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Impacts of Human Activities on the Marine and Climate Environment and Measures for Their Protection

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Abstract. Over the past few decades, human activities have had a significant impact on the global climate and marine systems, with industrialization exacerbating the greenhouse effect and accelerating the degradation of the marine environment. In particular, rising temperatures, changes in atmospheric composition and pollution emissions are already polluting terrestrial and marine ecosystems. Current research has focused on the role of greenhouse gas emissions as a driver of climate warming, revealing the impacts of climate change on precipitation patterns, biodiversity, and marine ecosystems. At the same time, a few studies have begun to focus on the moderating effects of nuclear contamination, changes in microbial structure and human governance measures on ecosystems. However, the ecological stability of marine microorganisms, the mechanisms of long-term spread of nuclear contamination and their specific impacts on biological chains are also currently being explored. This paper focuses on how human activities affect global climate and marine ecosystems through greenhouse gas emissions, chemical pollution, and physical disturbances, explores changes in the structure and function of marine organisms because of different environmental stressors, and assesses the effectiveness of the implementation of existing marine protected areas. This study contributes to a deeper understanding of the interactions between human activities and marine ecology and provides a reference for the future development of more scientific and effective ecological protection policies in the context of global warming.

Keywords: Anthropogenic climate change, ocean acidification coral reef degradation, marine conservation policies, nuclear contamination

1. Introduction

Over the past few decades, human activities have led to changes, and in some cases deterioration, in the global climate and ocean systems. Due to the rapid development of industry, the burning of fossils and unrestricted deforestation, this has greatly increased the greenhouse effect. These changes have not only affected the organisms on land. Many marine organisms and environments have been more affected. It is important to understand how human behavior is changing the ecosystem and to start planning ways to mitigate environmental degradation and find ways to protect it.

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Recent studies have been able to demonstrate how human activities directly and briefly affect the climate. According to Masson-Delmotte et al. (2021), the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) confirms this with a high degree of confidence [1]. Because of human activities, many industrial emissions have led to warming of the atmosphere and oceans as well as the land. This warming intensifies the global water cycle, which can cause significant changes in precipitation levels. This time around, there have been many extreme natural disasters, which have also harmed the marine environment.

The oceans, which are a major carbon sink and regulator of the Earth's climate, have also been severely affected, with research by Gattuso et al. showing that an increase in airborne carbon dioxide can lead to ocean acidification, which lowers the pH value of surface water [2]. This has led to threats to marine organisms that form their shells and skeletons from calcium carbonate, such as coral mollusks and plankton. In addition, changes in the temperature and chemical composition of the oceans can cause the balance of the marine system to be disrupted. This is why there is a massive bleaching of many corals and a migration of species. This has reduced the biodiversity of the oceans.

Humans also have a lot of polluting waste that cannot be immediately decomposed by the land, such as plastic waste. This is a growing situation that will exacerbate the degradation of the marine environment. Jambeck et al. estimate that more than 8 million metric tons of plastic enter the oceans each year, affecting hundreds of marine species through ingestion and entanglement. Fertilizers also contain excessive amounts of nitrogen as well as phosphorus, which eutrophies the ocean and creates hypoxic zones. This has caused serious damage to the marine ecological environment.

This paper will focus on the specific ways in which human activities are causing climate change and disruption of the ecological balance of the oceans. This paper will assess the environmental stressors, including greenhouse gas emissions and marine pollution, as well as look at current measures to protect the environment and evaluate their effectiveness. By neutralizing the research and identifying where innovations can be made, this research will plan for more effective climate and ocean governance programs.

2. Anthropogenic climate change

2.1. Temperature

With the acceleration of industrialization, human activities have dramatically altered the Earth's climate system, the most direct manifestation of which is the rise in global temperatures. According to the Sixth Assessment Report of the IPCC, the global average temperature has increased by about 1.1°C since the end of the 19th century [3]. This authoritative report makes it clear that greenhouse gas emissions, mainly from the burning of fossil fuels and land-use changes, are contributing to the Earth's energy imbalance and continued global warming. The report emphasizes that differences in carbon emissions across sectors and countries have a significant impact on the rate and extent of regional temperature rise. If stronger mitigation measures are not taken in the future, global temperatures could exceed the 1.5°C or even 2°C threshold within this century, triggering more frequent and extreme climate events.

2.2. Precipitation

Climate change has not only led to an increase in global temperatures, but has also significantly altered precipitation patterns around the world. Trenberth noted that as the atmosphere warms, the amount of water vapor that can be carried in the air increases by about 7% for every 1°C of

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warming, which exacerbates the imbalance in the global water cycle, leading to an increase in precipitation in some areas, while others face more severe droughts [4]. This change has resulted in a high incidence of extreme weather events, posing a major threat to agriculture, ecology and human society.

For example, the Midwestern region of North America has experienced significant inter-annual precipitation fluctuations in recent years, with spring precipitation totals in some years about 15% above average, resulting in excessively wet soils and delayed planting, while drought years have resulted in loss of soil moisture and reduced crop yields, which have severely impacted the yields of corn and soybeans. In addition, the South Asian monsoon system has also been erratic, causing precipitation in some parts of India, such as Maharashtra, to deviate by more than 30 percent from the long-term average each year, worsening water stress in agriculture.

Trenberth also points out that this precipitation variability is not randomly distributed but is closely related to natural processes such as atmospheric circulation and ocean currents [4]. This uncertainty not only disrupts crop growth cycles but also threatens ecosystems with plants and animals that depend on seasonal precipitation, especially in the African savannah ecoregion.

Changing precipitation patterns are therefore not only a climate issue, but a systemic challenge that cuts across ecological, agricultural, and social sustainability.

2.3. Changes in air composition

Human activities have altered the composition of many gases in the atmosphere, particularly the concentrations of GHGs and aerosols. Myhre et al. in the IPCC Fifth Assessment Report said that human emissions of GHGs, such as CO2, CH4, and Freon, have been the main drivers of the increase in radiative forcing in recent decades [5]. These gases leave heat in the atmosphere, worsening the greenhouse effect. This has led to a rise in global temperatures. Data show that carbon dioxide concentrations have increased by more than 50 per cent since the industrial revolution and that methane levels have doubled. At the same time, industrial production, straw burning and agricultural activities continue to emit suspended particles into the sky. These tiny particles can have a cooling effect on the climate in the short term by reflecting sunlight back into space or interfering with rainfall systems by altering cloud structures. Studies have shown that emissions from industrial areas in Europe and the United States reduced the greenhouse effect by one-third in the 20th century, but that this regional cooling effect is diminishing as environmental protection measures are strengthened. The report notes that while suspended particles can temporarily mitigate warming, their effect lasts only a few weeks and is limited in scope, while greenhouse gases can remain in the air for centuries and continue to contribute to the buildup of global heat. The Earth is already absorbing as much excess heat as four atomic bombs per second. Worse, dramatic changes in atmospheric composition are not only accelerating the melting of glaciers and the acidification of seawater, but they are also causing 7 million deaths each year from respiratory illnesses, as 90% of the world's population breathes an excessive amount of air caused by a mixture of dust and pollutants. This environmental crisis is particularly acute in developing countries, where the South Asian plains and the industrial belts of East Asia often experience persistent haze in the winter, with fine particulate matter concentrations often reaching dangerous peaks, creating a dual dilemma of health threats and climate degradation.

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3. Anthropogenic impacts on the marine environment

3.1. Plants in seawater (coral reefs)

A study by Hughes et al. published in Nature revealed a direct link between ocean warming and coral crises [6]. According to the study, about 75% of coral reefs around the world experienced severe heat stress between 2014-2017, when seawater temperatures exceeded coral tolerance thresholds for several weeks (typically 1-2°C higher than the average summer temperature), symbiotic algae released toxic substances, forcing the corals to expel them from their bodies. Without these 'tenants', which provide 90% of their nutrients, coral skeletons gradually turn white, stagnating their growth and making them vulnerable to pathogens. Data show that mass bleaching, which occurred globally on average every 25-30 years in the 1980s, has been shortened to every six years, with the Great Barrier Reef losing half of its corals in 2016-2017. Tropical waters are particularly vulnerable, with coral cover having plummeted from 60% to less than 10% in parts of the Caribbean. As "marine rainforests", coral reefs make up only 0.1% of the seabed but support 25% of marine species, and their calcareous skeletons form a three-dimensional structure that provides habitat for more than 4,000 species of fish. At the same time, more than 500 million people around the world rely on coral reefs for food and income, and the annual value of coral reef fisheries in Southeast Asia reaches $2.6 billion. The study warns that if greenhouse gas emissions remain as they are, more than 90 percent of coral reefs will be threatened by 2030, which would not only mean a break in the marine biotic chain, but also the destruction of wave barriers in island nations such as the Maldives - healthy coral reefs can cut wave energy by 97 percent, and their demise would directly exacerbate the risk of coastal erosion.

3.2. Microorganisms

Climate change is already reshaping marine microbial communities that are critical to carbon cycling and nutrient transport. Sunagawa et al. found from a genomic analysis of marine microbes around the globe that the combined effects of global warming, ocean acidification, and pollution are reducing the abundance of certain key microbial taxa while leading to increased tolerance to high temperatures in certain to increase relatively [7]. This change in diversity structure disrupted the original ecological stability.

Specifically, samples from near the equator and in the North Atlantic showed a marked decline in microbial diversity, with suppression of carbon fixation capacity and nitrate cycling processes. Some taxa originally dominant in high-latitude cold-water waters gradually contracted poleward as the sea warmed, affecting phytoplankton productivity and carbon sink capacity in localized areas. This change in microbial composition will trigger a chain reaction in the food chain, affecting phytoplankton, zooplankton, and even fish and mammals at higher trophic levels.

In addition, the study suggests that warmer temperatures and lower pH will also affect microbial metabolic pathways, reducing their critical role in carbon fixation and nitrification. This means that the ability of the oceans to regulate the global climate and absorb carbon dioxide may be weakened, creating positive feedback that will worsen global warming. Therefore, Sunagawa et al. emphasize the importance of continuously watching the dynamics of marine microbes to assess their long-term impact on ecosystem stability and climate regulation [7].

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3.3. Marine life

The response of marine organisms to climate change and human activities is becoming more pronounced. Gattuso et al., through modeling of different CO2 emission scenarios, noted that under high emission scenarios, increased surface ocean temperatures and acidification would seriously threaten environmentally sensitive species such as coral reefs, crustaceans, and shellfish [8]. The decline of these species, which are fundamental to the ecosystem, would lead to changes in the structure of the biological chain, which in turn would affect fish stocks, marine mammals and human societies that depend on fishery resources. The study also noted that species in the polar regions such as krill, seals and penguins have also been severely affected by declining sea ice and rising water temperatures. Furthermore, Lubchenco and Grorud-Colvert also emphasized that overfishing and habitat destruction have worsened the subjective diminishing of marine biodiversity, and climate change is exacerbating these conditions [8]. Coral bleaching events, changes in plankton communities and a northward shift in the migratory ranges of species are all ongoing emergencies. These changes not only make the ecosystem less stable but also jeopardize the safety of food sources in coastal cities. Therefore, the conservation of marine biodiversity is one of the important environmental protection issues that require our attention.

3.4. Nuclear pollution

Nuclear pollution is an important but often overlooked current threat to the marine environment. As the share of nuclear energy in the global energy mix rises, nuclear wastewater discharges have attracted widespread attention. Taking the Fukushima nuclear accident in Japan as an example, the decision to store nuclear wastewater for an extended period and discharge it into the ocean has aroused heated discussions in the international community and the marine scientific community. Pachauri and Reisinger mentioned in the IPCC report that radioactive pollution in the marine environment is characterized by a prolonged period of time and is difficult to be degraded [9]. Nuclear pollution not only damages offshore ecosystems but also affects plankton and breaks the original ecological balance and biological chain. Even the trace elements that require radiation will enter the body of marine organisms so that we human beings will also receive the harm of radiation, perhaps in the future there will be a lot of people sick because of radiation. In addition, the unpredictable spreading path of radioactive isotopes may pose a long-term threat to the fishery resources and coastal ecosystems of neighboring countries. The problem of nuclear pollution has exposed the fact that the international ocean governance mechanism may not be able to harmonize views on the conflicts between each country, and that it is now important for everyone to work together to guard the ecology of the oceans. Scientists are calling for more international cooperation and long-term ecological monitoring to assess the impact of radioactive substances on the oceans and the harm done to human beings.

4. Human responses to climate and ocean change

In the face of the serious challenges posed by global warming and changes in the ocean system, human society has adopted a series of response measures, covering both mitigation and adaptation. In terms of climate, Pachauri and Reisinger point out that greenhouse gas emission reduction, energy system transformation and carbon trading mechanism are the three core pathways [8]. Through the Paris Agreement, many countries have set nationally owned contribution targets, aiming to limit global average warming to 2°C above pre-industrial levels, and even striving to limit it to 1.5°C. To

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achieve these goals, more countries and regions are phasing out the use of coal and investing heavily in renewable energy sources such as wind, solar and hydropower, as well as promoting the development of green transportation and building energy-saving technologies. In addition, carbon market mechanisms such as the EU ETS have been adopted globally to provide price signals to guide companies to reduce emissions.

In terms of marine protection, Lubchenco and Grorud-Colvert emphasize that the establishment of Marine Protected Areas, MPAs, is an important means of protecting marine ecosystems, alleviating human pressures, and achieving the sustainable use of fishery resources [9]. To date, about 7% of the world's oceans have been set aside in protected networks, and these areas restrict or even prohibit fishing and exploitation activities, helping to repair damaged ecosystems, improve biodiversity and enhance ecosystem resilience to climate shocks. However, a significant expansion in the number and quality of MPAs, as well as enhanced transnational collaborative management, is still needed to achieve the target of protecting 30% of the ocean area by 2030 in the QMGF.

Gattuso et al. suggest that the adaptive capacity of marine ecosystems should be assessed under different emission scenarios. High emission pathways may lead to increased ocean acidification, frequent coral reef bleaching, and loss of biological habitats, especially threatening environmentally sensitive species [10]. It is critical to develop site-specific mitigation and adaptation strategies to address the ecological vulnerability of different regions, such as coral protection projects in the tropics and fisheries restrictions in polar waters.

In addition, emerging strategies proposed by the National Academy of Sciences, such as CDR, are receiving increasing attention. These technologies, which include seaweed farming, artificial upwelling, ocean alkalinity enhancement, and deep-sea carbon sequestration, aim to enhance the ocean's ability to absorb and store carbon dioxide [11]. Although still at the research and pilot stage, they are seen as possible complementary options for climate governance and are expected to play a key role in the future.

Although the above measures are gradually being promoted globally, they still face a series of challenges, including high economic costs, insufficient technological maturity, imperfect management mechanisms and low public awareness and participation. Therefore, in the future, policy integration and financial support should be strengthened, international synergistic governance should be promoted, and public understanding and willingness to participate in climate and ocean protection should be enhanced through education and publicity, to improve the overall effectiveness and sustainability of the response.

5. Conclusion

This study systematically examines the multiple impacts of human activities on the climate system and the marine environment, including climate issues such as greenhouse gas emissions-induced warming, changes in precipitation patterns, and changes in atmospheric composition, as well as specific threats to marine ecosystems, such as coral bleaching, declining biodiversity, imbalances in the structure of microbial communities, and nuclear contamination. The article also analyzes several measures taken by humans in response to climate change and marine degradation, such as carbon reduction, marine protected area construction, and carbon capture strategies, and points out the effectiveness and challenges of these actions.

This study shows that human activities have profoundly changed the Earth's climate system and marine ecological patterns, reflecting the interdependence between humans and the natural environment and the complexity of feedback mechanisms. This study emphasizes the importance of an integrated assessment of environmental pressures, response mechanisms and policy tools from a

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systemic perspective, which can help provide theoretical support and practical references for future environmental governance and ecological restoration and echoes the urgency of ecosystem preservation raised at the beginning.

However, this study still has some limitations. Due to the limitation of space and data sources, it is not possible to explore in depth the interactive effects of regional differences and socio-economic factors on environmental change, nor can it fully cover the deeper chain effects of extreme weather events on human migration and public health. In addition, the long-term effects of emerging response technologies and eco-ethical issues need to be further studied.

Going forward, research should further strengthen multidisciplinary integration, especially in building a closer bridge between environmental science, policy research and social behavior. At the same time, data monitoring and modeling capabilities need to be strengthened to provide decision makers with a timelier and more targeted scientific basis to achieve the goal of sustainable development in which human beings live in harmony with nature.

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