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Sources, spatial distribution, and abundance of marine debris on Thondi coast, Palk Bay, Southeast coast of India

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Abstract

Background: The Thondi coast is rich in valuable natural marine resources and socio-economically significant activities like agriculture, aquaculture, and fishing. The area receives an excess of untreated solid and liquid waste as a result of these activities. The study focuses on the abundance, distribution, and status of the Clean-Coast Index (CCI) of marine debris from the Thondi coast, Palk Bay, Southeast coast of India. This is the first research work focused on assessing the type and quantity of marine debris on the Thondi coast.

Results: A total of 1636 marine debris items/m^2 and their 4.09 concentration of the items/m^2 were determined in the marine debris: plastics (77.49%), cotton swabs (8.62%), cigarette butts (10.15%), and food containers (3.73%). From the result, the CCI had ranged between 4.25 (clean) and 20.4 (extremely dirty) with a mean of 8.92 (moderate) in the Thondi coast assessed.

Conclusion: This study was conducted for the first time in this region. Finally, the high CCI value of 20.4 on the coast indicated that the marine debris pollution levels were high at the time of sampling in the middle part of the Thondi coast (most of the beaches are covered with plastic) due to land-based marine debris (62.45%), sea-originated marine debris (21.14%), and unknown sources (16.41%) of the items. Our findings served as a baseline for potential evaluations of the marine environment. Input prevention should be the goal of management efforts, including proper waste management, plastic recycling, and stringent penalties for illegal waste dumping.

Keywords: Marine debris, Clean-Coast Index, Plastics, Waste management, Beach, Thondi coast

Background

Marine debris (solid waste), marine litter (discarded man-made), and microplastics have been affecting and threatening marine life, hinder navigation safety, and throws human health at risk [1]. Our oceans and rivers are clogged with a range of aquatic waste, from soda cans and plastic bags to discard fishing gear and ships. Along with other major environmental problems such as climate change, ocean acidification, and biodiversity depletion, marine debris has been described as a global concern [2]. It is considered one of the most severe issues facing the coastal and marine ecosystem and a significant threat to biodiversity.

Storm drains, sewers, shorelines, and outdoor events like picnicking and beach-going contribute to the bulk of the garbage and debris that litter our beaches. Abandoned or discarded fishing gear is also a major issue, as it can entangle, kill, maim, and drown marine animals and cause property harm. Since the 1950s, plastic production has increased exponentially, expected to continue in the coming decades. In a recent study, the annual amount of plastic waste entering the marine environment from

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land approaches was 4.8 million tons (Mt), potentially reaching 12.7 Mt [3–6]. Plastic waste is rapidly entering the ocean, with cumulative plastic waste inputs to the ocean possibly exceeding 250 Mt by 2025. In 2010, India had 0.09–0.24 million tons of mismanaged plastic waste and a coastal population of 187.5 million people [3]. In India, 0.01 kg per person on per day was consumed by Indians in 2010 [3]. Marine debris is a global challenge that has been addressed in different coastal regions [7, 8]. Marine debris is found in all marine environments, from beaches to the farthest reaches of the oceans [9]. Plastic, paper/cardboard, wood textile, metal, fabric, glass, rubber, fishing gear, and e-waste were found in the ocean [10, 11], with plastics being the dominant portion [12–15]. The marine debris (plastic) were classified as microplastics (<5 mm), mesoplastics (>5 mm), or macroplastics (>25 mm) based on the size ranges [1, 16–19].

A Clean-Coast Index (CCI) was developed and suggested as a new tool for determining coast cleanliness [20]. Globally many researchers apply CCI for assessing the cleanliness of coastal regions [13, 20–32]. Several past studies were focused on the distribution of heavy metals and pollution status of marine sediments (near the coast and shelf) in various regions in the Bay of Bengal, India [33–45]. The objective of this study is (i) to identify the sources of marine debris; (ii) to determine the spatial distribution, abundance, and Clean-Coast Index (CCI) of marine debris of marine debris, and (iii) to elucidate the health status of Thondi coast, Palk Bay, Southeast coast of India.

Materials and methods

Description of the study site

Thondi (9°43′26″N and 79°02′55″E) is located in the Palk Bay, Southeast coast of India (Fig. 1). The research area is rich in economically valuable marine resources and socio-economically beneficial activities like agriculture, aquaculture, and fishing. This area receives a lot of untreated waste from agricultural land (75%), built-up land (5%), wastelands (7%), and water bodies (13%) [45].

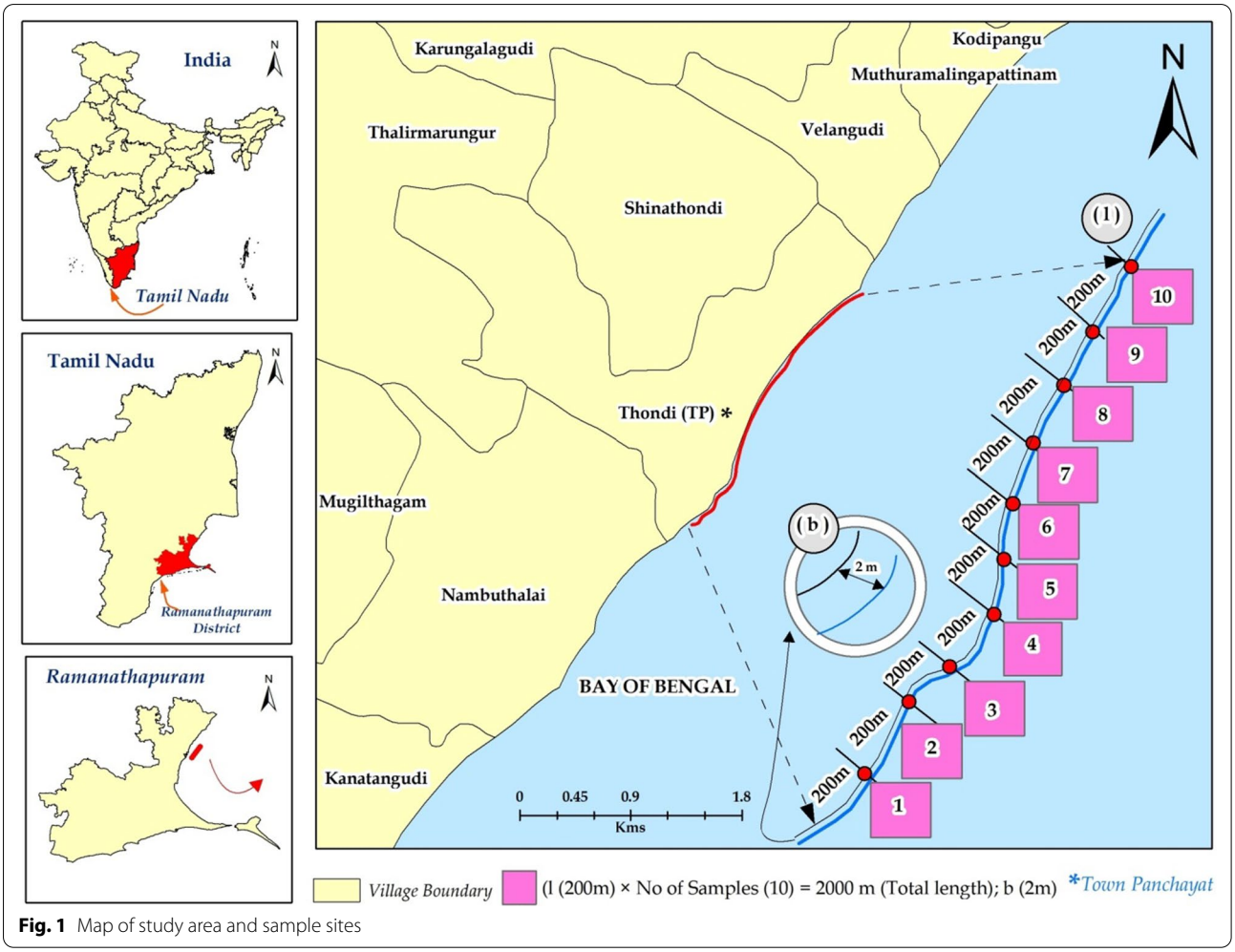

Fig. 1 Map of study area and sample sites

Fishing is a significant economic activity in the Thondi coast region. Oils and paints used in boats become major contaminants, along with plastics and ghost nets. The area is rich in marine algae such as brown, red, and green algae. Coral reefs, seagrass, lobsters, mollusks, and coelenterates are among the marine life found in Palk Bay. The leading economy of the Thondi coast is based on crab exports. Seagrass plays a vital role in producing commercially valuable fishes in this region as it provides food and shelter for various marine organisms and is involved in recycling nutrients. Thondi is an economically and environmentally significant coast. It is home to several endangered species such as sea anemones, sea cucumbers, sea horses, sea urchins, sponges, etc. In the past, Thondi was once the home of endangered *Dugong*, but hunting for meat has drastically reduced their population (see https://wii.gov.in/dugong_field_sites_Tamil_Nadu). The region generally receives rainfall from southwest and northeast monsoons. The seawater is nutrient-rich and turbid, with an average depth of 1–2 m. Because of the low wave action, the sediments are muddy [45]. Except for the ones carried out in the sense of this report, there are no formal beach cleanups on the Thondi coast.

Marine debris collection

The collection of marine debris is carried out following the NOAA Marine Debris Program [19]. The marine debris was collected from the Thondi coast at low tide in March 2021 (Fig. 2) at each location from 10 transects [Length (200 m) Width (2 m)] that had been measured, identified, counted, and recorded [19]. The Global Positioning System (GPS) is used to track the position of each location. The longest dimension of each type of debris has been measured for the quantity of beach macro-debris larger than 2.5 cm (macro-debris). Smaller meso debris particles (0.5–2.5 cm) such as cigarette butts were included in the study. Following the classification of the debris, the contents of each transect were stored in separate bin bags. The debris was then returned to the laboratory and rinsed in pipe water to remove any soil or sand that might have cause inaccuracy during the weighing process. The debris was air-dried and identified individually in the lab before being weighed. According to [46], the marine debris included plastic stirrers, straws, plastic silverware, cotton swabs, plastic cling wrap, cigarette butts, plastic resealable bags, and food containers.

The concentration of marine debris

The concentration of marine debris (macro) (items/m^2) per transect was determined [19, 47] as follows:

$$C_i = \frac{n_i}{a_i \times b_i}, \tag{1}$$

where the concentration (C_i) of marine debris items is calculated as the number of items/m^2, n_i = total number of marine debris items per transect, and a_i—Length (200 m) and b_i—width (2 m) of the transect, and i for the beach on which transects surveys took place. Many researchers were mainly focused on the concentration and density of marine debris in different coastal regions [6, 9, 21, 47–49].

Clean-Coast Index (CCI)

Clean-Coast Index (CCI) was used to measure the cleanliness of the coast [20]. The CCI, which classified beaches based on the amount of marine debris found on them, is expressed as follows:

$$CCI_i = C_i \times K, \tag{2}$$

where K is a constant (20 involved in the equation), to make the numerical value of the CCI comprehensible, K is a meaningless constant. In the Mediterranean environment, the K value was set at 20 [30]. The very same value had been used here as a comparator. According to the scale provided for the number of plastic particles on the coast, the beaches were classified as 'clean' to 'extremely dirty'. The values of C_i (items/$m^{2)}$, CCI_i, Coast index, and visual assessment are given in Table 1. The main objectives for many researchers are to find the spatial distribution, abundance, CCI, and concentration of marine debris in various coastal regions [13, 20–31].

Sources identification

The Matrix Scoring Technique (MST) was used to classify the sources of marine debris along the coast [50]. The source of marine debris is classified as land, river, sea, and unknown sources. Recreational use of the shore, public littering, agricultural activities, and sewage-related debris cause land-based marine debris [51]. Sea waste may be carried to the sea by rivers, industrial discharges, runoffs, and waves. The debris from commercial shipping, fishing and boating activities (traps, fishing nets, and buoys) and fish market sites that have drifted to the shore from the sea are the source of the sea-based sources. Unknown sources may be found on land or at sea, with no labels indicating their origin [52].

GIS analysis

The inverse distance weighted (IDW) method uses ArcGIS (10.2 software) to analyze the spatial distribution of marine debris in the study area.

Results and discussion

Marine debris sources

The three main categories of sources that contribute to the marine debris input along the Thondi coast are

Fig. 2 Plastic debris observed on the coast of Thondi: **A–C** plastic bottles, **D** plastic cup **E** fishing nets, and **F**–**H** plastic bags

Table 1 The values of C_i (items/m^2), CCI_i values, Coast index, and visual assessment of the CCI [17]

S. no.	C_i (items/m^2)	CCI_i values	Coast index	Visual assessment
1	0–0.1	2	Very clean	No debris is seen
2	0.1–0.25	2–5	Clean	No debris is seen over a large area
3	0.25–0.5	5–10	Moderate	A few pieces of debris can be detected
4	0.5–1	10–20	Dirty	A lot of debris on the shore
5	1 +	20 +	Extremely dirty	Most of the beach is covered with plastic

land-based, sea-based, and unknown sources. According to the findings of the study, litter from land-based sources contributes the most to the total amount of debris generated. Overall, the land-based marine debris was reported for 62.45% of the items, sea-originated marine debris examined for 21.14% items, and marine debris 16.41% items could not be identified (Fig. 3). Similarly, Ref. [24] reported that 45.3% of the items account for land-based marine litter, 8.75% of the items represent sea-originated marine litter, and 25.4% of the items could not be identified on the west coast of Qatar. Any man-made product that has ended up in the marine environment after being lost or dumped at sea or on land is marine litter. A few litters float in the oceans, some washes up on our shores, but the majority settles on the seafloor. Unprocessed waste from sewage treatment facilities, products washed down rivers, and discarded fishing boats are all sources of marine debris. Plastic bottles drink containers, cigarette butts, and microplastics are examples of marine debris.

Marine debris distribution

The spatial distribution, concentration, and Clean-Coast Index (CCI) of the debris in this study are measured at ten separate locations in the study region (Table 2). The spatial distribution of marine debris identified in the study area is plastic bottles, plastic bags, cigarette butts, plastic cling wrap, plastic cups, fishing nets, cotton swabs, plastic silverware, straws, plastic stirrers, and food containers (Fig. 4).

Marine debris abundance, Clean-Coast Index (CCI), and coastal health status

The result of marine debris abundance, CCI, and coastal health status in the study area is shown in Fig. 5. In the present study, major distribution of marine debris such

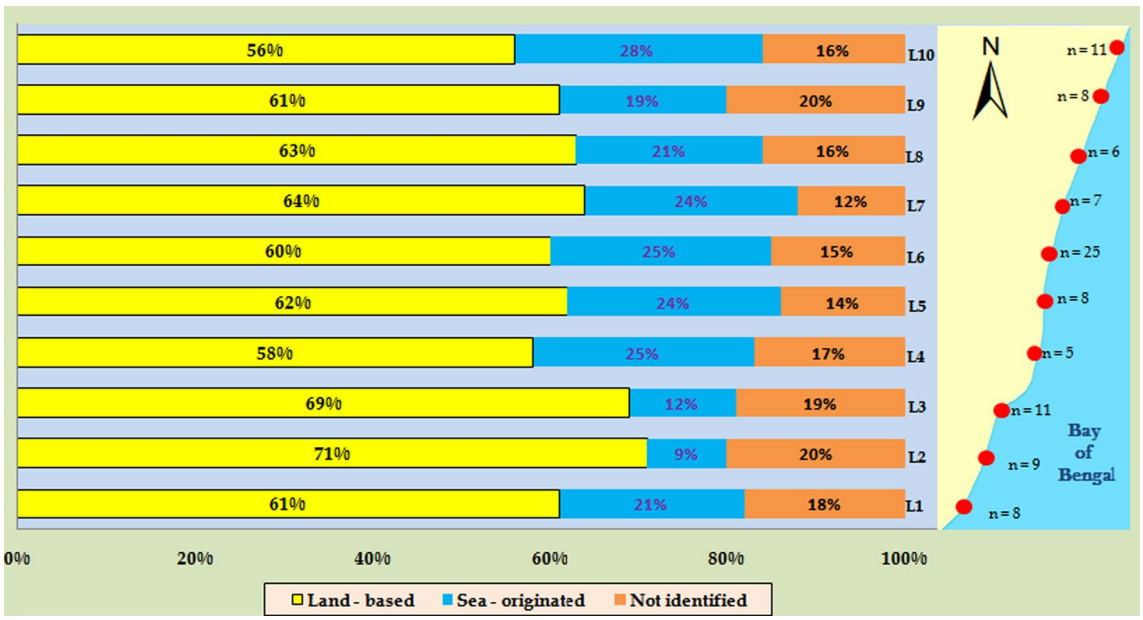

Fig. 3 Sources of marine debris (items/m^2) distribution in the Thondi coast

Table 2 Marine debris (area (m^2), concentration of the debris (items/m^2), and Clean-Coast Index (CCI_i), and grade in Thondi coast

Locations	Marine debris count	Area (m^2)	Concentration (items/m^2)	CCI_i values	Grade
L.1	124	400	0.3	6.2	Moderate
L.2	153	400	0.4	7.7	Moderate
L.3	176	400	0.4	8.8	Moderate
L.4	85	400	0.2	4.3	Clean
L.5	132	400	0.3	6.6	Moderate
L.6	407	400	1.0	20.4	Extremely dirty
L.7	113	400	0.3	5.7	Moderate
L.8	93	400	0.2	4.7	Clean
L.9	129	400	0.3	6.5	Moderate
L.10	224	400	0.6	11.2	Dirty

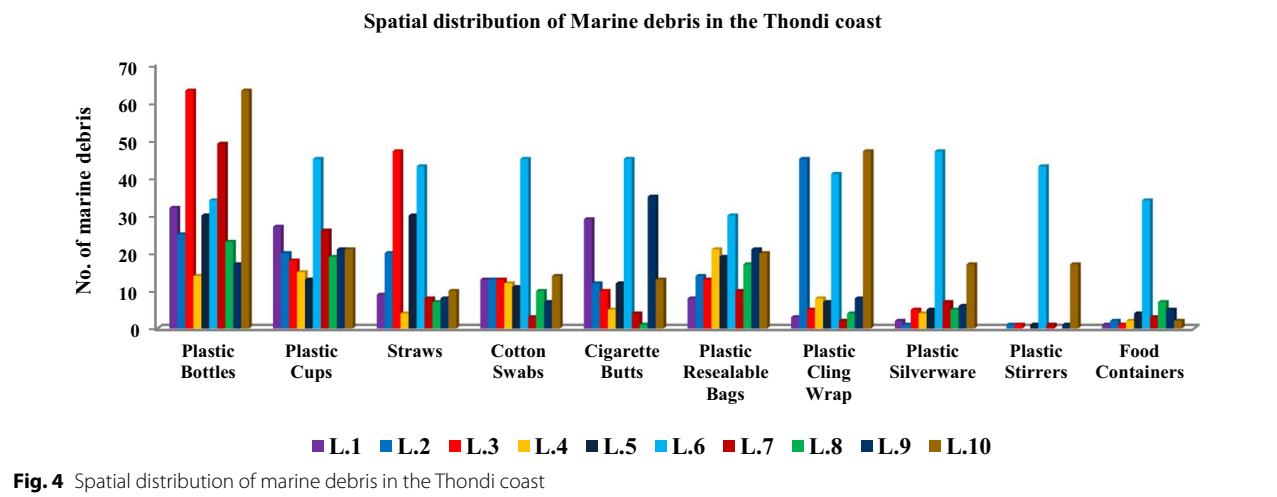

Fig. 4 Spatial distribution of marine debris in the Thondi coast

as plastic bottles (26%), cigarette butts (23%), plastic cups (22%), cotton swabs (10%), straws (7%), plastic resealable bags (6%), plastic cling wrap (2%), plastic silverware (2%), and food containers (1%) was recorded in location 1; and their concentration values of 0.3 items/m^2 and CCI values of 6.2 indicates moderate. The major distribution of marine debris such as plastic cling wrap (29%), plastic bottles (16%), plastic cups (13%), straws (13%), plastic resealable bags (9%), cotton swabs (8%), cigarette butts (8%), plastic silverware (1%), plastic stirrers (1%), and food containers (1%) was recorded in location 2; and their concentration values of 0.4 items/m^2 and CCI values of 7.7 indicates moderate. The major distribution of marine debris such as plastic bottles (36%), straws (27%), plastic cups (10%), cotton swabs (7%), plastic resealable bags (7%), cigarette butts (6%), plastic cling wrap (3%), plastic silverware (3%), plastic stirrers (1%), and food containers (1%) was recorded in location 3; and their concentration values of 0.4 items/m^2 and CCI values of 8.8 indicates moderate. In the present study, major distribution of marine debris such as plastic resealable bags (25%), plastic bottles (16%), plastic cups (18%), cotton swabs (14%), plastic cling wrap (9%), cigarette butts (6%), plastic silverware (5%), straws (5%), and food containers (2%) was recorded in location 4; and their concentration values of 0.2 items/m^2 and CCI values of 4.3 indicates clean. In the present study, major distribution of marine debris such as plastic bottles (23%), straws (23%), plastic resealable bags (14%), plastic cups (10%), cigarette butts (9%), cotton swabs (8%), plastic cling wrap (5%), plastic silverware (4%), plastic stirrers (1%), and food containers (3%) was recorded in location 5; and their concentration values of 0.3 items/m^2 and CCI values of 6.6 indicates moderate.

In the present study, major distribution of marine debris such as plastic silverware (12%), plastic cups (11%), straws (11%), cotton swabs (11%), cigarette butts (11%), plastic stirrers (11%), plastic cling wrap (10%), plastic bottles (8%), food containers (8%), and plastic resealable bags (7%) was recorded in location 6; and their concentration values of 1 item/m^2 and CCI values of 20.4

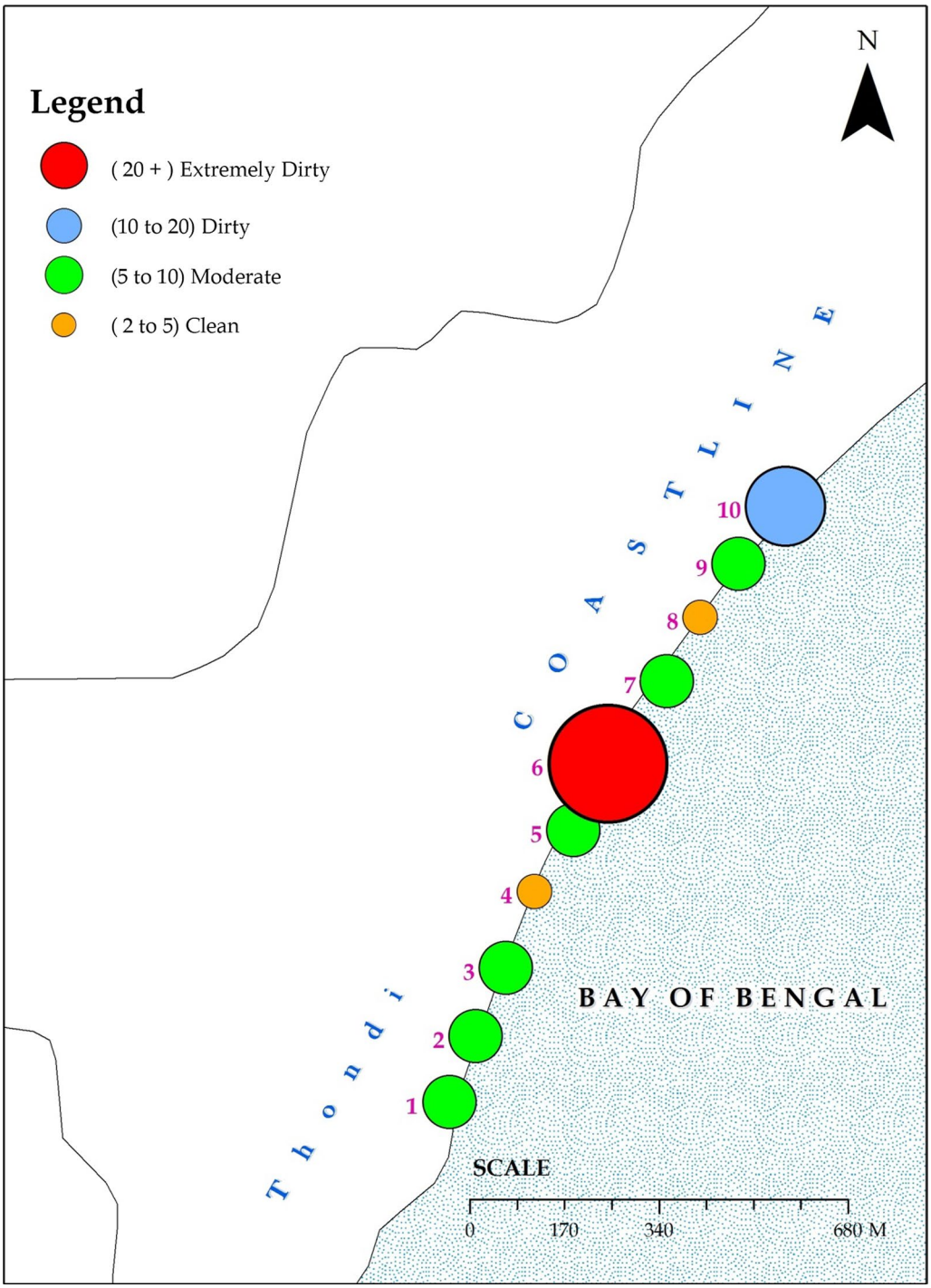

Fig. 5 Coastal health status of the Thondi coast according to the Clean-Coast Index (CCI)

indicates extremely dirty. In the present study, major distribution of marine debris such as plastic bottles (43%), plastic cups (23%), plastic resealable bags (9%), straws (7%), plastic silverware (6%), cigarette butts (4%), cotton swabs (3%), food containers (3%), plastic cling wrap (2%), and plastic stirrers (1%) was recorded in location 7; and their concentration values of 0.3 items/m^2 and CCI values of 5.7 indicates moderate. In the present study, major distribution of marine debris such as plastic bottles (25%), plastic cups (20%), plastic resealable bags (18%),

cotton swabs (11%), straws (8%), food containers (8%), plastic silverware (5%), plastic cling wrap (4%), and cigarette butts (1%) was recorded in location 8; and their concentration values of 0.2 items/m^2 and CCI values of 4.7 indicates clean. The major distribution of marine debris such as cigarette butts (27%), plastic resealable bags (16%), plastic cups (16%), plastic bottles (13%), straws (6%), plastic cling wrap (6%), plastic silverware (5%), cotton swabs (5%), food containers (4%), and plastic stirrers (1%) was recorded in location 9; and their concentration values of 0.3 items/m^2 and CCI values of 6.5 indicates moderate. In the present study, major distribution of marine debris such as plastic bottles (28%), plastic cling wrap (21%), plastic cups (9%), plastic resealable bags (9%), plastic silverware (8%), plastic stirrers (8%), cotton swabs (6%), cigarette butts (6%), straws (4%), and food containers (1%) was recorded in location 10; and their concentration values of 0.6 items/m^2 and CCI values of 11.2 indicates moderate.

According to the findings, the observed debris distribution per transects ranged from 85 to 407 items, with an average of 163.6 items, a concentration of 0.21 to 1 item/m^2, and computed CCI values ranging from 4.3 to 20.4 (average of 8.2), indicates moderate pollution in the study region. Total debris of 85 and 93 items with a concentration of 0.21 and 0.23 items/m^2 and the calculated CCI values are 4.25, and 4.65 which indicates clean in locations 4 and 8, respectively. In Location 6, total debris of 407 items with a concentration of 1.02 items/m^2 and the calculated CCI values is 20.4, which indicates extremely dirty; and location 10, total debris of 224 items with a concentration of 0.56 items/m^2 and the calculated CCI values is 11.2 which means dirty. In this study, a total of 1,636 items were observed in all locations, 1268 of which were plastic (Table 2) in ten transects. The debris concentration during the ten locations ranged between 0.21 and 1.02 items/m^2 with a mean of 0.408 items/m^2 in the Thondi coast (Table 2). In the present study, the Clean-Coast Index ranged between 4.3 (Clean) and 20.4 (Extremely dirty) with a mean of 8.9 (moderate) on the Thondi coast. According to this research, the study area is mostly moderate (60%) as the result of CCI in the Thondi coast. In previous studies and the results, the values of the CCI were compared to those of the international region and shown in Table 3.

The CCI represents that the locations of 1, 2, 3, 5, 7, and 9, which indicate a visual assessment of a few pieces of debris that can be detected. Shoreline and recreational activities, smoking-related activities, fishing activities, and medical/personal hygiene were the main cause of marine pollution in the Thondi beach. Apart from the loss of esthetic value, the presence of marine debris on the beach could have an economic impact, such as reduced tourism and increased cleaning expenses. The ecological harm caused by debris ingestion, notably the uptake of microplastics, could have a significant impact on marine biota. Similarly, Ref. [26] reported a marine debris concentration of 0.42 items/m^2 at Asparuhov beach, Varna, in Bulgaria. The debris identified the plastic cups and industrial packaging. CCI rates the beach as moderate in the spring and clean in the autumn seasons; Ref. [29] suggested that marine debris concentration of 6.06 units/m^2 at the beach of Arraial do Cabo in Rio De Janeiro, Brazil. The debris in the study area is identified as food packages, straw, bottle caps, disposal cups, swab rods, light sticks, and bottles. According to CCI, the beach Prainha is categorized as dirty to moderate, Pontal beach is categorized as dirty, and the grand beach is categorized as clean to moderate, and Ref. [23] explained that marine debris abundance of 0.1–0.35 items/m^2 in Red sea, Eritrea. Marine debris has been identified, such as cloths, foamed plastics, and plastics. Red Sea (Eritrea) is determined as very clean—moderate by CCI.

At locations 4 and 8 (4.3, 4.7 values indicate clean by CCI, which indicates no debris seen over a large area in the locations. In similarly, Ref. [22] reported marine debris abundance of 9.3 items/m^2 in Cyprus. The marine debris was identified as PP and PE. The Cyprus beach is categorized as clean by CCI, and Ref. [20] identified plastic debris along Isreal coast and according to Clean-Coast Index the coast is classified as clean; and Ref. [13] reported marine debris concentration of 0.2 litter item/m^2 in North West Adriatic beaches. The debris is identified as cigarette butts, unrecognizable plastic pieces, bottle caps. The beaches are categorized as clean–dirty according to CCI. A similar report Ref. [21], reported that marine debris abundances of 0.042 items/m^2 in the Mkomani beach, Kenya. The marine debris is identified as food products packaging, PC, HP, PET, SL, HDPE, PP, and PVC. The Mkomani beach is determined extremely dirty by CCI. Ref. [24] reported marine debris concentration of 1.98 items/m^2 in Qatar, and the debris are identified as plastics, metal, glass, paper, fabric, rubber, and processed food and Qatar beach is identified as dirty to extremely dirty by CCI. Ref. [28] studied that marine debris concentration of 34,027 items/m^2 at Pelagos sanctuary (Ligurian Sea—NW Mediterranean Sea). The debris was identified as glass, rubbers, textiles, foam/sponge, plastic, and PS. The Ligurian sea is categorized as very clean–extremely dirty by CCI. Ref. [30] researched that marine debris of 3305 items/m^2 in Eastern Mediterranean. The debris was identified as foam, cloth, glass, metal, papers, rubber, and wood. The Eastern Mediterranean is categorized as very clean–extremely dirty by CCI. Ref. [32] reported that the marine debris concentration of 1.51 items/m^2 in Slovenia. The debris is identified

Table 3 Spatial distribution of Clean-Coast Index in international region

S. no.	Region	Abundances	Marine debris	CCI	Author
1	Thondi, Palk Bay, Southeast India	1636 items/m^2	Plastics, cotton swabs, cigarette butts, and food containers	Clean–extremely dirty	Present study
2	Mkomani beach, Kenya	0.042 items/m^2	Food products packaging, PC, HP, PET, SL, HDPE, PP, and PVC	Extremely dirty	Okuku et al. [21]
3	Cyprus	9.3 items/m^2	PP, and PE	Clean	Loizia et al. [22]
4	Red Sea, Eritrea	0.1 to 0.35 items/m^2	Plastics, cloths, and foamed plastic	Very clean–moderate	Tewelde et al. [23]
5	Qatar	1.98 items/m^2	Plastics, metal, glass, paper, fabric, rubber, processed wood	Dirty to extremely dirty	Veerasingam et al. [24]
6	Dungonab and Mukkawar Island Marine National Park, Sudan, Red Sea	506.2 items/m^2	Plastics, wood, fishing gears, Textile, class, food wrapper/pack, and metals	Very clean–dirty	Ibrahim et al. [25]
7	Asparuhovo Beach, Varna, Bulgaria	0.41 items/m^2	Cigarette butts, plastic/polystyrene pieces, industrial packaging, plastic cups	Moderate	Panayotova et al. [26]
8	Beach off southwestern Luzon, Philippines	0.26 item/g	Plastic bag, disposable cup and a sachet	Dirty	Paler et al.[27]
9	Pelagos sanctuary (Ligurian Sea—NW Mediterranean Sea)	34,027 items/m^2	Plastic, foam/sponge, textiles, rubber and glass, polystyrene	Very clean–extremely dirty	Giovacchini et al. [28]
10	Beaches of Arraial do Cabo, RJ, Brazil	6.06 unites/m^2	Food packaging, straw, bottle cap, disposable cup, swab rod, light stick, and bottle	Prainha beach: dirty–moderate Pontal beach: moderate–dirty Grande beach: clean–moderate	Silva et al. [29]
11	Eastern Mediterranean	3305 items/m^2	Foam, cloth, glass, metal, paper, rubber, and wood	Very clean–extremely dirty	Portman and Brennan [30]
12	Salvador, Brazil	50.82 items/m^2	Plastic, metal, glass, wood, cloth, plastic bag, beverage cans, barbecue wooden sticks, and plastic fragments	Dirty	Fernandino et al. [31]
13	North-western Adriatic beaches	0.2 litter items/m^2	Cigarette butts, unrecognizable plastic pieces, bottle caps,	Clean–dirty	Munari et al. [13]
14	Slovenia	1.51 items/m^2	Caps and lids, lolly sticks, cutlery, cups, drink bottles, drink bottles, fishing ropes, string, cosmetics packaging, fishing net floats, and foam	Extremely dirty	Laglbauer et al. [32]
15	Israeli coast	–	Plastic debris	Clean	Alkalay et al. [20]

as fishing ropes, cutlery, lolly sticks, cups, drink bottles, cosmetics packaging, string, caps and lids, fishing net floats, foam, and drink bottles. The area is categorized as extremely dirty by CCI. The estimated CCI value for position 10 is 11.2 (dirty), indicating that there is a lot of debris on the beach. Likewise, Ref. [25] reported that the marine debris concentration of 506.2 items/m^2 at Sudan, Red sea. The debris was identified as plastics, textiles, fishing gears, metals, and wood, glass, food, and wrappers/packs. The beach is categorized as very clean–dirty by CCI. Ref. [27] studied that marine debris concentration of 0.26 items/gram at the beach of southwestern Luzon in the Philippines. The debris is identified as plastic bags, disposable cups, and a sachet. The beach is categorized as dirty by CCI. Ref. [31] explained that marine debris of concentration 50.82 items/m^2 in Salvador, Brazil. The debris is identified as plastic, metal, glass, wood, cloth, plastic bags, beverage cans, barbecue, wooden sticks, and plastic fragments. The area is categorized as dirty by CCI. The sampling was done in response to the fishing activity; it was unevenly distributed across the 2 km study area. According to similar findings, fishing

activity polluted the Azores archipelago and Madeira (NE Atlantic) [47]. Ref. [53] detected a decline in macro-debris density from coastal to oceanic areas in the South Atlantic Ocean. Ref. [54] used beach surveys to validate the prevalence of small plastic fragments on the Azores coastline over large macro-debris, a conclusion consistent with a previous study that found a significant abundance of microplastics throughout the archipelago [55].

Conclusions

The present study is the first of its type to examine marine debris pollution in the Thondi coast, Palk Bay, Southeast coast of India. The samples of marine debris such as plastic bottles, bags, cigarette butts, plastic cling wrap, plastic cups, fishing nets, cotton swabs, plastic silverware, straws, plastic stirrers, and food containers were collected from the Thondi coast, and their concentration, spatial distribution, and Clean-Coast Index (CCI) were assessed in the study area. A total of 1636 marine debris items/m^2 and their concentration of 4.09 items/m^2 with abundance of plastic bottles (22%), plastic cups (14%), straws (12%), cotton swabs (9%), cigarette butts (9%), plastic resealable bags (10%), plastic cling wrap (11%), plastic silverware (6%), plastic stirrers (4%), and food containers (4%) were determined. From the result, the CCI had ranged between 4.25 (clean) and 20.4 (extremely dirty) with a mean of 8.92 (moderate) in the Thondi coast assessed. The CCI suggested that the study region is severely unclean because most of the beach is littered with plastics. According to the conclusion of this study, the majority of marine debris on beach originates relatively from land-based sources. Improved waste disposal facilities and public awareness campaigns against plastic debris are critically needed, especially along the Thondi coast. The limitation of this study is the fact that it only provides a glimpse of newly deposited marine debris particles. Furthermore, feasible strategies for reducing the production and usage of plastic and/or seeking alternatives can be developed.

Abbreviations

CCI: Clean-Coast Index; Mt: Million tons; NOAA: National Oceanic and Atmospheric Administration; MST: Matrix scoring technique; IDW: Inverse distance weighted; PC: Personal care products; HP: Household products; PET: Polyethylene terephthalate; SL: Single-layered; HDPE: High-density polyethylene; PP: Polypropylene; PE: Polyethylene; PS: Polystyrene; PVC: Polyvinyl chloride.

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Authors' contributions

KP: conceptualization, supervision, investigation, methodology, writing—original draft, writing—review and editing; VB: data curation, formal analysis; SC: supervision, investigation; SM: software; data analysis; investigation; PR: software; data analysis; investigation. All authors have read and approved the final manuscript.

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Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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