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The Silent Crisis: Marine Plastic Pollution and Its Impact on Marine Biodiversity

Devendra J. Solanki[1],V. M. Chavda[2], H. K. Kardani[3], Sweksha Chauhan[1] and Ketan Makwana[1]*
[1]Dept. of Fisheries Resource Management, College of Fisheries Science, Kamdhenu University, Veraval (362265), Gujarat, India
[2]Dept. of Fisheries Resource Management, College of Fisheries Science, Kamdhenu University, Himmatnagar (383010), Gujarat, India
[3]Fisheries Research Station, Kamdhenu University, Sikka (361140), Gujarat, India
Corresponding email : ketankm2002@gmail.com
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Abstract

Plastic pollution has become a serious global threat to marine ecosystems since the rapid expansion of plastic production after World War II. Global plastic production increased from about 1.5–2 million metric tons (MMT) in 1950 to nearly 368 MMT in 2019. By 2017, around 76% of the 8,300 MMT of plastics produced had become waste, while only 9% was recycled effectively. Large plastic debris gradually breaks down into microplastics and nanoplastics, which persist in marine environments for long periods. Plastic pollution originates from both land- and sea-based sources and severely affects marine organisms through entanglement, ingestion, habitat damage, and chemical contamination. Harmful additives such as phthalates, BPA, and persistent organic pollutants can disrupt the reproductive and physiological systems of marine species. Increasing evidence of polluted coastlines and affected marine life highlights the urgent need for improved waste management, sustainable alternatives, and global efforts to reduce plastic pollution and protect marine biodiversity.

Keywords: Marine plastic pollution, Microplastics, Marine biodiversity loss, Plastic debris accumulation, Ecotoxicological impacts, Marine ecosystem degradation

1. INTRODUCTION

Plastic pollution has become one of the most serious environmental problems worldwide (MacLeod et al., 2021). Plastics were once considered highly beneficial because of their durability, flexibility, and wide range of applications, but their excessive use has created severe environmental concerns (Picuno, 2014). Since the expansion of large-scale plastic production after World War II, both plastic manufacturing and plastic waste entering marine environments have increased rapidly (Elias, 2018). Global plastic production rose from nearly 1.5–2 million metric tons (MMT) in 1950 to 50 MMT in 1977, 100 MMT in 1989, 200 MMT in 2002, and eventually reached 368 MMT in 2019 (Geyer et al., 2017). Nearly half of all plastics ever produced were manufactured between 2003 and 2016. In 2016, around 19–23 MMT of plastic waste was estimated to enter the oceans annually (Cressey, 2016). By 2017, total global plastic production reached approximately 8,300 MMT, of which nearly 76% (6,300 MMT) had already become waste. Of this waste, only 9% was recycled and 12% was incinerated, while only a small portion of recycled plastics was reused more than once (Martin et al., 2019). The remaining plastic accumulated in landfills and natural environments.

Plastic pollution in marine ecosystems poses serious threats to aquatic organisms and ecological balance (Pawar et al., 2016). Marine animals such as sea turtles, seabirds, and marine mammals frequently mistake plastic debris for food, resulting in ingestion that can cause internal blockages, malnutrition, and mortality (Thiel et al., 2018). Plastics can also absorb toxic chemicals from surrounding waters, which may negatively affect marine organisms and potentially humans through seafood consumption (Rochman, 2015). Coral reef ecosystems are particularly vulnerable, as plastic debris can smother corals and increase environmental stress on these sensitive habitats (Ford et al., 2022).

In addition to ecological impacts, plastic pollution also causes significant economic losses. Coastal communities that depend on tourism and fisheries are increasingly affected as beaches and marine environments become polluted with plastic waste (Isangedighi et al., 2020). The costs associated with cleanup operations, biodiversity loss, and declining fishery resources are becoming increasingly substantial (Wyles et al., 2017). To address this growing problem, several global initiatives have been introduced to reduce plastic production, improve recycling systems, and restrict single-use plastics (Issifu and Sumaila, 2020). The United Nations' proposed plastics treaty represents an important international effort aimed at reducing plastic waste through global regulations and reduction targets (Wysocki and Billon, 2019).

Public concern regarding plastic pollution has increased considerably due to alarming reports and visual evidence of marine organisms suffering from plastic ingestion and entanglement (Soares et al., 2021). Social media platforms have played an important role in spreading awareness and encouraging environmental action worldwide (Sedek, 2021). Campaigns such as Break Free from Plastic encourage governments, industries, and individuals to reduce plastic consumption and adopt sustainable practices (Ravazzani and Maier, 2022). A major concern is that larger plastic materials gradually degrade into microplastics and nanoplastics, which continue to accumulate in the environment even if plastic emissions are reduced immediately (Lebreton and Andrady, 2019). Images of beaches, coral reefs, and marine organisms heavily affected by plastic debris have significantly increased global awareness regarding the seriousness of plastic pollution (Peng et al., 2020). Therefore, urgent and effective measures are essential to minimize plastic pollution and reduce its environmental impacts through sustainable management strategies and international cooperation (Borrelle et al., 2020).

2. SOURCE OF PLASTIC POLLUTION

Plastic pollution originates from both land-based and sea-based sources. Among these, land-based plastic waste transported into marine environments through rivers and coastal areas is considered the major contributor, accounting for nearly 80% of marine plastic debris by quantity (Senevirathna and Thushari, 2020).

2.1. Land-based Sources

2.1.1. Storm Water Discharges

Storm water drains collect runoff produced during heavy rainfall events and discharge it directly into nearby rivers, streams, or coastal waters. Various types of waste materials and street debris are often carried into these drainage systems, which subsequently transport the accumulated rubbish into aquatic environments and eventually to the ocean (Brudler et al., 2019).

2.1.2. Combined Sewer Overflows

Combined sewer systems carry both domestic sewage and stormwater runoff through the same drainage network. During periods of intense rainfall, the capacity of wastewater treatment facilities may be exceeded, leading to the direct release of untreated sewage and stormwater into nearby rivers or marine environments. Such discharges often contain various forms of debris, including condoms, tampon applicators, syringes, and different types of street litter (Gasperi et al., 2008).

2.1.3. Littering

Improper disposal of waste by beach visitors significantly contributes to marine debris accumulation along coastal regions. Common litter items include food wrappers, beverage bottles, cigarette butts, and plastic recreational products. Abandoned or discarded fishing gear from fishing activities also represents an important source of marine pollution. Furthermore, waste generated in inland areas can be transported through rivers and streams into marine environments. Marine debris may additionally originate from improperly managed waste produced during forestry, agricultural, construction, and mining activities (Sheavly, 2005).

2.1.4. Solid Waste Disposal and Landfills

Runoff originating from landfills located near rivers or coastal regions can transport waste materials into marine ecosystems. During waste collection and transportation, garbage may also accidentally enter aquatic environments and eventually reach the ocean. In addition, illegal disposal of domestic and industrial waste into coastal and marine waters is another significant contributor to marine debris accumulation (Idris et al., 2004).

2.1.5. Industrial Activities

Industrial operations can contribute to marine debris through improper waste disposal practices or accidental losses during transportation, loading, and unloading processes at ports and shipping facilities (US EPA, 2002). Small plastic resin pellets, generally measuring 2–6 mm in diameter, are widely used as raw materials in plastic manufacturing industries. These pellets frequently enter marine environments through accidental spills during production, processing, storage, transport, and handling activities. Consequently, plastic pellets are commonly detected in seawater, sediments, and coastal beaches, where they may be ingested by various marine organisms (Derraik, 2002).

2.2. Sea-based Sources

Around 20% of marine plastic pollution originates from sea-based sources such as fishing nets, ropes, and fishing vessels. In 2016, approximately 19–23 million metric tons (MMT) of macroplastic entered aquatic ecosystems from land-based activities. Nearly 1,000 rivers transport about 0.8–2.7 MMT of plastic waste annually, contributing around 80% of global riverine plastic emissions. Although river deltas cover only 0.87% of the global coastline, they receive nearly 52% of river-borne plastic pollution, resulting in high plastic accumulation near river mouths (Harris et al., 2021).

2.2.1 Commercial Fishing

Commercial fishing activities contribute significantly to marine debris through the loss or improper disposal of fishing gear and other waste materials into the ocean. Common debris generated from these activities includes fishing nets, ropes, lines, strapping bands, bait containers, plastic bags, gillnet or trawl floats, along with domestic and galley waste from fishing vessels (Morishige et al., 2007).

2.2.2 Recreational Boaters

Recreational boating activities also contribute to marine pollution through the disposal of waste materials directly into the water. Common debris includes plastic bags, food packaging materials, and discarded fishing gear (Sheavly, 2005).

2.2.3 Merchant, Military, and Research Vessels

Merchant, military, and research vessels can contribute to marine debris through the accidental loss or intentional disposal of waste materials into the ocean. Large vessels carrying numerous crew members generate considerable amounts of solid waste daily, which may enter marine environments if not properly stored, managed, or secured onboard (Walker et al., 2019).

2.2.4 Offshore Oil and Gas Platforms and Exploration

Offshore oil and gas activities contribute to marine debris through the accidental or intentional release of materials such as gloves, hard hats, storage drums, survey equipment, and personal waste into the marine environment (Liu, 2015).

3. RIVER INPUTS TO THE OCEAN

Most major rivers contributing to global plastic emissions are located in Asia, with additional important sources identified in East Africa and the Caribbean region. Among the top ten plastic-emitting rivers, seven are situated in the Philippines, two in India, and one in Malaysia. The Pasig River in the Philippines alone contributes nearly 6.4% of global riverine plastic emissions. These findings differ from earlier studies that identified large Asian rivers such as the Yangtze, Xi, and Huangpu rivers in China, along with the Ganges River in India, as the dominant contributors to marine plastic pollution (Meijer et al., 2021).

4. TYPES OF PLASTIC DEBRIS

Plastic pollution is mainly classified into three categories: microplastics, mesoplastics, and macroplastics. Higher concentrations of microplastics and mesoplastics are commonly observed in the Northern Hemisphere, particularly around urban regions and coastal areas. Ocean currents also transport plastic debris to the shores of remote islands (Ryan et al., 2009). Common sources of mesoplastics and macroplastics include footwear, packaging materials, and various household products that are discarded into landfills or washed into marine environments. In contrast, remote islands are often affected by debris associated with fishing activities. These categories of plastic waste are generally referred to as micro-, meso-, and macro-debris (Thushari and Senevirathna, 2020).

Table 1. Different types of plastic waste based on size range (Thushari and Senevirathna, 2020).

Particle category	Diameter range
Nanoplastics	< 0.0001 mm (0.1 µm)
Small microplastics	0.00001–1 mm
Large microplastics	1–4.75 mm
Mesoplastics	4.76–200 mm
Macroplastics	> 200 mm

Microplastics are widely distributed in marine and coastal ecosystems, where they can interact with organic pollutants and heavy metals. Their distribution within the water column is largely influenced by their density. Low-density plastics such as polypropylene (PP) and polyethylene (PE) are buoyant and tend to float on the water surface. In contrast, higher-density plastics including polystyrene (PS), polyvinyl chloride (PVC), polyamide (PA), and polyethylene terephthalate (PET) generally sink and accumulate at different depths within aquatic environments (Hidalgo-Ruz et al., 2012).

5. EFFECT ON MARINE BIODIVERSITY

Marine and coastal ecosystems are highly productive environments that include important habitats such as coral reefs and seagrass beds. These ecosystems support rich biodiversity, ranging from primitive organisms like horseshoe crabs to highly evolved species such as dolphins. Since oceans cover nearly 71% of the Earth's surface, increasing plastic pollution has become a major threat to marine life. Plastic debris can cause severe physical damage to aquatic organisms. Fish, seabirds, and other marine animals often become entangled in plastic waste, leading to injuries, infections, restricted movement, and sometimes death (Corinaldesi et al., 2021). Marine animals also face difficulties reaching the water surface for breathing when trapped in plastic materials, which may result in drowning. In addition, microplastics closely resemble plankton, an important food source for many marine organisms. As a result, marine animals frequently ingest plastic particles, causing choking, internal injuries, digestive blockage, and mortality. Since plastics are difficult to digest, they can accumulate in the stomach and create a false sense of fullness, reducing food intake and nutrient absorption. This eventually leads to starvation and weakened health conditions in marine organisms (Galloway and Lewis, 2016).

6. THE PHYSICAL IMPACT OF PLASTIC POLLUTION ON MARINE ORGANISMS

6.1. Entanglement with Plastic Debris

Entanglement occurs when rope-like or loop-shaped plastic materials become wrapped around marine organisms. Common sources include ghost nets, monofilament lines, plastic sheets, rings, balloons, and plastic bags, all of which pose serious risks to marine life (Wilcox et al., 2016). Studies have reported entanglement impacts in 276 species, causing injuries, restricted movement, and mortality. For example, kelp gulls (*Larus dominicanus*) in northern Patagonia were found entangled in fishing lines, with many individuals either severely injured or dead (Yorio et al., 2014). Air-breathing animals may drown when unable to reach the surface, while fish and invertebrates can suffer starvation or predation after prolonged entanglement. Additionally, carcasses trapped in lost fishing gear may attract other animals, increasing further entanglement risks (Woods et al., 2019).

6.2. Ingestion of Plastic Debris

Many marine organisms, including whales, turtles, seabirds, fishes, crustaceans, molluscs, worms, and plankton, ingest plastic debris. Consumption of macroplastics can cause intestinal blockage, internal injuries, reduced feeding, and death (Mascarenhas et al., 2004).

Microplastic ingestion has also been linked to reduced growth, reproduction, physiological stress, oxidative damage, metabolic disturbances, and toxic effects on the nervous system (Prokić et al., 2019).

6.3. Colonisation of Plastic Debris

Floating plastic debris in the ocean is commonly colonised by microbes, algae, and marine animals. Studies have reported colonisation in about 1,187 species, with many organisms using plastics for dispersal to new locations (Latva et al., 2022). This process can threaten marine ecosystems by spreading invasive species beyond their natural geographic ranges.

6.4. Chemical Interactions

Plastic materials contain various polymers and chemical additives that can leach into marine environments. In 2015, nearly 190 metric tons of chemical additives from seven common plastic products were estimated to have entered the oceans, contributing to marine chemical pollution (Frond et al., 2019).

7. IMPACTS OF PLASTIC POLLUTION ON SPECIES

7.1. Impacts on Seabirds

Seabirds, including albatrosses, gulls, penguins, pelicans, petrels, and terns, depend heavily on marine ecosystems for survival and are highly vulnerable to plastic pollution (Wilcox et al., 2015). Between 1950 and 2010, global seabird populations declined by nearly 70%. Plastic ingestion has been reported in 74% of seabird species examined in the northeast Atlantic, and it is predicted that nearly all seabird species may be affected in the future. Entanglement in plastic materials used for nesting can also result in injuries and mortality among adult and juvenile birds (Avery-Gomm, 2020).

7.2. Impacts on Marine Mammals

Studies have shown that 71 of 123 marine mammal species interact with plastic debris. Harmful effects from ingestion and entanglement have been recorded in dolphins, whales, seals, sea lions, sea otters, polar bears, and manatees. These impacts include restricted movement, injuries, reduced feeding, and death (Wilcox et al., 2016). Plastic items such as nets, ropes, bags, and packaging materials have been found in the digestive tracts of stranded sperm whales (*Physeter macrocephalus*) in the North Sea.

7.3. Impacts on Sharks and Rays

Although overfishing remains the major threat to sharks and rays, plastic pollution is becoming an emerging concern. Filter-feeding species such as whale sharks, manta rays, and basking sharks can ingest large amounts of microplastics while feeding on zooplankton. Studies from Indonesia reported that manta rays (*Mobula alfredi*) and whale sharks (*Rhincodon typus*) may consume significant quantities of microplastics each hour (Fossi et al., 2014). However, the long-term effects of microplastic ingestion on these species are still not fully understood (Germanov et al., 2019).

7.4. Impacts on Other Marine Species

Plastic interactions have been reported in 1,089 marine species, including microbes, algae, crustaceans, molluscs, and other marine organisms. Many species ingest plastics, which can cause false satiation, reduced feeding, lower fertility, and mortality (Tekman et al., 2022). High rates of plastic ingestion have been observed among crustaceans and molluscs. Zooplankton and microscopic organisms also consume microplastics, potentially affecting the entire marine food web and ecosystem functioning (Vegter et al., 2014).

8. CONCLUSION

Plastic pollution has become a serious threat to marine ecosystems and biodiversity, with nearly 19–23 million metric tons of plastic entering the oceans each year, primarily from land-based sources. Marine organisms such as seabirds, marine mammals, sharks, and other aquatic species are severely affected through entanglement, ingestion, and exposure to toxic chemicals, resulting in injuries, behavioural changes, population decline, and mortality. Therefore, effective management strategies, improved waste disposal systems, and the adoption of sustainable alternatives are urgently required to reduce plastic pollution and protect marine ecosystems.

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