Abundance, Composition, Spatial Distribution and Management Practices of Marine Litter Along the Bay of Bengal Coast of Bangladesh

Md. Kawser Ahmed[1, 2*], Michael Bennett[3] Md. Ohiduzzaman1, Md. Habibullah-Al-Mamun[4], Seema Rani[2, 5] Md. Saiful Islam[6, 7], Antaya March[3, 8], Pierre Failler[3], and Gordon Watson[9]

Abstract

This study provides an assessment and characterization of marine litter pollution among various beaches of the Bay of Bengal coastline of Bangladesh, through standardised surveys. The data suggests that marine litter density was greatest in areas where anthropogenic activity was highest, such as Cox's Bazar (a popular tourist attraction) and Chittagong (second largest urban concentration in the country). The majority of collected litter originated from domestic and recreational sources, indicating that marine litter pollution is of local origin instead of being washed ashore through ocean current deposition; as well as further emphasising the pattern of increasing marine litter pollution with increasing human presence. Plastic, polystyrene, and paper and cardboard litter was present among all sites surveyed, with plastic dominating in abundance. Limited beach cleaning activities were being conducted among the beaches surveyed, and marine litter management programmes were also limited. Recommendations include the provisioning of increased numbers of refuse bins, the development of long-term monitoring programmes on the coastlines as well as along marine litter source pathways, reviewing the "National Municipal Solid Waste Management" program, and the development of a National Marine Litter Policy to reduce and control marine litter pollution along the shores of Bangladesh. The application of these recommendations are likely to contribute to regional and global initiatives such as the upcoming Global Plastics Treaty.

Key Words: Beach Litter Management; Plastic Policy; Waste Analysis; Waste Composition; Solid Waste Management

[1] Department of Oceanography, Faculty of Earth and Environmental Science, University of Dhaka, Dhaka-1000

[2] International Centre for Ocean Governance (ICOG), Faculty of Earth & Environmental Sciences, University of Dhaka, Dhaka-1000, Bangladesh

[3] Centre for Blue Governance, University of Portsmouth, UK

[4] Department of Fisheries, Faculty of Biological Sciences, University of Dhaka, Dhaka-1000.

[5] Coastal and Ocean Management Institute (COMI), Xiamen University, Fujian Province, China

[6] Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo 113-8657, Japan

[7] Department of Soil Science, Patuakhali Science and Technology University, Dumki, Patuakhali 8602, Bangladesh

[8] Global Plastics Policy Centre, University of Portsmouth, UK

[9] Institute of Marine Sciences, University of Portsmouth, UK

[*] Corresponding author: Md. Kawser Ahmed (kawser_du@yahoo.com)

Highlights

- The abundance and composition of marine litter in the Bay of Bengal was investigated.
- A total of 9471 litter items were collected from five beaches.
- Plastic litter formed the majority of all the litter items (66 %).
- Domestic and recreational activities are the major possible sources of marine litter.
- Lack of adequate existing marine litter management programmes and facilities highlight the need for a national marine litter policy.

1. Introduction

Marine litter, also known as 'marine debris', is commonly defined as ''any persistent, manufactured, or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (Galgani et al., 2010, p4). Litter arrives in marine reservoirs from land and sea-based sources with rivers, illegal dumping, beach abandonment by visitors, and the disposal from ships, offshore installations, drainage systems, flooding, and wind action all contributing to the transportation of marine debris. (UNEP/MAP, 2012; Anfuso et al., 2015; Prevenios et al., 2018), such that marine litter pollution is increasingly being reported worldwide (Schneider et al., 2018). The accumulation of marine litter along marine and coastal environments has become a considerable problem for low, middle and high income countries (UNEP, 2014; Jang et al., 2018), as it causes harmful environmental problems (Gregory, 2009; Todd et al. 2010; Votier et al., 2011), threatens human health (Whiting, 1998; Campbell et al., 2019; Landrigan et al. 2020), and affects the aesthetic value of beaches and other coastal environments (Tudor and Williams, 2003; Anfuso et al., 2015, 2017).

More than 80% of marine pollution originates from land-based activities (UNEP/Oceans Conservancy/Regional Seas/GPA, 2009). Marine litter generally consists of slowly-degradable waste materials from constructed plastic, polystyrene, various metals and glass. Marine litter can thus persist and move in marine and coastal environments for long periods of time, floating on the water surface, drifting through the water column, sink to the sea bed, or become caught along shallow coastlines (such as beaches and tidal pools). With the increasing concentration of humans along global coastlines and coastal migration (Nieeuman et al. 2015; Hugo 2011; McGranahan et al. 2007), and locals and tourists visiting attractive beach destinations, marine pollution is likely to intensify among beaches and other coastal environments, increasing the risk to human and environmental health.

Of the five coastal countries) in the South Asian Seas (SAS) region (Bangladesh, India, Maldives, Pakistan and Sri Lanka, information regarding marine litter is available from India (for example Quasim et al. 1988; Shanmugam et al. 2007; Anbuselvan et al. 2018; Perumal et al. 2023), Sri Lanka (for example Darmadasa et al. 2021; Koongolla et al. 2018; Jang et al. 2018), and Bangladesh (Islam et al. 2022a and 2022b; Mubin et al. 2023; Nawar et al. 2023; Al Nahian et al. 2022; Rakib et al. 2022; and Afnan and Khanam 2021), but data on marine litter pollution is generally limited. Where regional assessments of marine debris have been conducted in the past for the SAS region (SACEP 2007), the information is outdated and does not accurately reflect the current status of marine pollution on a national level. Other sources of information about marine litter in the SAS region include national reports (including from Bangladesh, Ahmed et al. 2019) for the development of the Regional Marine Litter Action Plan for the South Asia Seas (SACEP 2019a).

Regional initiatives for addressing marine pollution in the Bay of Bengal include the "Regional Marine Litter Action Plan for the South Asia Seas" (SACEP 2019a); "Roadmap for Sustainable Waste Management and Resource Circulation in South Asia 2019-2030" (SACEP 2019b); "Regulating Marine Litter and Plastic Wastes in SAS Region" (Desai 2019), and the SACEP "Plastic free Rivers and Seas for South Asia project" (SACEP 2020). Relevant larger international agreements include the "Contributions of Regional Seas Conventions and Action Plans to a Healthy Ocean" report (UNEP 2022), and SACEP ratification of international legal agreements such as the London Agreement (and others, SACEP 2021). Being signatories to these regional agreements and plans demonstrates a country's commitment to addressing marine pollution on a national level through national programmes, as well as supporting similar initiatives beyond its socio-political borders in neighbouring countries. The Global Plastics Treaty, currently under development (UNEP 2023), presents a new international agreement, which, once signed, will mandate countries to tackle plastic pollution issues in a globally coordinated manner (March et al., 2023).

Marine litter research is limited in Bangladesh and more data on marine plastic pollution is required to develop national initiatives for addressing marine plastic pollution. The current study was initiated to establish baseline data and information on the distribution of marine litter in Bangladesh through beach surveys (the first of its kind), as well as investigate the legal and institutional frameworks concerning waste management along the Bay of Bengal coastline of Bangladesh. The findings of this paper are intended to inform the development of future marine pollution monitoring programmes for Bangladeshi coastal systems, and national policy development concerning the growing problem of marine plastic pollution.

The rest of this paper is structured as follows: section 2 details the methodologies used for the surveys in this study, section 3 presents the results from the surveys, section 4 contextualises the research findings, and the paper concludes with recommendations for future management, research, and policy development (section 5).

2. Materials and Methods

In this study, specific research questions were addressed- (I) What is the amount and composition of marine debris found on specific beach areas in Bangladesh? (II) What beach litter management practices are implemented in Bangladesh? On the basis of the above questions, this study is concerned with a comprehensive monitoring program, in alinement with the "National Programme of Action for the Protection of the Coastal and Marine Environment from land-based activities" (Ministry of Environment and Forests 2006), and is devoted to the characterisation of marine litter on the Bangladeshi coastline in the Bay of Bengal.

2.1. Description of the study area

According to Cheshire et al. (2009), site selection for the study of beach litter is specified by a minimum length of 100m (however beaches with smaller amounts of marine debris may need to be longer in length to accurately capture representative density data), clearly accessible to the sea, beaches need to be of a low to moderate slope (150–450), accessible year round, and the survey should only be conducted when there is minimal risk of danger surveyors, or where protected species are not found. This above criteria was used to select five popular tourist beaches along the coastal zone of Bangladesh. Most of the beaches were in tourist areas where human presence is concentrated and thus where the occurrence of marine litter may represent a considerable environmental, socio-economic and health problem. The five beaches that were selected are Cox's Bazar, Chittagong, Kuakata, Kotka and Saint Martin's Island (Figure 1).

Cox's Bazar is the southernmost location among all the districts in Chittagong division of Bangladesh. It is characterised by the world's longest unbroken natural sea beach (120km), and is one of the most popular tourist spots both in Bangladesh and in Asia (Hasssan and Shahnewaz 2014). It has two separate important beach areas for tourist attraction, one is Laboni beach and other is Inani beach. Chittagong is the second largest urban concentration in the country and located in south-eastBangladesh. In Chittagong, many smaller stretches of beach are situated along the coastline, however Patenga and Ananda Bazar beach was surveyed in this study. Kuakata is in Kalapara Upazila, Patuakhali District. This town is known for its panoramic beach from where it can offer a full view of sunrise and sunset. It is locally known as Shagor-Kannya. Kotka is in the eastern part of Sundarban mangrove forest which is the world largest natural mangrove

forest (Hassan and Shahnewaz 2014). This beach is only accessible for tourists during the winter season and is not as large as other beaches. Saint Martin's Island is a small isle (8 km^2) formed on the southernmost part of Bangladesh. However, there is another small adjoining island which becomes separated at high tide, Chera Dwip. The observation of marine litter was conducted on both Saint Martin's Island and Chera Dwip.

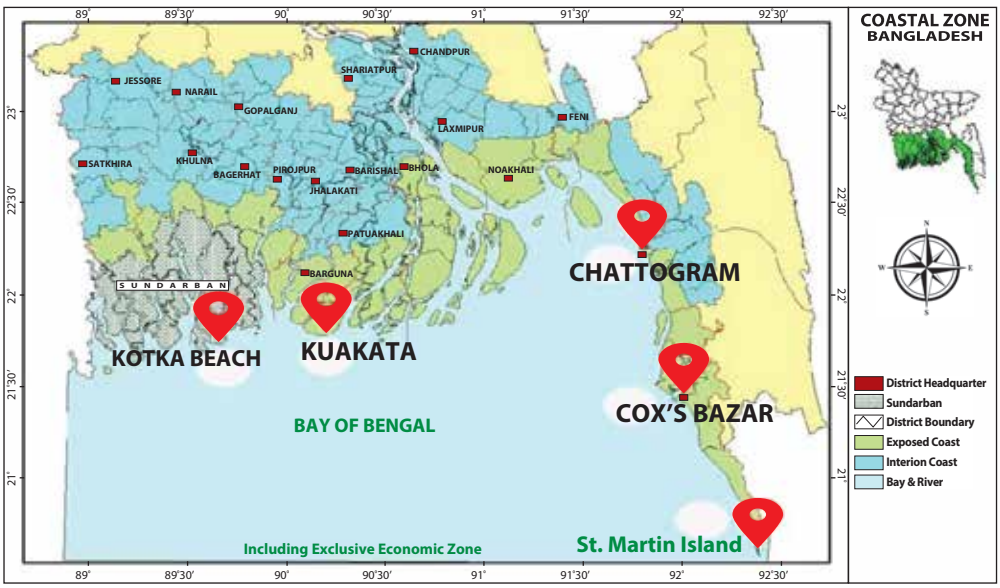

Figure 1: Study areas showing marine litter survey sites along the Bangladeshi coast in the Bay of Bengal are indicated by red markers (beaches from east to west: Saint Martin's Island, Cox's Bazar, Chittagong, Kuakata, and Kotka beach)

2.2. Litter survey, classification and quantification

The standardised approach proposed by Cheshire et al. (2009) was adhered to for rapid beach litter monitoring to assess the accumulation of beach litter during the study period (the same procedure was followed for each of the five locations). Litter items were recorded along 10m wide transects of variable length (depending on beach topography, although over a length of 100m) from an access point based in the central part of the beach (Table 1). The extent of the transects included the strandline up to to the marine landward boundary, which was usually dunes, a cliff base, seawall or other anthropogenic structures (EA/NALG, 2000). To quantify the litter, a datasheet was prepared by grouping marine litter into nine major categories: plastic, foamed plastic (polystyrene), cloth, glass and ceramic, metal, paper and cardboard, rubber, wood, and others. Marine debris items that were too small or too degraded to be identified were categorised as 'others', and left out of further analyses (Table 1 data includes "others"

in the totals, but the proportions in Figure 3 does not include 'others' in the totals from which they were calculated). Items of debris were gathered, identified, categorised based on their composition, and then quantified (Cheshire et al., 2009; Galgani et al., 2013). The composition of marine litter is important as it provides vital information on individual items, which can be traced back to their sources (Browne, 2015). The marine debris were further characterised according to five broad categories of origin according to the "International Coastal Cleanup Report from 2009" (Ocean Conservancy 2009): "shoreline/recreational", "ocean/waterway", "smoking related", "dumping", and "medical/personal hygiene". "Cleanliness of beaches" was inferred by using the density of marine litter as a proxy. Density of marine items was calculated as the total number of collected items per square metre of beach surface, using the following formula:

$$\text{Density} = \frac{\text{Total litter on transect}}{\text{Total area of transect)}}$$

where the total area of the transect was calculated by multiplying transect length with transect width. Location and transect measurements were made using a GPS enabled smartphone, bearing the tidal regimes of each location in mind.

During the marine litter surveys, the presence of refuse bins for the disposal of marine litter was recorded, as well as the organisation that maintains them (if any). The presence of any regular marine litter collection activities by private organisations or public authorities were also investigated, through professional networks and local enquiries.

Marine litter surveys were conducted from November 2017 to February 2018. The beach surveys were conducted during winter to create a synopsis overview of marine litter characteristics and distribution during a period where beach cleaning operations were not conducted.

3. Results and Discussion

3.1. Abundance, composition, and density of marine litters

The abundance, composition and average density of collected marine litter from the study areas are presented in Table 1 and Table 2 (Annex 1). A total of 9471 items of marine litter in 9 different categories was recorded from the surveyed areas of Cox's Bazar, Chittagong, Kuakata, Kotka and Saint Martin's Island (Table 2). Among the total recorded marine litter, approximately 66% of plastic, 10% of foamed plastic, 3% of cloth, 1% of glass and ceramic, 1% of metal, 9% of paper and cardboard, 3% of rubber, 2% of wood, and 5% other materials were categorised. A clear spatial variability of the abundance of marine litter was observed in the surveyed beaches. The highest amount of marine litter was recorded from Cox's Bazar (4573 items) followed by Chittagong

(2132 items), Saint Martin's Island (1916 items), Kuakata (709 items) and Kotka (141 items) (Table 1). The highest density of marine litter was recorded from Cox's Bazar (0.114 items/m^2), followed by Chittagong (0.102 items/m^2), Kuakata (0.047 items/m^2), Saint Martin's Island (0.095 items/m^2), with the lowest density recorded from Kotka (0.035 items/m^2, Table 1).

Table 1: Abundance and densities (items/m^2) of marine litter in the five coastal beaches of Bangladesh.

Coastal area	Transect Width (m)	Transect Length (m)	Area (m^2)	Number of Litter Items	Density (items/m^2)
Cox's Bazar	10	4000	40000	4573	0.114
Chittagong	10	2100	21000	2132	0.102
Kuakata	10	1500	15000	709	0.047
Kotka	10	400	4000	141	0.035
Saint Martin's Island	10	2000	20000	1916	0.095

Analysis of the make-up of litter collected from various coastal regions in Bangladesh indicate that "plastics", (including petroleum-based synthetic materials of any kind), made up the greatest fraction of the total amount of identified marine litter. Product packaging materials, fishing equipment such as nets, and unidentifiable pieces of plastic and polystyrene accounted for the majority of marine debris items that were recorded in this category, as has been found in other research (Galgani et al. (2013). Furthermore, these results are in accordance with other studies, in that they highlighted that plastic was the most dominating and frequent material among marine litter on beaches (Ivar do Sul and Costa, 2007; Oigman-Pszczol and Creed, 2007; Eriksson et al., 2013; Portman and Brennan, 2017; Poeta et al., 2016; Kumar et al., 2016).

The collected litter items were also categorised according to source-of-origin categories: "shoreline/recreational", "ocean/waterway", "smoking related", "dumping", and "medical/personal hygiene activities" (according to Ocean Conservancy 2009). Shoreline/recreational activities that produced litter, such as paper and plastic bags, plastic cups, and corn stalks and food wrappers, (etc.) were the largest source of litter identified (70.6%, Figure 2). Litter derived from dumping actions (13.64%) which included items such as building materials, metal and glass fragments, fabric waste, and paper-based products (including cardboard) constituted the second

greatest source. The rest of the marine debris items originated from smoking related actions (8.85%), ocean/waterway activities (2.8%), medical/personal hygiene categories (0.07%), and others (4.04%).

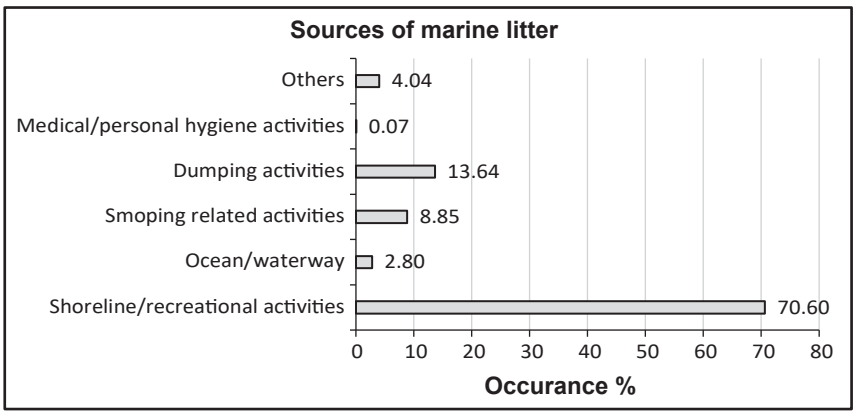

Figure 2: Sources of marine debris (according to Ocean Conservancy 2009).

The relative proportion of types of marine debris on the different surveyed beaches (Figure 3) indicates that plastic marine litter dominated on these beaches (>58%), followed by either foamed plastic (3-11%) or paper and cardboard litter types (5-17%) depending on beach location, but were found in all sites surveyed. Metal, cloth, rubber, glass and ceramic, as well as wood items were found in relatively low proportions (<10%, Figure 3). The relative proportions of marine litter on each of the five surveyed beaches (Figure 3) should be interpreted with the consideration of the total number of litter items collected (Table 1). Marine litter on Kotka beach consisted of only three types: plastic, paper and cardboard, and cloth (Figure 3-E), whereas Cox's Bazar and Saint Martin's Island had all 8 types of marine litter (Figure 3-A and C, respectively). Kuakata beach and Chittagong beach did not have any metal marine litter (Figure 3-B and D, respectively).

There was variation in the abundance and make-up of beached marine debris between the study locations. The variability can be explained by differences in anthropogenic elements (such as the presence of bleach clean-up programmes, number of visitors, presence of waste disposal facilities like bins) as well as physical considerations (e.g. environmental variables such as the waves, winds, and tides; beach location and orientation with respect to the Bay of Bengal, and coastline morphology). The abundance of collected litter items increased with the increasing area of the transect surveyed (Table 1), and smaller transects were associated with fewer marine litter items. Marine litter density should thus be used as a more robust indicator of marine litter pollution, when comparing different locations, but the data (Table 1) suggests this

indicator may also be influenced by the size of the area studied (albeit to a lesser extent). The greater density of marine litter found on Cox's Bazar can be explained by the

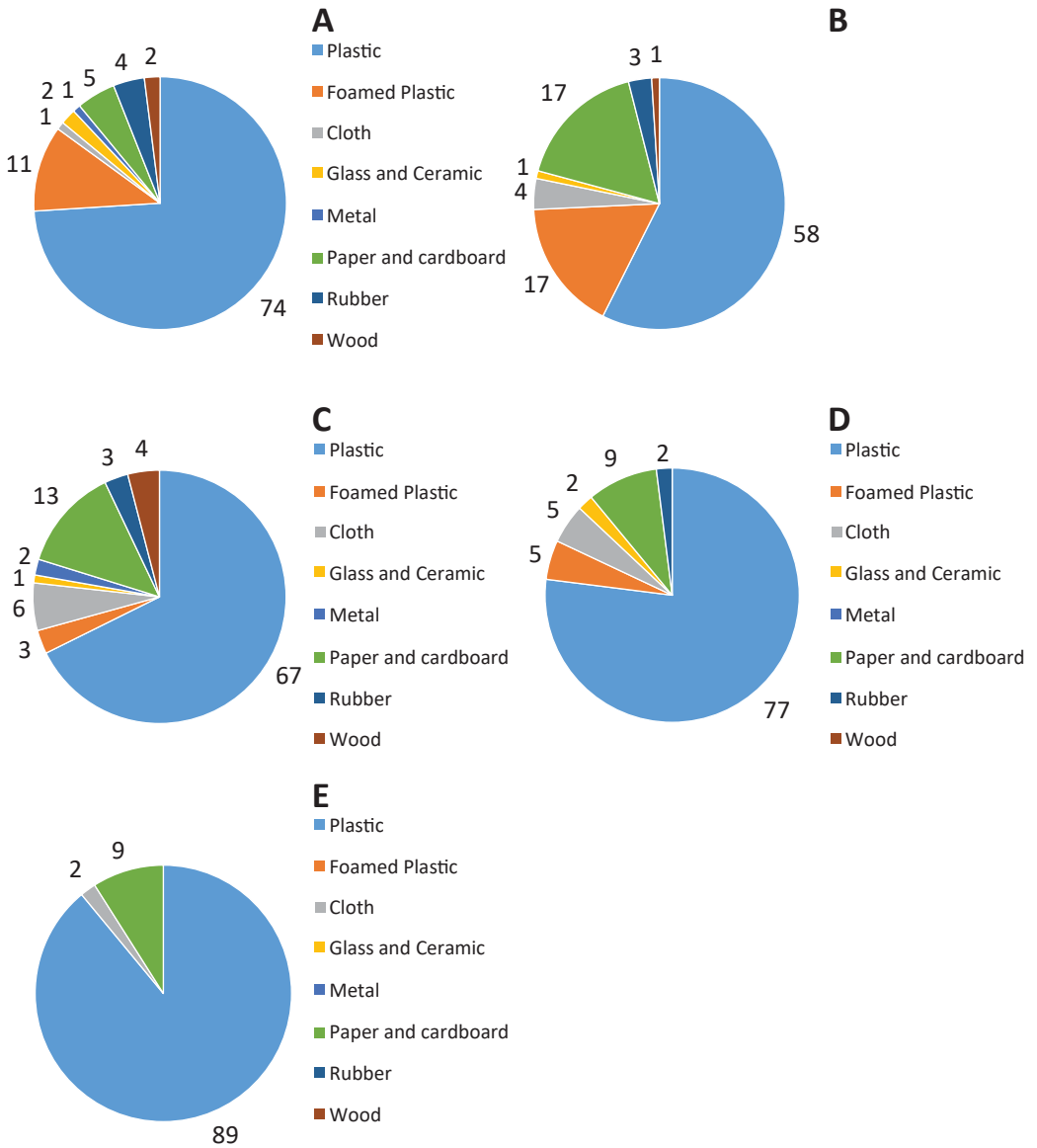

Figure 3: Relative proportion (%) of different types of marine debris among the five beaches surveyed on the coast of the Bangladeshi coastlines in the Bay of Bengal. Data labels indicate the relative proportion (%) of the total collected on each beach (with 'others' removed). A- Cox's Bazar, B - Chittagong, C- Saint Martin's Island, D - Kuakata, E - Kotka.

occurrence of large congregations of people (large numbers of tourists) at Cox's Bazar as it is the more more attractive and famous tourist destination in Bangladesh when compared to the other beaches surveyed in this study (Hasssan and Shahnewaz 2014). The relatively high marine litter density in Chittagong is likely due to Chittagong being the second largest city and industrial hub in Bangladesh (Mia et al. 2015) and therefore also hosts a large number of people on its beaches. Saint Martin's Island is also a popular tourist destination (Kamruzzaman 2018). This data presents a pattern whereby the larger concentrations of human activity is associated with larger degrees of marine litter pollution. This pattern could then explain the relatively low marine litter density of the less popular locations, Kuakata and Kotka beaches. However, the size of the transects surveyed in each location was directly associated with the number of marine litter items collected, i.e. the larger the transect, the more marine litter was collected. In future surveys, multiple transects of standardised dimensions per location, should yield more robust data with which to confirm the observed pattern.

The results suggested that the average density of litter items recorded in the present study (0.1 items/m^2) was lower than the global density of 1 items/m^2 as well as other studies elsewhere in the world (Table 3, Annex 1). Specifically, The litter density of the Bangladeshi coastal areas (0.1 items/m^2) was similar to those recorded from Australia (Cunningham and Wilson, 2003) and lower than those from Brazil (Oigman-Pszczol and Creed, 2007), Taiwan (Kuo and Huang, 2014), Italy (Munari et al., 2016), Russia (Kusui and Noda, 2003), Turkey (Aydin et al., 2016), and Ireland (Benton, 1995). The contextualisation of our results with other research suggest that beaches along the coastline of Bangladesh are less polluted by marine litter, than the other locations globally (Table 3), despite having been ranked 10th as one of the world's greatest marine debris polluters (Jambeck et al. (2015). However, the above studies may have been conducted using different size ranges and categorisations of marine litter in their surveys. Nevertheless, generalised patterns indicate elevated concentrations of plastic litter closer to urban areas and tourist destinations (Barnes et al., 2009).

Density, and counts of marine litter items as proxies for marine litter pollution does not account for size differences of marine litter items, and may thus fail in accurately representing the status of marine litter pollution in different locations (but density remains a more robust indicator than counts of marine litter items). Size differences are important to consider with comparisons of the density of marine litter, as the number of individual items of marine litter tends to increase as size decreases, with segments breaking off the original item as it deteriorates (Martins and Sobral, 2011). This problem highlights the challenge of synergising different marine litter databases and sources, and emphasises the need for standardised indicators and surveying approaches.

Marine litter has commonly been observed and recorded everywhere throughout the marine environment with available information suggesting that the occurrence of marine debris is highly dynamic in time and space (UNEP 2021). Debris can make its way into the ocean from sources on land, ships, and sea installations, both through specific points and diffuse origins, and may traverse significant distances before ultimately settling. The majority of the litter items recorded in this study was derived from domestic and recreational activities (Figure. 2) suggesting a large degree of anthropogenic pressure on beaches in Bangladesh. Most of the litter can be inferred to be local origin, and is thus more likely to occur due to human-related activities on beaches (including tourism activities), rather than being washed in from ocean current deposition. Further evidence such as the presence of foamed plastic, and paper and cardboard litter types on all surveyed sites, potentially indicated fast food wrappers and packaging (and thus human activity), which could explain why these litter types were found in high proportions, second to plastic litter (Figure. 3), as well as the source of this litter being of local origin.

The marine litter samples collected in the present study were gathered up to the high strandline, which may have led to an overestimation of the amounts of marine debris, as debris tends to accumulate at the strandline, and subsequently influenced our composition data (Hidalgo-Ruz et al., 2012; Lee et al., 2017, UNEP 2021 p68). Differences in the size of transects among different locations (such as due to specific beach topography) may also skew interpretations, like the transect from Kotka beach which was relatively small and may thus not have been able to reflect the full extent of the variation in marine litter beyond only three types (Figure.3-E). The study is also limited in that it uses data collected in 2017 - 2018 and may not be representative of the scale of current marine pollution in the surveyed areas, thus necessitating the use of fractional indicators (such as percentage data) to elucidate patterns in marine litter distribution.

3.2. Marine litter collection and disposal facilities on the surveyed beaches

Cox's Bazar sea beach is the longest beach of the world (Hasssan and Shahnewaz 2014), and marine litter collection facilities along the 120 km stretch of coastline varied. The district commission has provided refuse bins next to some public benches and chairs, for the disposal of marine litter, as well as billboard/posters encouraging tourists to keep the beaches clean. Local private organisations (such as Robi, Banglalink, and Berger Paints Bangladesh Ltd.) have sponsored various collection bins along the beach (facilitating the advertisement of their businesses). An estimated thirty women conduct beach cleaning activities on the Cox's Bazar beach (from Laboni Point to Kolatoli Point) twice a day at 8:00 am and 3:00 pm, collecting marine litter in bins, burning the flammable waste, and burying other waste in landfills in nearby Tamarisk

sp. forests. The local Bangladesh Tourist Police also assist the Cox's Bazar Beach Management Committee in keeping the beach clean. Every fortnight on Inani beach, local authorities and local businessmen participate in beach cleaning activities. The Bangladesh Army maintains the coastline and locality around their camp, near Cox's Bazar.

No cleaning activities or initiatives were taken in the Chittagong area. In Kuakata, some dustbins were present near some of the beach benches and Kuakata Union Parishad claimed that they maintained them. Refuse bins were cleaned when they became dirty, and flammable waste was burned or buried in a safe place, away from the public on the beach. No cleaning activities were present in the Kotka area and no dustbins were present either except one near the forest office of Kotka, Sundarban. In Saint Martin's Island, the company Berger Paints Bangladesh Ltd. provided some dustbins near beach benches (with associated advertisement). Along the beach, no cleaning activities were conducted through local government bodies at the time of survey, however some NGOs do conduct beach cleaning events sporadically.

3.3. Management recommendations and solutions

Marine litter cleaning activities varied between the different beaches. Cox's Bazar and Kuakata locations have some cleaning activities, whereas no regular organised cleaning or removal of marine litter occurred in Chittagong, nor Kotka. Furthermore, limited numbers of refuse bins were present among the beaches surveyed, with the only bins present in some locations having been sponsored by local companies. Given that a significant portion of marine litter appeared to stem from recreational activities (Figure 2), ensuring there are sufficient litter bins near popular recreational spots could contribute to a decrease in the amount of litter left behind by local beachgoers and tourists (Shubo et al. 2013). There is also the option of developing and installing "smart dustbins" to optimise the collection routes of refuse vehicles, and reduce service costs (Mishra and Kumar Ray 2020). Sourcing financing from local businesses may be a cost-efficient solution for the initial provisioning of bins (as it appeared to have been successful in the past), but the cost for maintenance of these refuse locations would need to be absorbed by local government for their long term effectiveness. Additionally, awareness programs can be developed to inform the public on the negative consequences of marine litter to environmental and human health, which may incentivise voluntary public participation in disposing of marine litter (Sarker et al. 2012). Where beach cleaning activities are conducted, training for those involved, especially local managers charged with conducting beach clean-up programs, may be facilitated such that the use of standardised indicators and protocols can be followed. This will facilitate the integration of the data collected during these beach clean-up activities with other local, national, regional, and global databases (UNEP 2021 p74).

While global monitoring programmes (NOAA Marine Debris Monitoring Assessment Project, Ocean Data Platform, LITTERBASE, etc.) attempt to consolidate marine debris observations and data on a global scale, many such initiatives remain fragmented and hard to compare with one another, as they are not structured according to the same indicators (UNEP 2021, p74). There is a need for increased standardisation and interoperability of these global datasets and platforms for global marine litter initiatives to be effective (UNEP 2021 p74). It is thus recommended that a smaller regional-scale data repository be developed specifically for the SAS region, incorporating globally accepted indicators, facilitating its interoperability with other global and regional datasets (see UNEP 2021 Figure 8 - p74). Together with the development of national marine litter policies, such a platform would encourage the continued monitoring of marine litter, collecting the necessary data needed for informing future policy decisions (such as the Global Plastics Treaty), remediative initiatives to address marine pollution, and establishment preventative measures to limit the extent of marine pollution in future.

Transitioning to a circular economy may reduce the extent of marine pollution in Bangladesh. The circular economy requires that products have a closed life-cycle in that they are either repurposed or reconstituted into a different product, as opposed to the linear life-cycle of products today (which end with being disposed of). Some types of marine litter such as metal, paper, plastic and rubber can be recycled and used again. The reduce-reuse-recycle (3R) approach to the lifespan of products may limit the abundance of marine litter in beach environments but sufficient awareness campaigns and infrastructure need to be developed for this approach to be effective.

Proposed alternatives, such as encouraging the use of easily biodegradable materials to minimise plastic usage, providing financial incentives for marine litter removal via subsidy programs, and regularly monitoring the accumulation of plastics and other debris in beaches and coastal waters, have the potential to mitigate the enduring effects of litter pollution on Bangladesh's coastal beaches.

The banning of single-use plastic (polyethene) bags in 2002 was intended to reduce pollution and debris in Bangladesh’s waters, through the elimination of a key waste item, however, it had limited impact on reducing plastic pollution associated with this plastic item (March et al., 2022). There is a pressing need to review the “National Municipal Solid Waste Management” program to implement widely-approved beach litter management actions that centre on the determination and control of different sources of waste, and the implementation of cleaning programs throughout the entire year. This will contribute to the identification of the relative contribution of different waste streams to marine debris pollution, as well as identify unnecessary key waste

items that could be removed from production, and thus limit marine litter pollution. This information can then also inform more upstream measures on plastic pollution that are needed to manage sources of plastic ultimately ending up on the shores (March et al., 2023) of Bangladesh.

While there are national policies that combat other forms of marine pollution ("National Environment Policy 2018"; "Bangladesh Environmental Conservation Act 1995" - amended in 2010; "Environmental Conservation Rules 1997"; "Solid Waste Management Rules 2021"; "Ecologically Critical Area Management Rules 2016"; "Bangladesh Biological Diversity Act 2017"; "Marine Pollution Ordinance 1977"; "Integrated Coastal Zone Management Plan (ICZMP)"; "Coastal Development Strategy (CDS)", 2004; Coastal Zone Policy", 2005; "Coastal Zone Strategy", 2006), there is no specific policy on addressing marine litter pollution (Afnan and Khanam 2021). Since Bangladesh has no "National Marine Litter policy", one of the key recommendations of this study is to develop such policies with the specific aim of reducing and eliminating marine litter pollution along Bangladeshi coasts and river systems. SACEP-SAS, as the regional focal point under the "UNEP Global Partnership on Marine Litter (GPML)", has recently submitted a request for the allocation of grant funding for the development of "National Marine Litter Action Plans" for the Bangladeshi and Indian governments (SACEP 2021). Comprehensive policy frameworks for marine pollution control in Bangladesh, with analyses of national and international legislation already exist in available literature, to assist in the development of such national policies (Alam and Xiangmin 2018, Alam 2022, Hossain et al. 2021). The development of national policies to curb pollution also align with international initiatives such as advancing the objectives of the Global Plastics Treaty.

Once national policies on marine litter have been developed, it is necessary to review them periodically (every few years), such that they may be updated and remain effective and relevant to the current state of national marine litter pollution (Kulratne 2020). This includes assessment of effectiveness of the policy, identification of any loopholes (particularly in terms of imposing liabilities to marine pollution offenders), and alignment with international agreements and development conventions (March et al., 2022) as well as remaining coherent with other national policies. In their examination of current national laws and regulations aimed at preventing marine pollution in Bangladesh, Hossain et al. (2021) assessed their efficacy, as discussed further in Alam (2022). The study unveiled gaps in addressing all forms of marine pollution within the existing legal framework of the country, highlighting the need for more effective measures. The authors emphasised the constitutional and international obligation of Bangladesh to implement such measures for safeguarding the well-being of the marine environment (Hossain et al. 2021).

Since the data regarding marine litter is still limited in Bangladesh, regular monitoring of marine litter pollution is needed to better understand the scope of the problem, as well as develop tailored solutions in addressing it. The environmental, and socio-economic impacts of marine debris on Bangladeshi coastal environments is not fully understood with further research required to address this knowledge gap. To effectively diminish and address marine litter pollution along the coasts of Bangladesh as well as addressing key knowledge gaps, it is crucial to undertake prolonged monitoring of the varieties, concentrations, and likely origins of marine debris. This effort should be complemented by public education initiatives and the implementation of a sound solid waste management plan. These measures are essential to eliminate risks to both environmental and human health. Moreover, the identification of marine litter pollution pathways and sources, (such as stormwater drainage systems, rivers and the cities and businesses that operate along them) can facilitate targeted efforts in halting litter pollution before it reaches the coastlines, potentially reducing the impact coastal marine litter pollution has on the environment and tourism operations. Future work would benefit from the development of site specific coastal zone management practices and policies, while considering the potential combined effects of climate change and marine pollution on Bangladeshi beaches and coastlines (as has been done in India, Lincoln et al. 2023).

Acknowledgement

The United Nations Environment Programme (UNEP) provided support for this project, with technical assistance from the South Asia Co-operative Environment Programme (SACEP). Gratitude is extended to the esteemed individuals including representatives from the Department of Environment (DoE), Ministry of Environment, Forest and Climate Change (MoEFCC), Government of Bangladesh (GoB) for their contributions and support.

References

Afnan, Z. and Khanam, S.M., 2021. Marine Litter: A Persistent Cumulative Threat to Bangladesh Environment. BMJ Vol 7 Issue 1 ISSN 2519-5972. Accessed at: https://bsmrmu.edu.bd/public/files/econtents/63e1f17749bf415

Ahmed, Md.K.; Habibullah-Al-Mamun, Md.; Ahammed, A.K.M.R. 2019. Country Report - Bangladesh, for Preparation of Regional Marine Litter Action Plan in the South Asian Seas (SAS) Region. Accessed at: http://www.sacep.org/pdf/Reports-Technical/2019.03-Bangladesh-Country-Report-for-Prepration-of-Regional-Marine-Litter-Action-Plan-for-South-Asia.pdf

Alam, Md.W. 2023. Land-Based Marine Pollution: An Emerging Threat to Bangladesh. Environmental Sciences. IntechOpen. DOI: 10.5772/intechopen.107957. Accessed at:https://www.intechopen.com/chapters/85545

Al Nahian, S., Rakib, M.R.J., Haider, S.M.B., Kumar, R., Walker, T.R., Khandaker, M.U. and Idris, A.M., 2022. Baseline marine litter abundance and distribution on Saint Martin Island, Bay of Bengal, Bangladesh. Marine Pollution Bulletin, 183, p.114091.

Anbuselvan, N.D.S.N. and Sridharan, M., 2018. Heavy metal assessment in surface sediments off Coromandel Coast of India: Implication on marine pollution. Marine pollution bulletin, 131, pp.712-726.

Anfuso, G., Lynch, K., Williams, A.T., Perales, J.A., Pereira da Silva, C., Nogueira Mendes, R., Maanan, M., Pretti, C., Pranzini, E., Winter, C., Verdejo, E., Ferreira, M., Veiga, J., 2015. Comments on marine litter in oceans, seas and beaches: characteristics and impacts. Ann. Mar. Biol. Res. 2, 1008–1012.

Anfuso, G., Williams, A.T., Casas Martínez, G., Botero, C.M., Cabrera Hernández, J.A., Pranzini, E., 2017. Evaluation of the scenic value of 100 beaches in Cuba: implications for coastal tourism management. Ocean Coast Manag. 142, 173–185.

Aydın, C., Güven, O., Salihoğlu, B. and Kıdeyş, A. E., 2016. The influence of land use on coastal litter: an approach to identify abundance and sources in the coastal area of Cilician Basin, Turkey. Turkish Journal of Fisheries and Aquatic Sciences, 16(1), 029-039.

Benton, T.G., 1995. From castaways to throwaways: marine litter in the Pitcairn Islands. Biol. J. Linnean Soc. 56, 415–422.

Biswas, J.C., Haque, M.M., Maniruzzaman, M. and Kalra, N., 2021. Coastal and marine pollution in Bangladesh: pathways, hotspots and adaptation strategies. European Journal of Environment and Earth Sciences, 2(4), pp.26-34.

Browne, M. A. (2015). Sources and pathways of microplastic to habitats. In M. Bergmann, L. Gutow & M. Klages (Eds.), Marine anthropogenic litter (pp. 229–244).

Campbell, M.L., Peters, L., McMains, C., Rodrigues de Campos, M.C., Sargisson, R.J., Blackwell, B., Hewitt, ChL., 2019. Are our beaches safe? Quantifying the human health impact of anthropogenic beach litter on people in New Zealand. Sci. Total Environ. 651 (2), 2400–2409. https://doi.org/10.1016/j.scitotenv.2018.10.137.

Cheshire, A.C., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., Jeftic, L., Jung, R.T., Kinsey, S., Kusui, E.T., Lavine, I., Manyara, P., Oosterbaan, L., Pereira, M. A., Sheavly, S., Tkalin, A., Varadarajan, S., Wenneker, B. and Westphalen, G., 2009. UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter. UNEP Regional Seas Reports and Studies, No. 186; IOC Technical Series No. 83, xii + 120 p.

Cunningham, D.J., Wilson, S.P., 2003. Marine debris on beaches of the greater Sydney Region. J. Coast. Res. 19, 421–430.

Ministry of Environment and Forests 2006. Bangladesh National Programme of Action for Protection of the Coastal and Marine Environment from Land-Based Activities. Department of Environment. Bangladesh. Accessed at: https://doe.portal.gov.bd/sites/default/files/files/doe.portal.gov.bd/publications/2686e3bc_b152_44fb_964b_1746bc42092d/NPA%20Final%20Draft.pdf

Mishra, A. and Kumar Ray, A., 2020. IoT cloud-based cyber-physical system for efficient solid waste management in smart cities: a novel cost function based route optimisation technique for waste collection vehicles using dustbin sensors and real-time road traffic informatics. IET Cyber-Physical Systems: Theory & Applications, 5(4), pp.330-341.

Desai, B.H. 2019. Regulating Marine Litter and Plastic Wastes in the South Asian Seas Region. Consultancy report. Published: SACEP. Accessed at: http://www.sacep.org/pdf/Reports-Technical/2019.07.02-Regulating-Marine-Litter-and-Plastic-Wastes-in-SAS-Region-Final.pdf

Dharmadasa, W.S., Andrady, A.L., Kumara, P.T.P., Maes, T. and Gangabadage, C.S., 2021. Microplastic pollution in marine protected areas of Southern Sri Lanka. Marine Pollution Bulletin, 168, p.112462.

EA/NALG (Environment Agency and The National Aquatic Litter Group), 2000. Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme. pp. 15 May, 2000.

Eriksson, C., Burton, H., Fitch, S., Schulz, M. and Van den Hoff, J., 2013. Daily accumulation rates of marine debris on sub-Antarctic island beaches. Marine Pollution Bulletin, 66, 199–208.

Galgani, F., Fleet, D., Van Franeker, J., Katsanevakis, S., Maes, T., Mouat, J., Oosterbaan, L., Poitou, I., Hanke, G., Thompson, R., Amato, E., Birkun, A. and Janssen, C., 2010. Marine Strategy Framework Directive, Task Group 10 Report, Marine Litter. Luxembourg.

Galgani, F., Hanke, G., Maes, T., 2015. Global distribution, composition, and abundance of marine litter. In: Marine Anthropogenic Litter. Springer, pp. 29–56.

Galgani, F., Hanke, G., Werner, S., Oosterbaan, L., Nilsson, P., Fleet, D., Kinsey, S., Thompson, R.C., van Franeker, J., Vlachogianni, T., Scoullos, M., Veiga, J.M., Palatinus, A., Matiddi, M., Maes, T., Korpinen, S., Budziak, A., Leslie, H., Gago, J., Liebezeit, G., 2013. Guidance on Monitoring of Marine Litter in European Seas. Scientific and Technical Research series, Luxembourg, pp. 128. http://mcc.jrc.ec.europa.eu/documents/201702074014.pdf accessed March 2019.

Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2013–2025.

Hassan, M.M. and Shahnewaz, M., 2014. Measuring tourist service satisfaction at destination: A case study of Cox's Bazar sea beach, Bangladesh. American Journal of Tourism Management, 3(1), pp.32-43.

Hidalgo-Ruz, V., Gutow, L., Thompson, R.C., Thiel, M., 2012. Microplastics in the marine environment: a review of the methods used for identification and quantification. Environ. Sci. Technol. 46 (6), 3060–3075.

Hossain, Md. M., & Mamun, S. M. S. (2021). Marine pollution in Bangladesh-framing legal responses: A critical study. Environmental Law Review, 23(3), 210–227. https://doi.org/10.1177/14614529211023458

Hugo G. Future demographic change and its interactions with migration and climate change. Global Environmental Change 2011; 21, Supplement 1: S21–S33.

Islam, K. S., Xue, X. Z., and Rahman, M. M., 2009. Successful Integrated Coastal Zone Management (ICZM) program model of a developing country (Xiamen, China)–implementation in Bangladesh perspective. Journal of Wetlands Ecology, 2(1), 35-41.

Islam, M.S., Phoungthong, K., Islam, A.R.M.T., Ali, M.M., Ismail, Z., Shahid, S., Kabir, M.H. and Idris, A.M., 2022a. Sources and management of marine litter pollution along the Bay of Bengal coast of Bangladesh. Marine Pollution Bulletin, 185, p.114362.

Islam, T., Li, Y., Rob, M.M. and Cheng, H., 2022b. Microplastic pollution in Bangladesh: research and management needs. Environmental Pollution, p.119697.

Ivar do Sul, J. and Costa, M., 2007. Marine debris review for Latin America and the wider Caribbean area, and where do we go from here? Marine Pollution Bulletin,54(8), 1087–1104.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347 (6223), 768–771.

Jang, YC, Ranatunga, R.R.M.K.P., Mok JY, Kim KS, Hong SY, Choi YR, Gunasekara A.J.M., 2018. Composition and abundance of marine debris stranded on the beaches of Sri Lanka: Results from the first island-wide survey. Mar. Pollut. Bull. 128, 126–131.

Kamruzzaman, M., 2018. Assessment of destination-specific factors of Bangladesh: A review of Saint Martin Island as an emerging tourist destination. Journal of Business Studies, 39(1).

Koongolla, J.B., Andrady, A.L., Kumara, P.T.P. and Gangabadage, C.S., 2018. Evidence of microplastics pollution in coastal beaches and waters in southern Sri Lanka. Marine pollution bulletin, 137, pp.277-284.

Kularatne, R.K.A. 2020. Sri Lanka's legal framework for marine pollution control: an evaluation of the Marine Pollution Prevention Act, No. 35 of 2008, Journal of the Indian Ocean Region, 16:3, 244-267, DOI: 10.1080/19480881.2020.1816364. Accessed at: https://www.tandfonline.com/doi/abs/10.1080/19480881.2020.1816364

Kumar, A., Sivakumar, R., Reddy, Y.S.R., Raja, B., Nishanth, T., Revanth, V., 2016. Preliminary study on marine debris pollution along Marina beach, Chennai, India. Reg. Stud. Mar. Sci. 5, 35–40. https://doi.org/10.1016/j.rsma.2016.01.002.

Kuo, F.-J., Huang, H.-W., 2014. Strategy for mitigation of marine debris: Analysis of sources and composition of marine debris in northern Taiwan. Mar. Pollut. Bull. 83, 70–78.

Kusui, T., Noda, M., 2003. International survey on the distribution of stranded and buried litter on beaches along the Sea of Japan. Mar. Pollut. Bull. 47, 175–179.

Landrigan, P.J., Stegeman, J.J., Fleming, L.E., Allemand, D., Anderson, D.M., Backer, L.C., Brucker-Davis, F., Chevalier, N., Corra, L., Czerucka, D. and Bottein, M.Y.D., 2020. Human health and ocean pollution. Annals of global health, 86(1).

Lee, J., Lee, J., Hong, S., Hong, S.H., Shim, W.J., Eo, S., 2017. Characteristics of mesosized plastic marine debris on 20 beaches in Korea. Mar. Pollut. Bull. 123 (1–2), 92–96.

Lincoln, S., Chowdhury, P., Posen, P.E., Robin, R.S., Ramachandran, P., Ajith, N., Harrod, O., Hoehn, D., Harrod, R. and Townhill, B.L., 2023. Interaction of climate change and marine pollution in Southern India: Implications for coastal zone management practices and policies. Science of the Total Environment, p.166061.

March, A., Roberts, K.P. & Fletcher, S. A new treaty process offers hope to end plastic pollution. Nat Rev Earth Environ 3, 726–727 (2022). https://doi.org/10.1038/s43017-022-00361-1

March, A., Salam, S., Evans, T., Hilton, J., and Fletcher, S. (2022) A global review of plastics policies to support improved decision making and public accountability. Global Plastics Policy Centre. https://plasticspolicy.port.ac.uk/final-report/

Martins, J., Sobral, P., 2011. Plastic marine debris on the Portuguese coastline: a matter of size? Mar. Pollut. Bull. 62 (12), 2649–2653.

McGranahan, G., Balk, D. and Anderson, B., 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environment and urbanization, 19(1), pp.17-37.

Mia, M.A., Nasrin, S., Zhang, M. and Rasiah, R., 2015. Chittagong, Bangladesh. Cities, 48, pp.31-41.

Mubin, A.N., Arefin, S., Mia, M.S., Islam, A.R.M.T., Bari, A.M., Islam, M.S., Ali, M.M., Siddique, M.A.B., Rahman, M.S., Senapathi, V. and Idris, A.M., 2023. Managing the invisible threat of microplastics in marine ecosystems: Lessons from coast of the Bay of Bengal. Science of The Total Environment, p.164224.

Munari, C., Corbau, C., Simeoni, U. and Mistri, M., 2016. Marine litter on Mediterranean shores: Analysis of composition, spatial distribution and sources in north-western Adriatic beaches. Waste Management, 49, 483-490.

Nawar, N., Rahman, M.M., Chowdhury, F.N., Marzia, S., Ali, M.M., Akbor, M.A., Siddique, M.A.B., Khatun, M.A., Shahjalal, M., Huque, R. and Malafaia, G., 2023. Characterization of microplastic pollution in the Pasur river of the Sundarbans ecosystem (Bangladesh) with emphasis on water, sediments, and fish. Science of The Total Environment, 868, p.161704.

Neumann B, Vafeidis AT, Zimmermann J, Nicholls RJ. Future coastal population growth and exposure to sea-level rise and coastal flooding--a global assessment. PLoS One. 2015 Mar 11;10(3):e0118571. doi: 10.1371/journal.pone.0118571. Erratum in: PLoS One. 2015;10(6):e0131375. PMID: 25760037; PMCID: PMC4367969.

Ocean Conservancy 2009. A rising tide of ocean debris: and what we can do about it. International Coastal Cleanup Report. Ocean Conservancy, p. 65.

Oigman-Pszczol, S. S., and Creed, J. C., 2007. Quantification and classification of marine litter on beaches along Armação dos Búzios, Rio de Janeiro, Brazil. Journal of Coastal Research, 23(2), 421-428.

Perumal, K., Muthuramalingam, S. and Chellaiyan, S., 2023. Marine litter on the beaches of the Kanyakumari, Southern India: An assessment of their abundance and pollution indices. Marine Pollution Bulletin, 186, p.114443.

Poeta, G., Battisti, C., Bazzichetto, M., and Acosta, A. T., 2016. The cotton buds beach: Marine litter assessment along the Tyrrhenian coast of central Italy following the marine strategy framework directive criteria. Marine pollution bulletin, 113(1-2), 266-270.

Portman, M. E., and Brennan, R. E., 2017. Marine litter from beach-based sources: Case study of an Eastern Mediterranean coastal town. Waste Management, 69, 535-544.

Prevenios, M., Zeri, Ch, Tsangaris, C., Liubartseva, S., Fakiris, E., Papatheodorou, G., 2018. Beach litter dynamics on Mediterranean coasts: distinguishing sources and pathways. Mar. Pollut. Bull. 19 (2), 448–457. https://doi.org/10.1016/j.marpolbul.2017.10.013.

Qasim, S.Z., Gupta, R.S. and Kureishy, T.W., 1988. Pollution of the seas around India. Proceedings: Animal Sciences, 97, pp.117-131.

SACEP 2007. Marine Litter in the South Asian Seas Region. ISBN 978-955-8074-09-1.

SACEP 2019. Regional Marine Litter Action Plan for South Asian Seas Region. ISBN 978-955-8074-24-4. Accessed at: http://www.sacep.org/pdf/Reports-Technical/2019.11.06-Regional-Marine-Litter-Action-Plan-for-South-Asian-Seas-Region.pdf

SACEP 2019b. Roadmap for Sustainable Waste Management and Resource Circulation in South Asia 2019-2030. ISBN: 978-955-8074-23-7. Accessed at: http://www.sacep.org/pdf/Reports-Technical/2019.11.06-Roadmap-for-Sustainable-Waste-Management-and-Resource-Circulation-in-South-Asia,-2019-2030.pdf

SACEP 2020. Plastic free Rivers and Seas for South Asia (P171269). ENVIRONMENTAL AND SOCIAL MANAGEMENT FRAMEWORK (ESMF). Accessed at: http://www.sacep.org/library/technical-reports

SACEP 2021. Update on the activities of the South Asia Co-operative Environment Programme (SACEP) – South Asian Seas Programme (SASP) – for the 2020 Report of the SG on oceans and the law of the sea. Report. Published: United Nations. Accessed at: https://www.un.org/depts/los/general_assembly/contributions_2021/SACEP.pdf

Sarker, B.C., Sarker, S.K., Islam, M.S. and Sharmin, S., 2012. Public awareness about disposal of solid waste and its impact: a study in Tangail Pourashava, Tangail. Journal of Environmental Science and Natural Resources, 5(2), pp.239-244.

Schneider, F., Parsons, S., Clift, S., Stolte, A., Marcell, C., McManus, 2018. Collected marine litter - a growing waste challenge. Mar. Pollut. Bull. 128, 162–174. https://doi.org/10.1016/j.marpolbul.2018.01.011.

Shanmugam, P., Neelamani, S., Ahn, Y.H., Philip, L. and Hong, G.H., 2007. Assessment of the levels of coastal marine pollution of Chennai city, Southern India. Water Resources Management, 21, pp.1187-1206.

Shubho, M.T.H., Hassan, M.T., Hossain, M.R. and Neema, M.N., 2013. Quantitative Analysis of Spatial Pattern of Dustbins and its Pollution in Dhaka City-- A GIS Based Approach. Asian Transactions on Engineering (ATE ISSN: 2221-4267) vol, 3, pp.1-7.

Rakib, M.R.J., Ertaş, A., Walker, T.R., Rule, M.J., Khandaker, M.U. and Idris, A.M., 2022. Macro marine litter survey of sandy beaches along the Cox's Bazar Coast of Bay of Bengal, Bangladesh: land-based sources of solid litter pollution. Marine Pollution Bulletin, 174, p.113246.

Todd, P.A., Ong, X. and Chou, L.M., 2010. Impacts of pollution on marine life in Southeast Asia. Biodiversity and conservation, 19, pp.1063-1082.

Tudor, D.T., Williams, A., 2003. Public perception and opinion of visible beach aesthetic pollution: the utilisation of photography. J. Coast. Res. 19, 1104–1115.

UNEP 2023. Intergovernmental Negotiating Committee on Plastic Pollution. United Nations Environmental Programme. Website. Accessed at: https://www.unep.org/inc-plastic-pollution. Accessed on: 7 September 2023.

UNEP 2022. Contributions of Regional Seas Conventions and Action Plans to a Healthy Ocean. United Nations Environment Programme. Nairobi. ISBN No: 978-92-807-3927-5. Accessed at: https://wedocs.unep.org/bitstream/handle/20.500.11822/38622/Regional_Seas_Conventions.pdf

UNEP 2021. From Pollution to Solution: A global assessment of marine litter and plastic pollution. United Nations Environment Programme, Nairobi. Accessed at: https://www.unep.org/interactives/pollution-to-solution/

UNEP, 2014. Valuing Plastics: Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry. Nairobi. 116 p. http://wedocs.unep.org/handle/20.500.11822/9238 accessed January 2019 .

UNEP/MAP, 2012. State of the Mediterranean Marine and Coastal Environment. UNEP/MAP, Athens, Barcelona Convention.

UNEP/Oceans Conservancy/Regional Seas/GPA, 2009: Marine Litter: A Global Challenge. Nairobi, Kenya.

Votier, S.C., Archibald, K., Morgan, G., Morgan, L., 2011. The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Mar. Pollut. Bull. 62, 168–172. https://doi.org/10.1016/j.marpolbul.2010.11.009.

Whiting, S.D., 1998. Types and sources of marine debris in fog Bay, northern Australia. Mar. Pollut. Bull. 36, 904–910. https://doi.org/10.1016/S0025-326X(98)00066-6. whyy.org/articles/butt-out-n-j-beach-park-smoking-ban-goes-into-effect/, accessed April 2019.

Annex 1

Table 2: Quantity of marine litters in the five survey beaches of Bangladeshi coastline in the Bay of Bengal (empty cells represents zero values).

Litter Type	Cox's Bazar	Chittagong	Saint Martin's	Kuakata	Kotka
Bottle caps & lids	229	13	29	21	16
Bottles < 2 L	228	72	213	54	37
Bottles, drums, jerrycans & buckets > 2 L	15	3	33	10	2
Knives, forks, spoons, straws, stirrers, (cutlery)	10	2	56		
Drink package rings, six-pack rings, ring carriers	73	1	37		3
Food containers (fast food, cups, lunch boxes etc.)	120	7	45	41	
Plastic bags (opaque & clear)	1311	871	578	276	47
Toys & party poppers	1	7	13	1	
Cigarette lighters	11	1	3		
Cigarettes, butts & filters	442	28	147	87	19
Syringes	5	1			
Baskets, crates & trays		5			
Plastic buoys	25		11	4	
Mesh bags (vegetable, oyster nets & mussel bags)	6				
Sheeting (tarpaulin or other woven plastic bags)	19				
Fishing gear (lures, traps & pots)		22			
Rope	208	59	30	13	
Fishing net	125	22	32	8	
Other	244	7	145	29	2
Foam sponge	225				
Cups & food packs	10	12			
Foam buoys	17	3			
Foam (insulation & packaging)	207	382	48	37	
Other	4				
Clothing, shoes, hats & towels	29	70	107		3
Backpacks & bags	3	7			
Canvas, sailcloth & sacking (hessian)		2			
Rope & string		8		22	
Other cloth (pampass)	27			12	
Bottles & jars	60	7	18	7	
Tableware (plates & cups)		16			
Light globes/bulbs	2	3			
Glass or ceramic fragments		2		10	
Bottle caps, lids & pull tabs	11				
Aluminium drink cans	12	4	23		
Other cans (< 4 L)	5	1			
Fragments		3			
Wire, wire mesh & barbed wire			4		
Paper (including newspapers & magazines)	74	249	48	7	5
Cardboard boxes & fragments	2				
Cups, food trays, food wrappers, cigarette packs etc.	96	54	97	41	
Tubes for fireworks	1				
Other (Tissue)	34	99	71	17	7
Balloons, balls & toys	3	2			
Footwear (flip-flops)	111	38	54	12	
Tyres		8			
Inner-tubes and rubber sheet		7			
Rubber bands	1	5			
Condoms	2				
Other (specify)	61				
Ice-cream sticks, chip forks, chopsticks etc.	6	17	68		
Processed timber and pallet crates	35	7	6		
Matches & fireworks	15	3			
Other	7				
Appliances & Electronics		2			
Other	441				

Table 3: Comparison of densities of marine litter reported globally.

Country	No. of Surveyed Beaches	Density (Items/m^2)	References
Bangladesh	5	0.1	*This study*
Italy	5	0.2	Munari et al., 2016
Russia	8	0.2	Kusui and Noda, 2003
Taiwan	6	0.15	Kuo and Huang, 2014
Turkey	13	0.92	Aydin et al., 2016
Brazil	10	0.14	Oigman-Pszczol and Creed, 2007
Australia	6	0.1	Cunningham and Wilson, 2003
Ireland	1	0.2	Benton, 1995
Global		1	Galgani et al., 2015