

Climate Change, Coral Bleaching, and Hurricanes: Insights from Antigua & Barbuda's 2023/2024 Coral Reef Crisis

Cambio Climático, Blanqueo de Corales y Huracanes: Perspectivas desde la Crisis de Arrecifes de Coral en Antigua y Barbuda, 2023/2024

Changement Climatique, Blanchissement des Coraux et Ouragans : Aperçus de la Crise des Récifs Coralliens à Antigua-et-Barbuda, 2023/2024

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EXTENDED ABSTRACT

INTRODUCTION

Coral reef ecosystems worldwide are increasingly threatened by human-induced climate change, which has been identified as one of the top five drivers of biodiversity loss by the Inter-Governmental Science Policy Panel on Biodiversity and Ecosystem Services (IPBES). Specifically, the rising frequency and intensity of tropical cyclones and elevated sea temperatures directly threaten the survival of coral reef ecosystem and the entire marine biosphere. In 2023, elevated sub-sea temperatures were directly linked to the largest Caribbean bleaching event in recorded history, with some territories recording over 90% loss of live coral tissue in coral nursery systems. The year 2024 has provided no respite, with daily average sub-sea temperatures exceeding what was observed in 2023. Extreme cyclonic events, such as Hurricane Irma (Category 5+++) in 2017, cause extensive physical degradation of marine ecosystems, while the excessive CO₂ in the atmosphere traps heat and leads to rises in land and sea temperatures. Despite the largescale negative impacts of excessive cyclonic activity due to Climate Change, they can also have positive impacts as they draw energy away from the marine system, resulting in a reduction in heat stress which can provide benefits to coral reefs and other marine ecosystems.

The Nelson Dockyard National Park (NDNP), established and designated in Antigua and Barbuda in 1984 under the National Park Authority (NPA) Act of 1984, designates a multi-use Ridge-to-Reef area on the southern portion of Antigua that encompasses 45% marine space. It is designated under the International Union for Conservation of Nature (IUCN) management as a Category VI designation, emphasizing sustainable resource use. It stands as one of the few self-financed environmental management institutions within the Caribbean region. Initiated in 2021, the NDNP's coral restoration program aims to rehabilitate coral ecosystems, enhance coastal resilience, and address climate change impacts. Observations of rapid tissue loss (RTL) and coral bleaching in 2023 and 2024 underscore the urgency of these efforts, with a survival rate as low as 7% during the largest recorded Caribbean bleaching event in 2023.

METHODOLOGIES

Since June 2022, HOBO temperature loggers have been deployed at approximately 25 feet depth in the coral nursery at NDNP, where they are set to record temperatures every 10 minutes. Multiple temperatures have been deployed throughout the nursery to reduce variance and possible device error, with a minimum of two loggers in operation at any one point. Data is inputted into R and plotted as daily averages to track fluctuations over time. Coral restoration efforts focus on *Acropora* species, known for their ecological significance and rapid growth, as well as to facilitate a low maintenance program given capacity restrictions. Parent colonies were GPS located, and assumed genetically diverse corals were separated using coral trees for each genotype. Coral nursery observations were based on weekly visits, photos and yearly counts. Storm activity information on "named" tropical weather events was collected from the Antigua and Barbuda Metrological Office. Data collection correlates temperature fluctuations with observed Rapid Tissue Loss (RTL), coral bleaching events and storm activity. Observations of Rapid Tissue Loss and Coral Bleaching in 2023, paired with these data, offer valuable insights into sub-sea surface temperature fluctuations and their influence on biological events in the coral reef ecosystem.

RESULTS AND DISCUSSION

Data from the coral nursery reveal a strong correlation between elevated sea temperatures, RTL, bleaching severity, and storm activity. During the 2023 bleaching event, sea temperatures spiked significantly, leading to widespread coral mortality. Storms, traditionally perceived as destructive, showed potential benefits in 2023 by temporarily mitigating thermal stress and reducing bleaching severity. In 2024, temperatures spiked once more, resulting in widespread mortality. However, a lack of storm activity led to temperature levels remaining isolated for an extended period, unlike the earlier reduction observed in 2023.

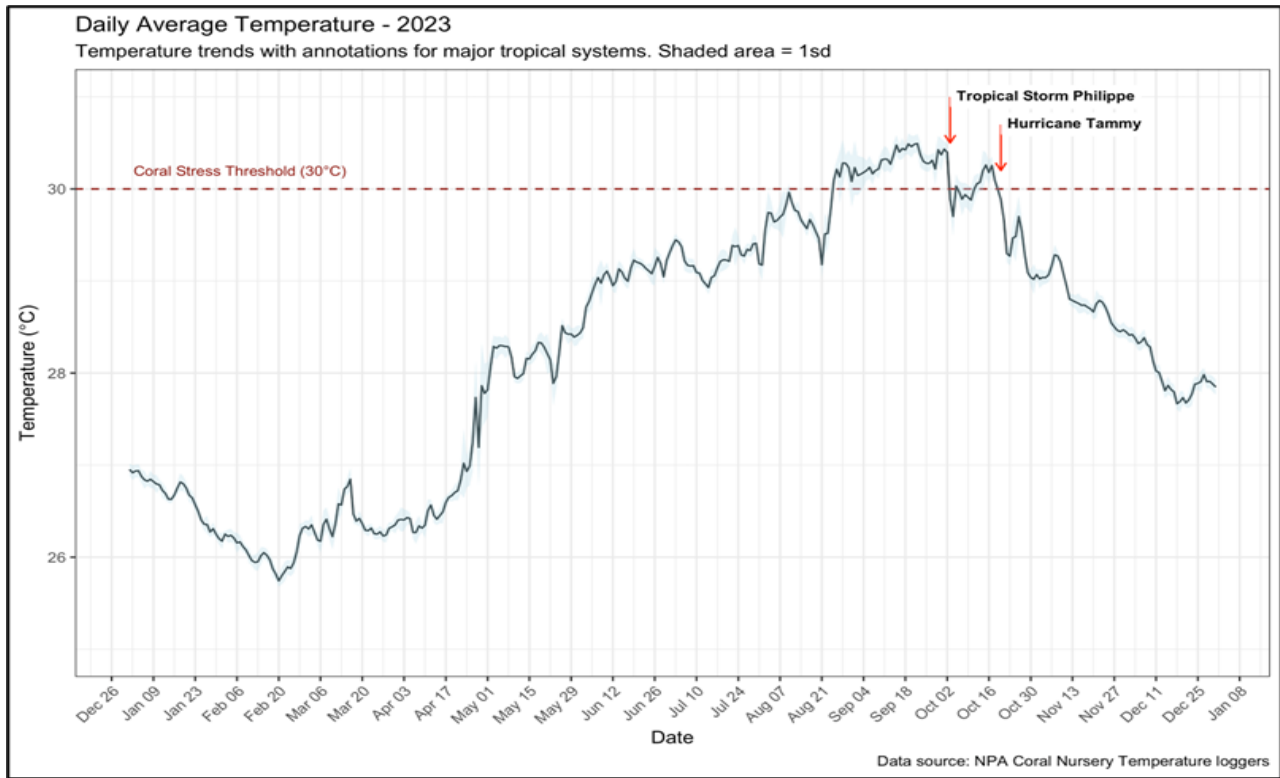


Figure 1. Daily average temperature trends with indicative storm activity at the NPA Coral Nursery in 2023.

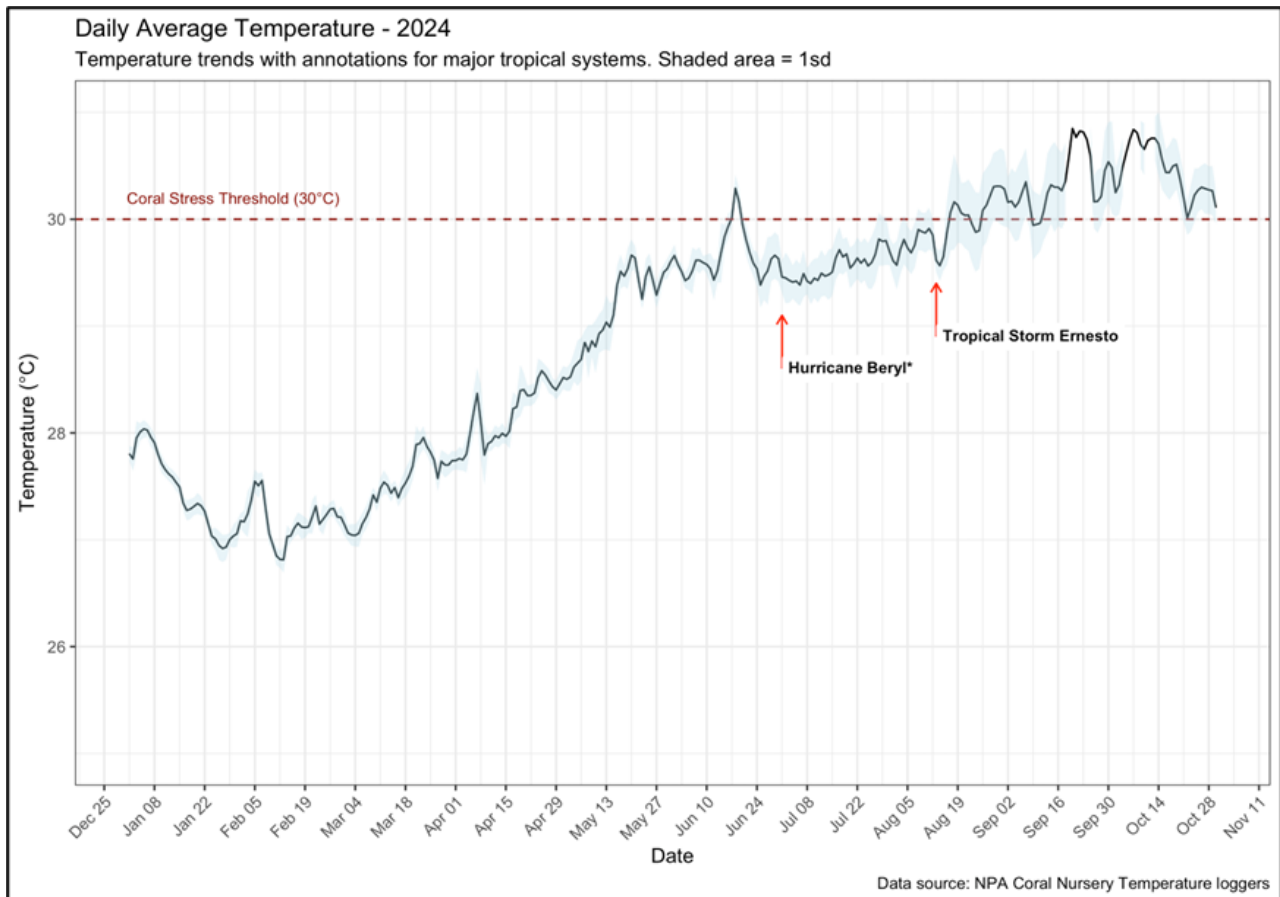


Figure 2. Daily average temperature trends with indicative storm activity at the NPA Coral Nursery in 2024.

Notable findings include:

- A consistent rise in sea temperatures from 2022 to 2024, surpassing thresholds critical for coral survival.
- Rapid tissue loss observed prior to bleaching is potentially linked to prolonged heat stress.
- Observed relief in heat stress on coral provided by storm activity.

While storms provided some relief by cooling sea temperatures, their frequency and intensity pose other risks to coral health, reef structure, and overall ecosystem services. The interplay between warming oceans, storm dynamics and coral ecosystem responses remains a critical area for further investigation. Additional fluctuations in sea-temperature data could also be influenced by “non-named” tropical systems, and these are being investigated further.

CONCLUSIONS AND RECOMMENDATIONS

The ongoing coral restoration efforts within NDNP underscore the need for adaptive management strategies to address the dual threats of climate change and extreme weather events. Key recommendations include:

1. Expanding monitoring networks to capture more granular temperature data across different reef zones.
2. Prioritizing resilient coral genotypes for outplanting.
3. Enhancing regional collaboration to share findings and refine restoration techniques.

As the Caribbean grapples with a warming ocean and the increasing frequency of hurricanes, integrated approaches that leverage both ecological and socio-economic factors are essential to safeguarding coral reef ecosystems.

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KEYWORDS: Coral bleaching, sea temperature, hurricanes, coral restoration, climate change