

Investigating marine pollution in the Mediterranean Sea as a main threat to organisms

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Abstract

Marine pollution has emerged as one of the most significant threats to the health and survival of marine organisms. With increasing human activities and industrialization, various pollutants find their way into the world's oceans, causing detrimental effects on marine ecosystems. This paper aims to provide an overview of the impacts of marine pollution on marine organisms. The paper highlights the sources and types of pollutants that contribute to marine pollution, including chemical contaminants, plastics, oil spills, heavy metals, and excess nutrients. These pollutants enter the marine environment through various pathways such as industrial discharges, agricultural runoff, sewage systems, and improper waste management practices. Understanding these impacts is crucial for developing effective strategies aimed at preventing further degradation of our oceans' ecosystems. By implementing sustainable practices at individual and collective levels globally, precious marine environments efforts are preserved for future generations.

Keywords: Marine pollution; Mediterranean Sea; Water contaminant; Strategy management.

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1. Introduction

The Mediterranean Sea is a unique and diverse marine ecosystem that faces significant challenges due to pollution. Assessing the extent of marine pollution and understanding its impact on organisms is crucial for effective conservation and management strategies. According to researches, the Mediterranean Sea is one of the most polluted seas in Europe. Thousands of tons of waste end up in the Mediterranean Sea every year, injuring or even killing iconic marine species, some of which are protected and threatened, such as sea turtles, cetaceans, etc., while at the same time significantly degrading marine and coastal ecosystems (Senet, 2019).

1.1. *Main Threats to Organisms*

1) Chemical Pollution:

- Discharge of untreated or poorly treated industrial effluents containing heavy metals, pesticides, pharmaceuticals, plastics, and other toxic substances.
- Accumulation of persistent organic pollutants (POPs) through long-range transport from distant sources.

2) Nutrient Enrichment:

- Excessive nutrient inputs from agricultural runoff or sewage discharge leading to eutrophication.
- Algal blooms causing oxygen depletion (hypoxia) and subsequent mass mortality events.

3) Marine Debris:

- Accumulation of plastic debris impacting marine organisms through ingestion or entanglement.

4) Overfishing:

- Unsustainable fishing practices leading to declines in fish populations and disruption of food webs.

5) Habitat Destruction:

- Coastal development projects causing habitat loss for many species including seagrasses, coral reefs, and mangroves.

1.2. *Main Threats to Organisms*

The European Marine Strategy Framework Directive ranks litter among the main pressures on marine ecosystems that should be reduced in order to achieve Good Environmental Status of

Ecosystems. Good Environmental Status refers to ecologically diverse and dynamic oceans and seas that are clean, healthy and productive. The aim is to ensure the preservation of the marine environment for current and future generations.

Moreover, the Barcelona Convention for the Protection of the Mediterranean Sea from Pollution, which has been signed by 22 Mediterranean countries, includes its main objectives "the protection of the marine environment and coastal areas, through actions, with the aim of preventing and reducing pollution and, as far as possible, its elimination, whether it is due to activities on land or at sea, as well as the preservation of biodiversity" (Tavoso, 1997). One of the main causes of pollution is insufficiently treated urban sewage, which through waste transport pipes, streams, rivers and other passages ends up in the sea. In addition, the Mediterranean Sea is a hub for international maritime transport, gathering 20% of the world's maritime trade and 10% of cargo ships for the transport of goods. Thus, the risk of accidents, as well as the usual discharges of waste from ships, are permanent aggravating factors. Nevertheless, it is encouraging that the problem of marine pollution has been at the center of the public dialogue in recent years and is gathering the interest of researchers, institutional actors, non-governmental organizations (NGOs) and especially citizens. Supranational bodies such as the EU and the United Nations have bent over this enormous problem. According to the United Nations Environment Program (UNEP), marine litter is any manufactured or processed solid material that has been discarded, deposited or abandoned in the marine and coastal environment. Marine litter consists of objects that have been manufactured or used by humans and have been intentionally abandoned in the sea, rivers or beaches; that have been transported indirectly to the sea by rivers, sewers, storm-water or wind; that have been accidentally lost, including those lost at sea due to bad weather conditions (fishing gear, merchandise); or intentionally left by people on beaches and shores (Jeftic *et al.*, 2009).

The European Commission expanded the above definition, adding to the category of marine litter "semi-solid residues, e.g., from mineral and vegetable oils, paraffin and chemicals, which sometimes pollute the sea and the coasts" (Geyer *et al.*, 2017).

1.2.1 Global Impact

Marine litter is a global matter with huge environmental and economic effects and attitudes a major threat to human health. Even today, all forms of waste and garbage are dumped into seas and oceans, which is an inexpensive method of disposal. Cigarette butts as a toxic plastic pollution, plastics and other types of waste can be found even in the most remote corners of the planet, thousands of kilometers away from populated areas. It is estimated that 80% of all marine litter comes from land-based sources, while 20% is derived from sea-based sources and human activities at sea (Paul, 2021). The complex issue of marine litter is rooted in ineffective solid waste management, lack of adequate infrastructure, failure to adopt effective legislation and control mechanisms, and lack of financial resources. On an individual level, it

is worth underlining the limited knowledge and understanding of the consequences of our actions and daily habits towards this issue (Kaza *et al.* 2018).

1.2.2 Marine debris

Every year, turtles, birds and other marine animals are hurt and may even die from consumption marine litter, especially plastic, because of its shape, size and smell. In particular, sea turtles mislead plastic bags in the sea with their favorite regale: sea urchins. A recent study indicated that plastic waste has the smell of food in the sea, as algae and other microorganisms adhere to them, giving them odors identical to those of the food of sea turtles. These smells confuse sea turtles, who eat the plastics as a food source (Pfaller *et al.*, 2020). Ingesting plastic can cause sea turtles to suffocation, block their digestive tract. Additionally, because the plastics keep air bubbles, they create buoyancy and the turtle eating them as the food.

Marine debris, including fishing equipment lost or abandoned at sea, can cause injury in marine animals. The weight of these tools hinders the animals' movements and prevents them from swimming quickly, making them more vulnerable to their predators. On nesting beaches, litter can become death traps for hatchlings. Garbage hinders the tiny turtles from reaching the sea quickly, making them easy prey for their natural predators (eg seabirds, crabs, etc.). Finally, if a baby turtle gets trapped on the beach and does not manage to reach the sea, there is a risk of dehydration from the heat of the sun (Kaza *et al.* 2018).

1.2.3 Microplastics

Due to solar radiation, wind and waves, plastic breaks down into smaller pieces. Pieces whose size is less than 5mm are known as microplastics. In many ecosystems around the world, microplastics are more abundant than any other man-made material, and can, in addition to water, enter food and air. Another major problem is synthetic microfibers, released from washing synthetic clothing, as well as microbeads contained in personal care products and cosmetics (scrubs, exfoliating creams, shower gels, toothpastes, etc.), which escape from filters of laundries and biological purification units, respectively, and end up in the marine environment.

Microplastic pollution in the shoreline is an important problem as increasing population density, tourism, marine harboring and coastal activities that are contributing to a great extent to the release of complex and toxic contaminants including daily used plastic items. It is approximately 8.8 kg/capita/year of macroplastics, and 0.18 kg/capita/year of microplastics released into marine bodies as a result of different coastal activities (Van-Wijnen *et al.*, 2019). They are gradually increasing in significant quantities in the marine environment and we still have limited knowledge of the consequences of the phenomenon. Because of their small size, they are highly likely to be ingested by fish and other animals higher up in the food chain. The

effects that consumption of seafood and fish can have on human health need further scientific research.

The paper focuses on the harmful effects of marine pollution on different marine organisms. It discusses how chemical wastes can damage physiological procedures in fish and other aquatic species, leading to impaired growth, reproductive abnormalities, weakened immune systems, and increased susceptibility to diseases. The detrimental effects of plastic debris are explored in relation to entanglement and ingestion by marine mammals, seabirds, turtles, and fish.

Furthermore, the consequences of oil spills on marine organisms is addressed. It highlights how oil slicks can cover feathers of seabirds or fur of animals like seals, impairing their insulation properties and leading to hypothermia or drowning. Oil contamination in water can also disturb fish gills and decrease their oxygen uptake capacity. Additionally, heavy metals like mercury are discussed for their poisonous effects on marine organisms' nervous and reproductive experiences. Surplus nutrients from farming overflow or sewage discharge give to the harmful algal bloom (HAB) that produce toxins which can basis for mass mortalities among fish populations (Landrigan *et al.*, 2020). Finally, the importance of qualifying measures such as developed waste management experiments, firmer rules on pollutant discharges into water environments, supporting sustainable fishing practices, reducing plastic consumption and raising consciousness among people about responsibility and environmental behavior are represented. In conclusion, the marine pollution poses a severe threat to various forms of marine life.

2. Data collection methods

The data and method section purposes to make an overview of the methods used to evaluate marine pollution in the Mediterranean Sea, as well as highlight the main threats posed to organisms within this ecosystem (Tuncel *et al.*, 2007).

1) Water quality monitoring

- Regular sampling of water from various locations within the Mediterranean Sea.
- Analysis of physical and chemical parameters such as temperature, salinity, dissolved oxygen levels, pH, nutrient concentrations (nitrate, phosphate), heavy metal concentrations, and presence of organic pollutants.
- Use of standardized protocols and equipment for accurate measurements.

2) Sediment analysis

- Collection of sediment samples from different areas in the Mediterranean Sea.
- Analysis for contaminants such as heavy metals, hydrocarbons, pesticides, and other persistent organic pollutants.

- Evaluation of sediment toxicity through bioassays using indicator species.

3) Biological monitoring

- Sampling and identification of key indicator species (e.g., phytoplankton, zooplankton, benthic organisms) at different depths and locations.
- Assessment of biodiversity indices to determine changes in community structure.
- Biomarker analysis to evaluate physiological responses (e.g., enzyme activity, DNA damage) in organisms exposed to pollutants.

4) Remote sensing

- Utilization of satellite imagery to detect surface oil spills or algal blooms.
- Measurement of sea surface temperature anomalies indicating thermal pollution or climate change impacts.
- Mapping coastal areas affected by land-based pollution sources using remote sensing.

2.1. Study area

The Mediterranean Sea lies at the crossroads of three continents: Europe, Africa, and Asia (Figure 1). It is connected with the Atlantic Ocean by the Strait of Gibraltar, with the Red Sea by the Suez Canal, and with the Black Sea by the Sea of Marmara and the Bosphorus (<https://www.nationsonline.org/oneworld/map/Mediterranean-Region-Map.htm>). An average of 450 million people lives in the Mediterranean, and it is estimated that by 2025 this number will have reached 520 million, of which 150 will be concentrated in or near coastal areas. In addition, the Mediterranean is a popular tourist destination, attracting approximately 200 million visitors each year. However, apart from this massive influx of visitors, the Mediterranean and its shores are also home to unique ecosystems of plants and animals, with pollution being one of the biggest threats (AEE, 2006).



Figure 1. Map of the Mediterranean Sea basin

3. Analysis the issue

Table 1 represents the countries which had the most water threats during a year. During a 5-year (2015-2019) investigation, the most Plastic waste, Oil spills, and chemical discharges were recorded in 2018 in Turkey.

Table 1. A 5-year (2015-2019) marine pollution investigation in the Mediterranean Sea (WWF report, 2019)

	Year	Country	Plastic waste (tons)	Oil spills (barrels)	Chemical discharges (liters)
1	2015	Spain	5,000	1,000	20,000
2	2016	Italy	4,000	500	15,000
3	2017	Greece	3,000	800	18,000
4	2018	Turkey	6,000	1,200	25,000
5	2019	France	3,500	600	17,000

As Table 1 indicates, the following wastes were recorded during above research:

1) Plastic waste:

- Average: 4300 tons
- Maximum: 6000 tons (Turkey, in the year of 2018)
- Minimum: 3000 tons (Greece, in the year of 2017)

2) Oil spills

- Average: 620 barrels
- Maximum: 1200 barrels (Turkey, in the year of 2018)
- Minimum: 500 barrels (Italy, in the year of 2016)

3) Chemical Discharges

- Average: 19000 liters
- Maximum: 25000 liters (Turkey, in the year of 2018)
- Minimum: 15000 liters (Italy, in the year of 2016)

These statistics provide an overview of marine pollution in the Mediterranean Sea by the contaminants like plastic waste, oil spills, and chemical discharges. It is important to note that this research may cannot represent a big picture of marine pollution in the region, by the way, a comparison between some countries about activities that have been done to manage the marine pollution in different years, can provide a clear point of view about how to manage the issues.

1) United States

- Year 2010: The Deepwater Horizon oil spill in the Gulf of Mexico caused significant marine pollution, affecting marine life and coastal ecosystems.

- Year 2020: Efforts have been made to reduce pollution through stricter regulations on industrial waste disposal and increased awareness about plastic pollution.

2) China

- Year 2015: China was one of the largest contributors to marine pollution, primarily due to industrial waste discharge and improper waste management practices.
- Year 2021: The Chinese government has implemented stricter regulations on industrial waste disposal, invested in wastewater treatment facilities, and launched campaigns to reduce plastic consumption.

3) India

- Year 2010: India faced significant challenges with marine pollution due to untreated sewage discharge, industrial waste, and plastic litter.
- Year 2021: Efforts have been made to improve waste management systems, promote recycling initiatives, and raise awareness about the impact of marine pollution.

4) Australia

- Year 2015: Australia faced issues with marine pollution caused by plastic debris, oil spills, and agricultural runoff.
- Year 2021: The Australian government has implemented measures to reduce plastic consumption, improve water quality through better agricultural practices, and increase protection for marine ecosystems.

It is important to note that this information provides a general overview of the situation in each country during those specific years. Marine pollution is an ongoing issue that requires continuous efforts from governments, industries, and individuals worldwide. To compare the assessment activities for confronting marine pollution in the Mediterranean Sea between neighboring countries, the following factors should be considered; legislation and policies, monitoring and surveillance, research and data collection, response mechanisms, international cooperation, public awareness and education, progress over time. By analyzing these factors across different years for neighboring countries in the Mediterranean Sea region, deep insights into their respective efforts to confront marine pollution and identify any trends or areas that require improvement are gained (Kurtela and Antolović, 2019).

1) Plastic pollution

The Mediterranean Sea has one of the highest concentrations of microplastics globally, with an estimated 1.25 million tons of plastic entering the sea each year.

- A study conducted in 2018 found that the Mediterranean Sea had an average microplastic concentration of 1.25 particles per liter, higher than any other marine region studied.

- Plastic debris, such as bags and bottles, accounts for approximately 95% of all waste found in the Mediterranean Sea.

2) Oil pollution

- The Mediterranean Sea is highly vulnerable to oil pollution due to its high shipping traffic and numerous oil extraction activities.
- According to a report by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), between 2005 and 2019, there were around 3,000 reported oil spills in the Mediterranean region.
- The majority of these oil spills were caused by accidents during ship-to-ship transfers or collisions.

3) Eutrophication

- Eutrophication is a process where excessive nutrients (such as nitrogen and phosphorus) enter the marine environment, leading to harmful algal blooms and oxygen depletion.
- The Mediterranean Sea experiences eutrophication due to agricultural runoff, sewage discharge, and industrial activities along its coastlines.
- A study published in 2019 estimated that around 40% of coastal waters in the Mediterranean are affected by eutrophication.

4) Marine debris

Apart from plastics, other types of marine debris are also prevalent in the Mediterranean Sea. Fishing gear, including nets and lines, accounts for a significant portion of marine debris found in the region. A study conducted by MEDSEALITTER project estimated that fishing gear represents approximately 27% of all litter items observed on beaches across several countries bordering the Mediterranean (Guitart *et al.*, 2019).

5) Heavy metals contamination

- Heavy metals such as mercury, lead, and cadmium can accumulate in marine organisms and pose risks to human health through seafood consumption.
- Studies have shown elevated levels of heavy metals in various fish species from different parts of the Mediterranean Sea.
- Industrial discharges and urban wastewater are major sources contributing to heavy metal contamination.

It's important to note that these statistics provide a general overview of marine pollution in the Mediterranean Sea basin. However, specific data may vary depending on location and time period studied.

Three Mediterranean countries account for two-thirds of plastic leaked into the nature (Geyer *et al.*, 2017). Every Mediterranean country is mismanaging a portion of its waste, as seen in Table 2 and Figure 2, but given their plastic production and consumption patterns, size of economy, and current waste management systems, the biggest contributors to mismanaged waste in the region are Egypt (43.1 per cent), Turkey (19.1 per cent), and Italy (7.6 per cent) (Kaza *et al.*, 2018). France in comparison with other considered countries has the highest level of controlling the waste treatment with 25.2% value.

Table 2. Plastic marine pollution in the Mediterranean Sea (WWF report, 2019)

	Plastic production (MT %)	Plastic waste generation (MT %)	Controlled waste treatment (MT %)	Mismanaged waste (MT %)	Plastic leakage into sea (MT %)
Italy	21/1	16/3	19/7	7/6	0/04
Turkey	20/9	15/4	14/1	19/1	0/11
France	15/1	18/6	25/2	1/4	0/01
Spain	10/4	9/9	13/2	1/4	0/01
Egypt	10/2	12/6	1/1	43/1	0/25
Greece	2/5	3	3/9	0/8	0/01
Morocco	1/9	2/3	1/2	5/2	0/01
Croatia	1/4	1/7	2/1	0/7	0/01
Tunisia	0/8	1	0/9	1/4	0/01
Other	15/7	19/2	18/6	19/3	0/11

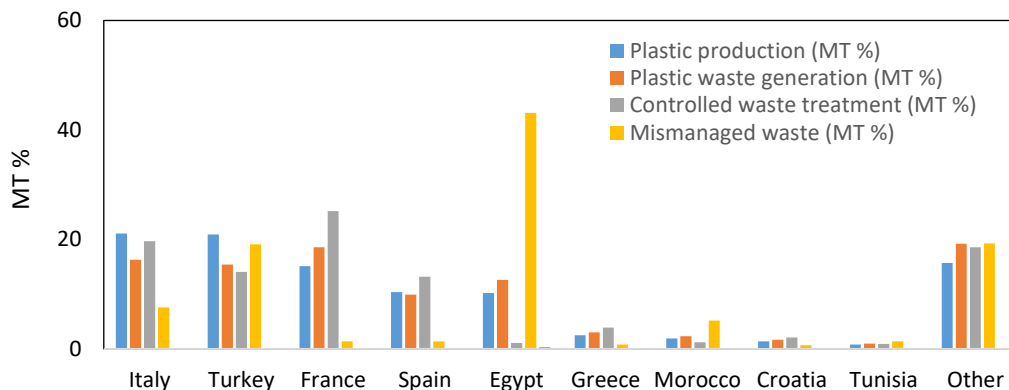


Figure 2. Comparison the status of plastic marine pollution in the Mediterranean Sea

The revenue generated from solving marine pollution issue in the neighboring countries of the Mediterranean Sea would depend on various factors, such as the scale and effectiveness of the solutions implemented, the economic activities dependent on a clean marine environment, and the potential for increased tourism and sustainable fisheries. While it is challenging to provide an exact figure without specific data, it is widely recognized that addressing marine pollution can have significant economic benefits. For example:

- 1) Tourism: The Mediterranean region attracts millions of tourists each year who are drawn to its pristine beaches and diverse marine ecosystems. By reducing pollution and maintaining a healthy marine environment, tourism revenues could increase as more visitors are attracted to the area.
- 2) Fisheries: The Mediterranean Sea supports a significant fishing industry, providing livelihoods for many communities. By reducing pollution and protecting fish stocks, sustainable fisheries can be maintained or even improved, leading to increased revenue for fishermen and related industries.
- 3) Coastal development: A clean marine environment can enhance coastal development opportunities such as real estate, resorts, and recreational activities. This can lead to increased investment and revenue generation in coastal areas.
- 4) Environmental services: A healthy marine ecosystem provides various ecological services such as carbon sequestration, water filtration, and habitat preservation. These services have economic value that can be monetized through mechanisms like carbon credits or payments for ecosystem services.

4. Applicable strategies

Applicable strategies refer to specific methods or techniques that can be used in a given situation or context. These strategies are designed to address a particular problem or achieve a specific goal. They are practical and relevant, meaning they can be implemented effectively and have a positive impact on the desired outcome. Applicable strategies can vary depending on the situation, but some common examples include problem-solving techniques, communication strategies, and decision-making processes. These strategies are important in both personal and professional settings as they help individuals and organizations navigate challenges and achieve success. By understanding and utilizing applicable strategies, individuals can improve their problem-solving skills, enhance their decision-making abilities, and ultimately achieve their goals.

In this paper, 15 applicable strategies are represented, these strategies can be useful for the managing the marine pollution in Mediterranean Sea even in every water basin.

- 1) Implementing strict regulations and laws: Governments and international organizations should establish and enforce strict regulations and laws to control and reduce marine pollution in the Mediterranean Sea. This includes setting limits on pollutant levels, imposing fines for non-compliance, implementing monitoring systems, and enforcing compliance with existing laws, as well as introducing new measures to reduce pollution from industries, shipping, and coastal activities.

- 2) Promoting sustainable fishing practices: Overfishing is a major contributor to marine pollution in the Mediterranean Sea. Governments should implement sustainable fishing practices, such as limiting fishing quotas, promoting selective fishing methods, minimize bycatch, protect vulnerable species, and establishing protected marine areas.
- 3) Encouraging the use of eco-friendly products: Many products used in daily life contain harmful chemicals that end up in the sea through runoff or improper disposal. Governments can promote the use of eco-friendly products by providing incentives to businesses that produce them and educating consumers about their benefits.
- 4) Improving waste management systems: Proper waste management is crucial in preventing marine pollution. Governments should invest in modern waste management systems, including recycling facilities, proper disposal sites, and waste-to-energy plants.
- 5) Enhancing oil spill response capabilities: Oil spills are a major threat to marine life in the Mediterranean Sea. Governments should invest in advanced technology for early detection of oil spills and have effective response plans in place to minimize their impact.
- 6) Collaborating with neighboring countries: Marine pollution is a transboundary issue that requires cooperation between countries sharing the Mediterranean Sea. Governments should work together to develop joint strategies for managing pollution, sharing resources, and conducting joint research projects.
- 7) Educating the public: Raising awareness among the public about the importance of protecting the Mediterranean Sea is crucial for long-term success in managing marine pollution. Governments can organize educational campaigns targeting different age groups to promote responsible behavior towards the environment.
- 8) Investing and monitoring: Continuous research on marine pollution is essential for understanding its causes, impacts, and developing effective solutions. Governments should allocate funds for research projects focused on identifying sources of pollution, monitoring pollution levels, and assessing the health of marine ecosystems.
- 9) Encouraging the use of alternative energy sources: The Mediterranean Sea is a popular destination for tourism and shipping, both of which contribute to pollution. Governments can promote the use of alternative energy sources, such as wind and solar power, to reduce emissions from these activities.
- 10) Supporting clean-up initiatives: Governments can support clean-up initiatives by providing funding and resources to organizations working towards cleaning up the Mediterranean Sea. This can include beach clean-ups, removal of marine debris, and restoration of damaged habitats.
- 11) Support research and innovation: Invest in research and development of innovative technologies that can help mitigate marine pollution in the Mediterranean Sea. This includes developing efficient wastewater treatment systems, exploring alternative

materials to replace single-use plastics, and finding new ways to clean up existing pollution.

- 12) Encourage sustainable tourism practices: Promote responsible tourism activities that minimize negative impacts on marine ecosystems. This includes educating tourists about proper behavior while visiting coastal areas (e.g., not littering or disturbing wildlife), supporting eco-certified accommodations and tour operators, and promoting sustainable recreational activities like snorkeling or diving.
- 13) Establish protected areas: Create marine protected areas (MPAs) within the Mediterranean Sea to safeguard in danger habitats and species from pollution threats. These areas should be properly managed with clear regulations on fishing activities, tourism operations, and other potential sources of pollution.
- 14) Engage stakeholders: Involve various stakeholders such as government agencies, NGOs, industry representatives, scientists, local communities, and fishermen in decision-making processes related to marine pollution prevention strategies. Their input can help ensure effective implementation of measures while considering social-economic factors.
- 15) Monitor progress: Regularly assess the effectiveness of implemented strategies through comprehensive monitoring programs that track key indicators of marine health such as water quality, biodiversity levels, fish stocks abundance, and plastic debris accumulation rates. Adjust strategies accordingly based on scientific findings to maximize their impact over time.

Conclusion

Assessing marine pollution in the Mediterranean Sea requires a multidisciplinary approach combining water quality monitoring, sediment analysis, biological monitoring techniques along with remote sensing tools. The main threats faced by organisms include chemical pollution from various sources, nutrient enrichment leading to eutrophication events, marine debris accumulation causing harm to marine life. It is important to note that solving marine pollution requires collective efforts from multiple stakeholders including governments, industries, communities, and individuals. The revenue generated from solving this issue would not only benefit local economies but also contribute to long-term environmental sustainability and well-being in the region. By implementing these strategies collectively at local, regional, national levels along with international cooperation efforts will help combat Mediterranean Sea marine pollution effectively.

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