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

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Research Article

Keywords: Marine debris, clean - coast index, plastics, waste management, beach, Thondi coast

Posted Date: June 16th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-625168/v1

Version of Record: A version of this preprint was published at Environmental Sciences Europe on December 1st, 2021. See the published version at https://doi.org/10.1186/s12302-021-00576-x.

Abstract

Background: The Thondi coast is a rich source of valuable natural marine resources, as well as many socioeconomically 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 focus 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 research was the first to assess the type and quantity of marine debris on the Thondi coast.

Results: A total of 1636 marine debris items/m^2 and 4.09 density 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 is ranged between 4.25 (clean) and 20.4 (extremely dirty) with a mean of 8.92 (moderate) in the Thondi coast assessed.

Conclusion: These studies were conducted for the first time in this region. Finally, the high CCI value of 20.4 in the coast indicates that the marine debris pollution levels are high at the time of sampling in the middle part of the Thondi coast (most of the beach is 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 serve as a baseline for potential evaluations of marine environments. Input prevention should be the goal of management efforts, which include proper waste management, plastic recycling, and stringent penalties for illegal waste dumping.

Background

Marine debris (solid waste), marine litter (discarded man-made), and microplastics are affects and threatens 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 serious issues facing the marine ecosystem, as well as a major threat to biodiversity. This problem now affects every country on the planet. Storm drains and sewers, as well as shoreline 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, as well as cause property harm. Since the 1950s, plastic production has increased at an exponential pace, which is expected to continue in the coming decades. In a recent study, the annual amount of plastic waste entering the marine environment from land approaches 4.8 million tons (Mt), with the potential to reach 12.7 Mt. Plastic waste is rapidly entering the ocean, with cumulative inputs of plastic waste to the ocean possibly exceeding 250 Mt by 2025. In 2010, India had a total of 187.47 million tons of mismanaged plastic waste and a coastal population of 6 million people. In India, 0.01 kg per person per day was consumed by Indians in 2010 [3].

Marine debris is a global issue that has been investigated in a number of areas [4, 5]. It can be found in all marine environments, from beaches to the farthest reaches of the oceans [6]. Plastic, paper/cardboard, wood textile, metal, fabric, glass, rubber, fishing gear, and e-waste are all found in the ocean [7-9] with plastics being the most dominant portion [10-12]. The marine debris (plastic) were classified as microplastics (< 5 mm), mesoplastics (> 5 mm), or macroplastics (> 25 mm) based on the size ranges [1, 13-16].

[17] was developed and is suggested as a new tool for determining coast cleanliness. Many researchers were studied CCI using in worldwide regions in Mkomani beach [18], Kenya; in Cyprus [19]; in the Red Sea, Eritrea [20]; in Qatar [21]; in Dungonab and Mukkawar Island, Sudan, Red Sea [22]; in Asparuhovo Beach, Varna, Bulgaria [23]; in Beach off southwestern Luzon, Philippines [24]; in Pelagos sanctuary (The Ligurian Sea - NW Mediterranean Sea [25]; in Beaches of Arraial do Cabo, RJ, Brazil [26]; in Eastern Mediterranean [27]; in Salvador, Brazil [28]; in North-western Adriatic beaches [10]; in Slovenia [30]; and in Israeli coast [17]. The objective of this study is to identify the sources, spatial distribution, and abundance of marine debris along the Thondi coast, Palk Bay, Southeast coast of India, and to explore possible sources of marine debris, so as to come up with the preferences for enhanced future marine debris management in India.

Description of the study area

Thondi (9°43′26″N and 79°02′55″E) is located in the Palk Bay, Tamil Nadu, Southeast coast of India (**Fig. 1**). The study area serves as a treasure of various economically important marine resources, many socioeconomic important activities such as agriculture, aquaculture, and fishing. Due to these activities the area receives an abundance of untreated solids and liquid waste. The study area is mostly occupied by agriculture land (75%), built-up land (5%), wastelands (7%), and water bodies (13%). Fishing is a very important economic activity carried out in Thondi. It is also a major source of pollution as well as a threat to some of the marine species, especially to Sea Urchins, Star fishes, *Lambis lambis* due to the by catch of these species by fisherman. Oil and pain used in the boats is the primary pollutants along with plastics, ghost nets etc. The area is rich in valuable marine algae such as the marine brown algae, red algae, and green algae.

The Palk Bay area is known for its rich marine biodiversity and resources such as sea grass, shrimps, seaweed, lobsters, mollusks, coelenterates, crabs, shellfish, squids, and finfish. Crab exports are the economic backbone of Thondi. Sea grass plays a vital role in the production of commercially valuable fishes in this region as it provides food and shelter for various marine organisms and is involved in recycling of nutrients. Thondi is not just an economically important coast, but it is also an ecologically important coast. It houses many endangered species like sea anemones, sea cucumber, along with sea horses, sea urchins, sponges, fishing and lack of knowledge is causing serious destruction to the population of this species. Due to an abundance of sea grass Thondi was once the home of endangered *Dugong*, but due to hunting for meat *Dugong* population has faced extreme decline. The region generally receives rainfall from south, west and northeast monsoons. The shore water has an average depth of 1-2

m and the sea water is rich in nutrients with moderately high turbidity. The wave action is minimal and the sediments are muddy [33]. Except for the ones carried out in the sense of this report, there are no formal beach cleanup activities carried out on the Thondi coast.

Materials And Methods

Marine debris collection

All studies performed based on the guideline NOAA Marine Debris Program [16]. At each coast, ten transects measuring 200m × 2m of the shoreline identified, counted, and recorded using by [16]. The marine debris was collected from Thondi shoreline and conducted in March 2021 during low tide. The precise position of each location was marked out using GPS. The sample collection was done by field assistants during the survey, which took place during low tidal periods. For the abundance of beach macro-debris greater than 2.5 cm, the longest dimension of each type of debris was measured (macrodebris). The study has included smaller mesodebris particles (0.5 - 2.5 cm), such as cigarette butts. After sorting the debris into types, the contents of each transect were stored in separate bin bags. The debris was then returned to the laboratory and rinsed with pipe water to remove any soil or sand that could cause inaccuracy during the weighing process. Before being weighed, the debris was air-dried in the lab and identified separately. The marine debris was listed as plastic, plastic stirrers, straws, plastic silverware, cotton swabs, plastic cling wrap, cigarette butts, plastic reseal able bags, and food containers based on the labeled given by [31].

Density of marine debris

The density of marine debris (items/m^2) per transect was determined [32] as follows:

$$C = \frac{n}{(a \times b)} \quad \ldots\ldots\ldots\ldots (1)$$

Where, the density (C) of items will be calculated as the number of items m^2, n = total number of marine debris items per transect, and *a* - width (m) and *b* - length (m) of the transect. In different coastal regions, many researchers followed and successfully analyzed [6, 18, 33-35].

Clean-coast Index (CCI)

Clean - Coast Index (CCI) is being used to measure the cleanliness of the coast [17]. The CCI, which classifies beaches based on the amount of marine debris found on them, is expressed as follows:

$$CCI = \frac{X}{Y} \times K \quad \ldots\ldots\ldots\ldots (2)$$

Where, *X* is total plastic in parts on transect; *Y* is total area of transect; *K* is constant (20 involved in the equation). The CCI values, grade, and visual assessment are given in **table 1**. The following authors were

successfully completed in the CCI in various coastal regions [10, 17-28].

Source identification

To classify the origins of marine debris along the coast, the Matrix Scoring Technique (MST) is used [36]. The source of marine debris is classified as land or river, sea, or unknown. Land-based causes include recreational use of the shore, public littering, agricultural activities, and sewage-related debris [37]. 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 has drifted to the shore from the sea is the source of the sea-based sources. Unknown sources may be found on land or at sea, with no labels indicating where they came from [33]. All of those classifications were used to classify the sources in this article.

GIS analysis

The spatial distribution of marine debris in the study area was determined using the inverse distance weighted (IDW) method and ArcGIS 10.2 software.

Results

Density and spatial distribution of marine debris

The distribution, density, and Clean-Coast Index (CCI) of the debris in this study were measured at ten separate locations along the study region (**Table 2 and Fig. 2**). The result of spatial distribution of pollution status of CCI in the study area is shown in the **fig. 3.** In result of a total debris distribution of 124, 153, 176, 132, 113, and 129 items/m^2 with a density of 0.31, 0.38, 0.44, 0.33, 0.28, and 0.32 items/m^2 and the calculated CCI values is 6.2, 7.65, 8.8, 6.6, 5.65, and 6.45 which indicates moderate pollution in the locations 1, 2, 3, 5, 7, and 9 respectively. Total debris of 85, and 93 items/m^2 with a density of 0.21, and 0.23 items/m^2 and the calculated CCI values is 4.25, and 4.65 which indicates clean in the locations 4, and 8 respectively. In Location 6, total debris of 407 items/m^2 with a density 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/m^2 with a density of 0.56 items/m^2 and the calculated CCI values is 11.2 which indicates dirty. Total debris of 224 items/m^2 with a density of 0.56 items/m^2 and the calculated CCI values is 11.2 which indicates dirty. In this study, a total of 1,636 items/m^2 was observed in the all locations, 1268 of which were plastic (**Table 2**) in ten transect. The debris densities 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, clean coast index is ranged between 4.25 (Clean) and 20.4 (Extremely dirty) with a mean of 8.92 (moderate) in the Thondi Coast. We find the study area is mostly moderate in the result of CCI in the Thondi coast, Palk Bay of Southeast India. The distribution of debris identified in the study area

are plastic bottles, plastic bags, cigarette butts, plastic cling wrap, plastic cups, fishing net, cotton swabs, plastic silverware, straws, plastic stirrers, and food containers. In this baseline study described that Thondi coast is moderate (60%) be identified. In previous studies and the results, the values of the CCI are compared to those of the International region is shown in **table 3**. In present study, the calculated CCI values is concentration of 6.2, 7.65, 8.8, 6.6, 5.65, and 6.45 which indicates moderate pollution in the locations 1, 2, 3, 5, 7, and 9 respectively.

Discussion

The CCI represents that the locations 1, 2, 3, 5, 7, and 9 which indicates visual assessment of a few pieces of debris can be detected. Similarly, [23] reported marine debris concentration of 0.42 items/m^2 at Asparuhov beach, Varna in Bulgaria. The debris identified are plastic cups, and industrial packaging. The beach is categorized as moderate by CCI; [26] suggested that marine debris concentration of 6.06 units/m^2 at the beach of Arrial do cabo in Rio De Jeniro, Brazil. The debris in the study area is identified as food packages, straw, bottle caps, disposal cups, swab rod, light stick, and bottle. According to CCI the beach Prainha is categorized as dirty to moderate, Pontal beach is categorized as dirty and grand beach is categorized as clean to moderate, and [20] explained that marine debris abundance of 0.1-0.35 items/m^2 in red sea, Eritera. The marine debris identified are cloths, foamed plastics, and plastics. Red sea (Eritera) is determined as very clean – moderate by CCI.

At locations 4, and 8 (4.25, 4.65 values indicates clean by CCI which indicate no debris is seen over a large area in the locations. In similarly, [19] reported marine debris abundance of 9.3 items/m^2 in Cyprus. The marine debris identified are PP and PE. The Cyprus beach is categorized as clean by CCI, and [17] identified plastic debris along Isreal coast and according to clean-coast index the coast is classified as clean; and [10] reported marine debris concentration of 0.2 litter item/m^2 in NW Adriatic beaches. The debris is identified as cigarette butts, unrecognizable plastic pieces, bottle caps. The beaches are categorized as clean-dirty according to CCI. At similar reported, [18] reported that marine debris abundances of 0.042 items/m^2 in the Mkomani beach, Kenya. The marine debris identified are food products packaging, PC, HP, PET, SL, HDPE, PP, and PVC. In the Mkomani beach is determined extremely dirty by CCI.

[21] 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 & Qatar beach is identified as dirty to extremely dirty by CCI. [25] studied that marine debris concentration of 34,027 items/m^2 at Pelagos sanctuary (Ligurian Sea - NW Mediterranean Sea). The debris is identified as glass, rubbers, textiles, foam/sponge, plastic, and PS. The Ligurian sea is categorized as very clean-extremely dirty by CCI. [27] researched that marine debris of 3305 items/m^2 in eastern Mediterranean. The debris are indentified as foam, cloth, glass, metal, papers, rubber, and wood. The Eastern Mediterranean is categorized as very clean-extremely dirty by CCI. [29] reported that the marine debris concentration of 1.51 items/m^2 in Slovenia. The debris are identified 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 [22] reported that the marine debris concentration of 506.2 items/m^2 at Sudan, Red sea. The debris are identified as plastics, textiles, fishing gears, metals, and wood, glass, food, and wrappers/packs. The beach is categorized as very clean-dirty by CCI. [24] studied that marine debris concentration of 0.26 items/gram at the beach of southwestern Luzon in Philippines. The debris are identified as plastic bags, disposable cup and a sachet. The beach is categorized as dirty by CCI. [28] explained that marine debris of concentration 50.82 items/m^2 in Salvodar, Brazil. The debris is identified as plastic, metal, glass, wood, cloth, plastic bags, beverage cans, barbecue and wooden sticks and plastic fragments. The area is categorized as dirty by CCI.

Sources of marine debris

The three main categories of sources that contribute to the marine debris input along the Thondi coast are 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 litter generated. Overall, the land - based marine debris 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. Similarly [21] 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 in 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 referred to as marine litter. A few litter floats 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.

Conclusions

Studies were carried out for the first time at the Thondi coast in March 2021. In concluding that, the high CCI values of 20.4 are indicated extremely dirty (most of the beach is covered with plastic) in the coast indicates that the marine debris contamination levels are high at the time of sampling in the middle part of Thondi coast. The main sources of marine debris pollution identified are land and sea – based, and unknown sources in the study area. Even more research should be conducted to determine which plastic forms are most prevalent in the Thondi coastal and marine environments. The Thondi coast has been polluted by plastic marine debris, especially plastic bags and food packaging, according to this report. Improved waste disposal infrastructure is urgently needed in coastal areas, especially along the Thondi coast, as well as citizen outreach projects to raise public awareness about plastic debris. This research has drawbacks in that it only offers a snapshot of recently accumulated marine debris particles on beaches. Finally, potential measures to combat plastic waste in the country can be drafted, such as reducing the production and usage of plastic (sachet) packaging and/or seeking alternatives.

List Of 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.

Declarations

Acknowledgement

The authors are grateful to thank the Head of the Department, School of Marie Sciences, Department of Oceanography and Coastal Area Studies, Alagappa University, Karaikudi- 630 003.

Authors' contributions

Karthikeyan Perumal: conceptualization, supervision, investigation, methodology, writing - original draft, writing - review & editing; Vishwanath Boopathi: data curation, formal analysis; Subagunasekar Muthuramalingam: software; data analysis; investigation; Prakash Raja: software; data analysis; investigation.

Funding

No funding

Availability of data and material

http://doi: 10.17632/dmxsk2mjz6.2

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing Interest

The authors declare that they have no competing interests.

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Tables

Table 1 Values, grades and visual assessment of the CCI (Alkalay et al., 2007)

Value	Grade	Visual assessment
0-2	Very clean	No debris is seen
2-5	Clean	No debris is seen over a large area
5-10	Moderate	A few pieces of debris can be detected
10-20	Dirty	A lot of debris on the shore
20+	Extremely dirty	Most of the beach is covered with plastic

Table 2 Marine debris (area (m^2), density of the debris (Items/m^2), and Clean - Coast Index (CCI), and grade in Thondi coast

Locations	Debris count	Area (m^2)	Density	CCI	Grade
L.1	124	400	0.31	6.2	Moderate
L.2	153	400	0.38	7.65	Moderate
L.3	176	400	0.44	8.8	Moderate
L.4	85	400	0.21	4.25	Clean
L.5	132	400	0.33	6.6	Moderate
L.6	407	400	1.02	20.4	Extremely Dirty
L.7	113	400	0.28	5.65	Moderate
L.8	93	400	0.23	4.65	Clean
L.9	129	400	0.32	6.45	Moderate
L.10	224	400	0.56	11.2	Dirty

Figures

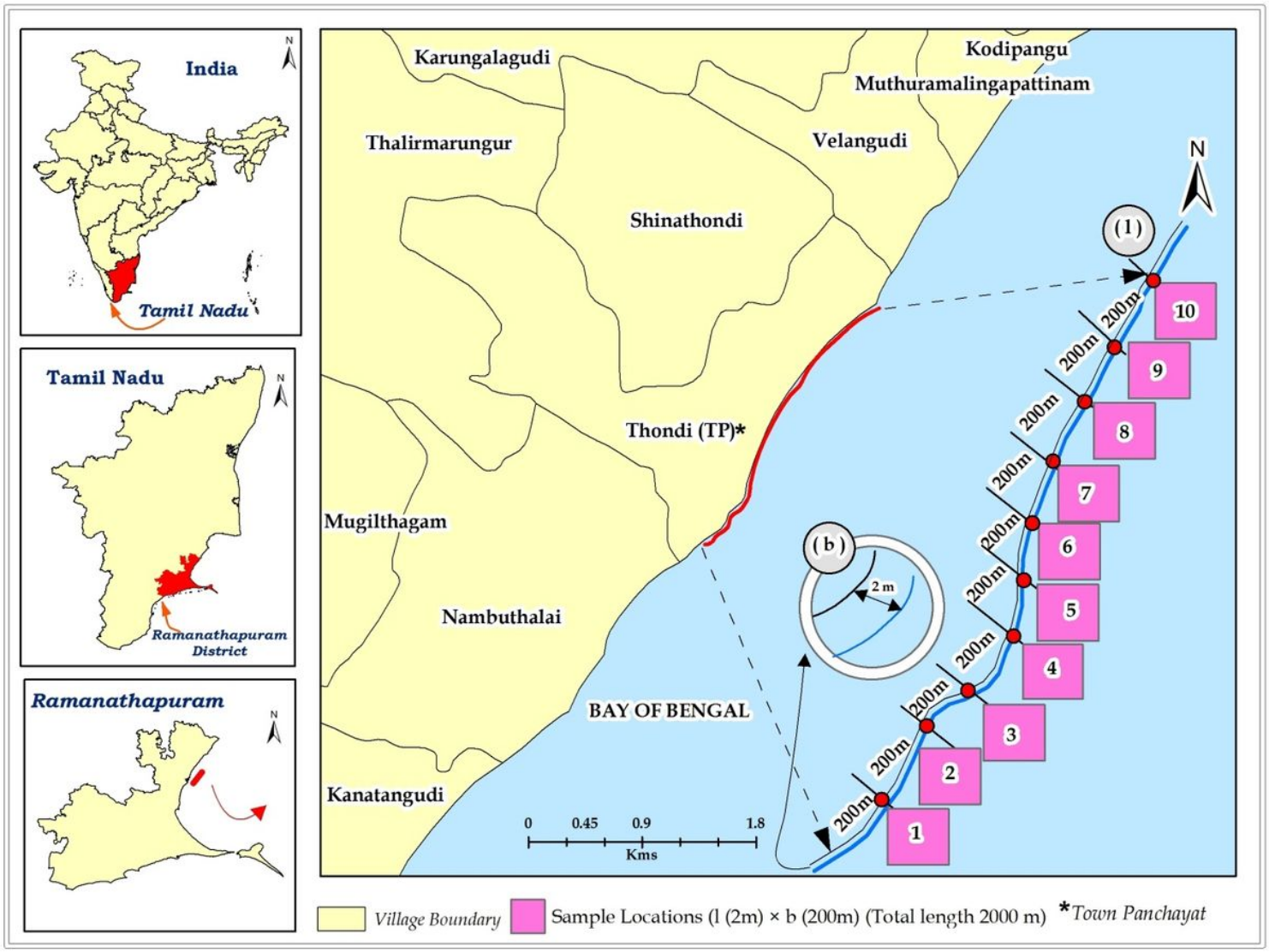

Figure 1

Map of study area and samples collections.

Figure 2

Plastic debris observed on the coast of Thondi: A-C. Plastic bottles, D. Plastic cup E. Fishing nets, and F-H. Plastic bags.

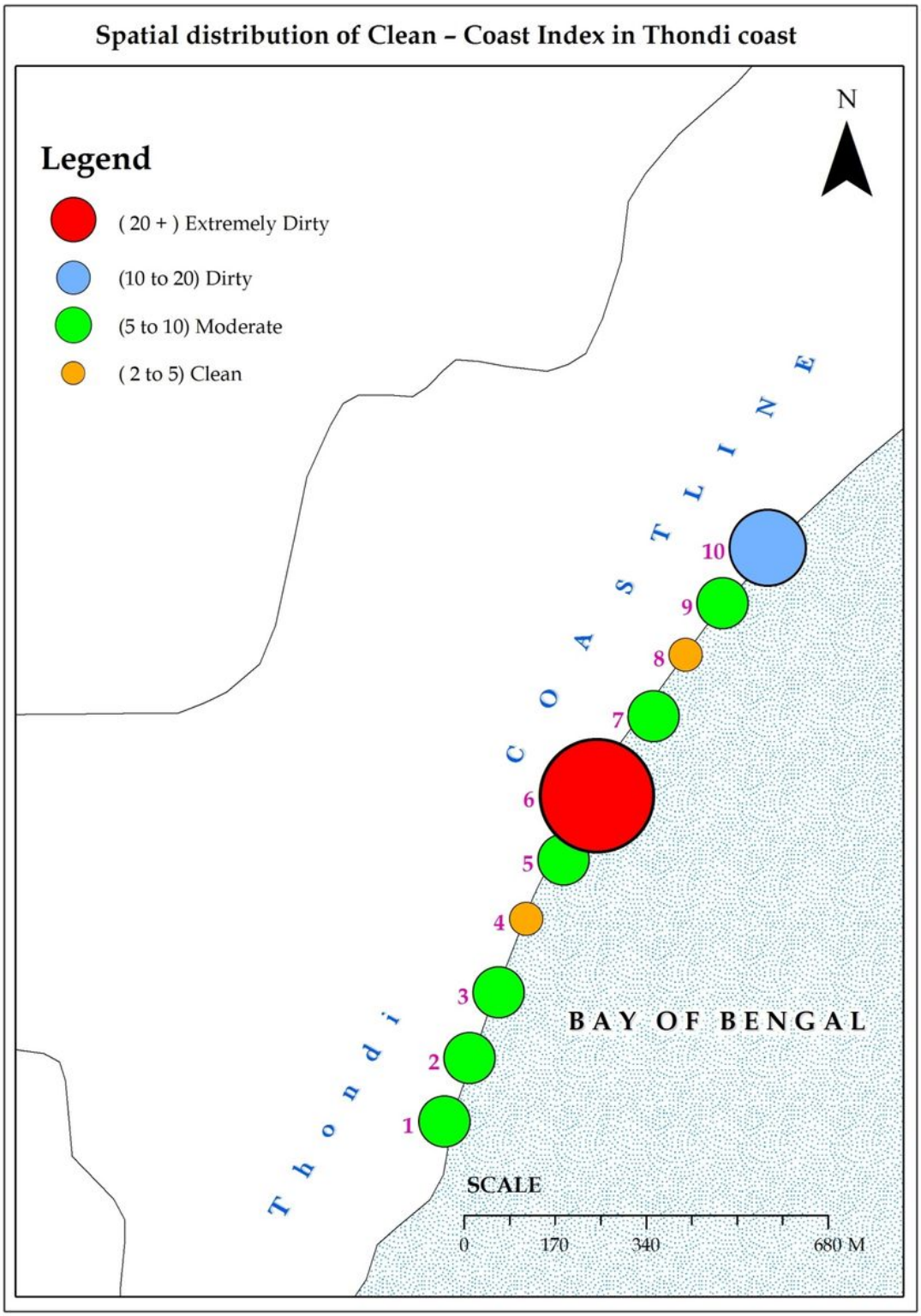

Figure 3

Pollution status of Thondi coast according to the Clean - Coast Index (CCI)

Supplementary Files

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