Impacts of marine litter on coastal and marine benthic ecosystems

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Abstract: Marine litter has been identified as one of the greatest threats to sustainability of aquatic ecosystems. The litter in the coastal and marine habitat can be those transported from the intertidal zone, terrestrial region through tidal waters, storm-water, wind, sewage and rivers, or it can be those directly deposited on the beaches or dumped into the aquatic systems by human interactions. About 50% of plastic marine litter is composed of low-density polymers like polyethene - PE and polypropylene – PP which readily sinks and reaches the benthic ecosystem where it can be trapped in hard rocky structures. Different items like plastic, rubber, glass, metal and other non-biodegradable items contribute to marine debris and UNEP has provided a code for categorizing each of these items. The dominant litter in each area differs, but in most areas, plastic has been found to be the major litter. The tiny micro-plastics have spread into different benthic realms of the coastal and marine eco-systems and in some locations even very high concentrations are observed. The impacts of marine litter on the benthic ecology and on the marine fauna are discussed briefly.

Keywords. Marine litter, coastal marine habitats, marine pollution

1. Introduction

Marine litter has been identified as one of the greatest threats to sustainability of aquatic ecosystems. Since 1970, there has been targeted research on different aspects of marine litter and its overall impact on life under water. It has been estimated that about 5.25 trillion plastic particles (weighing 269,000 tons) are floating in the sea. Globally more than 300 million tons of plastic is produced every year and about 75% of marine debris is made of plastic (Napper and Thompson, 2019). The litter in the coastal and marine habitat can be those transported from the intertidal zone, terrestrial region through tidal waters, storm-water, wind, sewage and rivers, or it can be those directly deposited on the beaches or dumped into the aquatic systems by human interactions. According to United Nations Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), 60 to 80%, of the global litter found in the coastal and marine ecosystems originate from land and only the rest from sea based activities. About 50% of plastic marine litter is composed of low-density polymers like polyethene - PE and polypropylene – PP which readily sink and reach the benthic ecosystem where it can be trapped in hard rocky structures. In areas where the water currents are low these will be transported to a considerable distance before settling down. Once it settles down, it impacts the functioning of benthic ecosystem services. Based on size, marine debris has been classified into micro (≤5 mm), meso- (5 mm – 2.5 cm) and macro (>2.5 cm). Different items like plastic, rubber, glass, metal and other non-biodegradable items contribute to marine debris and UNEP has provided a code for categorizing each of these items. The dominant litter in each area differs, but in most areas, plastic has been found to be the major litter. The tiny micro-plastics have spread into different benthic realms of the coastal and marine eco-systems and in some locations even very high concentrations are observed (Wright et al, 2013). The impacts of marine litter on the benthic ecology and on the marine fauna is briefly given below.

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2. Impact of litter on benthic ecology

Usually estuarine banks have good human population density and this has been found to increase the quantity of litter entering the estuaries. In most coastal villages there are no solid waste management programs. This has led to dumping of wastes in the open areas, shallow canals and directly into the estuaries. Studies conducted by CMFRI have indicated that the flow of tidal water is hindered by litter and the water becomes stagnant. Litter slowly settles to the bottom and smothers the substratum. In some open areas, the substratum has been found to have layers of marine debris and there were no benthic fauna. Based on the local current pattern and strength and presence /absence of obstructions, the floating litter settles down and forms hot spots. These hot spots become dead zones. Torn and discarded fishing gear by fishers near the shore has also been found to enter the estuaries during high tide and spread on the estuarine bottom. The plastics after getting trapped in the benthic ecosystem develop a micro community on them. The plastic-associated microbial community (the plastisphere) in the intertidal zone of Brazil was found to consist of bacteria as dominant group. Fungal filaments and spores were also associated with this sediment based microbial community (Neto et al., 2019). Though the main source of marine debris has been identified as terrestrial, several studies have indicated that micro plastics are mostly from fishery. Fishing related activities have been found to increase the quantity of plastic in the marine substrata. In the gut of Atlantic Bigeye (*Priacanthus arenatus*) which is a demersal species, plastic items were observed in 49.17% of the stomachs and the source of about 63% of these was fishing (Cardozo et al., 2018). Higher contamination of micro-plastic from weathering of fishing gear has been observed in estuarine region also (Ferreira et al., 2018). In the intertidal sediments of Vitória Bay estuarine system, Brazil, 77% of the micro-plastics were found to be from fishing net (Neto et al., 2019). In India, strands of nylon pieces have been obtained from several benthic fishes indicating the need to control entry of fishing based marine litter in the benthic ecosystem.

3. Marine litter and Mangrove ecosystem

Mangroves have been found to act as traps for marine litter. These macro-debris has been found to cover the breathing roots of mangroves. Litter is transported to these mangroves by water current but now a days, direct dumping of domestic solid waste is common in coastal areas which are becoming more populated. These obstruct the tidal flow in the mangrove and reduce the healthy habitat of several juvenile fishes and shrimps. However, impact of these on the physiology of mangrove has not been studied intensively.

4. Plastics in coral reef ecosystems

Impact of marine debris on coral reefs has been observed in several areas. In Marshall Islands, majority of the debris was identified to be from households and these can affect the health by causing tissue abrasion and other physical changes and eventually lead to mortality of corals (Richards and Beger, 2011). Along the south east coast of India also coral reefs are affected by marine litter including nylon sacks, ropes, and monofilament fishing lines. These were found entangled in branched corals and the sacks smothered the coral reefs and prevented penetration of light (Senthilnathan et al., 2018; Ranith et al., 2018). In India, the Gulf of Mannar and Palk Bay regions have intense fishing activity. Several fishing villages and tourists spots are around these critical habitats and litter from these locations should be controlled, to protect further degradation of coral reefs which are already under the threat from climate change.

5. Plastics in food chain

Micro plastics have been observed even in the Arctic and Sub-Arctic Sea with a possible transfer in the benthic trophic food chain since the highest number was recorded in a predator (Fang et al., 2018). Similarly in an estuarine top predator, *Cynoscion acoupa* entry of micro-plastic through direct ingestion and food chain has been observed (Ferreira et al., 2018). Through feeding trials using benthic animals like crabs and mussels it has been demonstrated that microspheres are transferred through food chain and that these tiny particles enter the stomach, hepatopancreas, ovary and gills of crabs (Farrell and Nelson, 2013). But the numbers have been found to decrease over time. In the Asian seabass (*Lateolabrax maculatus*) in coastal China, micro plastics were observed in the muscle as well as gut and gills indicating the threat to human beings via food chain (Su et al., 2019). In a study conducted along North east Atlantic 47.7% of the guts of demersal fishes sampled from coastal regions had both macro as well as micro plastics, while those from offshore regions had less quantity (Murphy et al., 2017). Similarly spotted cat sharks (*Scyliorhinus canicula*) which were caught in a demersal gear, the trawl operated in the North Sea had macro plastics (>20 mm) and micro plastic (<5 mm) (Smith, 2018). Observations on the distribution of micro plastics in sediment-dwelling and epi-benthic species such as fish, bivalves, echinoderms, crustaceans and polychaetes representative of different habitat, feeding modes and trophic levels within the inner Oslo fjord (Oslo, Norway) indicated that at least one or two pieces were found in each individual with a maximum of seven pieces (Bour et al., 2018). Bordbar et al.(2018) have found that number of micro plastics in the stomach is related to feeding intensity in shrimps which is in turn influenced by biological activity like spawning; higher feeding intensity prior to spawning. In India microplastics (single strands to more than 100 strands per gut with width and length ranging from 9.8 µm to 35.40 µm and 1.23 mm to 5.96 mm have been observed in the stomach of benthic Crustaceans like *Portunus sanguinolentus,* lobster *Panilurus polyphagus, Penaeus monodon, P. semisulcatus, F. merguiensis, M. affinis, M. monoceros, Parapenaeopsis hardwickii, P.stylifera, P.sculptilis, Solenocera choprai* and *S. crassicornis* from the continental shelf of NW coast (Rajan Kumar et al. 2018). These observations clearly indicate that the benthic ecosystem and the fauna which depend on this are facing a grave problem.

6. Other impacts of plastics on benthic ecology and fauna

Recently it has been observed that micro plastics act as vectors for catalysing biological invasion and transfer of pathogenic and antibiotic resistant genes through biofilms (Shen et al., 2019). Another threat is the leaching of chemical from plastics which are stuck in the marine ecosystem. Investigations indicate that estrogenic compounds are released by aged plastic especially PVC in water (Kedzierski et al., 2018). An outdoor mesocosm experiment conducted by Green et al. (2016) clearly shows that micro plastics in the benthic habitat affects the biota and reduces the primary productivity of the ecosystem. *Arenicola marina*, the lug worm produced less casts, its metabolic rate increased and micro-algal biomass decreased drastically clearly indicating the impact on benthic ecosystems. Similarly it was observed that micro plastics affected the benthic faunal biomass and abundance and settlement of *Scrobicularia plana* (peppery furrow shell clam) (Green, 2016). However, European flat oysters (*Ostrea edulis*) were found to be more study and were less vulnerable to micro plastic pollution. Significant correlations between plastic litter and biodiversity /benthic indices have also been observed. In India, in the clam fishing areas, marine litter was found to be high affecting the livelihood of the fishermen. In several places of Vembanad Lake, smothering of the benthic ecosystem by large plastic flexes have been found to reduce the faunal diversity. These have degraded the spawning habitat of several estuarine fishes which has resulted in low catch for small scale fishers. This calls for an urgent need to have a mass coastal benthic cleaning program followed by proper solid waste collection and segregation mechanisms in all villages.

7. International agreements and initiatives

Initially, considering the importance of marine environment in global economy, the Intergovernmental Oceanographic Commission (IOC) and the United Nations Development Programme (UNDP) initiated programs to conserve the resources and maintain the health of the marine environment. However these rules and guidelines did not directly target marine debris, though there were instructions that wastes should not be dumped and environment should be clean and healthy. The subsequent alarming rate of increase of marine debris in all regions and its ecological, social and economic impacts led to major global initiatives such as listed below.

Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA). of UNEPs goal is to prevent, reduce, control or eliminate and/or recover from the impacts of the degradation of the marine environment from land-based activities. The Global Partnership on Marine Litter (GPML) was launched in June 2012 at Rio + 20 in Brazil and seeks to protect human health and the global environment by the reduction and management of marine litter as its main goal, through several specific objectives. London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter an international treaty, created in 1972 and enforced in 1975, that limits the discharge of wastes generated on land and disposed of at sea, is one of the first global conventions to protect the marine environment from human activities.

FAO Code of Conduct for Responsible Fisheries was adopted in 1995, and its Principle 6.7 states that the management of fish harvesting processes should be carried out in a manner which reduces waste and Principle 6.8 promotes the protection of critical habitats from destruction, degradation and pollution from human activities. The Fish Stocks Agreement (UNFSA) adopted in 1995 and enforced in 2001 is based on the general provisions of the UNCLOS which states that fishing should be conducted in a manner that will protect the marine environment and prevent loss of fishing gear. Honolulu Strategy (created in 2011) is a framework for a comprehensive and global effort to reduce the amount and impact of land-based and ocean-based sources of marine debris introduced into the sea and accumulated marine debris on shorelines. MARPOL 73/78 – International Convention for the Prevention of Pollution from Ships seeks to prevent and reduce the amount of debris being discharged into the sea from ships. "The Future We Want," an outcome document of Rio+20 (2012) supports the sustainable management of wastes through waste minimisation activities such as the 3 R's (reduce, reuse and recycle) and also through energy recovery. It also called for the development and enforcement of comprehensive national waste management policies, strategies, laws and regulations.

8. Need for National Marine Debris Management Strategy

Though the UNEP was founded in 1972, a targeted program for marine debris control was initiated only since 2003. The problem of marine litter was recognized by the U.N General Assembly (UNGA), which in its Resolution A/60/L.22 (Nov. 2005) calls for national, regional and global actions to address the problem of marine litter. Now apart from Regional Seas programs, each nation is implementing its own Strategy for marine debris reduction and control. ICAR- CMFRI has been organising stakeholders meeting every year in all maritime states. Marine litter is one of the major problems identified by fishermen and they have demanded a solution for this. Fishermen of Kerala and Maharashtra have actually demanded an urgent action for reducing marine debris in fishing area. Considering the growing threat to resources sustainability and reduction in ecosystem functional services leading to loss of livelihood in fisheries sector, it is strongly recommend that there should be a National Marine Debris Strategy with specific goals for Prevention and Control of debris accumulating, spreading and in coastal and marine ecosystems affecting the fish production. The Ministry of Environment and Forest (MoEF) has issued MSW management and handling rules for scientific MSWM –but this has not targeted marine debris. Considering the global importance of plastics, we have to develop a responsible method of disposing used plastics instead of making it a "litter". The long term solution lies in proper development and utilization of waste management facilities in all villages, municipalities and corporation so that it does not become a regional and global issue.

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