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The Fourth Global Coral Bleaching Event (2023–2025): Assessing Gaps in Climate Action and Ocean Sustainability

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Abstract- The Fourth Global Coral Bleaching Event (2023–2025) poses a significant threat to ocean sustainability and the climate change agenda, potentially harming ecosystems and coral reef-dependent economic activity. This study examines the extent of coral bleaching worldwide and assess the discrepancy between global sustainability goals and real-world marine conditions. The study use descriptive and comparative methods of analysis based on secondary data gathered from official sources to examine shifts in the global coverage of coral bleaching during significant coral bleaching events.By comparing the actual indicators and the related targets in terms of sustainable development, a quantitative gap analysis is conducted to determine the accomplishments in SDGs 13 (Climate Action) and 14 (Life Below Water). Additionally, the paper discusses the recurrence of bleaching and changes in the state of coral reefs using the Great Barrier Reef in Australia as an example based on monitoring data and images. The findings show that bleaching-level heat stress and continuous reef condition degradation have significantly increased the global coverage.

Keywords- Gap analysis, ocean sustainability, Great Barrier Reef, coral bleaching, climate change, SDGs 13 and 14.

I. Introduction

In terms of biological diversity and importance, coral reefs are regarded as one of the planet's richest ecosystems (NOAA, 2018). For millions of people worldwide, these ecosystems provide marine life with a place to live, fish, and obtain other economic resources (UNEP, 2018). However, despite the fact that coral reefs are crucial from an ecological and economic standpoint, they are confronting many difficulties as a result of global climate change, particularly the rising ocean temperatures (IPCC, 2022). The process of corals losing their algae is known as coral bleaching, and it is one of the most obvious indicators of ocean warming. Corals may die as a result, harming the reef environment (Eakin et al., 2019).

The most recent case of global coral bleaching that has been documented across the world's oceans is known as the Fourth Global Coral Bleaching Event. The National Oceanic and Atmospheric Administration (NOAA) formally designated the event as a worldwide event in 2024 after it began in 2023 (NOAA, 2024). In 1998, 2010, and 2014–2017, three more cases of worldwide coral bleaching were documented (Eakin et al., 2019). The fourth episode of coral bleaching has become especially important for understanding how vulnerable coral reefs are to marine warming due to its unprecedented size and geographic reach (NOAA Coral Reef Watch, 2026). By 2025,

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the Fourth Global Coral Bleaching Event was considered likely to have ended, although its impacts on coral reefs continue to be assessed (NOAA, 2026).

This widespread occurrence shows how the health of coral reefs and climate change are closely related (IPCC, 2022). Long-term thermal stress caused by rising ocean temperatures may result in more frequent and severe bleaching episodes, as well as shorter recovery times for coral reefs following each stress event (Eakin et al., 2019; AIMS, 2025). In this way, the Fourth Global Coral Bleaching Event can be viewed as both a climatic and ecological problem (NOAA Coral Reef Watch, 2026).

Coral bleaching's impacts are far more extensive than only the destruction of corals. For coastal communities, coral reefs are essential for the preservation of biodiversity, fisheries, tourism, coastal protection, and other ecological functions (UNEP, 2018). This implies that habitats and economies that rely on coral reefs may become more vulnerable if coral reefs continue to deteriorate (IPCC, 2022). The Great Barrier Reef in Australia, which has recently experienced multiple mass bleaching events, is an illustration of such a habitat (AIMS, 2025).

Global marine ecosystem conservation and climate change are closely related to the protection of coral reefs. In this context, SDG 13 (Climate Action) and SDG 14 (Life Below Water) are particularly important (United Nations, 2015). We are questioning how much the existing set of goals and pledges is influencing the actual environmental outcomes in light of the ongoing occurrences of coral reef bleaching (UNEP, 2024). One method of determining the areas where progress is absent is to compare targets with reality through a gap analysis (UNEP, 2024).

In light of this, this study uses a gap analysis of ocean sustainability and climate action to examine the Fourth Global Coral Bleaching Event (2023–2025) (NOAA Coral Reef Watch, 2026). The study examines the frequency of coral bleaching episodes worldwide, examines the gaps pertaining to SDGs 13 and 14, and uses the Great Barrier Reef as an example of recurring coral bleaching and shifting coral reef conditions (AIMS, 2025). The study illustrates the continuous difficulty of preserving coral reefs in the face of mounting climate challenges through a synthesis of worldwide data, sustainability objectives, and a pertinent case study (IPCC, 2022).

II. Review of Literature

The Australian Institute of Marine Science (AIMS, 2025) provides recent evidence on the consequences of the Fourth Global Coral Bleaching Event through its long-term monitoring of the Great Barrier Reef. The 2024 bleaching event represented the fifth mass bleaching event on the Great Barrier Reef since 2016 and was associated with unprecedented accumulated heat stress and extensive bleaching. AIMS reported substantial declines in hard coral cover in 2025, with the decline primarily attributed to coral mortality following the 2024 bleaching event. The findings demonstrate that repeated climate-driven disturbances can reverse periods of coral recovery and highlight the vulnerability of reef ecosystems to increasing thermal stress.

Skirving et al. (2019) examined global and regional patterns of coral bleaching-level heat stress between 1985 and 2017. The study found that the proportion of coral reefs

experiencing bleaching-level heat stress increased over time, particularly during the most recent decade. Importantly, the researchers found that the increase was associated largely with longer periods of heat stress. During the 2014–2017 global bleaching event, more than three times as many reefs experienced bleaching-level heat stress compared with the 1998 global event. This study provides evidence of the increasing scale and persistence of thermal stress affecting coral reefs globally.

Hughes et al. (2018) investigated the ecological consequences of extreme heat exposure on coral reefs using the Great Barrier Reef as a major case study. The study found that severe heat exposure resulted in substantial coral mortality and major changes in coral assemblages. In particular, heat stress above critical thresholds caused significant changes in reef structure and ecological functioning. The findings demonstrate that repeated thermal stress can transform coral reef ecosystems rather than simply causing temporary bleaching, highlighting the long-term ecological consequences of climate change.

Eakin, Sweatman and Brainard (2019) reviewed the 2014–2017 global-scale coral bleaching event and described it as one of the most severe, widespread and prolonged bleaching episodes recorded. The study linked the event to successive record-breaking warm years and examined its consequences for coral mortality, reef structure and associated marine communities. The authors also emphasized that the impacts of bleaching extend beyond coral organisms to fish and invertebrate communities and that marine protected areas cannot fully protect reefs from large-scale climate-related heat stress.

Hughes et al. (2017) examined the relationship between rising ocean temperatures and recurrent coral bleaching, with particular focus on the Great Barrier Reef. Using aerial and underwater surveys combined with satellite-derived sea-surface temperature data, the study found that extreme temperatures were the primary driver of the 2016 mass bleaching event. The authors also showed that previous bleaching exposure did not necessarily reduce the severity of subsequent bleaching. The study concluded that local reef protection alone cannot adequately protect coral reefs from extreme marine heat and emphasized the need for immediate global action to reduce climate warming.

Objectives of the Study

1. To examine the global extent of coral bleaching across major global bleaching events.
2. To assess the progress and gaps in achieving SDG 13 (Climate Action) and SDG 14 (Life Below Water) in relation to climate and ocean sustainability.
3. To examine the Great Barrier Reef as a case study of recurrent coral bleaching and changes in coral-reef condition.

III. Research Methodology

The study is based on secondary data, this study uses a descriptive and analytical research design. In addition to pertinent scientific literature, data is gathered from official sources such as NOAA, the United Nations, and the Australian Institute of Marine Science (AIMS).

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It examines the amount of coral bleaching worldwide during the Third and Fourth Global Coral Bleaching Events using descriptive and comparative analysis. For SDGs 13 (Climate Action) and 14 (Life Below Water), a quantitative gap analysis is carried out by contrasting official targets or benchmarks with the most recent observed status.The Great Barrier Reef is examined using a case study methodology, with an emphasis on how the state of the coral reef varies during periodic bleaching. The case study is supported by photographic evidence from North Keppel Island and AIMS data for 2024–2025. Tables, and a visual comparison are used to display the results.

IV. Results and Discussion

Table No.1: Global Coral Bleaching Events: Historical Progression and Extend

Global Coral Bleaching Event	Year/Period	Officially Reported Information
First Global Coral Bleaching Event	1998	Approximately 20% of global reef area experienced bleaching-level heat stress.
Second Global Coral Bleaching Event	2010	Approximately 35% of global reef area experienced bleaching-level heat stress.
Third Global Coral Bleaching Event	2014-2017	68.2% of global reef area experienced bleaching-level heat stress
Fourth Global Coral Bleaching Event	2023-2025	84.4% of global reef area experienced bleaching-level heat stress

Source: National Oceanic and Atmospheric Administration (NOAA), Coral Reef Watch.

The evolution of the four global coral bleaching events that have been identified is shown in this table. 1998 saw the first global coral bleaching event, while 2010 saw the second. Between 2014 and 2017, the Third Global Coral Bleaching Event occurred. However, the Fourth Global Coral Bleaching Event occurred in 2023 and likely concluded in mid-2025. This pattern suggests that coral bleaching is a recurring environmental phenomenon on a worldwide scale (NOAA Coral Reef Watch, 2026)

The Third Global Coral Bleaching Event was already regarded as one of the biggest. 68.2% of the world's coral reef area experienced bleaching-level heat stress between 2014 and 2017. However, the Fourth Event expanded the problem's breadth even further. Approximately 84.4% of the world's coral reef area experienced bleaching-level heat stress between January 2023 and September 2025 (NOAA Coral Reef Watch, 2026).

From 84.4% to 68.2%, the difference between the two events is 16.2 percentage points. This means that, compared to the previous major record-breaking event, a much larger percentage of the world's reef area experienced bleaching-level heat stress during the

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Fourth Event. In comparison, 84.4% is approximately 23.8% greater than 68.2%. Therefore, the most important finding from this comparison is the scale of the Fourth Global Coral Bleaching Event. The Fourth Event, which involved mass bleaching across at least 83 countries and territories throughout the world's coral reef regions, is the largest global coral bleaching event on record, according to NOAA (NOAA Coral Reef Watch, 2026).

Table No.2: Quantitative Gap Assessment of SDG 13 and SDG 14: Targets and Observed Status

Dimension	Official Target / Benchmark	Reference Year / Deadline	Latest Observed Status	Quantified Gap	Assessment of Progress Towards Target
SDG 13 – Climate Action	Limit global warming to 1.5°C above pre-industrial levels	2030 / Long-term	Global temperature reached approximately 1.55°C above pre-industrial levels in 2024; GHG emissions reached 57.7 Gt CO_2e in 2024	No formal numerical gap calculated because 1.5°C is a long-term climate goal, not an annual threshold	Insufficient progress towards the 1.5°C pathway
SDG 14 – Ocean Sustainability	Protect and conserve at least 30% of the world's ocean	2030	10.01% of the ocean was officially protected/conserved in April 2026	19.99 percentage points below the 30% target	Significant ocean-protection gap
Coral Reef Condition	Protect and restore marine ecosystems and strengthen their resilience	2030 / ongoing	84.4% of global coral reef area experienced bleaching-level heat stress during 1 January 2023–30 September 2025	No official numerical threshold for acceptable coral bleaching; therefore, no artificial numerical gap calculated	Severe coral-reef stress

Source: United Nations Sustainable Development Goals Reports and SDG 13 and SDG 14 official indicators.

The disparity between the existing state of the environment and the goals of international agreements on climate change and ocean sustainability is displayed in Table 2. The study makes it evident that there are still significant gaps between international targets and environmental reality, even in spite of progress in some areas. The 1.5°C indicator provides an important basis for assessing the effectiveness of international efforts to combat climate change in relation to SDG 13: Climate Action. According to the World Meteorological Organization (WMO), global average surface temperature in 2024 was 1.55°C above the 1850–1900 pre-industrial average, making

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2024 the first calendar year with a global mean temperature above 1.5°C (WMO, 2025). However, a single year exceeding 1.5°C does not constitute a failure of the Paris Agreement, whose temperature goal is assessed over a longer-term period (WMO, 2025). Furthermore, global greenhouse gas emissions increased by 2.3% to a record 57.7 gigatonnes of CO_2 equivalent in 2024, demonstrating that emissions remain at exceptionally high levels and continue to contribute to climate change (UNEP, 2025).

The aforementioned scenario is highly relevant to the condition of coral reefs since global warming and marine heat stress are major causes of coral bleaching. Therefore, the broader climatic scenario in which the Fourth Global Coral Bleaching Event under study occurs can be viewed as part of the climate gap identified under SDG 13 (Climate Action). According to NOAA Coral Reef Watch, from January 1, 2023, to September 30, 2025, bleaching-level heat stress affected approximately 84.4% of the world's coral reef area, demonstrating the extensive exposure of coral ecosystems to marine heat stress during the Fourth Global Coral Bleaching Event (NOAA Coral Reef Watch, 2026).

The table highlights the lack of marine protection in accordance with SDG 14: Life Below Water. By April 2026, only 10.01% of the world's ocean had been designated as conserved or protected, according to the United Nations. Although this represents progress in ocean conservation, it remains well below the 30% by 2030 target established under the Kunming–Montreal Global Biodiversity Framework, indicating a substantial gap between the existing level of marine protection and the international conservation target (United Nations, 2026).

In this instance, the coral-reef status indicator is closely related to the paper's central idea. The 84.4% figure does not represent an SDG target or an acceptable threshold of thermal stress for corals; rather, it is an empirical indicator of the extent of bleaching-level heat stress experienced by coral reefs during the Fourth Global Coral Bleaching Event (NOAA Coral Reef Watch, 2026). Because there is no internationally established numerical threshold specifying the proportion of coral reefs that can safely experience such heat stress, a precise numerical “gap” cannot be calculated for this indicator. However, the very high level of exposure indicates substantial climate-related stress on coral reef ecosystems (NOAA Coral Reef Watch, 2026).

Case Study: Recurrent Coral Bleaching and Changes in Coral-Reef Condition in the Great Barrier Reef

Coral Bleaching and Ecosystem Degradation and Its Impact on Economic Development

Australia's northeastern coast is home to the Great Barrier Reef (GBR), one of the world's most significant coral-reef ecosystems and an important natural asset for Australia's economy. The Reef supports tourism, fishing and recreational activities, with marine tourism in the Great Barrier Reef Marine Park supporting more than 60,000 jobs (Great Barrier Reef Marine Park Authority, n.d.). During the Fourth Global Coral Bleaching Event in 2024, the GBR experienced its fifth mass coral bleaching event since 2016.

During the 2023–2024 summer, elevated sea temperatures caused extensive heat stress across the Reef, and AIMS documented widespread coral bleaching through aerial and in-water surveys. AIMS reported that the 2024 event had the largest spatial footprint of

coral bleaching ever recorded on the Great Barrier Reef, with high to extreme bleaching prevalence observed across all three regions (AIMS, 2025).

Visual data from the Australian Institute of Marine Science (AIMS) can be particularly useful for North Keppel Island, as photographic evidence provides a clear visual comparison of reef condition before and during the 2024 bleaching event. Images of the same reef site in May 2023, before bleaching, and March 2024, during the bleaching event, demonstrate visible changes in coral condition associated with bleaching-level heat stress (AIMS, 2025). These images provide direct visual evidence of how coral reefs can change following exposure to prolonged marine heat stress and complement the quantitative monitoring data used in this study (AIMS, 2025).

Figure 3. Visual Comparison of Coral-Reef Condition Before and During the 2024 Mass Bleaching Event at North Keppel Island, Great Barrier Reef

(a) May 2023 – Before bleaching

(b) March 2024 – During bleaching

Source:Schaffelke et al. (2024), Australian Institute of Marine Science (AIMS); images: AIMS EcoRRAP.

The above Imagesshow a high level of bleaching of corals as compared to their state in May 2023. The pictures provide visual confirmation of how climate-related heat stress results in physical changes in coral reef communities.

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Case study Evidence from Reef Monitoring

The visual change was accompanied by measurable deterioration in coral cover. The Australian Institute of Marine Science (AIMS) surveyed 124 reefs between August 2024 and May 2025 following the 2024 bleaching event. Hard coral cover declined across all three regions of the Great Barrier Reef.

Region	2024 Coral Cover (%)	2025 Coral Cover (%)	Change (Percentage Points)
Northern GBR	39.8	30.0	−9.8
Central GBR	33.2	28.6	−4.6
Southern GBR	38.9	26.9	−12.0

Source: Australian Institute of Marine Science (AIMS), Annual Summary Report of Great Barrier Reef Condition 2024/25.

The Great Barrier Reef case study demonstrates that recurrent coral bleaching is associated with measurable deterioration in coral-reef condition. The photographic evidence shows visible changes in reef condition, while the Australian Institute of Marine Science (AIMS) monitoring data demonstrate declines in hard coral cover across all three regions of the Great Barrier Reef following the 2024 bleaching event. These findings provide a real-world example of the environmental pressures associated with climate change and support the broader SDG 13 (Climate Action) and SDG 14 (Life Below Water) gap analysis conducted in this study (AIMS, 2025).

Findings

The analysis of the four global coral bleaching events shows that coral bleaching has become a recurring environmental phenomenon with an increasing geographic scale. The First Global Coral Bleaching Event occurred in 1998, followed by the Second Event in 2010, the Third Event during 2014–2017, and the Fourth Event during 2023–2025 (NOAA Coral Reef Watch, 2026). A major finding is the substantial increase in bleaching-level heat stress between the Third and Fourth Events. During 2014–2017, approximately 68.2% of the world's coral reef area experienced bleaching-level heat stress, compared with 84.4% between January 2023 and September 2025 (NOAA Coral Reef Watch, 2026).

This represents an increase of 16.2 percentage points, with the Fourth Event affecting approximately 23.8% more reef area relative to the Third Event. The findings therefore indicate an expansion in the geographic extent of bleaching-level heat stress and increasing exposure of coral reef ecosystems to extreme marine heat. The Fourth Event was also associated with mass coral bleaching documented in at least 83 countries and territories, making it the largest global coral bleaching event recorded to date (NOAA, 2026). These findings highlight the growing challenge of achieving the objectives of SDG 13 (Climate Action) and SDG 14 (Life Below Water).

The findings from table2 shows a growing disparity between international climate and ocean sustainability commitments and the observed condition of marine ecosystems. Despite increasing conservation efforts, only about 10% of the global ocean is currently designated as protected or conserved, compared with the 30% conservation target for 2030, indicating a substantial gap in ocean protection (United Nations, 2026). At the

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same time, global greenhouse gas emissions continue to rise, reaching a record 57.7 gigatonnes of CO_2 equivalent in 2024, an increase of 2.3% from the previous year (UNEP, 2025). This continuing increase in emissions is consistent with the growing exposure of coral reefs to climate-related thermal stress, with 84.4% of the world's coral reef area experiencing bleaching-level heat stress during the Fourth Global Coral Bleaching Event (NOAA Coral Reef Watch, 2026).

The Great Barrier Reef case study further demonstrates how these global pressures are reflected at the ecosystem level. Overall, the findings provide quantitative evidence of a gap between sustainability commitments and environmental outcomes, highlighting the continuing challenges in achieving the objectives of SDG 13 (Climate Action) and SDG 14 (Life Below Water).

The Great Barrier Reef case study demonstrates a measurable deterioration in reef condition following the 2024 mass coral bleaching event. According to the Australian Institute of Marine Science (AIMS, 2025), hard coral cover declined across all three regions between 2024 and 2025. In the Northern GBR, coral cover decreased from 39.8% to 30.0%, a decline of 9.8 percentage points; in the Central GBR, it decreased from 33.2% to 28.6%, a decline of 4.6 percentage points; and in the Southern GBR, it declined from 38.9% to 26.9%, representing the largest decrease of 12.0 percentage points.

In relative terms, these correspond to declines of approximately 24.8%, 13.9%, and 30.6%, respectively. AIMS identified the 2024 mass coral bleaching event as the primary source of coral mortality, although cyclones, freshwater inundation and crown-of-thorns starfish also contributed to the decline. These findings provide quantitative evidence of deterioration in coral-reef condition and demonstrate the ecological consequences of repeated climate-related heat stress, supporting the broader SDG 13 (Climate Action) and SDG 14 (Life Below Water) gap analysis. (AIMS, 2025).

Suggestions of the Study

1. Reduce greenhouse gas emissions to limit ocean warming and climate-related heat stress on coral reefs (AIMS, 2025).
2. Strengthen management of local and regional pressures, including pollution, sediment and nutrient runoff, to improve reef resilience and recovery (AIMS, 2025; DCCEEW, 2024).
3. Improve water quality by reducing land-based runoff and pollutants entering reef ecosystems, as good water quality supports coral-reef resilience (AIMS, 2025).
4. Strengthen marine conservation and protected areas to support biodiversity protection and progress toward the 2030 ocean-conservation target (United Nations, 2026).
5. Continue long-term monitoring of coral reefs to track bleaching, coral mortality, coral-cover changes and other pressures affecting reef condition (AIMS, 2025).
6. Support research on reef adaptation, recovery and resilience to help coral ecosystems respond to climate change and repeated bleaching events (AIMS, 2025).

V. Conclusion

The Fourth Global Coral Bleaching Event (2023–2025) is a barrier to tackling climate change and ocean sustainability issues, according to the study's findings. By comparing the Fourth and Third Global Coral Bleaching Events, it is possible to see the expansion of the global bleaching-level heat stress and, consequently, the increased strain on coral reef environments. Furthermore, the gap analysis of SDGs 13 and 14 shows that there are still some discrepancies between environmental realities and global sustainability targets.

At the regional level, the Great Barrier Reef case study results corroborate the aforementioned conclusions. In particular, between 2024 and 2025, the Northern, Central, and Southern regions' hard coral cover decreased and the reef ecology deteriorated, as demonstrated by photographic evidence and AIMS monitoring data. Consequently, the study shows that recurrent coral bleaching is not only an ecological concern but also a significant indicator of issues related to addressing climate change and sustainable usage of marine ecosystems.

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