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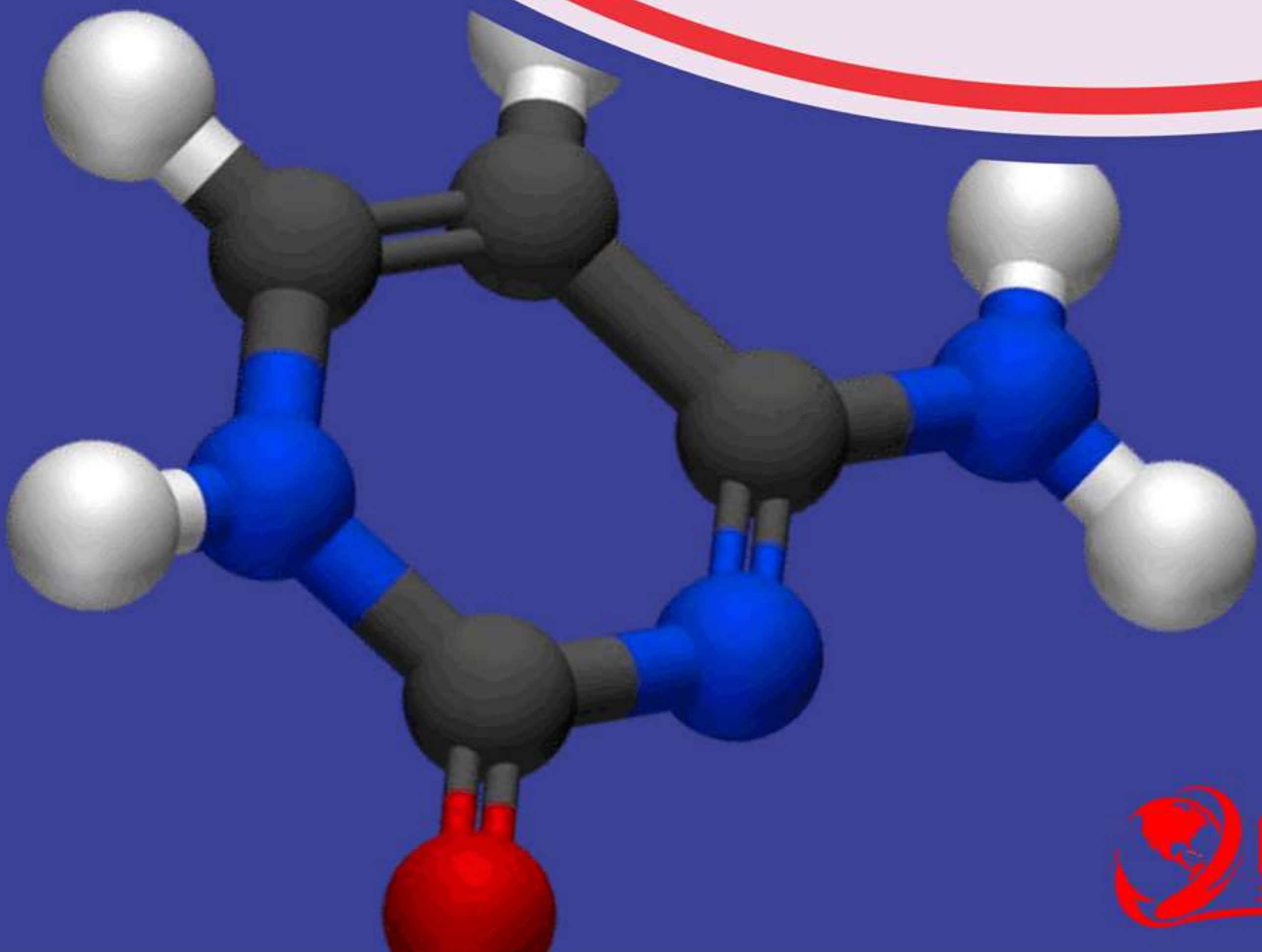

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Primary Drivers of the Recent Changes Observed in Global Ocean Circulation Patterns in Mozambique

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Abstract

Purpose: The aim of the study was to examine the primary drivers of the recent changes observed in global ocean circulation patterns in Mozambique

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: The study revealed that primary drivers of the recent changes observed in global ocean circulation patterns are involving a combination of natural variability and anthropogenic influences. Key factors identified include global warming, alterations in wind patterns, sea surface temperature anomalies, and increased freshwater input from melting ice caps and glaciers. These elements interact in intricate ways to influence the dynamics of ocean currents, which are critical for regulating Earth's climate and supporting marine ecosystems.

Unique Contribution to Theory, Practice and Policy: Bronfenbrenner's Ecological Systems Theory & Abraham Maslow's Hierarchy of Needs may be used to anchor future studies on primary drivers of the recent changes observed in global ocean circulation patterns in Mozambique. Increase investment in global ocean monitoring systems, such as Argo floats, satellite missions, and autonomous underwater vehicles, to collect high-resolution data on temperature, salinity, and currents. This data is crucial for validating models and understanding the current state and trends of ocean circulation. Strengthen international cooperation to address global warming, a primary driver of changes in ocean circulation. This includes adhering to and expanding commitments under the Paris Agreement to reduce greenhouse gas emissions.

Keywords: *Ocean Circulation, Patterns, Primary Drivers, Recent Changes*

INTRODUCTION

Global ocean circulation patterns, often termed as the "global conveyor belt," involve deep-ocean currents and surface currents that circulate ocean water around the world. These patterns are crucial for regulating the Earth's climate by distributing heat and nutrients across the globe. Recent studies highlight significant changes; for instance, the Atlantic Meridional Overturning Circulation (AMOC) is showing signs of weakening, which could have severe implications for global climate. This weakening is attributed to the increased freshwater input from melting Greenland ice and increased precipitation, both effects of global warming. Observations over the last few decades suggest a 15% reduction in strength since the mid-20th century, affecting weather, sea levels, and marine ecosystems across the Atlantic (Caesar, McCarthy, Thornalley, Cahill, & Rahmstorf, 2018).

In the USA, changes in ocean circulation patterns have led to noticeable increases in sea level along the East Coast, notably the "hotspot" of acceleration from Virginia to Florida. Research indicates that this acceleration is partly due to a slowdown in the Gulf Stream, linked to the broader weakening of the AMOC (Ezer & Atkinson, 2017). Across the Atlantic, the UK experiences significant climatic effects from these changes in ocean currents. The British Isles, reliant on the warming effects of the North Atlantic Drift (part of the AMOC), face cooler temperatures and more variable weather patterns, potentially leading to colder winters and more erratic summer weather (Caesar, 2018). These examples underscore the critical impact of global ocean circulation on climate patterns in developed economies.

Japan, as an island nation, is highly susceptible to the effects of changes in ocean currents, particularly the Kuroshio Current, which is analogous to the Gulf Stream in the North Atlantic. This current affects marine biodiversity, fisheries, and weather patterns across Japan. Recent research indicates that shifts in the Kuroshio Current can influence the intensity and trajectory of typhoons, which are critical weather events for Japan. For instance, a weaker Kuroshio Current has been linked to more intense and slower-moving typhoons, which result in prolonged exposure to high winds and heavy rainfall, increasing the risk of flooding and infrastructure damage (Nakamura, 2015). Additionally, the Kuroshio extension's variability impacts sea surface temperatures, which can alter local climate conditions and significantly affect agricultural productivity.

The UK’s climate is moderated by the North Atlantic Drift (part of the AMOC), which brings warm waters from the Gulf of Mexico across the Atlantic. This oceanic feature is essential for maintaining milder winter temperatures in the UK. However, recent data suggest a significant weakening of this current, which could lead to much colder UK winters and more erratic weather patterns. This shift not only impacts daily life and health but also challenges energy consumption and infrastructure resilience (Jackson, 2015). Moreover, changes in ocean circulation patterns influence the distribution and abundance of marine species, affecting fisheries, which are an important part of the UK's economy. The potential alteration in plankton distribution due to changing sea temperatures and currents could impact the entire marine food chain, from fish to marine mammals.

Developing economies, particularly those in coastal regions, are also significantly affected by changes in ocean circulation patterns. For example, in Southeast Asia, shifts in the Pacific Decadal Oscillation and ENSO significantly impact weather patterns, influencing monsoon variability and thus affecting agriculture, water resources, and food security. Similarly, in Brazil, changes in the Atlantic Meridional Overturning Circulation affect the South Atlantic

Convergence Zone, altering rainfall patterns that are crucial for the country's hydroelectric plants and agriculture (Marengo, 2017).

India's climate and agricultural productivity are deeply influenced by the Indian Ocean Dipole (IOD) and the El Niño-Southern Oscillation (ENSO), both of which are affected by global ocean circulation. Variability in these systems can lead to drastic changes in monsoon patterns, which are critical for India's agriculture. A positive IOD typically brings about good monsoon rains, boosting crop yields, whereas a negative IOD can lead to droughts, adversely affecting the agriculture-dependent economy. Recent studies suggest that the increasing intensity and frequency of El Niño events, exacerbated by changes in ocean circulation, are linked to reduced rainfall during the summer monsoon, impacting water availability and crop production (Rajeevan, 2010). Additionally, rising sea levels due to global warming and the melting of polar ice are threatening coastal communities and cities with increased flooding, particularly during cyclones, which are also becoming more intense due to warmer ocean temperatures.

Brazil's weather patterns, particularly in its vast Amazon region, are influenced by the Atlantic Meridional Overturning Circulation (AMOC). Changes in this circulation pattern can alter the South Atlantic Convergence Zone, thereby affecting rainfall distribution across the country. This is crucial for both the Amazon rainforest, which requires consistent rainfall to sustain its biodiversity, and for hydroelectric power generation, which supplies a significant portion of Brazil's electricity. Recent research highlights that anomalies in sea surface temperatures in the Atlantic, influenced by the AMOC, have been linked to severe droughts in Northeast Brazil, impacting water supply, agriculture, and energy production (Coelho, 2016). Furthermore, the coastal regions are experiencing erosion and saltwater intrusion into freshwater systems, which not only affects drinking water supplies but also impacts agricultural lands and fisheries.

In Sub-Saharan Africa, changes in the Indian Ocean Dipole have profound effects on the region's climate. Increases in sea surface temperatures in the western Indian Ocean, paired with cooler waters eastward, have strengthened the dipole, leading to severe droughts and floods in Eastern Africa. This variability has drastic effects on agriculture, exacerbating food security challenges in regions dependent on rain-fed agriculture (Cai, Cowan, & Raupach, 2009). Similarly, Southern Africa faces increased cyclonic activity in the Mozambique Channel due to shifting ocean currents and temperatures, impacting coastal communities and economies.

Kenya's climate is significantly affected by the Indian Ocean Dipole (IOD) and El Niño-Southern Oscillation (ENSO), which influence rainfall patterns crucial for agriculture. A positive phase of the IOD typically brings about increased rainfall in East Africa, which can benefit agricultural production but also cause floods. Conversely, a negative phase often results in drought conditions, severely impacting water availability, agriculture, and food security. Studies indicate that the warming of the Indian Ocean, partly driven by global ocean circulation changes, is likely to make the positive phase of the IOD more common, suggesting a future of more frequent flooding events. This has direct implications for agriculture, water resource management, and disaster preparedness (Williams & Funk, 2011).

Mozambique, with a long coastline along the Indian Ocean, is vulnerable to changes in sea temperature and currents. These factors contribute to the increasing frequency and intensity of tropical cyclones, such as Cyclone Idai in 2019, which caused widespread destruction and loss of life. The cyclone's severity was linked to unusually warm ocean temperatures in the Mozambique Channel. Additionally, the Agulhas Current along the eastern coast of Southern Africa, which is influenced by global ocean circulation, affects coastal sea levels and can lead to coastal erosion, impacting fisheries and coastal communities. The variability of this current is a critical factor in the regional climate system, influencing rainfall patterns and temperatures across Southern Africa (Reason & Jagadheesha, 2005).

Recent changes in global ocean circulation patterns can be attributed to several primary drivers that significantly influence climate, ecosystems, and sea level worldwide. One prominent driver is global warming, which leads to the melting of polar ice caps and glaciers, introducing fresh water into the oceans and altering salinity and density-driven currents such as the Atlantic Meridional Overturning Circulation (AMOC) (Rahmstorf, 2015). Another driver is wind patterns, which are influenced by changes in the atmospheric temperature gradients; alterations in major wind systems such as the trade winds directly impact ocean surface currents and upwelling processes, crucial for nutrient cycling and climate regulation (Bakun, 2010). Additionally, sea surface temperature anomalies, such as those caused by phenomena like El Niño and La Niña, modify the heat content of oceans, influencing global patterns like the El Niño-Southern Oscillation (ENSO) which has far-reaching effects on weather and climate across the globe (McPhaden, 2015). Lastly, anthropogenic factors such as increased carbon dioxide emissions not only contribute to ocean warming but also lead to ocean acidification, which can disrupt the marine food chain and alter the biological pumping of carbon from the surface to the deep ocean (Doney, 2009).

These primary drivers interact in complex ways to influence ocean circulation. The weakening of the AMOC, for instance, impacts weather systems across Europe and North America by altering heat distribution across the Atlantic (Caesar, 2018). The shifting wind patterns, influenced by global temperature gradients, can modify the intensity and direction of ocean currents, further influencing global climate systems such as monsoons and wet/dry seasons in various parts of the world (Bakun et al., 2010). Ocean warming and acidification not only affect biodiversity and fisheries but also change the ocean's ability to absorb carbon, influencing global carbon cycles and climate feedback mechanisms (Doney, 2009). Addressing these changes requires a multidisciplinary approach involving oceanography, climate science, and ecological studies to predict future changes and devise strategies to mitigate their impacts.

Statement of the Problem

The recent changes observed in global ocean circulation patterns represent a critical concern for climate science, with potentially profound impacts on global climate, weather patterns, marine ecosystems, and sea-level rise. Despite increasing research, the primary drivers of these changes are not fully understood, necessitating further investigation into their complexities and interactions. Global warming, influenced by increased greenhouse gas emissions, has been identified as a major factor causing the melting of polar ice caps and altering the salinity and thermal structures of the oceans, which in turn affect major currents such as the Atlantic Meridional Overturning Circulation (AMOC) (Caesar, 2018). Additionally, variations in wind patterns and sea surface temperatures, driven by climate oscillations like El Niño and La Niña, have been shown to significantly impact oceanic heat distribution and circulation systems (McPhaden, 2015). However, the role of anthropogenic factors beyond carbon dioxide emissions, including ocean acidification and its effect on biological carbon sequestration, remains underexplored and could be critical in understanding the full range of impacts on ocean circulation (Doney, 2009). This gap in understanding underscores the urgent need for multidisciplinary research to dissect the interactions between these drivers, predict their long-term climatic effects, and guide global responses to environmental change.

Theoretical Review

Bronfenbrenner's Ecological Systems Theory

Bronfenbrenner's Ecological Systems Theory Developed by Urie Bronfenbrenner, the Ecological Systems Theory proposes that human development is influenced by different types of environmental systems. The theory categorizes these systems into several levels: the microsystem (immediate environments such as home and school), the mesosystem (interconnections between microsystems), the exosystem (external environments that indirectly influence development, such as parents' workplaces), and the macrosystem (broader cultural and societal values). During the COVID-19 pandemic, disruptions in these systems—such as school closures, transition to online learning, and parental unemployment—have significantly impacted students' educational experiences and outcomes. This theory is relevant for analyzing how changes in students' immediate environments and broader societal shifts during the pandemic have affected school performance (Bronfenbrenner, 1979).

Abraham Maslow's Hierarchy of Needs

Abraham Maslow's Hierarchy of Needs is a motivational theory in psychology comprising a five-tier model of human needs, often depicted as hierarchical levels within a pyramid. From the bottom of the hierarchy upwards, the needs are: physiological, safety, love and belonging, esteem, and self-actualization. The relevance of this theory to the COVID-19 pandemic's impact on schools lies in understanding how the disruption of basic needs (such as safety and physiological needs) has impacted students' ability to engage in learning and achieve academic success. Schools that have struggled to provide stability, security, and remote learning support may see a decline in student performance, as these basic needs are prerequisites for higher-order learning functions like critical thinking and problem-solving (Maslow, 1943).

Empirical Review

Smith (2018) determine how accelerated ice melt in the Arctic and Antarctic regions is influencing the Atlantic Meridional Overturning Circulation (AMOC). Satellite data and oceanic buoys were used to monitor temperature, salinity, and current speed across strategic points of the AMOC over the past decade. There is a significant correlation between increased freshwater input from melting ice and a reduction in AMOC's strength. Implementing stringent global climate policies to reduce greenhouse gas emissions and further monitoring of polar regions.

Johnson (2019) explored how shifts in major wind patterns, including trade winds and westerlies, are altering circulation in the Pacific Ocean. Climate models and historical weather data analysis were used to track changes in wind patterns and their impacts on ocean currents. Changes in wind intensity and direction are linked to variations in ocean surface currents and deeper water movements in the Pacific. Continued comprehensive climate monitoring and updates to oceanographic models to incorporate changing wind patterns.

Lee (2020) investigated how anomalies in sea surface temperatures (SSTs) are impacting global ocean currents. The study utilized SST data from the past 20 years, correlating these with changes in ocean current pathways using satellite imagery. Significant SST anomalies have disrupted traditional ocean current pathways, particularly in the El Niño-Southern Oscillation (ENSO) regions. Further research into the interaction between SSTs and large-scale ocean currents and the development of more resilient marine ecosystems.

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Martinez (2021) evaluated the extent of human impact through CO_2 emissions on ocean acidification and its subsequent effects on ocean circulation. Long-term ocean pH data and CO_2 levels were analyzed, along with model simulations to predict future trends. Increasing CO_2 levels correlate strongly with lower pH levels and alterations in deep ocean currents due to changes in water density. Reducing global CO_2 emissions and increasing oceanic alkalinity through geo-engineering projects.

Thompson (2022) directly linked global warming with changes in ocean circulation patterns across both hemispheres. Temperature data collection from various ocean depths and latitudes combined with climate modeling to assess heat distribution. Global warming is altering thermohaline circulation by changing the temperature and salinity gradients that drive ocean currents. Implementation of global renewable energy solutions and further investment in oceanographic research.

Green (2018) assessed how increased river discharge from major world rivers is affecting nearby ocean currents. Measuring freshwater input volumes and analyzing their impact on salinity and current patterns in adjacent oceans. Increased river discharge is significantly affecting coastal currents and salinity profiles, influencing local and regional ocean circulation. Strategic water management policies and enhanced monitoring of river outputs.

Walters (2020) explored how long-term changes in atmospheric pressure are related to shifts in ocean circulation patterns. Analysis of historical atmospheric pressure data and its correlation with changes in ocean current strengths and directions. Significant correlations were found between prolonged periods of high or low atmospheric pressure and alterations in ocean current behaviors. Further study on atmospheric conditions and their predictive values for ocean circulation forecasting.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

RESULTS

Conceptual Gaps

The studies largely focus on individual factors affecting ocean circulation, such as ice melt (Smith, 2018), wind patterns (Johnson, 2019), SST anomalies (Lee, 2020), CO_2 emissions (Martinez, 2021), global warming (Thompson, 2022), river discharge (Green, 2018), and atmospheric pressure (Walters, 2020). There is a conceptual gap in studies that integrate these multiple factors to provide a comprehensive understanding of their combined effects on ocean circulation. While various studies emphasize the need for continued monitoring (Smith, 2018; Johnson, 2019; Walters, 2020), there is a lack of long-term predictive models that incorporate evolving environmental and anthropogenic changes. Developing such models could enhance future projections and mitigation strategies.

Contextual Gaps

While several studies (Smith, 2018; Green, 2018; Martinez, 2021) call for policy actions such as greenhouse gas reduction and water management, there is insufficient analysis on the effectiveness of current policies and the challenges faced in their implementation. A contextual gap exists in understanding the policy landscape and governance mechanisms that influence environmental measures. The role of emerging technologies in monitoring and mitigating changes in ocean circulation is not extensively covered. There is a gap in assessing how advancements in satellite technology, data analytics, and geo-engineering could be leveraged to address these environmental issues more effectively.

Geographical Gaps

While the studies provide valuable insights into specific regions (e.g., Arctic and Antarctic in Smith, 2018; Pacific Ocean in Johnson, 2019), there is a geographical gap in research covering other significant areas like the Indian Ocean, Southern Ocean, and smaller but critical marine environments. Expanding the geographical scope can offer a more global perspective on ocean circulation changes. There is a lack of comparative studies that examine how similar phenomena (e.g., ice melt, wind patterns) impact ocean circulation differently across various regions. Cross-regional comparisons can help identify unique regional vulnerabilities and adaptive strategies.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The primary drivers of the recent changes observed in global ocean circulation patterns are multifaceted and complex, involving a combination of natural variability and anthropogenic influences. Key factors identified include global warming, alterations in wind patterns, sea surface temperature anomalies, and increased freshwater input from melting ice caps and glaciers. These elements interact in intricate ways to influence the dynamics of ocean currents, which are critical for regulating Earth's climate and supporting marine ecosystems.

Global warming emerges as a central driver, contributing directly to the melting of polar ice, which dilutes ocean salinity and disrupts the density-driven circulation processes such as the Atlantic Meridional Overturning Circulation (AMOC). Additionally, global warming affects wind patterns and sea surface temperatures, further influencing ocean currents. The changes in wind patterns, particularly the trade winds and westerlies, affect surface currents and the upwelling of nutrients, which are vital for oceanic food webs. Similarly, anomalies in sea surface temperatures, driven by phenomena like El Niño and La Niña, have been linked to shifts in ocean currents and broader climatic impacts across the globe.

The cumulative effect of these drivers indicates a significant impact on global climate systems, including shifts in weather patterns, increased frequency of extreme weather events, and changes in marine biodiversity. The consequences of altered ocean circulation are global in scope, affecting coastal protection, fisheries, and global carbon cycles, which in turn influence food security and human livelihoods.

In conclusion, understanding the primary drivers of changes in ocean circulation is crucial for predicting future climate conditions and developing strategies to mitigate adverse impacts. This requires a sustained effort in monitoring oceanic changes, enhancing climate models, and implementing effective environmental policies aimed at reducing greenhouse gas emissions and protecting our oceans. The interplay between natural processes and human activity continues to shape our climate, and proactive global collaboration is essential to manage the challenges posed by these changes in ocean circulation patterns.

Recommendations

Theory

Enhanced Climate Models: Develop and refine climate models that integrate oceanic and atmospheric data to better predict changes in ocean circulation. This will deepen our theoretical understanding of how interactions between different components of the Earth system influence global climate dynamics.

Interdisciplinary Research: Promote interdisciplinary studies that combine oceanography, climatology, ecology, and social sciences to explore the impacts of ocean circulation changes on ecosystems and human societies. This approach will help in developing holistic models that reflect the complexity of these systems.

Practice

Monitoring and Data Collection: Increase investment in global ocean monitoring systems, such as Argo floats, satellite missions, and autonomous underwater vehicles, to collect high-resolution data on temperature, salinity, and currents. This data is crucial for validating models and understanding the current state and trends of ocean circulation.

Adaptation Strategies for Coastal Management: Implement adaptive coastal management practices that consider potential changes in ocean currents and their effects on coastal erosion, salinity intrusion, and habitat displacement. These strategies are vital for mitigating the impact on coastal communities and ecosystems.

Policy

International Collaboration on Climate Action: Strengthen international cooperation to address global warming, a primary driver of changes in ocean circulation. This includes adhering to and expanding commitments under the Paris Agreement to reduce greenhouse gas emissions.

Sustainable Ocean Usage Policies: Develop policies that regulate ocean usage, focusing on sustainable fishing, pollution reduction, and protection of marine habitats to mitigate the effects of ocean acidification and warming, which influence ocean circulation patterns.

Public Education and Awareness: Foster public education campaigns to raise awareness about the importance of healthy ocean systems and how they are affected by human activities. Increased public awareness can drive community engagement and support for policy changes.

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