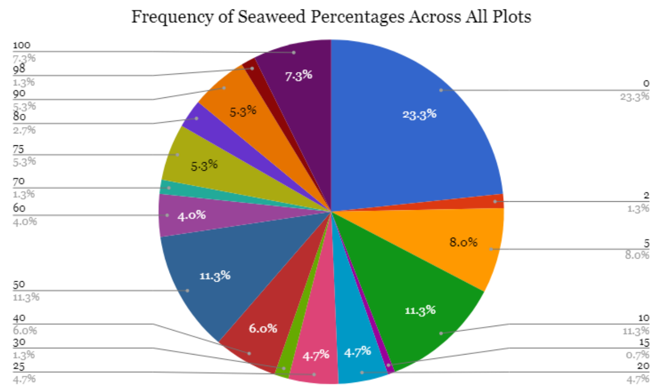


Figure 10: Frequency of Seaweed Cover Across All Plots

Impact of Different Areas of Human Activity

As described earlier, three different types of area were examined in this study. These groups were based on the type of human activity on the shoreline above the beach; resort beach, village beach, and uninhabited coastline (UC). The weight of the 50 plots in each group were statistically analyzed for a substantial difference in their values. The difference in plot weights between the three groups was found to be statistically not significant (F-ratio = 1.94187, p-value = 0.18594). The number of items in each plot was also compared across all three groups, and also found to be not significant (F-ratio = 0.54965, p-value = 0.591015). Additionally, the abundance of each of the top five common items was found to be not significant (Unidentified plastic: F-ratio = 0.92983, p-value = 0.421281; styrofoam: F-ratio = 1.91114, p-value = 0.190314; plastic fibers/strings: F-ratio = 0.69159, p-value = 0.519675; plastic wrappers: F-ratio = 0.89826, p-value = 0.432981; bottle caps: F-ratio = 0.54742, p-value = 0.592225). The impact of the three different areas on seaweed percentage in plots was also tested. Similar to the other calculations comparing these three areas, the difference in amount of seaweed at each was found to be not significant (F-ratio = 2.2777, p-value = 0.10612).

Though there was no significant difference between the three area types for any tested variable, there were still patterns to their relationship with total block weight and number of items. Three of the five blocks with the highest weight were UC blocks, and the remaining two UC blocks were both within the top ten heaviest blocks. Resort blocks were scattered throughout the weight rankings, and village blocks had three of the five lightest blocks. The pattern in total number of items per block was less distinct. The UC blocks were all clumped together in the middle of the ranking, while village blocks were spread almost evenly near the top and bottom. The resort blocks were distinctly split between three highly ranked blocks ranked 2nd, 3rd, and 4th, and two blocks ranked 12th and 13th at the bottom of the list. Concerning the top five most common items, for unidentified plastics, plastic fibers/strings, and plastic wrappers, the most were found in resort blocks. Bottle caps were located more in village blocks than the others, and styrofoam was found more often in UC blocks.

Resort Interviews

Though the resort interviews were only semi-structured, there were several core questions answered by all 5 institutions. No resorts had records of how much waste they generate, or specifically what types they generate. All answered that generally items generated are plastic bags, plastic wrappers, plastic bottles, and glass bottles from the bar, as well as food waste. Each resort sends employees out every morning to clean their beach properties. Two resorts (Tide's and Beach Crab) collect some of the seaweed as well, while the other three only collect non-natural items. All resorts have a location at the back of their property where they burn the majority of their waste, with a few exceptions. All resorts also stated that they believed high waste levels on the beach to be harmful to their business, as guests are often unsatisfied when they see trash on other parts of the beach.

A few of the resorts also have unique actions they take when it comes to waste disposal. While all five bury pieces of glass they find instead of burning them, Emayani's collects full bottles from its beach and bar to be sent to Arusha and fashioned into glass turtles. These glass turtles are then sold at their souvenir shop, and part of the profits go to a turtle conservation group, Friends of Maziwe. Tide's collects its glass soda and beer bottles to be returned to the plant they came from (part of Tanzania's glass refund system, explained further in Discussion). Tide's also composts its food waste to be used as fertilizer in their gardens.

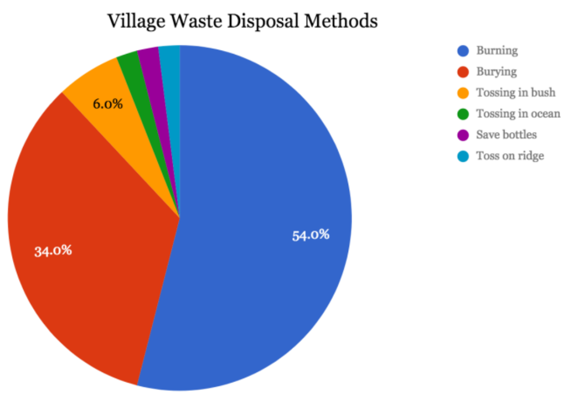


Figure 11: Village Waste Disposal Methods; The majority of village members interviewed dispose of waste by burning and/or burying

Village Interviews

The village interviews were more structured than resort interviews, and thus more comparable; they did have some open-ended questions as well, but responses to these were still fairly consistent. 71% of interviewees said they preferred to spend time on Coco Beach (near the UC area), with only 20% choosing to spend time by the village, and 9% preferred to spend time near the resorts. No one claimed varying trash levels as their reason for choosing a beach, though many answers were that they preferred a location because it was a "good environment". The majority of villagers burn and/or bury the waste they generate at home (Figure 11). Top answers for the type of waste generated at home were plastic bags, plastic bottles, food waste/organics, plastic containers, and weaved baskets. 100% of interviewees thought that trash on the beach was bad, and 6 people said they believed that natural waste (coconut fronds, seaweed, other dead plants) on the beach was not bad.

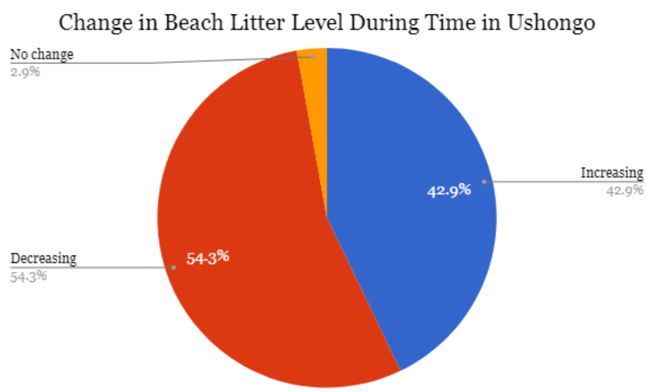


Figure 12: Changes in Beach Litter Level; Residents were asked how long they had been living in Ushongo, and if they believed waste levels on the beach to be increasing or decreasing

Reasons for believing the trash on the beach was bad for the environment centered around it being bad for the environment. 22 participants claimed that directly as one of the reasons it was harmful. Several other responses shared this sentiment in an indirect way; such as worry about chickens and fish eating it, spreading disease/being dirty, and releasing bad chemicals. Other responses were that it was dangerous to walk on/for kids to play near, it disturbed the village, and that it ruins the scenery. The majority of village members cited the ocean (i.e. Dar es Saalam, Zanzibar, etc) as the largest source of trash on the beach. The village itself and ships/sailors dumping from boats were also cited often, with only 2 people claiming the local resorts were major sources of waste. 49% of village members interviewed had been injured previously by the trash on the beach, and several of those that had not been hurt said they knew of others who had been injured before.

Villager members interviewed were almost evenly split when asked if they believed the trash levels on the beach had increased or decreased since they first arrived in Ushongo (Figure 12). Reasons for decline usually listed were that people were more educated and there were more beach clean ups now. Reasons for increase centered around the village population increasing, more plastic being produced in Tanzania, and too few/too shallow trash pits in the village. A wide range

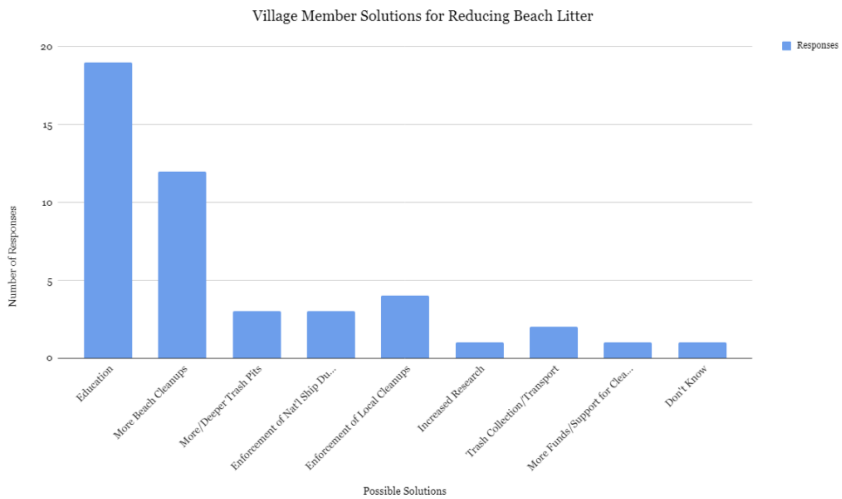


Figure 13: Village Member Solutions for Reducing Beach Litter; Responses include: Education, More Beach Cleanups, More/Deeper Trash Pits, Enforcement of Nat'l Laws, Enforcement of Local Cleanups, Trash Collection/Transportation

of answers were given when asked the question of what should be done to improve/reduce trash levels on the beach. 19 interviewees stated increased education (both in Ushongo and elsewhere) as one possible solution. Increased/improved beach cleanups were also listed often. Other responses can be found in Figure 13.

Village Pit Survey

In total, 21 active trash pits were found in the village. There was no pattern to their location; some were located behind houses or buildings, others in the middle of roads, and some on the edge of the village near the ridge to the beach. Pits ranged between about half a meter in diameter to around 4-5 meters across, with depth usually between a quarter of a meter (for shallow, sandy pits) and a meter and a half deep (for very defined, large pits). Items found in the pits included food waste/organics, plastic bottles, plastic bags, newspapers, cardboard boxes, clothing, diapers, rope, miscellaneous metal, weaved baskets, styrofoam, plastic wrappers, plastic containers, and miscellaneous plastic items.

Village Hotelini and Shop Inventory

The hotelini's surveyed all had the same items in use that may become beach litter. This included newspaper, plastic buckets and containers, metal trays, plastic plates and cups, plastic bags, and metal pots (as well as food waste). The shops contained an enormous range of items that may have lead to increased beach litter; however, due to the majority of the litter found in this study being unidentifiable, comparison between shop items and collected items was not a productive task. As such, the items identified will not be listed in this study.

<u>Discussion</u>

Since this study was built around understanding the who, what, when, where, and why of trash distribution, levels, and types along the beach in Ushongo, this Discussion section will be broken into five sections to examine each of those areas.

Who

Though originally a hope of this project was to identify the producers/manufacturers of as many pieces of garbage found on the beach as possible, this goal was very difficult to achieve. Aside from the large majority of items found being unidentifiable plastic, or items that have no form of identification to begin with (such as styrofoam), items that might have been identifiable at one point had often been worn down or exposed to enough UV rays that no information on brand or source could be extracted. The clearest example of product identification came from sorting the whole bottle caps that were found (Figure 14). Of the identifiable caps found, 34% of them came from Uhai water bottles, with brands such as Azam, Aqua, Podoa, and Kilimanjaro Water also making noticeable appearances. Several of the water bottles found were also from the Kilimanjaro Water brand.

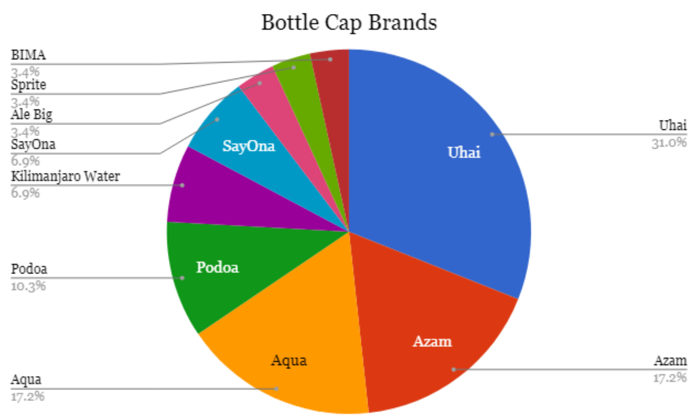


Figure 14: Bottle Cap Brands; Identifiable brands of bottle caps that were collected whole (69 total)

In several interviews both with village members and resort staff, the idea was raised to hold the companies responsible for producing the items that became beach trash. It was proposed that a trash collection take place, during which pictures of the items would be taken and a percentage would be calculated for how many of the items came from each company. Though this project had methods that were aimed at a slightly different overall goal and thus had methods that weren't the best for this type of item collection, the difficulty found in identifying any objects leads to the conclusion that a project such as the one suggested in interviews may be hard to achieve. Though it's a bold and promising idea to seek to change the problem of beach litter at its source of creation, unless there is a way to confidently associate items with their brand/company, this will be near impossible.

Concerning who it is that is disposing of the items in a way so that they end up as beach litter, it appears as though villagers play a fairly small role. Though most stated that they disposed of waste in the best way possible for this area (burying or burning), there was still a large amount of trash found in the streets and along the edge of the village near the beach ridge. Undoubtedly, a portion of this trash ends up being blown or washed by rain onto the beach; however, based on the responses of the villagers interviewed, it seems most likely that very few (if any) villagers are intentionally littering on the beach.

What

As described in the results, the majority of items found were made of plastic or styrofoam. Glass made up a shockingly small portion of the waste found, given the amount of glass bottles used in the country. Only 4 glass items were found, including an empty wine bottle. A possible reason for this low amount of glass waste could be the success of Tanzania's bottle-return system. Multiple interviewees described the system where shops can collect the glass soda and beer bottles they've sold, and when they return the full crate of empty bottles to the plant they bought them from, they recieve a small discount on their next crate order. The relative success of this system is demonstrated by the large number of shops, hotelini's, and other businesses both along the coast and throughout other locations in the country that collect empty bottles or ask customers to return them once they have been finished. The importance of this systems success in establishing itself is large; though decomposition time varies based on environmental conditions, the time it takes for glass to break down is undeniably high. Some sources cite it as taking up to 1,000,000 years to break down; so the more that glass items can be reused or recycled, the better (NOS, 2017).

The fact that this system has found some level of success also speaks to the idea that a similar system may be possible for other items that make up a large portion of litter - such as plastics. Nevertheless, there are smaller scale systems of reuse already being pursued by some. Many villagers stated that they thought plastic bottles were the most common type of trash on the beach, though surprisingly few were found during data collection (only 12). Though the small surface area that the plots covered relative to the size of the entire beach has to be taken into account, it was still curious that they stated this as a large portion of the garbage. A reason for this discrepancy may be that plastic bottles do indeed end up on the beach often, but are removed more than other types of trash are. When doing a beach cleaning, it is much easier to grab the large items such as bottles than it is to dig through the sand and seaweed to extract all the microplastics and smaller pieces. In addition, several interviewees stated that people will sometimes collect whole, capped bottles from the beach to clean and use to bottle oil, petrol, or juice.

When

The 'when' aspect of the trash presence in Ushongo has many aspects. Moving from small scale to large scale, the first aspect is the changes in distribution, level, and type throughout the day. As was described in the interview section of the results, all of the resorts collect trash from in front of their resort property each morning. If, during this project, general level estimations or block collections were done before the cleaning, it is likely that the results would be very different than if they were performed after the cleaning. The same holds true for data collection around the high and low tide times; in certain locations (such as near the village or most of the resorts), the tide came so high that it would sweep away all items on the beach; garbage and seaweed included. The distribution and levels analyzed in this study are then reliant upon the time of day during which they were collected.

'When' is closely tied to the impact that weather and currents have on the trash as well. Though the results were not solidly conclusive on the role that day-to-day weather and tide changes played on the distribution, level, and types of trash on the beach, it is likely that more long-term and broad patterns of weather and ocean currents are important. In Tanzania, the weather is

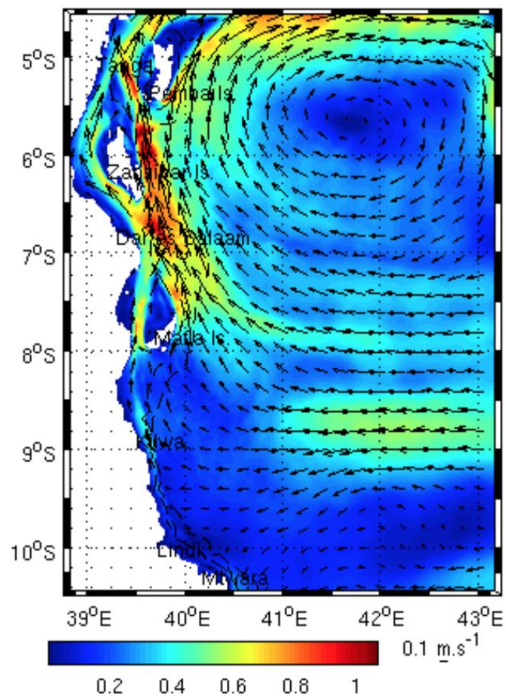


Figure 15: East African Coastal Current (EACC) Patterns off the coast of Tanzania (From Mahongo and Shaghude, 2014)

split into two main rainy seasons. At the onset of the spring rainy season in March, the South/East monsoons begin. At this time, the winds and the weather system switch from moving North to South, and begin instead moving from South to North. The winds and rain during this spring season are more intense than those of the North/East monsoon season in the fall (Mahongo and Shaghude, 2014). In addition, the movement of water off the coast of Tanzania is controlled by the East African Coastal Current (EACC), which generally moves the water in a South to North direction in the waters close to Ushongo (Figure 15). As shown on the map in Figure 15, these South/East currents and winds are moving from locations such as Zanzibar and Dar es Saalam in the direction of the mainland coast, where Ushongo is located. Based on that information, and the statements provided by a range of interviewees, trash presence due to washed up ocean debris should be higher in April through October.

Relating to these seasonal weather changes, it was described by one fisherman that there are good and bad times to fish, based on the level of seaweed in the water. When the water is 'dirty' (meaning so full of seaweed it looks red and brown), it's a bad fishing season; 'clean' water has low levels of seaweed. According to the results gathered by this study on the influence of seaweed on beach litter, trash levels likely increase during these bad fishing seasons. In addition, several of the resort workers noted that there tends to be more trash on the beach in front of their place of employment during high season for tourism. Since this study was conducted during low season, there were very few tourists around, and their impact appeared to be minimal.

An attempt was made to look at the changes over time of the trash distribution, levels, and types along the beach. As no past records of this information was found, and the duration of the study is a short 20 days, data on this topic relied heavily on responses from village members. However, this was inconclusive, as responses were nearly split down the middle, with 42% of village members claiming trash levels had increased, and 54% saying it had decreased in past years. The period over which these supposed increases and decreases were occurring was not standardized, and may have had an impact on how the interviewee answered. Their answer is also subject to how closely they pay attention to the level of trash, and how often they explore other areas of the beach. Since many responses concerning the cause of decrease were that there are more beach clean ups now, it is likely that some of those who said the level is decreasing are referring to the appearance of the village beach, rather than an overall level of trash that is ending up on the beach whether or not there are cleanings. Several responses also noted that upon the arrival of resorts to the area, the level of trash at different places on the beach went down, due to the resorts all cleaning their property everyday.

Finally, 'when' also refers to a more systematic and historic time frame, explaining the rise of plastic production and it's arrival in Tanzania. As was explained earlier in the paper, plastic production has increased rapidly in the last half a century, along with an increase in overall waste generation. One tourist interviewee spoke about how she had visited Tanzania in 1996, and couldn't remember seeing any Kilimanjaro Water bottles. By the time she returned in 2001, she said they were everywhere she went. The impact of globalization and the spread of international monopoly companies such as Coca Cola (owner of the Kilimanjaro Water brand, and producer of many other beverages) cannot be ignored when attempting to understand when and how the scene was set for current coastal garbage issues.

Where

Determination of the source of observed trash was nearly impossible. As described above, identification of products was almost futile, and though a portion of beach litter likely originated in the village and was washed down to the beach, there is no way to confirm this. No village members, resort staff, or tourists were directly observed littering on the beach. In addition, the weather and currents along the coast change direction and help carry items from separate locations to Ushongo. Most of the people spoken to in the area stated that the majority of trash came in from the ocean, having been carried to the shore from places such as Zanzibar and Dar es Saalam, or washed in after being illegally dumped by large vessels or local sailors. The significant role of seaweed in garbage retention and the high portion of broken and worn down unidentifiable plastics suggests that the ocean likely is the source of a large portion of the beach waste. However, there is no way to confirm this suspicion based on the study methods employed.

Even if the ocean was confirmed to be the source of a majority of the waste, that doesn't narrow down it's original location by much. As said above, it is possible that the ocean carried items from another island or city along the coast, or from a Tanzanian ship dumping offshore. Due to the long lifetime of many waste items, and their high mobility once in the ocean, it is quite possible that the trash originated in none of those places, and instead was carried from anywhere else connected to the Indian Ocean. Not only does that include countries with a shoreline along this ocean, but also any vessels passing through, such as ships from Western countries exporting their trash via ships to dumping locations on other continents.

Why

The 'why' of this study is focused around an analysis of the hypotheses and predictions stated at the beginning of the project, and the causes for the found results. The first hypothesis that the type of human activity along the shore would have a significant impact on the level and type of trash on the beach was rejected. For all variables studied, there was not a significant difference between the resort blocks, village blocks, and UC blocks. And though there were a few village blocks ranked highly for weight and number of items, overall, the prediction that trash levels would be highest in front of the village were also incorrect. It would appear that even though the resorts clean each morning, the village cleans weekly, and the UC is rarely (if ever) cleaned, they still manage to accumulate fairly similar levels of garbage. A large part of this may be due to the different types of waste found in each location. More microplastic and light-weight items were found in resort blocks, while heavier single items (such as glass bottles and shoes) were found more in the UC blocks, with a more even split of the two in village blocks. Had a more in depth analysis of the types of trash found at each location, there may be more evidence to back this claim up.

The second hypothesis and prediction set was that seaweed level would vary significantly at areas of human activity, and would be highest along the UC beach. This hypothesis was also rejected, as no significant difference in seaweed level was found for plots in each category. This was again a bit shocking, as several resorts make a point to clean their beach of seaweed each morning. However, even though no one is cleaning along the UC beach, there are naturally areas with larger clumps and distribution of seaweed, and areas with very little or widespread patches. The randomized selection of block locations lead to a block being set up directly next to (but not touching) patches of seaweed or piles of garbage multiple times. In addition, the high tides along the village area meant that regardless of if there was anyone cleaning it, the seaweed was being removed by the sea anyways. It seems that the lack of difference is a result mainly of chance, and of the methods employed (measuring the amount of seaweed on a very small scale).

The next hypothesis related to seaweed as well, predicting that the level of seaweed would have a significant impact on the level and type of garbage found at all sites. This was the only hypothesis not rejected, as seaweed cover was found to have a significant correlation with all variables it was tested against. Due to the texture and shape of the seaweed found at many locations along the beach (easily knotted with lots of fringed fronds), it is a rather ideal material to capture small pieces of plastic and styrofoam and carry them through the ocean. For instance, one of the top five items was plastic string/fiber; while part of the reason for it being so commonly found may have been due to the high concentration of fishermen in the area that used ropes of similar material, the fibers were also usually found tightly wound around a clump of seaweed. They were sometimes so tangled, the seaweed had to be brought back and cut away from the string with scissors. As far as the correlation between plot weight and seaweed presence, this is likely due to the seaweed's ability to retain a higher number of objects, and thus a more likely higher weight. The correlation was not tested for a relationship between seaweed cover and specifically heavy objects (such as glass bottles and shoes), though this may provide interesting insight.

Alternate Waste Disposal Methods and Reduction Possibilities

Throughout the study, interviewees provided a range of ideas when asked what they think should be done to reduce the amount of trash on the beach. This study is in no way claiming to know what solutions would work best for the people of Ushongo and the surrounding beaches. Instead, various solutions that were brought up will be listed and briefly explained.

Trash Collection and Transportation to Tanga or Pangani

Multiple people mentioned that while burying is a main method of disposal here, there is nowhere to dig pits in Tanga and Pangani, so a new disposal method has been created. In these areas, trash is dealt with more systematically. It is collected from people either by a car/truck loading from a central dumping area, or by local people who go door to door and charge 500 Tsh to collect household waste in a wheelbarrow. Interviewees claim that collection and disposal is maintained by government workers. Problems that were mentioned with implementation of this system in Ushongo are that it is unlikely any family would be able, or willing, to pay 500 Tsh or more to have their waste collected and moved by someone else, and that the roads going to the village are very low quality. It would be difficult to guarantee a car or truck easy access to collect trash year round.

Composting

Nearly every interviewee stated that a portion of their daily waste generation came from organics such as food waste, coconut fronds, and other dead plants. Rather than burning or burying this organic matter, it might be possible to follow the lead of Tide's and compost it to use as fertilizer in the sandy soil of the area.

Increased/Improved Beach Cleaning

The village chairman, along with several village members and resort interviewees, state that the village has scheduled beach cleanings every Saturday at 7AM. Knowledge of this was not obtained until late in the study period, so no cleanings were observed directly. However, based on the responses of many villagers that they would like to see more beach cleaning and more enforcement of beach cleaning, it is likely that there is fairly low participation in these events. People suggested finding ways for increased incentive to clean as well. In addition, it appears that nearly every type of community/institution along this stretch of the beach is involved in cleaning. However, there appeared to be little to no communication between them, and almost no cooperation and collaboration when cleaning. Improving communication between actors may help with the quality and the consistency of cleanings. Nevertheless, while cleanings are a good way to remove dangerous and ugly items, and to keep people feeling involved in their environment and health, it may not be a long term solution to the beach litter (if the litter is indeed being mainly carried in by the ocean).

National Enforcement of Waste Management Laws

As described briefly in the Background section, in the last few decades, Tanzania has worked to improve it's waste management laws. However, laws do not hold much weight if they are not followed or enforced. If illegal dumping and littering is occurring, enforcement of these laws will be necessary to help stop those actions. One interviewee pointed out that communication with other parts of Tanzania can be very difficult from Ushongo, as there is little service, and transportation to more connected places such as Pangani and Tanga can be long or expensive. Thus expression of any sentiments regarding national laws or regulations may be hard for community members to communicate as consistently and effectively as they may wish.

Education on the Dangers of Waste and Proper Disposal Methods

Education was mentioned both as a reason for recent reductions in waste levels, as well as a needed solution for future reductions. Access to materials and information on these topics is necessary for this education to occur. However, even if education levels increase, the current 'proper' disposal methods are still detrimental to both people's health and the environment. For education to be truly effective, improved disposal methods will need to accompany it.

Challenges, Limitations, and Biases

This study encountered a number of challenges and limitations. Both systematic and indeterminate errors occurred. Some of these were factors such as the storms and weather: rain pasted the seaweed together, making it hard to dig through; wind blew objects in and out of blocks; and the hot sun made it hard to see objects in the sand. Several times, chickens near the village or local dogs would come and try to walk through the block, potentially moving or removing pieces of trash. People were very curious about the collection, and sometimes children tried to 'help' by grabbing random pieces of garbage and adding them to the collection tin. The architecture of the lodging used was such that there were no 'indoor' spaces with full walls, and limited lighting; this made it difficult to sort and count collected items when it was at all windy outside or dark. As mentioned earlier, the scale used for weighing was fairly inspecific, and as such the weight of many lighter objects was registered as zero.

Aside from these specific problems, there were more general issues that faced the project. Results and data collection were often limited by personal inability; some microplastics were simply too small to collect, and sorting/identification was limited to eye sight. The translator used was a village elder, so there is a chance the interviewees edited their answers and opinions to appear more respectful in front of him. As only one researcher was collecting data for the project, very little area was able to be covered over the beach; and data was only gathered over a few weeks, a very limited time range to observe changes.

Conclusions

Based on the data gathered in this project, it appears that the level of seaweed on the beach plays a very influential role in determining the amount and type of garbage found. The type of institution and the cleaning that they employ was not found to have a significant impact on either the level of seaweed, or the level and type of garbage found along the beach. This study found that a variety of plastic items made up the majority of trash found along the beach at all locations, and were cited by interviewees as both a commonly generated waste item and a commonly found piece of beach litter. Awareness and concern for the presence of trash along the beach was found to be high among village members, though access to long term solutions (i.e. beyond increased beach cleanings and more areas to bury/burn trash) appear to be fairly low. The actions regarding waste management taken by resorts are effective in helping remove trash from the beach directly in front of their own property, but not always other locations along the beach. A main conclusion of this project is that there are many far-reaching and difficult to quantify factors that influence the level, distribution, and type of waste found along the beach; as well as the management and disposal by nearby communities.

Recommendations

Avenues for future research on this topic are almost endless. Provided below are multiple possible projects within or relating to this study that may be useful to examine.

- A more extensive study of garbage distribution, level, and type at more evenly spaced locations along the beach.
- Studying the impacts of current garbage disposal methods (burning, burying) on human health and the environment
- Quantifying the presence of specific objects (plastic bottles, shoes, etc) or specific companies (Coca Cola products) along the beach
- Studying the differences in garbage distribution, level, and type at the same locations used in this study during the North/East monsoon season, a dry season, or a tourist high season

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Appendix I → Estimates of Garbage Level on Daily Survey Walks

Photo 1: None

Photo 2: Very Low

Photo 3: Low

Photo 4: Medium (in the seaweed)

Photo 5: High (in the seaweed)

Appendix II → Complete List of Trash Types and Frequencies

Type of Trash	Frequency
Unidentified Plastics	2846
Styrofoam	375
String/Fibers	153
Wrappers	105
Bottle Caps	81
Small Straws	43
Miscellaneous Foam	41
Yellow Foam	37
Plastic Strips	21
Rope	18
Warped Plastic	14
Unidentified Caps	14
Plastic Ribbons	13
Large Straws	12
Plastic Bottles	12
Cap Rings	11
Toothpaste Caps	9
Plastic Bags	7
Newspaper	7
Shoe Soles	7
Cap Screws	4
Pens	4
Shoes	4
Plastic Mesh	4
Glass	4
Plastic Washers	4
Toothbrushes	4
Fluff Filling	3
Buoys	3
Stencils	3
Sponges	3
Plastic Containers	3
Plastic Rings	3
Cardboard	2
Lighters	2
Soap Dispenser Top	1
Plastic Heart	1
Plastic Spoon	1
Tip Squeeze Tube	1
Cigarette	1
Unidentified Rubber	1
Measuring Cup	1
Clothes Pin	1
Plastic Squeeze Tube	1
Toy Baby Bottle	1
Fake wood	1
Lightbulb	1
Velcro Strip	1
Carved Wood	1
Spray Bottle Cap	1
Plastic Comb	1
Plastic Brush	1
Bottle Cork	1
Toy Doll Spoon	1
Plastic Flower	1
Plastic Game Piece	1
Construction Piece	1
Woven Plastic	1
Plastic Screw	1
Plastic Tube	1
Plastic Circle	1

Appendix III → Questions asked to the village members and tourists

1. What do you do for work/throughout the day?
2. What activities do you do on the beach/in the ocean?
   a. Walking/exercising
   b. Swimming
   c. Fishing
   d. Sailing/going out on boats
   e. Snorkeling
   f. Relaxing
3. What area of the beach do you visit the most?
   . In front of the village
   a. Near one of the resorts
   b. Past the village, where there are no buildings
4. How do you get rid of trash that you have in your home?
   . Burning
   a. Burying in a trash pit
   b. Tossing in the bush
   c. Dumping in the ocean
   d. Tossing on the beach
   e. Recycling (plastic, glass, paper, etc)
   f. Composting
   g. Trash collection
5. What type of trash do you dispose of at home?
6. Is the trash on the beach good or bad?
7. Why? *(In reference to question 6)*
8. Where does the majority of the trash on the beach come from?
   . The resorts (staff and visitors)
   a. The village
   b. The ocean (ships, islands, etc)
9. How long have you lived in Ushongo?
10. In the time that you've lived here, do you think the trash level on the beach has increased, decreased, or stayed the same?
11. What do you think has caused that? *(In reference to question 10)*
12. What type of trash do you see the most of on the beach?
13. Have you ever been cut or otherwise injured by the trash on the beach?
14. What should be done to reduce the amount of trash on the beach?