STATUS OF RESEARCH CAPACITIES AND INFORMATION SYSTEMS ON MARINE PLASTIC LITTER IN INDIA

Norwegian Embassy
New Delhi

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ABBREVIATIONS

AICRP	All India Coordinated Research Projects
AICPML	All India Coordinated Project on Marine Litter
CEE	Centre for Environment Education
C:H:N analysis	Carbon, Hydrogen and Nitrogen Analysis
CIFRI	Central Inland Fisheries Research Institute
CSIR	Council of Scientific & Industrial Research
CSMCRI	Central Salt and Marine Chemicals Research Institute
CUSAT	Cochin University of Science and Technology
EU	European Union
FTIR	Fourier Transform Infrared
GOI	Government of India
ICAR	Indian Council for Agricultural Research
INCOIS	Indian National Center for Ocean Information Services
IR	Infrared
MPPs	Microplastic Pellets
MoEFCC	Ministry of Environment, Forest and Climate Change
MoU	Memorandum of Understanding
MPL	Marine Plastic Litter
NCSCM	National Centre for Sustainable Coastal Management
NGOs	Non-government organisations
PAHs	Polycyclic Aromatic Hydrocarbons
PE	Polyethylene
PP	Polypropylene
SACEP	South Asia Cooperative Environment Programme
SDG	Sustainable Development Goals
SICOM	Society of Integrated Coastal Management
SW	South west
UN	United Nations
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
wPE	Weathered Polyethylene

Executive Summary

India is currently considered the twelfth largest source of marine litter, and is predicted to become the fifth largest by 2025. The country produces nearly 26,000 tonnes of plastic waste every day, making it the fifteenth largest plastic polluter in the world. Studies have shown that a significant portion of this plastic waste is generated on land and ends up in the oceans due to mismanagement. It is estimated that the river Ganges carries the sixth highest amount of plastic debris to the ocean.

To address marine pollution, the Government of India (GOI) has signed a memorandum of understanding (MoU) with the Government of Norway to cooperate on fostering a 'Blue Economy'. A significant component of this is to set up programmes to combat marine plastic litter and microplastics. While lack of a country-wide policy on marine litter has been stated as a challenge, past studies by the United Nations Environment Programme (UNEP) have noted the lack of data on sources and extent of marine litter, along with a lack of effective coordination between institutions and stakeholders, are an immediate impediment.

Through a systematic literature review and stakeholder interviews, this report presents the status of data and research, and the capacities of research institutions on marine plastic litter in India. The literature review was carried out to assess the availability of data on marine litter in four different fates, as recognised under the SDG Target 14.1: on beaches or shorelines (beach litter), floating on the water or in the water column, on the seafloor/seabed, and ingested by biota (e.g., sea birds). Research institutions were surveyed and studied to understand their geographical presence, focus research areas and engagement, and their capacity to conduct research on marine litter.

A key observation of the literature review of 50 scholarly publication and reports is that marine plastic pollution is a growing problem on India's coasts and oceans. Studies indicate that microplastics have entered the food chain and are now found in water, salt, and marine organisms, including fish of commercial importance. Notwithstanding this, there is a notable lack of studies on marine litter, especially on floating debris, on seafloor/seabed and ingested by biota. Existing studies have also not followed standard methodologies or standard units, making any comparison difficult. There is also a need for periodic assessments as some of the data is quite old.

While there is a lack of data on marine litter, there is no dearth of institutions to undertake the research. There are at least 31 research/academic institutions that have worked in the past or have current programs on marine litter. A majority of these institutions are public universities (14) and central government research institutes (13). Among these, sixteen institutes are located on the west coast, 12 on the east coast, and three were located in non-coastal states but have research programs in coastal areas. Tamil Nadu and Kerala host the maximum number of these institutes. Most of the institutions are well equipped with laboratory facilities, and their capacity can be further enhanced to undertake focused research on marine litter.

Key Recommendations

There is a need for an integrated approach to manage the knowledge portfolio of marine litter, including research, awareness-raising, capacity building, and knowledge exchange. There are five major aspects that need specific attention.

1. Research focus: There is large scope to increase the body of knowledge on marine plastics, including plastics/microplastics in beaches and shorelines, seas surface, water column, seafloor (deep and shallow), ingestion by other marine organisms. Large-scale studies to capture the temporal and spatial variation of marine plastic litter are a requirement and need to be carried out across all coastal regions of the country. The top priorities for future research have been identified as:

(1) Litter source evaluation, chemical composition, transportation, and distribution modelling.

(2) Impact of litter on marine food web.

(3) Improvement of instrumentation capacity and advanced techniques for marine litter assessment.

2. Standardising marine litter monitoring protocol: A major challenge faced in this review was the difficulty with comparing the existing data. For example, units for sediments varied between g/ m^2, g/100m, or items/m^2. Following a more standardised scientific monitoring protocol for measuring marine debris is of utmost necessity to understand the source, distribution, abundance, pathway, and impact of debris on a local, national and global scale. In order to compare the debris data in context with local to the global scale, a standard methodology and reporting protocol should be practiced. The Ministry of Earth Sciences and MoEFCC must consider developing research and reporting protocols on marine litter using international guidelines, such as those developed for the SDGs.

3. Building capacity of institutions: It is important to augment the capacities of existing institutions so that they can lend their unique specialisation for studying the issue of plastic litter. Capacity-building among these institutions is required primarily to improve specific instrumentation that can help carry out studies on marine litter. In addition to instrumentation, training in advanced techniques was also stated as a need. There is also a need for consistent funding and a greater workforce to carry out large-scale surveys.

4. All India Coordinated Project on Marine litter: There is a need for an All India Coordinated Project on Marine Litter (AICPML) coordinated by the Marine Litter Cell, Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. The primary goal of the AICPML should be to strengthen the capacity of marine-related institutions, to understand the linkages between the various sources of waste and marine litter and to publish an annual report on the state of Marine Litter on India's coast and exclusive economic zone with special focus on plastic pollution, including microplastics.

5. Knowledge platform for Marine litter: Given the vast amount of data required on marine litter and its detrimental impacts, there is a need for developing a knowledge-sharing platform. One example of this is the MARINA project of the European Union (EU) commissioned in 2016, that was created to "engage citizens, researchers, policymakers, industrial and societal actors in order to share knowledge, include the citizens' vision and societal needs, create a synergy between research and innovation and the environmental safeguard", as underscored by the European Maritime Spatial Planning (MSP) platform, and the European Commission. India can create a similar knowledge-sharing platform to exchange knowledge on:

- Marine plastic litter
- Socio-economic impacts of marine litter pollution
- Ecological and health impacts of marine litter pollution
- Linkages between inland sources and marine pollution
- Mitigation measures
- Pollution control and waste management from sea transportation
- Impacts of tourism and coastal cities on marine litter

CHAPTER 1

Introduction

1.1 Marine litter pollution and global response

Marine litter is a growing global environmental problem with millions of tonnes of litter ending up in the oceans every year across the world. Given the diffused source of litter and its transboundary nature, the problem is extremely difficult to tackle and is increasing becoming a 'crisis', affecting the marine ecosystem, environment, public health, and overall, the economy.

The United Nations Environment Programme (UNEP) defines marine litter as any persistent, manufactured or processed solid material discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds; or discarded or lost at sea.[1] These include, plastics, processed timber, metals, glass, rubber, paper, and textiles (Table 1.1). Among these, plastics (and microplastics)[2] by far have been recognised to be the most significant pollutant accounting for about 80% of all marine debris.[3] It has been estimated that about 4.8 to 12.7 million tonnes of land-based plastic waste end up in the ocean every year. It has been further estimated that under business-as-usual scenario, an additional 33 billion tons of plastic will pile up around the globe by 2050.[4]

Table 1.1: Types of marine litter

Material	Source items
Plastics	Synthetic polymeric materials, including fishing nets, ropes, buoys and other fisheries- related equipment; consumer goods, such as plastic bags, plastic packaging, plastic toys; tampon applicators; nappies; cigarette butts, lighters and cigar tips; microplastic particles.
Metal	Drink cans, aerosol cans, foil wrappers and disposable barbeques
Glass	Bottles, Bulbs
Wood and paper	Processed timber, including pallets, crates and particle boards; cardboards, including cartons, cups and bags
Rubber and Tar balls	Tyres, balloons and gloves
Textiles	clothing, shoes, furnishings and towels

Source: iFOREST (2020); Adapted from: http://www.sacep.org/pdf/Reports-Technical/2018.05-India-Country-Report-for-Prepration-of- Regional-Marine-Litter-Action-Plan-for-South-Asia.pdf

Considering the potential severity of the crisis, the issue of marine litter has been increasingly gaining prominence in global policy platforms. The SDGs as outlined by the United Nations (UN), highlights the significance to 'conserve and sustainably use the oceans, sea, and marine resources for sustainable development' (SDG 14), and has set targets for countries to 'prevent and significantly reduce' marine pollution by 2025 (14.1). In 2016, in the United Nations Environment Assembly (UNEA-2), which focused on 'marine plastic litter and microplastics', countries adopted resolutions on marine litter.[5] In 2018, at the G7 summit, the urgency to reduce plastic pollution in our oceans was recognised, and leaders pledged to step up action on 'healthy oceans, seas, and resilient coastal communities.[6]

1.2 Marine litter pollution in India

India is considered to be the twelfth largest contributor of marine litter, and under business-as-usual is projected to become the fifth largest contributor by 2025.[7] A major source of this is the huge amount of plastic waste that is generated in the country on a daily basis (nearly 26,000 tonnes per day, as per Government of India estimates), and is poorly managed (60% of the generated waste is recycled).

Considering India's share of plastic and marine litter pollution, the country's engagement in tackling this global problem remain critical. Recognising the gravity and urgency of the issue, the Government of India (GOI) has signed a memorandum of understanding (MoU) with the Government of Norway (in 2019) to cooperate on fostering a blue economy. A significant component of this is setting up programmes to combat marine plastic litter and microplastics.

A key aspect that has been highlighted in these collaborations, is the need to develop a pan India policy on marine litter. Such a policy would be instrumental to control and manage the litter within the land boundary, as once it enters the marine environment the complexity and challenge of dealing with the issue is magnified. Besides a national level policy, the need for a country-specific action plan has also been emphasised on by the United Nations Environment Programme (UNEP) and the South Asia Cooperative Environment Programme (SACEP). The agencies in a report published in 2018, highlighted two significant factors that are potential drawbacks for effective policy development and action on marine litter.[8]

First, there is lack of data on the sources and extent of marine litter, and second, there is a lack of effective coordination between institutions and stakeholders. Besides, non-standardization of research methodologies (with respect to collection and measurement of marine litter data), and the lack of a platform for sharing data and information, have also been identified as significant challenges for a systematic evaluation of the problem.[9]

There is also a significant challenge with waste management as mentioned earlier. Given the significant role of land-based plastics in marine litter, better water management practices can contribute significantly to resolving this issue. However, across India, State Governments and local bodies/institutions, are still falling short of establishing reliable collection, treatment, and disposal system for the waste that is generated. The growing trend in production and consumption of plastic waste is adding to this burden, and now has been compounded by the COVID-19 pandemic which has increased the dependence on disposable items. These collectively can be only expected to worsen the problem of marine plastic pollution.

1.3 Focus and Approach

Considering that scientific knowledge and understanding of marine litter is important to precisely approach the problem, both from a policy and technical standpoint, this report has looked into two key questions:

1. What is the current state of knowledge on marine litter in India?

2. What is the institution capacity for research on marine litter in India?

For a comprehensive understanding of these, the report has relied on a systematic literature reviews on research conducted with respect to marine litter, marine pollution, and plastic pollution. Also interviews were conducted with concerned stakeholders to complement the systematic literature review, and to understand the capacity and engagement of institutions on marine litter research *(Box: Approach for a systematic review of research and institutional capacity with respect to marine litter).*

Based on observations of the literature, and stakeholder responses, the report attempts to offer a comprehensive understanding of the status of data, research, and institutional engagement and capacity, with respect to marine plastic litter in India. This report also provides recommendations to advance India's agenda on limiting marine plastic litter.

Box 1: Approach for a systematic review of research and institutional capacity with respect to marine litter

1. Evaluating current state of knowledge: To evaluate the state of knowledge on marine litter, a systematic review of existing literature on marine litter was undertaken. This included scientific and technical reports, and peer reviewed journal articles published between 2003 and 2021, focusing on aspects of marine litter in India. The evaluation included publications focussing on the various types of plastic litter, regional studies that have been undertaken to quantify marine litter, and a review of the methodologies used.

2. Mapping institutions and their capacity: To understand the state of research and institutional capacity, institutions currently working marine litter issues were identified and mapped. The institutions (a total of 31) were selected based on three criteria:

(i) Dedicated department/centre for marine research and coastal management;

(ii) Research program on marine pollution/ marine litter; and,

(iii) Published research papers on marine litter.

A questionnaire was sent to these institutions to collect information on their research, focus and capacity. A total of seven academic and research institutions (25% of the selected institutions) responded to the questionnaire. For the remaining institutions, information was collected from their website, published reports, and telephonic interviews.


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CHAPTER 2

State of Knowledge on Marine Litter in India

2.1 Background

Sustainable Development Goal (SDG) 14, that concerns 'Life below water', sets the aim to conserve and sustainably use the oceans, seas and marine resources for sustainable development. The following indicators of SDG 14 are related to coastal and marine ecosystems:

14.1.1a Index of Coastal Eutrophication (ICEP).

14.1.1b Floating plastic debris density.

14.2.1 Proportion of national exclusive economic zones managed using ecosystem-based approaches.

14.5.1 Coverage of protected areas in relation to marine areas.

The agreed upon SDG indicator for reporting on marine plastic litter is 14.1.1.b- 'floating plastic density'. There are four categories related to this indicator that are used by the Regional Seas Programmes of the UNEP, and other key intergovernmental, international or regional bodies, to monitor the status of marine plastic debris.[10] These include

1. On beaches or shorelines (beach litter)
2. Floating on the water or in the water column
3. On the seafloor/seabed
4. Ingested by biota (e.g. sea birds)

To evaluate the state of knowledge on marine litter in the Indian context, the observations of the literature review has been placed under four categories. Such categorization will also help to build the baseline for evaluating the progress towards the SDG 14.1.1b. One of the critical outcomes of the review, is also to identify aspects of marine litter that may be understudied.

2.2 Systematic literature review on marine litter

As mentioned in Section 1, an extensive review of literature has been undertaken to under that the status of knowledge, and extent of scholarly research on marine litter in India. This section outlines the salient research on this account, and the key findings of the studies, placing the studies under the four categories that are considered for monitoring and reporting against the SDG indicator 14.1.1.b.

2.2.1 On beaches or shorelines

Studies that have quantified marine litter (including identifying most prevalent items) on beaches and shorelines, can be divided into two broad categories, depending on the geographical expanse and location of these studies. These include:

(i) National level studies covering major coastal areas/coastlines; and,

(ii) Regional level studies covering particular coastal states/regions.

(i) National level

An extensive study covering 254 Indian mainland beaches, as well as the Union Territories (UT) of the Andaman & Nicobar Islands, and Lakshadweep was conducted between October 2013 and January 2014. The purpose of this study was to grade beaches based on the amount of beach litter.[11]

The study found that out of 254 beaches, 51 had less than 1g/m^2 of beach litter, while 122 had between 1.1-10 g/m^2 of beach litter.[12] The coast of Odisha had the least quantity of beach litter (0.31 g/m^2). Besides, Kerala and Maharashtra were also observed to have clean beaches (with beach litter averaging <1 g/m^2). On the contrary, the beaches of Goa had the highest beach litter (205.75 g/m^2).[13] The other heavily littered beaches (>100 g/m^2) were found in Karnataka, Gujarat and the Andaman Island.[14]

(ii) Regional level

There are a number of regional studies that have been conducted in states and beaches along the west coast and east coast of India (Map 2.1). The following are some of the most significant studies in this regard.

a. Studies in the west and south-west coast

Gujarat: A study (2021) conducted on Mandvi beach in Gujarat, found that the quantum of plastic litter on the beach on an average was 94.5 g/100m.[15] Some of the most common types of plastic materials were found to be, pouches of tobacco products (gutkha), food wrappers, plastic straws, cutlery, and plastic fragments of various dimensions and thickness, suspected to accumulate from recreational and tourism activities.[16]

Another study (2006), which aimed to assess the accumulation of small plastic debris in the intertidal sediments of the Alang-Sosiya ship-breaking yard in Gujarat, found that plastic fragments generated from ship breaking activities at ship-breaking yard comprised of elements, such as polyurethane, polystyrene, nylon, polyester and glass wool.[17] These small plastic fragments were found to accumulate in the intertidal sediments, and on average 81 mg of small fragments were found in per kg of sediment.[18]

Karnataka: A study (2014) conducted along three beaches of Mangalore, Chitrapur, Tannirbhavi and Panambur, found the concentration of marine litter along these three beaches were 901.5 g/m^2, 689.8 g/m^2 and 83.3 g/m^2, respectively.[19] A major source of this was persistent fishing litter (such as nylon and plastic ropes).[20] The study also suggested that two rivers (Nethravathi and Gurupur), discharging into the marine ecosystem had a significant correlation with respect to their contribution to the marine litter pollution.[21]

Maharashtra: A study (2013) on plastic litter in four major recreational beaches of Mumbai, viz., Juhu, Versova, Aksa and Dadar, observed that on an average the concentration of plastic litter in these beaches was 7.49 g/m^2. Among this, nearly 42% was microplastics.[22] Microplastic pollution was found to be highest in Juhu beach, followed by Versova, Aksa and Dadar.[23] The study also found that over 80% of plastic particles in the litter ranged between 5 - 100 mm in size, and about 67% were coloured plastics.[24]

Goa: A study (2021) focusing on microplastic pollution in the sediments of Goa beaches indicated high concentrations of microplastic particles in the beach sediment, estimated to the tune of 3,950 ± 930 particles per kg.[25]

Another study (2016) that looked into the characterization, seasonal distribution, and surface degradation features of microplastic pellets (MPPs) at six beaches of Goa, found that white-coloured pellets were the most common ones that were found on the beaches. With respect to polymer types of the MPPs, polyethylene and polypropylene were observed to be the most common ones.[26] There was also a clear seasonal pattern with respect to accumulation of MPPs on the coast. It was observed that the pellets were from ocean-based sources, which were driven by the south-west monsoon due to conducive hydrodynamic conditions.[27]

Kerala: A study (2017) on plastic litter in the Calicut and Kochi beaches of Kerala, found the average concentration of plastic litter to be 0.145 g/m^2 and 2.5 g/m^2 respectively, on these beaches.[28] Overall plastic litter pollution in Kerala coasts was observed to be low, with an average estimate of 0.92 g/ m^2.[29]

Another study (2020) that looked into the aspect of fishing related plastic debris in the beaches of Kerala, concluded that plastic constituted about 73.8% of beach litter, making it a major pollutant. There was also a close link between fishing related activities, and plastic debris in the beaches, as well as in the marine system.[30]

Microplastics were also found to be a significant component of marine litter in the coasts of Kerala. A study (2020) that assessed the abundance, distribution and characteristics of microplastics in coastal waters of the state, observed that the abundance of microplastics in the beach sediments were 40.7±33.2 particles/m^2, with higher concentration in the southern coast of the state.[31] It was further observed that urbanisation, river transport, fisheries and tourism activities were a significant cause of such pollution.[32]

b. Studies in the east and south east cost

Tamil Nadu and Andhra pradesh: The greatest number of studies on marine litter in the east coast has been conducted in the state of Tamil Nadu.

A study (2012) on plastic litter pollution on the three beaches- Mandapam and Tuticorin of Tamil Nadu, and Visakhapatnam of Andhra Pradesh, found that on an average the pollution concentration in these three beaches were 7.3 g/m^2, 9.8 g/m^2, and 8.7 g/m^2, respectively.[33]

Another study (2016) conducted on Marina beach in Chennai found a high concentration of plastic litter along the beach, estimated to be 3.24 kg/100m. This was largely due to recreational activities in the area.[34]

An extensive survey (2018) on microplastics in the south-east coast, that included 25 locations along the Tamil Nadu coast, found that beaches that were closer to the river mouth had higher abundance of microplastics, that were just influenced by tourism and fishing activities. With respect to the composition of the marine litter, plastic fragments were found to be predominant (47-50%), followed by line/fibres (24-27%) and foam (10-19%).[35]

Another study (2016) which evaluated that impact of the 2015 flood on the distribution and occurrence on MPPs on the Chennai coast observed that, post flood debris at the Elliot and Thiruvanmiyur beaches were essentially constituted of plastic items, including plastic bags (28.3%), bottle and caps (13.84%), straws (12.83%) and food wrappers (8.97%). It was further observed that waste generated from various land-based sources contributed significantly to beach litter. The highest proportion of this was from residential sources (68%), followed by commercial (16%), offices (14%) and industries (2%). At a more granular level, the flood debris study on the Chennai coast found that PE and PP pellets were the most common type of debris.[36]

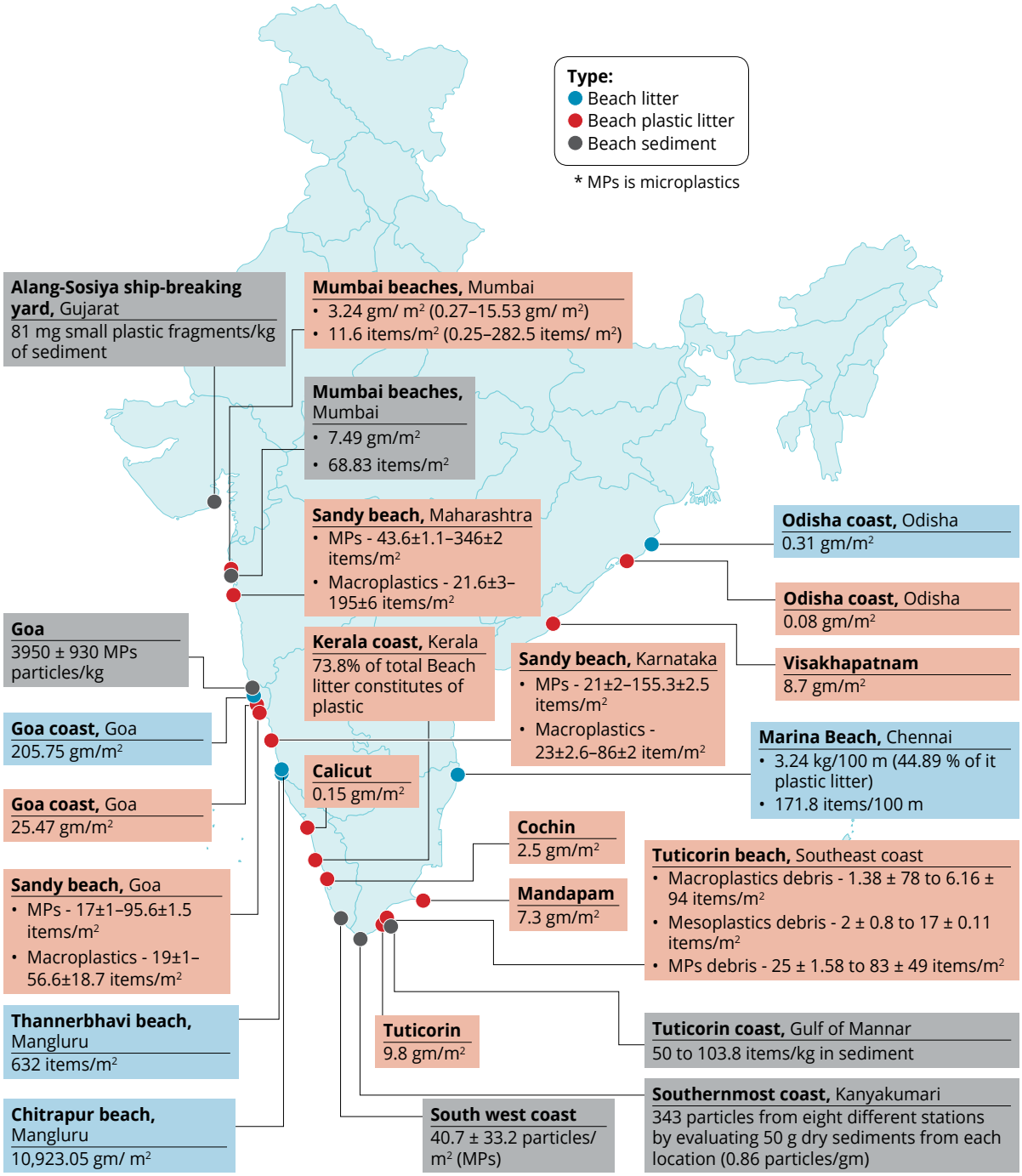
Another significant study was conducted in the southernmost coast of India, Kanyakumari, to estimate the abundance of microplastics in beach sediments. The study which covered eight monitoring stations, found that the tourist beaches had the highest concentration of microplastics (150 particles/50g dry sediment), followed by the harbors (99 particles/50g dry sediment). Fibers were the most abundant form of microplastic particles found in the area.[37]

A study (2020) conducted along eight beaches of Tuticorin coastline quantified the concentrations of macro, meso, and microplastic debris in the beach sediment. The mean concentrations of macro-plastic were found to range between 1.38 ± 78 to 6.16 ± 94 items/m^2, of meso-plastic between 2 ± 0.8 to 17 ± 0.11 items/m^2, and for microplastic between 25 ± 1.58 to 83 ± 49 items/m^2.[38]

Gulf of Mannar: A study (2018) on coastal debris in Nallathanni island (Gulf of Mannar), showed significant amount of microplastic pollution in the debris, the predominant ones being polyethylene, bottles and fibrous fishnet materials.[39]

Similarly, a study on marine litter (2011) in the the northern part of Gulf of Mannar found that, the litter consisted of three major items - plastics (48%), polystyrene (18%) and cloth (15%).[40]

Map 2.1: Marine plastic litter on beaches or shorelines



Source: iFOREST (2020)

Some of the key inferences that can be drawn based on the studies available on beach and shoreline litter include:

- All India studies are limited in number. The extensive survey by Kaladharan et al (2017) along the Indian coastline, is now old and may not be representative of current reality, wherein the use of plastic has increased.
- Most studies have been done at different time period and with different regional focus.
- There are a greater number of data points and studies along the western coast than the eastern coast.

- The plastic litter along the beaches of the western coast are significantly higher than those along the east coast.
- Tourism and recreational activities were commonly indicated to be the major source of plastic litter.
- Studies with focus on limiting/better managing marine plastic litter have emphasised on the need for adoption and implementation of plastic waste management rules through modernising the management systems and applying better enforcement mechanisms.[41, 42]
- Finally, even among the studies available, comparison is difficult due to lack of standardisation in units.

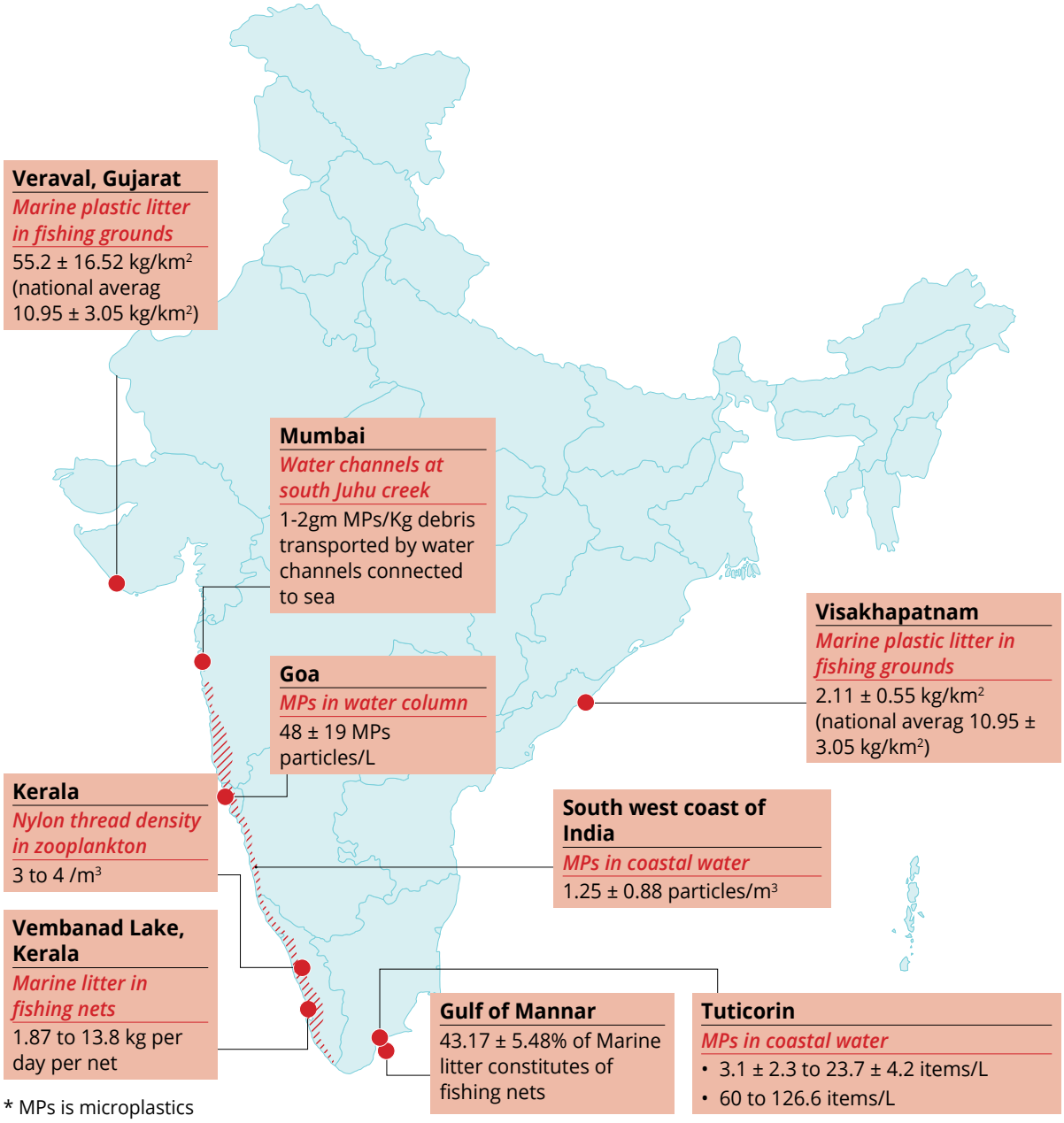
2.2.2 Floating on the water or in the water column

In addition to litter along the beaches and shorelines, floating plastics in the ocean or sea are common occurrences. So far, there is a paucity of extensive survey on floating plastic debris, or marine plastic litter (MPL) along the coasts of India. However, data from regional studies may provide some insight into the scale of the problem (Map 2.2).

- A study (2002) in Greater Nicobar established that the plastic debris found in the marine environment was not of local origin. The source of origin was observed to be improper handling of solid waste from fishing and mariculture activities, and ship traffic.[43]
- Some studies have also been undertaken in the marine environment of the east and west coasts to quantify plastic litter in the marine environment, as well as to understand the most prevalent form of items that contribute towards it.
- A survey (2020) in fishing grounds of Veraval, Gujarat found 55.2 ± 16.52 kg/km^2 of MPL in the trawl site.[44] The same study found MPL quantities to be 2.11±0.55 kg/km^2 in the trawl grounds of Visakhapatnam, and estimated the national average of be 10.95 ± 3.05 kg/km^2.[45]
- A few studies in Kerala also provide a quantitative understanding of MPL. Data from stake nets (used for catching shrimp) in Vembanad lake in the state, suggested litter quantities to range between 1.87 to 13.8 kg per day per net.[46] Analysis of zooplankton samples along the Kerala coast of Kerala showed nylon threads occurred at densities of 3 to 4 per m^3.[47] Another study undertaken to assess microplastics in various coastal environmental matrices in the southwest coast of India, found the presence of 1.25 ± 0.88 particles/m^3 of microplastics in the coastal water of Kerala.[48]
- A study quantifying MPL in the Gulf of Mannar estimated that 43.17 ± 5.48% of the marine litter consisted of fishing nets.[49] Another study on marine litter in the water column in Goa Sal estuary estimated 48 ± 19 microplastic particles per liter of coastal water.[50] Further, in water channels along the south Juhu creek, substantial quantities of plastic debris was transported into the sea, indicating that water channels connected to the sea mostly transport macro- and mega plastic, which may disintegrate to form microplastic in due course of time.[51] Another study undertaken in the Tuticorin coast found microplastic accumulation of 3.1 ± 2.3 to 23.7 ± 4.2 items L−1 in the coastal water.[52]
- The microplastic concentration in coral reefs ecosystem in Tuticorin coast was found to be 60 to 126.6 items/L in water and from 50 to 103.8 items/kg in sediment. Another study with data from Tinnakra island (west coast) and Chennai (east coast), found white and yellow plastic pellets to be the most common type of marine plastic litter.[53] The number of pellets found in Tinnakkara island (603) was three-fold higher than those on Chennai coast (201), though the former is located in the relatively remote oceanic location with no plastic manufacturing. Thus, the international tanker route ship accident and/or unintentional release and deposited by hydrodynamics were postulated to have resulted in it.[54]
- A qualitative study in Chilika lake, Odisha, stated the prevalence of plastics in the water body an issue not only to the Olive Ridley population but also a serious contributor to toxic compounds being consumed by birds and fish.[55]

Overall, the number of studies to estimate marine debris floating on the water or in the water column is rather limited. Fishing nets seem to be a major component of floating debris.

Map 2.2: Marine plastic litter floating on the water or in the water column



* MPs is microplastics

Source: iFOREST (2020)

2.2.3 On the seafloor/seabed

There are very few studies on plastic litter accumulation on the seafloor. The limited literature available offer some fragmented understanding in this regard, and does not provide substantial scope to make firm conclusions regarding the marine litter on the seafloor/seabed (Map 2.3).

A review (2017) on marine litter suggested that Polyethylene (PE) and Polypropylene (PP), are primarily the most used plastic raw material. The study also suggested that deep sea is a substantial sink for microplastics, and there is a need to undertake studies to confirm long-term fate of microplastics in the deep sea.[56]

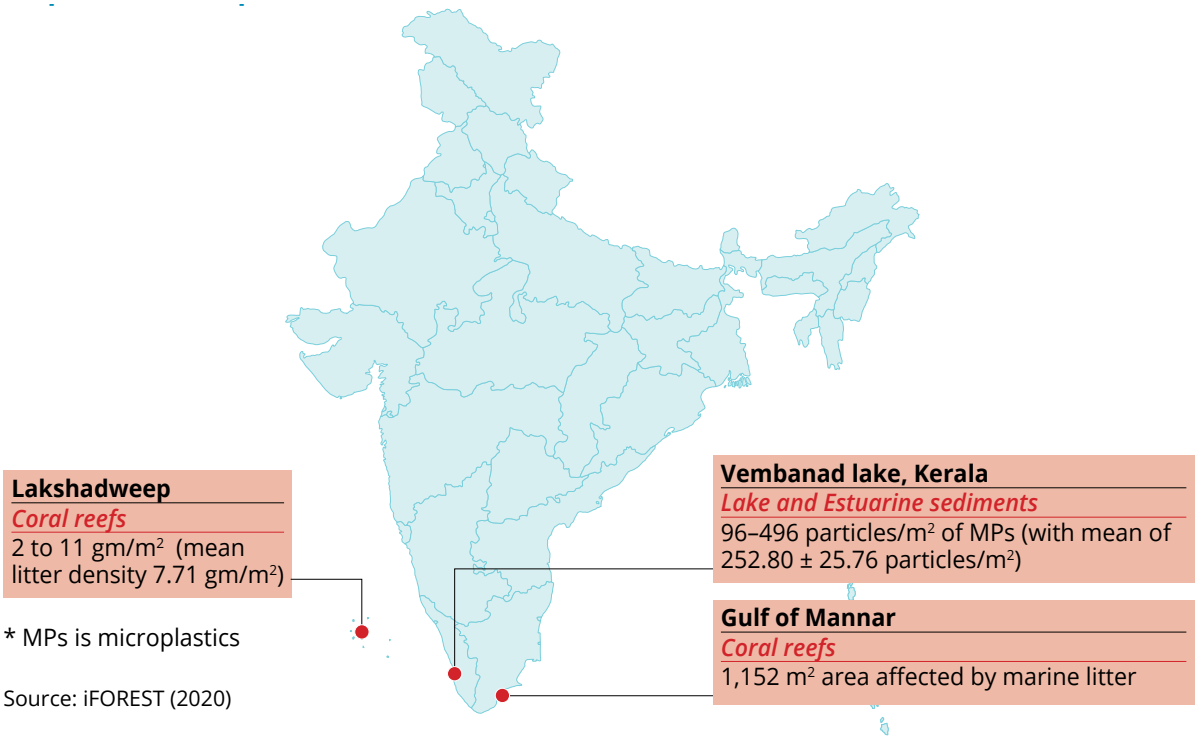
With respect to quantification of plastic litter on the sea floor/seabed, a study (2020) concerning coral reefs of Gulf of Mannar estimated that about 1152 m² of reef area was affected by marine debris.[57] A chief pollutant here was found to be abandoned fishing nets, constituting close to 50%

of the marine debris in this area. While live corals were found to be a common substrate for marine debris (39.11%), but a significant proportion of them were found to be affected in contact with debris, suffering from fragmentation (47.56%) and tissue loss (34%).[58]

Another study undertaken on plastic litter in the coral reefs of Lakshadweep, found the abundance of litter to be 7.71 g/m^2 in this ecosystem. In the Vembanad lake ecosystem, the abundance of microplastics in sediments from the lake bed was found to be 96–496 particles/m^2 (with a mean of 252.80 ± 25.76 particles/m^2).[59]

The corals and seagrass beds in Rameswaram[60] as well as the coral reefs in Tuticorin[61] showed the accumulation of microplastics can be largely attributed to human activities in the region.

Map 2.3: Marine plastic litter on sea floor/sea bed



* MPs is microplastics

Source: iFOREST (2020)

2.2.4 Ingested by biota

Scientific studies on the presence of plastics and microplastics in aquatic life, were reviewed to understand the extent of this issue (Map 2.4).

A gut analysis of commercially important fish along the south-eastern coast of India (Tamil Nadu) found that 10.1% of fish had ingested microplastics.[62] The samples further revealed that these were secondary microplastics of which 48% and 24% were fragments and fibers, respectively.[63] Similarly, edible oysters, clams, and epipelagic and mesopelagic fish collected along the Tuticorin coast had 0.81microplastic items/g of tissue,[64] 0.6 to 1.3 items/g of wet weight[65], and 0.11 ± 0.06 to 3.64 ± 1.7 items/individual[66] microplastics respectively.

Another study which evaluated the presence of microplastics in the salt of Tuticorin, revealed that on an average people consume approximately 216 particles of microplastics per year via sea salt, and 48 items per year via bore-well salt, if on an average, the daily salt intake of the person is 5 g.[67] The study further estimated the presence of 35 ± 15 to 72 ± 40 microplastic items/kg in sea salt, and 2 ± 1 to 29 ± 11 items/kg in bore-well salt obtained from the Tuticorin coast.[68]

A laboratory study on the green mussels found along the Chennai coast found that while the presence of weathered PE in the organism did not pose a mortality risk, it did show accumulation in the intestines with possible impact on the internal organs, growth and reproduction.[69]

A study on benthic fauna (Sternaspis scutata) in Kochi, revealed that the samples contained Polystyrene microplastic particles and thread-like fibres.[70] Organisms found in the Sal Estuary, Goa were found to contain microplastics in the following quantities: 4 ± 2 (Crassostrea sp.), 3.2 ± 1.8 (Perna viridis) and 0.7 ± 0.3 (Paphia malbarica) microplastics/g body weight.[71] The guts of oilsardine and mackerel captured in Mangalore coast contained nylon ropes of length 1mm and 4mm respectively.[72]

While a majority of studies focused on microplastics, a study (2014) along the Saurashtra coast of Gujarat, revealed the presence of four thick plastic sheets (shopping bags) inside a Longman's Beaked Whale. These sheets blocked the passage of food to the intestine of the species.[73]

Overall, there are several studies establishing that plastics and microplastics ingestion by marine organism is a growing problem in the country. However, microplastics in inland waterbodies is an equally major problem (Box: Microplastics in inland water). Also, the impact of microplastic ingestion by human beings is an important issue to study, as sea food constitutes a significant portion of the diet in the coastal areas.

Box 2: Microplastics in inland water

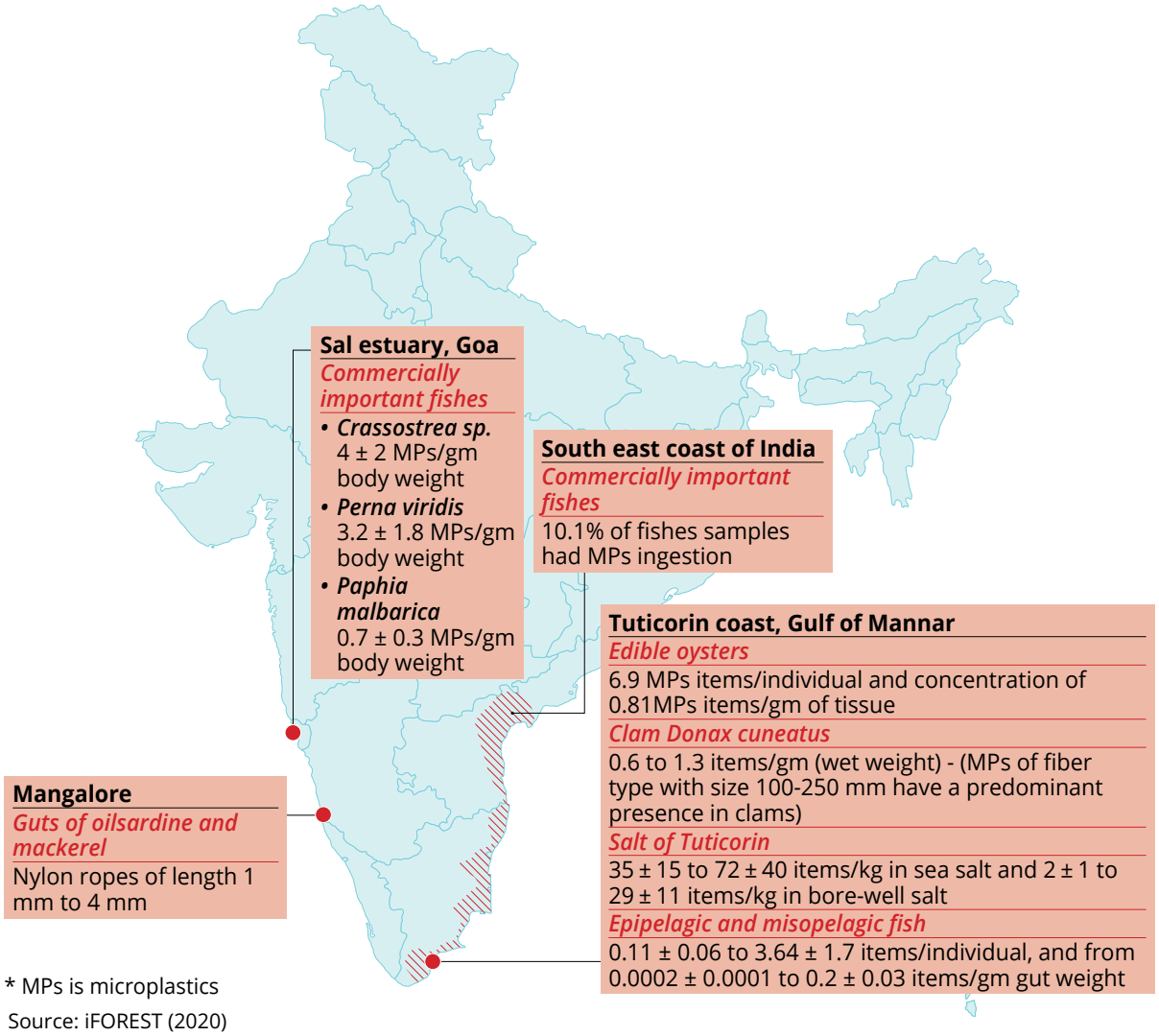

istockphoto.com

There are few studies that indicate that plastic and microplastic pollution of inland water is an equally major problem.

A study on the spatial distribution of plastics including microplastics in the sediments of river Ganga sat at lower stretch showed that in the lower stretch of river Ganga, the abundance of meso and microplastics is found to be at the lower side as compared to the other rivers of the world. However, a high abundance of plastic debris was found in few sites of Ganga (Buxar, Patna and Barrackpore) owing to direct inflow of plastic debris in the river through sewage whereas the abundance in the estuarine sites can be attributed to the plastic waste generated due to impaired fishing gears and accumulation of plastics due to tidal flux. The study also implies that plastic debris abundance in the selected sites of the river Ganga is associated with anthropogenic activity with a significant correlation of sediment and water pollution parameters with an abundance of plastic debris. The study indicates that the river Ganga is at risk from plastic pollution and requires more attention.[74]

Another study investigated the distribution of microplastics in East Kolkata wetlands which is considered to be the world's largest natural waste water treatment plant. The abundance of microplastics in the different treatment ponds of east Kolkata wetland was analysed and further microplastics contamination in the native treatment pond biota like fin fishes and macroinvertebrates was established. This provides insight on the role of wastewater canals in mediating microplastics transportation to East Kolkata Wetland, a natural wastewater treatment wetland system, ultimately providing cognizance on microplastics contamination of ecologically important wetland systems.[75]

Map 2.4: Marine plastic litter ingested by biota



* MPs is microplastics

Source: iFOREST (2020)

Based on the analysis of the scholarly studies (50) on marine and beach litter in India, the following can be broadly concluded:

1. The studies currently available have provided a vast reserve of quantitative data and some qualitative data, which indicate that marine litter is a growing problem on India's coast and seas. It also has implications for human health, as microplastics are being detected in considerable amounts in water, salt and fishes.
2. Most of the research is confined to studies of marine litter on beaches/coastal areas, and ingestion by biota. Studies on floating debris and debris on seafloor is limited.
3. Units used to report litter quantities are often not standardised, which makes comparison difficult. Units for sediments varied between g/m^2, g/100m or items/m^2. Some studies on microplastics also used units such as particles or items per L or m^3 of the sample. Moreover, standardization is not only essential for units, but also for research methodology and process, and materials used.
4. Several studies were done between 2010 and 2020, however, with rapid increase in plastic use across India, the data on marine plastic litter also needs to be updated. While general understanding on the scale of the issue exists, here is both a need for latest data on marine and beach litter, as well as analysis on the sources and polymer types commonly found.

CHAPTER 3

Research Capacity on Marine Litter

3.1 Background

Having adequate research capacity, including infrastructure to support scientific research, is an essential component for building on scientific knowledge on marine litter and marine pollution. A comprehensive knowledge base is also a key factor for developing evidence-based policy, that is crucial to tackle the problem of marine litter effectively.

To assess the research capacity in India on marine litter, institutions conducting research on any aspect of the issue were identified for this study. Institutions that met at least one of the following three criteria were selected for the assessment. These included institutions that have:

(i) Dedicated department/centre for marine research and coastal management;

(ii) Research programme on marine pollution/ marine litter; and,

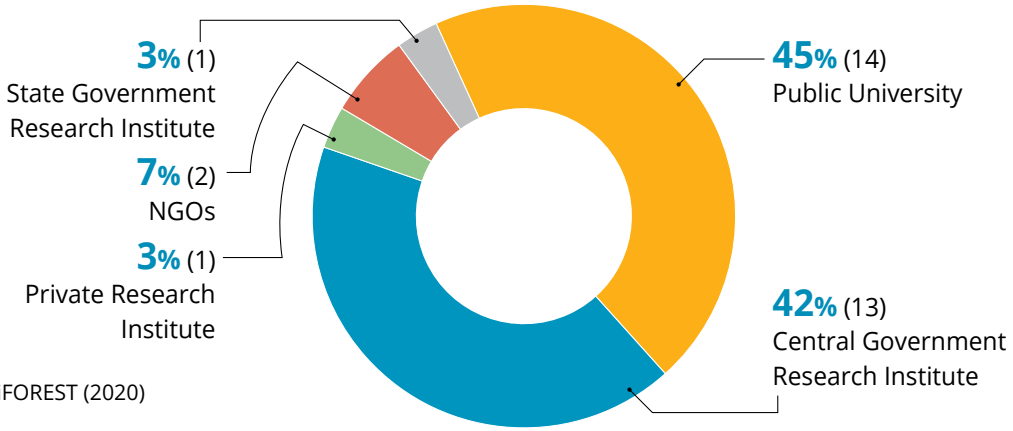
(iii) Scholarly publications on marine litter.

Based on the above criteria, 28 research/academic institutions[76] were identified. Additionally, three other institutes were short-listed, based on their work on policy, awareness and capacity building on marine litter.

3.2 Assessment of research capacity

The assessment of research capacity on marine litter showed that, institutions that are currently involved in marine litter/marine pollution research are public (Government) universities (14), and Central Government research institutions (13). The engagement of private, or State Government supported research institutes are a minimal (Figure 3.1). The two non-governmental organizations (NGOs) working on the issue are primarily engaged in awareness raising and capacity building.

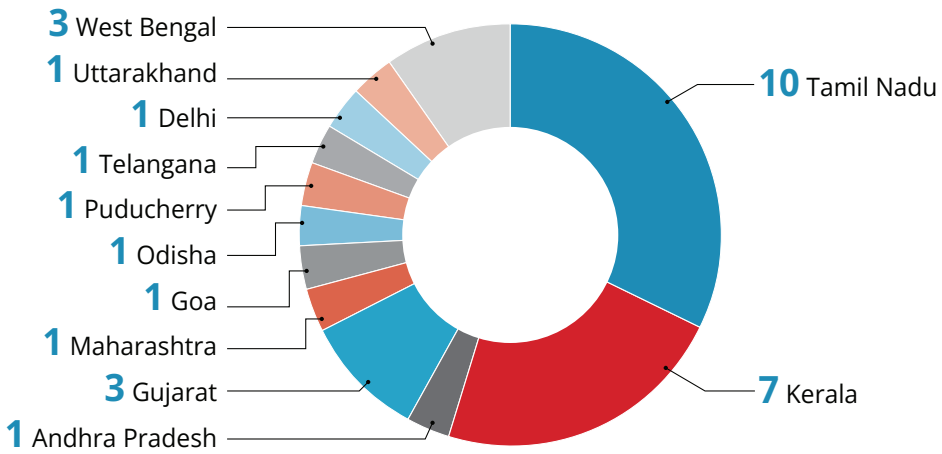
Figure 3.1: Key institutions on marine litter in India



Source: iFOREST (2020)

With respect to location, most of the institutions are concentrated in the coastal states, which evidently is conducive for sampling and scientific analysis (Map 3.1). Tamil Nadu (10) and Kerala (7) have the maximum number of research institutions. Overall, 16 institutes are located on the west coast, 12 on the east coast, and three in non-coastal states with research programmes in coastal areas (Figure 3.2).

Figure 3.2: State-wise distribution of institutions

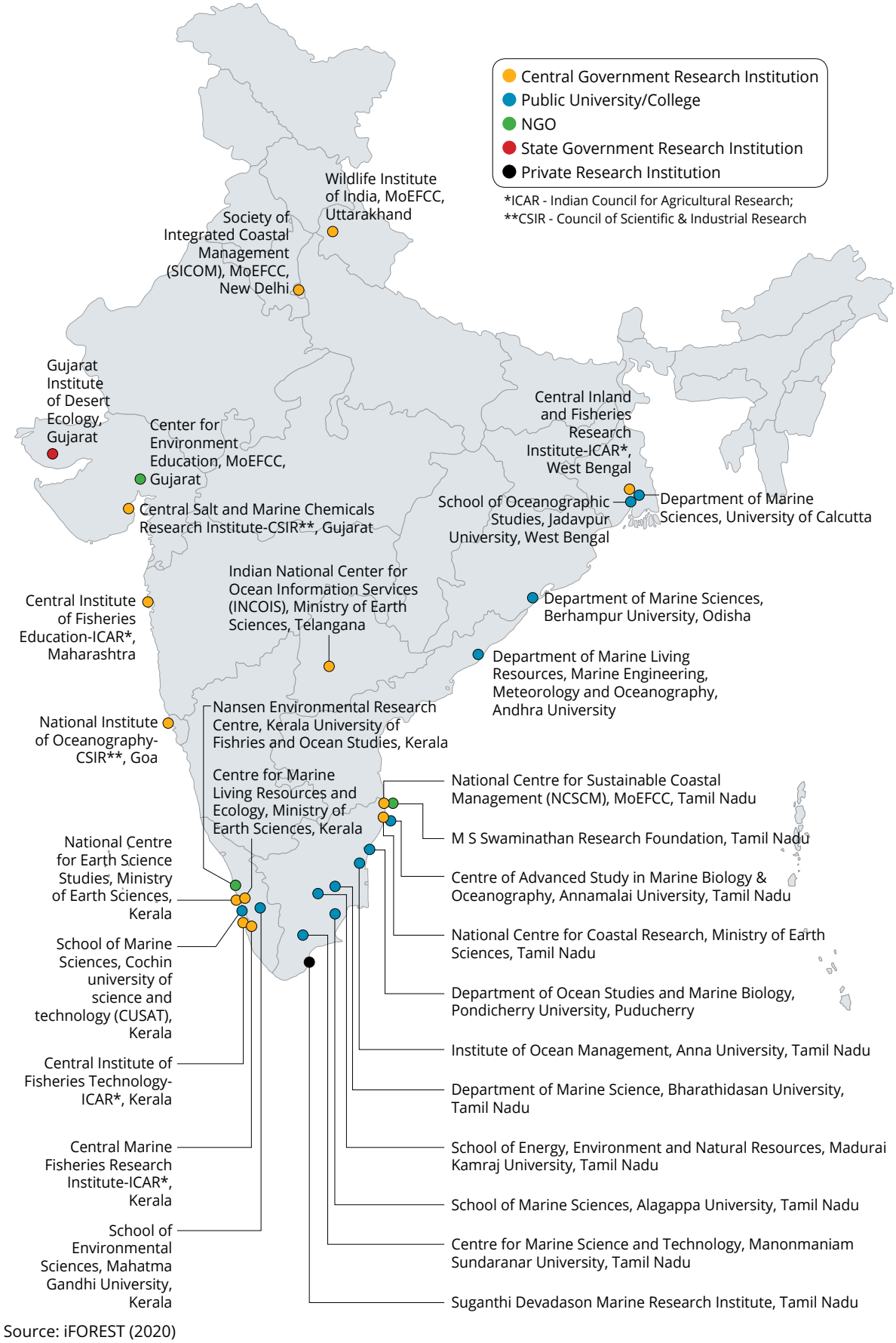


Source: iFOREST (2020)

The engagement of these institutions on marine litter/marine pollutions is primarily related to their affiliation. The universities are engaged in the capacity of both research and teaching, while the Central Government research institutions are mostly committed to research. Institutions, such as Centre for Environment Education (CEE), M S Swaminathan Research Foundation (MSSRF) and Society of Integrated Coastal Management, established by the Ministry of Environment, Forest & Climate Change (MoEFCC) are involved in capacity building (Table 3.1).

All the research and teaching institutions are well-equipped with research facilities (such as scientific laboratory) for marine litter studies (see Table 3.2).

Map 3.1: Key institutions engaged in marine litter and pollution research



Source: iFOREST (2020)

Table 3.1: Key activities, specialization and regional distribution of institutions

Institution	Department	Key Activities	Specialization	Location
Berhampur University	Department of Marine Sciences	Research and Teaching in Marine Sciences	Coastal water quality and coastal biodiversity	Odisha
Central Marine Fisheries Research Institute - ICAR*	Fishery Environment and Management Division	Research in Marine Sciences	Marine plastic litter quantification and assessment studies	Kerala
Central Inland and Fisheries Research Institute - ICAR*	Aquatic Environmental Biotechnology and Nanotechnology Division; Riverine and Estuarine Fisheries Division; Fisheries Resource Assessment and Informatics	Research on plastic pollution in inland freshwater	Plastic litter in inland freshwater, marine sediments, estuaries; Microplastics contamination in aquatic biota including fresh water fishes of commercial importance	West Bengal
Central Institute of Fisheries Education - ICAR*	Fishery Environment and Management Division	Research and Teaching of Fishery Science	Marine litter; Fisheries management, culture, health and nutrition	Maharashtra (Regional centres in Kolkata, Kakinada, Powerkheda, Rohtak, Motipur)
National Centre for Coastal Research, Ministry of Earth Sciences	Marine Litter and Microplastics Group	Research on coastal ecosystem	Marine plastic litter quantification and assessment studies	Tamil Nadu
Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences	Centre for Marine Living Resources and Ecology	Research in marine sciences	Deep sea marine living resources	Kerala
National Centre for Sustainable Coastal Management (NCSCM), Ministry of Environment, Forest and Climate Change		Research on coastal ecosystem	Marine plastic litter quantification and assessment studies	Tamil Nadu
National Institute of Oceanography - CSIR**	Chemical Oceanography Division	Research in Marine sciences	Marine plastic litter quantification and assessment studies	Goa
Pondicherry University	Department of Ocean Studies and Marine Biology	Research and Teaching of Marine sciences	Marine biology	Pondicherry
School of Marine Sciences, Cochin university of science and technology (CUSAT)	Chemical Oceanography Division; School of Industrial Fisheries	Research and Teaching of Marine sciences	Marine chemistry	Kerala
Suganthi Devadason Marine Research Institute	Division of Marine Pollution and Management	Research and Teaching of Marine sciences	Marine plastic litter quantification and assessment studies	Tamil Nadu

Institution	Department	Key Activities	Specialization	Location
Central Institute of Fisheries Technology - ICAR*	Central Institute of Fisheries Technology. Regional centres in Visakhapatnam, Mumbai and Veraval	Research on fishery science	Fisheries food science and technology	Kerala
Alagappa University, Karaikudi, Tamil Nadu, India	Department of Oceanography and Coastal Area Studies, School of Marine Sciences	Research and teaching in Marine sciences	Marine plastic litter quantification and assessment studies	Tamil Nadu
Indian National Center for Ocean Information Services (INCOIS), Ministry of Earth Sciences		Ocean information and advisory services	Research on ocean & climate modelling	Telengna
Nansen Environmental Research Centre (India)	Research Centre of Kerala University of Fisheries and Ocean Studies	Research on coastal ecosystem	Marine plastic litter quantification and assessment studies	Kerala
Jadavpur University	School of Oceanographic Studies	Research and teaching in marine sciences	Plastic litter quantification and assessment studies in estuaries	West Bengal
Annamalai University	Centre of Advanced Study in Marine Biology & Oceanography; Faculty of Marine Sciences	Research and teaching on coastal ecosystem	Marine biology and oceanography	Tamil Nadu
Manonmaniam Sundaranar University	Centre for Marine Science and Technology	Research and teaching on fishery science	Marine biotechnology, marine science, coastal aquaculture, microbiology	Tamil Nadu
Central Salt and Marine Chemicals Research Institute (CSMCRI) - CSIR**		Research in marine sciences	Plastic leakage into marine ecosystems and impact on salt production	Gujarat
Society of Integrated Coastal Management (SICOM), MoEFCC		Policy and Research on marine protection	Pollution abatement, management, and eco-tourism Infrastructure development.	New Delhi
University of Calcutta	Marine Sciences	Research and teaching on marine science	Marine biogeochemistry	West Bengal

Institution	Department	Key Activities	Specialization	Location
Andhra University	Department of Marine Living Resources; Marine Engineering; Meteorology and Oceanography	Research and teaching on marine science	Marine science and technology	Andhra Pradesh
Anna University	Institute of Ocean Management; Department of Geology	Research and teaching on marine science	Toxic contaminants and excessive levels of nutrients are released into coastal waters	Tamil Nadu
M S Swaminathan Research Foundation	Coastal System Research Programme	Capacity building and research on coastal ecosystem	Marine litter awareness and capacity building	Tamil Nadu
National Centre for Earth Science Studies, Ministry of Earth Sciences		Research in marine sciences	Biogeochemical studies of water environs including estuarine, coastal, springs and fresh waters in mainland/ island systems with emphasis on solute fluxes/ dynamics and speciation, pesticide/organics fragmentation and degradation, water quality monitoring, pollution assessment and mitigation strategies.	Kerala
Center for Environment Education	Coastal and Marine Programmes	Awareness on coastal ecosystem	Climate literacy and marine litter management, coastal biodiversity conservation studies, coastal samvaads - Marine Interpretation Programmes, Marine Camps etc.	Gujarat
Gujarat Institute of Desert Ecology	Coastal and Marine Ecology Division	Research on Coastal ecosystems	Coastal monitoring, mangrove restoration ecology marine impact assessment studies	Gujarat
Wildlife Institute of India, Ministry of Environment, Forest, and Climate Change		Research and teaching on Coastal ecosystems	Marine plastic quantification in sea sediment	Uttarakhand
Bharathidasan University	Department of Marine Science	Research and teaching on Coastal ecosystems	GIS and remote sensing, coastal ecosystem monitoring	Tamil Nadu

Institution	Department	Key Activities	Specialization	Location
Madurai Kamaraj University	Department of Marine and Coastal Studies, School of Energy, Environment and Natural Resources	Research and teaching in general sciences with some projects on coastal ecosystems	Interdisciplinary sciences	Tamil Nadu
Mahatma Gandhi University	School of Environmental Sciences	Research and teaching in general sciences with some projects on coastal ecosystems	Interdisciplinary sciences	Kerala

Source: iFOREST (2020); *Indian Council for Agricultural Research; **Council of Scientific & Industrial Research

Table 3.2: Research infrastructure at key institutions

Institution	Infrastructure	Remarks
Berhampur University	Laboratory	Laboratory facilities for Marine biology, Fisheries, Marine chemistry, Marine Geology, Physical Oceanography & Meteorology and Remote sensing
Central Marine Fisheries Research Institute - ICAR*	Laboratory	Raman spectroscopy; Plastic litter identification based on color, size and composition; Density separation; Chemical digestion of organic matter, filter and dry to observe microplastics; Visual inspection with naked eye or microscope
Central Inland and Fisheries Research Institute - ICAR*	Laboratory	IR/FTIR spectroscopy; Density separation; Chemical digestion of organic matter, filter and dry to observe microplastics; Visual inspection with naked eye or microscope; Nile red staining - fluorescence microscope
Central Institute of Fisheries Education - ICAR*	Laboratories, Field facilities, Research vessels	All equipments to measure plastic litter. Field Centres and Farm Facilities (Kolkata (West Bengal), Kakinada (Andhra Pradesh), Powerkheda (Madhya Pradesh) and Rohtak (Haryana)); Two fishing vessels namely MFV Saraswati (OAL-36m) and MFV Narmada (OAL-11m); Laboratory facilities.
National Centre for Coastal Research, Ministry of Earth Sciences	Laboratory and field equipment	Total Organic Carbon Analyzer; UIC Coulometer; CHNS Analyzer; Spectrophotometer; Spectrofluorometer; Particle Size Analyser; Alpha Linear Laminar Flow Cabinet; Stereo microscope; Sieve Shaker; AutoAnalyzer; Gel Imager; Rotary microtome; Microplate Reader; Upright microscope; Centrifuge; Fluorescence spectrophotometer. Field equipment - Trimble® R10 GNSS RTK System; Wave Rider Buoy; CTD Profiler; Valeport Waves & Tide Recorders; RADAR Tide Gauges; Aanderra Current Meters; Nortek Current Meters; Sontek, ADP, RDI ADCP, Sontek ADV Profilers; Single Beam Echo Sounders
Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences	Laboratories and Research vessel	Fishery Oceanographic Research Vessel (FORV) Sagar Sampada with the following facilities: Hydrographic Laboratory; Acoustic Room; Fishery Research Facilities; Plankton Research Facilities; Microbiology Lab

Institution	Infrastructure	Remarks
National Centre for Sustainable Coastal Management (NCSCM), Ministry of Environment, Forest and Climate Change	Laboratories and field equipment	Advanced instrumentation lab, wet chemistry, field instruments, pesticide and ecotoxicology lab etc.
National Institute of Oceanography - CSIR**	Laboratory	Spectroscopy, NMR, X-ray based analysis, Mass spectrometry, Chromatography, Organic elemental analysis
Pondicherry University	Laboratory	Automated weather station, BOD incubator, CHN analyzer, Current meter, Deep sea fluorometer, Ecosounder, GEL Electrophoresis, GELDOC, HPLC, Hydrolab, Microscopes with image analyser, Organic element analyser, Plankton nets & Flow meter, PCR, Rotary evaporator, TOC analyzer, SCUBA, UV spectrophotometer
School of Marine Sciences, Cochin university of science and technology (CUSAT)	Laboratory	Dry and wet laboratories - UV-VIS spectrophotometer, Gas chromatography, Rotary evaporator, Freeze dryer, Atomic Absorption Spectrophotometer, FT-IR among others
Suganthi Devadason Marine Research Institute	Laboratory	Density Separation with Subsequent C:H:N Analysis; IR/FTIR spectroscopy; Plastic litter identification based on color, size and composition; density separation; Chemical digestion of organic matter, filter and dry to observe microplastics; Visual inspection with naked eye or microscope; Scanning electron microscope/ energy dispersive X-ray spectrometer; X-ray fluorescence spectrometry
Central Institute of Fisheries Technology - ICAR*	Laboratory and research vessel	Gas Chromatography: HeadSpace Sampler, FID, ECD and MS; High Performance Liquid Chromatography (HPLC): FLD, DAD and UV-vis; Preparative HPLC; Atomic Absorption Spectroscopy (AAS); Flame photometer; ELISA Reader and Western Blotting Unit; Supercritical; Fluid Extraction Unit; Spectrophotometer; Refrigerated Centrifuge; Electrophoresis apparatus and gel imaging system; Iatroscan; Research vessels in Cochin, Veraval and Visakhapatnam
Alagappa University, Karaikudi, Tamil Nadu, India	Laboratory	Atomic Force Microscope;Micro-Laser Raman, Powder X-Ray Diffractometer; FE-SEM with EDAX;MALDI TOF-TOF Spectrometer; Confocal Microscope-LSM 710; JEOL-2100+ High Resolution Transmission Electron Microscope; PHI - VERSAPROBE III – X-ray Photoelectron Spectroscopy; Solar Cell Simulator; CHNS/O Elemental Analyser
Indian National Center for Ocean Information Services (INCOIS), Ministry of Earth Sciences	Laboratory	Computational laboratories
Nansen Environmental Research Centre (India)	Laboratory	HP high end server, ArcGIS, Matlab, Primer, various lab equipment,
School Of Oceanographic Studies, Jadavpur University	Laboratory	Details not available

Institution	Infrastructure	Remarks
Faculty of Marine Sciences, Annamalai University	Laboratory	Maldi-Tof, ICP, HPLC, HPTLC, Microbial Identification system, GCMS, CHNS O analyzer, Fluorescent Microscope, Elisa Reader, 2D Gel electrophoresis, Scintillation Counter, UV-VIS Spectrophotometer, Spectrofluorometer, High speed refrigerated centrifuges, Mercury analyzer, PCR, RT-PCR, Gel documentation system and freeze dryer. Other facilities include Cell and tissue culture facility, Seawater circulation system, Marine Botany research laboratory, Plankton identification and culture facility, Aquaculture demonstration ponds, cage culture materials, Gene bank of rare mangrove species, all physical oceanographic field instruments and INCOIS potential fishing zone electronic display board.
Centre for Marine Science and Technology, Manonmaniam Sundaranar University	Laboratory	Cooling centrifuge, PCR, ice flake machine, UV spectrophotometer, -80 Deep freezers, Sonicator, Geldoc, Rotary evaporator, ELISA Reader, nano drops, Phase contrast microscope, Fluorescent microscope, Real-time PCR and HPLC and wet lab/culture facilities
Central Salt and Marine Chemicals Research Institute (CSMCRI) - CSIR**	Laboratory	FT-NMR, FT-IR, FT-Raman, Elemental analysis CHN, Total organic carbon (TOC), Elemental Analysis by Inductively Coupled Plasma Spectrometer (ICP), MALDI-TOF, Single Crystal X-ray analysis, Powder X-ray Diffraction, Thermal Gravimetric Analysis (TGA, DTG) Analysis, DSC analysis, DMA analysis, Surface area and Porosity Measurement (BET), Particle size analysis, FE-SEM (Field Emission Scanning Electron Microscope), Transmission Electron Microscope (TEM), AFM - Scanning Probe Microscope (SPM), GC, GC-MS, LC-MS, HPLC analysis, GPC, Ion Chromatography (IC), UV-Vis/NIR spectra, Emission spectra (Luminescence), CD-Spectra, Moisture Analysis by Karl Fischer, Rheometer, Electrochemical analysis, Biodiesel Rancimat, Benchtop EPR, DNA SEQUENCER
Society of Integrated Coastal Management (SICOM), MoEFCC	No laboratory	
University of Calcutta	Laboratory	Vibra core sample Analyzer for analysis of marine samples and other analytical instruments
Andhra University	Laboratory	Various facilities including Aquaculture shore laboratory
Anna University	Laboratory	• Analytical laboratory for wet chemistry studies, including Atomic Absorption Spectroscopy (AAS), UV and visible spectrophotometry. • High precision field surveying (including GPS, spectro-radiometer), field sampling (including augers, and coring equipment) and field monitoring (in situ water quality probes). • Boat and acoustic profiling devices. • Remote sensing, GIS and modeling.
M S Swaminathan Research Foundation	No laboratory	Participatory research involving local communities called the Coastal System Research
National Centre for Earth Science Studies, Ministry of Earth Sciences	Laboratory	Ecological-Modelling; Facility for Geofluids Research and Raman Analysis; GIS-Facility; Central Geomatics Lab (CGL); Electronics and Instrumentation Laboratory; Munnar Observatory; Cloud Physics Observatories; Particle size Analyser Lab; Placer Mineral Testing lab; Offshore Facilities; Critical Zone Lab

Institution	Infrastructure	Remarks
Center for Environment Education	No laboratory	
Gujarat Institute of Desert Ecology	Laboratory	Environmental-Chemical-Analytical laboratories. Facilities for qualitative and quantitative analyses of marine fauna & flora from diverse marine/coastal habitats (benthic, Pelagic, intertidal, subtidal), different physical and chemical analyses of seawater and sediments. Atomic Absorption Spectrometer (AAS), Ion Chromatograph, Spectro-fluorometer, UV-Spectrophotometer, Rotary evaporator, Kjeldahl Nitrogen Apparatus, Flame Photometer, instrumentation kits to analyze nutrients, heavy metals, and productivity on site.
Wildlife Institute of India, MoEFCC	Laboratory	Physio-chemical lab
Department of Marine Science, Bharathidasan University	Laboratory	Details not available
School of Energy, Environment and Natural Resources, Madurai Kamaraj University	Laboratory and field equipment	Details not available
School of Environmental Sciences, Mahatma Gandhi University	Laboratory	Chemistry Lab, Biotechnology Lab, Remote Sensing and GIS Lab, Mass Spectrometric Lab, Mercury Analytical Facility, Instrumentation Rooms

Source: iFOREST (2020)

3.3 Past and present research and future priorities

Research on marine litter/marine pollution in India has been largely focused on the types of litter/ pollutants, the sources of pollution, the quantum and abundance of litter, and impacts of marine litter and pollution on the marine ecosystem.

A systematic review of the literature on marine litter, and past and existing/ongoing research projects of the various institutions, suggest that the research topics can be broadly placed under six categories. These include:

(i) Evaluating the abundance and composition of beach-litters;

(ii) Assessment of the level of macro and micro-litter contamination in the sea

(iii) Quantification of microplastics in marine biota

(iv) Assessment of microplastics in Coastal and Estuarine habitats

(v) Assessment of macro and microplastics in inland water

(vi) Impact of plastic pollution on marine life.

An overview of past and ongoing research projects on marine litter at various institutions in outlined below (Table 3.3). These studies have been (are being) undertaken using standard methodologies *(Box 3: Common methodology used for marine litter research in India).*

With respect to future research directions, most of these institutes plan to expand on their research capacity with respect to quantitative and qualitative assessment on marine litter. Some of the institutions are also planning to undertake research on practical mitigation measures and management plans, building on the scope of applied research on this issue.

Overall, future priority research areas of these institutions, as evaluated on the basis of their responses (obtained from seven institutions) can be summarised as follows:

- Litter source evaluation, chemical composition, transportation, distribution and modelling;
- Impact of litter on marine food web;
- Improvement of specific instrumentation capacity and advanced techniques for marine litter assessment;
- Practical mitigation and management plans to prevent plastic litter intrusion into the food web;
- Modelling the spatial distribution and dispersion of marine litter; and,
- Economic impacts of marine litter on the coastal communities.

Responses as obtained from the institutions, also elucidated the kind of support they would need in order to improve the quality of research on marine litter. The most common response was the need to secure long-term funding mechanisms to enhance the scope, and ensure continuity of marine litter research.

Some of the institutions also indicated the need of sophisticated and advanced instruments for scientific analysis. Some of the instruments mentioned by the respondents include, Raman Spectroscopy, Scanning Electron Microscope, X Ray-fluorescence spectroscopy, and Pyrolysis-GC/MS.

The need for training on advanced techniques for marine litter studies was also noted by few institutions. Collaboration with other institutes who have more advanced laboratories and required instruments, was also suggested as an alternative to bridge the current limitations. In addition, ICAR-CIFRI stated that they were working on plastics litter contamination in fresh water environments across all of the inland water sources in India. Considering the expanse of these inland water sources, there is a dire need of extra staff for such projects.

Table 3.3: Important past and present research on marine litter

Institution	List of past and existing projects on marine litter	Regional focus
ICAR - Central Marine Fisheries Research Institute, Kochi, Kerala, India	• Pollution and litter in the coastal and marine ecosystem and their impact; • Assessment of coastal and marine pollution in selected maritime states of India; • Observation and monitoring of coastal and marine pollution and its impact on sea life, prevention and mitigation	Kochi, Tuticorin, Visakhapatnam, Mangalore.
ICAR - Central Inland and Fisheries Research Institute, West Bengal	• Plastic litter contamination in inland open freshwater bodies for both sediments and water samples; • Distribution of microplastics in river Ganga; • Distribution of microplastics in natural wastewater treatment wetland system; • Occurrence and fate of microplastics in drinking water treatment plant	River Ganga and East Kolkata Wetland at Kolkata
ICAR - Central Institute of Fisheries Education (Mumbai)	• Plastic litter accumulation on high-water strandline of urban beaches in Mumbai, India	Mumbai
National Centre for Coastal Research, Ministry of Earth Sciences	• Assessment of Microplastic Impact on Marine Organism in Coastal and Estuarine habitats - Harnessing the functional microbiome possessing metabolic potential to degrade plastics; • Microplastic contamination in sediment and selected benthic organism of Arabian sea coast and a few estuaries of Kerala; • The fate and transport of Microplastic pollutants in presence of sunlight and suspended sediments in coastal marine ecosystem: An experimental study; • Assessment of Microplastics in the Northern Indian ocean	East coast of India and Lakshadweep Islands

Institution	List of past and existing projects on marine litter	Regional focus
NCSCM, MoEFCC	• Accumulation and ecotoxicological risk of weathered polyethylene (wPE) microplastics on green mussel (Perna viridis)	India
CSIR - National Institute of Oceanography	• Assessment of micro and macro plastics along the west coast of India: Abundance, distribution, polymer type and toxicity; Characteristics, seasonal distribution and surface degradation features of microplastic pellets along the Goa coast, India; Microplastics in seafood; • Polycyclic Aromatic Hydrocarbons (PAHs) and Hopanes in Plastic Resin Pellets as Markers of Oil Pollution via International Pellet Watch Monitoring	Goa, Kochi.
Suganthi Devadason Marine Research Institute	• Marine debris survey and assessment in reef area; • Assessment of microplastics in coastal areas, estuaries and lakes in Tamil Nadu (2019-2022)	Coastal areas, estuaries and lakes of Tamil Nadu
Alagappa University, Karaikudi, Tamil Nadu, India	• Critical Assessment of the Pearl Oyster Status, Prevailing Threats and Development Strategies for Management. • Present Status Distribution and Threats of Scheduled mollusks in Mandapam and Kilakarai group of islands. • Conservation and Sustainable development of Marine resources in Palk Bay Area	South East coast of India (Chennai to Kanyakumari, Palk Bay and Gulf of Mannar Area)
Jadavpur University	• Characterization of microplastics in the tourist-influenced beaches of West Bengal	West Bengal
CSIR - Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar, Gujarat, India	• Impact of plastics on marine environment from Gujarat coast, India and their decontamination or Chemical Recycling	Gujarat
Gujarat Institute of Desert Ecology	• Marine litter pollution along Mandvi beach, Kachchh, Gujarat	Gujarat

Source: iFOREST (2020)

Box 3: Common methodology used for marine litter research in India

The methodologies used in studies on marine litter commonly involved physical operations like density separation or visual inspection through naked eye or microscope as well as plastic litter estimation based on weight, colour, size and composition. Surveys were carried out using transect and quadrat method in most cases.[77] The litter samples collected were sorted and their quantity and weight being measured. Chemical methods were listed for digesting organic matter to then alienate plastics followed by C:H:N analysis for material identification.

For studies on microplastics, primarily samples were primarily sent to laboratory for observation and analysis. There were also spectroscopic analyses - IR, FTIR, X-ray and Raman for microplastic identification. For seawater and sediment collection microplastic particle pump, manta net and Van Veen grab are used.

Finally, in qualitative methods - participatory research involving local communities called the Coastal System Research was listed by M S Swaminathan Research Foundation.

CHAPTER 4

Advancing the Agenda of Marine Litter in India

The evaluation of the state of research and research institutions indicate that India has a large number of institutions who can be roped in to advance the research and knowledge agenda on marine litter. However, there is a need for an integrated approach to manage the knowledge portfolio on marine litter, including research, awareness raising, capacity building and knowledge exchange.

There are five key aspects which remain instrumental in advancing the agenda of marine litter in India as outlined below.

(i) Research focus

A majority of the research studies done so far have focused on beach plastics. On beach plastics also, the last all-India study was done in 2013-2014. So, there is an urgent need to increase the body of knowledge on marine plastics (including microplastics), specially across all the four different fates of marine plastics – beaches, seas surface/ water column, sea floor (deep and shallow) and ingestion by other marine organisms. The other key research areas include:[78]

- Hydrodynamic models to understand the source, transport and destination regions of marine litter around the country;
- Rate of degradation, behaviour and factors affecting litter;
- Environmental Impacts of marine litter in organisms;
- Impact of litter on marine food web;
- Practical mitigation and management plans to protect the plastic litter intrusion into the food web; and,
- Economic impact of marine litter on coastal communities.

Additional areas for future research priorities have been identified as follows:

- Litter source evaluation, chemical composition, transportation, distribution and modelling;
- Impact of litter on marine food web;
- Improvement of specific instrumentation capacity and advanced techniques for marine litter assessment;
- Practical mitigation and management plans to prevent plastic litter intrusion into the food web;
- Modelling the spatial distribution and dispersion of marine litter; and,
- Economic impacts of marine litter on the coastal communities.

(ii) Standardising marine litter monitoring protocol

A major challenge faced in this review was the difficulty with comparing the existing data obtained from published papers, often due to mismatched units. For example, units for sediments varied between g/m^2, g/100m or items/m^2. Studies on microplastics also used units such as particles or items per L or m^3 of the sample. Following a more standardised scientific monitoring protocol for measuring marine debris is of utmost necessity to understand the source, distribution, abundance, pathway, and impact of debris on a local, national and global scale. In order to compare the debris data in context with local to the global scale, a standard methodology and reporting protocol should be practiced. The Ministry of Earth Sciences and MoEFCC must consider developing research and reporting protocols on marine litter using international guidelines, such as those developed for the SDGs.

(iii) Capacity building of institutions

Several institutions dedicated to research in marine sciences have been set up under the aegis of the Ministry of Earth Sciences, MoEFCC, and public universities. As discussed in Chapter 3, each of these institutions specialise in a specific vertical - marine biology, biogeochemistry, oceanography, fisheries, to name a few, lending a unique approach to their research studies.

At a point when India needs greater focus on marine plastic litter, it is important to augment the current capacities of existing institutions so that they are able to lend their unique specialisation while studying the issue of plastic litter. Capacity building among these institutions are required primarily in the form of improvements in specific instrumentation that can help with carrying out studies on marine litter. Specifically, few institutions mentioned the need of following instruments:

- Raman Spectroscopy
- Scanning Electron Microscope
- X Ray-fluorescence spectroscopy
- Pyrolysis-GC/MS

In addition to instrumentation, training in advanced techniques was also stated as a need. There is also a need for consistent funding and a greater workforce to carry out large-scale surveys.

(iv) All India Coordinated Project on Marine Litter

The All India Coordinated Research Projects (AICRP) have been established to coordinate multiple institutions to do research on the same subject using the same methodology. There are 60 such projects on various aspects of agriculture.[79] There is a need for an All India Coordinated Project on Marine Litter (AICPML) coordinated by the Marine Litter Cell, Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. The primary goal of the AICPML should be to strengthen the capacity of marine-related institutions, to understand the linkages between the various sources of waste and marine litter and to publish an annual report on the state of Marine Litter on India's coast and exclusive economic zone with special focus on plastic pollution, including microplastics.

(v) Knowledge platform for marine litter

Given the vast amount of data required on marine litter and its detrimental impacts, there is a need for a knowledge-sharing platform. One example of this is the MARINA project of the EU created to "engage citizens, researchers, policymakers, industrial and societal actors in order to share knowledge, include the citizens' vision and societal needs, create a synergy between research and innovation and the environmental safeguard."[80] India can create a similar knowledge-sharing platform to exchange knowledge on:

- Marine plastic litter
- Socio-economic impacts of marine litter pollution
- Ecological and health impacts of marine litter pollution
- Linkages between inland sources and marine pollution
- Mitigation measures
- Pollution control and waste management from sea transportation
- Impact of tourism and coastal cities on marine litter

A key consideration for the long-term success of this effort is to ensure dedicated staff (database managers, subject-knowledge experts, software engineers, data scientists) and consistent funding.

ANNEXURE: Key contact person and institution working in the field of marine litter[81]

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REFERENCES

1 United Nations Environment Programme [UNEP]. (n.d.). Marine Litter. https://www.unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/marine-litter

2 Plastic debris comprises fishing related items, such as rope, nets, float etc. (48%), food packaging (13%), sandals (3%), plastic bottles (7%), bottle caps (2%), food containers (1%), and foamed plastics (8%). The major source of microplastics include those which are either manufactured as pellets and microbeads, or from fragmented parts of larger objects.

3 International Union for Conservation of Nature (IUCN). (2018). Issue Brief: Marine Plastics. https://www.iucn.org/ sites/dev/files/marine_plastics_issues_brief_final_0.pdf

4 Ramanamurthy, M. V., Mishra, P. & Vethamony, P. (2018). Marine Litter in the South Asian Seas (SAS) Region: Devel- opment of Regional Action Plan on Marine Litter, Country Report – India. United Nations Environment Programme, South Asia Cooperative Environment Programme, Ministry of Earth Sciences, Government of India. http://www. sacep.org/pdf/Reports-Technical/2018.05-India-Country-Report-for-Prepration-of-Regional-Marine-Litter-Action- Plan-for-South-Asia.pdf

5 Ibid.

6 G7 Leaders Summit. (2018). Charlevoix Blueprint for healthy oceans, seas and resilient coastal communities. https:// www.mofa.go.jp/files/000373849.pdf

7 Mangotra, K., & Chandrasekhar, K. (2020). Are we at sea on marine plastic pollution. Financial Express. https://www.financialexpress.com/opinion/are-we-at-sea-on-marine-plastic-pollution/2125852/#:~:text=Currently%2C%20India%20is%20considered%20the,the%20fifth%2Dlargest%20by%202025.&text=The%20global%20Marine%20plastic%20Pollution,into%20the%20ocean%20every%20minute.

8 Ramanamurthy, M. V., Mishra, P. & Vethamony, P. (2018). Marine Litter in the South Asian Seas (SAS) Region: Devel- opment of Regional Action Plan on Marine Litter, Country Report – India. United Nations Environment Programme, South Asia Cooperative Environment Programme, Ministry of Earth Sciences, Government of India. http://www. sacep.org/pdf/Reports-Technical/2018.05-India-Country-Report-for-Prepration-of-Regional-Marine-Litter-Action- Plan-for-South-Asia.pdfhttp://www.sacep.org/pdf/Reports-Technical/2018.05-India-Country-Report-for-Prepra- tion-of-Regional-Marine-Litter-Action-Plan-for-South-Asia.pdf

9 Ibid.

10 UN-Environment. (2018). Global Manual on Ocean Statistics- Towards a definition of indicator methodologies. https:// uneplive.unep.org/media/docs/statistics/egm/global_manual_on_ocean_statistics_towards_a_definition_of_indica- tor_methodologies.pdf

11 Kaladharan, P., Vijayakumaran, K., Singh, V. V., Prema, D., Asha, P. S., Sulochanan, B., Hemasankari, P., Loveson Edward, L., Padua, S., Veena, S., Anasukoya, A., & Bhint, H. M. (2017). Prevalence of marine litter along the Indian beaches: A preliminary account on its status and composition. Journal of the Marine Biological Association of India, 59(1), 19–24.

12 Ibid

13 Ibid

14 Ibid

15 Behera, D. P., Kolandhasamy, P., Sigamani, S., Devi, L. P., & Ibrahim, Y. S. (2021). A preliminary investigation of marine litter pollution along Mandvi beach, Kachchh, Gujarat. Marine Pollution Bulletin, 165, 112100.

16 Ibid

17 Reddy, S.M., Basha, S., Adimurthy, S. & Ramachandraiah, G. (2006). Description of the small plastics fragments in marine sediments along the Alang-Sosiya ship-breaking yard, India. Estuarine, Coastal and Shelf Science, 68, Issues 3-4.

18 Ibid

19 Sulochanan, B., Bhat G.S, Lavanya S., Dineshbabu A.P., & Kaladharan P. (2014). A preliminary assessment of ecosystem process and marine litter in the beaches of Mangalore. Indian Journal of Geo – Marine Science, 43(9), 1764–1769.

20 Sulochanan, B., Veena, S., Ratheesh, L., Padua, S., Rohit, P., Kaladharan, P., & Kripa, V. (2019). Temporal and spatial variability of beach litter in Mangaluru, India. Marine Pollution Bulletin, 149, 110541.

21 Sulochanan, B., Bhat G.S, Lavanya S., Dineshbabu A.P., & Kaladharan P. (2014). A preliminary assessment of ecosystem process and marine litter in the beaches of Mangalore. Indian Journal of Geo – Marine Science, 43(9), 1764–1769.

22 Jayasiri, H. B., Purushothaman, C. S., & Vennila, A. (2013). Quantitative analysis of plastic debris on recreational beaches in Mumbai, India. Marine Pollution Bulletin, 77(1), 107–112.

23 Ibid

24 Jayasiri, H. B., Purushothaman, C. S., & Vennila, A. (2013). Plastic litter accumulation on high-water strandline of urban beaches in Mumbai, India. Environmental Monitoring and Assessment, 185(9), 7709–7719.

25 Saha, M., Naik, A., Desai, A., Nanajkar, M., Rathore, C., Kumar, M., & Gupta, P. (2021). Microplastics in seafood as an emerging threat to marine environment: A case study in Goa, west coast of India. Chemosphere, 270, 129359.

26 Veerasingan, S., Saha, M., Suneel, V., Vethamony, P. Rodrigues, C.A., Bhattacharya, S. & Naik, B.G. (2016). Charac- teristics, seasonal distribution and surface degradation features of microplastic pellets along the Goa coast, India. Chemosphere, 159, 496-505.

27 Ibid

28 Kaladharan, P., Vijayakumaran, K., Singh, V. V., Prema, D., Asha, P. S., Sulochanan, B., Hemasankari, P., Loveson Edward, L., Padua, S., Veena, S., Anasukoya, A., & Bhint, H. M. (2017). Prevalence of marine litter along the Indian beaches: A preliminary account on its status and composition. Journal of the Marine Biological Association of India, 59(1), 19–24.

29 Ibid

30 Daniel, D. B., Thomas, S. N., & Thomson, K. T. (2020). Assessment of fishing-related plastic debris along the beach- es in Kerala Coast, India. Marine Pollution Bulletin, 150, 110696.

31 Robin, R. S., Karthik, R., Purvaja, R., Ganguly, D., Anandavelu, I., Mugilarasan, M., & Ramesh, R. (2020). Holistic as- sessment of microplastics in various coastal environmental matrices, southwest coast of India. Science of The Total Environment, 703, 134947.

32 Ibid

33 Kaladharan, P., Vijayakumaran, K., Singh, V. V., Asha, P. S., Sulochanan, B., Asokan, P. K., Valsala, K. K., Veena, S., Jayasankaran, L., & Bhint, H. M. (2012). Assessment of certain Anthropogenic Interventions and their Impacts along the Indian Coastline. Fishery Technology 49 (20212): 32-37.

34 Kumar, A., Sivakumar,R., Reddy, Y. S. R., Bhagya. Raja, M.V., Nishant,T., & Revanth, V., (2016). Preliminary study on marine debris pollution along Marina beach, Chennai, India. Regional Studies in Marine Science, 5, 35–40.

35 Karthik, R., Robin, R.S., Purvaja, R., Ganguly, D., Anandvelu, I., Raghuraman, R., Hariharan, G.Ramakrishan, A. & Ramesh, R. (2018). Microplastics along the beaches of southeast coast of India. Science of The Total Environment, 645, 1388-1399.

36 Veerasingam, S., Mugilasaran, M., Venkatachalapathy, R. & Vethamony, P. (2016). Influence of 2015 flood on the distri- bution and occurrence of microplastic pellets along the Chennai coast, India. Marine Pollution Bulletin, 109, 196-204.

37 Sundar, S., Chokkalingam, L., Roy, P. D. & Usha, T. (2020). Estimation of microplastics in sediments at the south- ernmost coast of India (Kanyakumari). Environmental Science and Pollution Research.

38 Jeyasanta, I., Sathish, N., Patterson, J. & Patterson, K.J.E. (2020). Macro, meso and microplastic debris in the beach- es of Tuticorin district, Southeast coast of India. Marine Pollution Bulletin, 154, 111055.

39 Krishnakumar, S., Srinivasalu, S., Saravanan, P., Vidyasakar, A. & Magesh S.N. (2018). A preliminary study on coastal debris in Nallathanni island, Gulf of Mannar Biosphere Reserve, Southeast Coast of India. Marine Pollution Bulletin, 131, 547-551.

40 Ganesapandian, S., Manikandan, S. Kumaraguru, K.A. (2011). Marine litter in the Northern part of Gulf of Mannar, Southeast Coast of India. Research Journal of Environmental Sciences, 5, 471-478.

41 Raha, K.U., Kumar, R.B., Sarkar, K.S. (2021). Policy framework for mitigating land-based marine plastic pollution in the Gangetic Delta region of Bay of Bengal – A review. Journal of Cleaner Production, 278, 123409.

42 Kapinga, P.C. & Chung, H.S. (2020). Marine plastic pollution in South Asia. United Nations Economic and Social Com- mission for Asia and the Pacific. https://www.unescap.org/sites/default/files/SSWA%20 Development_Paper20-02_ Marine%20Plastic%20Pollution%20in%20South%20Asia.pdf

43 Kaladharan, P., Vijayakumaran, K., Singh, V. V., Prema, D., Asha, P. S., Sulochanan, B., Hemasankari, P., Loveson Edward, L., Padua, S., Veena, S., Anasukoya, A., & Bhint, H. M. (2017). Prevalence of marine litter along the Indian beaches: A preliminary account on its status and composition. Journal of the Marine Biological Association of India, 59(1), 19–24.

44 Kaladharan, P., Singh, V.V., Asha, S.P., Edward, L. & Sukhadane, S.K. (2020). Marine plastic litter in certain trawl grounds along the peninsular coasts of India. Marine Pollution Bulletin, 157, 111299.

45 Ibid

46 Kripa, P., Kaladharan, P., Prema, D., Jeyabaskaran, R., Kumar, A.S.P., Shylaja, G., Sajikumar, K.K., Anasu Koya, A., Nair, G.P., Abhilash, S.K., Dhanya, M.A., Bose, J. Ambrose, V.T., Divya, D.N., Vishnu, G.P. &Mohan, J. (2016). A Na- tional Marine Debris Management Strategy to conserve marine ecosystems. Marine Fisheries Information Service: Technology & Extension Series, 228.

47 Ibid

48 Robin, R. S., Karthik, R., Purvaja, R., Ganguly, D., Anandavelu, I., Mugilarasan, M., & Ramesh, R. (2020). Holistic as- sessment of microplastics in various coastal environmental matrices, southwest coast of India. Science of The Total Environment, 703, 134947.

49 Veerasingan, S., Saha, M., Suneel, V., Vethamony, P. Rodrigues, C.A., Bhattacharya, S. & Naik, B.G. (2016). Charac- teristics, seasonal distribution and surface degradation features of microplastic pellets along the Goa coast, India. Chemosphere, 159, 496-505.

50 Saha, M., Naik, A., Desai, A., Nanajkar, M., Rathore, C., Kumar, M. & Gupta, P. (2021). Microplastics in seafood as an emerging threat to marine environment: A case study in Goa, west coast of India. Chemosphere, 270, 129359.

51 Manickavasagam, S., Kumar, S., Kumar, K., Bhuvaneswari, R.G., Paul, T. & Shukla, P.S. (2020). Quantitative assess- ment of influx and efflux of marine debris in a water channel of South Juhu creek, Mumbai, India. Regional Studies in Marine Science, 34, 101095.

52 Sathish, N.M., Jeyasanta, I. & Patterson, J. (2020). Occurrence of microplastics in epipelagic and mesopelagic fishes from Tuticorin, Southeast coast of India. Science of The Total Environment, 720, 137614.

53 Mugilasaran, M., Venkatachalapathy, R., Sharmila, N. & Gurumoorthi, G. (2015). Occurrence of microplastic resin pellets from Chennai and Tinnakkara Island: Towards the establishment of background level for plastic pollution. Indian Journal of Geo Marine Sciences, 46, 1210-1212.

54 Ibid

55 Sahu, B. Pati, P. & Panigraphy, C.R. (2013). Plastic litters: a major environmental issue in Chilika lagoon. Current Science, 104, 1133-1134.

56 Veerasingam, S., Saha, M., Suneel, V. & Vethamony, P. (2017). Microplastic pollution: A serious threat to the ma- rine ecosystem. Blue Waters Newsletter on Marine Environment Protection, Vol XVII.

57 Edward, P.K.J., Mathews, G., Diraviya Raj, K., Laju L.R., Selva Bharath, M., Dinesh Kumar, P. Arasamuthu, A. & Grimsditch, G. (2020). Marine debris – An emerging threat to the reef areas of Gulf of Mannar, India. Marine Pollu- tion Bulletin, 151, 110793.

58 Ibid

59 Sruthy, S. & Ramasamy, V.E. (2017). Microplastic pollution in Vembanad lake, Kerala, India: The first report of microplastics in lake and estuarine sediments in India. Environmental Pollution, 222, 315-322.

60 Jeyasanta, I. Patterson, J. Grimsditch, G. & Edward, P.K.J. (2020). Occurrence and characteristics of microplastics in the coral reef, sea grass and near shore habitats of Rameswaram Island, India. Marine Pollution Bulletin, 160, 111674.

61 Patterson, J., Jeyasanta, I., Sathish, N., Edward, P.K.J. & Booth M.A. (2020). Microplastic and heavy metal distribu- tions in an Indian coral reef ecosystem. Science of The Total Environment, 744, 140706

62 Karthik, R., Robin, R.S., Purvaja, R., Ganguly, D., Anandvelu, I., Raghuraman, R., Hariharan, G.Ramakrishan, A. & Ramesh, R. (2018). Microplastics along the beaches of southeast coast of India. Science of The Total Environment, 645, 1388-1399.

63 Ibid

64 Patterson, J., Jeyasanta, I., Sathish, N., Booth, N.A. & Edward, P.K.J. (2019). Profiling microplastics in the Indian edible oyster, Magallana bilineata collected from the Tuticorin coast, Gulf of Mannar, Southeastern India. Science of The Total Environment, 691, 727-735.

65 Sathish, N.M., Jeyasanta, I.K. & Patterson, J. (2020). Monitoring of microplastics in the clam Donax cuneatus and its habitat in Tuticorin coast of Gulf of Mannar, India. Environmental Pollution, 266, 115219

66 Sathish, N.M., Jeyasanta, I. & Patterson, J. (2020). Occurrence of microplastics in epipelagic and mesopelagic fishes from Tuticorin, Southeast coast of India. Science of The Total Environment, 720, 137614.

67 Sathish, N.M., Jeyasanta, I. & Patterson, J. (2020). Microplastics in salt of Tuticorin, Southeast Coast of India. Ar- chives of Environmental Contamination & Toxicology, 79, 111-121.

68 Ibid

69 Hariharan, G., Purvaja, R. Anandavelu, I., Robin, S.R. & Ramesh, R. (2021). Accumulation and ecotoxicological risk of weathered polyethylene (wPE) microplastics on green mussel (Perna viridis). Ecotoxicology & Environmental Safety, 208, 111765.

70 Naidu, A.S., Ranga Rao, V. & Ramu, K. (2018). Microplastics in the benthic invertebrates from the coastal waters of Kochi, Southeastern Arabian Sea. Environmental Geochemistry & Health, 40, 1377-1383.

71 Saha, M., Naik, A., Desai, A., Nanajkar, M., Rathore, C., Kumar, M., & Gupta, P. (2021). Microplastics in seafood as an emerging threat to marine environment: A case study in Goa, west coast of India. Chemosphere, 270, 129359.

72 Sulochanan, B. Subramanya Bhat, G. & Lavanya, S. (2011). Marine Litter in the coastal environment of Mangalore. Marine Fisheries Information Service T&E Ser., 208.

73 Kaladharan, P., Asokan, K.P., Koya, M.K. & Bhint, M.H. (2014). Plastic debris in the stomach of a Longman's Beaked Whale, Indopacetus pacificus (Longman, 1926) stranded off Sutrapada, Veraval, Saurashtra coast, India. Journal of the Marine Biological Association of India, 56.

74 Sarkar, J.D., Sarkar, D.S., Das, K.B., Manna K.R., Behera, K.B. & Samanta, S. (2019). Spatial distribution of meso and microplastics in the sediments of river Ganga at eastern India. Science of The Total Environment, 694, 133712.

75 Sarkar, J.D., Sarkar, D.S., Das, K.B., Sahoo, K.B., Das, A., Nag, K.S., Manna, K.R., Behera, K.B. & Samanta, S. (2021). Occurrence, fate and removal of microplastics as heavy metal vector in natural wastewater treatment wetland system. Water Research, 192, 116853.

76 One of the institutions in this list, the National Centre for Sustainable Coastal Management (NCSCM), MoEFCC, identified 15 research universities along India's coastline and created a consortium with these institutes in 2010. This consortium is between a central research institute, NCSCM, and regional universities aiming for information exchange on marine resources research. As most of these institutes were not found to be working on Marine litter issues, they have not been selected. However, these institutes may be considered in the future as part of the network of institutions working on marine litter.

77. Kripa, V., Kaladharan, P., Prema, D., Jeyabaskaran, R., Kumar, P. S. A., Shylaja, G., Sajikumar, K. K., Koya, A. A., Nair, P. G., Abhilash, K. S., Dhanya, A. M., Bose, J., Ambrose, T. V., Divya, N. D., Vishnu, P. G., & Mohan, J. (2016). A National Marine Debris Management Strategy to conserve marine ecosystems.

78 Ramanamurthy, M. V., Mishra, P. & Vethamony, P. (2018). Marine Litter in the South Asian Seas (SAS) Region: Devel- opment of Regional Action Plan on Marine Litter, Country Report – India. United Nations Environment Programme, South Asia Cooperative Environment Programme, Ministry of Earth Sciences, Government of India. http://www. sacep.org/pdf/Reports-Technical/2018.05-India-Country-Report-for-Prepration-of-Regional-Marine-Litter-Action- Plan-for-South-Asia.pdf

79 Indian Council of Agricultural Research (2021), Government of India. https://icar.org.in/content/aicrps-network-projects

80 The European Maritime Spatial Planning (MSP) Platform, a knowledge sharing platform funded by European Commission. https://www.msp-platform.eu/projects/marine-knowledge-sharing-platform-federating-responsi- ble-research-and-innovation

81 Experts were contacted to fill out questionnaires to examine research capacities in their respective institutions. This was done both via emails and phone calls over a period of two months (November & December 2020). Institutional websites were used to obtain information wherever stakeholders did not respond.

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