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The abundance and composition of shoreline litter on Malapascua Island, the Philippines: approaches to the solid waste management problem.

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Abstract

The amount of waste produced globally is continuously on the increase, leading to marine debris appearing on coastlines and oceans worldwide. There have been recent solutions to help reduce waste, as well as reusing and upcycling playing a significant role to minimise waste. This study examines the amount of marine debris on the beaches of Malapascua Island, in the Philippines, as an example. By conducting beach surveys, over 5000 pieces of rubbish were collected, with the study suggesting that the beaches with the greatest levels of debris occur next to villages. This highlights how the lack of education and different attitudes on the island is leading to poor waste disposal and management strategies. As a hotspot for tourists, especially divers, Malapascua must find solutions and alternatives to the poor waste management, to keep the numbers of tourists on the increase. With the help of the NGO 'People and the Sea' and these findings, there have been some positive steps taken with the solid waste management problem.

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Abbreviations

AIC – Aikaike Information Criteria

GLM – Generalised Linear Model

IOC – Intergovernmental Oceanographic Commission

MRF – Material Recovery Facility

NOAA – National Oceanic and Atmospheric Administration

UNEP – United Nations Environment Programme

VIF – Variance Inflation Factor

Translations

(Tagalog → English)

Dimalata – non-biodegradable waste

Magamit Pa – recyclables

Malata – biodegradable waste

Sari-Sari store – convenience/grocery store

1. Introduction

1.1 Shoreline litter

The volume of debris from anthropogenic origin in marine ecosystems is ever-growing, with over five trillion plastic particles currently floating in our oceans and weighing approximately 268,000 tons (Eriksen et al., 2014). The greatest influence of high levels of debris in the marine ecosystems is due to the poor waste management and improper human behaviour, primarily littering and insufficient disposal capacity (Barnes et al., 2009). The main concern lies within the properties of plastics, due to the inexpensive costs and durability compared to other materials, however around half of the total plastics are single-use and disposed of after use (Hopewell et al., 2009). It is suggested that plastics form up to 80% of the marine debris from anthropogenic sources (Derraik, 2002). Despite plastics being able to deteriorate through photodegradation, via ultraviolet light (UV), the haline conditions of marine environments are not favourable for the breakdown of plastics in the short term (Barnes at al., 2009; Gregory, 1999). This leads to the accumulation of the debris, which converge into gyres in subtropical regions, as well as beaches and coastlines around the world (Eriksen et al., 2014). The accumulation is influenced by a number of different factors which contribute to the high levels of debris found in marine environments. The land use of the surrounding area can play a significant role in the accumulation of marine debris. For instance, large cities on a coastline can be a substantial threat to the presence of shoreline litter, as cities draw in larger population densities, potentially adding to the levels of anthropogenic waste (Galgani, 2015). Additionally, the attitudes of the people living near to the shoreline has a part to play when disposing of their waste. Recent studies have shown that different continents around the world have varying attitudes when it comes to waste management. Approximately 57% of plastic in Africa and 40% in Asia is not managed correctly and, thus, becomes litter or is burned (UNEP, 2014). Debris is found in many marine environments, with the abundance continuously increasing, however it is on shorelines and beaches where the most studies have been carried out. The focus on shorelines is primarily due to the availability of assessment, as well as aesthetic reasons – making beaches look more appealing to the human eye, especially to tourists (Galgani et al., 2015). The origin of litter found on coastal environments can be categorised into marine sources or terrestrial origin. Debris coming from a marine source includes materials from fishing, oil and gas waste and rubbish dumped by vessels.

On the other hand, terrestrial debris can originate from landfill waste, sewage and tourists or residents of the surrounding land. The lack of education of beach users may be one of the most significant influencers of marine debris levels (Coe and Rogers, 1997).

An island that faces a problem of marine debris and waste management is the island of Malapascua in the Philippines: a tropical island located in the Visayan Sea, which comprises of approximately 9.5km of coastline. The small island has an increasing population with the 2010 census reporting just under 5,000 inhabitants, however the number was estimated at around 8,000 six years later. As well as inhabitants, Malapascua is becoming an increasingly popular destination for tourists, featuring in many guide books and videos on social media. Due to the coral reefs and presence of the pelagic thresher shark (*Alopias pelagicus*), tourists are acting as an economic source for the people of Malapascua, however creating a series of issues along with it. With this increase of tourism, people are migrating to the island in seek of a source of income for their family. The economy of the island relies heavily on tourism, but fishing can also act as a source of money for others. Furthermore, the Filipino government does not provide any sponsored services. For example, there are no police on the island or any medical services available. People must travel by boat in order to seek these kinds of services. However, there are three schools on the island: two primary schools and one high school.

As with many tropical islands, it is faced with a problem of waste, with the inhabitants heavily relying on single use plastics due to the inexpensive costs. A significant proportion of the purchases on the island are carried out in small quantities, such as plastic bags and sachets to transport them from the shop to houses. This has become a larger problem more recently as the waste station that holds the rubbish from Malapascua failed to follow the law standards and was made to close in 2006. However, the station was still in use until June 2017. Consequently, the residents living in the barangay must now dispose of their own waste themselves – either taking the segregated rubbish to a collection point, burying the waste, or even burning it. The current waste disposal situation on Malapascua is a single collection point in Barrio, on the west side of the island. The use of a waste collection truck is ruled out because of the lack of paved roads on the island with people travelling around the island on mopeds or bicycles. Only communities are permitted to use the collection points, making businesses dispose of their own waste, despite producing a large proportion of the total waste on the island. Therefore, it is important to gain an improved understanding of the amount of waste on Malapascua, as well as finding out the abundancy of varying material types.

1.2 Aims and hypotheses

The overall aim of this study is to gain an initial understanding of the shoreline litter abundance and composition around the island of Malapascua. To help achieve the aim, maps will be created using GIS software, to produce illustrative results of the findings of the study. Additionally, the use of a linear model will help to identify the most significant covariates, which may affect the abundancy and weight of the litter found on beaches. A further aim is to outline and create possible strategies to help reduce the amount of waste on Malapascua, with the help of work done by People and the Sea.

The hypotheses for the study are:

- Plastics occur in a significantly greater abundance than other material types on the beaches of Malapascua.
- There is a significant relationship between the surrounding land use of a beach survey site and the abundance and weight of debris found.

2. Materials and Methods

2.1 Study locations

Survey sites were selected around the entire island, as well as the surrounding barangays, based on accessibility and the surrounding land use of the beach. In total there were 20 survey sites, carried out on Malapascua Island and on beaches on the mainland and Carnaza Island. The location of each survey site can be seen in *Figure 1*, which shows the 100m transect as well as the midpoint. Malapascua is located approximately 7km northeast of the main island, Cebu and 18km south of Carnaza Island. Surveys were carried out on Malapascua and surrounding barangays in order to record and compare the spatial patterns of shoreline litter abundance.

2.2 Survey design and methods

Surveys were carried out over a period of six weeks from July 2017 to August 2017 with each site being surveyed once, due to the study time on the island. At least two people were present during each survey to help reduce human error, with a systematic approach being used to observe and collect the rubbish in each quadrat. The beach surveys were carried out at low tide, with a mean tidal range 0.375m and a maximum of 0.6m. Carrying out the surveys at low tide provides the greatest surface area for sampling the beaches (Rosevelt et al., 2013).

The method used in the survey was adapted from the NOAA Marine Debris Shoreline Survey Field Guide (Opfer et al., 2012) and previous surveys of similar interest (Laglbauer et al., 2014; Rosevelt et al., 2013). A 100m transect was placed parallel to the sea, on the mean high tide line, along the surveyed beach. This was due to similar studies carried out previously, which indicated that this region had the greatest deposition of debris derived from the sea (Cunningham and Wilson, 2003; Rosevelt et al., 2013). The start points of each transect was randomly chosen when at the survey site, so that the start point was not selected based on cleanliness prior to the survey, which helped to eliminate any bias. The transect was divided into 50 segments all with a width of 2m, with each segment numbered from 1 to 50 from left to right. The segments ran 2m perpendicularly to the sea, therefore creating a quadrat of $4m^2$ for each divided segment. *Figure 2* is a diagram illustrating the method used in the survey. Using the random number function on Microsoft Excel, ten segments were randomly chosen to be surveyed, helping to reduce bias. The number of segments was chosen in order to survey 20% of the total transect area ($200m^2$). Ten segments, all $4m^2$, creates a surveyed area of $40m^2$ for each site. The percentage of the surveyed beach was chosen because of the limited study period. GPS locations were recorded at the start, mid-point and end of the transect for each site, using a Trimble Juno with an accuracy of 5.0-6.4m. Other data recorded from each survey site was the gradient of the beach, measured in degrees (°) from the mid-point at the side furthest to the sea, using a Nikon Forestry Pro. The width of the beach was also taken at this point using the Forestry Pro, as well as the length of the entire beach in metres (m). Another variable recorded was the frequency of beach cleans per week. This data was collected from questionnaires carried out at beach resorts and businesses. From recording the locations, maps were produced using ArcMap to illustrate the collected data for the surveyed sites as well as mapping other spatial patterns.

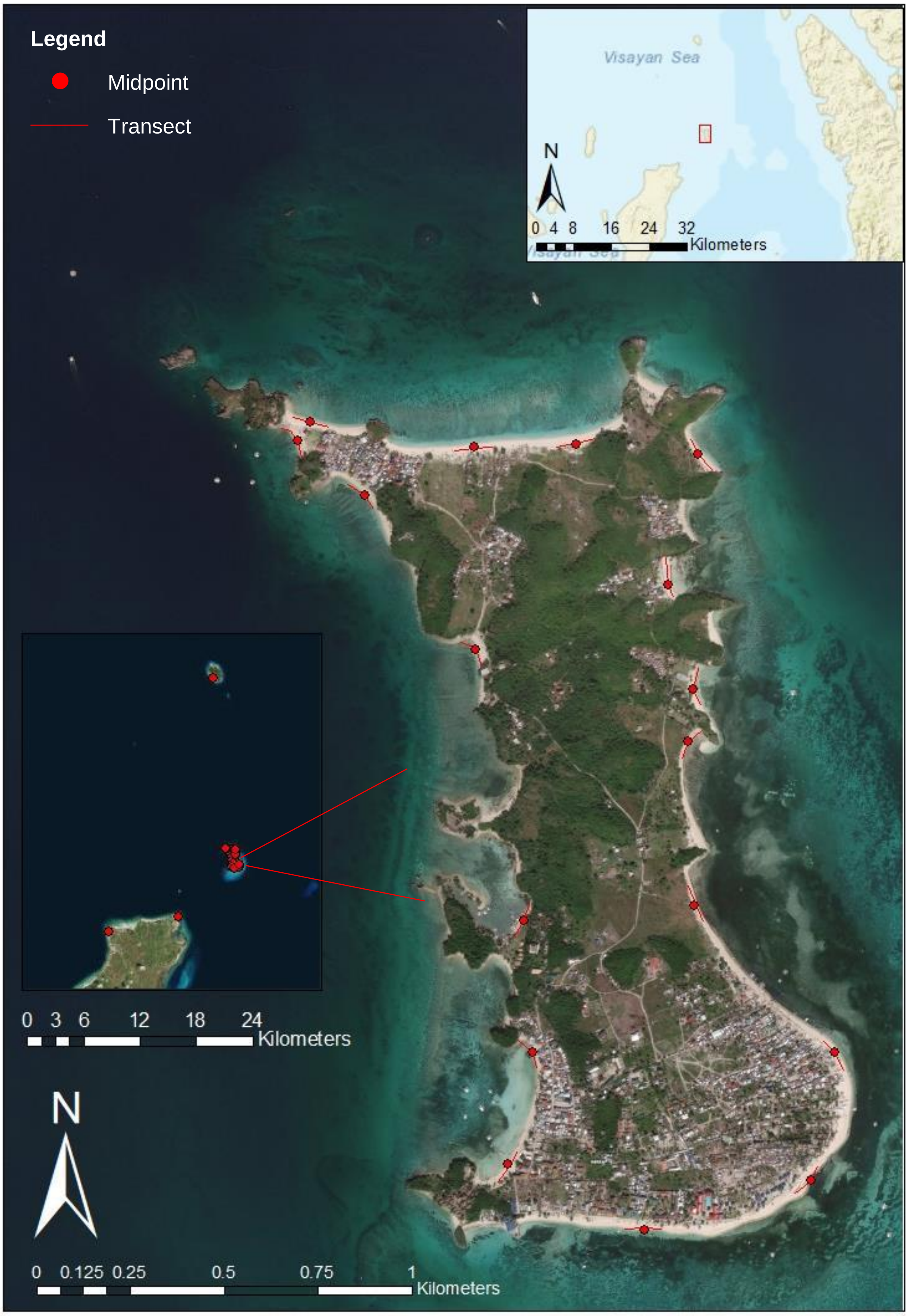


***Figure 1** A location map of the survey sites on Malapascua and the surrounding barangays: Daanbantayan and Carnaza Island.*

__Figure 2__ A diagram showing the method used to divide the 100m into fifty 2m2 quadrats along a beach sample site. Image taken by Rowell Bingham.

When observing and collecting the shoreline litter, only macro-debris (>2cm) is identified, due to debris smaller than 2cm usually being fragments of larger pieces of litter – an approach used in similar past studies (Terzi, 2017). Only debris protruding from the ground or on the surface is collected; digging under the material would require an alternative method to the survey (Frost and Cullen, 1997). The litter was recorded using a code classification system created by the UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter. For each site, a data entry form is required to record the metadata of the location (*Appendix A*).

2.3 Data analysis and assessment

Once all the litter was collected, categorised and weighed, the density was calculated using the following formula (*D = density of litter, N = total weight of litter, w = width (2m), l = length of transect (100m))*:

$$D = \frac{N}{w \times l}$$

As well as calculating the density of shoreline litter, the clean-coast index (CCI), implemented by Alkalay et al., (2007) was calculated, helping to evaluate the cleanliness of the coast. The index uses a quantitative scale in order to produce a clearer set of results for any audience to understand. It can be used a good indicator of the primary land use of the beach, such as tourist or local use. The CCI ranges from 0 - >20; very clean (0-2); clean (2-5), moderately clean (5-10), dirty (10-20), extremely dirty (>20). The coefficient of *K* = 20 was used for convenience, so that the value would not be between 0 and 1, as well as being used in similar litter studies (Portman and Brennan, 2017; Laglbauer et *al*., 2014). The density can also be classified by the following categories; very clean (0–0.1 parts/m^2); clean (0.1–0.25 parts/m^2); moderate (0.25–0.5 parts/m^2); dirty (0.5–1 parts/m^2); extremely dirty (>1 part/m^2):

$$CCI = \frac{Total\ number\ of\ items\ on\ transect}{Total\ area\ of\ transect}\ (\times K\ )$$

The method adapted from the UNEP/IOC survey included using a classification approach to the shoreline litter survey, which ranked the litter by abundancy and showed the composition of the debris found on the beach.

Furthermore, to help achieve one of the aims of this study, a linear model was created to identify the most significant covariates that may affect the weight and abundancy of the litter found on the beaches. When running the model, steps were taken to help create the results. One potential covariate for the model was material type, created using the individual debris categories, from the UNEP/IOC monitoring form. The finalised material types were plastics, foamed plastics/styrofoam, clothing, glass, metals, paper, rubber, wood and other. Other potential covariates used were primary land use, number of times a beach was cleaned (per week), gradient of the beach (°), width (m) and length (m). The land use of the survey site was recorded by using observations and using local knowledge of the surrounding area of each beach. The initial part of the model included analysing the multicollinearity between the covariates by using Variation Inflation Factor (VIF) analysis from the car R library (Fox and Weisberg, 2011). Collinearity was observed, therefore to reduce this, each covariate was removed in turn to see which had the greatest impact. From this, beach cleans, and the gradient of the beach were removed from the model. A generalised linear model (GLM) was used to fit Poisson regression models with the response variable of weight of rubbish. The response variable was scaled by 1000 to aid model convergence. Covariates of group, land use, width and length were included with no interaction terms. The model was then found to be overdispersed, which meant that the data set had a greater variability than that expected by the model. Due to the variance of the data being larger than the mean, a quasipoisson linear model was ran with the modified covariates and was checked for overdispersion again. Similarly, the data was overdispersed and a fourth model was ran using a negative binomial GLM instead, with a logit link function using the R MASS library (Venables and Ripley, 2002). Backwards model selection was run and Aikake Information Criteria (AIC) was used to determine the relative quality of the models, with a lower value indicating a better model. From a calculated value, it was suggested that the covariate ‘width’ should be removed, running a final negative binomial model. The AIC could not be improved after this model; therefore, it was chosen as the concluding model. Model validations were then run to check the model assumptions by plotting the residuals against the fitted values. Another plot was produced to help identify whether a polynomial was required for the covariate length.

From the collected data, all maps produced were created using ArcMap 10.5.1, statistical analysis was carried out using R 3.4.3 and IBM SPSS. Figures and tables were created on R 3.4.3 and Microsoft Excel.

3. Results

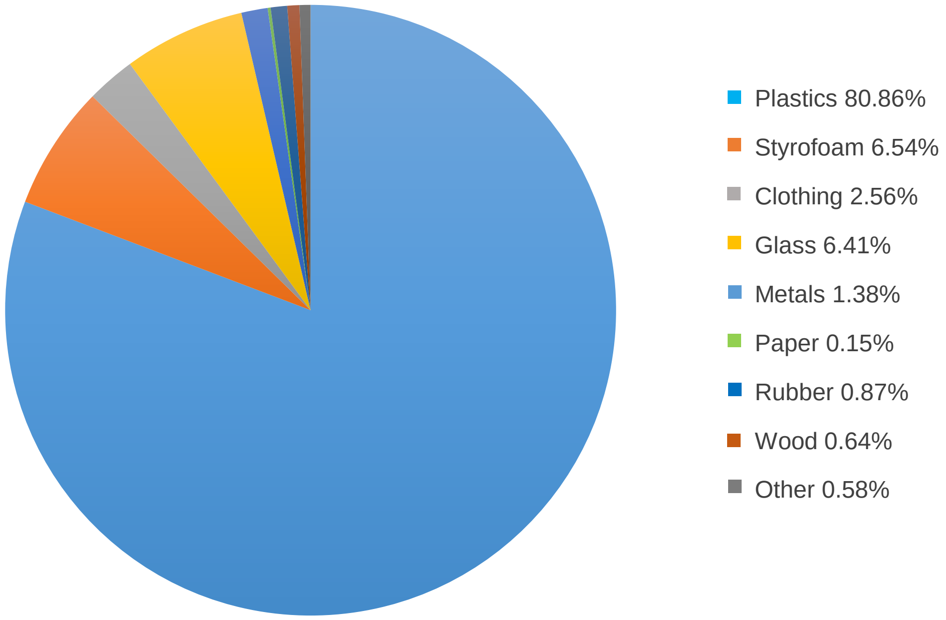
3.1 Abundance and weight composition

From twenty surveys, a total of 5183 pieces of litter weighing over 65kg was recorded over the six-week study period. These figures imply how the pieces of debris were relatively light in weight, facilitating the transport of the litter around the island. The range in debris varied substantially over the survey site locations. The largest number of items recorded was 1794 in Kalubi-An, a beach on the west side of the island used for the docking of boats (*Figure 4*). Contrastingly, the least number of items collected was 13 in the mangroves of Kabatangan. Over 80% of the collected material was categorised as a plastic, with the second most abundant material being styrofoam, amounting to only 6.5% of the total number of debris recorded (*Table 1*). As well as number of items, the weight of the material groups also plays a significant role. Plastics still had the greatest proportion of weight of the total debris collected, but making up 52.18%, instead of 80.86%. The material type that followed plastics was surprisingly, clothing, making up just over a fifth of the total weight. With clothing only comprising of 133 items out of 5183, 20% is a significant weight. Another material group with a greater weight proportion than number was rubber, making up 8% of the weight; ten times the percentage when looking at the number of items. Contrastingly, the lightweight properties of Styrofoam were observed during the survey, making up under 2% of the total weight, despite being the second most abundant material.

Using the more specific classification system, the most abundant material was plastic food containers, which accounted to 37.8% of the total debris recorded. The next most abundant category was plastic bags, making up 22.2% of all items. From the two largest categories of debris, food containers and plastic bags, 60% of all recorded items has already been accounted for, showing just how much plastic is used on the island. Moreover, the two heaviest classifications are also food containers and plastic bags. However, plastic bags had a combined weight of twice the size of food containers category with 16.7kg, whereas food containers weighed 8.8kg. Although plastics dominated the total count of the surveys, clothing makes up over 20% of the total weight collected over the samples, despite being the category with the fourth greatest abundance; making it an area of consideration when managing solid waste.

__Table 1__ The total number and weight of types of material, in order of number, collected from the 20 beach survey sites on and around Malapascua Island, expressed as a percentage.

Material Type	*n*	n (%)	Weight (%)
Plastics	4191	80.78	52.18
Styrofoam	339	6.57	1.95
Glass	332	6.43	5.87
Clothing	133	2.58	20.42
Metals	72	1.39	2.91
Rubber	45	0.87	7.03
Wood	33	0.64	3.80
Other	30	0.58	5.68
Paper	8	0.15	0.17



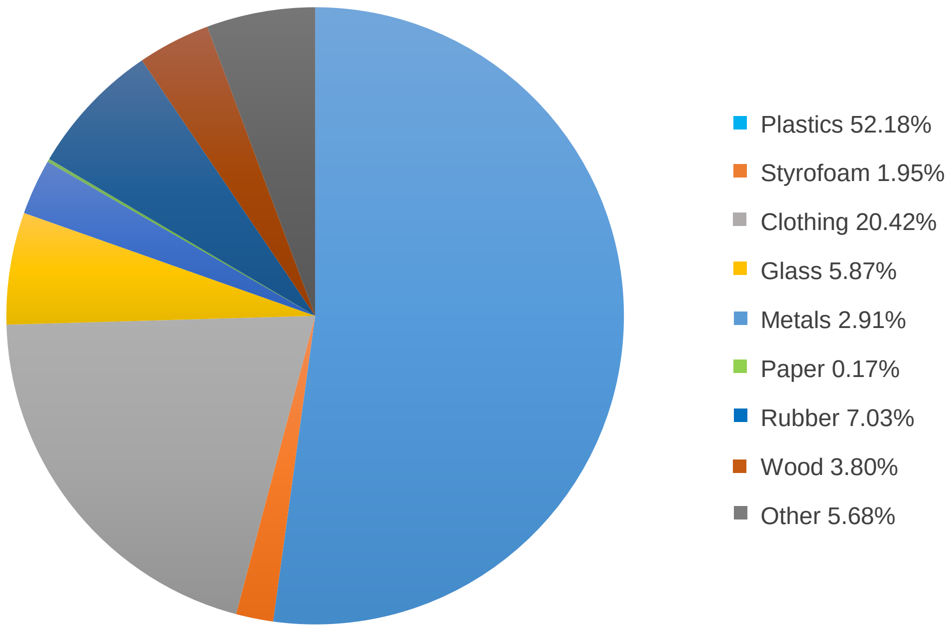


Figure 3a & 3b *(a) The number of items and (b) weight, as a percentage, of each litter material category for the 20 sites surveyed on Malapascua Island and the surrounding areas.*

Figure 4 *A photograph to show the amount of rubbish found at the survey site, Kalubi-An, with the greatest number of items recorded from the twenty survey sites. Image taken by Rowell Bingham*

Figures 5 and 6 illustrate the composition of marine debris collected for the number of items and weight. There are no obvious patterns when comparing the location and count or weight of rubbish. As distinguished earlier, plastic makes up over half the number of items for the majority of locations, with styrofoam making the next largest proportion. It can be observed that the two north west locations, Los Bamboos North and West, both have a greater amount of glass items in comparison to the remaining sites. This is also the case for the map showing the weight percentages, as glass makes up the largest proportion for a survey site out of all twenty surveys conducted. When looking at the distributions of weight over the sites, plastic makes up a similar amount to clothing, metals and other at some locations. Additionally, as expected, Styrofoam does not distinctively feature in the pie charts showing weight but features throughout in the map showing number of items. One particular location, ‘Bounty 1’, had a greater number of styrofoam items than plastic, a survey site located on the south east coastline, an area between a village and where the resorts end. Contrastingly, the corresponding survey site ‘Bounty 2’, had a different pattern to the site 200m north of it. Over half of the items and combined weight were plastic. Styrofoam was the next largest material category for number of items for this location, whilst glass made up the second largest weight. Therefore, this highlights how there is no evident pattern observed whilst looking at how the location may influence the amount of rubbish.

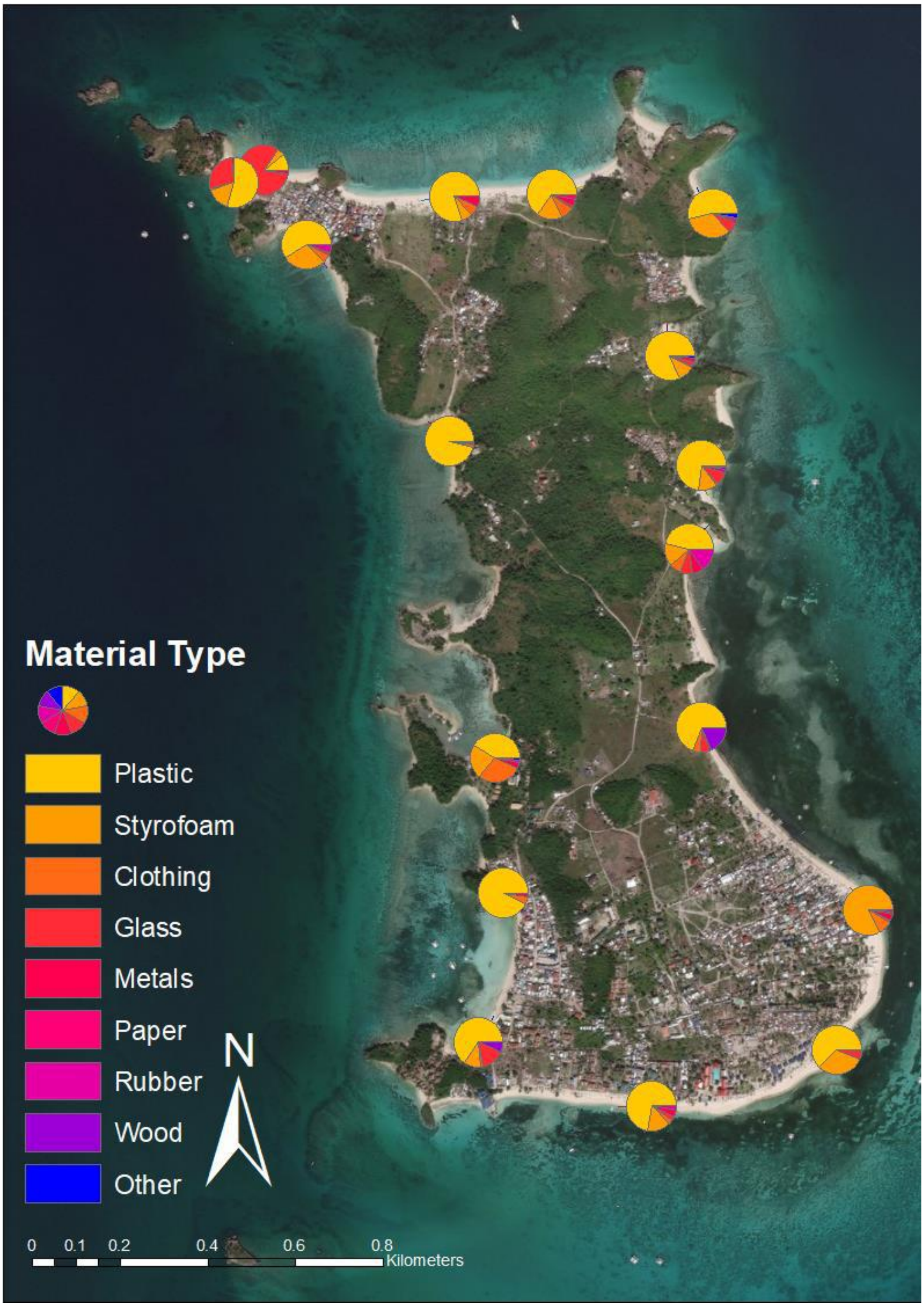


Figure 5 *A map showing the composition of debris found on the beach, based on the number of each material group. The pie charts represent the location of each survey site, with the different colours symbolising material groups.*

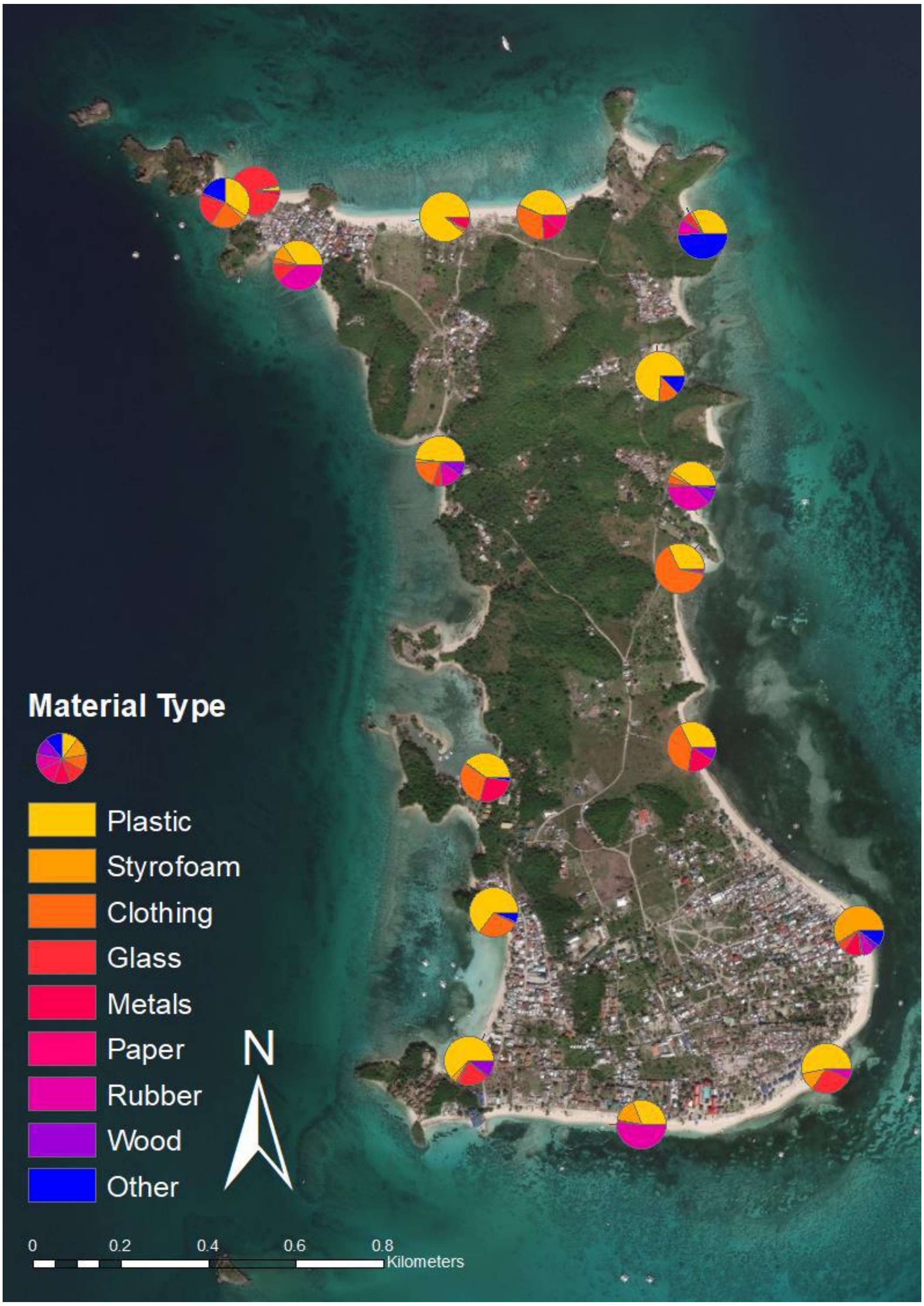


Figure 6 *A map showing the composition of debris found on the beach, based on the weight of each material group. The pie charts represent the location of each survey site, with the different colours symbolising material groups.*

3.2 Densities of debris

Figure 7 illustrates the density values of each survey site on Malapascua. The density fluctuates between 1-2 parts/m^2 for a significant proportion of the surveyed beaches. The calculated mean value was 1.29 parts/m^2 for all twenty sites. However, there is a clear outlier when looking at the results, as the calculated density for Kalubi-An is 8.97 parts/m^2, the survey site mentioned previously. In comparison to the other sites, the density was over four times that of the remaining nineteen sites. *Figure 4* is an image of Kalubi-An, demonstrating the amount of rubbish found on the sample site. The next greatest density value was for Barrio North, which had 3.38 parts/m^2, however, still under half of the Kalubi-An density. Taking this into account, the mean with the outlier removed gives a value of 0.88 parts/m^2, which is significantly less than the previous density. When calculating the mean CCI, the value equals 17.76 and using Alkalay's (2007) index, the beaches appear under the 'dirty' category, rather than 'extremely dirty' with the Kalubi-An value included. Using Alkalay's method of categorising the beaches, from very clean to extremely dirty, the definition of clean is very subjective, therefore using numerical values may be better to reduce confusion.

From recent studies in the same field, it was distinguished that the density of shoreline litter on an average beach equals 1 item/m^2 (Galgani et al., 2015), but comparing this value to other studies illustrates significant spatial variability. One major influencing factor that contributes to the variability is the size of the debris that is considered in the study. Some studies only factor in large debris (>25mm) (Jang et al., 2018) which had a value of 4.1 items/m^2 in Sri Lanka, whereas other studies record all sizes of shoreline litter which produces a density as high as 800 items/m^2 on Easter Island, Chile (Hidalgo-Ruz and Thiel, 2013). When comparing results from this study and Galgani et al (2015), the beaches of Malapascua are slightly under the 'average' beach with 0.88 parts/m^2.

Figure 7 *The densities of beach debris on the sites surveyed on Malapascua, measured in g/m³.*

3.3 Generalised linear modelling

As one of the aims of this study was to use a model to understand which covariate has the greatest influence on weight of marine debris found on a sample site, analyses were conducted using R 3.4.3 (R Core Team, 2017). Generalised linear models (GLM) were used to identify which covariates have the greatest effect on the weight of the litter found on the survey sites. Potential covariates were the material types (categorised into groups), number of beach cleans, land use, gradient, width and length of the beach. Multicollinearity between the covariates was tested using Variation Inflation Factor (VIF) analysis from the car R library (Fox and Weisberg, 2011). Table 2 indicates a high correlation between land use and other covariates (VIF = 71.6). To reduce collinearity, each covariate was removed from the analysis in turn. Table 3 shows two removed covariates, beach clean and gradient, resulting in a reduced VIF = 8.9 for land use (based on a threshold of VIF < 10). A GLM was used to fit Poisson regression models with the response variable of weight of rubbish. The response variable was scaled by 1000 to aid model convergence. Covariates of group, land use, width and length were included with no interaction terms. The model was found to be overdispersed (*theta* = 39.6), meaning that the data set had greater variability than that expected by the model. A value of *theta* = 1 for this test meant that the data were not over-dispersed.

Table 2a & 2b *(a) The variance inflation factor (VIF) analysis table for the original covariates for the first run model. (b) The variance inflation factor analysis table for the second run model, removing the two variates, producing a reduced correlation for land use. A high VIF value indicates that the variable is related to the other variables.*

Covariate	**VIF**	**Degrees of freedom (df)**	**VIF^(1/(2*df)**
Group	1.2	8	1.0
Primary Land Use	71.6	8	1.3
Beach Clean	4.6	1	2.1
Gradient	12.1	1	3.5
Width	17.7	1	4.2
Length	1.9	1	1.4

(a)

Covariate	**VIF**	**Degrees of freedom (df)**	**VIF^(1/(2*df)**
Group	1.2	8	1.0
Primary Land Use	8.9	8	1.1
Width	6.4	1	2.5
Length	1.6	1	1.3

(b)

Due to the variance of the data being larger than the mean, a quasipoisson linear model was ran with the modified covariates and checked for overdispersion (*theta* = 40.8), indicating that the data were still over-dispersed. A fourth model was ran using a negative binomial generalised linear model with a logit link function using the R MASS library (Venables and Ripley, 2002), used as the data set was strongly over-dispersed with *theta* > 20. Backwards model selection was run and Aikake Information Criteria (AIC) was used to determine the relative quality of the models, with a lower value indicating a better model. An AIC value of 1878.2 for the covariate 'width' suggested that the model would be better without the covariate. Therefore, a final model was run, removing width from the negative binomial model, producing the results shown in *Table 3b*. AIC could not be improved upon with this model. After this, the model was validated: checking the model assumptions by plotting the residuals against the fitted values for the model (*Figure 8*). A small curve was identified in the plot, showing a slight pattern, however, the plot should be random. A second plot was created to identify whether a polynomial was required for the covariate length. Similarly, there should be no pattern in the plotted graph and, in this case, no pattern was observed.

Table 3a & 3b *The table produced from a negative binomial model, showing the Aikake Information Criteria (AIC) value. A lower value suggests a better model – width has the lowest AIC, therefore should be removed. Degrees of freedom (df), Aikake Information Criteria (AIC), Likelihood ratio test (LRT)*

Covariate	**df**	**Deviance**	**AIC**	**LRT**	**P (Chi)**
All covariates		339.15	1879.8		
Group	8	375.46	1900.1	36.316	< 0.0001
Primary Land Use	8	449.07	1973.7	109.924	< 0.0001
Width	1	339.55	1878.2	0.406	0.5239
Length	1	362.17	1900.8	23.020	< 0.0001

(a)

Covariate	**df**	**Deviance**	**AIC**	**LRT**	**P (Chi)**
All covariates		339.00	1878.2		
Group	8	375.50	1898.7	36.483	< 0.0001
Primary Land Use	8	454.48	1977.6	115.459	< 0.0001
Length	1	364.12	1901.3	25.100	< 0.0001

(b)

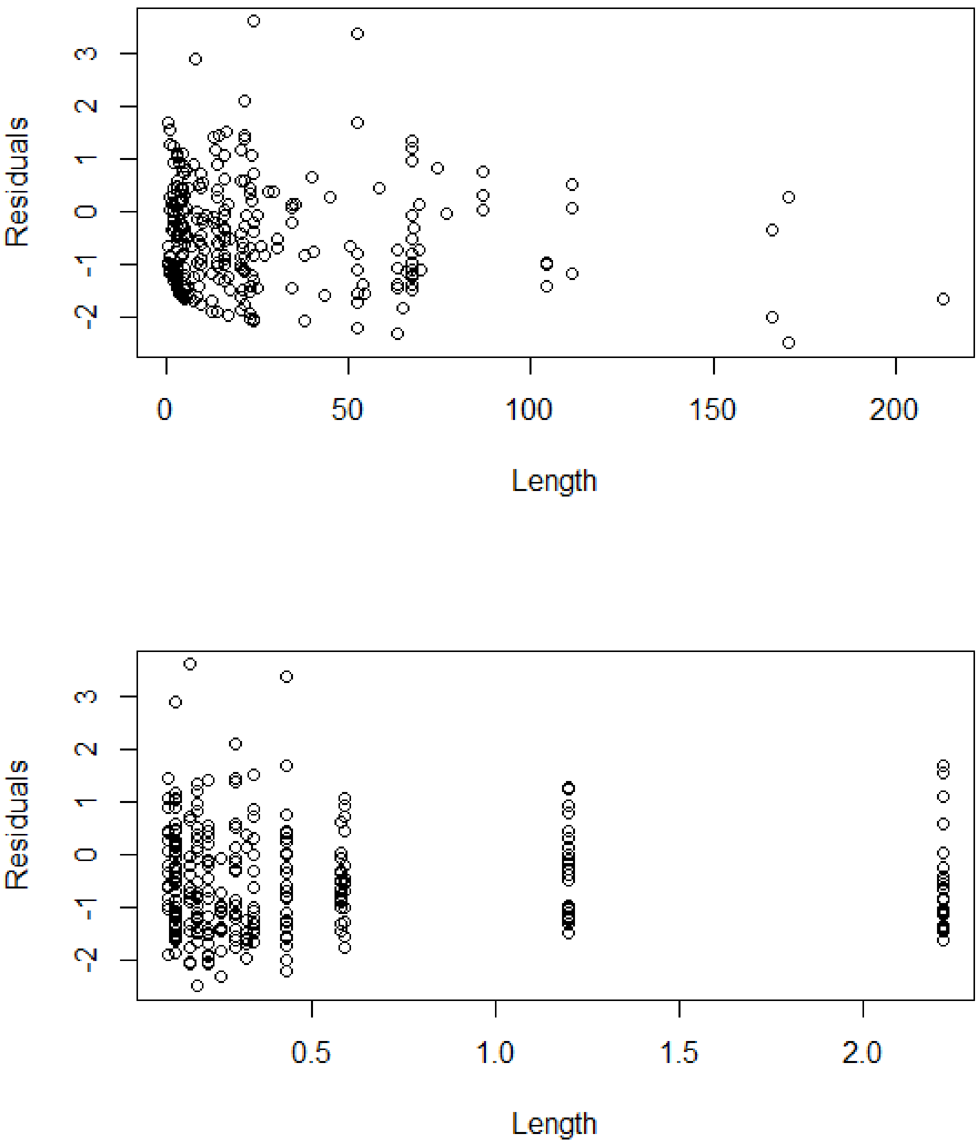


Figure 8 *Two plots to show the residuals against the fitted values for the final model (top) and a to observe whether a polynomial was required for the covariate length (bottom). However, from both plots, no obvious pattern can be observed.*

3.4 Final modelling stage

The table below shows a summary of the results produced from the negative binomial model ran using the data collected from the twenty survey sites on Malapascua and the surrounding barangays. Using the estimate value for primary land use, at a 99% (*p* = < 0.0001) confidence level that at a private beach resort, the weight of the litter on the beach is the lowest in comparison to the other types of land use. With an estimate value of -3.2, a lower negative number implies a lower weight of debris. Surprisingly, a restricted access beach and private beach resort has less weight than a beach on a marine protected area – with an estimate value of -2.4, whilst the restricted access beach has a value of -2.8. The covariate that the results are comparing to for primary land use is boat docking, which has the largest weight of all land uses, in accordance with the model. In contrast to this, the land use with the greatest weight are beaches with surrounding villages. This had the highest estimate value of -1.0 at a 100% confidence level (*p* = < 0.0001). Mangroves have the second greatest weight with a value of -1.2, also at a 99% confidence level (*p* = 0.0001).

Additionally, the material groups were also included in the model. Clothing was the material group used to compare values with the other material groups, perhaps due to the large weight in comparison to the number of items recorded. Paper and cardboard had the lowest weight, having an estimate value of -1.8 at a 99% confidence level (*p* = 0.003), which is reinforced by the low count of the material group as only eight pieces were recorded in the twenty samples. Metals were the second lowest weight category, producing an estimate value of -1.4. Likewise, this may be due to the relatively low count of 72 items recorded across the survey sites.

Table 4 The results produced from a negative binomial model using the covariates group, primary land use and length of beach. Standard error (Std. error), probability value (Pr(>|z|)).

Covariate	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	4.9	0.3	16.8	< 0.0001
Group Foamed Plastic	-1.3	0.4	-3.3	0.0009
Group Glass & ceramic	-0.5	0.4	-1.3	0.2018
Group Metal	-1.4	0.4	-3.8	0.0001
Group Other	0.6	0.4	1.5	0.1457
Group Paper & cardboard	-1.8	0.6	-2.9	0.0039
Group Plastic	-0.5	0.3	-1.8	0.0709
Group Rubber	0.4	0.5	0.9	0.3867
Group Wood	-0.4	0.6	-0.7	0.5069
Primary Land Use Closed down resort	-1.6	0.3	-5.0	< 0.0001
Primary Land Use Mangrove	-1.2	0.3	-3.7	0.0001
Primary Land Use Marine Protected Area	-2.4	0.4	-5.9	< 0.0001
Primary Land Use Port	-1.5	0.4	-3.6	0.0003
Primary Land Use Private beach resort	-3.2	0.4	-7.6	< 0.0001
Primary Land Use Resort beach	-2.4	0.3	-7.5	< 0.0001
Primary Land Use Restricted access beach	-2.8	0.4	-6.8	< 0.0001
Primary Land Use Village	-1.0	0.2	-4.2	< 0.0001
Length	-1.0	0.8	-5.9	< 0.0001

4. Discussion

4.1 Solid waste management problems

From the data analysis of this study, it is clear that plastics are the most significant problem when it comes to waste disposal and management. With over ten times the total count of the next most abundant material group, it is important that the use of plastics is reduced. The high number is most likely to be the result of single-use plastics that are used every day by the people of Malapascua. Just in the south region of Malapascua, there are 50 local businesses, all using plastics that are used once and then disposed of. These businesses include sari-sari stores, street food shops and bakeries. Items such as oil, water and other soft drinks are sold in plastic bags, allowing people to buy in smaller quantities rather than bulk for a cheaper option. Furthermore, perishable items are not the only things sold in plastic. Products like shampoo, washing powder and medicine are also sold in plastic sachets. Another anthropogenic factor that leads to high levels of litter is the lack of education of the people on Malapascua. From questionnaires and interviews carried out by People and the Sea, many people are unaware of how to dispose of waste as well as segregate their waste into biodegradables, non-biodegradables and recyclables. However, it is evident that people use upcycling to help reduce waste by reusing the recyclable product for another use. One example of this is the use of glass bottles, which can be used to create planting beds to grow fruit and vegetables. From the data collected from the questionnaire, twelve businesses are currently using this practice to help reduce the amount of waste produced. As many people think that glass is categorised as non-biodegradable, rather than a recyclable, this is a good way to upcycle old bottles. Additionally, bottles of soft drinks can be purchased in a glass bottle of a larger size, rather than a plastic bottle holding 500ml. These bottles are then returned to the shop and then refilled at the manufacturers. With over 180 plastic bottles and 250 bottle lids recorded on the surveys, educating people, especially children, to buy glass bottles that can be reused, is important as this may help to reduce the amount of plastics used.

As children are the future generation of Malapascua, it is essential that they are educated on how to correctly segregate and dispose of waste. One way People and the Sea are helping is by running weekly classes to year 5 students on waste management. To help get the children engaged, People and the Sea offer prizes, such as a snorkelling tour of the island, for completing work. There are two primary schools on Malapascua, one in the south (Barrio) and one in the north (Guimbitayan), therefore alternating schools every other week. Each class in the school in Barrio have three designated bins for biodegradable, non-biodegradable and recyclables. The school also has a Materials Recovery Facility (MRF) which holds the waste of the school until the day of collection, where it is taken to the collection point to be transported to the mainland. The MRF also has a composting facility for biodegradable waste, in which primarily paper and leaves kept. One problem the compost is facing is the presence of plastics in the composting area, thrown in the biodegradable disposal area by the school children. As well as dumping their rubbish into the compost, the school grounds are also littered with rubbish. This is due to the children not being educated on litter and waste, reinforcing the fact that education at a young age is one of the most important strategies to use. From questionnaires carried out in the villages, it is apparent that most children are better at segregating their waste than adults, due to the school classes being held. On the other hand, the waste management of the school in Guimbitayan is less known about. Each classroom has bins with segregating categories, but it is uncertain that the waste is being brought to the weekly collection point. Additionally, the pupils were less aware of the correct disposal method for rubbish, but with classes every other week it is likely that their knowledge is vastly improving.

As well as the schools disposing of waste, the communities must dispose of their waste properly. Currently, there are three days scheduled a week for waste collection, but this is dependent on a number of factors. Due to a boat being required to transport the waste from the island, the availability of a boat, the tide, weather and total amount of waste at the collection point has to be taken into account. It is unclear whether there is a collection point in the north of the island, so the waste is likely to be transported down to the south. Waste taken to the collection point must be segregated correctly and it is the owners' responsibility to take the rubbish on the designated days. Once transported to the main island in Maya, a truck collects the rubbish and the waste is segregated again by workers. The recyclable waste can be sold to scrap buyers, in an attempt to make money from disposal, whilst non-biodegradables are now taken to a landfill station in a different city. As mentioned previously, the nearby landfill site was closed down officially in July 2017 for failing to comply with the environmental law criteria.

4.2 Business association

Unlike the community, businesses of the tourist sector of Malapascua must dispose of their own rubbish, instead of using the collection points on the island. Providing a clean and aesthetically pleasing island is the goal of the resorts, to help give Malapascua a good name and increase the business. From carrying out the waste disposal questionnaire for businesses, it was established that eleven resorts have organised a collection, whereby one boat transports their waste three times a week. The resorts segregate their rubbish into the three categories, putting the biodegradable waste into a compost bin. The resorts take it in turns to pay for the boat each month, saving money and cutting down on the number of trips of the collection boat. The costs (as of 2017) are ₱2000 (£27) for the boat are four crew members and ₱100 (£1.35) to transport the rubbish from the resort to the collection point via a pushcart (van der Graaf, 2017). Since the report conducted by van der Graaf of Malapascua's solid waste management issue in 2016, four more resorts have since joined the business association for sharing the transport of waste. It was also suggested that the resorts will encourage the employees to bring their waste to the resort to be correctly disposed of. From the questionnaire asked to the resorts, it appeared that many of the staff of multiple resorts were enthusiastic about the topic of waste management and wanted to act upon the issue. With an island free of waste and clean in mind, some resorts also have enforced other techniques which help to reduce the amount of waste. Waste oil is one example of reusing a waste substance, with several resorts using waste cooking oil as fuel for candle lamps on tables. As well as this, used boat oil can also be used as a waterproof coating for roofs, thus helping to reduce the amount of waste that may have been disposed of in the collection point or even disposed of incorrectly. One resort, Exotic, have appointed a plot of land where they dispose of their own waste, instead of sending it off to the collection point. During the questionnaire, the resorts were asked to state which categories they use to segregate their waste. Exotic use a more widescale categorising method to separate the recyclables, with different waste bins for plastic bottles, glass bottles, cartons, cans and metal. In comparison to the other resorts, the categories used were usually recyclables all together.

4.3 Land use implications

Using the linear model, the findings of how the surrounding land of the beach is used can have an impact on the weight of debris found. With the private beach resort having the smallest weight, in comparison to others, this is likely to be down to the accessibility of the survey site. Upon entry of the beach, security was at the entrance of the resort, usually only allowing resort guests access. As well as this, the amount of beach cleans would have an impact on the weight of the rubbish. Using the data from the questionnaire, the private beach resort 'Thresher Cove' clean the beach once a day. Although it was not included in the model, beach cleans are likely to have an effect on the amount and weight of rubbish of a survey site. With this in mind, the most cleaned beaches on the island were cleaned twice a day, according to the questionnaire data. These two beaches had a relatively low debris count and weight, having a total of 51 and 41 items recorded, weighing 0.5kg and 0.2kg. On the other hand, the least cleaned beaches were cleaned twice a week, however each resort only cleans the beach that is adjacent to their land. With a large proportion of resorts located on Bounty beach, the amount of beach cleans would have a varying effect on the cleanliness of each resort. Additionally, external factors would have to be considered, such as the number of people who drop litter in the area, wind strength and prevailing direction, as well as the tide.

In contrast to this, the model implied that the beaches with the greatest weight of litter were those next to a village. Similarly, external factors must be considered when looking at the data, however in the length of this study period, the data for these factors were not able to be collected. The beaches next to a village appeared to have fluctuating debris counts and weights. This was also the case in similar research studies, in which more built up areas had less debris densities, primarily due to beach clean-ups (Leite et al., 2014). In contrast to this, other studies found that more urbanised beaches had higher densities of debris, perhaps because of the higher population in an urban environment (Andrades et al., 2016).

The largest amount of debris next to a village was 311 items, weighing 1.7kg, whereas the least amount was 15 and only 0.06kg. The location of the survey site is likely to have the greatest influence on the amount of rubbish. The beach with 311 items, Pasil, was located on the south east of the island, whilst the cleaner beach, Guimbitayan, was on the north coast. Guimbitayan was one of the villages included in the waste management questionnaire, which suggested that 80% of the residents bury their non-biodegradable waste, whilst the remaining 20% burn the waste. Using burying as a disposal method may lead to less rubbish ending up on the beaches, however creates a problem for the future generations. By burying their waste, people believe it is a cheap and efficient method to dispose of rubbish. A further problem on the island is the absence of rubbish bins, leading to people dropping their waste on the streets whilst out. The rubbish created by the lack of bins may be one of the sources of debris that ends up on the beach, therefore providing bins could help to reduce the levels of beach debris. Segregated bins are available around the tourist areas, in the south of the island, proving that they may be a solution to mitigate the problem. However, from personal observations it was clear that people, especially children, do drop their litter on the floor despite a bin being close by. As mentioned previously, education is one of the most important solutions to help reduce the levels of waste ending on the beaches of Malapascua. By carrying out classes on waste management, to children in the primary school, the amount of debris may be significantly less in the future; however, this is highly dependent on the attitudes of the people on the island.

4.4 Positive trends and possible solutions

Despite the high levels of beach debris around the island, positive trends have been observed over the past two years in waste collection and attitudes. From a report created by People and the Sea (2017) it has been noticed that the waste boat collection is running more frequently, suggesting that more people are perhaps segregating their rubbish as well as using the collection system instead of burning or burying their waste. A possible solution to further this progress of waste management is to improve the education of the island. Workshops carried out by resorts can help the people of the villages to learn how to manage and dispose of their waste correctly. Nevertheless, as reducing the amount of single-use plastics may be very challenging on a developing island, a possible solution to this may be to inform the people of Malapascua how to reuse or upcycle their waste. One method used by People and the Sea is to shred plastics to use as a pillow or beanbag filler, as an alternative to styrofoam filling.

As well as non-biodegradables, biodegradable waste must be disposed of to help reduce the amount of waste that is transported off the island. The local government authority announced that biodegradable waste should not be part of the waste collection. In addition to this, incorrect disposal of biodegradable waste can lead to waste contamination such as attracting insects and stray dogs, which are in abundance on the island. Although most people know that food waste can decompose, many people of Malapascua are unaware of composting and how food waste can be used to help produce high-nutrient soil. With the island creating nutrient poor soils of a sandy composition, producing a more fertile soil can be helpful for people living in the villages. During the study period, a workshop was hosted by People and the Sea to one of the resorts in order to teach the staff how to set up a compost, as well as providing a 'starter kit' to help get the compost running. As well as resorts, People and the Sea also offer the starter kit to residents of the villages, with an increasing amount of people knowing about composting. As of 2017, over 100 families are using a form of composting with the help of the NGO's compost kit. In return for creating the nutrient-rich soil, People and the Sea offer families to generate income by selling the compost to either themselves or resorts. After gaining an understanding of the debris groups that appear in greatest abundance, it is important to try to reduce the number, in order to protect the fragile coral reef ecosystems that occur around Malapascua. There have been several actions implemented to help manage waste on the island. One method used to help reduce the rubbish is beach clean ups. A community event ran by People and the Sea on a weekly basis, which draws in people of all backgrounds to pick up litter from a different beach with the help of diving resorts. Despite plastics being the most abundant group in terms of frequency and weight, textiles make up the second greatest weight, using results from this study. Additionally, textiles had a relatively low frequency in the beach surveys, thus, making it a significant material type to manage on the island. However, unlike plastics, fabrics do decompose at a faster rate, but can also be upcycled to reduce the amount of waste. Stall-Meadows and Goudeau (2012) indicated how all items of household clothing and textile items can be recycled in some way. Although this is the case, 85% of clothing items in the United States of America end up in landfill (Council for Textile Recycling, 2014; Weber et al., 2016). This demonstrates the lack of awareness of recycling of clothes, not just in the Philippines but worldwide too. A study focusing on the habits of fashion disposal suggested how people are aware of the mass production of clothing, as fashion trends are continuously changing, however few are aware of the potential environmental or social impacts this may have. Furthermore, the study implied that the sample felt that any steps taken to reduce textile waste would prove to be insignificant in the long term (Morgan and Grete, 2009). Therefore, this indicates how the disposal of textiles is more unfamiliar than plastics and other recyclables, despite being a significant debris type in this study.

4.5 Future studies

Additionally, this study was the first comprehensive study of shoreline marine debris on Malapascua, therefore provides an initial understanding of the extent of the waste disposal problem. Only larger debris was collected during the surveys, as well as only collecting debris found on the surface. Including micro-debris and debris below the surface of the sand would require a different methodology, presenting a whole new study. However, microplastics and fragments creates another major problem for the marine environment, highlighted through past studies (Andrady, 2015; Pasternak et al., 2017). This study was a cost-effective and efficient way to gain a better understanding of the levels of litter around Malapascua, using a standardised method that can be carried out by a non-specific audience. However, due to the study time on the island of seven weeks, only one study was carried out for each site, rather than multiple repeats over time to create litter levels temporally as well as spatially. Various factors may have influenced the results depending on the time of year the study was carried out. Previous research in the field indicates that the amounts of marine debris varies with currents, tides and the typhoon season. Eriksson et al. (2013) indicated how more focus has been placed on developing efficient methods to survey marine litter on beaches rather than investigating how the trends and estimates of debris are dependent on the frequency of samples carried out. Therefore, to help further this study, beach surveys at the same sample sites can be carried out at different times of the year. Environmental and anthropogenic factors may create varying results at different points throughout the year, producing temporal results to help identify the most influencing factors on beach debris. One environmental factor that was not used in this study was the tides, as sufficient data could not be found. The tides around Malapascua may have had an impact on the results and should be considered during possible future studies. Furthermore, repeating the study can help to track any positive progress with the abundance and weight of beach clean in the years to come.

5. Summary

To conclude this study, Malapascua is an island facing a problem with waste management, particularly with the reliance upon single-use plastics as well as the closest landfill site closing on the mainland. As this study was the first of its kind on the island, the aim was to gain an understanding of which materials make up the greatest abundance and weight of coastal debris. It was expected that plastics dominated both the abundance and weight of the survey sites around Malapascua. From the creation of maps, using GIS software, this hypothesis was accepted as plastics made up over 80% of the total collected items and 50% of the total weight. Surprisingly, clothing and textiles contributed to a greater proportion of weight than anticipated, perhaps putting a larger emphasis on the recycling and reusing of clothing to help reduce the weight. As an island overall, the amount of debris is a problem in particular locations, however this could be due to more environmental factors than anthropogenic. To help reduce the amount of rubbish, with the help of the NGO People and the Sea, correct disposal of biodegradable waste is essential. With over 100 families using composting, less biodegradable waste will be transported to the landfill facility on the mainland. It was recognised that providing education on waste management to people of all ages is an effective strategy to help reduce the waste on the island. With People and the Sea presenting lessons to both Year 5 primary school classes, the children are likely to have a greater knowledge than the current generation on how to cut down on waste. As well as People and the Sea, resorts could also carry out workshops to people of the villages, educating them in the reduction of solid waste. Additionally, it is encouraging to see that some sari-sari stores around the island are holding plastic-free days, where customers must bring their own bag to transport their groceries from the shop to their house.

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Appendices

Appendix A

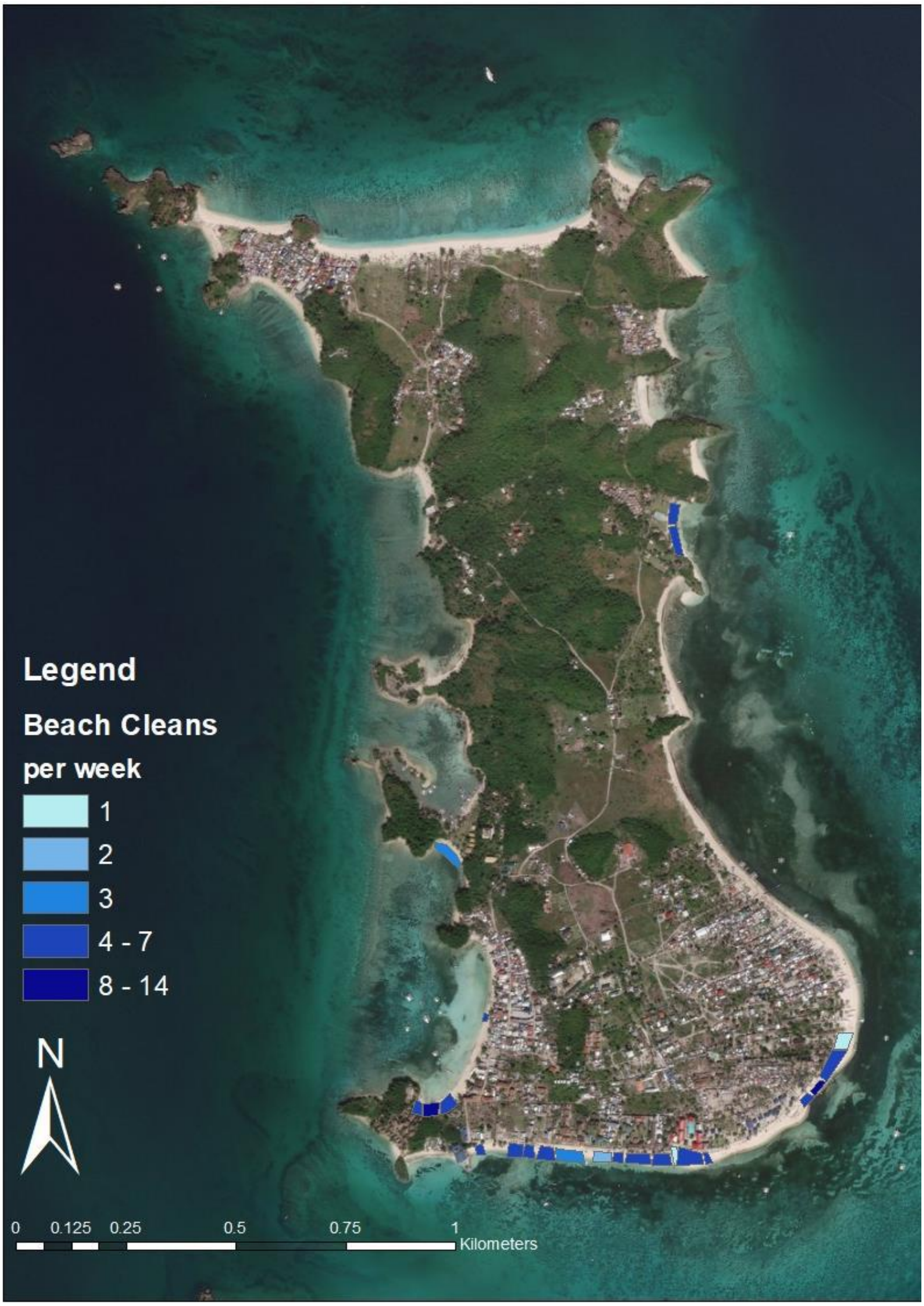
The classification system used in the study to categorise the debris found on the survey sites, taken from the UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter.

Number	Material	Code	Litter type
1	Plastic	PL01	Bottle caps & lids
2	Plastic	PL02	Bottles < 2 L
3	Plastic	PL03	Bottles, drums, jerrycans & buckets > 2 L
4	Plastic	PL04	Knives, forks, spoons, straws, stirrers, (cutlery)
5	Plastic	PL05	Drink package rings, six-pack rings, ring carriers
6	Plastic	PL06	Food containers (fast food, cups, lunch boxes & similar)
7	Plastic	PL07	Plastic bags (opaque & clear)
8	Plastic	PL08	Toys & party poppers
9	Plastic	PL09	Gloves
10	Plastic	PL10	Cigarette lighters
11	Plastic	PL11	Cigarettes, butts & filters
12	Plastic	PL12	Syringes
13	Plastic	PL13	Baskets, crates & trays
14	Plastic	PL14	Plastic buoys
15	Plastic	PL15	Mesh bags (vegetable, oyster nets & mussel bags)
16	Plastic	PL16	Sheeting (tarpaulin or other woven plastic bags, palette wrap)
17	Plastic	PL17	Fishing gear (lures, traps & pots)
18	Plastic	PL18	Monofilament line
19	Plastic	PL19	Rope
20	Plastic	PL20	Fishing net
21	Plastic	PL21	Strapping
22	Plastic	PL22	Fibreglass fragments
23	Plastic	PL23	Resin pellets
24	Plastic	PL24	Other (specify)
25	Foamed Plastic	FP01	Foam sponge
26	Foamed Plastic	FP02	Cups & food packs
27	Foamed Plastic	FP03	Foam buoys
28	Foamed Plastic	FP04	Foam (insulation & packaging)
29	Foamed Plastic	FP05	Other (specify)
30	Cloth	CL01	Clothing, shoes, hats & towels
31	Cloth	CL02	Backpacks & bags
32	Cloth	CL03	Canvas, sailcloth & sacking (hessian)
33	Cloth	CL04	Rope & string
34	Cloth	CL05	Carpet & furnishing
35	Cloth	CL06	Other cloth (including rags)
36	Glass & ceramic	GC01	Construction material (brick, cement, pipes)

Number	Material	Code	Litter type
37	Glass & ceramic	GC02	Bottles & jars
38	Glass & ceramic	GC03	Tableware (plates & cups)
39	Glass & ceramic	GC04	Light globes/bulbs
40	Glass & ceramic	GC05	Fluorescent light tubes
41	Glass & ceramic	GC06	Glass buoys
42	Glass & ceramic	GC07	Glass or ceramic fragments
43	Glass & ceramic	GC08	Other (specify)
44	Metal	ME01	Tableware (plates, cups & cutlery)
45	Metal	ME02	Bottle caps, lids & pull tabs
46	Metal	ME03	Aluminium drink cans
47	Metal	ME04	Other cans (< 4 L)
48	Metal	ME05	Gas bottles, drums & buckets (> 4 L)
49	Metal	ME06	Foil wrappers
50	Metal	ME07	Fishing related (sinkers, lures, hooks, traps & pots)
51	Metal	ME08	Fragments
52	Metal	ME09	Wire, wire mesh & barbed wire
53	Metal	ME10	Other (specify), including appliances
54	Paper & cardboard	PC01	Paper (including newspapers & magazines)
55	Paper & cardboard	PC02	Cardboard boxes & fragments
56	Paper & cardboard	PC03	Cups, food trays, food wrappers, cigarette packs, drink containers
57	Paper & cardboard	PC04	Tubes for fireworks
58	Paper & cardboard	PC05	Other (specify)
59	Rubber	RB01	Balloons, balls & toys
60	Rubber	RB02	Footwear (flip-flops)
61	Rubber	RB03	Gloves
62	Rubber	RB04	Tyres
63	Rubber	RB05	Inner-tubes and rubber sheet
64	Rubber	RB06	Rubber bands
65	Rubber	RB07	Condoms
66	Rubber	RB08	Other (specify)
67	Wood	WD01	Corks
68	Wood	WD02	Fishing traps and pots
69	Wood	WD03	Ice-cream sticks, chip forks, chopsticks & toothpicks
70	Wood	WD04	Processed timber and pallet crates
71	Wood	WD05	Matches & fireworks
72	Wood	WD06	Other (specify)
73	Other	OT01	Paraffin or wax
74	Other	OT02	Sanitary (nappies, cotton buds, tampon applicators, toothbrushes)
75	Other	OT03	Appliances & Electronics
76	Other	OT04	Batteries (torch type)
77	Other	OT05	Other (specify)

Appendix B

The number of beach cleans illustrated through the varying shades of blue. Data was collected through a questionnaire asked to the resorts around the island.



Appendix C

A map showing the known land uses around Malapascua, indicated by the different colours. Data was collected from local knowledge, as well as observations when walking around the island. Focus was on the south of the island as this is the area of greatest tourism, however there are more shops and street food buildings in the northern part of the island.