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Abundance of Marine Macrodebris on the northern Coast of Jaffna Peninsula, Sri Lanka

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Abstract

Marine plastic debris has become a major concern on the northern coast of Jaffna, Sri Lanka, where it poses a threat to marine resources. A preliminary study was conducted to investigate the abundance and characteristics of marine plastic debris at four major fish landing sites in the northern coast of Jaffna, using the Clean Coast Index (CCI) and Plastic Abundance Index (PAI). The results revealed that the average abundance of marine debris and plastic debris were 1.71 ± 0.42 items/m^2 and 1.66 ± 0.57 items/m^2, respectively. The most common types of plastic debris were plastic rope and net pieces (23.2%), followed by unidentified weathered plastic fragments (16.7%), beverage bottles (16.2%), bottle caps and lids (13%), and styrofoam (14.1%). The recognized sources of plastic debris were mainly fishing-based activities, recreation activities, transboundary sources, and unidentified sources. The cleanliness level of the fish landing sites were categorized as extremely dirty, with high levels of plastic debris, resulting in a CCI above 10 and a PAI value over 8. This study realized the consequence of implementation of a proper plastic waste management framework in the northern coast of Jaffna and highlights the necessity to address buoyant debris on the northern Indian Ocean.

1 Introduction

Marine plastic pollution is a growing concern worldwide, with evidence of its presence in oceans across the globe (do Sul, et al., 2013; Akenji, et al., 2020; Athawuda, et al., 2020). The Great Pacific Garbage Patch, for example, contains up to 16 times more plastic than previously estimated. The Indian Ocean is no exception to this global issue, with records indicating the severity of plastic pollution in the region (Pattiaratchi, et al., 2022). Asian countries, particularly those in South Asia such as China, Indonesia, Philippines, Vietnam, Sri Lanka, Thailand, Malaysia, and India, are among the top 20 countries for marine plastic production (Jambeck, et al., 2015) .

Sri Lanka, an island nation in the Indian Ocean with a population of 22 million (Ono, et al., 2023), has a responsibility to address plastic pollution due to its high ranking on the list of countries with improper plastic waste management (Jang, et al., 2018). However, scientific efforts to identify marine plastic pollution in Sri Lanka lag far behind other countries (Athawuda, et al., 2020). Though most studies have focused on microplastic pollution, the limited research was concentrated on the fate of macroplastic pollution.

The northern Coast of Jaffna is an important region for fisheries activities in the Indian Ocean. The local fishing industry plays a vital role in the economy of the area and is home to several important fishery resources (Ragavan, et al., 2021). However, plastic pollution has significant negative impacts on the marine environment and fishery resources (Thushari & Senevirathna, 2020). Few studies have been conducted to identify the level of plastic pollution in the coastal area and ocean of the northern Province of Sri Lanka.

This study aims to investigate plastic pollution in the Palk Strait region of Sri Lanka. This area is crucial for fisheries, yet it has received limited attention in previous studies, detailed surveys were conducted at four major fishery and populated sites on the northern coast of Jaffna Peninsula to identify spatial plastic distribution and potential risks resulting from plastic accumulation. The study assesses plastic litter density, composition, and distributional patterns while identifying possible sources of plastic debris and beach cleanliness using various survey techniques and approaches.

2 Material and methodology

2.1 Study site description

Four sites in the northern coastal belt of Jaffna were selected as the study area (Fig. 1). Table 1 synopsizes the characteristics of the surveyed beaches. The sites selected for the study were Point Pedro, Valveddithurai, Myliddy, and Mathagal, which are closely located to major tourism-based beaches such as Lighthouse beach, Munai beach, Revady beach, Thalsevana beach, and Thambukolapattuna beach, as well as to harbor operational and commercial fishing regions in Jaffna. The length of the northern coastal belt of the Jaffna Peninsula from Point Pedro to Ponnalai-Karainagar junction is approximately 41 kilometers. The northern coastal belt and marine zones are characterized by sandy, rocky, and pebble beaches. The selected study sites were located in close proximity to the fishing villages, at a distance of approximately 100 meters from the study sites.

Table 1
Details of sampling beaches in the northern coast of Jaffna

Sites	Beach Name	Coordinates		Substrate	Activities
		Latitude	Longitude		
S1	Point Pedro	9.82584	80.251401	Sandy	Recreational, Tourism Activities, Fishing activity, Harboring area
S2	Valveddiththurai	9.824988	80.168204	Sandy	Fishing Activity
S3	Myliddy	9.812864	80.065391	Pebble	Fishing Activity, Harboring area
S4	Mathagal	9.802169	79.966103	Rocky	Fishing Activity

2.2 Survey Method

The survey followed the OSPAR protocol with a few modifications (de, et al., 2021). It was conducted twice a month from May to July 2022 at four sampling locations selected at an equal distance from each site. Six samplings and surveys were conducted per the NOAA Marine Debris Shoreline survey field guide. A 100 m length of shoreline was selected during low tide, divided into 5 m width and length of 20 segments (Fig. 1). From the 20 segments, four transect segments were randomly chosen for the debris assessment. Debris items measuring over 2.5 cm were recorded in the Debris Density Data Sheet. On any sampling day, 20 m of 100 m shoreline site marine debris density was analyzed, and the GPS coordinates for each transect were recorded at the center. During each survey, the recorders walked along the 100-meter transects in both directions and collected visible human-made litter in labeled plastic bags. Buried items were not excavated unless they were visible on the beach surface, and only surface debris was removed.

2.3 Classification and Quantification

Plastic litter was separated from the rest of the marine litter and categorized as beverage bottles, food wrappers, nets and ropes, personal care products, utensils, styrofoam, cups, and six-pack rings, bottle caps, and fragments based on the studies developed by(de Melo Nobre, et al., 2021; Whiting, 1998) .The macro litter density was calculated as the total number of marine litter items per transect (Chambault, et al., 2018).

CM = N/ $(w*L)$

Where CM is the number of marine litter densities per m^2, n is the number of macro-litter items observed, w is the width of the shoreline (transect width), and L is the length of shoreline sampled (5 m). Marine litter density was calculated for each transect area (four per sampling day) and finally considered the mean marine density for each study site. The cleanliness level of the beach was assessed based on the Clean Coast Index (Alkalay, et al., 2017)

Beach cleanliness (CCI) was calculated as follow

CCI = $C_M * K$

Where CM is the number of marine litter densities per m^2, K is a constant that equals 20 (Marin, C.B, et al., 2019). The CCI index was created to quantify the real level of cleanliness, which has a wide range of probable phases from very clean (CCI = 0–2) to extremely dirty (CCI = 20+)

The Plastic Abundance Index (PAI) measures the amount of plastic debris concerning the total amount of litter on a beach (Perumal, et al., 2023). The PAI for each of the seven sites was calculated as follows:

PAI = $\sum$Plastic litter items/ Log10$\sum$Total litter items × 20

Length (m)*Width (m)

The PAI scores beaches in terms of plastic concentration into five categories; 0 corresponds to very low abundance, 0.1-1 ‘low abundance’, 1.1–4 ‘moderate abundance’, 4.1–8 ‘high abundance’, and > 8 ‘very high abundance’.

These categories of plastic debris were further characterized into five broad categories of origin namely, tourist / recreational activities, domestic activities, fisheries activities, transboundary sources, hazardous activities ,unidentified sources with some modification of the studies (de Melo Nobre, et al., 2021; Suteja, et al., 2021).Statistical analysis to identify the abundance variation (number of items and weight) between seasons and locations in this study was carried out with non-parametric Kruskal-Wallis test($p < 0.05$) As a result of the Shapiro-Wilk normality test,non-parametric test was done to analyze the data ($p < 0.05$). All statistical tests were conducted using the IBM SPSS software.

3 Results and Discussion

This survey is the first comprehensive study of macroplastic debris on the northern coast of Jaffna. The spatial distribution, concentration, and PAI of plastic debris, as well as the concentration and CCI of marine debris, were assessed at four distinct sites along the northern coast of Jaffna (Fig. 2)(Table 2). The most abundant marine debris found in coastal and intertidal zones were bottles, fishing nets, cups, and food wrappers (Xanthos & Walker, 2017). Similarly, the spatial distribution of plastic debris at the study sites included plastic bottles, food wrappers, plastic ropes and net pieces, Styrofoam, personal care products, plastic fragments, buoys, and medical wastes such as plastic medicine bottles and medical ointment covers (Fig. 3).

Table 2
Beach classification into the one of the categories belonging to the CCI, PAI in the study area

Sites	Beach Name	CCI	CCI Type	PAI	PAI Type
S1	Point Pedro	32.53	Extremely Dirty	17.98	High abundance
S2	Valveddiththurai	27.73	Extremely Dirty	16.74	High abundance
S3	Myliddy	50.2	Extremely Dirty	27.72	High abundance
S4	Mathagal	29.93	Extremely Dirty	17.58	High abundance

A total of 4212 items of marine debris were recorded at the study sites, with 3780 items being plastic debris, accounting for 92.3% of the total debris. This is consistent with recent studies that have found plastic debris to be the most abundant type of litter (Arun Kumar, et al., 2019; Paler, et al., 2019; Buckingham, et al., 2020; de Melo Nobre, et al., 2021; Watson, et al., 2022). The most abundant types of plastic debris were identified as plastic ropes and net pieces, plastic fragments, beverage bottles, Styrofoam, and bottle caps (Table 3).

In this study, the Myliddy site had the highest abundance of marine debris distribution at 2.34 items/m^2, with plastic being the major component. This was followed by Point Pedro at 1.44 items/m^2, Mathagal at 1.41 items/m^2, and Valveddithurai at 1.29 items/m^2. These sites had comparatively lower amounts of marine debris distribution compared to other sites. Similar studies conducted along the Indian coastline (Jeyasanta, et al., 2020; Arun Kumar, et al., 2019; Priyanka, et al., 2022) revealed that beaches in Tamil Nadu had marine debris densities ranging from 1.37 to 6.06 items/m^2.

Few investigations have been conducted regarding plastic pollution in marine waters in Sri Lanka (Koongolla, et al., 2018) .A study by Jang, et al. (2018) reported that plastic litter was found on 22 beaches in Sri Lanka at a density of 158 items/m^2.Athapaththu, et al. (2020) Revealed that plastic pollution is a growing risk in the southern coastal belt of Sri Lanka. According to Thennakoon, et al. (2018), per capita plastic waste generation in Jaffna is 0.08kg.

The assessment of marine litter in this study varied from 2.51 items/m^2 at Myliddy to 1.39 items/m^2 at Valveddithurai. The CCI value was used to assess the coastal cleanliness level of the study sites and varied from 50.2 at Myliddy to 27.73 at Valveddithurai (Fig. 2). All study sites were categorized as extremely dirty due to fisheries activities, transboundary sources, tourism and recreational activities, and domestic Sources. The major distribution of plastic debris was observed at the Myliddy site (Fig. 3) (Table 3), including plastic rope and net pieces (9.7%), plastic fragments (20.8%), beverage bottles (21.6%), caps and lids (24.6%), and styrofoam (10.2%). The average values of (CCI) and (PAI) at this site were 50.2 and 27.72 respectively.

At the Mathagal site, the most abundant plastic debris consisted of Styrofoam (42.4%), plastic fragments (10.1%), beverage bottles (17.3%), and plastic rope and net pieces (16.1%). The average CCI and PAI values at this site were 29.93 and 17.58 respectively. The Point Pedro site exhibited visually observed abundant plastic litter, including plastic ropes and net pieces (49.3%), plastic fragments (13.5%), beverage bottles (8.8%), and caps and lids (8.8%). The average CCI and PAI values at this site were 32.53 and 17.98 respectively.

At Valveddithurai, major marine debris included plastic rope and net pieces (24.6%), plastic fragments (20%), beverage bottles (13.1%), bags (6.2%), cups (6.2%), and caps and lids (9.2%). The average CCI and PAI values at this site were 27.73 and 16.74 respectively.

The PAI results (Fig. 2) indicated that the presence of plastics was consistent across all study sites, with similar observations in the sample units. According to visual observations, the highest marine density was observed during the first sampling period due to long-term deposition of debris. Plastic fragments and Styrofoam were the predominant plastic classes in all landing sites throughout the survey.

However, microplastic pollution can occur due to macro- and mesoplastic pollution (Lim, et al., 2021). Several studies have focused on microplastic pollution throughout Sri Lanka (Shobiya, et al., 2022; Athapaththu, et al., 2020). Although limited studies have been conducted regarding macroplastic pollution, this highlights a significant data gap and poses a technical challenge for assessing secondary microplastic pollution.

A significant amount of microplastic has been reported in Point Pedro and Mathagal on the northern coast of Jaffna. Fragments have been identified as the most abundant type of microplastic in the northern coastal belt of Jaffna (Shobiya, et al., 2022). This is possibly explained by their difficulty in being removed from the environment and their ability to be broken down into smaller sizes through physical, chemical, or biological processes (Andrades, et al., 2020; Cheshire, et al., 2009).

Plastic particles that are carried into beaches by large waves will break down over time due to their exposure to weathering and how long they remain on the beach. Eventually, they will break into smaller fragments that can be carried back into the sea by swash waves and currents near the shore (Kataoka, et al., 2015). Plastic fragments have been found to be a dominant class in several investigations (Liu, et al., 2013; Smith & Markic, 2013; Watts, et al., 2017).

Another predominant category that was visually observed at all study sites was white-colored styrofoam. This included items such as fishing buoys, lunch boxes, and packaging materials. Similar observations of white-colored styrofoam were also made in the coastal area of Uswetakeiyawa beaches in Sri Lanka (Athawuda, et al., 2020), consistent with findings at the study sites.

It is important to note that white- or colorless-colored plastic categories pose a major threat to sea turtles (Bugoni, et al., 2001). These types of items are difficult to manage due to their ability to accumulate and disperse in the environment, representing an increased risk of ingestion by fish, sea birds, mammals, sea turtles (Barnes, et al., 2009), as well as numerous damages to macrofauna in sandy seashores (Amaral, et al., 2016). (Handunnetti, 2019) reported that plummeting fish stocks in Sri Lanka's island are a growing concern, primarily due to microplastic contamination.

Table 3
List of Plastic litter collected in the study area according to the (de Melo Nobre, et al., 2021; Whiting, 1998)

Plastic debris categories	Number of items				
	S1	S2	S3	S4	Total
Cigarette lighters	1	2	5	2	10
Jugs or containers	0	0	2	0	2
Styrofoam	4	5	24	59	92
Bags	6	8	2	4	20
Beverage Bottles	13	17	51	24	105
Bottle caps	13	12	58	1	84
Buoys& floats	2	2	2	3	9
Cigar Tips	1	1	0	0	2
Cigarettes	1	0	0	0	1
Cups	2	8	0	0	10
Food wrappers	5	5	4	3	17
Personal care products	5	6	14	6	31
Plastic fragments	20	26	49	14	109
Plastic rope/ small net pieces	73	32	23	23	151
Plastic Utensils	1	3	1	0	5
Straws	1	3	1	0	5
Point pedro-S1, Valveddithurai –S2, Myliddy- S3, Mathagal-S4					

Macro debris items made of plastics, accounting for 87% of debris, were found in the North of the subtropical front to the Southern Ocean (Suaria, et al., 2020). Beverage bottles made of PET were determined as the heaviest macroplastic group in Setubal Lake, a larger floodplain lake of the Parana River. Cups were identified as common debris at the Valveddithurai site located near a children's park. Additionally, food wrappers and bottle caps, reported by de Melo Nobre, et al. (2021), were found as debris associated with tourism and recreational activities.

In this study, plastic ropes and small net pieces were identified as the most abundant plastic litter across all study sites. (Shobiya, et al., 2022; Thennakoon, et al., 2018) reported that the possibility of plastic pollution in Jaffna is primarily attributed to fisheries activities. Rope pieces can be generated through abrasion caused by haulers and gear being dragged along the seabed, which may lead to pollution by microplastics (Syversen & Lilleng, 2022). Survey results coincided with some studies (Edward, et al., 2020; Kaladharan, et al., 2020), which showed that dominant plastic litter such as plastic rope and net pieces revealed that irresponsible fisheries activities contribute to plastic pollution at landing sites.

Especially at the Point Pedro landing site, there were many scratched pieces of fishing nets visible on the shoreline compared to other landing sites. Discarded or lost fishing gear along the shoreline indicates a lack of fisheries management (van Hoytema, et al., 2020). According to reports, the availability, comfort, and fees of shoreside collection facilities for old or unwanted fishing gear are major issues driving the disposal of undesirable gear by fishers. Most fishing gears have a finite lifespan, after which they cannot be used and must be disposed of. Major difficulties in estimating the level of ALDFG are that most gears are not deliberately discarded and gear lost from IUU fishing.

Most countries such as the United Kingdom, Korea, and France are considering prevention of the ALDFG issue (Lusher, et al., 2017). Recently, IUU fishing has become a major issue in the northern part of Sri Lanka by South Indian people (Kularatne, 2020) and it acts as one of the reasons for plastic pollution in northern Sri Lanka (Gallagher, et al., 2023). There are many unpublished reports indicating that disposal of solid waste from these trawling vessels is a major threat to the marine environment. This mostly includes plastic and polythene wastes as well as fishing gear representing a high volume of waste with a large negative effect on habitats and living organisms. Ghost nets in particular are a death trap for many marine species including sea turtles and prawns (Haas, et al., 2019).

The results showed that plastic debris mostly originated from fisheries activities and transboundary sources followed by unidentified sources predominantly dominated by plastic ropes and net pieces, fragments, and plastic litters with foreign labels. Emphasizing its significance, it should be noted that various origins and pathways exist for items to enter the coastal zone (Veiga, et al., 2016). For instance, a plastic beverage bottle may be left behind by individuals visiting the beach or fishing and subsequently carried away by wind or rainwater drainage systems. Statistical analysis shows that there is no significant difference among plastic litter among study areas.

Throughout the survey, buoyant plastic debris was found mostly from countries such as China, Thailand, India, and Indonesia. This debris included beverage bottles, personal care products, and medical ointment covers with foreign language letters. Countries in close proximity to the Bay of Bengal were mostly influenced by plastic debris (Van Der Mheen, et al., 2020). The countries included in the report were India, Myanmar, Thailand, and Indonesia.

There have been no studies in the Indian Ocean regarding the transport and sinking of plastic debris through the water column and along the sea floor (Pattiaratchi, et al., 2022). Marine debris' buoyancy allows it to be transported over long distances by prevailing winds, ocean currents, and tides. This leads to build-up along shorelines, even on the most distant islands (L. Lavers & L. Bond, 2017) (Pattiaratchi, et al., 2022), as well as in the open ocean and deep-sea (Barnes, et al., 2009). The accumulation of buoyant debris has caused the formation of garbage patches in subtropical basins (Van der Mheen, et al., 2019).

Particularly large garbage patches exist in the southern Indian Ocean, which may be caused by microplastic pollution (Li, et al., 2022).

Throughout the survey, intact bottles with foreign labels were mostly found compared to medical ointment covers. This is because plastic items that contain trapped air further enhance their buoyancy and lead to transport over long distances from their sources (Van Sebille, et al., 2020) (Andrady, 2003). Sri Lanka is not the only country facing the issue of floating debris; the south-east coast of India is also experiencing threats from floating debris, some of which originate from Sri Lanka. Buoyant plastic debris is identified as the main reason for fouling of organisms (Mghili, et al., 2023).

The coastal area around Sri Lanka continuously faces various hydrodynamic factors such as tides, winds, waves, thermo gradients, and a unique upwelling pattern (De Vos, et al., 2014). These characteristics also influence debris accumulation. Monsoonal action plays a significant role in the distribution of plastic litter (Athapaththu, et al., 2020). Notably, Sri Lanka is expecting the May to September South-West monsoon action which brings windy weather and rains at any time of the day (Bandurathna, et al., 2021). Athapaththu, et al. (2020) reported that during the South-West monsoon period macro mesoplastic density is significantly high in the southern belt of Sri Lanka.

Mobilik, et al. (2015) reported that most abundant marine debris items were observed during the Southwest monsoon period in Malaysia. Throughout the survey plastic fragments were observed as the predominant plastic litter in all study sites (Table 3). They also led to secondary microplastic in the South-West monsoon period in the northern coastal belt of Jaffna. Future studies are recommended to identify seasonal variation in marine debris accumulation in the northern coastal belt of Jaffna.

In the world ocean, the Indian Ocean Gyre is an important part of the global ocean circulation. It has unique dynamic characteristics and a complex and variable circulation structure (Schott, et al., 2009). As a result, the dynamics of plastic in the Indian Ocean differ from those in other oceans (Van der Mheen, et al., 2019).However, the role of the Indian Ocean in transporting plastic debris is still not fully understood. Surveys have occasionally identified transboundary plastic debris. This raises a critical question: Does the stranded plastic debris on the northern coast of Jaffna originate from within or is it transported from other countries? Further studies are needed to elucidate the distribution and density of debris with oceanic gyres and geographic regions.

4 Conclusion

In all sampling periods, plastic ropes and fishing net pieces (23.2%) and unidentified weathered plastic fragments (16.7%) were the most common marine plastics, both by abundance and weight. Plastic debris were dominated by fisheries-based sources, recreational and tourism activities and unidentified sources. The mean abundance of marine debris and plastic litter was 1.71 ± 0.42 items/m^2 and 1.66 ± 0.57 items/m^2, respectively. The CCI value and PAI used to assess environmental cleanliness indicated that all major fish landing sites on the northern coast of Jaffna were highly polluted. This suggests that more routine beach cleaning activities are needed to minimize pollution loading and impacts on the environment and fisheries of Jaffna.

The present study provides primary data to support local government policy reformulation to reduce plastic debris in the coastal environment. However, local waste management alone will not completely solve the problem. More integrated management is needed nationally and internationally, and existing regulations could be evaluated for effectiveness in reducing plastic litter.

Declarations

Ethical Approval

Not applicable

Consent to participate

The consent of participants in this study was sought. All participants were informed the study was purely for academic purposes.

Consent to publish

All authors agreed with the content and gave explicit consent to submit the article for publication.

CRediT authorship contribution statement

Urmila S : Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing **Wijesinghe R.D.N**.: Methodology, Investigation, Conceptualization, Validation Writing – review & editing, ,Supervision **Ashani.A**: Methodology, Investigation, Conceptualization, Validation, Writing – review & editing, Supervision.

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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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Figures

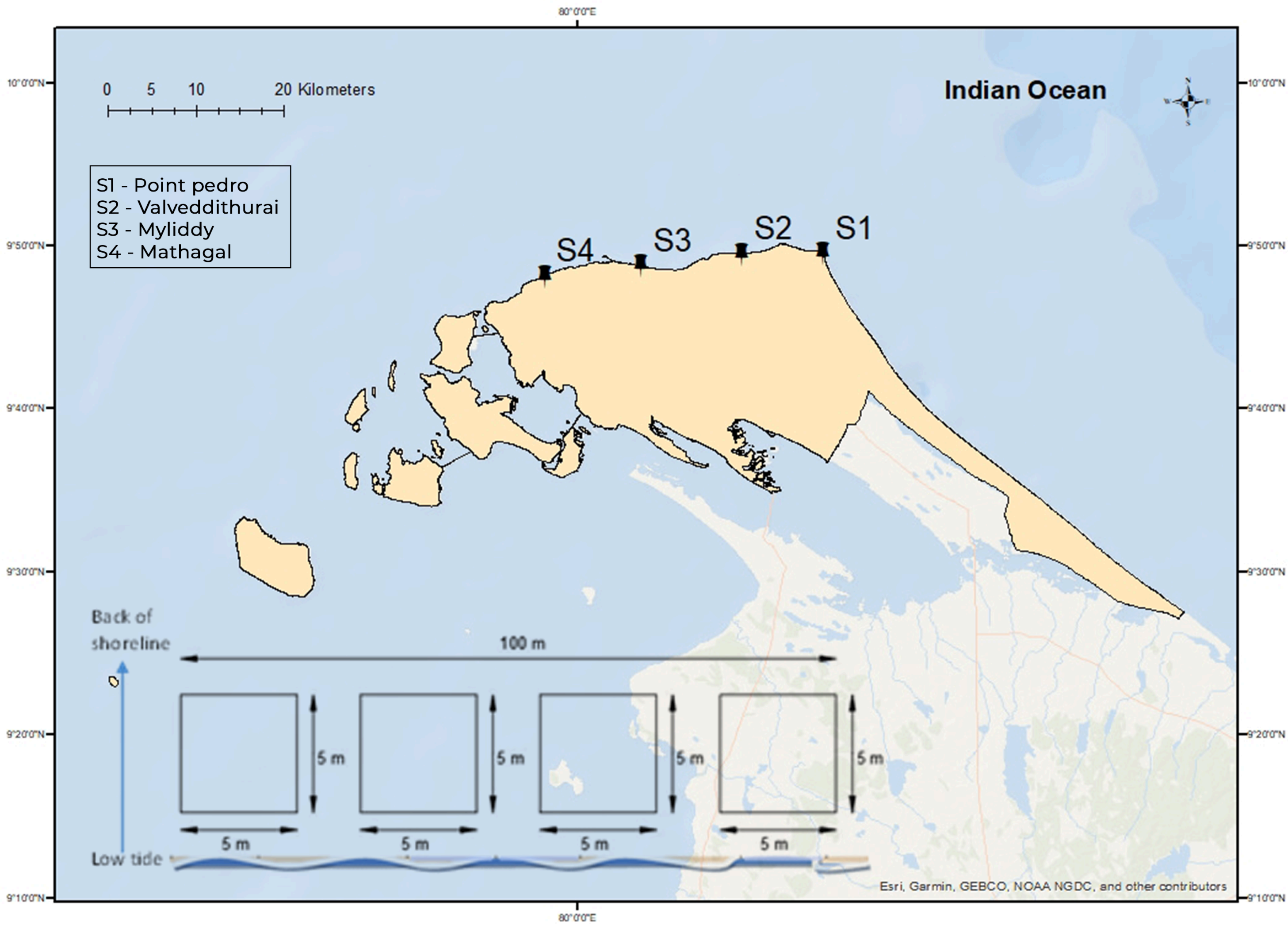

Figure 1

Northern coast of Jaffna indicating the surveyed beaches, marine litter sampling pattern comprised the area between shoreline and the low tide area.

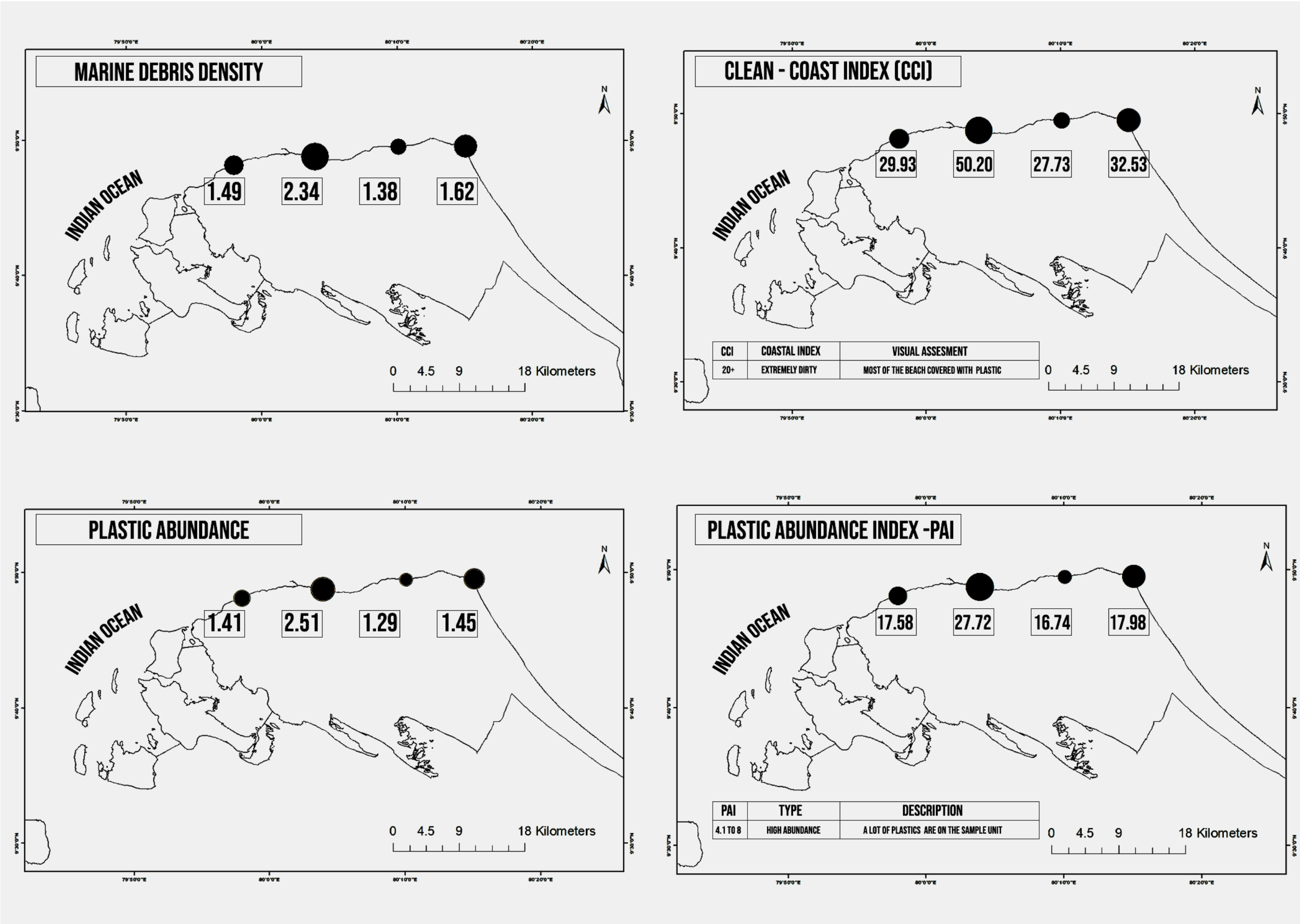

Figure 2

Geographical distribution of marine litter densities,CCI,plastic densities, PAI in the study area.

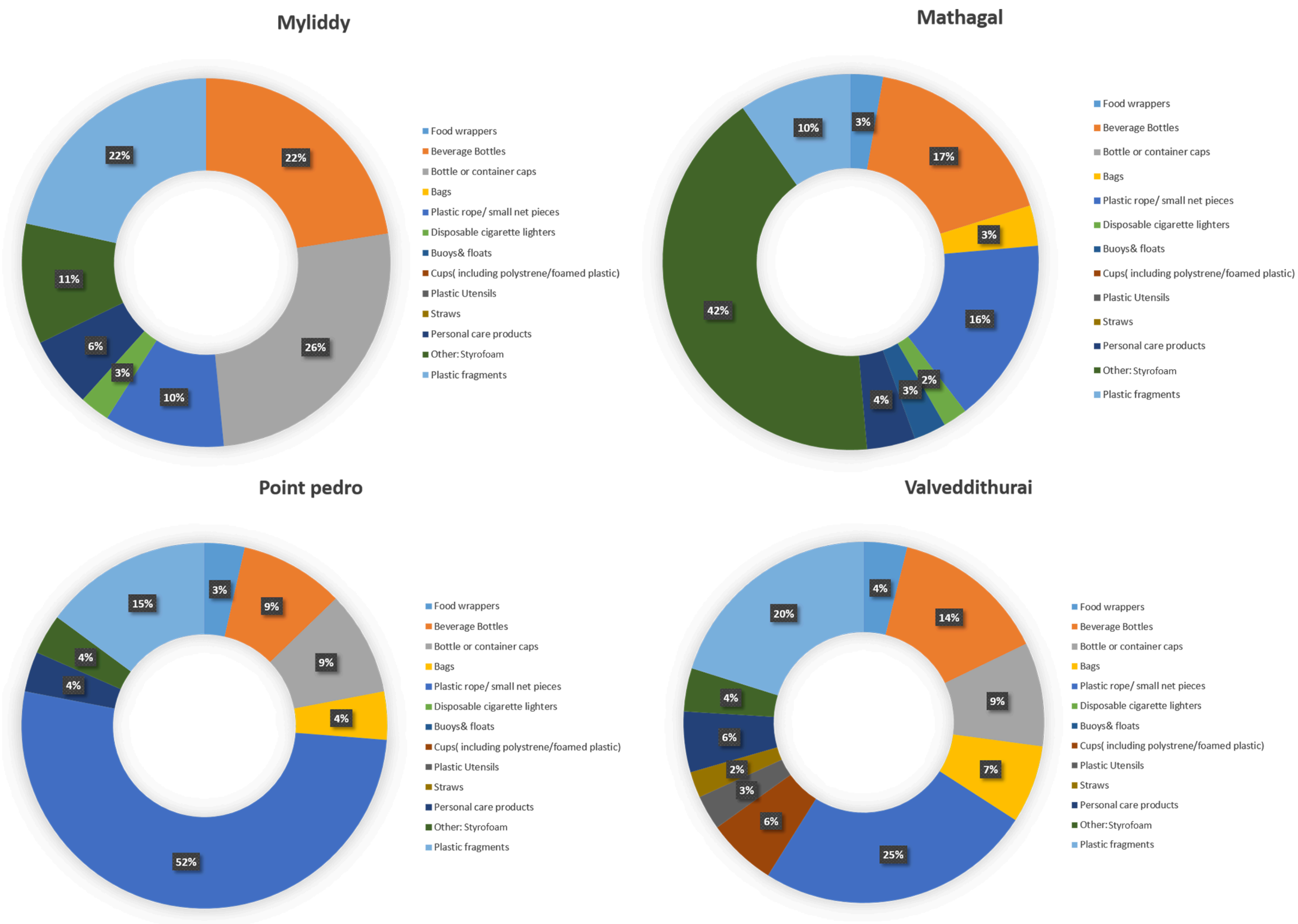

Figure 3

Spatial distribution of plastic litter in the study area. (considered above 2% of plastic debris)