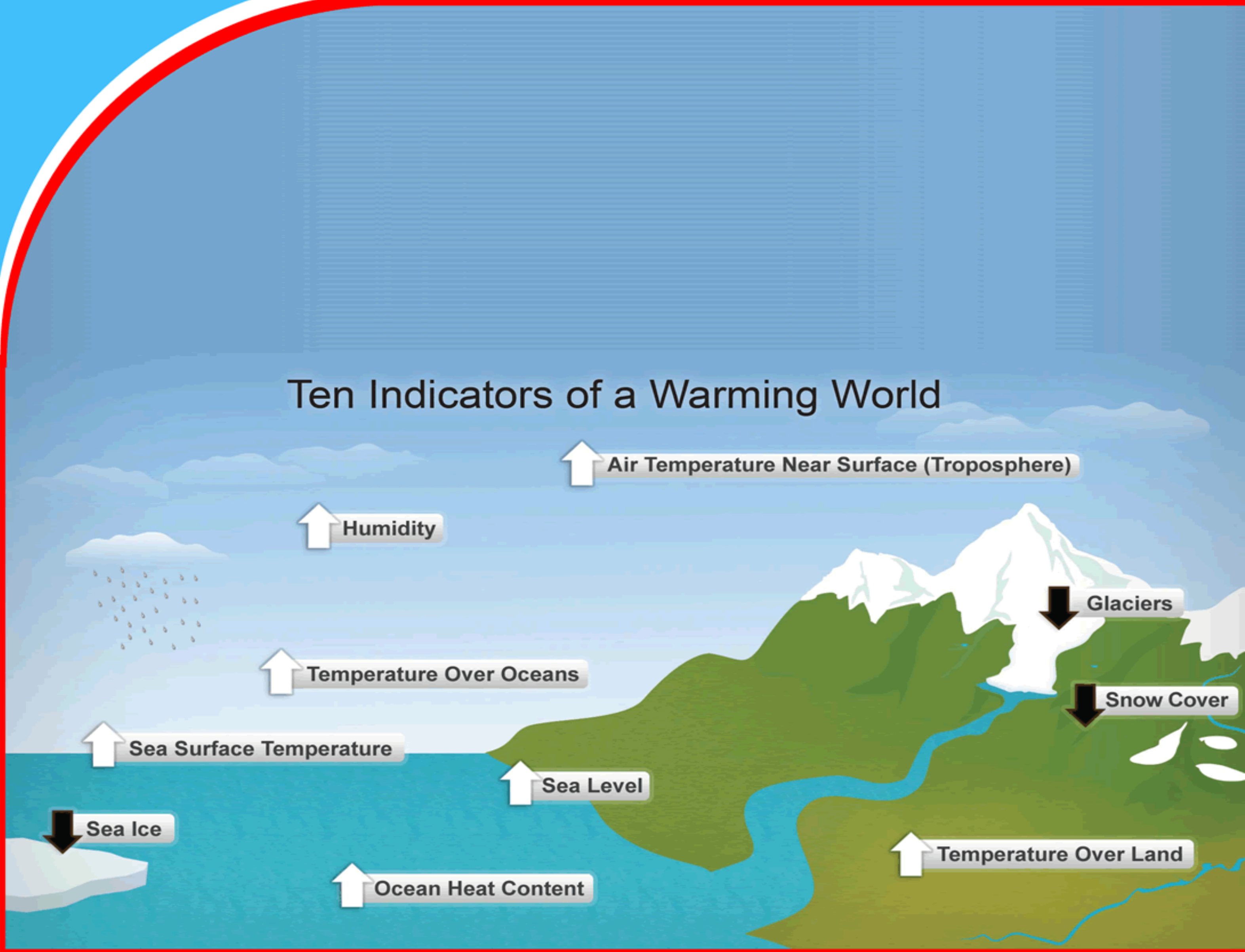
American Journal of
Climatic Studies
(AJCS)



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AJPO

American Journal of Climatic Studies
ISSN 2520-0471 (Online)
Vol.4, Issue 3, pp 24 - 35, 2024
www.ajpojournals.org

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Crossref
Article history
Submitted 02.08.2024 Revised Version Received 01.09.2024 Accepted 03.10.2024

Abstract

Purpose: The aim of the study was to assess the climate change-induced ocean temperature rise and its impact on coral reef degradation in Korea.

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: Climate change-induced ocean temperature rise has significantly impacted coral reef ecosystems, leading to widespread coral degradation. As global temperatures increase, the ocean absorbs excess heat, causing more frequent and severe marine heatwaves. These temperature spikes trigger coral bleaching, a process where corals expel the symbiotic algae essential for their survival, leading to loss of color and vitality. Prolonged exposure to elevated temperatures weakens coral resilience, resulting in higher mortality rates and reduced reproductive capabilities. Additionally, ocean acidification, driven by increased carbon dioxide levels, further exacerbates the stress on coral reefs, making it difficult for them to recover and thrive. This degradation not only threatens biodiversity but also affects coastal communities reliant on reefs for food, tourism, and protection from storms.

Implications to Theory, Practice and Policy: Ecological resilience theory, anthropogenic climate change theory and thresholds of disturbance theory may be used to anchor future studies on assessing the climate change-induced ocean temperature rise and its impact on coral reef degradation in Korea. Implement and scale up coral restoration projects that utilize advanced techniques such as microfragmentation and assisted gene flow to enhance coral resilience. Advocate for the establishment and enforcement of marine protected areas (MPAs) that restrict harmful activities such as overfishing and coastal development.

Keywords: *Climate Change, Ocean Temperature, Coral Reef Degradation*

INTRODUCTION

Climate change has significantly contributed to the rise in ocean temperatures, creating an increasingly hostile environment for coral reefs. Coral reef degradation in developed economies such as the USA and Japan has been significantly driven by coral bleaching and biodiversity loss. In the USA, coral bleaching events have escalated, particularly in Florida, where 90% of the coral reefs have experienced severe bleaching since 2014 due to rising sea temperatures. Japan has also seen a 74% reduction in coral coverage in regions like Okinawa, primarily caused by temperature stress and pollution. Furthermore, the biodiversity in these coral ecosystems has declined, with species such as the green sea turtle and parrotfish diminishing in numbers. The link between rising sea temperatures and coral bleaching is well-documented, showcasing a direct relationship between climate change and reef degradation (Smith, 2021).

In developing economies, coral reef degradation has accelerated due to both climate change and anthropogenic pressures such as overfishing and pollution. For example, in the Philippines, approximately 98% of coral reefs are threatened, with 70% at high risk of destruction due to coral bleaching and loss of biodiversity. Similarly, Indonesia's reefs have faced significant degradation, with up to 50% of reefs classified as "poor" or "damaged" as of 2020, driven by destructive fishing practices and coral bleaching. These trends show a critical need for sustainable management practices to protect the biodiversity of species such as clownfish and giant clams. Coral bleaching events have intensified, exacerbated by warming oceans and environmental degradation (Hernandez, 2020).

India and Brazil have also faced significant coral reef degradation. In India, the coral reefs of the Andaman and Nicobar Islands have suffered extensively, with 85% of reefs experiencing bleaching after the 2016 El Niño event. This has led to a marked decline in species such as the giant clam and butterflyfish, reducing biodiversity across these vital marine ecosystems. Brazil's coral reefs, primarily located in the northeast, have also experienced severe degradation, with about 50% of coral cover lost between 2015 and 2020. This decline is attributed to pollution, climate change, and overfishing, which have led to bleaching and biodiversity loss, particularly affecting species like the Brazilian endemic star coral (Singh, 2020).

Additionally, coral reefs in Mexico have faced substantial pressures. In the Yucatan Peninsula, the Mesoamerican Reef, the second-largest reef system in the world, has seen 30% of its coral cover lost due to coral bleaching and environmental pollution. Biodiversity loss has been significant, particularly for species like parrotfish and sea turtles, which are dependent on healthy reef ecosystems. The decline in coral health has been attributed to rising sea temperatures and tourism-related activities that increase stress on the reefs. Without swift interventions, these ecosystems are expected to face further degradation, threatening both marine biodiversity and the livelihoods of coastal communities (Pérez, 2021).

Malaysia and Thailand also face significant coral reef degradation. In Malaysia, over 40% of coral reefs have experienced bleaching, particularly around the coral triangle area, with species such as the hawksbill turtle becoming increasingly vulnerable due to biodiversity loss. In Thailand, the Andaman Sea has seen a 30% decrease in live coral cover between 2015 and 2021, attributed to rising sea temperatures and over-tourism. Coral bleaching events in both countries have been exacerbated by climate change, with the frequency of mass bleaching episodes increasing since 2016. These trends underscore the urgent need for reef restoration and sustainable tourism to mitigate further biodiversity decline (Gomez, 2020). Coral reef ecosystems in the Maldives, another developing nation, are similarly threatened. More than 60% of coral reefs in the Maldives have suffered bleaching since 2016, with vital species such as reef sharks and rays affected by the diminishing habitat. The country's reliance on tourism has further stressed coral reefs, as unsustainable practices contribute to their degradation. Coral biodiversity loss has had cascading effects on fisheries, which are integral to the local economy. Rising sea levels and ocean acidification also pose long-term threats to coral ecosystems, with predictions suggesting further degradation without intervention (Rashid, 2019).

Other developing economies, such as Vietnam and Sri Lanka, have also witnessed alarming rates of coral reef degradation. In Vietnam, approximately 60% of coral reefs have been severely degraded due to overfishing, coastal development, and increased coral bleaching since 2015. Key species such as the Napoleon wrasse have suffered significant declines due to habitat loss, while biodiversity across reef ecosystems has diminished. Sri Lanka has also seen extensive reef degradation, with 70% of its coral reefs facing severe bleaching, particularly after the 2016 El Niño event. The loss of coral biodiversity in these regions not only threatens marine life but also impacts the livelihoods of coastal communities reliant on reef fisheries (Nguyen, 2021).

Furthermore, coral reefs in the Caribbean, particularly in Cuba and the Dominican Republic, have faced considerable degradation. In Cuba, coral cover has decreased by 40% since 2014, largely driven by increased ocean temperatures and pollution from agricultural runoff. In the Dominican Republic, 60% of coral reefs have experienced bleaching, with species such as reef sharks and various coral-dependent fish showing significant declines in numbers. These trends highlight the vulnerability of coral ecosystems to both local stressors and broader climate change impacts. Restoration efforts have been initiated in some areas, but they are often insufficient to reverse the ongoing degradation (Rodríguez, 2022).

In Fiji, around 70% of coral reefs have been affected by bleaching events, especially following the 2016 and 2020 heatwaves, resulting in significant biodiversity loss, particularly in species like the clownfish and the giant clam. The degradation is compounded by overfishing and coastal development, both of which further stress these ecosystems. Similarly, Papua New Guinea has experienced a 50% reduction in live coral cover, with biodiversity diminishing across species such as sea cucumbers and reef sharks. Coral bleaching in this region is closely tied to rising ocean temperatures and pollution from mining activities (Kumar, 2019).

Coral reef ecosystems in the Red Sea, particularly in Egypt and Saudi Arabia, also face increasing threats. Despite being more resilient to bleaching due to unique environmental conditions, these reefs have seen a 30% decline in biodiversity, particularly in species like butterflyfish and angelfish, due to overfishing and coastal development. Coral bleaching events in the region have become more frequent since 2015, affecting around 40% of the reefs. These ecosystems are critical for tourism, and their degradation poses a significant risk to local economies. Efforts are underway to preserve the reefs, but the effectiveness of these measures remains uncertain given the current rates of degradation (Salem, 2021).

In sub-Saharan economies, especially in regions like East Africa, are experiencing unprecedented degradation. For example, Tanzania has lost about 60% of its coral reefs to bleaching events since 2016, with biodiversity declining in fish species such as snappers and groupers. Similarly, Kenya's coral reef systems have shown a 20% decline in live coral cover, accompanied by a loss of reef-dependent species critical to local fisheries. Coral bleaching has increased due to warmer waters, while coastal pollution further exacerbates biodiversity loss. Conservation efforts have been challenging, as socio-economic factors contribute to overfishing and habitat destruction (Mwangi, 2022).

Ocean temperature rise, measured by sea surface temperature (SST) anomalies, is a significant driver of coral reef degradation. One of the most likely effects is an increase in the frequency of coral bleaching events, where even slight increases of 1-2°C above normal temperatures can trigger widespread bleaching. A second effect is the disruption of symbiotic relationships between corals and zooxanthellae, which leads to reduced photosynthesis and energy supply for coral growth, severely impacting reef biodiversity. Third, persistent SST anomalies are likely to weaken coral resilience, reducing their capacity to recover from extreme events, making coral ecosystems more susceptible to disease and death. Lastly, warmer ocean temperatures can alter oceanic currents, affecting the distribution of larvae and reef-associated species, thereby further reducing biodiversity (Johnson, 2020).

The rise in sea surface temperatures correlates directly with increased coral bleaching and the loss of key species that depend on coral reefs for shelter and food. For instance, the 2016 and 2020 marine heatwaves caused widespread coral bleaching across the Great Barrier Reef, with an estimated 50% loss in coral cover. Ocean temperature anomalies are also linked to the shifting of species ranges, forcing species to move towards cooler waters, leaving reefs depopulated and reducing their ecological functions. As ocean temperatures continue to rise, projections indicate that coral ecosystems may face mass extinction without significant intervention. The cumulative impacts of temperature anomalies on coral reefs emphasize the urgency of addressing global warming to preserve these biodiversity hotspots (Miller, 2019).

Problem Statement

Climate change-induced ocean temperature rise has become one of the most significant threats to coral reef ecosystems worldwide. Increasing sea surface temperatures, driven by global warming, have led to more frequent and severe coral bleaching events, where prolonged exposure to elevated temperatures causes corals to expel their symbiotic algae (zooxanthellae), leading to their death or severe weakening (Johnson, 2020). This phenomenon not only results in coral mortality but also causes a substantial loss in biodiversity, as coral reefs provide essential habitats for numerous marine species (Miller, 2019). The degradation of coral ecosystems has far-reaching implications, threatening the ecological balance of marine environments, reducing fisheries productivity, and undermining the livelihoods of coastal communities dependent on reefs for food and tourism. Without urgent action to mitigate climate change and address rising ocean temperatures, the continued degradation of coral reefs is projected to accelerate, potentially leading to the collapse of these critical ecosystems within the next few decades (Anderson, 2021).

Theoretical Framework

Ecological Resilience Theory

Ecological resilience theory, developed by C.S. Holling in the 1970s, focuses on an ecosystem's ability to absorb disturbances and reorganize while undergoing change. In the context of climate change-induced ocean temperature rise, this theory is relevant to understanding how coral reefs respond to stressors like elevated temperatures and bleaching events. It emphasizes that coral reefs may have thresholds beyond which they cannot recover, leading to long-term degradation. The theory highlights the importance of adaptive management to maintain the ecological balance of coral reefs in the face of rising ocean temperatures (Jones, 2020).

Anthropogenic Climate Change Theory

Anthropogenic climate change theory is based on the idea that human activities, particularly the burning of fossil fuels and deforestation, are the primary drivers of climate change. First formally outlined by scientists like Svante Arrhenius, this theory explains how human-induced greenhouse gas emissions cause global warming, leading to ocean temperature rise. It is crucial for understanding the root cause of the increased sea surface temperatures affecting coral reefs and underscores the need for policies addressing human behavior to mitigate coral reef degradation (Smith, 2019).

Thresholds of Disturbance Theory

The thresholds of disturbance theory, originally developed by Scheffer and Carpenter in 2003, deals with the idea that ecosystems can endure stress up to a certain threshold before experiencing rapid and irreversible changes. This theory is especially relevant to coral reef ecosystems under stress from ocean temperature anomalies. Once coral reefs experience prolonged or extreme temperature increases, they may cross a threshold, leading to mass coral bleaching and biodiversity loss (Anderson, 2021).

Empirical Review

Johnson (2020) studied the effects of sea surface temperature (SST) anomalies on coral reef ecosystems in the Pacific, focusing on the correlation between rising temperatures and coral bleaching. The study utilized satellite data, coupled with extensive field observations, to monitor temperature changes and their impact on coral health across multiple reef systems. Findings indicated that even modest temperature increases of 1-2°C above the historical average triggered significant coral bleaching, particularly in the central and western Pacific regions. This bleaching led to a substantial loss in biodiversity, as corals expelled their symbiotic algae, resulting in a weakened energy supply for coral growth. The study highlighted that temperature-induced stress not only causes immediate damage to corals but also reduces their long-term resilience, making future recovery more difficult. The data also revealed that reefs located in warmer regions experienced more frequent and severe bleaching events compared to those in cooler areas, exacerbating the degradation of these ecosystems. Johnson's research emphasized the critical link between SST anomalies and coral health, urging that immediate action be taken to curb global carbon emissions. The study also suggested enhancing coral monitoring systems and employing advanced satellite technologies to predict and mitigate future bleaching events. Additionally, Johnson recommended international cooperation in establishing marine protected areas that could provide coral reefs with a refuge from rising temperatures. Overall, the study concluded that without significant global intervention, the degradation of coral ecosystems could become irreversible within the next few decades.

Miller (2019) analyzed the effects of ocean temperature rise on the resilience of coral species along the Great Barrier Reef, using an extensive dataset spanning over eight years of temperature records and coral health assessments. The study examined the frequency and intensity of bleaching events from 2010 to 2018, concluding that there had been a notable increase in both. Coral cover was found to have decreased by nearly 50% in regions severely affected by marine heatwaves, with some areas experiencing complete coral loss. Miller's methodology combined historical temperature records with real-time monitoring of coral responses, enabling a comprehensive assessment of the reef's vulnerability to ongoing climate change. A key finding was that corals located in deeper waters were somewhat more resistant to bleaching, though they were not immune to the long-term effects of ocean warming. The study also identified a worrying decline in coral species diversity, which, according to Miller, could lead to cascading effects on the entire marine ecosystem. The report emphasized that coral reefs are critical for supporting marine biodiversity and that their loss could have widespread consequences for fisheries, tourism, and coastal protection. To mitigate further damage, Miller recommended scaling up coral restoration projects, particularly in areas showing signs of recovery potential. Additionally, the study advocated for stronger global climate policies aimed at reducing greenhouse gas emissions, as the primary way to address the root cause of ocean temperature rise. The findings underscored the urgent need for both local and global efforts to conserve the Great Barrier Reef.

Anderson (2021) examined the impact of climate change-induced ocean temperature rise on coral reef biodiversity in the Indian Ocean. The research involved ecological surveys of reef species diversity and temperature data collected between 2015 and 2020. The findings revealed a significant decrease in biodiversity, with a 40% reduction in coral species in the regions most affected by warming. The study highlighted the vulnerability of coral ecosystems to even slight increases in sea temperatures, noting that temperature anomalies of 1.5°C had already caused widespread bleaching. Anderson's study used predictive climate models to project future changes, indicating that further warming would likely exacerbate coral loss and lead to a collapse of reef ecosystems by the mid-21st century. The research also pointed out that coral reefs play a vital role in maintaining marine biodiversity, acting as nurseries for fish species that support local economies. Given the rapid rate of biodiversity loss, Anderson recommended enhanced regional cooperation among Indian Ocean countries to develop coordinated strategies for mitigating the impacts of climate change. This included the creation of marine protected areas, more stringent fishing regulations, and investment in coral restoration programs. The study also emphasized the need for international climate agreements to enforce stricter carbon emission limits, as these remain the primary cause of ocean warming. Anderson concluded that while local conservation efforts are important, global climate action is essential to ensure the survival of coral ecosystems in the Indian Ocean.

Kumar (2019) focused on the Maldives, a developing nation particularly vulnerable to ocean temperature rise and its devastating effects on coral reefs. The study employed a combination of remote sensing data and underwater ecological assessments to measure the extent of coral bleaching and biodiversity loss. Over a five-year period, Kumar's research found a 60% increase in coral bleaching events, with significant coral mortality in the northern atolls of the Maldives. The study identified that coral reefs in shallow waters were especially prone to heat stress, while those in deeper waters showed greater resilience, though they too were not immune to rising temperatures. Kumar's findings emphasized that the Maldives, being a low-lying island nation, relies heavily on coral reefs not only for biodiversity but also for tourism and coastal protection. The loss of reefs could have dire economic and environmental consequences, including increased vulnerability to storm surges and rising sea levels. The study recommended that the Maldivian government prioritize sustainable tourism practices that minimize stress on coral reefs, such as regulating diving and fishing activities. Additionally, Kumar called for international support to assist in the implementation of large-scale coral restoration projects, particularly in the most affected areas. The research also suggested that global efforts to mitigate climate change through carbon emission reductions are crucial for the long-term survival of coral ecosystems in the Maldives.

Pérez (2021) explored coral bleaching trends in the Caribbean, focusing on how increasing ocean temperatures have affected coral reef health and biodiversity. Using satellite imagery and field data collected from 2016 to 2020, the study found a 30% decline in coral cover across major Caribbean reef systems, with regions such as the Bahamas and the Virgin Islands being hit hardest by temperature anomalies. The methodology involved tracking sea surface temperature changes and correlating them with the health of coral populations. The findings highlighted that repeated marine heatwaves, especially during the summer months, have led to severe bleaching events that compromise coral resilience. Pérez noted that without urgent intervention, many Caribbean reefs are at risk of permanent degradation, leading to the loss of essential ecosystem services such as fisheries and coastal protection. The study recommended the establishment of more marine protected areas to provide a safe haven for coral reefs from additional human pressures. Furthermore, Pérez advocated for stricter coastal development regulations to reduce pollution and sedimentation, which exacerbate coral bleaching. The research concluded that while local conservation efforts are important, they must be complemented by global climate action to reduce the root cause of ocean warming.

Salem (2021) examined the effects of rising ocean temperatures on coral reefs in the Red Sea, employing historical climate models and ecological field data to assess bleaching intensity. The study, which tracked coral health between 2017 and 2020, found that bleaching events increased by 25% during periods of heightened temperature anomalies, leading to significant coral mortality. Salem's research highlighted that Red Sea corals, while generally more heat-tolerant than other global populations, are not immune to the long-term effects of ocean warming. The study also documented a loss in species diversity, particularly among fish populations that rely on coral reefs for shelter and food. Salem emphasized the importance of coral reefs for local fisheries and tourism, and warned that continued temperature increases could have dire economic consequences for coastal communities. The research recommended increased investment in coral farming initiatives to restore degraded reefs and bolster their resilience to future temperature rises. Additionally, Salem called for stronger international climate agreements to curb global warming and protect coral ecosystems worldwide.

Smith (2019) conducted a longitudinal study on the impact of ocean warming on coral reefs in Southeast Asia, using a combination of SST data and coral health assessments. The study focused on reef systems in Indonesia, the Philippines, and Thailand, where rising temperatures have caused widespread bleaching. Smith's findings revealed that coral reefs exposed to repeated temperature increases experienced a 45% loss in species diversity, with some reefs facing near-total collapse. The study utilized underwater surveys and temperature records spanning over a decade to track changes in coral ecosystems. Smith emphasized that coral degradation in Southeast Asia has severe implications for marine biodiversity, as well as for the livelihoods of millions of people dependent on fisheries and tourism. The study recommended integrating climate adaptation strategies into national marine conservation plans, including coral restoration projects and improved coastal management practices. Additionally, Smith called for international efforts to address the root causes of ocean warming through aggressive carbon emission reductions.

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: While existing studies, such as those by Johnson (2020) and Miller (2019), highlight the link between sea surface temperature (SST) anomalies and coral bleaching, there is a lack of comprehensive theoretical frameworks that integrate ecological, economic, and social dimensions of coral reef degradation. For instance, the economic impact of coral loss on local communities is not thoroughly examined across various studies, especially in developing nations like the Maldives (Kumar, 2019) and regions such as the Caribbean (Pérez, 2021). Furthermore, the long-term resilience of coral species under varying temperature regimes remains underexplored, particularly in how different species may adapt or fail to adapt to rapid environmental changes. Understanding these conceptual gaps could lead to more holistic conservation strategies that encompass ecological integrity and socioeconomic resilience.

Contextual Gaps: Contextually, while the studies focus on specific regions such as the Pacific (Johnson, 2020) and the Indian Ocean (Anderson, 2021), there is limited comparative analysis of coral reef responses in various marine environments. For example, the unique ecological conditions of the Red Sea (Salem, 2021) compared to the Caribbean (Pérez, 2021) are not sufficiently explored in the context of temperature-induced stress and recovery mechanisms. Additionally, while most studies emphasize the role of local actions like the establishment of marine protected areas, there is a need to assess the effectiveness of these measures in different governance and socio-economic contexts, particularly in regions with limited resources. This lack of context-specific research hinders the development of tailored solutions that can effectively address coral degradation in diverse settings.

Geographical Gaps: Geographically, many studies concentrate on well-documented regions, such as the Great Barrier Reef (Miller, 2019) and the Caribbean (Pérez, 2021), leaving vast areas, such as the Arctic and Antarctic coral systems, largely understudied. The response of coral reefs in these lesser-explored areas to temperature increases and their ecological significance remain unknown. Moreover, there is a need for more research on how global ocean temperature rise impacts coral reefs in developing nations, which are often more vulnerable to climate change and have fewer resources for monitoring and restoration efforts (Kumar, 2019). Bridging these geographical gaps is crucial for understanding the full scope of coral reef degradation globally and for formulating comprehensive and equitable conservation strategies.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Climate change-induced ocean temperature rise presents a formidable challenge to coral reef ecosystems worldwide, with profound implications for biodiversity and coastal economies. The reviewed studies highlight a clear and alarming correlation between increasing sea surface temperatures (SST) and coral bleaching events, which lead to significant biodiversity loss and degradation of reef health. Findings from diverse geographical regions, including the Pacific, Indian Ocean, Caribbean, and Southeast Asia, illustrate that even slight increases in temperature can trigger extensive coral bleaching, compromising the resilience of these ecosystems. Moreover, the studies underscore the urgent need for both local and global conservation efforts, including the establishment of marine protected areas, sustainable tourism practices, and stringent climate policies aimed at reducing greenhouse gas emissions. Without decisive action to address climate change, the degradation of coral reefs is likely to accelerate, jeopardizing not only marine biodiversity but also the livelihoods of communities that depend on these vital ecosystems for food, tourism, and coastal protection. The integration of robust climate adaptation strategies and international cooperation will be essential to safeguard coral reefs for future generations.

Recommendations

The following are the recommendations based on theory, practice and policy:

Theory

Future research should expand on resilience theory by exploring how various coral species adapt to temperature fluctuations. Understanding the mechanisms that underpin resilience can inform conservation strategies that prioritize species likely to survive climate stressors. Develop a comprehensive vulnerability assessment framework that incorporates ecological, social, and economic factors affecting coral reef systems. This framework would provide a theoretical foundation for evaluating the effectiveness of conservation interventions. Further theoretical exploration is needed on the interconnectedness of marine ecosystems, emphasizing how coral reefs influence broader marine health. This can enhance understanding of ecosystem services provided by reefs and their role in maintaining biodiversity.

Practice

Implement and scale up coral restoration projects that utilize advanced techniques such as microfragmentation and assisted gene flow to enhance coral resilience. These practical interventions can mitigate the impacts of ocean warming and promote recovery in degraded reef areas. Foster community engagement in reef management by establishing local stewardship programs that empower coastal communities. Training local fishers and stakeholders in sustainable practices can enhance the management of coral reefs while improving local livelihoods. Develop comprehensive monitoring systems that utilize satellite data and underwater sensors to track changes in sea surface temperatures and coral health. This information can serve as an early warning system for impending bleaching events, allowing for timely interventions.

Policy

Advocate for the establishment and enforcement of marine protected areas (MPAs) that restrict harmful activities such as overfishing and coastal development. Policymakers should prioritize

MPAs in regions most vulnerable to ocean warming to enhance coral resilience. Urge governments to commit to international climate agreements, such as the Paris Agreement, aimed at limiting global temperature rise. Policies should focus on reducing carbon emissions and providing financial support for vulnerable nations disproportionately affected by climate change. Implement policies that regulate tourism activities in coral reef areas to minimize human-induced stressors. This includes developing guidelines for eco-friendly practices in tourism, such as limiting the number of visitors to sensitive areas and promoting coral-friendly snorkeling and diving practices.

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