PKP
PUBLIC KNOWLEDGE PROJECT

Journal of Biological Studies
ISSN 2209-2560

JBS
An Open Access Peer Reviewed Journal

Review Full-Text Paper

Plastic pollutions in the ocean: their sources, causes, effects and control measures

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Received: January 20, 2023; **Accepted:** February 04, 2023; **Published online:** May 10, 2023

Abstract: Plastic pollution in the ocean is a global concern; concentrations reach 580,000 pieces/km^2 and production is increasing exponentially. Plastic pollution is a widespread problem affecting the marine environment. It threatens ocean health, the healthiness of marine species, food safety and quality, human health, coastal tourism, and contributes to climate change. Given the persistent nature of plastic and its toxicity, pollution caused by plastic is a significant threat to biodiversity. It threatens ecosystems, animal and plant species, impeding their ability to deliver essential services to humanity. The most visible impacts of plastic debris are the ingestion, suffocation and entanglement of hundreds of marine species. Marine wildlife such as seabirds, whales, fish and turtles mistake plastic waste for prey; most then die of starvation as their stomachs become filled with plastic. They also suffer from lacerations, infections, reduced ability to swim, and internal injuries. Floating plastics also help transport invasive marine species, thereby threatening marine biodiversity and the food web. Microplastics have been found in tap water, beer, salt and are present in all samples collected in the world's oceans. Several chemicals used in the production of plastic materials are known to be carcinogenic and to interfere with the body's endocrine system, causing developmental, reproductive, neurological, and immune disorders in both humans and wildlife. Recently, microplastics are found in human placentas but more research is needed to determine if this is a widespread problem. Toxic contaminants also accumulate on the surface of plastic as a result of prolonged exposure to seawater. When marine organisms ingest plastic debris, these contaminants enter into their digestive systems, and over time accumulate in the food web. The

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transfer of contaminants between marine species and humans through consumption of seafood has been identified as a health hazard, and research regarding the matter is going on. Plastic waste damages the aesthetic value of tourist destinations, leading to decreased income from this sector. It also generates major economic costs related to the cleaning and maintenance of the sites. The build-up of plastic litter on beaches can have a negative impact on a country's economy, wildlife, and the physical and psychological wellbeing of people. Plastic production contributes to climate change. For example, if plastic waste is incinerated, it releases carbon dioxide and methane (from landfills) into the atmosphere, thereby increasing emissions. Plastic has invaded every corner of the Earth, from glaciers in the Arctic to the sands of the Sahara. It is not surprising to find plastic bottles, snack packages, abandoned fishing gear and many other pieces of waste floating alongside beautiful corals and schools of fish. But one can help prevent an even more plastic-filled future for our oceans. Here are 5 tips to get one started such as (a) Do not buy it in the first place (but if you do, reuse it); (b) Do a mental checklist every time of shopping; (c) Shop for food locally and sustainably; (d) Shrink the carbon footprint; (e) Clean up; and (f) A roadmap for using nature as a climate solution.

Keywords: Plastic pollution, Sources, Effects, Oceanic Ecosystem, Marine biodiversity, Prevention measures

1 Introduction

Aquatic ecosystems are inter-connected with the terrestrial environment; therefore, changes in one system have impacts on another. For decades, different factors, including anthropogenic activities, have stressed the coastal and marine ecosystems (Adams, 2005; Richmond, 2015). These stresses include pollution and the physical destruction of the environment. Debris or litter accumulation is one of the human-created severe threats on marine and coastal systems due to unsustainable development and construction activities. Compared with other categories of debris such as glass, cloth, paper, food waste, metal, rubber, medical/personal hygiene-related items, smoking/firework items, and wood (Nualphan, 2013; Rosevelt et al., 2013), plastic litter is persistent in the ocean basins due to unique characteristics of plastics (e.g., the potential of ready transportation by water current and wind due to long shelf-life). Plastic debris with counts of five trillion, weighing more than 260,000 tones, is floating over the world's ocean surface as a result of improper waste disposal (Eriksen et al., 2014). Currently, plastic pollution has become a serious concern over almost all parts of ocean basins (Figure 1) irrespective of developed or underdeveloped regions in the world (Thushari and Senevirathna, 2020).

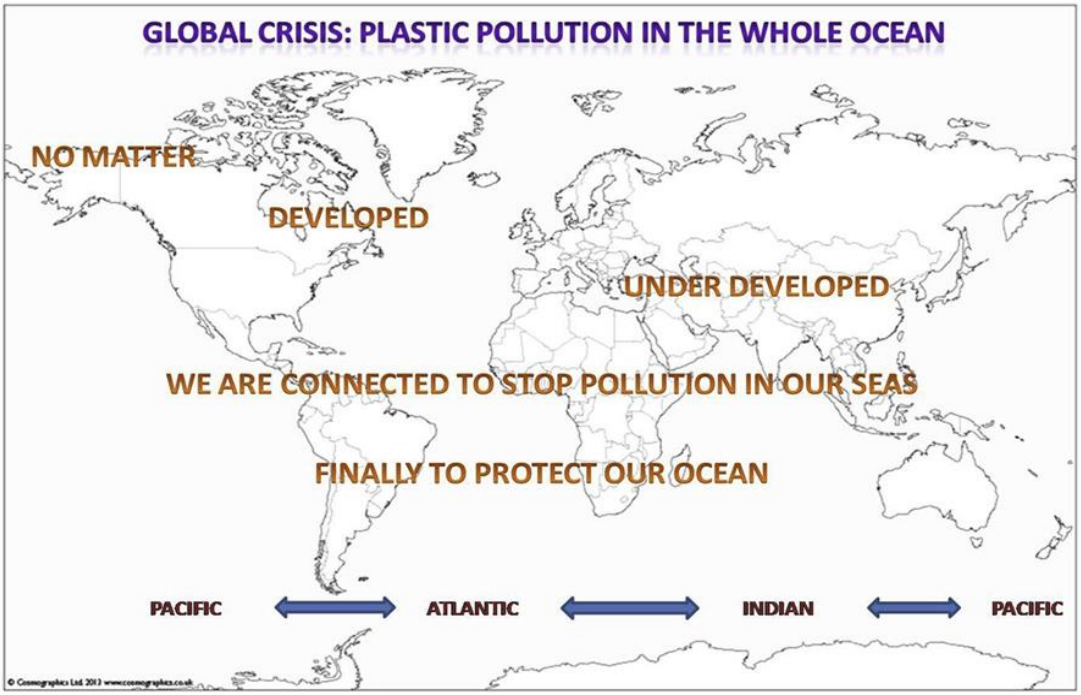

Figure 1. Overview of the global crisis of plastic pollution in the ocea (Thushari and Senevirathna, 2020).

Pollution caused by different forms of plastics and their derivatives in the ecosystem have attracted increasing public attentiveness. The Plastic Industries produce 359 million tons of plastic every year, which illustrate the extent of present environmental challenges that occurs when a vast amount of them ends up as garbage in the ecosystem each year (Plastic Europe, 2019; González-Pleiter et al., 2021). Plastic pollution is now found everywhere in the oceanic ecosystem (Figure 2), and almost every marine species is likely to have encountered it. According to a conservative assessment of current research, a total of 2,141 species have so far been found to encounter plastic pollution in their natural environments (Tekman et al., 2022). The accumulated plastics in the ocean basins can be broadly classified into four levels based on their sizes: megaplastics, macroplastics, mesoplastics, and microplastics. Microplastics are found in commonly manufactured, commercial products such as personal care and cosmetic products or microplastic particles produce from in-situ environmental degradation and subsequent fragmentation of larger size plastics by physical, chemical, and biological processes (Browne et al., 2010; Wang et al., 2018). Microplastics are mostly abundant in marine and coastal systems, while synthetic pollutants chemically interact with organic pollutants and metals (Guo and Wang, 2019).

Figure 2. Plastic pollution under the ocean

The density of microplastics also affects the distribution of microplastics in the water column. Polypropylene (PP) and polyethylene (PE) float in water due to low density of plastics, while polystyrene (PS), polyvinyl chloride (PVC), polyamide (PA), and polyethylene terephthalate (PET) with higher density do not float in water, but deposit by inclination through the water column (Guo and Wang, 2019). Accordingly, microplastic pollutants are widely distributed in every sub-zone/layer (pelagic and benthic) of coastal and marine systems (Thushari and Senevirathna, 2020). Salinity is one of the key factors affecting on chemical degradation of plastic. Hence, coastal and marine systems, which range at approximately 0.5–35°/00 (ppt: parts per thousand) of salinity, are highly susceptible to the formation of microplastics (Thushari and Senevirathna, 2020).

Accordingly, scientific evidence of the distribution and persistence of microplastic pollutants must focus on ocean basins and coastal ecosystems to identify the nature of the emerging issue (Thushari and Senevirathna, 2020). The marine and coastal ecosystems are complex and dynamic ecosystems that provide ecological and commercial values with services by ensuring human wellbeing. Currently, all oceans and many coastal zones are adversely affected by different kinds of natural and anthropogenic activities. Industrialization and urbanization are recognized as major factors for human-induced pollution, including plastic debris accumulation in the marine and coastal habitats. Estuaries are one of the major coastal ecosystems affected by plastic pollution. Currently, plastic pollution is caused by primary and secondary sources with a terrestrial or ocean-based origin. Megaplastic, macroplastic, mesoplastic, and microplastic (in primary and secondary forms) are major plastic pollutants that can be classified based on size variations. Megaplastic, macroplastic, and mesoplastic are bulk plastic debris, while primary and secondary microplastics are minute (microscopically observed) pollutants with the size range of 1–6 mm or <1 mm. larger debris are also subjected to the formation of microplastics through physical, chemical, and biological processes. Mainly,

estuarine ecosystems in some countries (e.g., several countries of the South American and Asian region) are negatively affected by the distribution of microplastics in sediment and water column.

Plastic pollution has a wide range of ecological consequences at the individual, assemblage, and ecosystem levels. Because microplastics are similar in size to food particles ingested by most marine and coastal creatures at lower trophic levels, these micro-contaminants are especially prone to accumulation in such biota by ingestion, with potentially deleterious consequences. Microplastic would also target humans and other species at higher trophic levels via food chains and webs. As a result of interactions between plastic pollution and other harmful chemical substances including POPs, antibiotics, and heavy metal ions, ecotoxicological effects are gradually brought about. The buildup of plastic waste has adverse ecological effects on the ecology, but it also poses diverse threats to the socioeconomic facets of human life. Yet, there are connections between the socioeconomic and ecological effects of plastic pollution.

Plastic pollutants are abundantly accumulating in these zones with adverse effects on ecological aspects, including biodiversity, economic activities, and human health (Galgani et al., 2010; Wang et al., 2018). Microplastics are ingested by different kinds of marine organisms (Cole et al., 2013; Leslie et al., 2017). Evidence on microplastics in the aquatic environment (Cozar et al., 2014; Martin et al., 2017) signifies the alarm on environmental issues by plastic pollution. They mark the importance of an integrated approach with international, regional, and national efforts as mitigatory strategies to improve plastic waste management by reducing the load of plastic garbage patches in the world ocean basins. Monitoring and dissemination of scientific information on distribution, contamination levels, sources, and possible effects by plastic pollution are required to identify management priorities and implementation of mitigation measures accordingly. Stakeholders should especially be aware of the current situation of the problem, degree of severity and harmfulness of the problem, novel trends, and present scenario and scientific approaches for strategies of prevention or reduction of plastic waste accumulation (Law, 2017). Thus, scientific reviewing of plastic pollution in the ocean basin and coastal zones are essential to derive a clear overall picture. The systematic study of the sources, pathways, transformation modes, adverse effects, and sinks of plastics in the marine environment has been conducted only during the last decade (Browne et al., 2015; Law, 2017).

Through the carefully evaluation of trustworthy scientific data on all facets of plastic pollution in marine and coastal environments, this study seeks to fill the aforementioned gap and provide guidance for safeguarding the world's ocean basins and coastal areas. Therefore, this review paper is concerned with: i) identifying the sources of plastic pollution, ii) determining the current status of the effects of plastic debris accumulation with a clear picture over the world's ocean basins and coasts, and iii) presenting an overview of the current situation and recommendations of initiatives on controlling plastic pollution at international, regional, and national levels, rules, regulations and legislation, and potential management measures for the consciousness.

2 Effect of Plastic Pollution in the Oceanic Ecosystem

Plastic pollution is now found everywhere in the ocean that plastics have negative effects on most marine life, the details of which are depicted in Figure 3 and briefly described below:

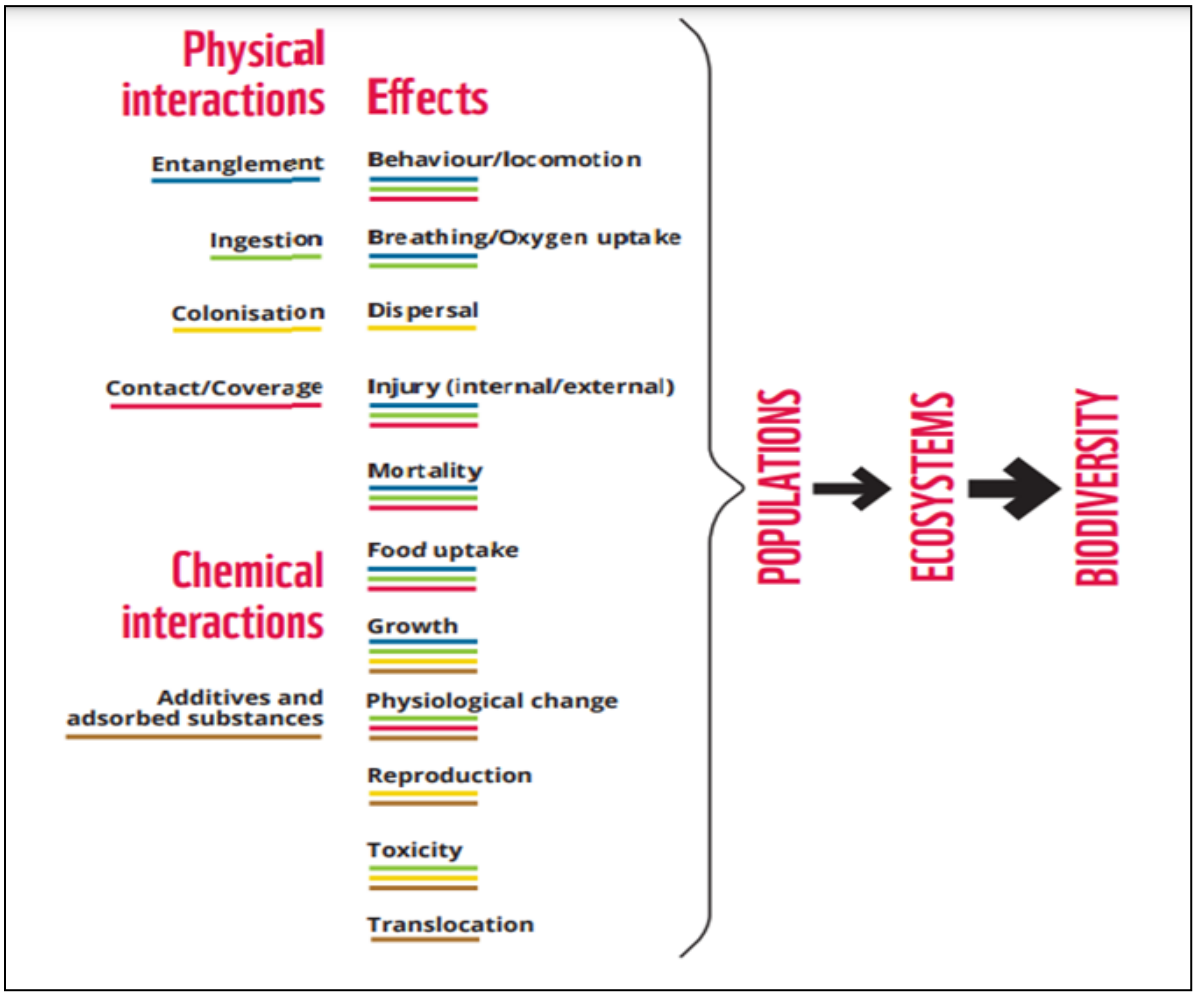

Figure 3. Diagram of the most frequently reported interactions and their effects on organisms (LITTERBASE). The colors represent the respective interactions.

2. 1. Entanglement

Items like ropes, nets, traps and monofilament lines from abandoned, lost or discarded fishing gear wrap themselves around marine animals causing strangulation, wounds, restricted movement and death. Birds also use marine debris for their nests, which can entrap parents and hatchlings. Fishing lines entangled 65% of coral colonies in Oahu, Hawaii, 24% and 80% of these colonies were entirely or partially dead. Even in the remote Arctic deep sea, up to 20% of sponge colonies have been entangled with plastic, and entanglements increased over time (Parga Martínez et al., 2020).

2. 2. Ingestion

All kinds of marine plants, from apex predators down to the plankton at the base of the

food chain, ingest plastics. These can cause severe harm to the animals, affecting food uptake by creating a false sense of satiation or blockages in digestive systems, as well as leading to internal damages. Several studies in the laboratory experiments have shown reduced growth in fish when their food is contaminated by higher amounts of microplastics; (Naidoo and Glassom, 2019) while at the other extreme a single plastic drinking straw in its digestive system likely caused the death of a whale shark in Thailand (Haetrakul et al., 2009). Plastic ingestion in seabirds is global, pervasive, and increasing (Wilcox et al., 2015). It has been estimated that up to 90% of all seabird (Wilcox et al., 2015) and 52% of all sea turtle individuals nowadays ingest plastics (Schuyler et al., 2015). Many emaciated whales and dolphins found stranded are also found to have ingested macroplastics (Barros et al., 1990; Kasteleine and Lavaleye, 1992; Baird and Hooker, 2000; Lusher et al., 2018). Several studies have shown altered or decreased food uptake, and negative impacts on growth (Dickerman and Goelet, 1987; Macedo et al., 2011; De Stephanis et al., 2013; Byrd et al., 2014), immune response, fertility and reproduction as well as altered cell functions and behaviors in the impacted species; with levels of harm directly related to exposure concentrations of plastic (Prokić et al., 2019).

2. 3. Smothering

Plastic pollution deprives corals, sponges and bottom dwelling animals of light, food and oxygen, making sediment oxygen deficient and reducing the numbers of organisms in the sediment (Green et al., 2015; Balestri et al., 2017). This can negatively affect ecosystems and give pathogens a foothold, which can have detrimental effects on marine life. Smothering is particularly harmful in coral reefs and mangroves. Recent findings reveals that plastic litters can smother marine life, dramatically reducing the number of organisms and compromising the ecosystem services they provide in coastal marshes (Gall and Thompson, 2015).

2. 4. Chemical pollution

All the ingredients in plastics are not harmful, but many of them are and can leach from plastics (Rochman, 2015) into the marine ecosystem. The smallest plastic particles can cross into the body cells and some of them can even reach the brains of marine animals (Mattsson et al., 2017; Prüst et al., 2020), and cause severe health hazards.

Effects of plastic on marine ecosystems should not be considered separately. Plastic pollution is one of several manmade threats including ocean warming, overharvesting, ocean acidification, eutrophication, deoxygenation, shipping and underwater noise, invasive species, habitat destruction and fragmentation, as well as other forms of chemical pollution. Although plastic pollution is now found everywhere in the global ocean, certain key marine and coastal ecosystems are particularly at risk as they are already facing multiple threats in addition to growing levels of plastic pollution. These ecosystems – coral reefs and mangroves are notable examples – provide vital services to people as well as marine life, so humans are directly affected when plastic negatively affects how they function (Gall and Thompson, 2015).

3 Impact on Biodiversity for Plastic Pollution in the Ocean

Poor air quality frequently contributes to eutrophication, the process of nutrient accumulation in aquatic bodies (especially nitrogen). In aquatic ecosystems, nutrient excess can result in algal blooms, which ultimately reduce oxygen availability and life. The biological diversity is impacted at the same rate as ecosystems. Wildlife and biodiversity are directly and fatally impacted by plastic waste. Each year, hundreds of thousands of seabirds, sea turtles, seals, and other marine mammals perish after consuming or becoming tangled in plastic trash.

The cornerstones of marine ecosystems, corals, can be smothered or even killed by plastic bags and nets (Gall and Thompson, 2015). Recent study also indicates that exposure to plastic particles boosts coral disease outbreaks. Ecosystems, animal, and plant species are put in danger, which hinders their capacity to provide vital services to humanity. The effects of plastic pollution on freshwater and terrestrial ecosystems have not received as much attention as those of plastic pollution in the ocean and its effects on marine life. Marine animals are directly impacted by climate change brought on by human activities. Their variety, abundance, and distribution are changed. Their development, reproduction, and connections with other species are all impacted. Species-specific behavioral tendencies are affected by rising temperatures. Seventy-five percent of the world's reefs are thought to be in danger. The dissolution of shell in organisms like oysters, shrimp, and lobsters is one of the many repercussions of ocean acidification, which is brought on by a rise in atmospheric carbon dioxide.

Even the deepest parts of the oceans now contain plastic. Up to 12 million metric tons of the 275 million metric tons of plastic waste created annually flow into the ocean, destroying ecosystems and livelihoods (CIEL, 2020). The result is that marine ecosystems sustain annual environmental losses of about $13 billion. By a number of different mechanisms, including as ingestion, entanglement, toxic effects, and others, plastic pollution has an influence on marine life. Since studies reveal that around 800 marine species are impacted by plastic pollution, the Convention on Biological Diversity (CBD) Secretariat acknowledged in a 2016 report that marine debris is a worldwide major stressor on the marine and coastal ecosystem. The detrimental impacts of plastic wastes on various organisms in the marine environment are depicted in Figure 4.

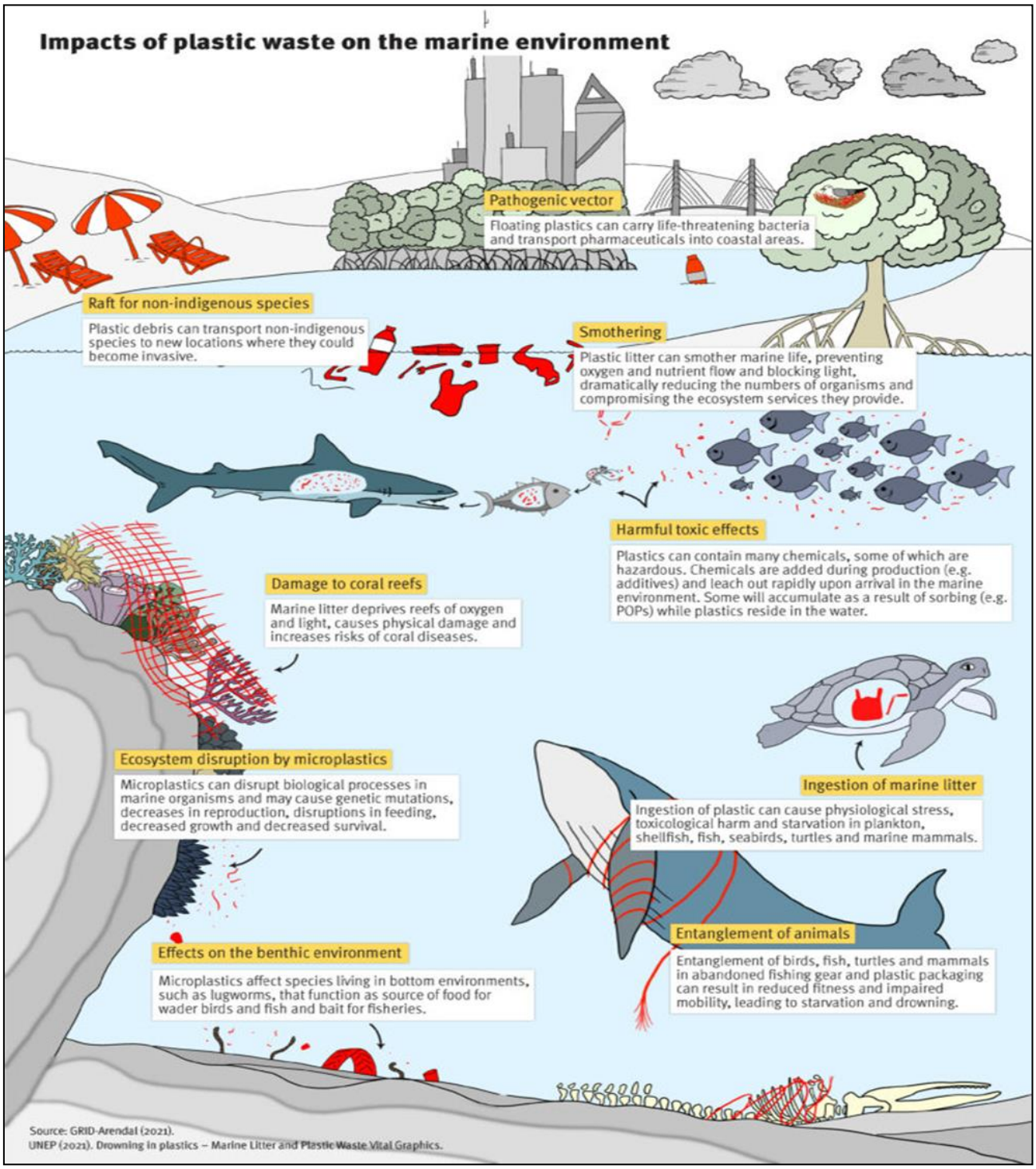

Figure 4. Impacts of plastic wastes on the marine environment (GRID-Arendal, 2021; UNEP, 2021).

4 Control Measures of Plastic Pollution

The problem of plastic pollution can be solved by everyone, and millions of individuals around the world are already making efforts to use less plastic. These are seven ways to start

changing things right now. The best thing we can do to save our rivers is make an effort to keep as much plastic out of the trash stream as we can. We can make a significant difference in many ways as follows:

4. 1. Continue to wean off plastic bags

Grocery bags, plastic wrap, disposable cutlery, straws, and coffee cup lids are just a few of the everyday products made of plastic that we use only once before throwing them away. We must have to keep track of how frequently we use these things and switch to reusable alternatives. Until it gets ingrained, it just takes a few occasions to carry own bags to the shop, silverware to the workplace, or travel mug to Starbucks.

4. 2. Avoid the buying of water in plastic bottles

Over 20 billion plastic bottles are thrown in the trash each year. If we keep a refillable bottle in our backpack, we will never be forced to drink Poland Spring or Evian again. We should have to get a model with a built-in filter if we are concerned about the caliber of the tap water in our area.

4. 3. Avoid the using of microbeads

Even while the tiny plastic scrubbers in body washes, toothpaste, and other beauty items appear to be innocuous, their tiny size allows them to pass through water treatment facilities. Unfortunately, some marine species mistake them for food. Instead, use products that contain natural exfoliants like salt or oats.

4. 4. Continue to prepare food

Making our own food is not only healthier, but it also eliminates the need for takeaway containers and doggy bags. When we do order takeout or go out to dine, let the restaurant know that we do not need any plastic flatware or, for some major bonus credit, bring our own food storage containers.

4. 5. Invest in used goods

Particularly new toys and electrical devices come with a variety of plastic wrapping, from frustratingly difficult-to-crack shells to twisty ties. Look for products that are just as nice when used on the shelves of thrift stores, in our community at garage sales, or in internet advertisements. Also, we can save a few dollars.

4. 6. Recycle of used plastics

It seems obvious, but we are not doing a great job of it. For example, less than 14 percent of plastic packaging is recycled. Confused about what can and cannot go in the bin? It is prerequisite to check out the number on the bottom of the container. Most beverage and liquid cleaner bottles will be #1 (PET), which is commonly accepted by most curbside recycling companies. Containers marked #2 (HDPE; typically, slightly heavier-duty bottles for milk, juice, and laundry detergent) and #5 (PP; plastic cutlery, yogurt and margarine tubs, ketchup bottles) are also recyclable in some areas. For the specifics on your area, check out Earth911 Organizers

Recycling Directory.

4. 7. Advocate for a bag fee or ban

The elected officials must have to introduce or support legislation that would make using plastic bags less attractive, like those in San Francisco, Chicago, and almost 150 other cities and counties.

4. 8. Purchase larger amounts

Considerations should be given on the product-to-packaging ratio of the goods we frequently purchase and choose the larger container rather than purchasing multiple smaller ones over time. Single-serving yogurts, travel-size shampoos, and tiny packages of almonds are just a few examples.

4. 9. Bring a garment bag with cloth to the dry cleaner

Investing in a zipped fabric bag and asking that it be used to return the cleaned belongings rather than being wrapped in plastic. (While we are at it, make sure we go to a dry cleaner that doesn't use perc, a hazardous substance that is present in some cleaning solvents).

4. 10. Apply pressure to producers

Even if we can change our personal habits, companies undoubtedly have a much larger impact. Let our opinion be known if we think a company's packaging could be more intelligent. If we trust a company could be smarter about its packaging, we have to raise our voice strong. Afterwards, we have to write a letter, send a twist, or hit them where it actually hurts and then provide financial supports to a more competent and sustainable competitor.

4. 11. Institutional arrangements and construction of awareness

Countries have to use their power and authority to control plastic pollutions by establishing some related organizations/institutes, which can manage and protect the marine ecosystems in a significant manner. Additionally, these organizations can provide necessary educations and trainings to the peoples about the alternatives they can shift to for processing, bagging, storing and packaging. Through these ways, peoples will be conscious about the causes and effects of plastic pollutions as well as they would be able to find the ways to prevent them.

4. 12. Policies, rules and regulations

Food and Drug companies and Environment Protection organizations are given mandate to assess the safety of new chemicals prior they are permitted for use. Afterwards, appropriate policies are always keep in place to help towards the reduction of plastic pollutions and their detrimental effects. To ban the use of some harmful chemicals in specific plastic products, government should have to impose strict rules and regulations. High tax should be used as a potential way to discourage particular ways of plastic management. Stabilization of compostable plastics should also be utilized to reduce its prolific production.

5 Conclusion

At the global, regional, and national levels, it is commonly acknowledged that plastic pollution in marine and coastal areas must be minimized and managed. The ocean is currently being actively saved from plastic pollution by a number of international organizations and non-profit social groups working together in diverse nations and regions. In certain nations, like South America, regional level procedures have already suggested to evaluate estuarine contamination, while concentrating on plastic pollution for the brackish water habitats. Some national governments have passed legislation to address the problem of plastic pollution by outlawing the use of plastic products and promoting the reuse and recycling of plastics at the local, state, and federal levels. After carefully examining the biological and ecological contexts of distinct ecosystems in nations like South America, implementation of environmental governance with pollution management was advised. Nonetheless, at the aforementioned levels, actions for preventing and regulating plastic pollution need to be substantially enhanced. As a result, the current study suggests a few effective strategies to handle this issue with buy-in from various stakeholders. Reuse, Recycle, and Reduction (3Rs) of plastic pollutants, promoting the collection of recyclable plastic waste, EPR towards manufacturer accountability, eco-friendly programs through public-private partnerships, awareness and capacity building campaigns focusing on the cleaner environment, scientific studies on the nature and severity of this emerging environmental issue, and innovations are suggested as the most effective ways to reduce and control the plastic pollution. This review study concludes by outlining the overall picture of marine and coastal plastic contamination from a variety of perspectives. Other uses for these secondary data include serving as the basis for site-specific plastic pollution management and control initiatives. Human activity makes up a little part of the biosphere; as such, it is our duty to contribute as much as possible to a plastic-free, cleaner, and greener environment.

Acknowledgments

We take this opportunity to express grateful thanks and appreciations to the anonymous reviewers for their scholastic suggestions and valuable comments to improve the overall quality of the paper.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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