Centre for Environment Fisheries & Aquaculture Science

Cefas

Commonwealth Litter Programme - Belize

Marine litter monitoring and monitoring training report

Author(s): Briony Silburn, Bryony Meakins, Josie Russell, Fiona Preston-Whyte, Dr Umberto Binetti, Dr Nanne van Hoytema, Peter Kohler

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Project Manager:	Julia Baker (PM), Thomas Maes (PI),
Report compiled by:	Briony Silburn, Bryony Meakins, Josie Russell, Fiona Preston-Whyte, Umberto Binetti, Nanne van Hoytema
Quality control by:	Peter Kohler (CLiP Country Lead)
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Executive Summary

Marine litter has been recognised by science, government and the public as one of the most urgent global issues. The vast majority of marine litter consists of various types of plastic. Plastic is cheap, strong and lightweight, all these properties make plastic abundantly useful for human activities, but these same properties make it a global threat when it enters the environment. Plastic items can trap and constrict many forms of life, can be ingested by animals and transport invasive species. Photodegradation, oxidation and mechanical abrasion, slowly fragment plastic and it can persist in the marine environment for a long time, as well as being transported long distances by ocean currents and winds due to its low density.

Understanding the issue of marine litter requires knowledge on quantities, composition and distribution across geographic regions. This report presents marine litter data collected in Belize in May and June 2019, during the Commonwealth Litter Programme (CLiP) by Cefas scientists and trained volunteers. Sampling was centred around the population hotspot of Belize City, including sampling of the Belize River and its tributaries. The data collected in this study are intended to provide the Belizean government with an understanding of the magnitude and the criticalities of marine litter in their nation and the capability to produce a baseline to evaluate the efficiency of planned legislative measures.

Beaches were surveyed along the Belizean coast to the north and south of Belize City as well as at offshore Tobacco Caye. An urban canal and storm drain were surveyed in Belize City to look at urban litter composition and the Belize River was monitored at multiple locations upstream from Belize City. The analysis of litter composition was conducted using a protocol with standard categories used previously in CLiP surveys which was amended to include items specifically abundant in Belize (e.g. plastic drinking water pouches). The top 30 item categories were compared between locations by abundance and weight and standardised per 100 m beach length. Several of the beach sites, one river site and the storm drain were surveyed repeatedly to calculate accumulation rates of litter abundance over time.

The surveys were also used to train local stakeholders in the survey protocol to build in country capacity for a continued monitoring programme. Eight surveyors from government and business were trained in the methods, including health and safety aspects, as well as the use of monitoring equipment.

The composition of litter found across the sites was similar to that found in other regions. On average, 77 % of litter (by number of items) at a site consisted of plastic, and on most of the beaches the top item categories were unidentifiable plastic pieces and bottle caps/lids. The one exception was Belize Beach Carpark where there were abundant pieces of broken glass. This beach is commonly used for recreation and people discard litter from vehicles. This clearly indicated that besides wind and currents depositing litter, human activity in the area is a defining characteristic of litter composition. Litter weights did not show a consistent picture across beach sites because of single heavy items such as wood or clothing dominating results per beach.

A clear difference between up-river surveys and those on the coast and offshore at Tobacco Caye was that the river surveys found far lower numbers of unidentifiable plastic fragments. This could support the hypothesis that plastic items degrade at sea, breaking into abundant smaller fragments before washing back into shore, while items in the river have not yet had the chance to degrade. The survey at Tobacco Caye found similarly high numbers of those unidentifiable fragments, while typically Belizean litter items, for example the plastic drinking pouches, did not make the top 30 there.

The CLiP beach survey protocol is adapted from OSPAR, which focuses on north-western European beaches, and therefore had to be adapted for the Belizean shoreline. For example, the OSPAR method assumes at least 100 m of clear beach length, while Belize's coasts are often dominated by mangroves, leading to reduced sample areas and the mangrove trees impacting litter accumulation. Additionally, Belize's beaches had a lot of Sargassum seaweed washing in over the survey period. This is a regional problem impacting both the environment and the local tourism industry. This seaweed impacted the planned accumulation surveys, particularly at one site where the built-up seaweed prevented further litter from reaching the beach, causing that site to be abandoned for further sampling.

Table of Contents

Tables

Figures

1 Introduction

Marine litter is 'any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment' (UNEP, 2009). The presence of litter in the marine environment has been noted since the 1960s (Kenyon and Kridler, 1969), but its magnitude grew substantially in the past decades (Galgani, 2015; Watts et al., 2017; Ostle et al., 2019). The academic community, policy makers and the general public now recognise this problem as a priority and the pressure to reduce marine litter sources and find solutions for the debris that is already in the environment is mounting from all parts.

Understanding and characterising the generation and distribution of marine litter is a fundamental piece of knowledge to tackle the sources of marine litter effectively. The analysis of litter found on beaches has been used to study abundance and composition of marine litter in several geographical areas (Galgani et al., 2015). These studies showed that plastic is the main component of marine litter, accounting for the largest proportion of the man-made objects and pieces found stranded on the shoreline. Low production cost, strength, durability and lightweight nature are characteristics which have made plastic ideal for a range of manufacturing and packaging applications, but also made it a global threat to the marine environment (Kershaw et al., 2011). Photodegradation, oxidation and mechanical abrasion, slowly break down plastic in small fragments that can persist in the marine environment for a long time (Barnes et al., 2009). Plastic's low density means it can be transported long distances by ocean currents and winds, concentrating in defined oceanic convergence zones and ocean gyres (Kershaw et al., 2011; Maes et al, 2016).

This report presents marine litter data collected in Belize in May and June 2019, during the Commonwealth Litter Programme (CLiP) by Cefas scientists and trained volunteers. Sampling for marine litter was centred around the population hotspot of Belize City. Riverine litter was also sampled along the Belize River to investigate influences from other settlements up-river of Belize City. The data collected in this study are intended to provide the Belizean government with an understanding of the magnitude and the urgent need to tackle marine litter in their nation, as well as a baseline tool to evaluate the efficiency of planned legislative measures. The methodology used to collect these data (as described in section 2.1) is used in all the countries in the CLiP project and possibly in future monitoring programmes in all these countries. Data collected in accordance with this method can be fed into the United Nations Environment Programme (UNEP) as the methods are compatible. This means that a global comparison of Belizean data will be facilitated by this programme and dataset.

2 Monitoring methods

Beach and city monitoring were focused around the urban centre of Belize City, while river monitoring was conducted along the Belize River and the rivers tributaries. An overview of station locations can be seen in Figure 2.1. The aim of the surveys was to gather macro litter data from multiple locations to the north and south of Belize City, providing an insight into potential transport systems of litter entering the ocean from this large urban centre. In addition, sampling along the Belize River from the river's inland tributaries to the estuaries within Belize City will provide an insight into changing quantity of macro litter being transported downstream. Additional sampling was carried out to analyse the levels of sedimentary microplastics along the Belize River (Cefas, 2020[a]).

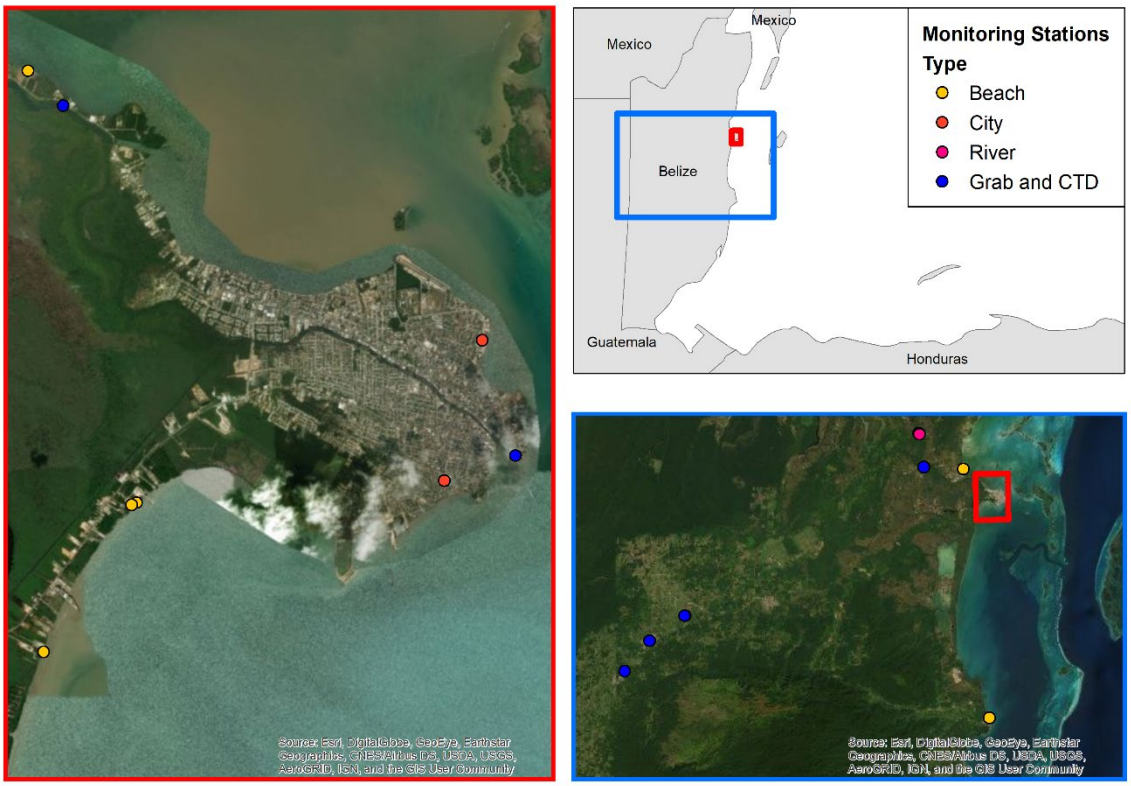

Figure 2.1: Map of monitoring locations across Belize for both macrolitter surveys (beach, city and river) and microplastic sampling (grab and CTD).

Monitoring consisted of two activities; microplastic sampling (river sediments only) and macro/mesolitter sampling, with the latter then split into beach, river and city locations (Table 2.1). The raw data is open access and can be found on the Cefas website (cefas.co.uk/data-and-publications/dois/) (Cefas, 2020[b]).

Table 2.1: Monitoring locations and dates of surveys.

Type of monitoring	Location	1st Survey	2nd Survey	3rd Survey	4th Survey
Sediment Microplastics and CTD	Succotz Ferry	22/05/2019	-	-	-
	San Ignacio Board Bridge	22/05/2019	-	-	-
	Mennonite Beach	23/05/2019	-	-	-
	Burrell Boom Bridge	27/05/2019	-	-	-
	Haulover Creek Pier	06/06/2019	-	-	-
	Belize River Northern Highway	06/06/2019	-	-	-

Macrolitter Beach	Marine Fish Farm	17/05/2019	28/05/2019	11/06/2019	18/06/2019
	Caribbean Shrimp Farm	21/05/2019	-	-	-
	Belizean Beach Carpark Beach	29/05/2019	12/06/2019	19/06/2019	-
	Belizean Beach Mangrove Bay	04/06/2019	14/06/2019	20/06/2019	-
	Manatee Sign Beach	06/06/2019	14/06/2019	19/06/2019	-
	Dangriga Beach	16/06/2019	22/06/2019	-	-
Macrolitter River	Mennonite Beach	23/05/2019	13/06/2019	-	-
	Adventure Zone Beach 1	31/05/2019	-	-	-
	Adventure Zone Beach 2	31/05/2019	-	-	-
Macrolitter City	Storm Drain BTL Park	15/05/2019	24/05/2019	10/06/2019	17/06/2019
	Collett Canal	03/06/2019	-	-	-

2.1 Material and methods

The Oslo-Paris (OSPAR) convention for the protection and conservation of the North East Atlantic (the agreement by which 15 European governments and the EU cooperate to protect the marine environment of the North East Atlantic) have produced a standardised guideline for monitoring marine litter on beaches (OSPAR, 2010). This guideline was used in CLiP as a uniform way of monitoring to allow for national interpretation of the litter and for comparisons between regions. Data collected in accordance to this protocol can be fed into the UNEP programme as the methods are compatible, as reviewed and discussed in Caporusso and Hougee (2019). The categories had already been adapted to allow for Pacific specific items in Vanuatu and Solomon Islands during phase 1 of CLiP. These categories were further developed as Caribbean specific items were added.

On Thursday 09 May 2019, CLiP convened a meeting of key monitoring stakeholders as identified by the Department of Environment. This included the Department of Environment, University of Belize, Belize Fisheries Department (but could not attend), National Hydrographic Office (but could not attend), CZMAI and Scouts Association. The site selection categories were presented to stakeholders along with some initial sites suggested by the CLiP team. Recommendations were made based on the suggestions, stakeholder local knowledge and where existing sites already existed. The CLiP team then reviewed these sites to confirm access, health and safety issues and value. Therefore, the sites

selected for this project are based on recommendations from this group, many of whom were later trained on marine litter monitoring through further involvement in CLiP monitoring.

Beaches were selected following the criteria defined in the OSPAR guidelines (OSPAR, 2010). Beaches included were selected by matching as many of the following criteria as possible:

- composed of sand or gravel and exposed to the open sea
- accessible all year round
- accessible by vehicle nearby for easy removal of items
- a minimum length of 100 m
- ideally not subject to any other litter collection activities
- free of buildings

The sites were chosen to represent a mix of environments (urban and rural) and variable distances from the capital, Belize City. The prevailing winds and ocean currents were also considered as well as distance of the beach to the nearest river mouth.

The beach surveys were carried out by experts and trained volunteers following a protocol based on the OSPAR standardised procedure for beach surveys. The survey area was defined to all operators through the identification of the high tide line (sea-side limit) and the back of the beach (the line where vegetation changed, land-side limit) as is shown in Figure 2.2. The GPS coordinates (WGS84) of the start and end point of the transect were recorded and where the beach was not 100 m in length, the length was recorded in order to normalise the data post-survey, standardising the results and enabling site comparisons. Metadata were collected using the OSPAR form and the photo guide, which is part of the guidelines, assisted the identification and classification of litter items. As a rule, information unknown or not measurable were omitted rather than guessed. All items which were visible to the naked eye were collected (> 0.5cm). All items in the defined survey area were removed.

Figure 2.2: Example of beach survey area for marine litter, as described in the OSPAR guide (2010).

After the collection, items were counted and categorised, subdivide into nine material groups: plastic, rubber, textile, metal, paper, wood, sanitary, medical and other. Items were recorded onto adjusted OSPAR survey forms, which included additional Caribbean specific items, totaling 174 individual item categories across the nine material groups. The individual item categories were then weighed using a hanging scale.

The OSPAR guidelines were also used for the river surveys, where a sandy meander on the riverbank was selected where possible and the length recorded to normalise the data to 100 m as per the standard protocol. In analogy to the beach surveys, everything between the high waterline and the vegetation was collected and categorised using the identical category list to allow comparison. The Belize River and its tributaries were selected because the river's source starts across the border in Guatemala and crosses the central width of Belize (around 120 km).

The sites for city surveys were selected in areas which are not routinely cleaned by city workers and where litter could visibly make a way into the sea via a waterway. The sites were either a storm drain or a canal, which were surveyed along the shore to the nearest boundary either side, e.g. a fence. The OSPAR guidelines and extended categories were again used to ensure data between the different surveys can be compared.

2.2 Beach monitoring locations

Sixteen beach surveys were carried out between 13 May and 20 June 2019 at six sites in Belize. Repetition of the sites varied, with four surveys conducted at Marine Fish Farm, two at Dangriga Beach, one at Caribbean Shrimp Farm and three at the remaining three sites: Belizean Beach Carpark; Belizean Beach Mangrove Bay; Manatee Sign.

A 

B 

C 

D 

E  F 

Figure 2.3: Beach survey sites A) Caribbean Shrimp Farm, B) Manatee Sign, C) Belizean Beach Carpark, D) Belizean Beach Mangrove Bay, E) Marine Fish Farm, and F) Dangriga Beach.

The sites chosen to carry out the surveys were all identified due to accessibility and location around Belize City. The sediment type and topography of each beach varied, as well as the level of Sargassum seaweed build up (Figure 2.3).

Description of the six beach sites in Belize in geographical order (North to South);

Caribbean Shrimp Farm: Located within a private shrimp farm 10 km north of Belize City and 6.5 km north of the Belize River mouth, this stretch of coastline is inaccessible to the public and completely covered by mangroves. The back of the beach was signified by a change in vegetation where there was felling of the mangroves by the farm owners. The high tide line was identified by mounding of the Sargassum within the mangroves. Litter is not removed by the farm owners along this part of the coastline. Therefore, it represents an area of natural litter accumulation. The total stretch of mangroves was 100 m, while the surveyed area was 31 m long.

Manatee Sign Beach: A rocky beach along the stretch of the coastline between Belize City and Ladyville, just 2.5 km north of the Belize River mouth. The area is surrounded by sparse residential and business premises, but sits on an undeveloped plot of land, inaccessible to the public. Litter removal does not occur at this beach and the total length was 75 m, with the survey area being 65 m in length.

Belizean Beach Carpark: A sandy beach located next to the Belize coastguard station, 3 km south of Belize City and 6 km south of the Haulover Creek mouth. The beach is popular with Belize residents for recreational use, with the back of the beach survey area being used as a car park. The beach is regularly patrolled by the police and littering was witnessed during survey. Some litter removal is performed by local outreach groups on an annual basis. The total length of the beach was 120 m, broken by some shrubbery and the survey area was 35 m long.

Belizean Beach Mangrove Bay: Adjacent to the southern end of Belizean Beach Carpark, this beach is a small sandy bay, mostly covered in a layer of old Sargassum. The beach has mangroves either side and to the rear and is not as frequently used by locals. The bay is 45 m in length, with the survey area stretching 20 m.

Marine Fish Farm: This beach is located 5 km south of Belize City and 7.5 km south of the Haulover Creek mouth, in a rural location away from built up residential areas. It is an adjacent to a disused fish farm, with a small residential property 100 m inland from the beach. The site is accessed occasionally by the public, but it not cleaned by the city council or local residents. There was a considerable build

up of Sargassum at the location, which increased in volume throughout the monitoring period. The length of beach was 66 m and the entire stretch was surveyed.

Dangriga Beach: Located 65 km south of Belize City, Dangriga Beach is the most southerly site and provides a location that is likely not influenced by input from Belize City. It is a narrow sandy beach with managed scrub before a road to the rear. The beach had one recreational seating area, with a shaded cover and is also used to load boats (wooden steps were stored on the beach). The total beach length was 100 m, but due to a collection of tyres along the water's edge influencing litter accumulation only 65 m was surveyed.

2.3 River monitoring locations

Four river surveys were carried out between 13 May 2019 and 20 June 2019 at three chosen sites in Belize. Mennonite River was surveyed twice.

A 

B 

C 

Figure 2.4: River survey sites A) Mennonite Beach, B) Adventure Zone 1, and C) Adventure Zone 2.

Description of the three river sites along the Belize River in geographical order (West to East);

Mennonite River: Located 10 km east of San Ignacio and 90 km west of Belize City and the coast. A sandy river beach 71 m long on a meander of the Belize River, this beach is popular during the summer with locals. There is a track to the river and a large grass area to park. Locals were witnessed swimming and fishing during surveys. No known cleaning takes place although there are visible 'No trash' signs and evidence of bagged waste.

Adventure Zone (1 and 2): Adventure Zone 1 and 2 are small rocky/sandy beach banks located 25 km from Belize City on adjacent river bends. Adventure Zone 1 was situated directly on a river bend, there

is a clear path to the beach leading to a fire pit with a canoe in storage. The fire pit was neatly packed with glass bottles and a stored pair of shoes. Adventure Zone 2 was situated just beyond the river bend, with a clear path to the bank. However, this area was clearly utilised as a latrine rather than a social gathering spot. Both beaches were just over 20 m long.

2.4 City monitoring locations

Five city surveys were carried out between 13 May 2019 and 20 June 2019 at two chosen sites in Belize. BLT Park was surveyed four times and Collet Canal once. At BLT Park the water was shallow and narrow, so litter was collected if at the surface. Collet Canal was deeper and unsafe, so litter was collected from the water edge to the end of the grass verge.

A  B 

Figure 2.5: City survey sites A) BLT Park, and B) Collet Canal.

Description of the two city sites in Belize City in geographical order (North to South);

BTL Park: This site was located in the centre of Belize City, next to a hotel and at the side of a children's park/ play area which has food stalls and seating areas. It was a 64 m long grassy verge with a storm drain running through. The park was cleaned regularly, but not the section next to the storm drain which was the survey area. The storm drain had a mesh barrier at the end to try and reduce litter reaching sea, but also Sargassum from encroaching up the drain.

Collet Canal: This site is in the centre of Belize City in a heavily residential area. Collet Canal extends for 1.4 km though the city and the survey area was 100 m of the canal nearest the seaward outflow. The banks of this canal backed onto a busy road and both the bank and the water's edge are cleaned daily by the city municipal cleaners and the bank had been cleaned 24 hours previous to when the survey was conducted. However, litter in the canal itself flows freely out to sea and litter was observed floating down the canal during the survey. The canal is joined by smaller canals and storm water drains. This site was only surveyed once as it was found to be in an area which was cleaned regularly.

3 Monitoring training

One key goal of CLiP is to engage and involve local stakeholders to develop expertise in country, building capacity in the public sector to assess, monitor and evaluate changes in marine litter. The training activities were based on knowledge transfer between CLiP scientist and local officers, who joined CLiP beach, river and city surveys and received practical training on collection, sorting and categorisation of marine litter. Training was also carried out for grab sample collection, CTD deployment and data entry.

A total of eight officers, from a range of stakeholders including private, NGO and government sectors, were trained during the project. A summary of the type of training activities is given in Table 3.1.

Table 3.1. Summary of Training Activities in Belize for the CLiP monitoring programme.

Institution	Beach monitoring	City monitoring	River monitoring	Data training	CTD deployment	Grab deployment
CZMAI 1x male	X	X	-	X	X	X
Department of Environment 1x male, 2x female	X	-	X	-	X	X
Bowen & Bowen Ltd. 1x male	X	-	-	-	-	-
BATSUB 2x male	X	-	-	-	-	-
Tobacco Caye Marine Station 1x male	X	-	-	-	-	-

3.1 Beach, city and river monitoring

The training during beach and river litter monitoring included a demonstration of site risk assessment, the definition of the survey area (e.g. high tide line to back of the beach), the active collection of items, their sorting with the explanation of the groups and the categorisation guidelines, counting and weighing. Frequency of ongoing monitoring surveys were discussed, and recommendations made to capture seasonal changes in litter. Initial data recorded from trainee's ongoing monitoring is included as a subsection of the results in Section 4.4.

Officers were also trained in the safe deployment, recovery and maintenance of an RBR Concerto handheld CTD and the correct procedure for using a mini Van Veen grab for sediment sampling for PSA and microplastic analysis.

Figure 3.1: Monitoring training with local officers.

3.2 Data training

Local officers were taken through the process of entering monitoring data with the importance of data management explained. Participants were taken through the data entry, including the metadata. Participants were given a simplified data entry spreadsheet that produced simple graphics for each survey logged.

3.3 Equipment left in country

In order to facilitate operations, the following gear was left at E and C office to be used in future monitoring:

- 3 x 50 m measuring tape
- 2 x wooden clipboards
- 3 x metal buckets
- 2 x digital scales
- 1 x needle scale
- 6 x cut gloves

A digital copy of the spreadsheet used to log litter counts and metadata was also provided.

4 Monitoring results

4.1 Beach monitoring overview

Over the six-week monitoring period, every beach was revisited at least once to assess litter accumulation. Five of the beaches were surveyed as repeat visits (between one and three times), and the resulting accumulation rates calculated. The exception was Caribbean Shrimp Farm where, on returning to the site, it was noted that the increased accumulation of Sargassum entangled in the mangrove roots was preventing litter from being deposited on the beach beyond the high tide line. Therefore, no repeat survey was performed, and no accumulation rate has been calculated.

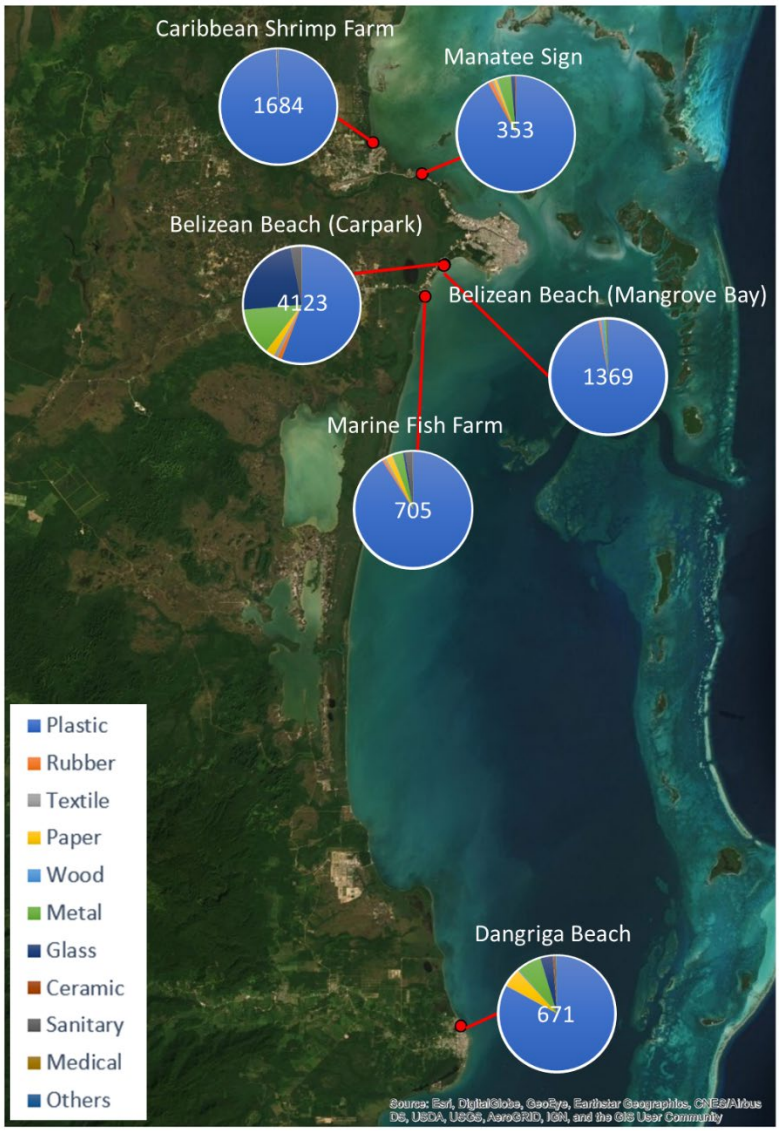

Figure 4.1: Map of T1 beach surveys, with results split by material type (count). The total number of items collected is indicated by the value.

The baseline beach surveys (T1) are presented in Figure 4.1. At all of the sites, plastic was the most numerous material category, equating to >80 % of all litter items removed at five of the six beaches. The exception was Belizean Beach Carpark, where plastic only accounted for 56 % of the composition. This was also the most touristic site, suggesting the non-plastic litter present at the location was brought onto the site by visitors rather than from marine sources, for example the increased amount of glass as a result of soft drink and alcohol bottles. This is also supported by the results from the adjacent site, Belizean Beach Mangrove Bay, where plastic was numerous, but the location was not heavily used by the public.

The top 30 most abundant item categories across the six T1 surveys are reported in Figure 4.2. Of these top 30, 22 are in the plastic material category. In most cases, the remaining item categories summed made up <10 % off the remaining litter items, apart from at Manatee Sign where this was closer to 20 %. 'Plastic pieces 0-2.5 cm' and 'plastic pieces 2.5-50 cm' were the two largest item

categories, making up between 26 % (Belizean Beach Carpark) and 57 % (Caribbean Shrimp Farm) of the composition by number. However, the prevalence of these two categories was reduced as some sites, for instance 'glass broken' at Belizean Beach Carpark and 'foam sponge (foam cups/food packs and trays) 0-2.5 cm' at Dangriga Beach.

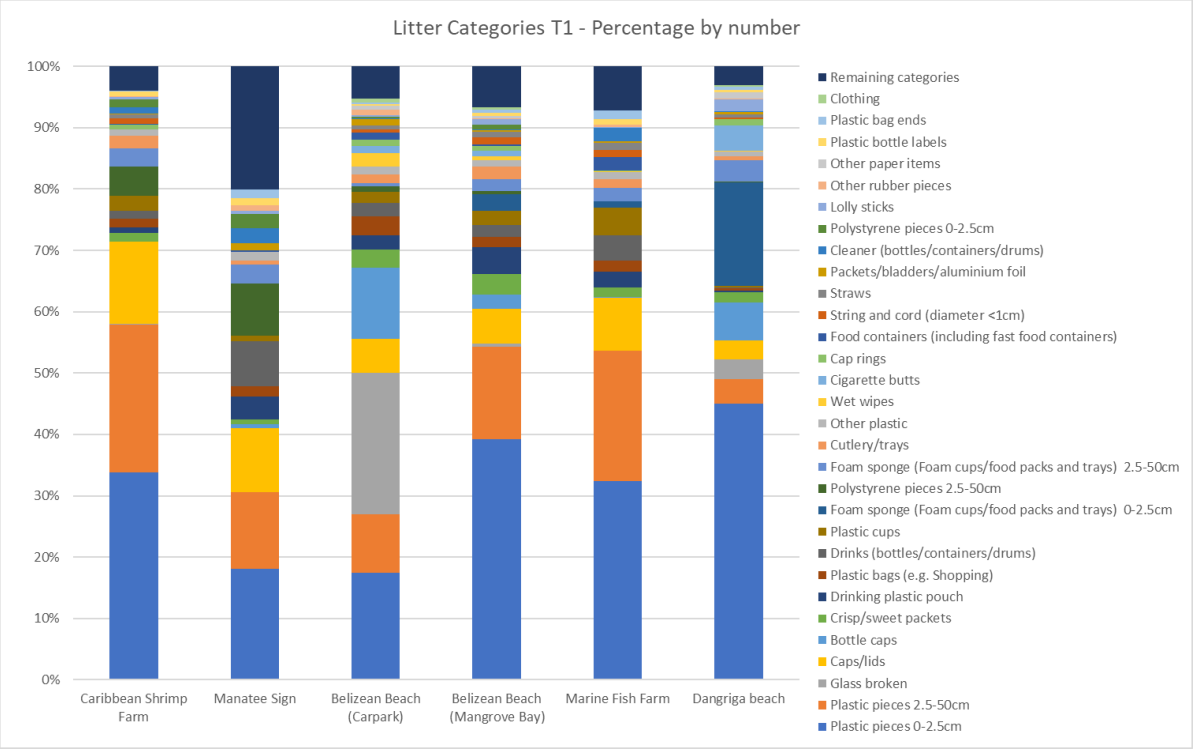

Figure 4.2: Top 30 most numerous item categories across all T1 beach surveys, presented as count percentage.

The results are normalised by beach length, giving the number of items per 100 m in Figure 4.3. Here there is a significant difference between the beaches, on a scale greater than an order of magnitude, where the beach with the least litter has 543 items, while the beach with the most contains 6804 items. Manatee Sign has the fewest items per 100 m, potentially caused by the rocky nature of the beach causing smaller items of litter to become hidden under the large rocks and gravel particles. The highly touristic beach, Belizean Beach Carpark, has the highest number of items per 100 m, likely due to the higher level of recreational activities and therefore littering that occurs at the location. Caribbean Shrimp Farm and Belizean Beach Mangrove Bay are both likely influenced by the presence of the mangroves that trap a greater numbers of litter items per 100 m.

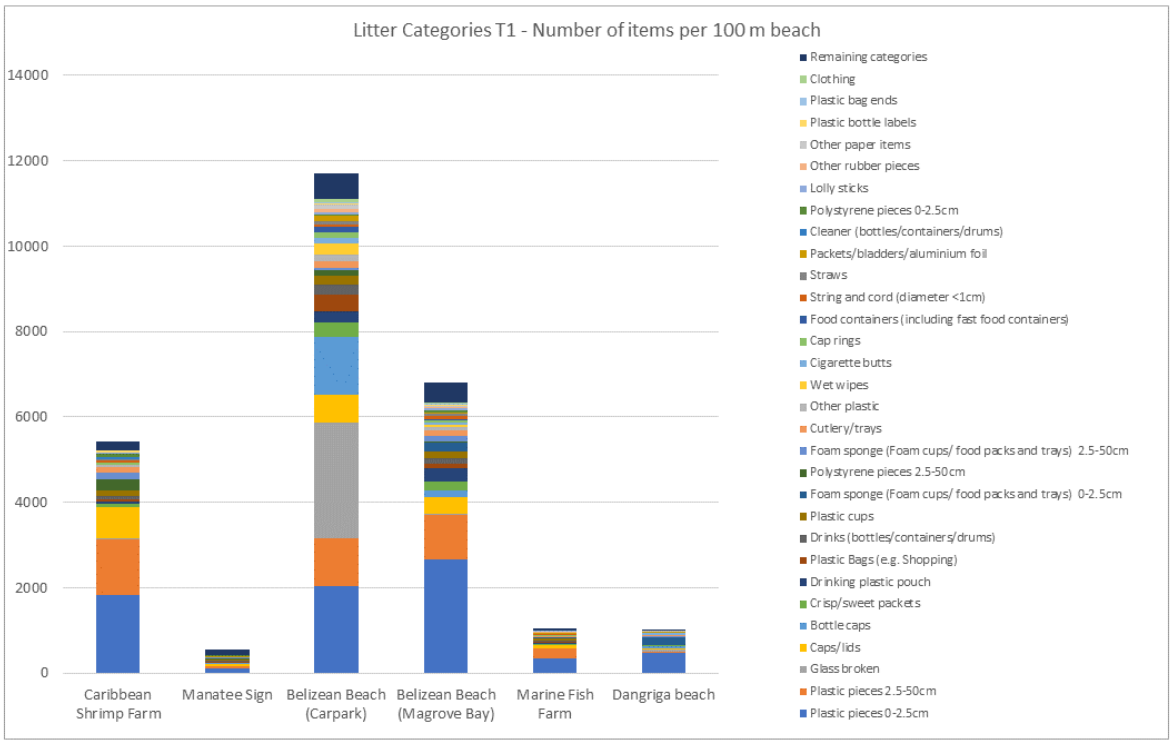

Figure 4.3: Top 30 most numerous item categories across all T1 beach surveys, presented as count normalised to 100 m beach length.

The top 30 most abundant item categories by weight are presented in Figure 4.4 and are very different to those by number. In general, there is no consistent pattern between the surveys, with only Caribbean Shrimp Farm and Manatee Sign having the same most abundant by weight category, 'plastic drinks bottles'. This is due to large, infrequent single items outweighing numerous but small item categories, in particular large metal and wooden items.

When normalised by weight per 100 m (Figure 4.5), Belizean Beach Carpark and Belizean Beach Mangrove Bay have significantly more litter by weight. These locations were also the first and second most numerous per 100 m (Figure 4.3). This suggests that large number and volume of litter items are being transported and deposited in the regions immediately to the south of Belize City in favour of the regions to the north. Dangriga, the most southern site located 65 km south of Belize City has considerably less litter by weight per 100 m, likely a result of the smaller local urban cluster and distance from the larger urban centre of Belize City, meaning only smaller items are transported that distance.

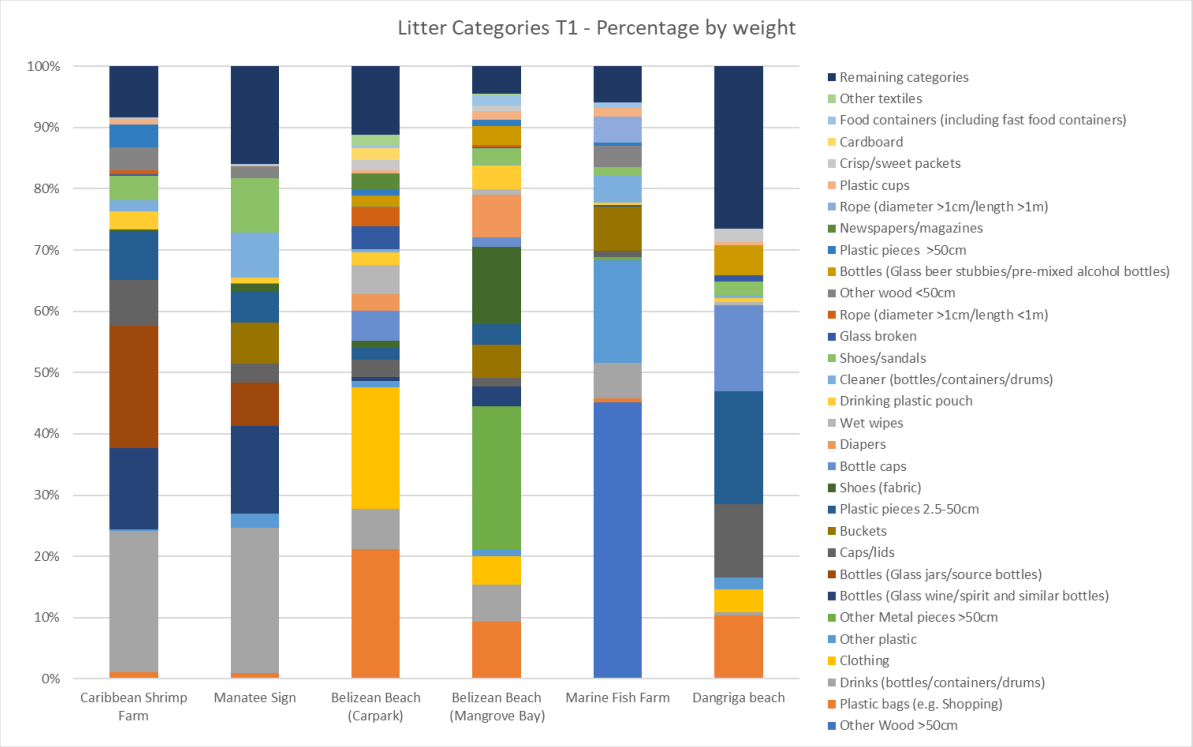

Figure 4.4: Top 30 item categories by weight (g) across all T1 beach surveys, presented as weight percentage.

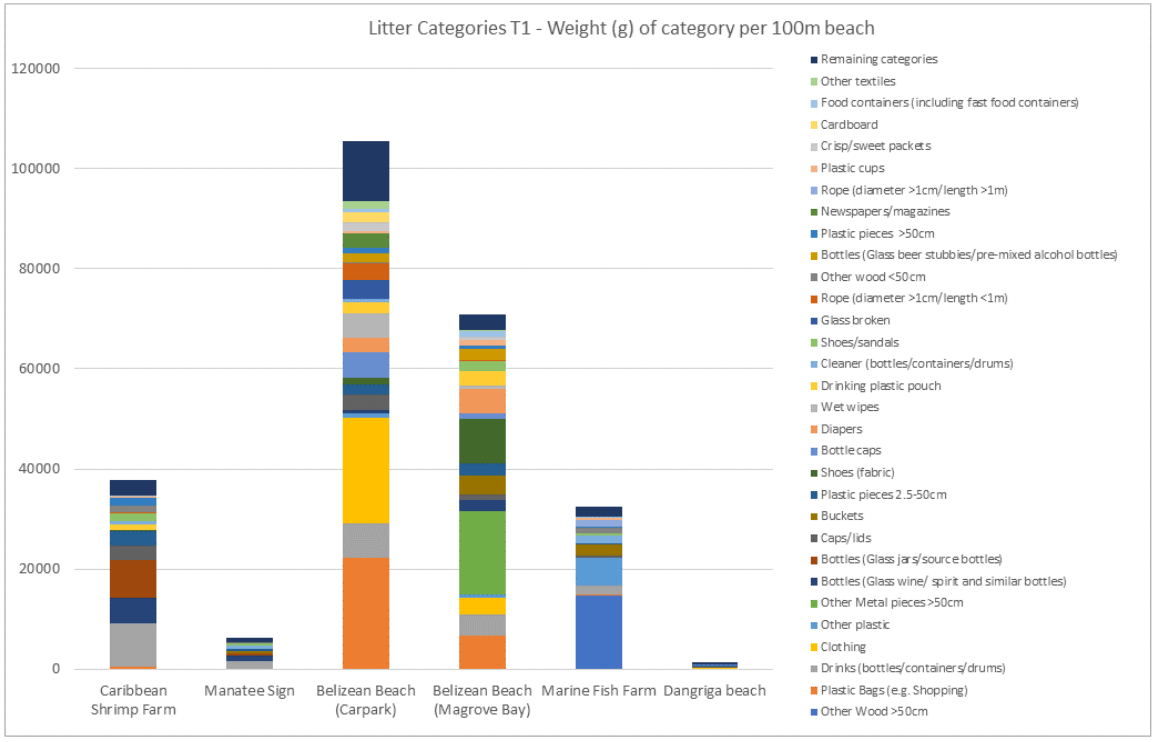

Figure 4.5: Top 30 item categories by weight across all T1 beach surveys, presented as weight (g) normalised to 100 m beach length.

The overall top 20 items by number and weight from all 16 surveys combined are displayed in Table 4.1 and Table 4.2.

The top 10 item categories equate to 71 % of the total number of items and 69 % of the weight removed, which increases to 86 % and 83 % respectively for the top 20. Of the top 20 item categories by number, only three are not in the plastic material category: 'broken glass', 'metal bottle caps', and 'cigarette butts'. In contrast, less than half of the item categories in the top 20 by weight are in the plastic material category.

For a more detailed breakdown of the top 10 items at each site per survey, see Appendix 1.

Table 4.1: Overall top 20 item categories by count (all surveys) at the marine beach locations.

Item Category		Mean % Composition	% Cumulative
Top 10 Items	Plastic pieces 0-2.5cm	28.83	28.83
	Plastic pieces 2.5-50cm	10.84	39.67
	Caps/lids	6.10	45.77
	Broken glass	4.84	50.61
	Foam sponge (Foam cups/food packs and trays) 0-2.5cm	4.24	54.85
	Crisp/sweet packets	3.56	58.41
	Drinking plastic pouch	3.47	61.88
	Foam sponge (Foam cups/food packs and trays) 2.5-50cm	3.21	65.09
	Plastic bags (e.g. Shopping)	3.03	68.12
	Metal bottle caps	2.98	71.10
Top 11-20 Items	Polystyrene pieces 0-2.5cm	2.80	73.90
	Drinks (bottles/containers/drums)	2.35	76.25
	Plastic cups	1.81	78.06
	Polystyrene pieces 2.5-50cm	1.78	79.84
	Cutlery/trays	1.35	81.18
	Cigarette butts	1.20	82.39
	Other plastic	1.20	83.59
	Small plastic bags (e.g. freezer bags)	0.94	84.52
	Food containers (including fast food containers)	0.93	85.46
	String and cord (diameter <1cm)	0.75	86.21

Table 4.2: Overall top 20 item categories by weight (g) (all surveys) at the marine beach locations.

Item Category		Mean % Composition	% Cumulative
Top 10 Items	Other wood >50cm	15.44	15.44
	Other wood <50cm	12.82	28.25
	Drinks (bottles/containers/drums)	11.45	39.70
	Plastic bags (e.g. Shopping)	9.40	49.10
	Other plastic	8.38	57.48
	Glass bottles (wine/spirit and similar bottles)	2.99	60.47
	Plastic buckets	2.26	62.73
	Glass bottles (jars/source bottles)	2.25	64.98
	Drinking plastic pouch	2.11	67.09
	Plastic pieces 2.5-50cm	2.07	69.15
Top 11-20 Items	Clothing	2.04	71.19
	Caps/lids	2.03	73.22
	Glass bottles (beer stubbies/pre-mixed alcohol bottles)	1.85	75.07
	Plastic shoes/sandals	1.84	76.91
	Cleaner (bottles/containers/drums)	1.49	78.40
	Diapers	1.37	79.77
	Metal bottle caps	1.13	80.90
	Other rubber pieces	1.11	82.00
	Fabric shoes	0.99	82.99
	Broken glass	0.92	83.91

At the sites where multiple surveys were conducted, accumulation rates normalised by per 100 m per day have been calculated (Table 4.3). Accumulation ranged from 239.40 items per 100 m per day at Belizean Beach Mangrove Bay, to just 19.63 items per 100 m per day at Marine Fish Farms. The highest accumulation rates were consistently seen at Belizean Beach Mangrove Bay and Belizean Beach Carpark throughout the study, with over 70 more items accumulating per 100 m per day compared to any other location or time-point. These locations are adjacent to each other, thus have similar accumulation rates, and are the two closest southern sites from Belize City. This demonstrates the beaches are highly influenced by the outflow from Belize City, but also by the increased recreational use at these locations. This can be observed in the high accumulation of sanitary and medical litter compared to other locations, suggesting these sites are highly influenced by the urban outflow from Belize City. In contrast, Manatee Sign to the north of Belize City has much lower accumulation rates, likely caused by the southerly offshore current (Ezer et al.) transporting the majority of litter input from the Belize River, Haulover Creek, city canals and storm drains down the southern coastline. Plastic was consistently the most accumulated material category at each site and on each repeat time-point. Figure 4.6 shows the top 25 most rapidly accumulated items across all beach locations. Twenty of these top 25 items are from the plastic material category. 'Plastic pieces 0-2.5 cm' is on average (black dot) the most numerous item category to accumulate, with 'plastic pieces 2.5-50 cm' also coming third.

Table 4.3: Accumulation rates of litter on the beach locations presented as number of items per 100 m per day.

Site Name	Repeat	Acc. Period (days)	Number of items (100 m)$^{-1}$ d^{-1}											
			Plastic	Rubber	Textile	Paper	Wood	Metal	Glass	Ceramic	Sanitary	Medical	Other	Total
Manatee Sign	T2	8	43.65	0.19	0.00	0.38	0.19	0.38	0.96	0.00	0.19	0.00	0.00	45.96
Manatee Sign	T3	5	52.37	0.95	0.32	0.63	0.32	0.95	0.63	0.00	0.00	0.00	0.00	56.15
Belizean Beach (Carpark)	T2	14	84.82	2.64	4.06	6.70	0.41	18.06	35.31	0.20	5.48	0.20	0.00	157.87
Belizean Beach (Carpark)	T3	7	129.87	3.65	0.81	16.23	0.81	22.73	53.98	0.00	5.28	0.41	0.00	233.77
Belizean Beach (Mangrove Bay)	T2	10	170.97	1.99	0.00	7.46	0.50	8.45	0.99	0.00	7.95	0.00	0.00	198.31
Belizean Beach (Mangrove Bay)	T3	6	217.03	1.66	0.00	6.63	0.83	7.46	2.49	0.83	1.66	0.83	0.00	239.40
Marine Fish Farm	T2	11	41.77	0.00	0.41	0.00	0.27	0.55	0.41	0.00	0.27	0.27	0.00	43.95
Marine Fish Farm	T3	14	19.09	0.21	0.00	0.00	0.00	0.11	0.11	0.00	0.11	0.00	0.00	19.63
Marine Fish Farm	T4	7	38.61	0.21	0.00	0.00	0.21	0.00	0.21	0.00	0.00	0.00	0.00	39.25
Dangriga Beach	T2	6	79.74	0.00	0.26	2.05	0.26	3.33	2.56	0.00	0.26	0.00	0.00	88.46

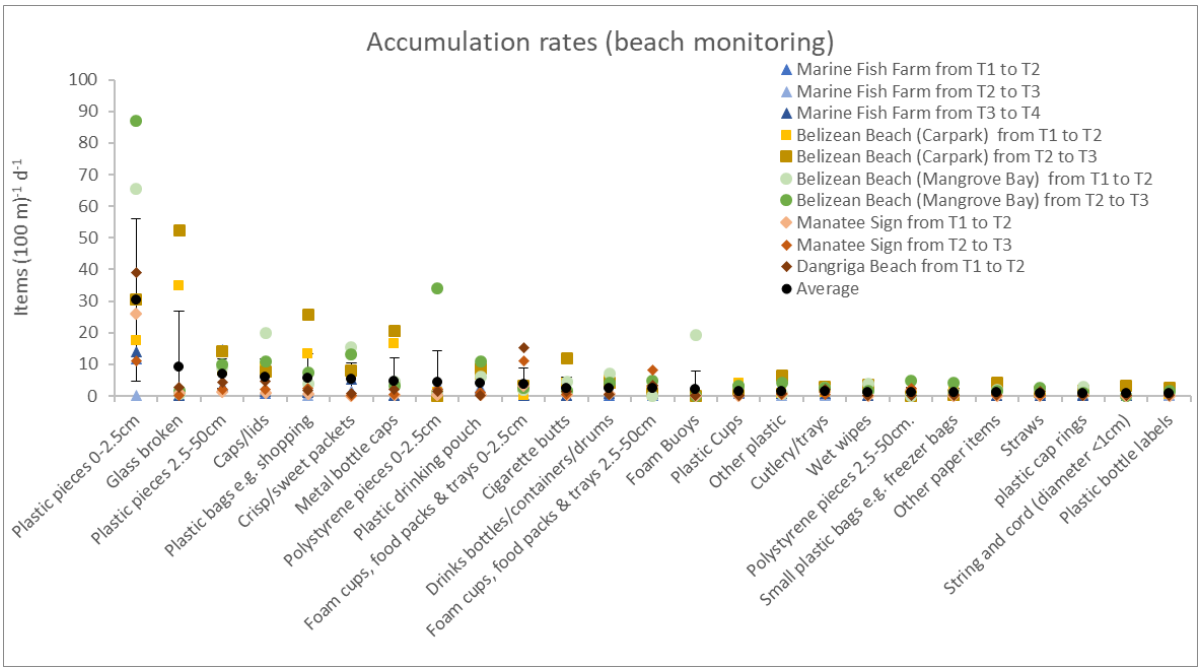

Figure 4.6: The top 25 most rapidly accumulating item categories on marine beaches.

4.2 River monitoring overview

During the six-week monitoring period, three river sites were identified and surveyed, but only one return visit was achieved at Mennonite Beach to assess accumulation rates. Adventure Zone 1 and 2 were unsuitable for ongoing monitoring because of the morphological nature of the beaches and the heavy use by local residents living adjacent. Unfortunately, there was not the time to return to Mennonite Beach more than once within the monitoring programme.

Figure 4.7: Map of T1 river surveys, with results split by material type (count). The total number of items collected is indicated by the value.

The baseline river surveys (T1) are presented in Figure 4.7. Far fewer items were collected at two of these locations, Adventure Zone 1 and 2, in comparison to the beach surveys. At Adventure Zone 1 and Adventure Zone 2 the most numerous material category was plastic, equating to >47 % of the litter removed at each of the sites. Whereas, at Mennonite Beach the most numerous material category was metal, equating to 52 % while plastic only made up 29 %. This area was heavily used recreationally, therefore, higher amount of metal was likely brought to the site and incorrectly disposed of by the public, rather than transported down the river.

The top 30 most abundant item categories across the three T1 surveys are reported in Figure 4.8. The three river sites have produced very different results and proportions of each item category, particularly noticeable between Adventure Zone 1 and Adventure Zone 2, even though the sites are adjacent. This variability is likely as a result of the different uses of the beaches as well as the position of the beach in relation to meanders on the river and therefore the differing deposition rates of litter. 'Metal bottle caps' are the most numerous item category, largely due to the substantial number found at Mennonite Beach. However, only four other metal item categories appear on the top 30 list. Seventeen of the top 30 item categories are from the plastic category, far fewer than from the beach survey results.

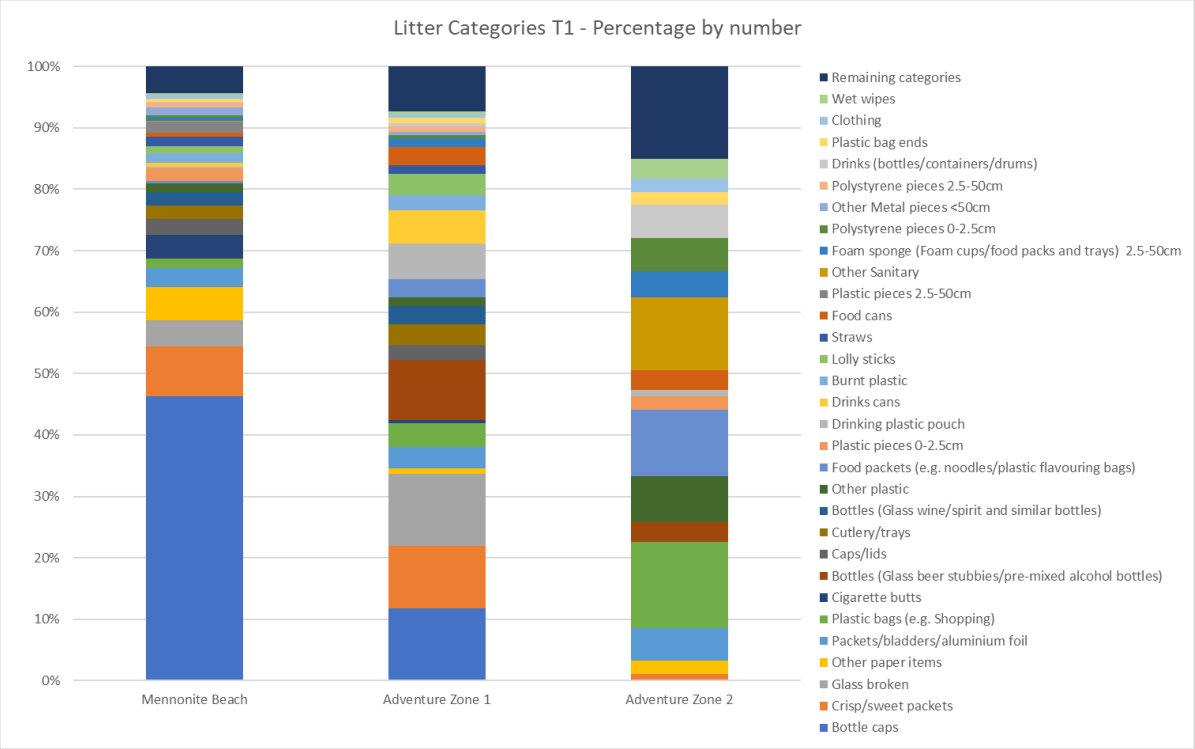

Figure 4.8: Top 30 most numerous item categories across all T1 river surveys, presented as count percentage.

The top 30 most abundant item categories by weight are presented in Figure 4.9. As with the number per item category, the three sites have very varying results. At Mennonite Beach, the greatest item categories by weight were 'plastic drinks bottles' and 'metal bottle caps'. However, at Adventure Zone 1 and 2 it was 'glass bottle (beer/pre-mixed alcohol)' and 'glass bottles (wine)' or 'glass bottle (beer/pre-mixed alcohol)' and 'plastic bags' respectively. However, these top two items by weight account for only 51 % of the total litter collected at Mennonite Beach, but make up 81 % of the litter from Adventure Zone 1. This suggests there were more large, heavy items further downstream of the Belize River. However, these could also be items that were deposited on the site by recreational users, as noted during the survey by the operators.

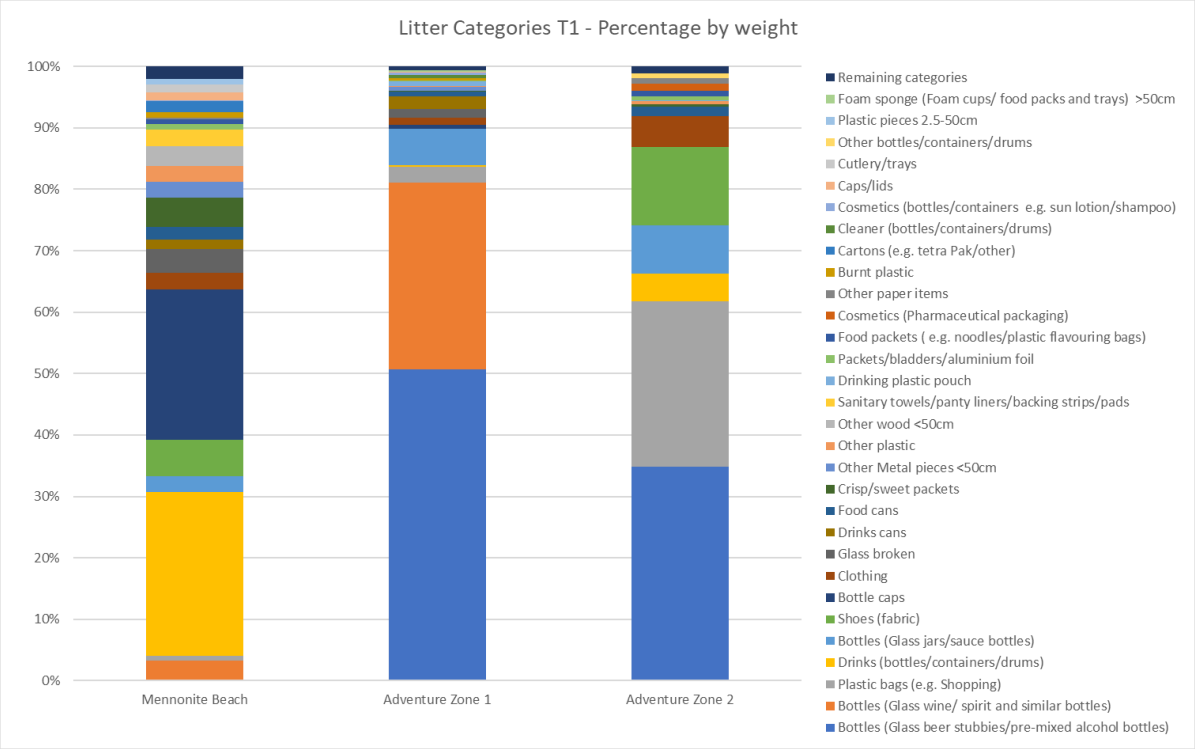

Figure 4.9: Top 30 item categories by weight (g) across all T1 river surveys, presented as weight percentage.

The overall top 20 items by number and weight from all four surveys combined are displayed in Table 4.4 and Table 4.5. The top 10 item categories equate to 62 % of the total number of items and 81 % of the weight removed, which increases to 81 % and 94 % respectively for the top 20. Of the top 20 item categories by number, 12 are from the plastic material category, while in the top 20 by weight there are just six from the plastic material category. This indicates that there may be far less plastic litter in the riverine environment, by both number and weight, compared to the marine beaches.

Table 4.4: Overall top 20 item categories by count (all surveys) at the river beach locations.

Item Category		Mean % Composition	% Cumulative
Top 10 Items	Bottle caps	24.05	24.05
	Crisp/sweet packets	6.91	30.96
	Broken glass	6.55	37.51
	Plastic Bags (e.g. Shopping)	4.86	42.37
	Packets/bladders/aluminium foil	4.18	46.54
	Food packets (e.g. noodles/plastic flavouring bags)	3.54	50.08
	Bottles (glass beer stubbies/pre-mixed alcohol bottles)	3.42	53.50
	Other sanitary	3.00	56.49
	Other plastic	2.68	59.17
	Cutlery/trays	2.51	61.69
Top 11-12	Other paper items	2.48	64.17
	Plastic pieces 0-2.5cm	2.33	66.50
	Caps/lids	2.13	68.63

	Food cans	1.87	70.49
	Burnt plastic	1.86	72.35
	Drinking plastic pouch	1.81	74.16
	Drinks cans	1.75	75.91
	Plastic drinks (bottles/containers/drums)	1.59	77.50
	Polystyrene pieces 0-2.5cm	1.58	79.09
	Plastic pieces 2.5-50cm	1.58	80.67

Table 4.5: Overall top 20 item categories by weight (g) (all surveys) at the river beach locations.

Item Category		Mean % Composition	% Cumulative
Top 10 Items	Bottles (Glass beer stubbies/pre-mixed alcohol bottles)	25.22	25.22
	Metal bottle caps	14.98	40.20
	Bottles (Glass wine/spirit and similar bottles)	8.39	48.60
	Plastic drinks (bottles/containers/drums)	8.00	56.60
	Plastic bags (e.g. shopping)	7.60	64.20
	Shoes fabric	4.66	68.86
	Bottles (Glass jars/source bottles)	4.11	72.97
	Glass broken	3.24	76.21
	Drinks cans	2.83	79.05
	Food cans	2.39	81.44
Top 11-12 Items	Clothing	2.22	83.66
	Burnt plastic	2.11	85.77
	Packets/bladders/aluminium foil	2.08	87.85
	Caps/lids	1.74	89.59
	Crisp/sweet packets	1.45	91.04
	Other metal pieces <50cm	0.99	92.03
	Other plastic	0.83	92.86
	Other wood <50cm	0.80	93.66
	Sanitary towels/panty liners/backing strips	0.68	94.34
	Other medical (swabs/bandaging etc.)	0.51	94.86

At Mennonite Beach where a repeat survey was conducted, accumulation rates normalised by per 100 m per day have been calculated (Table 4.6). The accumulation rate was 19.52 items of litter per day per 100 m, a similar accumulation rate to the T3 beach monitoring at Marine Fish Farms. Metal was the most accumulated material category at Mennonite Beach, with plastic a close second. As shown in Figure 4.10, 13 of the top 25 accumulating items are from the plastic material category, where only five of the top 25 are in the metal material category. However, 'metal bottle caps' have accumulated in such high numbers, (>7 'metal bottle caps' per 100 m per day) resulting in metal being the most accumulated material category overall.

Table 4.6: Accumulation rates of litter on the river beach locations presented as number of items per 100 m per day.

Site Name	Repeat	Acc. Period (days)	Number of items (100 m)$^{-1}$ d^{-1}											
			Plastic	Rubber	Textile	Paper	Wood	Metal	Glass	Ceramic	Sanitary	Medical	Other	Total
Mennonite Beach	T2	21	7.24	0.20	0.13	0.47	0.00	8.99	2.15	0.00	0.07	0.27	0.00	19.52

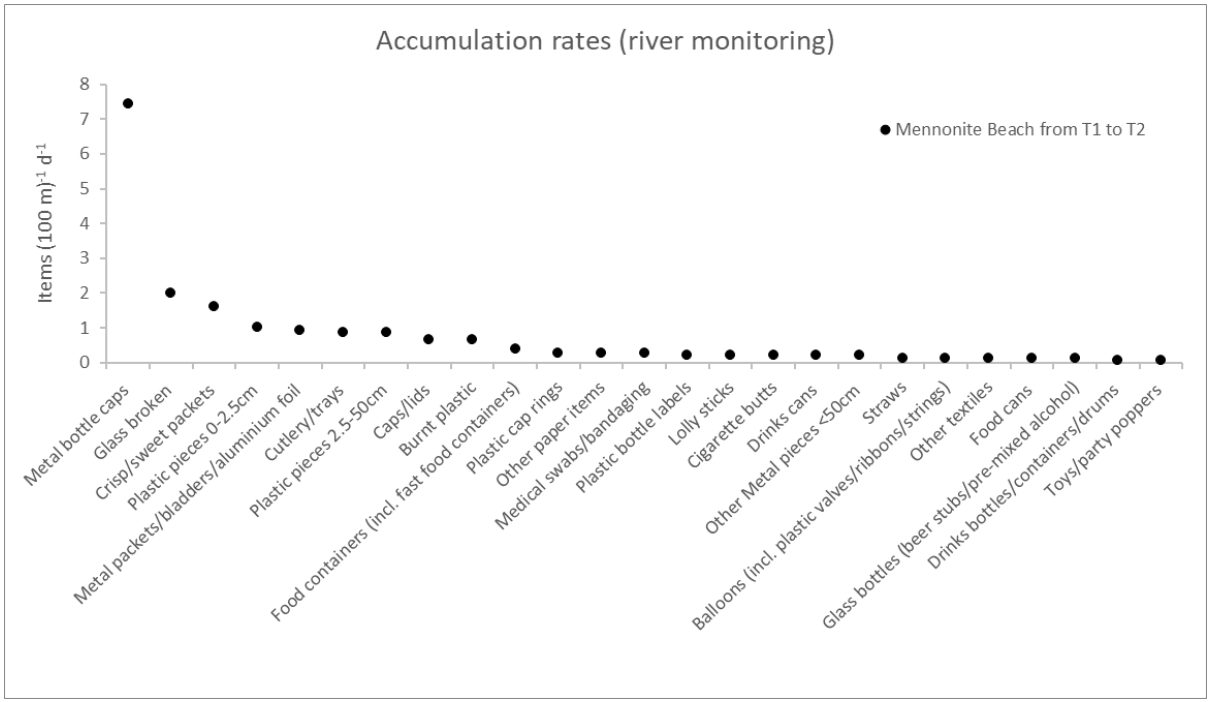

Figure 4.10: The top 25 most rapidly accumulating item categories on river beaches.

4.3 City monitoring overview

During the six-week monitoring period, two city sites were identified and surveyed a total of five times during the monitoring period. However, only one of the sites (BTL Park) was repeated multiple times to assess accumulation rates. This was due to the unsuitability of Collet Canal for ongoing monitoring, due to frequent cleaning (daily) by the municipal cleaners.

Figure 4.11: Map of T1 city surveys, with results split by material type (count). The total number of items collected is indicated by the value.

The baseline city surveys (T1) are presented in Figure 4.11. At both locations, plastic accounted for around 75 % of the litter collected during the preliminary surveys. The percentages for paper and metal are also very similar between the two sites.

The top 30 most abundant item categories across the two T1 surveys are reported in Figure 4.12. Both sites have very similar proportions of each of the top 30 items, suggesting that there is a similar composition of litter throughout the city. The most numerous item categories were 'plastic pieces 0-2.5 cm' and 'caps/lids' at BTL Park and 'plastic pieces 0-2.5 cm' and 'plastic pieces 2.5-50 cm' at Collet Canal. Eighteen of the top 30 item categories are from the plastic material category, a very similar number to that found on the river surveys (17).

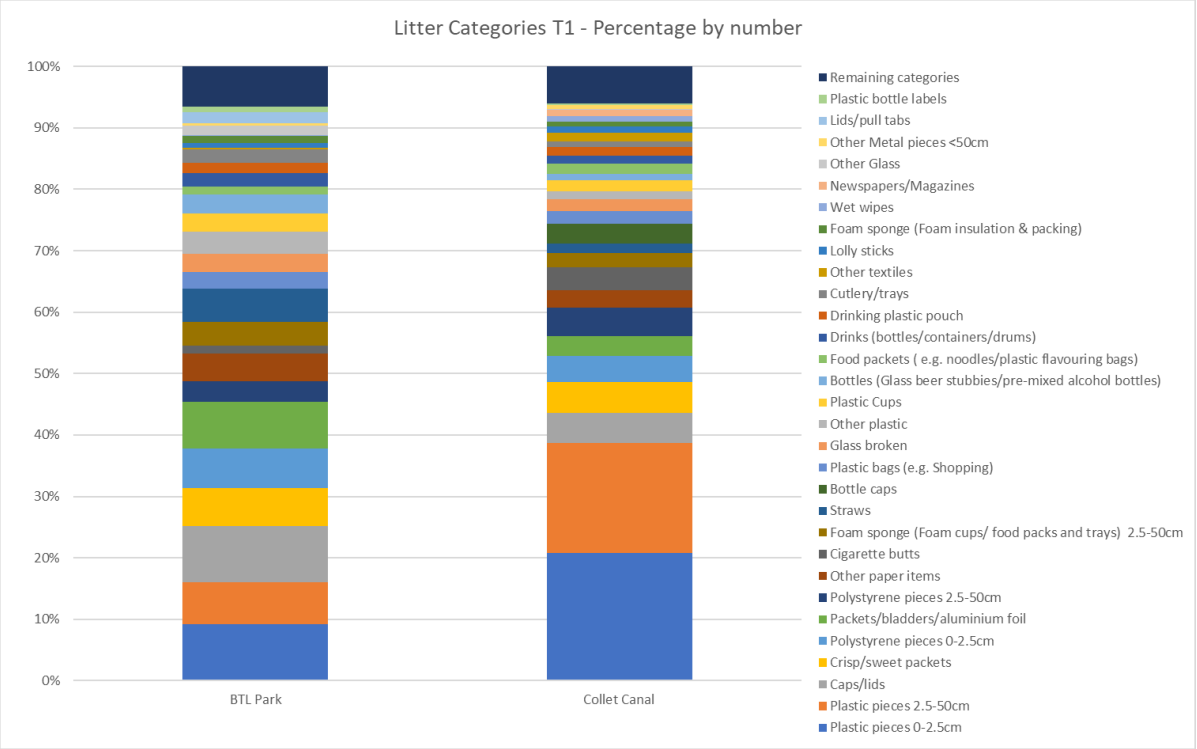

Figure 4.12: Top 30 most numerous item categories across all T1 city surveys, presented as count percentage.

The top 30 most abundant item categories by weight are presented in Figure 4.13. Unlike the top 30 by number, the two locations have quite different proportions by weight. At Collet Canal the top two by weight are the same as by number; 'plastic pieces 0-2.5 cm' and 'plastic pieces 2.5-50 cm'. However, at BTL Park the top two item categories by weight are 'broken glass' and 'other metal pieces >50 cm'. At both locations the top two items by weight only made up around 29 % of the total composition, substantially less than the top two items at the river sites. This suggests there were fewer large heavy items at the city sites, likely due to the municipal cleaners favouring the removal of larger items as these are easier to spot and remove.

The overall top 20 items by number and weight from all five surveys combined are displayed in Table 4.7 and Table 4.8. The top 10 item categories equate to 67 % of the total number of items and 66 % of the weight removed, increasing to 87 % and 85 % respectively for the top 20. Of the top 20 item categories by number, 14 are from the plastic material category, while nine are from the plastic material category in the top 20 by weight. This is slightly more plastic composition than was found in the riverine environment, but not as much as on the marine beaches.

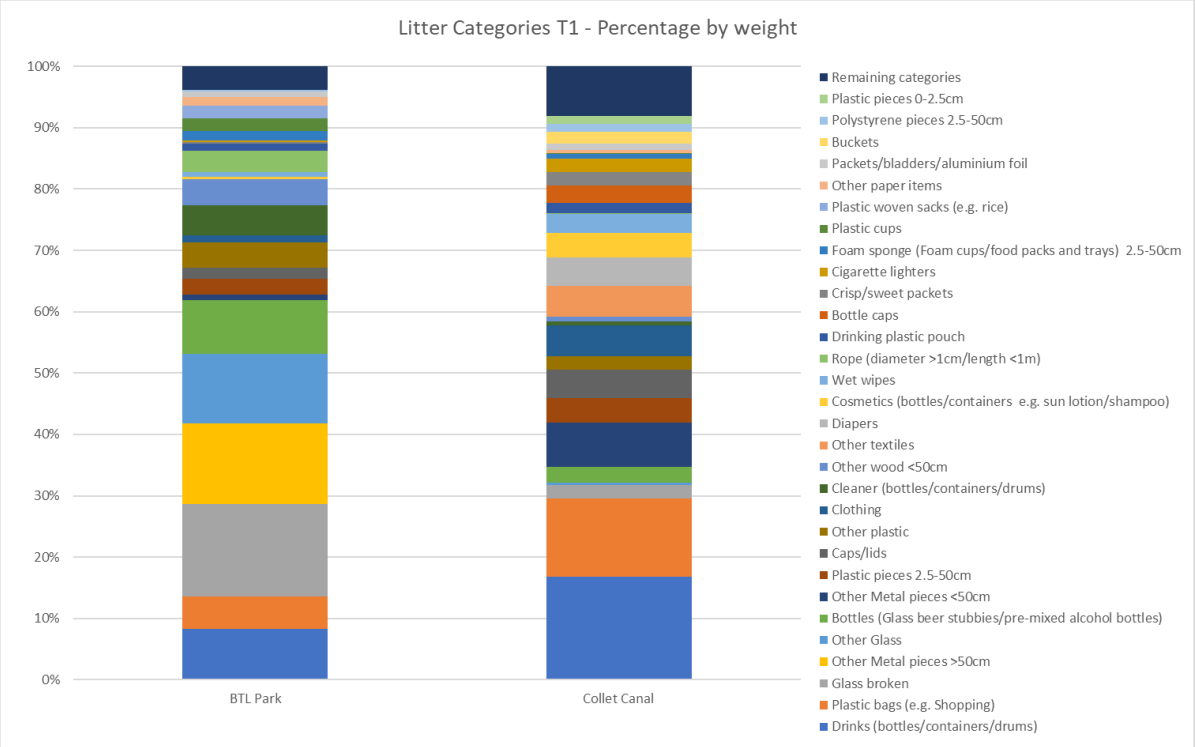

Figure 4.13: Top 30 item categories by weight (g) across all T1 city surveys, presented as weight percentage.

Table 4.7: Overall top 20 item categories by count (all surveys) at the city locations.

Item Category		Mean % Composition	% Cumulative
Top 10 Items	Plastic pieces 0-2.5cm	14.85	14.85
	Plastic pieces 2.5-50cm	9.10	23.95
	Crisp/sweet packets	6.48	30.43
	Caps/lids	6.47	36.90
	Other paper items	5.88	42.78
	Plastic bags (e.g. shopping)	5.47	48.25
	Foam sponge (foam cups/food packs and trays) 2.5-50cm	5.32	53.57
	Straws	5.19	58.76
	Packets/bladders/aluminium foil	4.77	63.53
	Plastic cups	3.16	66.68
Top 11-12 Items	Plastic drinks (bottles/containers/drums)	3.14	69.82
	Polystyrene pieces 0-2.5cm	2.93	72.75
	Drinking plastic pouch	2.58	75.34
	Broken glass	2.50	77.84
	Polystyrene pieces 2.5-50cm	1.90	79.74
	Other plastic	1.80	81.53
	Small plastic bags (e.g. freezer bags)	1.75	83.28
	Cigarette butts	1.67	84.95
	Bottles (Glass beer stubbies/pre-mixed alcohol bottles)	1.34	86.29
	Bottle caps	0.94	87.23

Table 4.8: Overall top 20 item categories by weight (g) (all surveys at the city locations).

Item Category		Mean % Composition	% Cumulative
Top 10 Items	Plastic drinks (bottles/containers/drums)	16.06	16.06
	Plastic bags (e.g. shopping)	11.86	27.92
	Other wood <50cm	8.34	36.26
	Bottles (Glass beer stubbies/pre-mixed alcohol bottles)	5.39	41.65
	Other Metal pieces >50cm	5.01	46.66
	Glass broken	4.69	51.35
	Other Glass	3.98	55.33
	Construction material (e.g. tiles)	3.93	59.26
	Foam sponge (foam cups/food packs and trays) 2.5-50cm	3.63	62.89
	Cardboard	2.85	65.74
Top 11-12 Items	Small plastic bags (e.g. freezer bags)	2.47	68.20
	Packets/bladders/aluminium foil	2.43	70.63
	Caps/lids	2.33	72.96
	Drinking plastic pouch	2.04	75.00
	Plastic pieces 2.5-50cm	1.86	76.86
	Other paper items	1.71	78.57
	Plastic cups	1.64	80.21
	Other Metal pieces <50cm	1.63	81.84
	Other plastic	1.45	83.29
	Other textiles	1.40	84.70

At BLT Park, where the repeat surveys were conducted, accumulation rates normalised by per 100 m per day have been calculated (Table 4.9). The average accumulation was 76.79 items per 100 m per day, with a range across the three surveys of 58.73 - 92.19 items per 100 m per day. This is a far greater number of items per day than at the river beaches, and closer to results seen on the marine beaches. Plastic was the most accumulated material category at BTL Park, with paper, glass or metal being the second most accumulated material category at the three return surveys, T2, T3 and T4, respectively. As shown in Figure 4.14, eighteen of the top 25 accumulating items are from the plastic material category, with six of the remaining seven item categories from either paper, glass or metal. 'Other paper' was the second most accumulating item and 'aluminium foil' was the ninth. This was due to the large number of paper napkins found at the site, which was located adjacent to a number of food stalls.

Table 4.9: Accumulation rates of litter at the city locations presented as number of items per 100 m per day.

Site Name	Repeat	Acc. Period (days)	Number of items (100 m)$^{-1}$ d^{-1}											
			Plastic	Rubber	Textile	Paper	Wood	Metal	Glass	Ceramic	Sanitary	Medical	Other	Total
BTL Park	T2	9	63.19	0.17	0.35	17.01	0.35	5.90	3.65	0.52	0.69	0.35	0.00	92.19
BTL Park	T3	17	47.52	0.28	0.18	2.76	0.18	2.48	3.58	0.18	1.29	0.28	0.00	58.73
BTL Park	T4	7	69.87	0.45	0.00	3.13	0.00	4.24	1.12	0.00	0.67	0.00	0.00	79.46

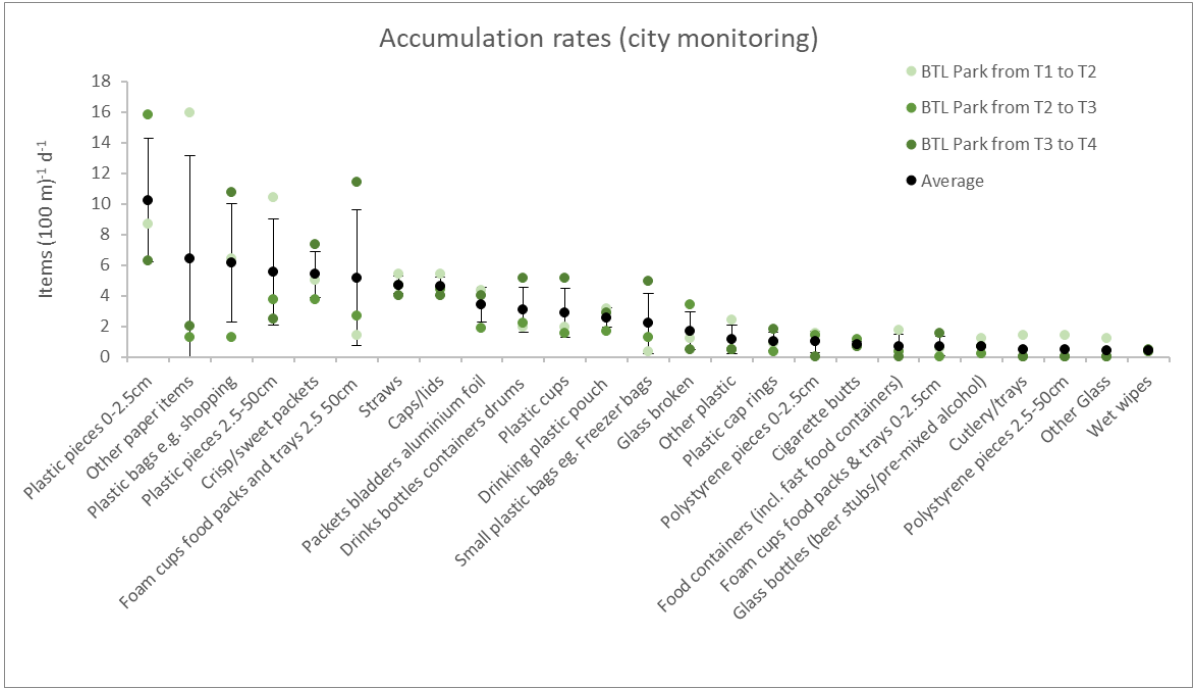

Figure 4.14: The top 25 most rapidly accumulating item categories at the city locations.

4.4 Combined monitoring overview

Across the three monitoring types, the accumulation per survey and overall average per monitoring site type is displayed in Figure 4.15. Here we can see that accumulation rates varied more between each of the beach surveys than the river surveys. However, this may be a factor related to the number of overall sites surveyed; five for beaches, but only two for river locations. There is an overall trend of increased accumulation of litter further into the marine system, from river to city to beach.

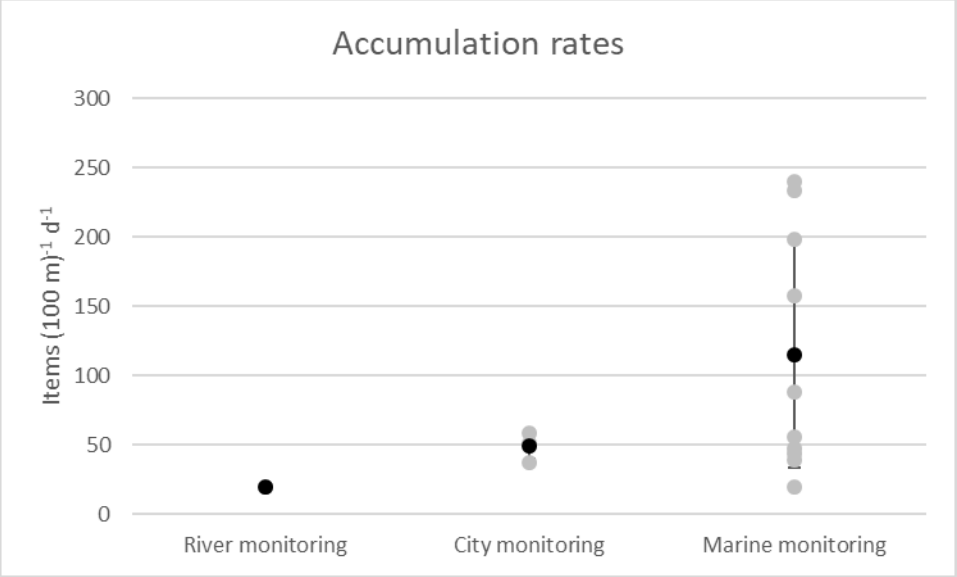

Figure 4.15: Accumulation rates of litter presented as number of items per 100 m per day at all monitoring sites, split by type, with the average per type indicated in black.

4.5 Results from training

Data collected by CLiP beach survey trainees at the Tobacco Caye Marine Station are shown below. This station is one of the outer Cayes along the Belizean Barrier Reef and provides a useful insight into the differences between marine locations from beaches inside the barrier reef lagoon and beaches on the barrier reef. The survey location is an old reef crest that is now exposed above water level and is offered protection by the Department of Environment, where access by humans is prohibited. Tobacco Caye Marine Station is granted access in order to carry out cleaning activities and surveys which gives them the unique opportunity to collect data that could be fed into national monitoring programmes.

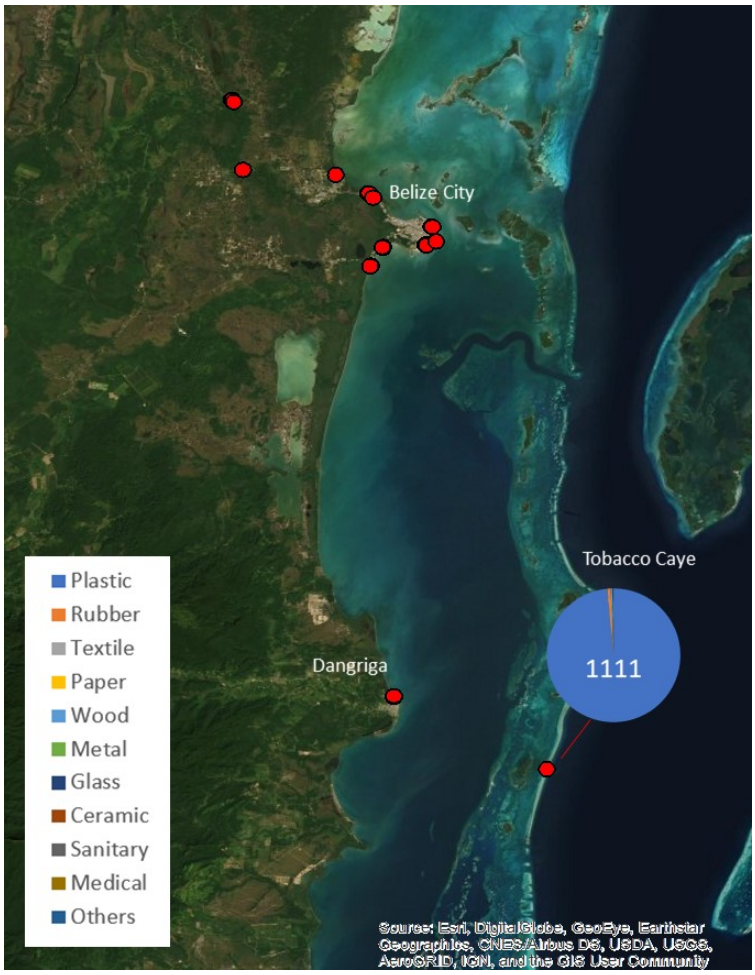

Figure 4.16: Map of T1 Tobacco Caye Beach training survey, with results split by material type (count). The total number of items collected is indicated by the value and the red dots indicate the other monitoring survey locations.

The data reveals, when analysed by number, 98.5 % plastic materials (Figure 4.16), with small numbers of rubber, wood, glass, metal and sanitary items. All of the top 30 litter items are plastic (Figure 4.17), with 'plastic pieces 0-2.5 cm', 'caps/lids' and 'plastic pieces 2.5-50 cm' making up the largest item categories. All the items found are light and low density suggesting they could have travelled long distances to be washed up in Belize. In contrast to the data collected from around Belize City, drinking plastic pouches were not common. When the data is normalised for comparison with other sites (Figure 4.18), the number of litter items is comparable to the highest surveyed, Belizean Beach (car park), although the composition of litter items is very different suggesting a different origin. Whereas Belizean Beach had a large amount of litter derived from recreational beach usage, Tobacco Caye has no recreational beach use and any small range anthropogenic effect comes from fishing boats.

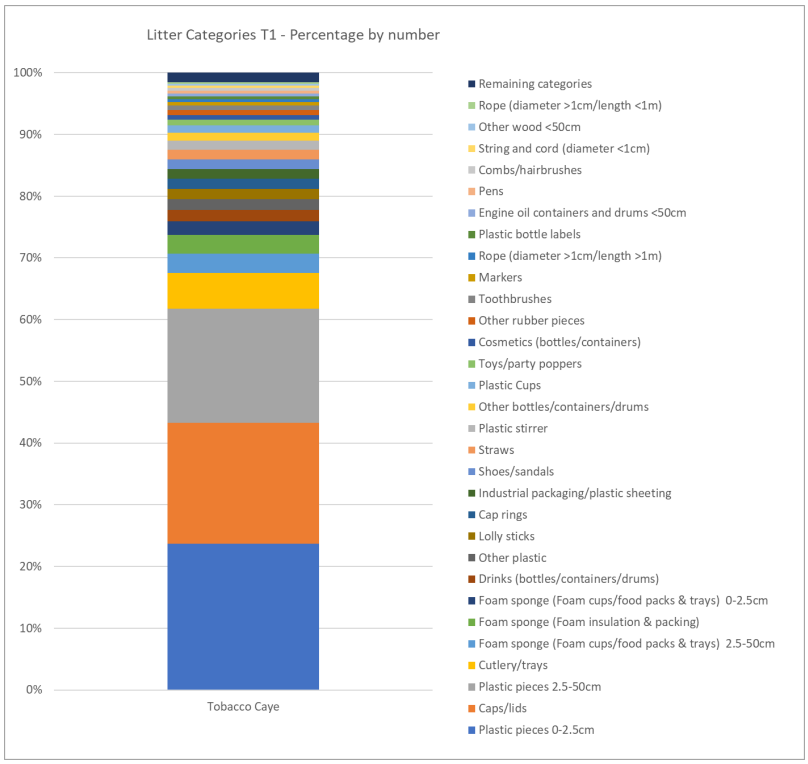

Figure 4.17: Top 30 most numerous item categories from the T1 beach survey for Tobacco Caye, presented as percentage counts.

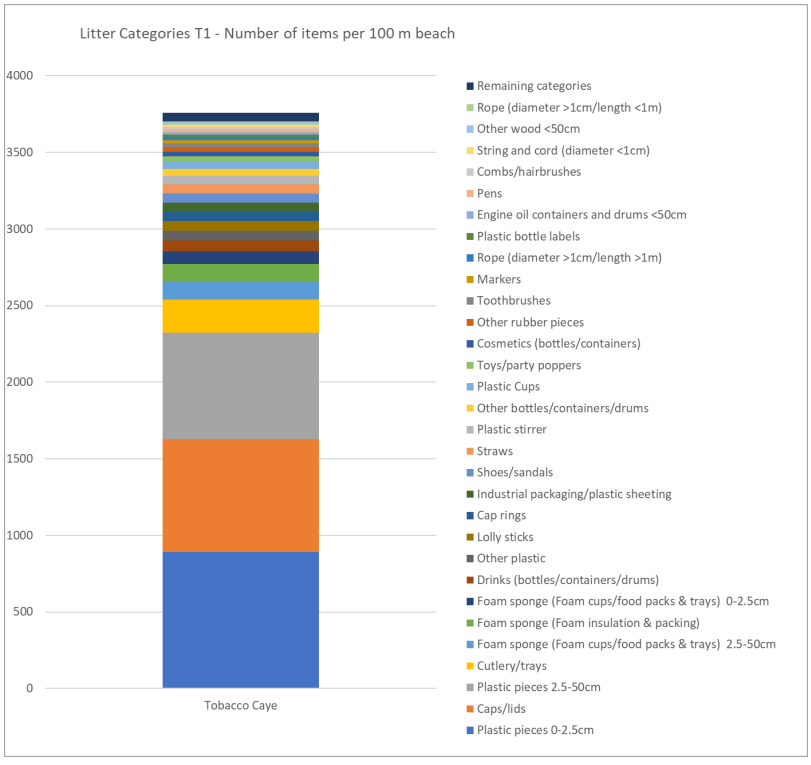

Figure 4.18: Top 30 most numerous item categories from the T1 beach survey for Tobacco Caye, presented as count normalised to 100 m beach length.

5 Discussion

The CLiP protocol used for these surveys was developed based on the existing OSPAR method, which was designed for north-western European beaches. Transplanting this method to other regions means that adaptations have to be made. In contrast with the European long, sandy and clear coastlines, the Belizean coast consists of long stretches of mangroves. The method assumes a standard length of 100 m of beach, but this requirement was never met in Belize with all beaches surveyed between 30 m and 70 m long. The data were extrapolated to 100 m but the surrounding vegetation or objects which limited the beach length may well have affected the litter accumulated on the beach. Additionally, there was a large difference in beach width between locations. The method limits the beach to the start of vegetation or a strong difference in gradient. At Belizean beach car park this included the area where cars could park. While wind might move beach litter out of the survey area within a few meters at other beaches, it remained inside to be counted at the car park. Additionally, the results may well have been affected by the composition of the beach. Rocky beaches, sandy beaches, and beaches with mangrove roots all have different characteristics affecting litter turnover rate.

Another factor affecting the litter found at the beaches was human use for activities like recreation. The survey method assumes that litter comes from the sea and therefore works with a standard unit of beach width, but active littering such as was observed at Belize Beach car park can be a secondary source of litter, confounding any results and making it difficult to estimate the relative importance of the different inputs. Indeed, the effect of active littering at that location can be seen in the high abundance of broken glass which was found.

Next to litter, another issue impacting Caribbean shores is the high abundance of Sargassum seaweed washing into shore. This seaweed mixes with the litter making surveys more complex, but also forms a barrier for litter moving beyond the high tide line. This seaweed build up differs per location due to local morphology and currents. It reached such levels at the Caribbean Shrimp Farm site that further monitoring was discontinued because normal accumulation of litter was no longer possible.

The beach survey sites around Belize City were thought to be unaffected by cleaning which means that the data collected is fully representative. This is not the case for Dangriga, where it is suspected external cleaning occurred between samples.

The beach method was then adopted and used as standard for the monitoring on river shores. While this method does not provide data on the flow of litter down the river, it does provide a proxy for the amount of litter in the watershed (González et. al, 2016). There are multiple settlements and larger urban areas along the length of the Belize River and the river's tributaries, stretching the width of the country, with the catchment area housing 130,000 Belizeans and a further 100,000 individuals outside of Belizean boarders (Boles and Boles, 2016).

The river is used for transport (there are multiple ferry crossings and small vessels traverse up and down the river), fishing, swimming and other recreational activities on the riverbanks. The monitoring of the waterways in Belize City used locations which were very different to the standard shoreline. Data from these surveys should therefore be taken as a preliminary survey to get an idea of dominant litter item categories and not readily comparable to other locations. This is especially the case for Collet Canal which was later found to be actively cleaned by city workers.

Although both city locations were still waterways and outflowed towards the sea they did show higher presence of unidentified plastic particles than the river sites further away from the coast. Other item categories in the city were again mostly related to food and drink.

Overall, litter along the Belizean coast consisted of a very small number of litter items classified as coming from sea-based sources, the one exception being 15 pieces of fishing line found at the Manatee Sign site. No categories with a clear link to sea-based sources of litter were part of the top 30 item categories across beach sites. However, 'string/cord < 1 cm' may well have a maritime origin and other item categories such as food and drink packaging could of course have been discarded during activities at sea. These low levels of sea-based litter are comparable to estimates of global marine litter composition (Jambeck et al., 2015; Turrell, 2020).

On the beaches, the top item categories were unidentified fragments of plastic of various size classes together with various food and drink holders and plastic bags, a very common composition across the globe (e.g. OSPAR, 2017; Verlis and Wilson, 2020). The presence in large numbers of the region-specific items, for example the 'plastic drinking water pouches' item category, and a high percentage of broken glass fragments indicated local recreational use and frequent littering at Belizean Beach Car Park. While the material category percentage by count revealed a reasonably comparable picture between all marine beaches, the percentage by weight was very different. This shows that abundance and weight of litter tell very different stories and the use of either parameter should be dependent on the research topic and scientific question to be answered. For example, total mass of litter building up on a shore, or number of fragments with which marine wildlife could interact. Additionally, the litter by weight was dominated by a few heavy items, leading to non-plastic material categories dominating the results. In this respect, care should also be taken when determining the weight of item categories such as bags, clothing and wood which can often contain sediment or water, which can increase their weight.

An interesting trend can be seen in the litter composition moving from inland to offshore. Where the river litter contains just a few percent of unidentified plastic fragments, this group is the most numerous on the beaches and in the Belize City waterways next to the sea as well as offshore on Tobacco Caye where there is no direct human presence, reaching more than 60 % on certain beaches. This difference indicates various sources of litter to Belize's coastal environment with waterways transporting litter such as food and drink containers to the coast while these item categories also wash in from the open sea joined by large amounts of weathered broken plastic fragments.

6 Forward look and recommendations

This study has provided a baseline dataset for the assessment of marine litter in the vicinity of Belize City and tested the limitations of the European OSPAR method of monitoring in a Caribbean location. These data are useful to suggest actions to tackle the problem of marine litter and to suggest further investigations. Many of the top items identified are related to food packaging (foam food packs, metal bottle caps, crisp/biscuits packets, plastic drinking pouches), some of which are already being targeted by national bans and plastic alternatives.

From a technical point of view, it is important to use an adaptable protocol that can record region-specific items. The presence of Belize specific categories in the top 10 items, such as 'plastic drinking water pouches', show the importance of a static item category list, as this information would have otherwise been lost. This approach, allowing the identification of specific items in marine litter, provides useful data to help identify problem areas and provide evidence to prioritise actions.

In accordance with the Belize Marine Litter Action Plan developed in collaboration with CLiP, we provide here some initial recommendations for ongoing monitoring activities and advances. Continuing on from this base dataset, a one-year monitoring programme should be established to regularly monitor consistent locations in order to establish any temporal patterns in litter accumulation. The programme, for example, could be used to assess the impact of legislative bans and to identify risks posed to wildlife. Regular microplastic samples collected at monitoring locations and analysed at the CLiP supported laboratory would enable similar monitoring for microplastics in the environment. These monitoring activities could be achieved by the establishment of a monitoring group, to share responsibilities and tasks and to encourage knowledge sharing and training opportunities. This monitoring group would also be responsible for ensuring data quality and standards, maintaining a reliable database. In addition, the group could continue coordination and engagement with stakeholders, such as Tobacco Caye, who are keen to use citizen science to feed into monitoring programmes. Working together, the monitoring group and stakeholders could lead outreach and awareness activities around marine litter, focusing on items not currently covered by legislation bans, for example plastic drinking water pouches and metal bottle caps.

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8 Appendix 1: Detailed beach survey top 10 items by count

Table 8.1: Caribbean Shrimp Farm top 10 items per survey, count and % of composition.

Caribbean Shrimp Farm T1	
Plastic pieces 0-2.5cm	569
	33.79 %
Plastic pieces 2.5-50cm	405
	24.05 %
Caps/lids	227
	13.48 %
Polystyrene pieces 2.5-50cm	80
	4.75 %
Foam sponge (foam cups/food packs and trays) 2.5-50cm	50
	2.97 %
Plastic cups	41
	2.43 %
Cutlery/trays	36
	2.14 %
Plastic bags (e.g. shopping)	23
	1.37 %
Crisp/sweet packets	23
	1.37 %
Polystyrene pieces 0-2.5cm	23
	1.37 %

Table 8.2: Manatee Sign Beach top 10 items per survey, count and % of composition.

Manatee Sign T1		Manatee Sign T2		Manatee Sign T3	
Plastic pieces 0-2.5cm	64 18.13 %	Plastic pieces 0-2.5cm	132 55.23 %	Foam sponge (foam cups/food packs and trays) 0-2.5cm	35 19.66 %
Plastic pieces 2.5-50cm	44 12.46 %	Foam sponge (foam cups/food packs and trays) 0-2.5cm	16 6.69 %	Plastic pieces 0-2.5cm	35 19.66 %
Caps/lids	37 10.48 %	Foam sponge (foam cups/food packs and trays) 2.5-50cm	15 6.28 %	Foam sponge (foam cups/food packs and trays) 2.5-50cm	26 14.61 %
Polystyrene pieces 2.5-50cm	30 8.50 %	Foam sponge (Foam insulation/packing)	9 3.77 %	Plastic bags (e.g. shopping)	8 4.49 %
Drinks (bottles/containers/drums)	26 7.37 %	Polystyrene pieces 2.5-50cm	9 3.77 %	Fishing line (angling)	8 4.49 %
Fishing line (angling)	15 4.25 %	Cutlery/trays	7 2.93 %	Polystyrene pieces 2.5-50cm	8 4.49 %
Drinking plastic pouch	13 3.68 %	Plastic pieces 2.5-50cm	6 2.51 %	Caps/lids	7 3.93 %
Foam sponge (foam cups/food packs and trays) 2.5-50cm	11 3.12 %	Caps/lids	5 2.09 %	Polystyrene pieces 0-2.5cm	7 3.93 %
Plastic shoes/sandals	10 2.83 %	Plastic shoes/sandals	5 2.09 %	Plastic pieces 2.5-50cm	7 3.93 %
Cleaner (bottles/containers/drums)	9 2.55 %	Broken glass	5 2.09 %	Foam sponge (Foam insulation/packing))	6 3.37 %

Table 8.3: Belizean Beach Carpark top 10 items per survey, count and % of composition.

Belizean Beach Carpark T1		Belizean Beach Carpark T2		Belizean Beach Carpark T3	
	949		171		129
Broken glass	23.02 %	Broken glass	21.98 %	Broken glass	22.40 %
	721		87		75
Plastic pieces 0-2.5cm	17.49 %	Plastic pieces 0-2.5cm	11.18 %	Plastic pieces 0-2.5cm	13.02 %
	476		82		63
Metal bottle caps	11.55 %	Metal bottle caps	10.54 %	Plastic bags (e.g. shopping)	10.94 %
	391		65		51
Plastic pieces 2.5-50cm	9.49 %	Plastic bags (e.g. shopping)	8.35 %	Metal bottle caps	8.85 %
	230		45		35
Caps/lids	5.58 %	Caps/lids	5.78 %	Plastic pieces 2.5-50cm	6.08 %
	132		39		29
Plastic bags (e.g. shopping)	3.20 %	Plastic pieces 2.5-50cm	5.01 %	Cigarette butts	5.03 %
	125		33		21
Crisp/sweet packets	3.03 %	Crisp/sweet packets	4.24 %	Drinking plastic pouch	3.65 %
	93		32		20
Drinking plastic pouch	2.26 %	Drinking plastic pouch	4.11 %	Crisp/sweet packets	3.47 %
	91	Drinks	24		19
Wet wipes	2.21 %	(bottles/containers/drums)	3.08 %	Caps/lids	3.30 %
Drinks	87		20		16
(bottles/containers/drums)	2.11 %	Plastic cups	2.57 %	Other plastic	2.78 %

Table 8.4: Belizean Beach Mangrove Bay top 10 items per survey, count and % of composition.

Belizean Beach Mangrove Bay T1		Belizean Beach Mangrove Bay T2		Belizean Beach Mangrove Bay T3	
	537		132		105
Plastic pieces 0-2.5cm	39.28 %	Plastic pieces 0-2.5cm	33.08 %	Plastic pieces 0-2.5cm	36.33 %
	207		40		41
Plastic pieces 2.5-50cm	15.14 %	Caps/lids	10.03 %	Polystyrene pieces 0-2.5cm	14.19 %
	77		39		16
Caps/lids	5.63 %	Foam sponge (Foam Buoys)	9.77 %	Crisp/sweet packets	5.54 %
	61		31		13
Drinking plastic pouch	4.46 %	Crisp/sweet packets	7.77 %	Drinking plastic pouch	4.50 %
	46		18		13
Crisp/sweet packets	3.37 %	Plastic pieces 2.5-50cm	4.51 %	Caps/lids	4.50 %
Foam sponge (foam cups/food	38	Drinks	14		12
packs and trays) 0-2.5cm	2.78 %	(bottles/containers/drums)	3.51 %	Plastic pieces 2.5-50cm	4.15 %
	32		12		9
Plastic cups	2.34 %	Drinking plastic pouch	3.01 %	Plastic bags (e.g. shopping)	3.11 %
	31		9	Foam sponge (foam cups/food	6
Metal bottle caps	2.27 %	Cigarette butts	2.26 %	packs and trays) 2.5-50cm	2.08 %
	28		9		6
Cutlery/trays	2.05 %	Metal bottle caps	2.26 %	Polystyrene pieces 2.5-50cm	2.08 %
Drinks					
(bottles/containers/drums) /	26		8		
Foam sponge (foam cups/food		Plastic bags (e.g. shopping) /			
packs and trays) 2.5-50cm	1.90 %	Wet wipes	2.01 %		

Table 8.5: Marine Fish Farm top 10 items per survey, count and % of composition.

Marine Fish Farm T1		Marine Fish Farm T2		Marine Fish Farm T3		Marine Fish Farm T4	
Plastic pieces 0-2.5cm	228 32.34 %	Plastic pieces 2.5-50cm	106 32.92 %	Polystyrene pieces 0-2.5cm	35 19.13 %	Plastic pieces 0-2.5cm	65 35.52 %
Plastic pieces 2.5-50cm	150 21.28 %	Plastic pieces 0-2.5cm	87 27.02 %	Plastic pieces 2.5-50cm	28 15.30 %	Crisp/sweet packets	25 13.66 %
Caps/lids	61 8.65 %	Drinking plastic pouch	15 4.66 %	Drinking plastic pouch	24 13.11 %	Plastic pieces 2.5-50cm	14 7.65 %
Plastic cups	32 4.54 %	String and cord (diameter <1cm)	15 4.66 %	Caps/lids	18 9.84 %	Small plastic bags (e.g. freezer bags)	12 6.56 %
Drinks (bottles/containers/drums)	29 4.11 %	Food containers (including fast food containers)	14 4.35 %	Foam sponge (foam cups/food packs and trays) 2.5-50cm	13 7.10 %	Drinking plastic pouch	9 4.92 %
Drinking plastic pouch	18 2.55 %	Plastic bags (e.g. shopping)	10 3.11 %	Crisp/sweet packets	12 6.56 %	Caps/lids	7 3.83 %
Food containers (including fast food containers)	16 2.27 %	Crisp/sweet packets	10 3.11 %	Drinks (bottles/containers/drums)	10 5.46 %	Plastic bags (e.g. shopping)	5 2.73 %
Cleaner (bottles/containers/drums)	15 2.13 %	Caps/lids	7 2.17 %	Plastic cups	10 5.46 %	Plastic bottle labels	5 2.73 %
Foam sponge (foam cups/food packs and trays) 2.5-50cm	15 2.13 %	Plastic cups	6 1.86 %	Food containers (including fast food containers)	8 4.37 %	Plastic cups	5 2.73 %
Plastic bags (e.g. shopping)	13 1.84 %	Other plastic	6 1.86 %	Small plastic bags (e.g. freezer bags)	7 3.83 %		

Table 8.6: Dangriga Beach top 10 items per survey, count and % of composition.

Dangriga Beach T1		Dangriga Beach T2	
Plastic pieces 0-2.5cm	302	Plastic pieces 0-2.5cm	152
	45.07 %		44.06 %
Foam sponge (foam cups/food packs and trays) 0-2.5cm	113	Foam sponge (foam cups/food packs and trays) 0-2.5cm	60
	16.87 %		17.39 %
Metal bottle caps	42	Caps/lids	18
	6.27 %		5.22 %
Plastic pieces 2.5-50cm	27	Plastic pieces 2.5-50cm	17
	4.03 %		4.93 %
Cigarette butts	27	Foam sponge (foam cups/food packs and trays) 2.5-50cm	13
	4.03 %		3.77 %
Foam sponge (foam cups/food packs and trays) 2.5-50cm	23	Broken glass	10
	3.43 %		2.90 %
Caps/lids	21	Cutlery/trays	8
	3.13 %		2.32 %
Broken glass	21	Metal bottle caps	8
	3.13 %		2.32 %
Lolly sticks	13	Plastic bags (e.g. shopping)	7
	1.94 %		2.03 %
Crisp/sweet packets	11	Cigarette butts	6
	1.64 %		1.74 %

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Head office
Pakefield Road
Lowestoft
Suffolk
NR33 0HT
Tel: +44 (0) 1502 56 2244
Fax: +44 (0) 1502 51 3865

Weymouth office
Barrack Road
The Nothe
Weymouth
DT4 8UB

Tel: +44 (0) 1305 206600
Fax: +44 (0) 1305 206601

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