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Microplastic in the Marine Environment of the Indian Ocean

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Abstract

Microplastic has been found in all major waterbodies in the world. Many examples of ingestion of microplastic by marine organisms have been reported. This presence of microplastic in marine organisms gives it the possibility to penetrate the human food chain by increasing the chance of microplastic in seafood targeted for human consumption. Although it is known that parts of the Indian Ocean suffer from significant plastic pollution, much of the systematic research on the microplastic abundance in different regions of the Indian Ocean stems only from the last five years. This manuscript reviews the available literature of 2015-2022 on the presence of microplastics in commercially important fish species in the Indian Ocean. The literature data on microplastic content on beaches, in subtidal sediment, in the sediment from the ocean floor, and in surface water of different regions of the Indian Ocean is reviewed, also.

Keywords

Review, Commercial Fish, Indian Ocean, Microplastic, Environmental Pollution

1. Introduction

Microplastics (MPs) are defined as small plastic particles of 5 mm or less in size [1], with mesoplastics making up the category of next larger-sized plastics (5 mm - 25 mm). Microplastics are categorized as primary MPs (plastic particles that have been synthesized in this small size to fulfill a certain purpose such as abrasives) and as secondary MPs (particles stemming from the fragmentation of larger plastic pieces). MPs can be made of a variety of polymeric materials such as Polythene (PE), Polypropylene (PP), Polystyrene (PS), Polyamide (PA), and Polyalkylene Terephthalate (PPT and PET), among others. In addition, additives are associated with MPs such as dyes and colorants, plasticizers, photo-stabilizers, antioxidants, and flame retardants [2]. There is significant transport of MP from land to water through riverine systems [3] [4] [5], run-offs [6] [7], effluents of wastewater treatment plants [8] [9] [10], and through air movement and subsequent atmospheric deposit of the MPs on the water [11] [12], so that the oceans of the world act as a "sink" for MPs [13]. Best estimates see 82 - 358 trillion plastic particles weighing 1.1 - 4.9 million tons in the marine environment [14]. MPs are not only found on the water surface [15], but rather the majority of MPs are located along the water column [15] [16], the ocean floor [17], and in the ocean sediments [18]. In addition, anthropogenic activity on and near the oceans contributes to the influx of MP. These activities include fishing [19] [20] and shipping [21] [22] operations, and recreational activities [20]. In all world's oceans, MP has been found. This includes the Arctic [23] [24] and Antarctic waters [25] [26].

The Indian Ocean is the third largest ocean covering 70,560,000 km^2 and corresponding to 19.8% of the earth's water surface [27], when the marginal seas are included. For this manuscript, the Arabian Sea (3.862 million km^2), the Bay of Bengal (2.172 million km^2), the Andaman Sea (797,700 km^2), the Laccadive Sea (786,000 km^2), the Gulf of Aden (410,000 km^2), the Mozambique Channel (700,000 km^2), and the Oman Sea (181,000 km^2) as marginal seas were included, while the Timor Sea, the Java Sea, the Banda Sea, the Malacca Strait, and the Great Australian Bight were excluded. As the situation of MP presence in the Red Sea [28] and the Arabian Gulf [29] has been discussed and reviewed previously, also these two were excluded from the current review. The countries bordering those regions of the Indian Ocean that are subject of this review, starting off with the Northeastern tip of the Arabian Sea and then circulating clockwise are Iran, Pakistan, India, Bangladesh, Myanmar, Thailand, Malaysia, Indonesia, Australia, South Africa, Mozambique, Tanzania, Kenya, Somalia, Djibouti, Yemen, Oman, and the United Arab Emirates in addition to the island nations Sri Lanka, Madagascar, Comores, Mauritius, Seychelles, and Maldives. In addition, there are French, UK, and Australian-administered territories in the region such as Reunion, Mayotte, the Chagos archipelago, and Christmas and Cocos and Keeling Islands. About 270 million people live in coastal areas on the Indian Ocean, with 60 million people living in Western Indian Ocean coastal areas alone [30]. Some of the most populous cities lying on the Indian Ocean are Karachi (Pakistan, 14.9 million), Surat (India, 6.9 million), Mumbai (India, 18.4 million), Kochi (India, 2.1 million), Chennai (India, 8.9 million), Visakhapatnam (India, 2.4 million), Bandar Lampung (Sumatra, Indonesia, 1.2 million), Padang (Sumatra, Indonesia 909.000), Denpasar (Bali, Indonesia, 2.2 million), Yogyakarta (Java, Indonesia, 376,300), Perth (Australia, 2.2 million), Darwin (South Africa, 3.4 million), Maputo (Mozambique, 1.8 million), Mombasa (Kenya, 3.5 million), Mogadishu (Somalia, 2.4 million), Djibouti (600.000), and Aden (863.000). The Zambezi (Mozambique), Ganges-Brahmaputra (Bangladesh), Indus (Pakistan), Jubba (Somalia), Murray (Australia), and Limpopo (Mozambique), which are some of the world's largest rivers, end in the Indian

Ocean.

The Indian Ocean offers a livelihood to millions of people. Alone for Kerala, it is estimated that in 2017 there were 240.000 people earning a livelihood from marine fishing [31]. Sri Lanka reported 250.000 active fishers and another 100.000 support personnel [32], Pakistan reported 194.400 people, in Mauritius 22.000 people worked in the fishing sector [33], and in the Maldives, the fishing sector accounts for 11% of employment. Bangladesh is one of the world's leading fish-producing countries with a total production of 4.28 million metric tons in 2017-2018, with 300,000 people directly involved in marine fishery [34] [35]. Although many stocks are overfished already, certain fishing sectors have expanded significantly in recent times. A typical example is the squid fishing off the coast of Oman, which has increased by 830% from 2015 to 2019 [36]. It is believed that about 13% - 14% of globally wild-caught fish stems from the Indian Ocean [37] [38]. In 2018, the end value of Indian Ocean yellowfin alone was more than US$4 billion, making it one of the world's most valuable fisheries [39]. In 2022, India reported exports of marine products valued at US$7.74 billion [39]. The species taken vary from region to region. Thus, Bangladesh harvests Bombay duck (*Harpadon nehereus*, 58,263 tons), pomfret (46.643 tons), Jewfish (*Argyrosomus japonicas*, 35,743 tons) as well as shrimp (52.217 tons) in the Bay of Bengal [40], especially in the Sundarbans. Mocambique has tuna and shrimp fishing (5878 tons) [41], but on a smaller scale. The dominant bottom fishery in the high seas of the South West Indian Ocean over the past several years has been the mid-water and bottom trawl fishery on or around seamounts for alfonsino (*Beryx splendens*) and orange roughy (*Hoplostethus atlanticus*). Other deep-sea species caught in this fishery include black oreo (*Allocyttus niger*), spiky oreo (*Neocyttus rhomboidalis*), smooth oreo dory (*Pseudocyttus maculatus*), black cardinal fish (*Epigonus telescopus*), bluenose warehou (blue-eye trevalla) (*Hyperoglyphe antarctica*), boarfishes (Caproidae), and pelagic armourhead (*Pseudopentaceros richardsoni*) [42].

It is known that parts of the Indian Ocean suffer from significant plastic pollution, however, much of the systematic research on MP abundance in different regions of the Indian Ocean stems only from the last five years. Typically, this can also be seen from the studies coming out of Bangladesh, where a review on plastic pollution in aquatic systems in Bangladesh [35] mentions solely two studies [43] [44] on MP ingestion by marine organisms in Bangladesh. Two years later, the interaction between marine organisms and MPs in the Gulf of Bengal is the topic of numerous papers [45]-[50]. MPs can be incorporated into the food chain at all trophic levels. Thus, it has been established by Botterell *et al.*, who have studied 39 zooplankton species from 28 taxonomic orders including holo- and meroplanktonic species that already zooplankton can ingest MPs [51]. These then will be transferred to secondary consumers [51]. Although the physiological effects of MPs on marine organisms are not yet well understood, Guzzetti *et al.* see MPs as one of the greatest threats to marine biodiversity in the world [52]. Botterell *et al.* stated that of the 22 studies that they reviewed 10 studies (45%)

showed a detrimental effect of MPs on zooplankton in regard to feeding behaviour, growth, development, reproduction, and lifespan [51]. Goswami *et al.* [53] detected MPs in 27 out of 30 samples of zooplankton, collected in Port Blair Bay, Andaman Islands. The average MP retention in whole zooplankton communities in Port Blair Bay was found to be 152.58 ± 177.09 MP/m^3 with a range between 18.89 MP/m^3 and 502.26 MP/m^3 [53]. For zooplankton sampled from the Sundarban mangrove forest in Bangladesh, Sarker *et al.* give an average number of 0.56 ± 0.25 MP/individual [50].

In fish, MPs have been seen to lead to a reduction in food intake, delayed growth, oxidative damage, and abnormal behavior [54]. Tissue damage in fish has been noted due to MPs, with MP ingestion leading to intestinal lesions in the Chilean nibbler (*Girella laevifrons*) [55]. MPs trigger a series of immune responses in fish [56]. At a molecular level, ROS levels in fish were seen to increase with exposure to MPs, leading to oxidative injury to tissues [57]. MPs also have been found to lead to transcriptional changes in adult zebrafish [56]. There is a persisting worry that MP content in commercially used marine organisms translates to a penetration of MPs into the human food chain, both through the direct consumption of seafood [58] and the use of fishmeal as feed for livestock and aqua-cultured species [59] [60]. It is thus of great importance to gauge the level of MP pollution in different regions of the world's oceans and in the marine organisms living there and being caught for human consumption.

Lately, there have been a number of reviews on the presence of plastics in general [37] and on MP presence in particular in different areas of the Indian Ocean [61] [62] [63] [64]. In the following, the authors have collated the available research data on MP contamination in commercially important fish species of the Indian Ocean, especially in the last decade. Data on MP presence in surface water, ocean sediments, intertidal sediments, and beaches in the Indian Ocean have been collected and are presented here, also.

2. Methods

To undertake this review, the authors have used the databases Scopus®, Scifinder® and Web of Science®. Typical keyword combinations used were "Indian Ocean AND microplastic", "Indian Ocean AND microplastic AND fish", "Indian Ocean AND beach AND microplastic", Indian Ocean AND sediment AND microplastic" to give as an example 81 entries, 26 entries, 30 entries, and 38 entries, respectively, in Web of Science®. In addition, combinations that included the name of a country bordering the Indian Ocean were looked for, also. Typical examples of such combinations are "Bangladesh" AND "microplastic", "Bangladesh" AND "microplastic" AND "beach", "Bangladesh", "microplastic" AND "fish", which gave 82 entries, 18 entries, and 30 entries, respectively, in Web of Science®. Publications by governmental organizations, Intergovernmental Organizations (IGOs) and or Nongovernmental Organizations (NGOs), which are often not abstracted by the databases named above, were searched for on the world-wide-web, utilizing the search words above. Abstracts of all entries were examined. When the abstract indicated that a quantitative analysis of microplastic in the region of the Indian Ocean was presented, the paper was obtained through the UAEU University library. All pertinent references in the given papers were analyzed for any missed publications. The "forward" citations given in the databases for the entries found in the databases were also examined for any missed publications. Papers were included in this review that detail quantitative analyses of microplastic in fish, water, beaches/coasts and sediments within the region of the Indian Ocean. No review was discarded on the basis of the actual data presented. Where data seemed to be in conflict with other published data, the conflict was stated in the review without evaluation of the actual data. To decide upon the commercial values of different fishes, capture production statistics from FAO Fisheries & Aquaculture were used. Species tables of fishbase (e.g. at https://www.fishbase.se/) were consulted for information on different fish species.

3. Abundance of Microplastic in the Indian Ocean

3.1. Influx of Microplastic into the Indian Ocean from Rivers and the Coastline and Beaching of the Microplastic

The nations surrounding the Indian Ocean as well as the island nations in the Indian Ocean have divergent policies in regard to plastic production, plastic usage and plastic waste disposal. Thus, after years of plastic bags challenging the solid waste management of its larger cities [65], Kenya put in place a ban on the manufacture, sale and use of single-use plastic carrier bags and has enforced a rather strict implementation of the policy, starting in 2017/2018 [66]. Other African countries, namely 34 out of 54 African countries have also exacted bans on plastic bags, but the bans are often difficult to implement, including in two other countries along the Indian Ocean, Somalia and Tanzania [67]. In Pakistan a plastic-bag free initiative was implemented to ban the manufacture and sale of plastic bags. Up to that point it is believed that about 55 million single use plastic bags were utilized in Pakistan, annually. Pakistan generated 6.41 million tons of plastic waste in 2010, making it the 6th largest producer of plastic waste at the time, but only generated 2.73 million tons in 2016 [68]. In contrast, Bangladesh was one of the first countries to ban single use plastic shopping bags, however, the enforcement of this ban has been difficult to achieve to date. In 2020, the High Court directed the authorities to ban single-use plastic in coastal areas and in the service industry throughout the country [69]. It has been estimated that India produces 26.3 million tons of plastic annually. According to the Indian Central Pollution Control Board, India produced about 3.5 million tons of registered plastic waste in 2019/2020, 50% of which was recycled. Nevertheless, it was calculated that every year 0.126 million tons of plastic are released from India into the marine environment [63], meaning into the Indian Ocean. Indonesia (3rd worldwide) and Thailand (5th worldwide) follow with 0.056 million tons and 0.023 million tons [63], respectively, a good portion of which flows into the

Indian Ocean. Also, South Africa with its long coastline along the Indian Ocean has been ranked within the top 20 countries with highest amount of mismanaged plastic debris in the world [70]. Altogether, it has been estimated that Indian Ocean rim countries produce between 41 million tons (2010) [71] and 24 million tons (2018) [72] of plastic waste. As a comparison, the estimate for plastic waste production in China for 2010 [71] and 2018 [72] was 59 million tons and 39 million tons, respectively. About 73% of this waste is thought to be mismanaged [37] [73]. Some of this plastic lands as macro- and mesoplastic on the shorelines, where it has been discarded, some of which will degrade to MP over time through physical and chemical action, through the action of wind, waves and tidal action on the one hand and through exposure to UV radiation and air oxygen on the other hand [74]. A significant percentage of the shorelines along the Indian ocean exhibit a high concentration of macro- and mesoplastic litter [75]. This includes the shorelines of islands in the Indian Ocean [76]. In addition, MPs are entering the Indian Ocean through load spillages from ocean-going ships. Typical examples of such accidents are the spillages of 1680 tons of 55 mm sized nurdles from the cargo ship M/V X-Press Pearl 18 km off the west coast of Sri Lanka in May 2021 [70] and of 49 tons of plastic pellets in the harbor of Durban, South Africa [77].

It is estimated that up to 15% of all coastal plastic and 20% of all riverine plastic enters the Indian Ocean [37] [78] [79]. However, of the main oceans, the Indian Ocean has been the least studied in respect to MP until about 5 years ago. It is considered that the MP concentration in the Indian Ocean is highly affected by the inflow of MPs from rivers. The Ganges is deemed the 2nd most polluting ocean bound waterway [80], with 0.10 - 0.17 million tonnes of plastic being released into the Bay of Bengal per year [78]. Napper *et al.* estimated that the Ganges, with the combined flows of the Brahmaputra and Meghna rivers could release up to 1 - 3 billion (10^9) MPs into the Bay of Bengal per day [81]. Therefore, the Bay of Bengal alongside the Eastern part of the Arabian Sea is seen as the largest coastal and riverine source for MP in the Northern Indian Ocean [37]. Other rivers have been looked at in regard to transporting MPs to the Indian Ocean. Different river estuaries move plastics into the marine environment in different degrees. Thus, most of the litter carried by a small seasonal river near Cape Town in South Africa, emptying a wetland area, was found to strand within 0.5 km of the river mouth during storm events, when the river mouth opened. Selvam *et al.* studied the Punnakayal estuary located on the south-east coast of India. It was found to be contaminated with up to 19.9 MPs per L, indicating the capability of this estuary to transport MPs from inland areas to the Gulf of Mannar [82]. Manickavasagam *et al.* [83] studied the transport of plastic debris from densely populated areas to seas through the South Juhu creek. Although the study revealed that a major proportion of transported plastic debris was comprised of macroplastic, fragmentation of such macroplastic can ultimately convert the material into MPs.

Elsewhere, a significant amount of MPs may be transported by the Indonesian throughflow from the North Pacific to the Indian Ocean. This means a prevailing westward transport by relatively fresh surface waters. Nevertheless, it has been found that MP abundances and variability of MP types along E-W transects in the Indian Ocean do not point exclusively to an MP origin from large river sources and the advection with low-salinity surface water of the Indonesian throughflow [84]. Rather the findings often suggest a regional or even local origin [84].

3.2. Transport of Microplastics with Ocean Currents and the Role of the Accumulation of Microplastics

Transport of buoyant MPs with currents takes place in the India Ocean (**Figure 1**). However, it must also be noted that in the Northern Hemisphere Indian Ocean (NHIO) buoyant plastic particles that have reached the ocean often end up beached along the northern coastline [85]. Due to the large South Indian landmass jutting into the Indian Ocean, there are two distinct subtropical basins, but there is no subtropical gyre in the NHIO with an associated plastic garbage patch. Some buoyant plastic pieces cross over to the Southern Hemisphere Indian Ocean (SHIO), especially along the East African coastline [85]. Some of the plastics then join the SHIO garbage patch. Van der Mheen *et al.* have noted that in the NHIO, the transport of plastics is dominated by seasonally reversing monsoonal currents, which transport plastics back and forth between the Arabian Sea and the Bay of Bengal. Thus, during the Southwest monsoon season, the flow is mostly towards the east, when there is no westward directed North Equatorial Current (NEC). During the NE monsoon season, the flow in NHIO is to the west, towards the Arabian Sea. At that time, the West Indian Coastal Current (WICC) and the East Indian Coastal Current (EICC) reverse their direction as does the Southwest Monsoon Current (SMC), which becomes the Northeast Monsoon Current (NMC). According to the simulation studies of van der Mheen *et al.*, the majority of the transported buoyant plastic beaches within a few years [85]. However beached material can refloat [86] [87]. It is interesting to note that much of the terrestrial debris beaching at remote western Indian Ocean islands such on the Seychelles is of plastic drifting from Indonesia, India, and Sri Lanka [88]. Previously, in 2015, Duhec *et al.* had already stated that much of the marine litter found on Alphonse Island, Seychelles, was derived from SouthEast Asia [89].

In the SHIO, there is a subtropical gyre with a garbage patch. The most important currents in the SHIO are the westward South Equatorial Current (SEC), the eastward flowing South Indian Counter Current (SICC), which flows through the center of the SHIO subtropical gyre, as well as the boundary giving Agulhas current (to the west, pointing towards the south), the Leuwin Current (to the east, pointing to the south), and the Antarctic Circumpolar Current (ACC, to the south, pointing to the east). The Indian Ocean meets the Pacific Ocean through an interface provided by the Indonesian archipelago, and as stated above, buoyant MP can travel through the Indonesian through-flow westward. SHIO meets the South Atlantic Ocean at about 35˚S, connecting through the Agulhas Retroflection

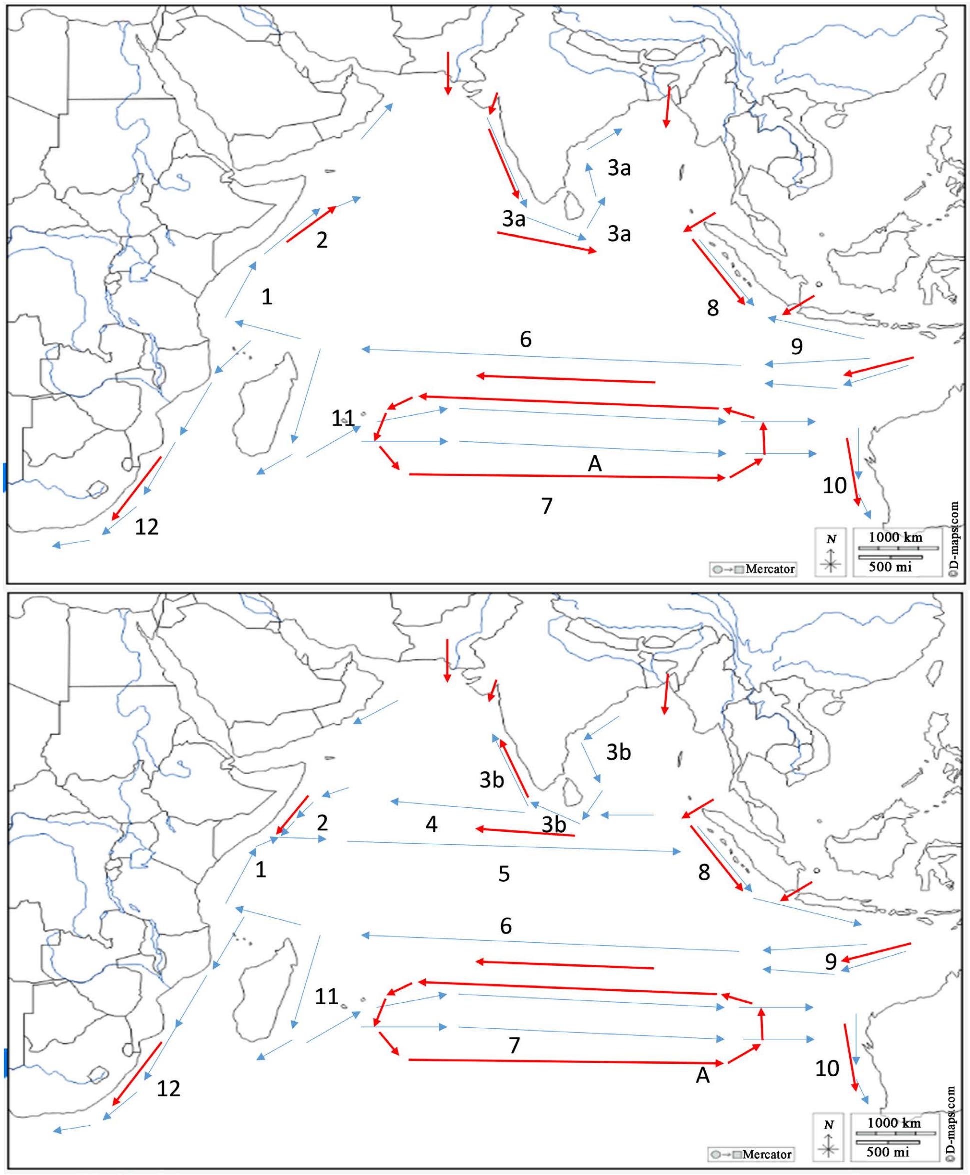
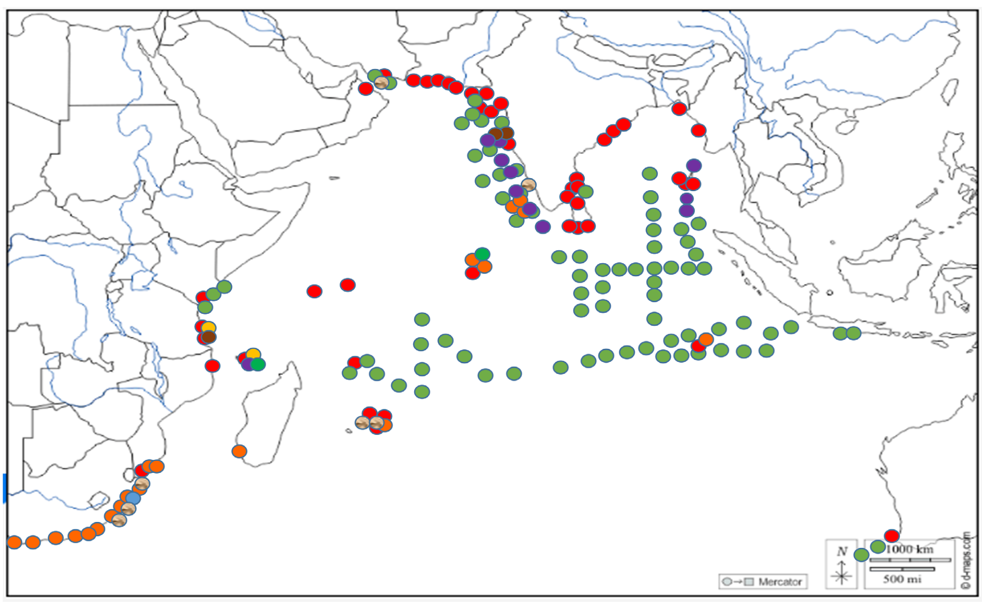


Figure 1. Major currents are shown (blue arrows): 1.) East African Coastal Current; 2.) Somali Current; 3a.) Southwest Monsoon Current; 3b.) Northeast Monsoon Current; 4.) North Equatorial Current; 5.) South Equatorial Counter Current; 6.) South Equatorial Current; 7.) South Indian Counter Current; 8.) South Java Current; 9.) Indonesian Throughflow; 10.) Leeuwin Current; 11.) East African Coastal Current; 12.) Agulhas Current. Major plastic inflows and transport pathways are shown, also (red arrows) (analogous to Ref. [37]).

and the Agulhas Leakage, and this allows for plastic transport between the two oceans [37]. When looking at the coastline of South Africa, however, Ryan noted that only a fraction of the plastic calculated to have been released from land into the Indian Ocean can physically be accounted for. While ultimately the seabed is likely to be the main long-term sink for the plastics, there is no proof of heightened concentrations of plastic and specifically of microplastic on the seabed off South Africa [90]. Little study has been carried out on the sinking of MPs through the water column to the Indian Ocean floor and its deposition within the ocean's sediments [37]. Solely, a study by Goswami *et al.* has looked at MP presence on the ocean floor of the Arabian Sea along the West Coast of the Indian subcontinent and of the Andaman Sea along the Andaman and Nicobar Island chain [91].

There have been investigations on the accumulation of MP at different locations in the Indian Ocean due to the occurrence of ocean fronts [37]. Physical processes can lead to situations where ocean currents flow towards each other. Fronts can be from a couple of hundreds meters in length to some thousand kilometers. They can be short-lived or semi-stationary. They can also re-emerge periodically in the same location. Water will sink at the front due to the convergent flow, however, MPs as buoyant material will float along the front, accumulating with new MP material transported by the incoming current. As the fronts are also areas, where heightened concentrations of nutrients attract fish and other marine organisms, they are also areas with a heightened MP ingestion by marine organisms [37]. Typical fronts are formed during the southwest monsoon season, where high-salinity upwelling water is pushing against low-saline run-off water stemming from rivers along the Indian Ocean coastline. A typical such studied example can be found along the coast of Sri Lanka [37] [92], another off the west coast of India [93].

Modeling combined with physical inventories of plastic on shorelines has shown the scale of plastic transport throughout the Indian Ocean. Thus, 52.4% of Kenyan mismanaged plastic that reaches the Indian Ocean ends up on the beaches of 26 countries, with India, Myanmar and Indonesia most affected [94]. In contrast, much of the South African mismanaged plastic that has been swept



● (beach) ● (beach, mesoplastics) ● (surface water) ● (subtidal) ● (sediments of shallow coastal water) ● (sediments off-shore) ● (harbor sediments) ● (surface water, harbor) ● (mangrove forest) ● (reef)

Figure 2. Main MP sampling locations on beaches, in subtidal sediments, in surface water and in mangrove and coral ecosystems.

out to sea is moved with the Agulhas current southward [94]. As mentioned above, much of the plastic litter found on the Seychelles Island chain stems for South East Asia [89].

3.3. Abundance of Microplastics in Offshore surface Waters of the Indian Ocean

Hildebrandt *et al.* [84] collected particulate matter from subsurface (6 m) water from 21 locations along an E-W transect through the tropical Indian Ocean, from off the southern coast of Sumatra through the south of the British Indian Ocean Territory to Mauritian waters. They found a concentration for the MP fraction > 300 μm of 0.1 ± 0.4 $MP{\cdot}m^{-3}$ [84]. This is similar to data gained for the North Sea (0.05 - 4.42 MP/m^3 for MP > 500 um in coastal surface waters) [95] and for the Northeast Pacific Ocean (0.19 MP/m^3 for MP > 500 um in subsurface waters) [96]. These numbers do not include fibers, where Hildebrandt *et al.* measured a blue anthropogenic fiber concentration of 3.2 ± 1.7 $fibers/m^3$ [84]. Here, the authors found the majority of the fibers to be natural fibers [84]. It had already been stated by Suaria *et al.* that natural fibers dominate the fiber contamination of our world's oceans [97] and that synthetic fibers only account for a small portion of the whole [96]. For MP of size 20 - 300 μm, Hildebrandt *et al.* measured a concentration of 8 to 132 $particles/fibers{\cdot}m^{-3}$ with an average of 50 ± 30 $MPs{\cdot}m^{-3}$ [84]. In comparison, Li *et al.* found a MP concentration of 1.3 ± 0.6 MP/m^3 for surface waters, 1.3 ± 1.0 MP/m^3 for intermediate waters and 1.3 ± 0.4 MP/m^3 for halocline waters, reporting only those MP particles above 62 μm [98]. In a further study, Li *et al.* found a MP concentration of 0.27 ± 0.19 MP/m^3, when sampling with a filter with a mesh size of 330 μm. For this, the ocean water was continuously pumped onboard from a depth of 5 m with an underway ship intake system [99]. Interestingly, Hildebrandt *et al.* did not find very high MP concentrations in the southern Indian Ocean gyre that was estimated to have the highest debris concentrations among all Ocean regions of the southern hemisphere [100].

Hildebrandt in their study found of the identified 1287 microparticles 49% to be acrylates/polyurethane (PU)/varnish (49%), followed by PET (26%), PP (8%), Ethylene-Vinyl Acetate (EVA) (4%), PE (4%), PS (2%), Polyvinyl Chloride (PVC) (2%), PC (2%), rubber (2%), Polyamide (PA) (1%), Chlorinated Polyethylene (PE-Cl) (<1%), PMMA (<1%), acrylonitrile butadiene (<1%) and silicone (<1%) [84]. Of the identified 194 MPs collected from the water column of the East Indian Ocean by Li *et al.*, 45.4% were Polytetrafluoroethylene (PTFE), followed by PET (14.4%), PP (10.8%), PMMA (9.3%), and PE (5.7%) [98]. In another study, Li *et al.* examined MP in the Eastern Indian Ocean with a size of more than 300 μm. Here, the dominant polymer type was PP (28.1%) [99].

4. Abundance of Plastic Debris and Specifically Microplastic in Coastal Sediments and on Beaches in the Indian Ocean

An abundance of research work on environmental presence and impact of MPs comes from Iran [101]. Hosseini *et al.* samples 10 locations along the shoreline of Chahabar Bay, Iran. MP density in beach sediments was found to be between 112 and 468 MP/kg with an average density of 262 ± 17 MP/kg [102]. The most abundant MP forms were fragments (42.34%) and fibers (32.22%), with PE (38%) and PET (29%) being the most common polymer [102]. Ahmed *et al.* looked at 25 locations along the Pakistani shoreline in Sindh and Balochistan and found an average MP concentration of 987.4 ± 617.1 MP/kg dw sediment, which is the highest MP concentration in sediments of beaches along the Indian Ocean [103]. In the autumn/winter season 2021/2022, Rabari *et al.* investigated 20 beaches on the Gujarat coast, India [104]. They found MP contamination varying between 1.4 MPs/kg sediment to 26 MPs/kg sediment. Fibers were by far the most abundant MP (89.98%). PP (47.5%), PE, and PS (25%) were seen to be the most common polymers [104]. A report from 2016 investigated the presence of Microplastic Pellets (MPPs) on beaches along the coast of Goa [105]. MMPs had already been reported as early as 1982 [106]. MMPs have been reported from many other beaches, such as from beaches along the Chennai coast, India [107], but also from different locations along the South African shoreline [108] [109]. Many MMPs derive from accidental land- and especially sea-based spillages. According to the carbonyl index values of the MMPs collected at different times of the year, it was noted that MMPs reach the coast predominately from the sea during the time of the Southwest monsoon [105]. In 2017, Tiwari *et al.* looked at Tuticorin beach in Thoothukudi district, Tamil Nadu. The beach is near a busy port and there are a number of industries nearby. The authors found 181 ± 60 MP/kg sediment (2.75 ± 0.03 mg MP/kg sediment), where fibers constituted the most abundant MP type, followed by plastic granules [110]. In winter 2020, Patchaiyappan *et al.* carried out a survey of 9 beaches in Odisha and reported a MP contamination of 258.7 ± 90.0 MP/kg sediment, with ranges from 378.3 ± 39.7 MP/kg to 153.3 ± 27.3 MP/kg. Interestingly, the authors reported dominance of plastic fragments (70.65%) over fibers (27.05%), followed by plastic spherules (2.30%) [111]. A similar distribution was found by Karthik *et al.* who screened 25 beaches in South East India along the Tamil Nadu coast [112]. Again, plastic fragments (47% - 50%) dominated over fibers (24% - 27%) [112], with an average MP concentration of 46.6 ± 37.2 MP/m^2 top soil of beach [112]. Mohan *et al.* investigated the MP contamination on tourist beaches of Port Blair in the Southern and Western part of the Andaman Islands. The particle count ranged from 72.5 - 475 particles/kg sediment [113]. The dominant polymeric forms were found to be High-Density Polyethylene (HDPE), Polystyrene (PS), Polypropylene (PP) and Polyethylene Terephthalate (PET) [113]. The beach at Cox's Bazar on the Southeastern tip of Bangladesh showed 8.1 ± 2.9 particles/kg sediment, with PP (47%) and PE (23%) being the main plastics involved. Along the Cox Bazar beach, there are salt pans. The reclaimed salt has been found to carry MP as well at a concentration of 28.5 ± 2.4 - 93.5 ± 4.2 P/kg [114]. Here, interestingly, the dominant MP material is polyester, so that the MP found on the beach and within the salt pans may well stem from different sources

[115].

In 2017, beaches along 91 km of coastline in Southern Sri Lanka were scrutinized for MP content, where 60% of the sites showed MP contamination. 2 sites showed the presence of pristine plastic micropellets, stemming from accidental spillage [116]. Abundant polymers were PE, PP and PS [116].

Not much studied is the Myanmar coast, the coast of Thailand facing the Indian Ocean, and Indonesia, specifically the coast of Western Sumatra facing the Indian Ocean [117]. Balasubramanian and Phillott give an average of 3.3 MP/25 g sediment, mostly fibers, as the plastic contamination on Ngapali Beach, near Thandwe, Rakhine State, Myanmar [117]. For a review on work on microplastic in Indonesia, the reader is referred to Sari *et al.* [118]. Hardesty *et al.* have studied the distribution of marine debris along the coastlines of Australia by surveying 175 sites [119]. They found three hotspots with elevated levels of debris, namely the west coast of Tasmania, the stretch between Brisbane and Melbourne and the Southwestern tip of Australia, south of Perth, which is facing partially the Indian Ocean [119]. 68% of the debris was found to be plastic [119].

Dunlop *et al.* have studied the accumulation of marine debris on the beaches of Cousine Island, Seychelles, in 40 surveys stemming from the years 2003 to 2019. The mean accumulation was measured to be 0.0082 items$\cdot m^{-1}\cdot$(beach)$\cdot d^{-1}$ for debris in general, 0.00249 items$\cdot m^{-1}\cdot d^{-1}$) for polystyrene fragments and, 0.00135 items$\cdot m^{-1}\cdot d^{-1}$ for plastic items in general [120]. Little information was available about MP presence on the Mauritian coastline until a study by Mattan-Moorgawa *et al.* in 2021, who reported MP concentration ranging from 8.4 ± 1.00 MP/m^2 at Baie du Cap to 196 ± 2.84 MP/m^2 at La Cambuse. In Mauritius, the highest meso-plastic density obtained was 5.67 items/m^2 [121].

By 2018, 85 sites on South Africa's coast had been scrutinized for mesoplastic and 15 for microplastic [122]. Thus, Ryan *et al.* have sampled 82 South African beaches for mesodebris (2 - 25 mm) in 1994, 2005, and 2015. The litter was found to be mostly comprised of plastic items (99% by number, 95% by mass). Industrial pellets were the dominant type of litter. From the distribution of the plastic the authors came to the conclusion that the plastic was derived from local land-based sources. Little differences in quantity or distribution of beached plastic were found over the two decades 1995-2015 [108]. Also, Chitaka and von Blottnitz studied the accumulation rate of plastic debris, this time along five beaches in Cape Town, some which of are on the South Atlantic coast [123]. The authors calculated a debris accumulation of 36 - 2961 particles per day along 100 m of beach front. Plastic made up 94.5% - 98.9% of the particles [123]. In 2013, Lamprecht found an average load of 30.900 MP/m^3 sediment when sampling Milnerton Beach, Table Bay, Cape Town [124]. In 2015, Nel and Froneman looked at the MP concentration at 21 sites along the south-eastern coastline of South Africa [125]. They found a MP density between 688.9 ± 348.2 MP/m^2 sediment and 3308 ± 1449 MP/m^2 [125]. Five years later, Vetrimurugan *et al.* published on MP presence at nine southeastern South African touristic beaches along the KwaZulu-Natal coast and found the highest density of MPs (506 MP/30 g sediment) in beach sediments in the Durban area [126]. The majority of MP were found to be microfibers, and in 2016-2017, S. De Villiers looked at the microfiber concentration in South African beach sediments, both along the Indian Ocean coastline and along the South Atlantic coastline and found 41 ± 23 F/dm^3 for the South Coast in Spring 2017, 97 ± 122 F/dm^3 for the South-East coast and 127 ± 96 F/dm^3 for the East coast [122]. Few investigations on microplastic presence in the marine environment have come out of Mozambique, although Mozambique and its territorial waters encompasses some of the most productive ecosystems in the Indian Ocean with high biodiversity [127], being home to 264,000 hectares of mangroves [128], an estimated 186,000 hectares of coral reefs [129], and 43,900 hectares of seagrass beds [130]. Interestingly, in their seminal paper on MP density on beaches around the world from 2011, Browne *et al.* [131] included one sampling site (Pemba) from Mozambique. Earlier, Barnes had studied macro- and mesoplastic contamination (particle size > 1 cm^2) on Quirimbas Island and Inhaca Island [132]. In the most comprehensive study out of Mozambique to date, in 2015, Karlsson described in a MSc thesis the plastic contamination of 3 coastal locations in the Maputo area that include Inhaca Island [133]. In Tanzania, Barnes studied mesoplastic contamination on beaches in Pemba [132]. For Dar es Salaam's beaches and shoreline sediments, a very high average MP concentration of 864.15 ± 275.10 MPs/kg sediment has been reported [134].

Physical studies on the occurrence of MPs along the coast, the water column, the sea floor and in marine organisms of the Indian Ocean have become quite extensive over the last 5 years (**Figure 2**). Overall, MP quantification in sediments along the coastline of the Indian Ocean, especially on beaches has been carried out in a large number of locations (**Figure 2**). Starting with the Northwestern coastline and then turning clockwise, the following are some of the values that have been published, given either as number of MP per kg of dry sediment or number of MP per m^2 surface with a defined thickness of layer analyzed: Chahabar Bay, Iran: Chahabar City (urban) (431 ± 27 MP/kg); Tis (urban) Sampling Site 1 (urban) (324 ± 12 MP/kg); Site 2 (rural) (272 ± 22 MP/kg); Site 3 (rural) (169 ± 16 MP/kg); Site 4 (rural) (137 ± 11 MP/kg); Site 5 (desalination plant) (145 ± 7 MP/kg); Nassarabad Village sampling Site 1 (semi-rural) (302 ± 19 MP/kg); Site 2 (commercial site) (216 ± 14 MP/kg); Konarak City (urban, commercial site) (374 ± 25 MP/kg); Konarak City, Site 2 (urban, recreational activity) (256 ± 18 MP/kg) [102]; Balochistan, Pakistan: Thaq (Taak) (beach, rocky, rural) (475 P/kg); Ormara (rocky coast, urban) (650 P/kg); Ballro (rural) (510 P/kg); Kund Malir (beach, rocky, rural) (450 P/kg); Sapat (beach, rural) (850 P/kg); Sonmiani (bay area; urban) (2090 P/kg); Hub estuary (sandy, rural) (475 P/kg); Sunehri (beach, rocky, rural) (895 P/kg); Mubarak village (beach, rocky, rural) (1170 P/kg) [103]; Sindh, Pakistan: Shah Bandar (Indus delta, muddy, rural) (0 P/kg); Kharochan (Indus delta, muddy, rural) (1155 P/kg); Jhangisur (Indus delta, muddy, rural) (1110 P/kg); Ketibandar (Indus delta, muddy, rural) (2080 P/kg); Khararo creek (Indus delta, muddy, rural) (630 P/kg); Ibrahim hyderi (creek area, muddy, urban) (1280 P/kg), Clifton beach (beach, urban) (1710 P/kg); Manora (rocky, urban) (2645 P/kg); Sandspit (beach, urban) (1105 P/kg), Hawksbay (beach, urban) (700 P/kg) [103] (12P/25g = 480 P/kg [fibers]) [117]; Abdul Rehman Goth (beach, rocky, urban) (735 P/kg); Buleji (rocky beach, urban) (795 P/kg); Cape Monze (beach, rocky, urban) (645 P/kg) [103]; Gujurat, India: Mandvi (beach) (21.1 ± 28.4 MP/kg), Asharmata (beach) (18.0 ± 12.7 MP/kg), Dhamlej (beach) (17.2 ± 7.2 MP/kg), Kodinar (beach) (19.8 ± 13.5 MP/kg), Sutrapadar-1/-2 (for 1: 25.9 ± 29.0 MP/kg; for 2: 9.8 ± 11.2 MP/kg) (beach), Dwarka (22.6 ± 16.4 MP/kg) (beach), Mithapur (8.7 ± 10.7 MP/kg) (beach), Shivrajpur (14.2 ± 13.1 MP/kg) (beach), Okha (8.1 ± 6.1 MP/kg) (beach), Ghoghla (2.1 ± 3.7 MP/kg) (beach), Diu (3.8 ± 2.9 MP/kg) (beach), Vanakbara (6.0 ± 8.4 MP/kg) (beach), Somnath (21.9 ± 20.7 MP/kg) (beach), Veraval (12.9 ± 11.1 MP/kg) (beach), Madhavpur (2.5 ± 6.0 MP/kg) (beach), Porbandar (1.4 ± 1.0 MP/kg) (beach), Kuchhdi (12.4 ± 9.6 MP/kg) (beach), Serena (1.3 ± 2.4 MP/kg) (beach), Modhva (3.3 ± 5.6 MP/kg) (beach) [85]; Mumbai, India: Girgaon-Chowpatty (beach) (220 ± 50 MP/kg) [110]; Mumbai, India: Juhu (85.9 MP/m^2) [135]; Tamil Nadu, Thoothukudi, India: Vembar (beach) (19.0 ± 18.62 MP/kg); Threspuram (beach) (78.55 ± 95.17 MP/kg) [136]; Goa, India: Palolem Beach (beach) (13.0 P/25g [fibers]) [117]; Tuticorn group of GoM islands, South India: Vaan (126.9 ± 18.3 MP/kg); Koswari (111.4 ± 12.4 MP/kg); Kariyachalli (82.0 ± 12.1 MP/kg); Vembar group of GoM islands, South India: Upputhanni (59.1 ± 13.9 MP/kg), Pullivinichalli (65.3 ± 12.4 MP/kg); Nallathanni (92.9 ± 17.3 MP/kg); Keelakarai group of GoM islands: Anaipar (61.3 ± 11.5 MP/kg); Valimunai (50.2 ± 10.8 MP/kg); Appa (46.4 ± 10.8 MP/kg); Thalayari (40.2 ± 9.9 MP/kg); Valai (31.9 ± 9.0 MP/kg); Mulli (27.6 ± 11.1 MP/kg); Mandapam group of GoM islands, South India: Hare (32.2 ± 8.8 MP/kg), Manoli (36.8 ± 10.5 MP/kg), Manoliputti (32.5 ± 9.0 MP/kg), Poomarichan (70.3 ± 11.3 MP/kg), Pullivasal (56.3 ± 9.0 MP/kg), Krusadai (95.6 ± 11.7 MP/kg), Shingle (108.4 ± 15.8 MP/kg) [137] Tamil Nadu, Thoothukudi, India: Tuticorin (beach) (181 ± 60 MP/kg) [110]; Tamil Nadu, Pamban Island, India: Dhanushkodi (beach) (45 ± 12 MP/kg) [110]; Puducherry Coast, India: Auroville (beach) (23.40 ± 3.38 MP/kg), Bommayarpalayam (beach) (23.80 ± 3.80 MP/kg), Serenity (beach) (135.67 ± 12.00 MP/kg), Veerampattinam (beach) (106.50 ± 16.83 MP/kg), Paradise (beach) (48.17 ± 8.73 MP/kg), Pondicherry University (beach) (94.67 ± 10.38 MP/kg) [20]); Silver beach (beach), Gadilam river, Tamil Nadu: 204 MP/kg [138]; beaches along the coat of Tamil Nadu: Ennore (HTL: 68.9 MP/m^2; LTL: 21.6 MP/m^2) (beach near a river mouth); Cooum (LTL: 50 MP/m^2) (beach near a river mouth); Adyar (LTL: 64.5 MP/m^2) (beach near a river mouth); Muttukadu (HTL: 51.5 MP/m^2; LTL: 29.3 MP/m^2) (beach near a river mouth); Puducherry (HTL: 52.6 MP/m^2; LTL: 8.9 MP/m^2) (beach near a river mouth); Cuddalore (HTL: 48.7 MP/m^2; LTL: 2.9 MP/m^2) (beach near a river mouth); Pazahayar (HTL: 19.9 MP/m^2; LTL: 6.8 MP/m^2) (beach near a river mouth); Nagapattinam (LTL: 17.8 MP/m^2; HTL: 81.0 MP/m^2) (beach near a river mouth); Manamelkudi (LTL: 2.9 MP/m^2; HTL: 17.0

MP/m^2) (beach near a river mouth); Tuticorin (LTL: 5.0 MP/m^2; HTL: 43.3 MP/m^2) (beach near a river mouth) [138]; Marakkanam (HTL: 49.7 MP/m^2; LTL: 8.9 MP/m^2) (fishing beach); Parangipettai (HTL: 45.0 MP/m^2; LTL: 8 MP/m^2) (fishing beach); Mallipattinam (LTL: 2.9 MP/m^2; HTL: 22.3 MP/m^2) (fishing beach); Thondi (HTL: 32.0 MP/m^2; LTL: 3.0 MP/m^2) (fishing beach); Killakarai (HTL: 23.5 MP/m^2; LTL: 3.8 MP/m^2) (fishing beach); Manapad (HTL: 17.0 MP/m^2; LTL: 1.9 MP/m^2) (fishing beach); Idinthakarai (HTL: 8.9 MP/m^2; LTL: 2.9 MP/m^2) (fishing beach) [112]; Mahabalipuram (HTL: 49.4 MP/m^2; LTL: 13.5 MP/m^2) (beach); Poompuhar (LTL: 8.1 MP/m^2; HTL: 22.6 MP/m^2) (beach); Karaikal (LTL: 9.0 MP/m^2; HTL: 25.5 MP/m^2) (beach); Velankanni (LTL: 2.9 MP/m^2; HTL: 56.7 MP/m^2) (beach); Rameshwaram (HTL: 48.6 MP/m^2; LTL: 7.9 MP/m^2) (beach); Tiruchendur (HTL: 37.6 MP/m^2; LTL: 8.1 MP/m^2) (beach); Uvari (HTL: 17.0 MP/m^2; LTL 1.9 MP/m^2) (beach); Kanyakumari (HTL: 18.2 MP/m^2; LTL: 8.9 MP/m^2) (beach); Odisha, India: Chandipur (beach), (376.7 ± 25.8 MP/kg), Golden beach (273.3 ± 34.4 MP/kg), Sunapar (beach) (161.7 ± 32.5 MP/kg), Swargadwara (beach) (378.3 ± 39.7 MP/kg), Abhayachandpur (beach) 153.3 ± 27.3 MP/kg), Gopalpur (beach) (203.3 ± 18.6 MP/kg), Chandrabhaga (beach) (341.7 ± 37.6 MP/kg), Beleswar (beach) (258.3 ± 30.6 MP/kg), Paradeep (beach) (181.7 ± 64.9 MP/kg [111]); Northern Province, Sri Lanka: Thumpalai Beach (beach) 9/6 P/25 g [fibers]) [117]; Matara Province, Sri Lanka: Thalalla (0 MP/m^2); Dondra Harbor (738 ± 195 MP/m^2); Weligama (10m/20m from the waterline: 0 MP/m^2; 157 ± 94 MP/m^2); Galle Province, Sri Lanka: Koggala (0 MP/m^2); Unawatuna (0 MP/m^2); Galle (10m/20m from the waterline: 0 MP/m^2/54 ± 23 MP/m^2); Rathgama (10m/20m from the waterline: 125 ± 50 MP/m^2/133 ± 63 MP/m^2); Hikkaduwa (10m/20m from the waterline: 97 ± 93 MP/m^2/8 ± 8 MP/m^2); Kahawa (10m/20m from the waterline: 0 MP/m^2/21 ± 21 MP/m^2); Ambalangoda Harbor (10m/20m from the waterline: 6 ± 6 MP/m^2/48 ± 6 MP/m^2) [116]; Negombo, Western Province, Sri Lanka: Pitipana (beach) (7.20 ± 7.66 MP/m^3), Catamaran (beach) (2.80 ± 1.30 MP/m^3), Dūwana (beach) (5.20 ± 3.77 MP/m^3) [139]; Dune area, Bundala National Park, Sri Lanka (39 ± 3 MP/m^2 - 196 ± 13 MP/m^2) [140]; Hikkaduwa Marine National Park, Sri Lanka, high tide line (100 ± 1 MP/m^2 - 204 ± 16 MP/m^2); Andaman Islands, India: Corbyn's Cove beach, Port Blair (beach) (188.61 ± 81.15 MP/kg); Wandoor Beach, Port Blair (beach) (249.82 ± 105.78 MP/kg); Quarry Beach (beach) (135.625 ± 62.83 MP/kg) [113]; North Wandoor Beach (323.3 ± 36.7 MP/kg); Wandoor Beach (345.0 ± 57.9 MP/kg); Burmanullah (161.7 ± 32.5 MP/kg); Corbyn's Cove (250.0 ± 42.0 MP/kg); Haddo (510.0 ± 59.3 MP/kg); Chota Balu (378.3 ± 35.5 MP/kg) [141]; Bangladesh: Cox's Bazar (beach) (12.3 P/kg [fibers]) [84]; Myanmar: Ngapali Beach (beach) 3.3 P/25g [fibers]) [117]; Maledives: Dhuni Kolhu (beach) (4.3 P/25g [fibers]) [117]; Naifaru, Maledives: beach, average of 24 sampling points (241.88 ± 15.87 MP/kg) [142]; Trou d'Eau Douce, East coast, Mauritius (public beach), La Cambuse, South-east coast. Mauritius (public beach) [143]; Wolmar, West coast, Mauritius (beach) (VL: 21.8 MP/m^2; BS: 11.5 MP/m^2; SL: 8.3 MP/m^2); Flic en Flac, West coast, Mauritius (beach) (VL: 24.7 MP/m^2; BS: 14.2

MP/m^2; SL: 5.6 MP/m^2); Sable Noir, West coast, Mauritius (beach) (VL: 27.3 MP/m^2; BS: 19.7 MP/m^2; SL: 11.3 MP/m^2); Mon Choisy, North-west coast, Mauritius (beach) (VL; 32.0 MP/m^2; BS: 23.4 MP/m^2; SL:9.4 MP/m^2); Pointe aux Cannoniers, North coast, Mauritius (beach) (VL: 45.3 MP/m^2; BS: 32.5 MP/m^2; SL: 16.6 MP/m^2); Flat Island, North coast, Mauritius (beach) (VT: 83.0 MP/m^2; BS: 68.0 MP/m^2; SL: 28.1 MP/m^2); Baie du Cap, South coast, Mauritius (beach) (VL: 24.2 MP/m^2; BS: 5.4 MP/m^2; SL: 8.9 MP/m^2); Bel Ombre, South coast, Mauritius (beach) (VL:17.5 MP/m^2; BS: 15.6 MP/m^2; SL: 9.7 MP/m^2); La Cambuse, South-east coast, Mauritius (beach) (VL: 89.2 MP/m^2; BS: 67.8 MP/m^2; SL: 39/3 MP/m^2); Pointe D-Esny, South-east coast, Mauritius (beach) (VL: 88.5 MP/m^2; BS: 32.8 MP/m^2; SL: 38.0 MP/m^2); Vieux Grand Port, (VL: 52.7 MP/m^2; BS: 31.5 MP/m^2; SL: 29.5 MP/m^2); South-east coast, Mauritius (beach); Belle Mare, East coast, Mauritius (beach) (VL: 48.0 MP/m^2; BS: 35.7 MP/m^2; SL: 31.7 MP/m^2) [121]; Indonesia, Java: Cilacap Coast (16.8 - 41.6 macroplastics/m^2) [144]; Western Australia: Busselton Beach (21 - 30 MP/250 mL) [131]; Western Australia: Rottnest Island: Bickley Bay (15.5 ± 6.6 MD/50mT); Kingston Beach (13.8 ± 6.5 MD/50mT); South Thomson Bay (67.5 ± 14.4 MD/50mT); North Thomson Bay (81.3 ± 17.7 MD/50mT); Pinkies Beach (65.7 ± 44.8 MD/50mT); Parakeet Bay (13.0 ± 2.5 MD/50mT); Little Armstrong Bay (27.8 ± 6.6 MD/50mT); Ricey Beach (23.8 ± 4.2 MD/50mT); Stark Bay (142.5 ± 93.7 MD/50mT); Rocky Bay (22.8 ± 14.2 MD/50mT); Eagle Bay (158.5 ± 10.5 MD/50mT); Strickland Bay (200.3 ± 94.7 MD/50mT); Green Island Bay (Nancy Bay) 171.8 ± 36.6 MD/50mT); West Salmon Bay (142.3 ± 59.7 MD/50mT); Parker Point (38.0 ± 8.9 MD/50mT); Henrietta Rocks (Porpoise Bay) (48.5 ± 11.2 MD/50mT); on average 82% of MD count are plastic particles [145]; Exmouth (3.3 P/25g [fibers]) [117]; Cocos Keeling Islands (Australia): Direction Island (3.85 MP/m^2); Home Island (17.20 ± 18.08 MP/m^2); Horsburgh Island (12.69 ± 6.28 MP/m^2); South Island (8.13 ± 6.09 MP/m^2); West Island (18.78 ± 19.68 MP/m^2) [146]; Alphonse Island, Seychelles (4.7 MD/m T) [89]; Mayotte: Titi Moya (marine educational area, subtidal, at 3 m depth) [4.3 ± 0.5 ML/500m^2 (Aug. 2018); 5.3 ± 1.6 ML/500m^2 (Feb. 2019)]; Sakouli (beach at Voulé, subtidal, at 3 m depth; [1.8 ML/500m^2 (Aug. 2018); 0.8 ML/500m^2 (Feb. 2019); Ilot sable blanc Saziley (beach, subtidal, at 3m depth) [0.16 ML/500m^2 (Aug. 2018); 0.6 ML/500m^2 (Feb. 2019)]; Bambo SE (beach, subtidal, at 3 m depth) [0.08 ML/500m^2 (Aug. 2018); 3.9 ML/500m^2 (Feb. 2019)]; Musical Plage (beach, at 3 m depth) [4.8 ML/500m^2 (Aug. 2018); 2.7 ML/500m^2 (Feb. 2019)]; Tzoundzou (reef, subtidal, at 3 m depth) [2.8 ML/500m^2 (Aug. 2018); 3.8 ML/500m^2 (Feb. 2019)]; M'Tzamboro (beach, subtidal, at 4 m depth) [1.1 ML/500m^2 (Aug. 2018); 1.2 ML/500m^2 (Feb. 2019)]; Doimougno (GCRMN, subtidal, at 3 m depth) {17. ML/500m^2 (Aug. 2018); 2.2 ML/500m^2 (Feb. 2019)]; Handrema (beach, subtidal, at 3 m depth); Boueni (Znieff, subtidal, at 3 m depth); M'zouazia (Znieff, subtidal, at 3 m depth); Ngouja (Znieff, subtidal, at 3 m depth); Saziley (beach, GCRMN, subtidal, at 3 m depth); M'Tsanga Fanou (underwater boardwalk, subtidal; at 4 m depth); Tanaraki (GCRMN, subtidal, at 3 m depth); M'Tsanga Nyamba (Znieff, subtidal, at 3 m depth); Sada (beach, subtidal, at 3 m depth) M'Bouzi ouest (natural reserve, subtidal, at 3 m depth) [41.5 ± 8.5 ML/500m^2 (Aug. 2018); 36.5 ± 4.5 ML/500m^2 (Feb. 2019)]; M'Bouzi est (natural reserve, subtidal, at 4 m depth); Majikavo (beach, subtidal at 3 m depth); Koungou (GCRMN, subtidal, at 3 m depth); Longoni (GCRMN, subtidal, at 1.5 m depth) [147]; Southeast coast of South Africa along the KwaZulu-Natal coastline: Sodwana Bay (427 MP/30 g sediment); Saint Lucia (212 MP/30 g sediment); Richards Bay (212 MP/30 g sediment); Mtunzini, Zinkwazi (156 MP/30 g sediment); Ballito North (386 MP/30 g sediment); Ballito South (164 MP/30 g sediment); Durban North (476 MP/30 g sediment); Durban South (506 MP/30 g sediment) [126]; Southeast coast, South Africa: Aston Bay (618.0 ± 532.1 MP/m^2); Bluewater Bay (2215 ± 1305 MP/m^2); Diez Strand (1013 ± 755 MP/m^2); Hartenbos (1717 ± 790 MP/m^2); Jeffrey's Bay (1030 ± 567 MP/m^2); Keurbooms (1717 ± 670 MP/m^2); Kleinbrak (1288 ± 378 MP/m^2); Port Elizebeth Main (1597 ± 429 MP/m^2); Plettenberg Bay (1930 ± 343 MP/m^2); Robberg (1030 ± 652 MP/m^2); St. Francis (1185 ± 123 MP/m^2); Summerstrand (1373 ± 841 MP/m^2); Buffel's Bay (1116 ± 652 MP/m^2); Cannon Rocks (1579 ± 1123 MP/m^2); Danabaai (site 1) (1459 ± 1717 MP/m^2); Danabaai (site 2) (1545 ± 858 MP/m^2); Kenton (1116 ± 601 MP/m^2); Nature's Valley (1202 ± 772 MP/m^2); Oyster Bay (2636 ± 612.2 MP/m^2); Sedgefield (2411 ± 297.7 MP/m^2); Skuitbaai (3308 ± 1449 MP/m^2) [125]; Durban Harbor [1789 P/1200 mL (peak value)] [148]; Maputo, Mozambique: Marine Station, Inhaca Island (40 - 205 P/100mT); Catembe (980 - 37,575 P/100mT); Saco, Inhaca Island (0 - 47 P/100mT) [133]; Pemba, Mozambique (21 - 30 MP/250 mL) [131]; Pwani, Tanzania: Mission Cross Beach (beach) 589 ± 99 MP/kg; Dar es Salaam, Tanzania: Mtoni Kijichi Creek (beach) (2972 ± 238 MP/kg); Temeke (4.6 P/25g [fibers]) [117]; Mtwara, Tanzania: Ruvula (beach) 15 ± 4 MP/kg [149]; Tanzania, Dar es Salaam: Ocean Road (beach) (643.98 ± 77.13 MP/kg); Tegeta Estuary (shoreline) (1578.4 ± 38.2 MP/kg); Kundunchu (beach) (1176.88 ± 28.62 MP/kg) [134]; Tanzania, Zanzibar: Bububu (beach) (507.24 ± 36.93 MP/kg) [134]; (MD: Oman (non-specified) (11 - 20 MP/250mL) [131]. Abbreviations used: marine debris; ML: Microliter; T: transect; GCRMN: Global Coral Reef Monitoring Network; HTL: High Tide Line: LTL: Low Tide Line; SL: Strandline; BS: Beach Slope; VL: Vegetation Line; P: plastic particle of undefined size; ZNIEFF: Zone Naturelle d'Intérêt Écologique, Faunistique et Floristique).

Little is known about the MP contamination in offshore coastal sediments. Girjar *et al.* [150] reported an abundance of MP in sediments off the coast of Mumbai of 4400 particles/kg and 15,300 particles/kg dw sediment. Differences of MP presence at different depths were noted: 9700 - 15,300 particles/kg at <10 m depth, 6900 - 10,800 particles/kg at 10.1 - 15 m depth, 4400 - 7900 particles/kg at a depth of >15 m [150]. Gupta *et al.* looked at MP presence in the sediments of the estuarine area of the Mandovi-Zuari system in Goa, India, sampling up to 6 km away from the estuarine mouth. The depths of the nearshore sampling stations ranged from 12 to 30 m. MP contamination varied between the wet season (September, with 7314 MP/kg sediment) and the dry season (April, with 4873

MP/kg sediment) [151]. The estuary in Goa showed 3950 ± 930 MP/kg sediment at a depth of 2 - 3 m. Here, however, the samples were taken in the estuary at a location before the river meets the sea [152]. The Kayamkulam estuary near Kollam, Kerala, shows much less MP contamination at 433 M/kg sediment [153]. Dominant polymers were found to be polyester, followed by PE and PP. Here, again the sampling sites are at locations before the river meets the sea. Importantly, Goswami *et al*. sampled the ocean floor at 8 locations in the Arabian Sea along the West coast of India at depths of 76 to 264 m. Also, the study included sampling at 14 locations in the Andaman Sea. A mean MP value of 128.02 ± 33.92 particles per kg sediment was found for the ocean floor sediment in the Arabian Sea, 15.36 ± 2.61 particles per kg were found for the Andaman Sea ocean floor [91]. Here, fibers, followed by fragments and pellets were the dominant MP forms. On the African coast, Nchimbi *et al*. sampled the seabed at a depth of 10 - 30 m off the shoreline of Dar es Salaam and Zanzibar, Tanzania [134]. Interestingly, the study revealed significantly lower MP concentrations in the seabed sediments (79.9 ± 21.5 MPs/kg sediment) than in the beach sediments (864.15 ± 275.10 MPs/kg sediment), seeming to indicate little transfer of the plastic from the beaches to the seabed in these locations [134].

5. Abundance of Plastic Debris and Specifically Microplastic in Coastal Waters in the Indian Ocean

70% of the coastal water sites off the Southern coast of Sri Lanka that Koongolla *et al*. sampled in 2018 were found to have MP content [91] with a concentration of 1 - 29 MP/m^3 of surface water [116] (**Figure 2**). In 1977 and 1978, Ryan sampled surface water off the south-western Cape Province and found a mean particle density of 3.64 P/m^2, comprising mostly industrial pellets, fibers plastic product fragments, and foamed plastics [154]. In 2015, Nel and Froneman looked at the MP concentration in surf-zone water at 21 sites along the south-eastern coastline of South Africa [125]. They found concentrations of between 257.9 ± 53.4 P/m^3 and 1215 ± 276.7 P/m^3 [125]. In 2016, 43 manta trawl samples from 5 sites along the KwaZulu-Natal coastline were taken within 5 km of the shoreline. An average of 4.01 ± 3.28 plastic particles/100m^2 was found in the surface trawls. Plastic concentrations in the winter were significantly higher than those in the summer (5.54 ± 3.26 vs. 2.96 ± 2.94 particles/100m^2) [155]. Further north, along the Kenyan coast, coastal water samples were taken at Malindi, Mombasa and 4 other locations. MPs at an average concentration of 0.58 ± 1.29 MPs/m^3 were observed, with a maximum concentration of 3.22 ± 2.0 MPs/m^3 off Malindi [156]. Fragments and films were by far the most common MP type. Only 2% of the MPs were found to be fibers. The authors rationalized the overwhelming presence of fragments and fibers as part of the legacy of an extensive use of plastic bags, although at the time of the study single-use plastic bags had already been banned in Kenya. PP and PE, both HDPE and LDPE, were found to be the most common polymers [156]. Overall, the following measurements on the MP concentration in the surface water at different locations within the Indian Ocean have been published (**Figure 2**). The following gives some of the published values of MP in surface water along the coast, starting with the Northwestern coastline and then again turning clockwise: Chabahar Bay, Iran: Ramin (0.25 ± 0.15 MP/m^3); Daryabozorg (0.59 ± 0.22 MP/m^3); Beheshti (1.14 ± 0.27 MP/m^3); Tis (0.07 ± 0.03 MP/m^3); Konarak desalination plant (0.23 ± 0.13 MP/m^3), Konarak (0.98 ± 0.18 MP/m^3) [157]; Chahabar City (urban) (328 ± 32 MP/L); Tis (urban) Sampling site 1 (urban) (276 ± 17 MP/L); site 2 (rural) (238 ± 19 MP/L); site 3 (rural) (157 ± 12 MP/L); site 4 (rural) (123 ± 8 MP/L); site 5 (desalination plant) (104 ± 13 MP/L); Nassarabad Village sampling site 1 (semi-rural) (264 ± 20 MP/L); site 2 (commercial site) (198 ± 16 MP/L); Konarak City (urban, commercial site) (287 ± 21 MP/L); Konarak City, Site 2 (urban, recreational activity) (208 ± 19 MP/L) [102]; Balochistan, Pakistan: Kalmat (rural) (750 P/L); Thaq (Taak) (rural) (267 P/L); Ormara (rocky coast, urban) (351 P/L); Ballro (rural) (477 P/L); Kund Malir (rural) (296 P/kg); Sapat (rural) (383 P/L); Sonmiani (bay area; urban) (941 P/L); Hub estuary (rural) (251 P/L); Sunehri (rural) (554 P/L); Mubarak village (rural) (481 P/L) [103]; Sindh, Pakistan: Shah Bandar (Indus delta, muddy, rural) (464 P/L); Kharochan (Indus delta, rural) (569 P/L); Jhangisur (Indus delta, rural) (517 P/L); Ketibandar (Indus delta, rural) (883 P/L); Khararo creek (Indus delta, rural) (315 P/L); Ibrahim hyderi (creek area, urban) (686 P/L), Clifton beach) (urban) (778 P/L); Manora (rocky, urban) (1096 P/L); Sandspit (urban) (888 P/L), Hawksbay (beach, urban) (604 P/L); Abdul Rehman Goth (urban) (846 P/L); Buleji (rocky beach, urban) (939 P/L); Cape Monze (beach, rocky, urban) (394 P/L) [103]; Eastern Arabian Sea. India: off the Cape (near Trivandrum), transect: 0.009 - 0.041 P/m^3; off Kochi, transect: 0.004 - 0.017 P/m^3; off Mangalore, transect: 0.002 - 0.046 P/m^3; off Goa, transect: 0.008 - 0.022 P/m^3; off Mumbai, transect: 0.009 - 0.014 P/m^3; off Veraval, transect: 0.003 - 0.013 P/m^3; off Okha, transect: 0.010 P/m^3 [93]; Goa, India: Mandovi-Zuari estuary (0.107 MP/m^3, wet season) (0.099 particles/m^3, dry season) [151]; Kerala, India: Thottappally (3.58 MP/m^3); Thaikadappuram (0.22 MP/m^3); average over 14 sampling sites off the coast of Kerala, India (1.25 MP/m^3) [158]; Tuticorn group of GoM islands, South India: Vaan (102.4 ± 22.6 MP/kg); Koswari (74.9 ± 15.7 MP/kg); Kariyachalli (94.1 ± 22.6 MP/kg); Vembar group of GoM islands, South India: Upputhanni (54.0 ± 19.2 MP/kg), Pullivinichalli (47.5 ± 19.2 MP/kg); Nallathanni (67.9 ± 24.0 MP/kg); Keelakarai group of GoM islands: Anaipar (69.7 ± 26.1 MP/kg); Valimunai (63.6 ± 25.1 MP/kg); Appa (53.0 ± 19.2 MP/kg); Thalayari (54.4 ± 15.7 MP/kg); Valai (40.9 ± 10.8 MP/kg); Mulli (32.0 ± 11.1 MP/kg); Mandapam group of GoM islands, South India: Hare (47.0 ± 12.9 MP/kg), Manoli (48.1 ± 10.4 MP/kg), Manoliputti (41.4 ± 13.9 MP/kg), Poomarichan (82.9 ± 15.7 MP/kg), Pullivasal (59.6 ± 22.6 MP/kg), Krusadai (108.7 ± 17.4 MP/kg), Shingle (135.9 ± 10.5 MP/kg) [137]; Matara Province, Sri Lanka: Thalalla (0 MP/m^3); Dondra Harbor (15 MP/m^3); Weligama (5 MP/m^3);

Galle Province, Sri Lanka: Koggala (1 MP/m^3); Unawatuna (3 MP/m^3); Galle (0 MP/m^3); Rathgama (0 MP/m^3); Hikkaduwa (15 MP/m^3); Kahawa (0 MP/m^3); Ambalangoda Harbor (29 MP/m^3) [116]; average over 10 locations in Southern Sri Lanka (11.3 MP/m^3) [116]; Negombo, Western Province, Sri Lanka: Maha Oya estuary (11.84 ± 2.62 MP/dm^3) [159]; Pariaman City, West Sumatra, Indonesia: off Naras Hilur Beach (13.24 P/m^3) [160]; Java, Indonesia: Cilacap Coast 0.27-0.54 MP/m^3 [144]; Perth, Australia: Swan river estuarine area: (February: 14036 ± 8585 P/km^2; March; 2461 ± 1404 P/km^2; May; 47164 ± 2170 P/km^2; July: 12,417 ± 5015 P/km^2); near off-shore: (February: 17,717 ± 3646 P/km^2; March: 1199 ± 1144 P/km^2; May: 7846 ± 6177 P/km^2; July: 59,631 ± 32,892 P/km^2); off-shore: (February: 1518 ± 156 P/km^2; March: 948 ± 276 P/km^2; May: 15,042 ± 4715; July: 2319 ± 1222 P/km^2) [161]; Bay of Bengal (87ºE; 15ºN) (2.045 MP/m^2) [161]; off Sumatra (92˚E; 1˚N) (0.516 MP/m^2) [162]; Eastern Indian Ocean (87˚E; 0˚N) (0.160 MP/m^2) [105]; Southeast coast, South Africa: Aston Bay (475.9 ± 165.5 MP/m^3); Bluewater Bay (558.6 ± 248.3 MP/m^3); Diez Strand (413.8 ± 165.5 MP/m^3); Hartenbos (434.5 ± 356.9 MP/m^3); Jeffrey's Bay (481.0 ± 269.0 MP/m^3); Keurbooms (843.1 ± 331.0 MP/m^3); Kleinbrak (258.6 ± 155.1 MP/m^2); Port Elizebeth Main (465.5 ± 362.2 MP/m^3); Plettenberg Bay (486.2 ± 436.6 MP/m^3); Robberg (512.1 ± 155.2 MP/m^3); St. Francis (620.7 ± 232.7 MP/m^3); Summerstrand (569.0 ± 77.6 MP/m^3); Buffel's Bay (527.6 ± 282.4 MP/m^3); Cannon Rocks (351.7 ± 139.7 MP/m^3); Danabaai (site 1) (439.7 ± 41.4 MP/m^3); Danabaai (site 2) (248.3 ± 93.1 MP/m^3); Kenton (470.7 ± 181.0 MP/m^3); Nature's Valley (584.5 ± 157.2 MP/m^3); Oyster Bay (1215 ± 276.7 MP/m^3); Sedgefield (927.4 ± 114.5 MP/m^3); Skuitbaai (858.5 ± 241.0 MP/m^3) [125]; Kenyan coast (110 MP/m^3) [163] Kenya: Vanga (0.09 ± .0.07 MP/m^3); Gazi (0.02 ± 0.00 MP/m^3); Mombasa (0.07 ± 0.05 MP/m^2); Malindi (3.22 ± 2.04 MP/m^3); Kipini (0.02 ± 0.02 MP/m^3); Lamu (0.04 ± 0.02 MP/m^3) [156].

6. Microplastics in Mangroves and Coral Reefs along the Indian Ocean

Mangroves [164] [165], seaweeds, seagrass and coral reefs can act as sinks for microplastics, as has also been seen in other parts of the world. Mangroves cover about 80,980 km^2 of the Indian Ocean. The South Asian coastline includes the Sundarabans, the largest mangrove ecosystem in the world, making for overall 4795 km^2 of mangrove forests on the South Asian coastline along the Indian Ocean [166]. While mangroves have been seen as sinks of anthropogenic debris in general and of MPs in particular, Okuku *et al.* have shown in Kenya that the landward zone of mangroves often entangles land-derived debris, which often includes larger pieces of plastic, while the seaward zone traps ocean-going litter. Interesting is the middle zone, which retains liteter not trapped by either the landward and seaward zones. Often, this litter also constitutes soft plastic particles [167]. In the 7 mangrove forests that Okuku analyzed, the middle zone with 0.162 ± 0.150 items/m^2 exhibited more contamination than both the landward zone (0.066 ± 0.049 items/m^2) and the seaward zone (0.036 ± 0.028 items/m^2) [167]. In Mauritius, two mangrove forests were examined for accumulated anthropogenic litter. In Mahebourg, 0.20 ± 0.11 P/m^2 were found. These plastic particles made up 42.9% of the total anthropogenic litter. In Ferney, the plastic count was 0.10 ± 0.09 P/m^2, making up 43.7% of the total anthropogenic litter in the mangrove forest [168]. Measurements of MP concentrations in mangroves around the Indian Ocean (**Figure 2**), were reported as follows, starting with the Northwestern coastline and then turning clockwise: Gulf of Oman, Iran: Chabahar Bay (surface water) (0.14 ± 0.06 MP/m^3) [157]; Balochistan, Pakistan: Kalmat (sediment) (460 P/kg); (surface water) (331 P/L) [103]; Kwazulu-Natal; West coastline of South Africa: St. Lucia estuary (1.19 ± 1.12 MP/m^3 water; 18.5 ± 34.4 MP/500 g sediment); uMgeni (4.09 MP/m^3 water; 143.3 MP/500 g sediment); Durban harbor (2.23 MP/m^3 water; 74.5 MP/500 g sediment); Isipingo estuary (5.06 ± 5.60 MPs per m^3 water; 143.5 ± 93.0 MP per 500 g sediment) [169]. The MP concentration in the estuarine water along the mangrove forests varies with the season, with 1.31 - 9.42 MP/m^3 in the wet season compared to 0.33 - 2.23 MP per m^3 in the dry season [169]. Interestingly, the concentration of MPs in the mangrove sediments also fluctuates seasonally, with the higher MP concentration in the sediments in the dry season. This seasonal dependence of the MP concentration has also been found in mangrove forests in Brazil [170] and is explained with an increased deposition of otherwise laterally stationary MPs during periods of low river inflow. A similar seasonal trend has been demonstrated in the deposition of MP in river sediments in the Eastern Cape of South Africa [171]. Kenya: Makupa (0.022 ± 0.017 items/m^2, landward zone), Gazi (0.012 items/m^2, landward zone). Dabaso (0.01 ± 0.0004 items/m^2, landward zone), Shimoni (0.008 ± 0.003 items/m^2, landward zone)

Coral reefs cover about 200000 km^2 of the Indian Ocean. Along the Indian subcontinent, the Gulf of Mannar, the Gulf of Kachch, the Andaman, Nicobar and Lakshadweep Islands constitute large reef ecosystems [166]. In addition, Mayotte, the Chagos archipelago, Reunion, Mauritius, the Seychelles, all possess reefs. The South African coastline has about 150 km of reefs. There are important reefs in the Northern Mozambique channel, which are part of the second longest fringing reef in the world, stretching along the East African coast from Somalia to Mozambique. Measurements on MP concentrations nearby or in reefs have been carried out in Mayotte at 22 locations inside the perimeter of the Marine Natural Park of Mayotte (PNMM) by Mulochau *et al.* [147], who found an average concentration of 3.9 ± 1.3 ML/500m^2 sediment in the summer at 3 - 4 m depth, 92% of which was microplastic [147]. Approximately half of the coral colonies had come into contact with microplastic particles with 25% of the colonies impacted by the microliter, where the impact included broken and abraded colonies. The most impacted corals were branch or table corals [147]. Patti *et al.* have looked at the MP concentration in the reef flats and the fore reefs of the populated Malidivian island Naifaru. The reef flats exhibited a heavy MP contamination with 333 ± 31.20 MP/kg sediment [142]. In comparison, the fore reefs exhibited fewer MPs (249.81 ± 23.23 MPs/kg sediment) [142]. 2.6 km south of Naifaru, in the same Lhaviyani atoll, lies the island of Vavvaru, which itself is scarcely inhabited. Imhof *et al.* [143] performed studies on both long-term and short-term accumulation of MPs on this island. In one sampling site, they found 1664 MP/m^2, where the MPs were classified as large microplastics (1 - 5 mm). Also, the authors found a daily mean abundance of plastic particles down to 1 mm on the south shore of Vavvaru of 35.8 ± 42.5 P/m^2 which shows the MP contamination even at rather secluded sites, while being smaller than on highly contaminated urban beaches, for instance in Mumbai, India with a daily accumulation of 10 - 180 P/m^2 (plastic particles > 1 mm) [135]. Patterson *et al.* have studied the MP abundance in coral reef environments in the Gulf of Mannar, South India. The authors found that the shoreward side of coral islands presented higher concentrations of microplastic, where proximity to human population densities on the mainland as well as the waste handling in the nearby areas on the mainland influenced the abundance of MPs on the islands [137]. In general, it has been noted that the Gulf of Mannar has become a potential accumulation zone for MPs along the Indian coast as have the Gulf of Kachchh and the Gulf of Khambhat in Gujarat [166]. At the level of living organism, MPs were also found at a concentration of 0.056 and 1.113 MP/g dwt in the tube structure of the reef-building polychaete *Gunnarea gaimardi* (Quatrefages 1848), collected along the Southeast coast of South Africa [172] [173]. *In vitro* trials, experimental feeding assays, and wrapped MP polymers in the mesenterial tissue within the coral gut cavity showed that the ingestion of MPs could potentially impair the coral reef health. According to Reichert *et al.* (2017) [174] [175], coral species show different responses to MP exposure: attachment of microplastic to tentacles or mesenterial filaments, and ingestion of MP polymers, leading to mucus production on the reef-building corals, and overgrowth. In extreme cases, coral bleaching and tissue necrosis could ensue.

7. Ingestion of Plastic by Birds and Turtles in the Area of the Indian Ocean

Plastic ingestion has been studied in birds and in turtles (**Figure 3**) within area of the Indian Ocean. Cartraud *et al.* looked at plastic pollution in nine seabird species on Reunion (2002-2016) and Juan de Nova (2004-2008) (**Table 1**). The most affected species studied were the tropical shearwater (*Puffinus lherminieri*), with 79% of the birds affected and Barau's petrel (*Pterodroma baraui*) with 63% of the birds affected [176]. Most of the ingested plastic can be classified as MP with particle weights of between 10 and 15 mg. 50% of older wandering albatross (*Diomedea exulans*) chicks on Kerguelen were found with plastic fragments in their stomach [177].

Off the coast, a little into the interior of South Africa, in Strandfontein, the feathers and feces of five types of duck as were examined for MP [178]. 283 fecal

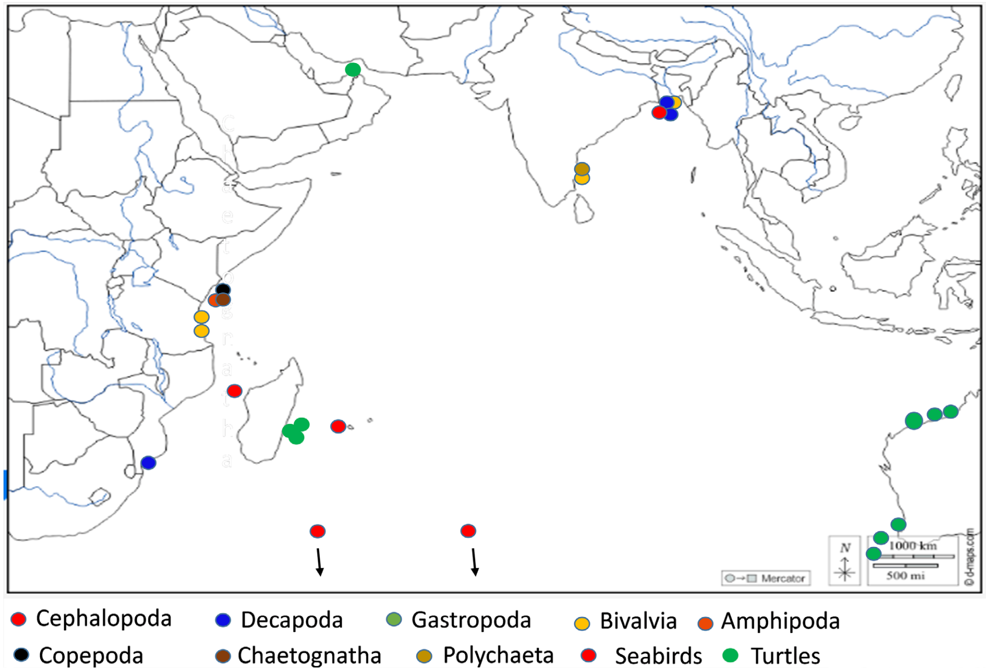


Figure 3. Sampling of MPs from living organisms other than fishes.

samples and 408 feather brushings were examined, and 5% of fecal samples and 10% of feather samples were found to contain micro-plastic fibres (**Table 1**). The level of MP contamination was observed to depend on the foraging method of the birds. While Egyptian Geese (*Alopochen aegyptiaca*), which graze mostly on shoreline vegetation had a relatively low occurrence of micro-fibres in their fecal samples, Cape Shovelers (*Anas smithii*), which filter feed on invertebrates exclusively near the water surface, exhibited a significantly higher concentration of MP in their feces [178].

Duncan *et al.* have studied the plastic ingestion of five species of turtles—the green sea turtle (*Chelonia mydias*), the loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), and flatback (*Natator depressus*) turtles—along the Pacific coast of Queensland, Australia and along the Indian Ocean coast of Western Australia. It was noted that fewer incidences of MP ingestion was observed—with turtles in the Indian Ocean as compared with the same turtle species in the Pacific Ocean. With 28% of 18 examined flatback turtle juveniles exhibiting MP ingestion, flatback turtles were found to be the most affected, followed by loggerhead turtles (21%, n = 13) and green sea turtles (9%, n = 22) [179]. The authors have found that whereas the majority of ingested plastic on the Pacific side was hard plastic, on the Indian Ocean side filamentous plastic (52%) dominated, followed by sheet plastic (35%). In both oceans the most commonly ingested plastics were polythene and polypropylene [179]. A higher percentage of loggerhead turtles were found to be affected in the vicinity of Reunion in the Western Indian Ocean with 51.4% of gut or fecal samples of loggerheads (*C. caretta*) by-catch from Reunion Island long liners exhibiting debris presence, most of which was plastic. While hard

Table 1. List of studies on microplastic contamination in birds.

Species (common name)	Latin name	Family name	Location	Number of specimen	Percentage of birds with MP	MP per specimen	Reference
Tropical shearwater	*Puffinus therminieri*	Procellariidae	Reunion	56	79%	6.10 ± 1.29	Cartraud (2019) [176]
Wedge-tailed shearwater	*Ardenna pacifica*	Procellariidae	Reunion	9	33%	3.84 ± 0.59	Cartraud (2019) [176]
Barau's petrel	*Pterodroma baraui*	Procellariidae	Reunion	62	63%		Cartraud (2019) [176]
Mascarene petrel	*Pseudobulweria aterrima*	Procellariidae	Reunion	1	100%		Cartraud (2019) [176]
White-tailed tropicbird	*Phaeton lepturus*	Phaetonitiidae	Reunion	35	29%		Cartraud (2019) [176]
Brown noddy	*Anous stolidus pileatus*	Laridae	Reunion	9	33%		Cartraud (2019) [176]
Lesser noddy	*Anous tenuirostis*	Laridae	Reunion	21	43%		Cartraud (2019) [176]
Sooty tern	*Ornithoprion fuscatus*	Laridae	Juan de Nova	27	15%		Cartraud (2019) [176]
Cape gennet	*Morus capensis*	Sulidae	Reunion	2	50%		Cartraud (2019) [176]
Wandering albatross	*Diomedea exulans*	Diomedea	Kerguelen	30	50%		Cherel (2017) [177]
Egyptian goose	*Alopochen aegyptiaca*	Anatidae	Strandfontein, RSA	55 (fecal samples) 119 (feathers)	1% (fecal samples) 8% (feathers)		Reynolds (2018) [178]
Yellow-billed duck	*Anas undulata*	Anatidae	Strandfontein, RSA	46 (feathers)	17% (feathers)		Reynolds (2018) [178]
Red-billed teal	*Anas erythrorhyncha*	Anatidae	Strandfontein, RSA	2 (feathers)	50% (feathers)		Reynolds (2018) [178]
Cape shoveler	*Anas smithii*	Anatidae	Strandfontein, RSA	35 (fecal samples)	17% (fecal samples)		Reynolds (2018) [178]
Cape teal	*Anas capensis*	Anatidae	Strandfontein, RSA	14 (fecal samples)	14% (fecal samples)		Reynolds (2018) [178]

plastic was the main contributor, it seems that the authors excluded the inventory of fibers from the study [180]. Yaghmour *et al.* found that 85.7% of the green sea turtles (*C. mydas*) examined on the Eastern shoreline of the United Arab

Emirates, in the Gulf of Oman (n = 14, all stranded animals) had consumed marine debris, with an average 61.9 ± 17.2 items weighing 1.0 ± 0.3 g, with plastic again being the dominant material [181].

8. Microplastic Abundance in Fish Species in the Indian Ocean

Over the last five years, numerous studies have appeared that have gauged the level of MP contamination in fishes from the Indian Ocean, specifically in fishes of commercial value (**Figure 4**). Before, investigations on the presence of plastic contamination in fishes had also been communicated, but less distinction was made between macro-, meso- and microplastic, and often the focus was on macro- and mesoplastics [182]. **Table 2** shows an overview of the published studies on MP presence in fishes in the Indian Ocean.

While most of the Iranian investigations on MP in the marine environment stem from the Arabian/Persian Gulf and are not within the scope of this research, Kord and Naji have looked at MP contamination in 5 species of fish in Chabahar Bay on the Arabian Sea [187]. With the Indian mackerel (*Rastrigeller kanagurta*), the orange spotted grouper (*Epinephelus coiodes*), the notched-fin threadfin bream (*Nemipterus peronei*), John's snapper (*Lutjanus johnii*), and Greater lizardfish (*Saurida tumbil*), all, with perhaps the exception of the lizardfish, are fish of high commercial value. It was seen that all fishes sampled contained MP. The most prevalent type of MP was fibers (55%), followed by fragments (26%) and pellets (18%). The most common polymeric material was PE, followed by PET and nylon [187]. From Pakistan comes a study on the MP contamination of five species of fish from the waters in the vicinity of Karachi. From the GIT of 3 Malabar thryssa (*Thryssa dussumieri*) 590 MPs were isolated, from the GIT of Indian mackerel (*R. kanagurta*) 330 MPs were isolated [200]. A number of studies on MP contamination have been performed on fish from off the coast of Kerala [158] [184] [199] [203]. Thus, James *et al.* investigated MP contamination in 8 pelagic and in 8 demersal fish species, among them the Indian oil sardine (*Sardinella longice*ps), the goldstripe sardinella (*Sardinella gibbosa*), the Indian anchovy (*Stolephorus indicus*), the Indian mackerel (*R. kanagurta*) and the Malabar tonguesole (*Cyanoglossus macrostomus*). In these five fish species, especially PP and PE microplastics were found [184]. Also, from the Eastern shorelines of the Indian subcontinent a larger number of studies on MP contamination in fish are available, especially from the Southeast coast of India [112] [183] [185] [186]. Karthik *et al.* examined 120 fish from 12 fish species, 11 species of them being carnivores such as groupers, hinds, and mackerels, along Palk Bay and the Gulf of Mannar coast, South India [194]. The authors found MP in 19.2% of the fish, albeit in low numbers per specimen, averaging 0.19 ± 1.3 MP per specimen over all fish species that were analyzed [194]. The study carried out in the summer of 2021 can be compared with a similar study reported 2018 from the same area [112], where 10.1% of the fish were found to

Table 2. Marine species assessed for MP content in the Indian Ocean—Part 1 (fish).

Fish species	Latin name	Fish family	Marine habitat	Region of the Indian Ocean	No. of specimen	Fish w. MP (%)	MP/fish	Reference
Acanthuriformes								
Surgeonfish	*Acanthurus* sp.	Acanthuridae	reef-associated	Ennore, Southeast India	10		4.8 MP/ individual	Harikrishnan (2023) [183]
Coitor croaker	*Johnius coitor*	Sciaenidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Bearded croaker	*Johnius amblycephalus*	Sciaenidae	demersal	Koyilandy, off coast of Kerala, India	2	50%	2	Robin (2020) [158]
Blotched croaker	*Nibea maculata*	Sciaenidae	demersal	Coast off Kochi, Kerala, India (pre-monsoon)	2	0%		James (2020) [184]
Silver croaker	*Pennahia argentatus*	Sciaenidae	benthopelagic	off Parangipettai, Southeast coast of India	20			Nithin (2022) [185]
Donkey croaker	*Pennahia anea*	Sciaenidae	demersal	off the coast of Kerala, India	11	18.2%		Robin (2020) [158]
Pama croaker	*Otolithoides pama*	Sciaenidae	benthopelagic	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Splendid ponyfish	*Leiognathus splendens*	Leiognathidae	demersal	Coast off Kochi, Kerala, India (post-monsoon)	6	0%		James (2020) [184]
Common ponyfish	*Leiognathus equula*	Leiognathidae	demersal	off the coast of Tamil Nadu, India	10	10%		Karthik (2018) [112]
Pennant coralfish	*Heniochus acuminatus*	Chaetodontidae	reef-associated	Thoothukudi, Gulf of Mannar, South India	25		9.6 MP/100g muscle 15 MP/100g intestine	Selvam (2021) [186]
Streaked spinefoot	*Siganus javus*	Siganidae	reef-associated	off the coast of Tamil Nadu, India	29	10.3%		Karthik (2018) [112]
Shortnose ponyfish	*Leiognathus brevirostris*	Leiognathidae	demersal	Thoothukudi, Gulf of Mannar, South India	15		12 MP/100g muscle 13.2 MP/100g instestine	Selvam (2021) [186]
Streaked spinefoot	*Siganus javus*	Siganidae	reef-associated	Adyar & Ennore, Southeast India	20		4.2 MP/ individual	Harikrishnan (2023) [183]
Pinspotted spinefoot	*Siganus fusescens*	Siganidae	reef-associated	Adyar & Ennore, Southeast India	20		3.9 MP/ individual	Harikrishnan (2023) [183]
Anabantiformes								
Spotted snake head	*Channa punctata*	Channidae	benthopelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Anguilliformes								
Indian mud moray eel	*Gymnothorax tile*	Muraenidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Aulopiformes								
Greater lizardfish	*Saurida tumbil*	Synodontidae	reef-associated	Chabahar Bay, Iran	10		2.28 ± 2.15	Kord (2019) [187]
Greater lizardfish	*Saurida tumbil*	Synodontidae	reef-associated	Coast off Kochi, Kerala, India (post-monsoon)	13	0%		James (2020) [184]

Continued

Greater lizardfish	*Saurida tumbil*	Synodontidae	reef-associated	Port Blair Bay, Andaman & Nicobar Islands	9	44.4%		Goswami (2020) [53]
Glassy Bombay duck	*Harpadon translucens*	Synodontidae	demersal	Chittagong and Cox's Bazar, Northern Bay of Bengal, Bangladesh	25		5.80 ± 1.41	Hossain (2019) [44]
Bombay duck	*Harpadon nehereus*	Synodontidae	benthopelagic	Chittagong and Cox's Bazar, Northern Bay of Bengal, Bangladesh	25		8.72 ± 1.54	Hossain (2019) [44]
Bombay duck	*Harpadon nehereus*	Synodontidae	benthopelagic	Sundarbans mangrove estuary, near Khulna, Bangladesh	10			Sultan (2023) [49]
Bombay duck	*Harpadon nehereus*	Synodontidae	benthopelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Bombay duck	*Harpadon nehereus*	Synodontidae	benthopelagic	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Bombay duck	*Harpadon nehereus*	Synodontidae	benthopelagic	Cox's Bazar, Bangladesh			28.5 MP/g	Hasan (2022) [46]
Bombay duck	*Harpadon nehereus*	Synodontidae	benthopelagic	Kuakata, Bangladesh			41.3 MP/g	Hasan (2022) [46]
Bombay duck	*Harpadon nehereus*	Synodontidae	benthopelagic	Tuticorin, Indian Southeast coast	20		3.64 ± 1.7 MP/ind. 0.008 ± 0.001 MP/g bw	Sathish (2020) [188]
Beloniformes								
Banded needlefish	*Strongylura leiura*	Belonidae	reef-associated	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Freshwater garfish	*Xenentodon cancila*	Belonidae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Tropical two-wing flyingfish	*Exocoetus volitans*	Exocoetidae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Long-billed half-beak	*Rhynchorhamphus georgii*	Hemiramphidae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Long-billed half-beak	*Rhynchorhamphus georgii*	Hemiramphidae	pelagic-neritic	Koyilandy, off the coast of Kerala, India	1	100%	2	Robin (2020) [158]
Dussumier's halfbeak	*Hyporhamphus dussumieri*	Hemiramphidae	reef-associated	off the coast of Kerala, India	1	0%		Robin (2020) [158]
Carangiformes								
Indian horse mackerel; Torpedo scad	*Megalaspis cordyla*	Carangidae	reef-associated	Kalamukku, Kerala, India	30			Daniel (2020) [189]
Indian horse mackerel; Torpedo scad	*Megalaspis cordyla*	Carangidae	reef-associated	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Cape horse mackerel	*Trachurus capensis*	Carangidae	reef-associated	Agulhas Bank, RSA	15		0.21 ± 0.06 MP/g	Sparks (2020) [190]

Continued

Cleftbelly trevally	*Atropus atropus*	Carangidae	pelagic-neritic	Thoothukudi, Gulf of Mannar, South India			15.2 MP/100g muscle 44.1 MP/100g intestine	Selvam (2021) [186]
Longnose trevally	*Carangoides chrysophrys*	Carangidae	reef-associated	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Blacktip trevally	*Caranx heberi*	Carangidae	reef-associated	off the coast of Kerala, India	2	0%		Robin (2020) [158]
Razorbelly scad	*Alepes kleinii*	Carangidae	reef-associated	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Shrimp scad	*Alepes djedaba*	Carangidae	reef-associated	off the coast of Kerala, India	8	25%		Robin (2020) [158]
Shrimp scad	*Alepes djedaba*	Carangidae	reef-associated	Port Blair Bay, Andaman & Nicobar Islands	6	50%		Goswami (2020) [53]
Long-fin trevally	*Carangoides armatus*	Carangidae	reef-associated	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Long-fin trevally	*Carangoides armatus*	Carangidae	reef-associated	Coast off Kochi, Kerala, India (post-monsoon)	20	0%		James (2020) [184]
Malabar trevally	*Carangoides malabaricus*	Carangidae	reef-associated	off the coast of Kerala, India	4	25%		Robin (2020) [158]
Malabar trevally (adults)	*Carangoides malabaricus*	Carangidae	reef-associated	Port Blair Bay, Andaman & Nicobar Islands	4	75%		Goswami (2020) [53]
Malabar trevally (juveniles)	*Carangoides malabaricus*	Carangidae	reef-associated	Port Blair Bay, Andaman & Nicobar Islands	6	33.3%		Goswami (2020) [53]
Malabar trevally	*Carangoides malabaricus*	Carangidae	reef-associated	Adyar & Ennore, Southeast India	20		5.9 MP/individual	Harikrishnan (2023) [183]
Big-eye scad	*Selar crumenophthalmus*	Carangidae	reef-associated	South Maledives	35	80%	4.03 ± 5.6 MP/fish 0.02 MP/g	Shiyana (2022) [191]
Big-eye scad	*Selar crumenophthalmus*	Carangidae	reef-associated	off Parangipettai, Southeast coast of India	20			Nithin (2022) [185]
Mackerel scad	*Decapterus macarellus*	Carangidae	pelagic-oceanic	South Maledives	21	76.2%	2.19 ± 2.0 MP/fish 0.04 MP/g	Shiyana (2022) [191]
Carcharhiniformes								
Copper shark	*Carcharhinus brachyurus*	Carcharhinidae	reef-associated	KwaZulu Natal, RSA				Cliff (2002) [182]
Dusky shark	*Carcharhinus obscurus*	Carcharhinidae	reef-associated	KwaZulu Natal, RSA				Cliff (2002) [182]
Black tip shark	*Carcharhinus limbatus*	Carcharhinidae	reef-associated	KwaZulu Natal, RSA				Cliff (2002) [182]
Bull shark	*Carcharhinus leucas*	Carcharhinidae	reef-associated	KwaZulu Natal, RSA				Cliff (2002) [182]

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Java shark (pigeye shark)	*Carcharhinus amboinensis*	Carcharhinidae	reef-associated	KwaZulu Natal, RSA				Cliff (2002) [182]
Spinner shark	*Carcharhinus brevipinna*	Carcharhinidae	reef-associated	KwaZulu Natal, RSA				Cliff (2002) [182]
Sandbar shark	*Carcharhinus plumbeus*	Carcharhinidae	benthopelagic	KwaZulu Natal, RSA				Cliff (2002) [182]
Spadenose shark	*Scoliodon laticaudus*	Carcharhinidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Milk shark	*Rhizoprionodon acutus*	Carcharhinidae	benthopelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Milk shark	*Rhizoprionodon acutus*	Carcharhinidae	benthopelagic	Bay of Bengal, Chennai	40		4.74 ± 1.82	Janardhanam (2022) [192]
Scalloped hammerhead	*Sphyrna lewini*	Sphyrnidae	pelagic-oceanic	KwaZulu Natal, RSA				Cliff (2002) [182]
Great hammerhead	*Sphyrna mokarran*	Sphyrnidae	pelagic-oceanic	KwaZulu Natal, RSA				Cliff (2002) [182]
Smooth hammerhead	*Sphyrna zygaena*	Sphyrnidae	pelagic-oceanic	KwaZulu Natal, RSA				Cliff (2002) [182]
Arabian smooth-hound	*Mustelus mosis*	Triakidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Centrarchiformes								
Crescent grunter, Thornfish (juvenile)	*Terapon jarbua*	Terapontidae	demersal	Umgeni, KwaZulu Natal, RSA	29	48%	0.66 ± 0.81	Naidoo (2020) [193]
Crescent grunter, Thornfish	*Terapon jarbua*	Terapontidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Crescent grunter, Thornfish	*Terapon jarbua*	Terapontidae	demersal	off Parangipettai, Southeast coast of India	20			Nithin (2022) [185]
Small-scaled terapon	*Terapon puta*	Terapontidae	benthopelagic	Coast off Kochi, Kerala, India (post-monsoon)	13	0%		James (2020) [184]
Cichliformes								
Mozambique tilapia (juvenile)	*Oreochromis mossambicus*	Cichlidae	benthopelagic	St. Lucia, KwaZulu, Natal, RSA	29	38%	0.41 ± 0.57	Naidoo (2020) [193]
Mozambique tilapia (juvenile)	*Oreochromis mossambicus*	Cichlidae	benthopelagic	Isipingo, KwaZulu, Natal, RSA	29	45%	0.59 ± 0.73	Naidoo (2020) [193]
Nile tilapia	*Oreochromis niloticus*	Cichlidae	benthopelagic	Adyar & Ennore, Southeast India	20		4.9 MP/individual	Harikrishnan (2023) [183]
Green chromide (Pearl spot)	*Etroplus suratensis*	Cichlidae	benthopelagic	off Parangipettai, Southeast coast of India	20			Nithin (2022) [185]

Continued

Green chromide (Pearl spot)	*Etroplus suratensis*	Cichlidae	benthopelagic	Adyar, Southeast India	10		4.9 MP/individual	Harikrishnan (2023) [183]
Clupeiformes								
Indian oil sardine	*Sardinella longiceps*	Clupeidae	reef-associated	Kalamukku, Kerala, India	30			Daniel (2020) [189]
Indian oil sardine	*Sardinella longiceps*	Clupeidae	reef-associated	Koyilandy, off the coast of Kerala, India	1	0%		Robin (2020) [158]
Chacunda gizzard shad	*Anodontostoma chacunda*	Clupeidae	pelagic-neritic	Kalamukku, Kerala, India	30			Daniel (2020) [189]
Chacunda gizzard shad	*Anodontostoma chacunda*	Clupeidae	pelagic-neritic	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Chacunda gizzard shad	*Anodontostoma chacunda*	Clupeidae	pelagic-neritic	Off the coast of Kerala, India	4	0%		Robin (2020) [158]
Hilsa shad	*Tenualosa ilisha*	Clupeidae	pelagic-neritic	Sundarbans mangrove estuary, near Khulna, Bangladesh	3			Sultan (2023) [49]
Hilsa shad	*Tenualosa ilisha*	Clupeidae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Hilsa shad	*Tenualosa ilisha*	Clupeidae	pelagic-neritic	Bay of Bengal, off the coast of Bangladesh			19.13 ± 10.77	Siddique (2022) [47]
Bigeye ilisha	*Ilisha megaloptera*	Clupeidae	pelagic-neritic	Pallithottam, off the coast of Kerala, India	1	0%		Robin (2020) [158]
Bloch's gizzard shad	*Nematalosa nasus*	Clupeidae	pelagic-neritic	Payyambalam, off the coast of Kerala, India	3	0%		Robin (2020) [158]
Hamilton's thryssa	*Thryssa hamiltonii*	Clupeidae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Moustached thryssa	*Thryssa mystax*	Clupeidae	pelagic-oceanic	Coast off Kochi, Kerala, India (pre-monsoon)	12	0%		James (2020) [184]
Longjaw thryssa	*Thryssa setirostris*	Clupeidae	pelagic-neritic	off Parangipettai, Southeast coast of India	20			Nithin (2022) [185]
Toli shad	*Tenualosa toli*	Clupeidae	pelagic-neritic	Sundarbans mangrove estuary, near Khulna, Bangladesh	3			Sultan (2023) [49]
Toli shad	*Tenualosa toli*	Clupeidae	pelagic-neritic	Adyar, Southeast India	10		5.2 MP/individual	Harikrishnan (2023) [183]
Deepbody sardinella	*Sardinella brachysoma*	Clupeidae	pelagic-neritic	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Goldstripe sardinella	*Sardinella gibbosa*	Clupeidae	pelagic-neritic	Palk Bay and Gulf of Mannar, India	12	16.7%		Karthik (2022) [194]
Goldstripe sardinella	*Sardinella gibbosa*	Clupeidae	pelagic-neritic	Kalamukku, Kerala, India	30			Daniel (2020) [189]
Goldstripe sardinella	*Sardinella gibbosa*	Clupeidae	pelagic-neritic	Chittagong and Cox's Bazar, Northern Bay of Bengal, Bangladesh	25		3.20 ± 1.16	Hossain (2019) [44]
Goldstripe sardinella	*Sardinella gibbosa*	Clupeidae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]

Continued

Goldstripe sardinella	*Sardinella gibbosa*	Clupeidae	pelagic-neritic	Coast off Kochi, Kerala, India (post-monsoon)	40	2.5%		James (2020) [184]
Fringescale sardinella	*Sardinella fimbriata*	Clupeidae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Indian oil sardine	*Sardinella longiceps*	Clupeidae	pelagic-neritic	Sundarbans mangrove estuary, near Khulna, Bangladesh	4			Sultan (2023) [49]
Indian oil sardine	*Sardinella longiceps*	Clupeidae	pelagic-neritic	Coast off Kochi, Kerala, India (monsoon)	40	5%		James (2020) [184]
Indian oil sardine	*Sardinella longiceps*	Clupeidae	pelagic-neritic	Coast off Kochi, Kerala, India (pre-monsoon)	50	0%		James (2020) [184]
Indian oil sardine	*Sardinella longiceps*	Clupeidae	pelagic-neritic	Coast off Kochi, Kerala, India (post-monsoon)	33	9.1%		James (2020) [184]
Razorbelly	*Hilsa kelee*	Clupeidae	pelagic-neritic	KwaZulu Natal, RSA				Naidoo (2017) [195]
Razorbelly	*Hilsa kelee*	Clupeidae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
South American pilchard	*Sardinops sagax*	Clupeidae	pelagic-neritic	Cape Town, RSA	24	88%	1.88	Bakir (2020) [196]
South American pilchard	*Sardinops sagax*	Clupeidae	pelagic-neritic	Mossel Bay, RSA	29	90%	2.38	Bakir (2020) [196]
South American pilchard (Australian sardine)	*Sardinops sagax*	Clupeidae	pelagic-neritic	Frenchman Bay, Western Australia	27	26%	0.26 ± 0.45	Crutchett (2020) [197]
South American pilchard (Australian sardine)	*Sardinops sagax*	Clupeidae	pelagic-neritic	off the coast of Perth, Western Australia	20	10%	0.80 ± 0.75	Wootton (2021) [198]
South American pilchard (Australian sardine)	*Sardinops sagax*	Clupeidae	pelagic-neritic	South coasts, RSA	25	76%	2.8	Ross (2017) [199]
White sardinella	*Sardinella albella*	Clupeidae	reef-associated	Tuticorin, Indian Southeast coast	20		1.2 ± 0.2 MP/ind. 0.75 ± 0.01 MP/gut 0.04 ± 0.005 MP/g bw	Sathish (2020) [188]
White sardinella	*Sardinella albella*	Clupeidae	reef-associated	off Parangipettai, Southeast coast of India	20			Nithin (2022) [185]
Rainbow sardine	*Dussumieria acuta*	Dussumieriidae	pelagic-neritic	Kalamukku, Kerala, India	30			Daniel (2020) [189]
Rainbow sardine	*Dussumieria acuta*	Dussumieriidae	pelagic-neritic	Coast off Kochi, Kerala, India				James (2020) [184]

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Whitehead's round herring	*Etrumeus whiteheadii*	Dussumieriidae	pelagic-neritic	Cape Town, RSA	25	72%	`1.20	Bakir (2020) [196]
Whitehead's round herring	*Etrumeus whiteheadii*	Dussumieriidae	pelagic-neritic	Mossel Bay, RSA	25	80%	1.80	Bakir (2020) [196]
Whitehead's round herring	*Etrumeus whiteheadii*	Dussumieriidae	pelagic-neritic	Agulhas Bank, RSA	15		0.05 ± 0.01 MP/g	Sparks (2020) [190]
Whitehead's round herring	*Etrumeus whiteheadii*	Dussumieriidae	pelagic-neritic	Indian Ocean, RSA	25	44%	0.8 MP/ind.	Ross (2017) [199]
European anchovy	*Engraulis encrasicolus*	Engraulidae	pelagic-neritic	Cape town, RSA	25	64%	0.96	Bakir (2020) [196]
European anchovy	*Engraulis encrasicolus*	Engraulidae	pelagic-neritic	Mossel Bay, RSA	25	48%	0.92	Bakir (2020) [196]
European anchovy	*Engraulis encrasicolus*	Engraulidae	pelagic-neritic	Indian Ocean, RSA	25	80%	2.68 MP/ind.	Ross (2017) [199]
Goldspotted grenadier anchovy	*Coilia dussumieri*	Engraulidae	pelagic-neritic	Sundarbans mangrove estuary, near Khulna, Bangladesh	25			Sultan (2023) [49]
Goldspotted grenadier anchovy	*Coilia dussumieri*	Engraulidae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Neglected grenadier anchovy	*Coilia neglecta*	Engraulidae	pelagic-neritic	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Malabar thryssa	*Thryssa dussumieri*	Engraulidae	pelagic-neritic	Kalamukku, Kerala, India	30			Daniel (2020) [189]
Malabar thryssa	*Thryssa dussumieri*	Engraulidae	pelagic-neritic	Coastal waters around of Karachi, Pakistan	3			Akhter (2022) [200]
Indian anchovy	*Stolephorus indicus*	Engraulidae	pelagic-neritic	Kalamukku, Kerala, India	30			Daniel (2020) [189]
Indian anchovy	*Stolephorus indicus*	Engraulidae	pelagic-neritic	Coast off Kochi, Kerala, India (monsoon)	40	0%		James (2020) [184]
Indian anchovy	*Stolephorus indicus*	Engraulidae	pelagic-neritic	Coast off Kochi, Kerala, India (pre-monsoon)	40	2.5%		James (2020) [184]
Indian anchovy	*Stolephorus indicus*	Engraulidae	pelagic-neritic	Coast off Kochi, Kerala, India (post-monsoon)	47	0%		James (2020) [184]
Gangetic hairfin anchovy	*Setipinna phasa*	Engraulidae	pelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Common hairfin anchovy	*Setipinna tenuifilis*	Engraulidae	pelagic-neritic	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Dorab wolf-herring	*Chirocentrus dorab*	Chirocentridae	reef associated	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]

Continued

Dorab wolf-herring	*Chirocentrus dorab*	Chirocentridae	reef associated	Tuticorin, Indian Southeast coast	20		2.81 ± 1.01 MP/ind. 0.08 ± 0.04 MP/g gut 0.004 ± 0.002 MP/g bw	Sathish (2020) [188]
Tardoore	*Opisthopterus tardoore*	Pristigasteridae	pelagic-neritic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Cypriniformes								
Swamp barb	*Puntius chola*	Cyprinidae	benthopelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Guntea loach	*Lepidocephalichthys guntea*	Cobitidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Gangetic scissortail rasbora	*Rasbora rasbora*	Danionidae	benthopelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Elopiformes								
Tenpounder	*Elops machnata*	Elopidae	pelagic-neritic	Ennore, Southeast India	10		3.2 MP/individual	Harikrishnan (2023) [183]
Gadiformes								
Cape hake	*Merluccius capensis*	Merlucciidae	bathydemersal	Agulhas Bank, RSA	15		0.25 ± 0.03 MP/g	Sparks (2020) [190]
Deep water Cape hake	*Merluccius paradoxus*	Merlucciidae	bathydemersal	Agulhas Bank, RSA	15		0.15 ± 0.04 MP/g	Sparks (2020) [190]
Gobiiformes								
Pointy-tailed goby	*Pseudapocryptes elongatus*	Gobiidae	demersal	Sundarbans mangrove estuary, near Khulna, Bangladesh	8			Sultan (2023) [49]
Pointy-tailed goby	*Pseudapocryptes elongatus*	Gobiidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Mudskipper	*Periophthalmus sp.*	Gobiidae	demersal	Ulhas River estuary, India	50	34%	3.75 ± 1.26 MP to 6.11 ± 1.17 MP/fish	Kumkar (2021) [201]
Tank goby	*Glossogobius giuris*	Gobiidae	benthopelagic	Sundarbans mangrove estuary, near Khulna, Bangladesh	5			Sultan (2023) [49]
Istiophoriformes								
Indo-pacific sailfish	*Istiophorus platypterus*	Istiophoridae	pelagic-oceanic	Tuticorin, Indian Southeast coast	10		0.11 ± 0.063 MP/ind. 1.1×10^{-6} MP/g bw 2×10^{-5} MP/g gut	Sathish (2020) [188]
Lamniformes								
Sand tiger shark	*Carcharias taurus*	Odontaspididae	reef-associated	KwaZulu Natal, RSA				Cliff (2002) [182]

Continued

Great white shark	*Carcharodon carcharias*	Lamnidae	pelagic-oceanic	KwaZulu Natal, RSA				Cliff (2002) [182]
Mulliformes								
Yellow-striped goatfish	*Upeneus vittatus*	Mullidae	reef-associated	Port Blair Bay, Andaman & Nicobar Islands	10	40%		Goswami (2020) [53]
Myliobatiformes								
Pale-edged stingray	*Telatrygon zugei*	Dasyatidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Leopard whipray	*Himantura undulata*	Dasyatidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Long-tailed butterfly ray	*Gymnura poecilura*	Gymnuridae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Perciformes								
Pink ear emperor	*Lethrinus Lentjan*	Lethrinidae	reef-associated	Palk Bay and Gulf of Mannar, India	10	20%		Karthik (2022) [194]
Estuarine mullet (Flathead grey mullet)	*Mugil cephalus*	Mugilidae	benthopelagic	Durban Harbor, RSA	70	73%	3.8 ± 4.5	Naidoo (2015) [148]
Estuarine mullet (Flathead grey mullet)	*Mugil cephalus*	Mugilidae	benthopelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Estuarine mullet (Flathead grey mullet)	*Mugil cephalus*	Mugilidae	benthopelagic	off coast of Tamil Nadu, India	12	16.7%		Karthik (2018) [112]
Estuarine mullet (Flathead grey mullet)	*Mugil cephalus*	Mugilidae	benthopelagic	off Parangipettai, Southeast coast of India	20			Nithin (2022) [184]
Estuarine mullet (Flathead grey mullet)	*Mugil cephalus*	Mugilidae	benthopelagic	off the coast of Kerala, India	5	40%	2	Robin (2020) [158]
Estuarine mullet (Flathead grey mullet)	*Mugil cephalus*	Mugilidae	benthopelagic	off the coast of Perth, Western Australia	20	50%	0.70 ± 0.18	Wootton (2021) [198]
Estuarine mullet (Flathead grey mullet)	*Mugil cephalus*	Mugilidae	benthopelagic	Adyar & Ennore, Southeast India	20		6.2 MP/individual	Harikrishnan (2023) [183]
Southern mullet (postflexion larvae)	*Chelon richardsonii*	Mugilidae	demersal	Algoa Bay, South Africa	96	overall 60%	2.1 MF/ind. <0.1 MP/ind.	McGregor 2020 [202]
Southern mullet (early juveniles)	*Chelon richardsonii*	Mugilidae	demersal	Algoa Bay, South Africa	6		3.3 MF/ind. <0.2 MP/ind.	McGregor 2020 [202]

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Southern mullet (juveniles)	*Chelon richardsonii*	Mugilidae	demersal	Algoa Bay, South Africa	4		1.2 MF/ind. <0.3 MP/ind.	McGregor 2020 [202]
Southern mullet (sub-adults)	*Chelon richardsonii*	Mugilidae	demersal	Algoa Bay, South Africa	8		1.5 MF/ind. 0.1 MP/ind.	McGregor 2020 [202]
Southern mullet (adults)	*Chelon richardsonii*	Mugilidae	demersal	Algoa Bay, South Africa	36		1.8 MF/ind. 0.1 MP/ind.	McGregor 2020 [202]
Mullet (juvenile)	*Mugil sp.*	Mugilidae	benthopelagic	Umgeni, KwaZulu Natal, RSA	29	59%	1.14 ± 1.25	Naidoo (2020) [193]
Mullet (juvenile)	*Mugil sp.*	Mugilidae	benthopelagic	Durban Harbor, KwaZulu Natal, RSA	29	55%	1.00 ± 1.46	Naidoo (2020) [193]
Largescale mullet	*Planiliza macrolepis*	Mugilidae	demersal	Thaikadappuram, off the coast of Kerala, India	2	50%	1	Robin (2020) [158]
Grooved mullet	*Liza dumerilii*	Mugilidae	demersal	Catemba beach, Maputo, Mocambique	20	15%	1-3	Karlsson (2015) [133]
Greenback mullet	*Liza subviridis*	Mugilidae	demersal	Coastal waters around Karachi, Pakistan	15			Akhter (2022) [200]
Malabar glassy perchlet (juvenile)	*Ambassis dussumieri*	Ambassidae	demersal	Durban Harbor, KwaZulu Natal, RSA	29	69%	0.93 ± 0.75	Naidoo (2020) [193]
Australian snapper	*Chrysophrys auratus*	Sparidae	reef-associated	off the coast of Perth, Western Australia	19	36.8%	1.32 ± 0.64	Wootton (2021) [198]
Bengal yellowfin seabream	*Acanthopagrus datnia*	Sparidae	demersal	Sundarbans mangrove estuary, near Khulna, Bangladesh	3			Sultan (2023) [49]
Carpenter seabream	*Argyrozona argyrozona*	Sparidae	benthopelagic	Agulhas Bank, RSA	15		0.03 ± 0.01 MP/g	Sparks (2020) [190]
Goldsilk seabream	*Acanthopagrus berda*	Sparidae	demersal	Sundarbans mangrove estuary, near Khulna, Bangladesh	1			Sultan (2023) [49]
Goldsilk seabream	*Acanthopagrus berda*	Sparidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Threadfin silver biddy	*Gerres filamentosus*	Gerridae	demersal	KwaZulu Natal, RSA				Naidoo (2017) [195]
Threadfin silver biddy	*Gerres filamentosus*	Gerridae	demersal	Payyambalam, off the coast of Kerala, India	1	0%		Robin (2020) [158]
Threadfin silver biddy	*Gerres filamentosus*	Gerridae	demersal	Port Blair bay, Andaman & Nicobar Islands	13	30.8%		Goswami (2020) [53]
Common silver biddy	*Gerres oyena*	Gerridae	reef-associated	Adyar, Southeast India	10		5.9 MP/individual	Harikrishnan (2023) [183]
Northern Whiting	*Sillago sihama*	Sillaginidae	reef-associated	KwaZulu Natal, RSA				Naidoo (2017) [195]
Northern Whiting	*Sillago sihama*	Sillaginidae	reef-associated	off the coast of Kerala, India	9	22.2%	1	Robin (2020) [158]

Continued

Northern Whiting	*Sillago sihama*	Sillaginidae	reef-associated	Marine Station, Inhaca Island, Maputo, Mocambique	20	40%	1 - 5	Karlsson (2015) [133]
Indian Sillago	*Sillago indicus*	Sillaginidae	demersal	Adyar, Southeast India	10		3.8 MP/individual	Harikrishnan (2023) [183]
King George Whiting	*Sillaginodes punctatus*	Sillaginidae	demersal	off the coast of Perth, Western Australia	24	12.5%	0.13 ± 0.08	Wootton (2021) [198]
Lane snapper	*Lutjanus synagris*	Lutjanidae	pelagic	Sundarbans mangrove estuary, near Khulna, Bangladesh	4		-	Sultan (2023) [49]
Bigeye snapper	*Lutjanus lutjanus*	Lutjanidae	reef-associated	off the coast of Kerala, India	1	0%		Robin (2020) [158]
Brownstripe red snapper	*Lutjanus vitta*	Lutjanidae	reef-associated	off the coast of Kerala, India	1	0%		Robin (2020) [158]
Brownstripe red snapper	*Lutjanus vitta*	Lutjanidae	reef-associated	Palk Bay and Gulf of Mannar, India	6	16.7%		Karthik (2022) [194]
Russell's snapper	*Lutjanus russellii*	Lutjanidae	reef-associated	Thottapally, off the coast of Kerala, India	2	50%		Robin (2020) [158]
Two-spot red snapper	*Lutjanus bohar*	Lutjanidae	reef-associated	Palk Bay and Gulf of Mannar, India	10	30%		Karthik (2022) [194]
Striped snapper	*Lutjanus indicus*	Lutjanidae	reef-associated	Adyar, Southeast India	10		5.8 MP/individual	Harikrishnan (2023) [183]
John's snapper	*Lutjanus johnii*	Lutjanidae	reef-associated	Chabahar Bay, Iran	10		2.44 ± 1.46	Kord (2019) [187]
Common archerfish	*Toxotes chatareus*	Toxotidae	pelagic	Sundarbans mangrove estuary, near Khulna, Bangladesh	4			Sultan (2023) [49]
Spotted scat	*Parascolopsis eriomma*	Scatophagidae	benthopelagic	Sundarbans mangrove estuary, near Khulna, Bangladesh	6			Sultan (2023) [49]
Spotted scat	*Scatophargus argus*	Scatophagidae	reef-associated	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Spotted scat	*Scatophargus argus*	Scatophagidae	reef-associated	Ennore, Southeast India	10		6.3 MP/indiividual	Harikrishnan (2023) [183]
False trevally	*Lactarius lactarius*	Lactariidae	pelagic-neritic	Coast off Kochi, Kerala, India (pre-monsoon)	15e	0%		James (2020) [184]
Barramundi	*Lates calcarifer*	Latidae	demersal	Sundarbans mangrove estuary, near Khulna, Bangladesh	3		-	Sultan (2023) [49]
Barramundi	*Lates calcarifer*	Latidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Saddle grunt	*Pomadasys maculatus*	Haemulidae	reef-associated	off the coast of Kerala, India	3	0%		Robin (2020) [158]
Japanese threadfin seabream	*Nemipterus japonicus*	Nemipteridae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]

Continued

Japanese threadfin seabream	*Nemipterus japonicus*	Nemipteridae	demersal	off the coast of Kerala, India	3	0%		Robin (2020) [158]
Japanese threadfin seabream	*Nemipterus japonicus*	Nemipteridae	demersal	Ennore, Southeast India	10		7.6 MP/individual	Harikrishnan (2023) [183]
Randall's threadfin bream	*Nemipterus randalli*	Nemipteridae	demersal	Coast off Kochi, Kerala, India (pre-monsoon)	7	0%		James (2020) [184]
Randall's threadfin bream	*Nemipterus randalli*	Nemipteridae	demersal	Coast off Kochi, Kerala, India (monsoon)	20	0%		James (2020) [184]
Randall's threadfin bream	*Nemipterus randalli*	Nemipteridae	demersal	Coast off Kochi, Kerala, India (post-monsoon)	11	0%		James (2020) [184]
Notched-fin threadfin bream	*Nemipterus peronei*	Nemipteridae	demersal	Chabahar Bay, Iran	10		2.62 ± 2.15	Kord (2019) [187]
Notched-fin threadfin bream	*Nemipterus peronei*	Nemipteridae	demersal	Port Blair Bay, Andaman & Nicobar Islands	8	25%		Goswami (2020) [53]
White cheek monocle bream	*Scolopsis vosmeri*	Nemipteridae	reef-associated	Palk Bay and Gulf of Mannar, India	11	0%		Karthik (2022) [194]
Thumbprint monocle bream	*Scolopsis bimaculata*	Nemipteridae	reef-associated	Palk Bay and Gulf of Mannar, India	3	0%		Karthik (2022) [194]
Moontail bullseye	*Priacanthus hamrur*	Priacanthidae	reef-associated	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Areolate grouper	*Epinephelus areolatus*	Epinephilidae	reef-associated	Palk Bay and Gulf of Mannar, India	12	8.3%		Karthik (2022) [194]
Spiny-cheek grouper	*Epinephelus diacanthus*	Serranidae	demersal	Coast off Kochi, Kerala, India (post-monsoon)	8	0%	-	James (2020) [184]
Orange spotted grouper	*Epinephelus coiodes*	Serranidae	reef-associated	Chabahar Bay, Iran	10		4.14 ± 4.9	Kord (2019) [187]
Bluelined hind	*Epinephelus formosa*	Epinephilidae	reef-associated	Palk Bay and Gulf of Mannar, India	13	0%		Karthik (2022) [194]
Tomato hind	*Cepphalopholis sonnerti*	Epinephilidae	reef-associated	Palk Bay and Gulf of Mannar, India	8	25%		Karthik (2022) [194]
Pleuronectiformes								
Largescale tonguesole	*Cynoglossus arel*	Cynoglossidae	demersal	off Parangipettai, Southeast coast of India	20			Nithin (2022) [185]
Bengal tonguesole	*Cynoglossus cynoglossus*	Cynoglossidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Roughscale tonguesole	*Cynoglossus lida*	Cynoglossidae	demersal	Port Blair bay, Andaman & Nicobar Islands	6	50%		Goswami (2020) [53]

Continued

Malabar tonguesole	*Cynoglossus macrostomus*	Cynoglossidae	benthopelagic	Coast off Kochi, Kerala, India (pre-monsoon)	46	0%		James (2020) [184]
Malabar tonguesole	*Cynoglossus macrostomus*	Cynoglossidae	benthopelagic	Coast off Kochi, Kerala, India (monsoon)	40	5%		James (2020) [184]
Malabar tonguesole	*Cynoglossus macrostomus*	Cynoglossidae	benthopelagic	Coast off Kochi, Kerala, India (post-monsoon)	20	0%		James (2020) [184]
Scombriformes								
Australian herring	*Arripis georgianus*	Arripidae	pelagic-neritic	off the coast of Perth, Western Australia	20	25%	0.50 ± 0.24	Wootton (2021) [198]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Chabahar Bay, Iran	10		3.85 ± 3.5	Kord (2019) [187]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Coastal waters around Karachi, Pakistan	2			Akhter (2022) [200]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Palk Bay and Gulf of Mannar, India	12	25%		Karthik (2022) [194]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Kalamukku, Kerala, India	30			Daniel (2020) [189]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Coast off Kochi, Kerala, India (monsoon)	40	55%		James (2020) [184]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Coast off Kochi, Kerala, India (pre-monsoon)	50	0%		James (2020) [184]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Coast off Kochi, Kerala, India (post-monsoon)	40	2.5%		James (2020) [184]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Tuticorin, Indian Southeast coast	20		0.98 ± 0.32 MP/ind. 0.008 ± 0.002 MP/g bw 0.13 ± 0.05 MP/g gut	Sathish (2020) [188]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	off the coast of Tamil Nadu, India	17	5.9%		Karthik (2018) [112]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	off Parangipettai, Southeast coast of India	20			Nithin (2022) [185]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Thalikulam, off the coast of Kerala, India	1	0%		Robin (2020) [158]
Indian mackerel	*Rastrelliger kanagurta*	Scombridae	pelagic-neritic	Ennore, Southeast India	10		4.7 MP/individual	Selvam (2021) [186]
Chub mackerel	*Scomber japonicus*	Scombridae	pelagic-neritic	Agulhas Bank, RSA	15		0.28 ± 0.05 MP/g	Sparks (2020) [190]
Skipjack tuna	*Katsuwonus pelamis*	Scombridae	pelagic-oceanic	Tuticorin, Indian Southeast coast	10		0.02 ± 0.06 MP/ind. 6.67×10^{-5} MP/g bw 0.001 ± 0.0005 MP/g gut	Sathish (2020) [188]
Frigate tuna	*Auxis thazard*	Scombridae	pelagic-neritic	Sundarbans mangrove estuary, near Khulna, Bangladesh	3			Sultan (2023) [49]

Continued

Obtuse barracuda	*Sphyraena obtusa*	Sphyraenidae	reef-associated	Kalamukku, Kerala, India	30			Daniel (2020) [189]
Barracuda	*Sphyraena* sp.	Sphyraenidae	reef-associated	Adyar, Southeast India	10		5.6 MP/individual	Harikrishnan (2023) [183]
Pickhandle barracuda	*Sphyraena jello*	Sphyraenidae	reef-associated	Palk Bay and Gulf of Mannar, India	10	10%		Karthik (2022) [194]
Large head ribbon fish	*Trichiurus lepturus*	Trichiuridae	benthopelagic	Sundarbans mangrove estuary, near Khulna, Bangladesh	3			Sultan (2023) [49]
Large head ribbon fish	*Trichiurus lepturus*	Trichiuridae	benthopelagic	Cox's Bazar, Bangladesh			34.2 MP/g	Hasan (2022) [46]
Large head ribbon fish	*Trichiurus lepturus*	Trichiuridae	benthopelagic	Kuakata, Bangladesh			46.0 MP/g	Hasan (2022) [46]
Scorpaeniformes								
Cape gurnard	*Chelidonichthys capensis*	Triglidae	demersal	Agulhas Bank, RSA	15		0.25 ± 0.04 MP/g	Sparks (2020) [190]
Siluriformes								
Long whiskers catfish	*Mystus gulio*	Bagridae	demersal	Sundarbans mangrove estuary, near Khulna, Bangladesh	9			Sultan (2023) [49]
Sona sea catfish	*Sciades sona*	Ariidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Sona sea catfish	*Sciades sona*	Ariidae	demersal	Bay of Bengal, off the coast of Bangladesh	10			Ghosh (2021) [48]
Spotted catfish	*Arius maculatus*	Ariidae	demersal	off Parangipettai, Southeast coast of India	20			Nithin (2022) [185]
Gangetic ailia	*Ailia coila*	Ailiidae	pelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Kata	*Nemapterix nenga*	Ailiidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Blacktip sea catfish	*Plicofollis dussumieri*	Ailiidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Threadfin sea catfish	*Arius arius*	Ariidae	demersal	Coast off Tamil Nadu, India	11	9.1%		Karthik (2018) [112]
Threadfin sea catfish	*Arius arius*	Ariidae	demersal	Kochi, off the Coast of Kerala, India	3	33.3%		Robin (2020) [158]
Threadfin sea catfish	*Arius arius*	Ariidae	demersal	Ennore, Southeast India	10		3.5 MP/individual	Harikrishnan (2023) [183]
Gray eel catfish	*Plotosus canius*	Plotosidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Tetraodontiformes								
Masked triggerfish	*Sufflamen fraenatus*	Balistidae	reef-associated	Thoothukudi, Gulf of Mannar, South India	20		51.2 MP/100g muscle 50.1 MP/100g intestine	Selvam (2021) [186]
Long-spined tripodfish	*Pseudotriacanthus strigilifer*	Triacanthidae	demersal	Thoothukudi, Gulf of Mannar, South India	20			Selvam (2021) [186]
Torpediniformes								
Spotted numbfish	*Narcine timlei*	Narcinidae	demersal	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]

carry MP. The results, however, compare positively with results from the coast of Kerala of 2020 [158] and from the coast of Australia from 2021 [198], where 31.4% and 35.5% of the sampled fish were found to have ingested MP, respectively. Fibers (48%) predominated, followed by fragments (35%), foams (9%) and films (8%) [194]. In April 2019, Selvam *et al.* [186] found a much higher MP concentration in five species of fish from the Gulf of Mannar. The species were the masked triggerfish (*Sufflamen fraenatus*), the pennant coral fish (*Heniochus acuminatus*), the cleftbelly trevally (*Atropus atropos*), the long spined tripod fish (*Pseudotriacanthus strigilifer*) and the silver belly (*Leiognathus brevirostris*) from Thoothukudi at the Gulf of Mannar coast, and MP content ranged as high as 51.2 MP/100g muscle tissue and 50.1 MP/100g intestines [186]. A third study comes out of the region around Tuticorin, where 5 fish species of commercial value have been scrutinized for MP content, among them the Bombay duck (*Harpadon nehereus*), the skipjack tuna (*Katsuwonus pelamis*) and the Indian mackerel (*R. kanagurta*) [188]. MP content ranged from 0.11 ± 0.06 to 3.64 ± 1.7 MP/individual. With 3.64 ± 1.7 MP/individual, the Bombay duck (*H. nehereus*) was found to exhibit the highest MP contamination. Nevertheless even higher MP concentrations in *H. nehereus* had been reported from other regions such as the Northern Bay of Bengal (8.72 ± 1.54 MP/individual) [44]. Fibers (70%) were again found to be the dominant type of MP ingested by the fish [188]. Nithin *et al.* collected 10 species of fish off Parangipettai, Tamil Nadu, on the southeast coast of India [185]. MP contamination in gills and GIT of the fish was investigated, and it was found that with 1.70 ± 0.01 MP/individual, the flathead grey mullet (*Mugil cephalus*) exhibited the highest MP concentration in its gills, while with 2.3 ± 0.26 MP/individual, the Indian mackerel (*R. kanagurta*) exhibited the highest MP concentration in GIT. 97% of MPs discovered in the fish were fibers, with the remaining 3% being pellets. LDPE, PP, and PS were the dominant polymers [185]. In recent times, a lot of work has emanated out of the Gulf of Bengal, from off the coast of Bangladesh. Ghosh *et al.* [45] studied the MP pollution in the gastrointestinal tract of 10 commercially important fish species. These were from 5 genera and 10 genera, among them the Indian mackerel (*R. kanagurta*) and the flathead grey mullet *(M. cephalus*). The fishes were selected based on their feeding behavior, where the diet comprises of phytoplankton, zooplankton and early stages of fish, crustaceans and molluscs which resemble the microplastic in their sizes. The fishes came from different zones, pelagic, demersal, benthic and reef. Overall, 100 fish specimen were analyzed, and a total of 215 MPs were recovered, making for an average of 2.2 ± 0.90 MP per specimen. In the study, pelagic fishes had more microplastic contamination than demersal fishes. Among the polymers found, PE (55%) and PP (33%) were by far the most abundant. Nearer to the Bangladeshi coastline, namely in the Sundarban's estuary, in 2022, Sultan *et al.* [49] studied the MP abundance in the muscle tissue and the gastrointestinal tract of 17 fish species, among the commercially important Hilsa shad (*Tenuoalosa ilisha*) and a number of seabream species

[49]. A concentration was found of 5.37 ± 1.07 to 54.30 ± 16.53 MP items/g wet body weight (dw) in muscle samples and of 7.33 ± 1.89 to 205.61 ± 136.88 MP items/g (dw) in GIT samples [49]. The variety of plastic types is higher nearer the coast, with again PE and PP constituting the largest share of MPs. However, with 17.5% each, PE and PP in the fish examined are not dominant. Clearly, the MP concentration in fish caught near the coast is higher than further off to sea [49]. Also, in the Sundarban mangrove forest, Sarker *et al.* have studied the transfer of MP between trophic levels. The abundance of MPs in collected samples varied between 0.56 ± 0.25 MP/individual and 6.06 ± 1.20 MP/individual. The maximum number of MPs was recorded in predators (5.5 ± 1.21 MP/individual), followed by filter feeders (5.1 ± 0.85 MP/individual), browsers (4.5 ± 0.39 MP/individual), deposit feeders (1.2 ± 0.26 MP/individual), selective planktivores (1.1 ± 0.28 MP/individual) and variable feeders (1.01 ± 0.25 MP/individual) [50]. An increase of MP concentration was found with a successive increase of trophic level. The authors found the highest MP abundance in quaternary consumers (4.17 items/individual) followed by tertiary consumers (3.17 items/individual), secondary consumers (2.74 items/individual) and primary consumers (0.56 items/individual) [50].

From the numerous islands in the Indian Ocean, studies of MP contamination in fish have also been published. Goswami *et al.* looked at the MP bioaccumulation by marine organisms in Port Blair Bay, Andaman Islands. With 22.5 ± 15.3 MP/fish, the maximum MP ingestion was observed in adult Malabar trevally (*C. malabricus*). 45.8% of all fish examined showed MP content [53]. In South Maldivian waters, Shiyana *et al.* sampled 35 specimen of big-eye scad (*Selar crumenophthalmus*) and 21 specimen of mackerel scad (*Decapterus macarellus*), finding that respectively 80% and 76% of the fish had ingested MP [191]. Big-eye scad carried 4.03 ± 5.6 MP/fish (0.02 MP/g), while mackerel scad was found with 2.19 ± 2.0 MP/fish (0.04 MP.g) [191]. Silva *et al.* reported MP contamination in fish and mussels in southern coastal waters of Sri Lanka [204]. PE was found in the gut content of *Sardinella gibbosa* in the Negombo lagoon, Sri Lanka [139].

In 2021, an appreciable abundance of MP in fish from the Southern coast of Australia was reported by Wootton *et al.* [198]. The fish sampled along the Southwestern Australian coast off Perth included sea mullet (*M. cephalus*), Australian herring (*Arripis georgianus*) and Australian sardine (*Sardinops sagax*). Throughout the Southern Australian coast Wootton *et al.* found 35.5% of the sampled specimen to contain MP [198]. Previously, Crutchett el al. had reported that only 26% of the sampled Australian sardines off the West coast of Australia contained MP [197].

A number of important studies have been carried out along the Eastern coast of Africa. From April to June 2019, Sparks and Immelman sampled 7 species of commercially important fish (*Trachurus capensis*, *Merluccius capensis*, *Merluccius paradoxus*, *Etrumeus whiteheadi*, *Scomber japonicus*, *Chelidonichthys capensis* and *Argyrozona argyrozona*) off Agulhas Bank, at a depth of 50 - 200 m

[190]. MPs were recorded in 86.67% fish sampled, with abundances ranging from 2.8 to 4.6 items/fish, with *S. japonicus* (0.28 ± 0.05 MP/g), *C. capensis* (0.25 ± 0.04 MP/g) and *M. capensis* (0.25 ± 0.03 MP/g) exhibiting the highest MP content. Fibers constituted the majority of MPs found [190]. A. Bakir looked at the difference in MP contamination in the three commercially important pelagic fish species European anchovy (*Engraulis encrasicolus*), West Coast round herring (*Etrumeus whiteheadi*) and South African sardine (*Sardinops sagax*) on the Atlantic coast of South Africa and along the Southern coast of South Africa that opens up to the Indian Ocean [196]. MP occurrence in European anchovy from 5 locations—from the Orange River mouth to Cape Agulhas—on the Atlantic coast was found in 50% - 68% of the sampled fish with an average of 1.10 - 1.50 MP/fish. On the Southern coast, from Cape Agulhas to Mossel Bay, 48% - 57% of the sampled fish had ingested MP, with an average concentration of 0.92 - 0.94 MP/fish [196]. The West Coast round herring also showed a slightly lower MP ingestion on the Atlantic side than along the South coast, with 50% - 88% of the fish contaminated on the Atlantic coast and 72% - 80% of the fish contaminated on the Southern coast. For the South African sardine, 56% - 88% of the fish were found with MP presence at different locations on the Atlantic coast, while 70% - 74% of the fish were found with MP along the Southern coast of South Africa. Fibers were by far the most dominant MP found in the fish [196]. McGregor and Strydom studied the feeding ecology and MP ingestion in different developmental stages of the Southern mullet (*Chelon richardsonii*) in the surf zone of Algoa Bay. 4-% of the sampled fish were found to have ingested fibers, 5% had ingested microplastic fragments. All developmental stages of the Southern mullet exhibited MP ingestion [202]. Naidoo *et al.* have published two studies from the KwaZulu Natal coast. In one, Naidoo *et al.* looked at MP presence in the Mozambique tilapia (*Oreochromis mossambicus*), the Crescent grunter (*Terapon jarbua*), the Malabar glassy perchlet (*Ambassis dussumieri*) and in mullets (*Mugil* sp.), within four mangroves along the east coast of South Africa [193]. 52% of the 174 fish that were analyzed contained MP. Rayon (70.4%), polyester (10.4%) and nylon (5.2%) were the most frequent polymers. All of these polymer types are associated with fibers, and fibers were also the most common form of MP found in the fish [193]. In the second, Naidoo *et al.* looked at the amount of MP ingestion in the estuarine mullet (*M. cephalus*) in Durban harbor. This study from 2015 showed that of the 70 mullets sampled 73% had MP in their gut with a mean of 3.8 MP/fish [205]. Furhter to the north, Karlsson studied the MP contamination in Northern Whitling off Inhaca Island, Mozambique and found that 40% of the 20 fish that were sampled showed MP presence, with a MP concentration of 1 - 5 particles/fish [133].

9. Microplastic Abundance in Shellfish Species in the Indian Ocean

In 2021, the global shellfish industry was marketed at $51.32 billion. In 2021-2022,

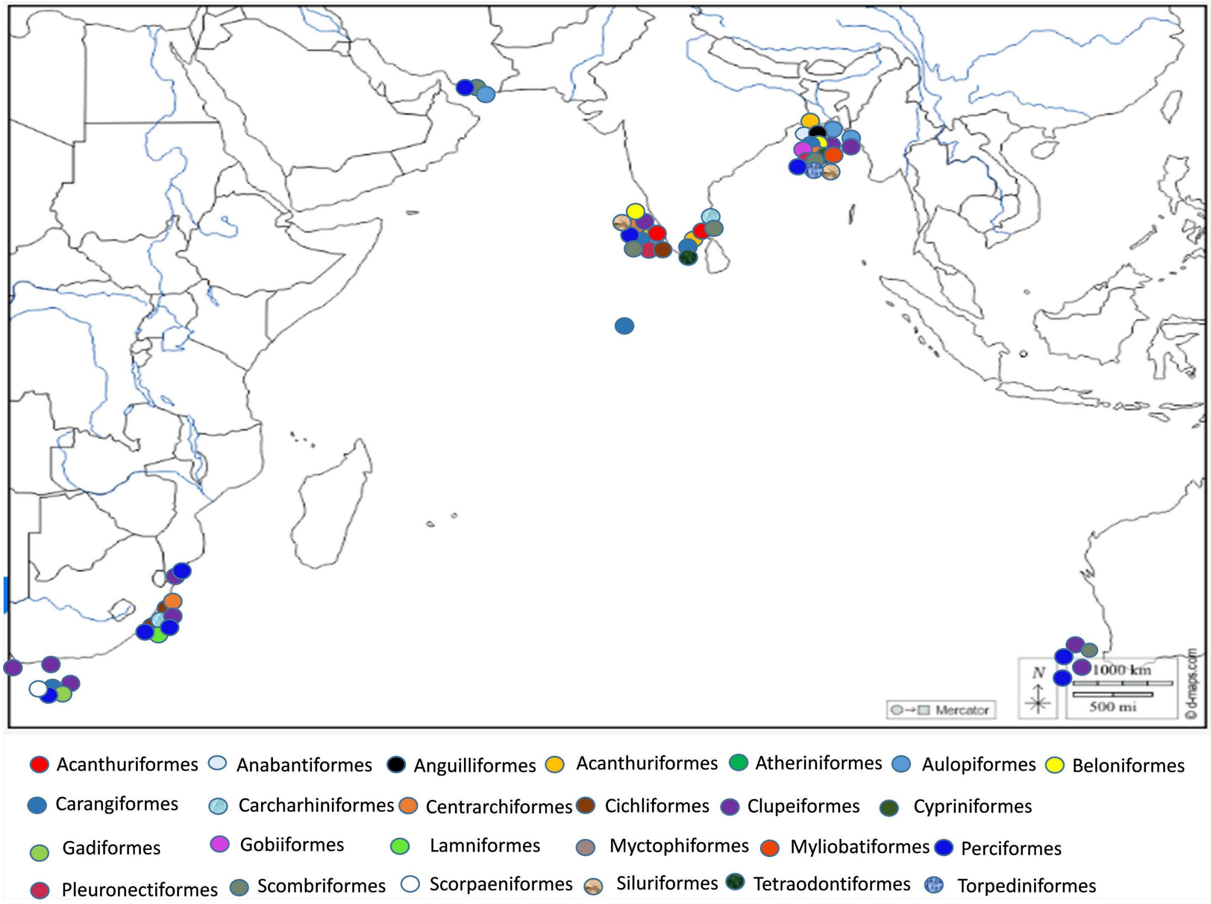

Figure 4. Sampling sites for different fish species for microplastic content screening.

frozen shrimp was the major seafood item exported from India, both in quantity and value, accounting for a share of 53 per cent in quantity and 75 per cent of the total revenue. India is the world's second-largest producer of whiteleg shrimp (*Litopenaeus vannamei*), with a production of 2.2 million metric tons worth $2.4 billion. Agreeably, much of the shrimp is farmed. The same goes for Bangladesh, where the majority of black tiger shrimp (*Penaeus monodon*) and fresh-water prawns (*Macrobrachium rosenbergii*) are farmed. Nevertheless, also farmed shrimps are potentially exposed to MP as has been found also in other parts of the world [206]. In general, it is believed that currently 49% of the world's supply of fish, crustaceans and molluscs is farmed. Especially in the Sundarbans extensive shrimp farming has established itself. Sultan *et al.* have also looked at MP presence in a limited number of shellfish in the Sundarbans mangrove estuary near Kulna, Bangladesh, in the wild such as the speckled shrimp (*Metapenaeus monoceros*), which exhibited 73 ± 17 MP/g GIT and 21.9 ± 6.7 MP/g muscle tissue and the yellow shrimp (*Metapenaeus brevicornis*), which exhibited 69 ± 18 MP/g GIT and 54.8 [49]. In 2020, Hossain *et al.* published a MP contamination in *M. monoceros* of 3.87 ± 1.05 MP/g tissue from the North Bay of Bengal [43]. In many cases, crab and prawn samples show an appreciable percentage of crabs with MPs. Thus, 40% of Indian-Pacific swamp carbs in Inhaca Island, Mozambique

[133], and 80% of flower crabs (*Portunus pelagicus*) and 80% of Indian prawns (*Penaeus indicus*) in Port Blair Bay [160] exhibit MPs. In Port Blair Bay, *P. pelagicus* was found to ingest MP pellets more frequently than other sampled animal species [53]. Sarker *et al.* have studied MP ingestion in the speckled shrimp, the Jinga shrimp, the Jawla paste shrimp, and the giant tiger prawn and found an average of 2.10 ± 0.25 MP/individual over all individuals sampled [50]. Crabs such as the long-legged spider crab, the indo-pacific swamp crab were overall found to have a slightly higher average contamination per individual, with 2.84 ± 0.30 MP/individual [50].

Patterson *et al.* have looked at the MP contamination of the Indian edible oyster (*Magallana bilineata*) along the Tuticorin coast, Southeast India [207]. The authors found a mean MP abundance of 6.9 ± 3.84 particles/oyster and 0.81 ± 0.45 particles/g tissues. The largest oysters contained both the most and the highest concentration of MPs [207]. Also, Sathyadith *et al.* have found microplastics in cultured oysters (*Crassostrea madrasensis*) in Kalpitiya Lagoon, Sri Lanka [208] (**Table 3**).

What danger MP containing seafood represents to humans is debatable, as with the gutting of fish most MP content is avoided. However, about 20% of fish landings go into fish meal which then is affected by the MP content in the fish. As fish meal also constitutes the offal of fish, the risk to utilize parts of the fish that hold MP is quite high [49] [211]. *E. encrasicolus is* one of the main fish species that contribute to fish meal production, and studies have shown that these species carry MP content, when caught in the Indian Ocean.

10. Conclusions

Until 2015, MP contents in the Indian Ocean and on the coastlines have been barely studied. In the last 5 years, however, there has been a considerable information outflow in regard to MP presence in the region of the Indian Ocean, including the input of MPs and the movement of MPs from location to location as well as among trophic levels. There is less information on the fate of MPs in the region, and almost nothing is known about the accumulation of MPs on the ocean floor or about hotspots of MPs in ocean sediments along the respective coastlines. Especially, the Iranian, Pakistani, Indian, Bangladeshi, South African, and Kenyan coastlines and coastal waters have been screened for MP contamination. Less studied are the Mozambique, Tanzanian, and Omani coastlines as well as the Indian Ocean coast of Myanmar, Thailand, and Indonesia. Not studied at all are the Somali and Yemeni coastlines. MP circulation with prevailing currents in Southern Tropics carries MP westward across the Indian Ocean, seasonally eastward in the Northern Tropics, and southward along the Australian, but especially also the African coast. Thus, islands in the Western Indian Ocean such as the Seychelles are affected by plastic litter originating from Southeast Asia.

To curb the increase in MP in the Indian Ocean, it is important to limit the

Table 3. Marine species assessed for MP content in the Indian Ocean—Part 2 (shellfish).

Species	Latin name	Family	Marine habitat	Region of the Indian Ocean	No. of specimen	Specimen w. MP (%)	MP/ind.	Reference
Cephalopoda								
Common octopus	*Octopus vulgaris*	Octopodidae	reef-associated	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Bivalve species	Latin name	Bivalve family	marine habitat	Region of the Indian Ocean	No. of specimen		MP/bivalve	Reference
Decapoda								
Yellow shrimp	*Metapenaeus brevicornis*	Penaeidae	benthic	Sundarbans mangrove estuary, near Khulna, Bangladesh	20		69 ± 18 MP/g GIT and 54.8 ± 16.0 MP/g muscle	Sultan (2023) [49]
Speckled shrimp	*Metapenaeus monoceros*	Peneaidae	benthic	Sundarbans mangrove estuary, near Khulna, Bangladesh	19		73 ± 17 MP/g GIT and 21.9 ± 6.7 MP/g muscle	Sultan (2023) [49]
Speckled shrimp	*Metapenaeus monoceros*	Peneaidae	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Speckled shrimp	*Metapenaeus monoceros*	Peneaidae	benthic	North Bay of Bengal, Bangladesh			3.87 ± 1.05 MP/g	Hossain (2020) [43]
Jinga shrimp	*Metapenaeus affinis*	Peneaidae	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Jawla paste shrimp	*Acetes indicus*	Sergestidae	pelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Giant tiger prawn	*Penaeus monodon*	Peneaidee	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Giant tiger prawn	*Penaeus monodon*	Peneaidee	benthic	North Bay of Bengal, Bangladesh			3.40 ± 1.23 MP/g	Hossain (2020) [43]
Indian prawn	*Penaeus indicus*	Peneaidee	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Indian prawn	*Penaeus indicus*	Peneaidee	benthic	Port Blair Bay, Andaman & Nicobar Islands	5	80%		Goswami (2020) [53]
Orange mud crab	*Scylla olivacea*	Peneaidae	benthic	Sundarbans mangrove estuary, near Khulna, Bangladesh	5			Sultan (2023) [49]
Indo-pacific swimming crab	*Charybdis helleri*	Portunidae	benthopelagic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Flower crab	*Portunus pelagicus*	Portunidae	reef-associated	Port Blair Bay, Andaman & Nicobar Islands	5	80%		Goswami (2020) [53]

Continued

Three-spot swimming crab	*Portunus sangiuiatus*	Portunidae	benthic	Coastal waters of Karachi, Pakistan	6			Akhter (2022) [200]
Indo-pacific swamp crab	*Scylla serrata*	Portunidae	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Indo-pacific swamp crab	*Scylla serrata*	Portunidae	benthic	Saco,, Inhaca Island, Maputo, Mocambique	20	40%		Karlsson (2015) [133]
Long-legged spider crab	*Macropodia rostrata*	Inachidae	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Horned ghost crab	*Ocypode ceratophthalmus*	Ocypodidae	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Gastropoda								
Lined nerite	*Nerita articulata*	Neritidae	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Obtuse horn shell	*Cerithidea obtusa*	Potamididae	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Telescope snail	*Telescopium telescopium*	Potamididae	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Bivalvia								
Asiatic hard clam	*Meretrix meretrix*	Veneridae	benthic	Sundarbans mangrove estuary, Bangladesh				Sarker (2022) [119]
Asian green mussel	*Perna viridis*	Mytilidae	benthic	Kasimedu fishing harbor, Chennai, India	5			Naidu (2019) [209]
Antique ark	*Anadara antiquata*	Arcidae	benthic	Tanzania				Mayoma (2020) [150)]
Indian edible oyster	*Magallana bilineata*	Ostreidae	benthic	Tuticorin, India (3 locations)			6.9 ± 3.94 MP/ind. 0.81 ± 0.45 MP/g	Patterson (2019) [207]
	Donax cuneatus	Donacidae	benthic	Tuticorin, India (11 locations)	225		0.29 - 32.31 MP/ind. [0.6 - 1.3 MP/g]	Sathish (2020) [188]
	Tellina sp.	Tellinidae	benthic	off the coast of Kochi, India				Naidu (2018) [210]
Polychaeta								
Scutate stermaspid worm	*Sternaspis scutata*	Sternaspidae	benthic	off the coast of Kochi, India				Naidu (2018) [210]
	Magelona cinta (*M. filiformis*)	Sternaspidae	benthic	off the coast of Kochi, India				Naidu (2018) [210]
	Gunnarea gaimardi	Sabellariidae	benthic	Off the Southeast coast of RSA			0.056 - 1.113 MP/g	Nel (2018) [174]

entry of plastics in general by better waste management at the community level. In many of the riparian states lining the Indian Ocean bans on single plastic have been signed into law, but the laws have in part only been weakly enforced. Interestingly, different locations along the Indian Ocean that have been sampled for MP presence have shown a diversity of plastic and polymer types. Thus, fibers have not always been seen as the dominant contributor to the overall MP balance in the region. Spillage of pristine industrial plastic micro-pellets contributes significantly in certain locations. This does not come as a surprise as the Indian Ocean possesses some of the most important shipping routes in the world, connecting Europe, Africa, and the Middle East with South and East Asia. Discarded fishing gear is another important source of MP in the Indian Ocean. Certain contributors to primary MPs such as microbeads in cosmetics have been phased out in many countries and will no longer be of importance. Others such as textile fibers and microtires will remain contributors to MPs in general, although microtires specifically have not been recorded in fish to date. Secondary MPs resulting from the gradual breakdown of the overall solid plastic waste entering the Indian Ocean will remain an important source of MPs in the Indian Ocean.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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