



## Characterising marine plastic debris accumulations on Tobago coastal environments

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### ABSTRACT

Caribbean small island developing states (SIDS) host biodiverse coastal habitats supporting endangered species and tourism-dependent local economies, yet remain underrepresented in marine litter research. Using the OSPAR beach monitoring protocol, this study provides a baseline snapshot of marine litter debris loads across eight rural coastlines in Tobago, four exposed to the Caribbean Sea, and four exposed to the Atlantic, surveyed between June and July 2024. A total of 2404 debris items were recorded, of which approximately 69% were plastic overall, rising to 97% on Atlantic-facing beaches compared to only 16% on Caribbean-facing shores, where glass dominated. Plastic items were size-classified as macroplastics (>2.5 cm), mesoplastics (≤ 2.5 cm), microplastics (≤ 0.5 cm). Polymer types were identified using Fourier Transmission Infrared Spectroscopy. Atlantic-exposed shorelines were significantly more polluted, the most littered beach (Hope Beach) having 4.6 plastic items m<sup>-2</sup>, over 100-fold higher than the average litter density across the Caribbean-facing sites (0.04 items m<sup>-2</sup>). Polystyrene (PS) was the dominant polymer in the meso- and microplastic fractions, despite a national import and use ban on PS in Trinidad and Tobago since 2020, highlighting a potential redundancy of this regulatory mitigation strategy. This study identifies Tobago as an overlooked marine biodiversity hotspot vulnerable to significant marine litter accumulation in the Wider Caribbean Region (WCR) and establishes key baseline monitoring sites to inform broader regional policy.

### 1. Introduction

The United Nations Sustainable Development agenda (2015) outlined an ambitious target to prevent inputs and significantly reduce marine debris by 2025 [1,2]. Approximately 85% of global marine litter debris is made of plastic [3]. The simplest way to monitor levels of marine litter debris is through standardised beach litter monitoring, which can inform legislation to reduce land-based inputs of plastic pollution into the marine environment [4]. Assessment of marine litter debris and specifically plastic loading onto coastlines can evidence sources and drivers of marine pollution and serve as a tool to assess the effectiveness of policy intervention and inform legislation [5,6]. Coastal environments are particularly vulnerable to marine litter debris accumulation from mismanaged waste and land-based sources, as well as

sea-based inputs from maritime activities [7,8]. Marine plastic debris represents a transboundary issue globally, as significant loads of plastic items leach into marine environments every year and can be carried to distant and remote land sites, creating detached pollution problems and making remediation onus difficult to apportion. Solutions require global collaboration [8,9].

Some of the highest concentrations of marine plastic debris in the world reside in the Wider Caribbean Region (WCR) [10]. The WCR hosts the highest number of global small island developing states (SIDS), with the Eastern islands proximate to the North Atlantic gyre featuring large accumulations of plastic debris [11,12]. Onshore wind belts, wave action and the Guiana current are all conduits for floating debris passage from the Atlantic [1]. This is evident from the mass influxes of other buoyant material including Sargassum seaweed from the great Atlantic

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Sargassum belt, where mass deposits have been building on Atlantic-facing beaches across these islands in recent years [1,13]. Yet published data on marine litter debris for SIDS in the region remains limited [14]. Kanhai et al. [1] reviewed published data on marine debris assessments from 1980 to 2020, highlighting 17 studies conducted on windward islands of the WCR, with some of the outermost islands, including Trinidad and Tobago, having received no formal standardised assessment. Although formal assessments are lacking, citizen science initiatives have yielded some insights. Volunteer clean-ups under the International Coastal Cleanup (ICC; Ocean Conservancy) placed Caribbean coastline marine litter density over three times higher than the global average in 2016: 2014 items/km compared to 573 items/km globally; a figure widely cited in peer-reviewed literature [5,15–17]. The most recent ICC report suggests this problem is worsening, with Caribbean litter density now over four times the global average (3107 versus 724 items km<sup>-1</sup> respectively) [18]. These coastal ecosystems are becoming sinks for marine litter potentially transported from distant off-island sources [19].

Globally, marine litter is predominantly comprised of plastic materials [3,6]. Plastics are durable and cheap, and their largely unregulated, single-use application has resulted in a persistent and ubiquitous pollution crisis [20]. Despite UN and national voluntary agendas aligning to reduce plastics production and usage, global plastic production continues to reach new heights annually, with pollution levels now recognised as a growing threat to both human health and the environment [9,21]. The aquatic environment is particularly vulnerable, where estimates suggest 19–23 million tonnes of plastic waste leak into aquatic ecosystems annually, having devastating consequences for aquatic life and ecosystem services [9,22]. The detriment is particularly profound in the Caribbean, where polluted beaches negatively impact the tourism industry, which contributes 15.5% of regional GDP [23–25]. Beyond individual nations' responsibilities, marine plastic litter occupies a difficult regulatory space, where regional economic losses and clean-up costs run into billions of USD [26] and are difficult to apportion to the true polluter.

The Republic of Trinidad and Tobago represents a lower Antilles twin-island Caribbean SIDS that intersects the Guiana current. The nation is considered one of the top plastic polluters in the WCR, holding the highest mismanaged plastic waste per capita of any WCR nation, averaging 52.43 kg per person in 2019 [23,24]. Clean-up and monitoring efforts, such as the ICC, are often concentrated in the larger island of Trinidad, where significant inputs of marine plastic waste flow from land to sea [10]. Estimates of plastic waste production infer that only 2.5% of the nation's total plastic waste originates in Tobago, likely owing to its significantly lower population [27,28]. Modelling estimates identify Tobago's shorelines as vulnerable to accumulations of beached plastic waste [10], however empirical field data on Tobago's marine plastic litter loads is lacking. Moreover, as an island with comparatively low land-based plastic inputs, Tobago could be a strategically important location for standardised marine litter monitoring representative of both the Caribbean Sea and North Atlantic marine litter debris loads, as sites with low human disturbance are recommended [29,30]. Tobago's coastal ecosystems host an array of plastic-sensitive species including corals and reef fishes [31], as well as multiple species of protected nesting turtles; particularly vulnerable to plastic ingestion, including the critically endangered hawksbill turtle [32–35]. Described as an overlooked biodiversity hotspot in the WCR [36], Tobago represents a Caribbean island where data on beached marine plastic remains scarce, highlighting a significant knowledge gap impeding effective mitigation efforts in this part of the WCR.

In 2017, the OSPAR Commission (North-East Atlantic Region) and the Cartagena Convention (WCR) entered a voluntary commitment to facilitate marine litter management strategies benefiting both regions, in support of Sustainable Development Goal 14 [37]. A lack of harmonised monitoring across WCR nations continues to hinder the production of coordinated, policy-relevant reports [1]. Synchronised beach litter

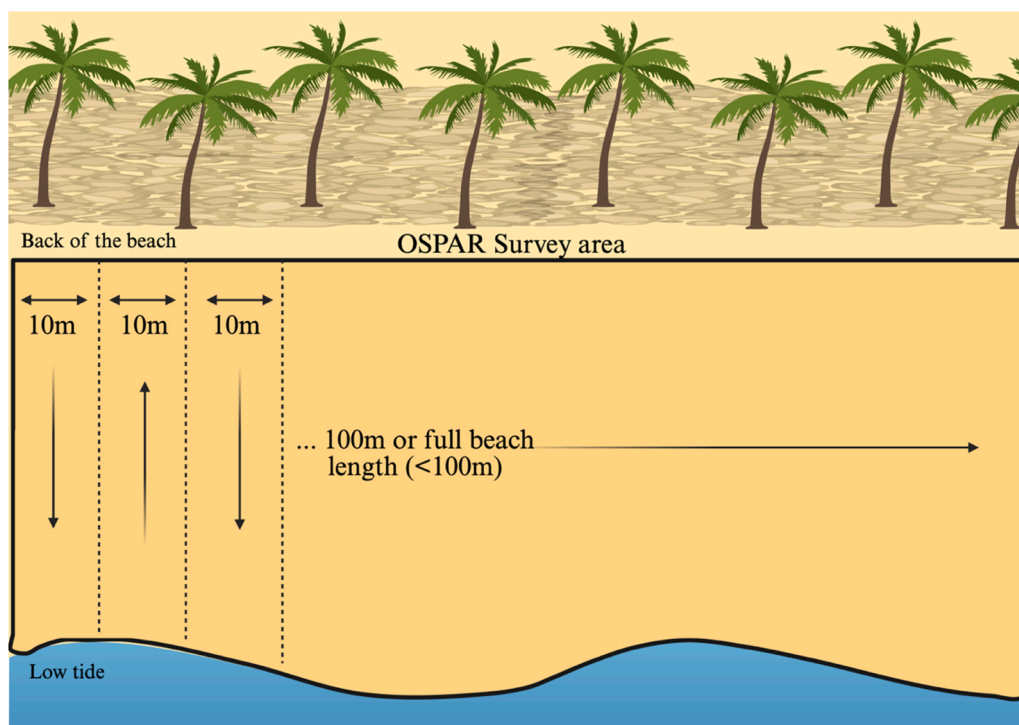
monitoring could establish baselines on the source, pathways, and distribution of marine plastics, helping to inform mitigation strategies and assess their effectiveness over time. The OSPAR Marine Litter Monitoring Survey Protocol offers potential as a standardised monitoring method in the WCR, though it has been criticised for excluding meso- and microplastic recording; size fractions shown to dominate plastic litter on other WCR coastlines [5,38]. The current study therefore aims to establish a baseline of marine litter debris loads across Caribbean Sea and Atlantic-facing rural coastlines in Tobago using the OSPAR beach monitoring protocol. Macro, meso, and microplastic fractions are separately quantified and characterised to identify the most common litter types and size categories across survey sites. Polymer composition of plastic litter is identified using Fourier Transform Infrared Spectroscopy (FTIR), enabling an assessment of whether polymer types reflect known regulatory interventions in Trinidad and Tobago. Litter loads and composition are compared between Caribbean-facing and Atlantic-facing coastlines, with consideration given to the influence of oceanographic and human factors on debris distribution. Together, these findings provide the first formal assessment of marine litter debris pollution on Tobago's coastlines and contribute baseline data to ongoing marine monitoring programmes in the WCR, enabling more informed pollution management for this data-deficient SIDS.

## 2. Methods

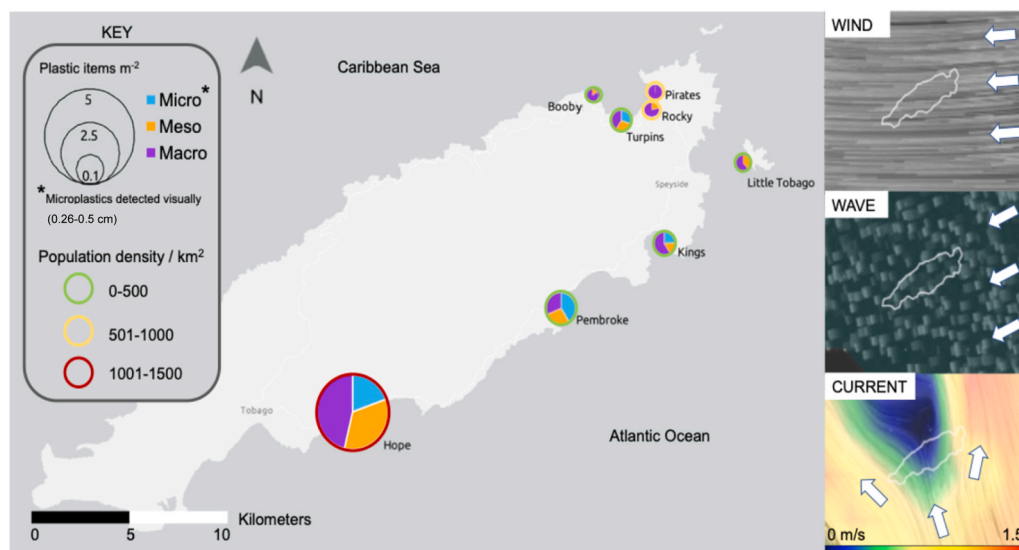
Tobago is an island within Republic of Trinidad and Tobago, located 35 km Northeast of Venezuela, South America. Westerly facing coastline meets the Caribbean Sea whilst Eastern coastlines are exposed to Atlantic waters, prevailing onshore winds and currents. Eight accessible beaches (rural, unfrequented, far from major densely populated towns, presence of litter) were selected based on anecdotal information from locals of Charlotteville village (Northeast Tobago, Speyside) and minimal human disturbance [30]. Four beaches were located on the Caribbean side (Booby, Pirates, Turpin's and Rocky) and four on the Atlantic side of the island (Little Tobago, Kings, Pembroke and Hope) (Fig. 2). One beach, Turpin's, was sampled twice, before and after the 2024 Hurricane Beryl struck the coastline of North Tobago on 30th June 2024, to provide insight into the impact of extreme weather on the occurrence of beach litter, sampling data for this site is indicated as 'Turpin's Beryl'.

The OSPAR guidelines for beach monitoring surveys were closely followed [30], where visual sampling was completed within a 100 m transect area of each site (Fig. 1). If 100 m transect was not possible for a location (Booby, Hope and Pembroke sites), the litter counts, and plastic abundances were normalised to 100 m as in Binetti et al. [29]. There is a threshold value for OSPAR beach litter counts of 20 items per 100 m, all beach sampling locations exceeded this value [39]. An adjustment of the litter classifications in the OSPAR protocol was the additional sorting of micro and mesoplastic particles within the OSPAR-ID 117 category 'Plastic/polystyrene pieces 0–2.5 cm'. This category was further split to create 'Microplastics ≤ 0.5 cm' and 'Mesoplastics > 0.5–2.5 cm' categories in the current study. Beach clean transects were marked across the coastline of Tobago using the MAPS.ME app to record latitude and longitude of starting and finishing positions. The length of the transect and the width of the surveyed area were used to calculate plastic litter m<sup>-2</sup> to allow comparison with other literature measuring beach litter abundance using similar protocols [29]. Using the coordinates and beach area, a bubble map of sampling sites was built using R, where bubble size indicated plastic loads found at each site (items m<sup>-2</sup>), the map (Fig. 2) was drawn using R Studio and ArcGIS [online] ([40]; Posit [41]).

Collected beach litter from each site was transported back to Charlotteville village, weighed on Accuweight portable scales (or Reelfishing digital scales for large items), sorted and disposed, as this site has recycling collection facilities. Samples from all plastic items (1 cm pieces cut from macro and mesoplastics, and all individual microplastics) collected from the beach surveys were stored in labelled aluminium foil



**Fig. 1.** Design of OSPAR beach surveys, following the guidance document [30]. 10 m transect sweeps were conducted perpendicular from the back of the beach to the water line at low tide. The back of the beach was defined by a seawall, or presence of permanent terrestrial vegetation [30]. These continued the length of the beach, parallel to the back of the beach, for 100 m (or the full beach length if this was under 100 m). Width of surveys varied depending on beach, detailed in Table S5. Image created in Biorender by CRS.



**Fig. 2.** Spatial distribution of plastic litter size composition of the litter collected from beaches around the island of Tobago, using OSPAR beach monitoring survey with the adjustment of separating microplastics (plastic items 0.26 – 0.5 cm) and mesoplastics (> 0.5 cm and ≤ 2.5 cm). Pie charts indicate the percentage composition of each size category (macro, >2.5 cm, meso and microplastic) while pie size indicates the abundance of plastic items at each site. The population of each survey locations' corresponding borough is indicated by either a green (0–500 km<sup>2</sup>), yellow (501–1000 km<sup>2</sup>) or red (1001–1500 km<sup>2</sup>) coloured ring surrounding each pie. The images on the right show the ocean surface currents, wave and wind directions around the island of Tobago on 19 June 2024.

parcels and transported back to Cardiff University for Fourier Transmission Infrared Microscopy (FTIR) analysis (Shimadzu, IRAffinity-1S). Absorbance peaks of each plastic sample were collected in absorbance measurement mode in the 400 cm<sup>-1</sup> - 4000 cm<sup>-1</sup> range (4 cm<sup>-1</sup> resolution) and Happ-Genzel apodization filter. Additionally, spectra were collected in groups of 20 and background corrections measurements were taken immediately before each group. Peaks were identified using

OpenSpecy (<https://www.openanalysis.org/openspecy/>), as suggested for newly published OSPAR guidelines for the monitoring of microlitter (max dimension < 0.5 cm) [42,43]. Spectra were processed using the default preprocessing settings (Min/-Max normalisation, 3rd order polynomial SG filter smoothing) but adjusting the conform wavenumbers function to a wavenumber resolution of 4 cm<sup>-1</sup>. Spectrum type was set to FTIR and spectra were identified using the supplied reference

library, based off a threshold correlation (Pearson's  $r \geq 0.7$ ) appearing as at least two of the top three results provided by OpenSpecy. If these criteria were met the plastic was assigned as the initial match. Where a single unambiguous match was not identified using peaks of the processed spectrum in OpenSpecy (Pearson's  $r < 0.7$  and/or no consistent polymer IDs in top three matches), the sample was re-scanned. Rescanned samples are indicated in the [supplementary information \(Table S2\)](#) and if these did not meet Pearson's identification criteria (Pearson's  $r < 0.7$ ) samples were regarded as unidentified matter and not included in polymer statistics or litter counts. If consistent matches were not achieved, but all suggested matches were plastic materials and met the threshold correlation (Pearson's  $r \geq 0.7$ ), these samples were assigned 'unclassified' plastic ID (UN) and included in counts as plastic material [44]. Statistics were carried out in R studio (R 2023.9.1.494) to perform a linear regression model to test whether plastic finds between size category differed considering all sites as replicates.

The Plastic Abundance Index (PAI) quantifies the abundance of plastics on a beach relative to the total number of litter items collected. First proposed by Rangel-Buitrago et al. [45], this index helps proportionately assess coastal environments plastic accumulation over a defined area ( $m^2$ ). The PAI for each of the beaches surveyed was calculated using the following formula:

$$PAI = \frac{\sum \text{Plastic litter items}}{\log_{10} \sum \frac{\text{Total litter items} \times 20}{\text{Area}}}$$

PAI scores range in the following classifications: Very Low Abundance (0), Low Abundance (0.1–1.0), Moderate Abundance (1.1–4.0), High Abundance (4.1–8.0), Very High Abundance ( $>8$ ).

To investigate various sources of pollution, oceanographic information was captured from Earth Nullschool [46], set to the time of the first beach survey conducted on 19th June 2024. Illustrated in [Fig. 2](#), prevailing oceanographic parameters including wind, currents (measured 5 m below surface) and wave directions are indicated. Population density is also shown to consider the relationship with litter density ([Fig. 2](#)). Population data was collated from the Central Statistical Office [47], transformed using population growth data up to 2026 [48]. The population density of the boroughs closest to each sampling site is indicated in [Table S6](#).

### 3. Results and discussion

This study provides the first standardised assessment of marine litter across rural coastlines of Tobago, identifying clear spatial variation in both composition and abundance ([Fig. 2](#)). A total of 2404 debris items were recorded across eight beach surveys. [Supplementary Table S4](#) provides a summary of marine litter and plastic items collected across sampling locations, including start and end coordinates of each transect, dates, beach characteristics, and survey effort. Overall, approximately 69% of the total litter composition was plastic, however composition differed markedly between coastlines. Plastics accounted for 97% of litter on Atlantic-facing beaches, compared with 16% on Caribbean-

facing sites, where glass dominated. Atlantic-facing beaches exhibited consistently higher plastic densities, with Hope Beach ([Figure S2](#)) representing a significant plastic accumulation hotspot (3.7 plastic items  $m^{-2}$ ; [Table 1](#), [Fig. 2](#)). These findings align with previous studies from small island and remote coastal systems, where windward shorelines frequently accumulate higher loads of marine debris [49,50].

The frequency of plastic finds in each size category declined with decreasing size; macroplastic was the most abundant form of plastic removed during the surveys, averaging 0.3 plastic items  $m^{-2}$ , ( $p < 0.05$ ), likely reflecting the visual sampling methods used. Hope Beach was classified as having 'very high' plastic abundance (PAI = 24.89), the only site to reach this threshold. Very high PAI classifications have been recorded in heavily impacted coastal sites in India and along Turkish Black Sea coastlines, where land-based mismanagement and maritime sources (namely capture fisheries) were the key drivers of this pollution [51,52]. Given that Hope Beach reaches the same threshold despite Tobago's comparatively low land-based plastic inputs suggests the significant role of oceanic transport as the primary driver of accumulation of litter at this site. Pembroke Beach recorded 'moderate' abundance (PAI = 1.55), while all other sites, including all Caribbean-facing beaches, fell within the 'low' abundance categories ([Table 1](#)). The relatively low PAI values across the majority of Tobago's surveyed sites reflect their rural, low-disturbance character. These findings are consistent with remote SIDS elsewhere; PAI values within the low to moderate range have been reported for remote island beaches in Japan (0.1–4.0; [53]) where impinging oceanic currents are suspected as they key drivers of litter deposition. Hope Beach represents a localised accumulation hotspot warranting targeted management intervention.

The distribution of litter across Tobago appears driven by hydrodynamic exposure rather than population density alone ([Fig. 2](#)). Although Hope Beach is situated within a relatively high population density area (PAI: 28.89, 1001–1500 people  $km^{-2}$ ), other highly polluted Atlantic-facing sites (Pembroke and Kings) are located in sparsely populated areas (0–500 people  $km^{-2}$ ; [Fig. 2](#)). This indicates that local land-based inputs are insufficient to explain observed patterns in litter deposition in Tobago. During sampling, prevailing surface currents, wind and wave conditions were directed onto Atlantic-facing coastlines, providing a mechanism for enhanced debris deposition ([46]; [Fig. 2](#)). In contrast, Caribbean-facing beaches were located within a sheltered northern bay with limited exposure to onshore winds, waves, and surface currents, resulting in substantially lower plastic densities, despite moderate population densities in the areas surrounding Pirates Bay and Rocky Beach ([Fig. 2](#)). Similar patterns have been documented globally. Windward beaches on the remote Christmas Island exhibited plastic accumulation rates over 25 times higher than on leeward shores, located only 2 km away [49]. Studies along the Colombian Caribbean coast have identified currents and wind-wave driven transport as dominant controls on litter distribution at beaches with limited local pollution sources [54]. Together, these findings suggest that oceanographic processes, rather than proximity to human populations, are the key drivers of plastic accumulation on Tobago's rural coastlines.

**Table 1**

Litter density and Plastic Abundance Index (PAI) of coastlines for Tobago coastal environments (only including plastic items  $> 0.5$  cm).

| g                | Water     | % plastic | Overall litter density ( $m^{-2}$ ) | Plastic items density ( $m^{-2}$ ) | PAI   | PAI classification  |
|------------------|-----------|-----------|-------------------------------------|------------------------------------|-------|---------------------|
| Hope             | Atlantic  | 97.88     | 3.78                                | 3.7                                | 24.89 | Very High Abundance |
| Pembroke         | Atlantic  | 94.12     | 0.18                                | 0.17                               | 1.55  | Moderate Abundance  |
| Kings            | Atlantic  | 86        | 0.07                                | 0.06                               | 0.61  | Low Abundance       |
| Little Tobago    | Atlantic  | 82.86     | 0.03                                | 0.02                               | 0.29  | Low Abundance       |
| Turpin's         | Caribbean | 40.71     | 0.11                                | 0.05                               | 0.45  | Low Abundance       |
| Rocky            | Caribbean | 2.4       | 1.17                                | 0.03                               | 0.2   | Low Abundance       |
| Pirates          | Caribbean | 48.78     | 0.04                                | 0.02                               | 0.25  | Low Abundance       |
| Booby            | Caribbean | 30.65     | 0.08                                | 0.02                               | 0.27  | Low Abundance       |
| Turpin's (Beryl) | Caribbean | 86.57     | 0.07                                | 0.06                               | 0.64  | Low Abundance       |

While plastic litter dominated Atlantic sites, Caribbean-facing beaches were characterised by substantial accumulations of non-plastic litter, namely glass (Table 2). Rocky Beach had the highest recorded total litter density among Caribbean sites ( $1.17 \text{ items m}^{-2}$ ; Table 2), almost entirely driven by glass fragments. The sheltered conditions of the northern bay and reduced hydrodynamic input suggest that this material is locally derived, likely associated with recreational use, highlighting an important distinction between ocean-driven plastic pollution and locally generated general litter in Tobago. Although less frequently studied, accumulations of litter items such as glass negatively affect coastal aesthetics and contribute to negative tourism perceptions, potentially affecting tourism value and recreational use [55,56]. Beaches on the Caribbean side, including Kings, Pirates and Turpin's and Rocky, are popular tourist areas, hence local litter interventions here would benefit local economies.

Turpin's had the highest level of plastic pollution of the beaches surveyed along Caribbean Sea coastline (Fig. 3). The rapid re-accumulation of litter at Turpin's following Hurricane Beryl highlights

**Table 2**  
Top 5 littered items across sampling locations in Tobago [30].

| Beach                   | Litter                                                                            | Frequency /<br>100 m |
|-------------------------|-----------------------------------------------------------------------------------|----------------------|
| <b>Atlantic Beaches</b> |                                                                                   |                      |
| Hope                    | Mesoplastics > 0.5–2.5 cm                                                         | 786                  |
|                         | Macroplastic pieces 2.5 cm > < 50 cm                                              | 450                  |
|                         | String and cord (dia < 1 cm)                                                      | 274                  |
|                         | Caps/lids                                                                         | 118                  |
|                         | Crisp/sweet_packets                                                               | 62                   |
| Pembroke                | Mesoplastics > 0.5–2.5 cm                                                         | 136                  |
|                         | Macroplastic pieces 2.5 cm > < 50 cm                                              | 68                   |
|                         | Drinks (bottles/containers/drums)                                                 | 22                   |
|                         | Crisp/sweet_packets                                                               | 18                   |
|                         | String_and_cord [diameter_less_than_1cm]                                          | 8                    |
| Little Tobago           | Other_paper_items                                                                 | 8                    |
|                         | Mesoplastics > 0.5–2.5 cm                                                         | 11                   |
|                         | Macroplastic pieces 2.5 cm > < 50 cm                                              | 4                    |
|                         | Fishing line (angling)                                                            | 4                    |
|                         | Drinks (bottles/containers/drums)                                                 | 3                    |
| Kings                   | Plastic bag ends                                                                  | 2                    |
|                         | String and cord (dia < 1 cm)                                                      | 2                    |
|                         | Other plastics (drinks bottle label, mesh drinks cover)                           | 2                    |
|                         | Mesoplastics > 0.5–2.5 cm                                                         | 19                   |
|                         | String_and_cord (dia < 1 cm)                                                      | 16                   |
| Caribbean Beaches       | Drinks (bottles/containers/drums)                                                 | 12                   |
|                         | Other plastics (5 x toothbrush, 3 x medicine bottle, 4 x plastic bottle wrappers) | 12                   |
|                         | Caps/lids                                                                         | 10                   |
|                         | Pirates                                                                           |                      |
|                         | Cigarette butts                                                                   | 6                    |
| Booby                   | Other Glass                                                                       | 5                    |
|                         | Plastic bag ends                                                                  | 5                    |
|                         | Fishing line (angling)                                                            | 4                    |
|                         | Caps/lids                                                                         | 4                    |
|                         | Other Glass                                                                       | 67                   |
| Rocky                   | Plastic bag ends                                                                  | 11                   |
|                         | Small plastic bags (e.g. Freezer bags)                                            | 9                    |
|                         | Crisp/sweet_packets                                                               | 7                    |
|                         | Mesoplastics > 0.5–2.5 cm                                                         | 7                    |
|                         | Other paper items                                                                 | 7                    |
| Turpin's                | Bottle caps                                                                       | 7                    |
|                         | Other Glass                                                                       | 518                  |
|                         | Construction material (e.g. tiles) [Ceramic]                                      | 22                   |
|                         | Other metal pieces < 50 cm                                                        | 13                   |
|                         | Other metal pieces > 50 cm                                                        | 5                    |
|                         | Cardboard                                                                         | 4                    |
|                         | Other                                                                             | 4                    |
|                         | Other Glass                                                                       | 32                   |
|                         | Mesoplastics > 0.5–2.5 cm                                                         | 19                   |
|                         | Cigarette butts                                                                   | 10                   |
|                         | Macroplastic pieces 2.5 cm > < 50 cm                                              | 9                    |
|                         | Crisp/sweet_packets                                                               | 7                    |
|                         | Wire                                                                              | 7                    |

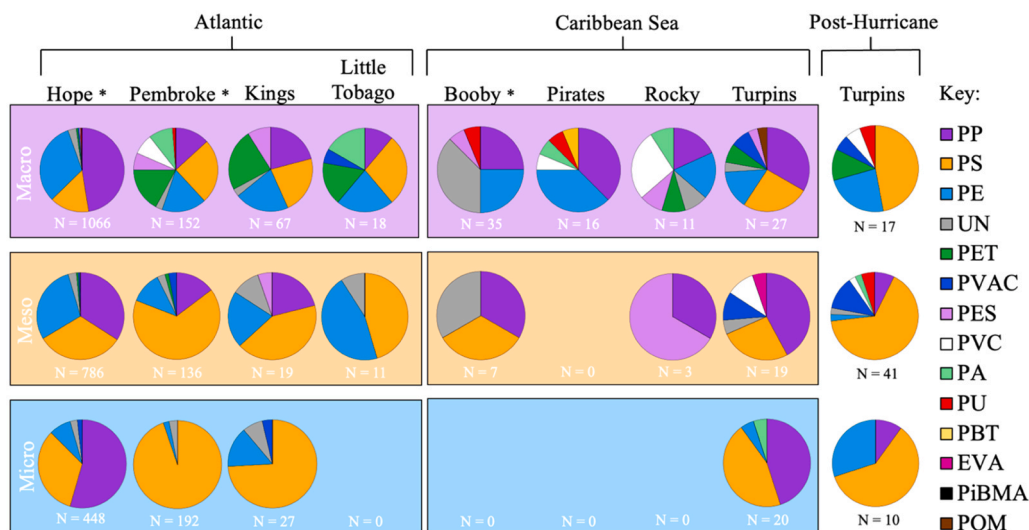
the importance of extreme weather events in controlling short-term litter dynamics. Within two days of the same 100 m transect clearance, litter levels returned to pre-clean conditions, with plastic composition increasing from 40.7% to 80.6% (Table 1). This shift was accompanied by an increase in mesoplastics and polystyrene fragments (Fig. 3), likely driven by fragmentation of existing debris under the high-energy conditions of the storm, given the widespread use of PS fishing buoys in Tobago. Similar post-storm litter re-accumulation has been observed following storm events in the Baltic Sea. Fetisov et al. [57] demonstrated post-storm mass of plastic litter on surveyed beaches was 100 times higher than when surveyed under normal conditions, recommending that cleaning after storm is an effective way to remove plastic from marine environment. Taken with the results from the current study, post-storm clean-up strategies and formal surveying may represent an efficient intervention point in resource-limited SIDS, including in Tobago.

Polypropylene (PP), polystyrene (PS), and polyethylene (PE) were the most common polymers identified, with PS dominating the meso- and microplastic size fractions (Fig. 3; 418 PS items versus 293 PP and 160 PE). This contrasts with regional studies where PE typically dominates plastic pollution profiles, including in the Caribbean [58,59]. The prominence of PS may reflect both methodological bias (expanded PS more conspicuous and more likely to be deposited on the strandline) and local sources, including fishing related material such as home-made PS buoys widely used in the area. However, the high abundance of PS is notable given the national ban on polystyrene imports introduced in 2019 [60]. Several factors may explain this discrepancy, including continued local production of PS materials despite the import ban [25], limited enforcement of this regulation, and potential transboundary transport of PS litter. Moreover, the identification of a “biodegradable” item as polypropylene further highlights broader issues surrounding plastic manufacturing, regarding mislabelling and greenwashing, raising concerns about consumer misinformation and ineffective mitigations strategies in Tobago (Fig. 4).

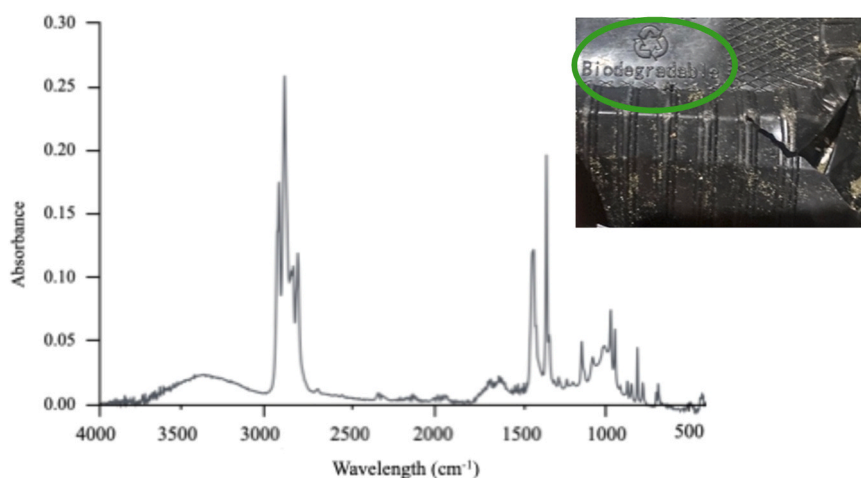
The current study demonstrated the value of standardised monitoring approaches such as OSPAR, in identifying site-specific litter characteristics and informing targeted interventions. As plastic hotspots, Atlantic-facing beaches are priority sites for formal litter monitoring (Hope, Pembroke). The data produced from such surveys can support targeted clean-up efforts and resource allocation through local CSOs and citizen science initiatives like North-East Sea Turtles, Speyside Eco-Marine Park Rangers, and engagement with the annual International Coastal Clean-up (ICC), which can be coupled with OSPAR surveying [16,61]. Given that Atlantic-facing beaches consistently show high counts of OSPAR-ID 117 items (‘Plastic/polystyrene pieces 0–2.5 cm’), future work should adopt the MPEG guidelines to quantify microplastic loads beyond visual detection in Tobago to better assess environmental risks [43]. Additionally, more sampling of the Caribbean-exposed coastline is needed, particularly at ecologically sensitive sites like the protected Buccoo Reef shoreline in the island's southwest coastline.

#### 4. Limitations to the study

Firstly, microplastics reported in this study were limited to visually detectable particles (0.26–0.5 cm) and therefore do not represent the full microplastic size spectrum. The absence of visually identified microplastics at some sites (Little Tobago, Booby, Pirates, and Rocky) should not be interpreted as true absence but rather reflects methodological constraints. Robust quantification of microplastics requires sediment sampling and laboratory processing (e.g., density separation and spectroscopic analysis), which were beyond the scope of this study. Future work should adopt recently developed OSPAR microlitter protocols enable more comprehensive assessments of microplastic loads in these coastal environments [43]. Secondly, population density data were extrapolated from 2011 census data to estimate 2024 borough-level values relevant to survey sites ([47,48,62]; Table S5).



**Fig. 3.** The number (N), size distributions (macro, meso and microplastics) and polymer types of plastic litter collected during OSPAR beach monitoring surveys from 19/06/2024–01/07/2024. The abbreviations for all other polymer types detected is indicated in the [supplementary information \(Table S1\)](#). Asterisks (\*) indicate beaches with normalised litter counts to 100 m, as these beaches did not have a full 100 m survey completed.



**Fig. 4.** Plastic dinner tray removed from Hope beach labelled as biodegradable was identified as polypropylene material in FTIR analysis ( $r^2 = 0.96$ )– sample ID H\_Mac\_52. Polymer spectra for other plastics identified are included in the [supplementary material \(Fig. S3\)](#).

While this introduces uncertainty, the data provides a useful proxy for exploring relationships between human population and litter accumulation (Fig. 2). Statistical comparisons between Caribbean and Atlantic-facing coastlines were not performed due to limited spatial independence among Caribbean sites, which were all located within a single sheltered bay (Fig. 2). A non-parametric test to compare between exposures assumes statistical independence between sampling sites and sufficient replication within groups [63]. This constraint resulted from adverse weather conditions that prevented broader sampling along the Caribbean coastline. Future surveys should prioritise more geographically distributed sites, particularly along the southern Caribbean coast. Finally, the study represents a temporal snapshot based on a single sampling campaign. Repeated surveys across seasons are necessary to capture temporal variability and improve the robustness of baseline assessments.

## 5. Conclusion

This study presents the first standardised assessment of marine litter across Tobago's rural coastlines, establishing a baseline for future

monitoring in this data-deficient Caribbean SIDS. A total of 2481 debris items were recorded, with spatial differences between litter abundances on Atlantic- and Caribbean-facing environments. Atlantic coastlines were characterised by substantially higher plastic loads (up to 97% composition), while Caribbean-facing sites were dominated by non-plastic litter, particularly glass. These patterns suggest that hydrodynamic exposure, rather than population density alone, is the dominant control on plastic litter accumulations in Tobago. The identification of hotspot locations, particularly on windward coastlines, highlights priority areas for monitoring and intervention. The persistence of polystyrene despite regulatory bans highlights gaps in enforcement and potential transboundary pollution sources. Overall, this study demonstrates the value of standardised monitoring approaches for understanding marine litter dynamics and provides a foundation for targeted management strategies in Tobago.

## CRediT authorship contribution statement

**Devon Eastman:** Investigation, Conceptualization. **Kathryn E. Whitney:** Writing – review & editing, Investigation, Conceptualization.

**Stephen J. Cheung:** Writing – review & editing, Investigation. **Franческа. C. Mason:** Writing – review & editing, Investigation. **Charlotte Robison-Smith:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jo Cable:** Writing – review & editing, Supervision, Investigation, Conceptualization. **Sarah E. Perkins:** Writing – review & editing, Supervision, Investigation, Conceptualization. **Lanya Fanovich:** Writing – review & editing, Conceptualization. **Ryan S. Mohammed:** Writing – review & editing, Conceptualization. **Kimron Eastman:** Investigation, Conceptualization.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.hazmp.2026.100077](https://doi.org/10.1016/j.hazmp.2026.100077).

## Data availability

The data link is included in the manuscript file. <https://doi.org/10.17035/cardiiff.30199831>.

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