Guest Editorial

2024 MASS CORAL BLEACHING: TIPPING POINT FOR TOBAGO'S REEFS?

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The world is currently reeling from the fourth global coral bleaching event on record, declared by the National Oceanic and Atmospheric Administration (NOAA) in April 2024 (NOAA, 2024). For the Caribbean, this means two consecutive years of severe heat stress: mass bleaching experienced in the Northern Caribbean in 2023, and the Southern Caribbean in 2024. We are in the midst of a coral crisis with Tobago reefs experiencing record levels of heat stress. I will recap how we got here, what it means for us, and highlight imperatives that may help curb the worst for our future.

History of mass coral bleaching in Trinidad & Tobago

Coral reefs of Tobago experience warm 'summertime' temperatures typically between the months of July and November, and during this time, many coral species carry out sexual reproduction. However marine heat waves may expose corals to unseasonably warm temperatures or an extended period of exposure to warmer temperatures that results in heat stress. The thermal tolerance threshold for corals (1°C above the highest summertime mean temperature) in Tobago is 29.4˚C and once water temperatures exceed this threshold corals begin to accumulate heat stress, which can result in bleaching (NOAA, Coral Reef Watch, 2024). Degree Heating Weeks (DHW) is a measure of the accumulated heat stress over 12 weeks, and bleaching is typical above 8 DHW.

Overall, the wider Caribbean Region has suffered from eight mass bleaching events (1998, 2005, 2010, 2011, 2015, 2017, 2023, 2024) over the past 30 years. In the preceding decades, coral bleaching was recorded on localised scales, once every 25 to 30 years (Hughes *et al.* 2018). During these marine heat waves, heat stress is not evenly distributed across the Caribbean and hotspots have varied geographically throughout the years. The Eastern and Southern Caribbean regions have a history of exposure to greater heat stress compared to the Western, Northern and Southwestern areas of the Caribbean (Muñiz-Castillo *et al.* 2019). As a result, Tobago is one of the islands that has higher bleaching and mortality risk compared to the rest of the Caribbean.

While the 1998 bleaching event mostly impacted the Western Caribbean and The Bahamas, the Global Coral Reef Monitoring Network (GCRMN) reported that Buccoo Reef (Eastern Reef monitoring site) showed no impacts of bleaching to its coral cover (1996: 29%, 2000: 31%) (Hoetjes *et al.* 2002). However, the impacts to other reefs around the island remained unknown.

The 2005 marine heat wave, resulting in the most extensive bleaching in the region (until now), impacted 42% of Caribbean reefs, including Tobago (Muñiz-Castillo *et al.* 2019). Bleaching assessments conducted by Buccoo Reef Trust, found that an average of 66% of corals were bleached across Tobago, with sites along the Caribbean coast showing up to 85% bleaching (O'Farrell and Day 2006). Meanwhile, sites in Speyside showed relatively low bleaching. At that time, Buccoo Reef Trust recommended that Speyside's reefs be designated a marine protected area given their presumed resilience to heat stress. While bleaching was extensive, the coral mortality (of surveyed sites) was low at ~ 18%, where the most impacted were brain corals (73% of the mortality), and 32% of the bleached corals suffered partial mortality (O'Farrell and Day 2006). In the aftermath of the 2005 bleaching event, coral diseases became more prevalent on Tobago's reefs and coral recruitment was significantly reduced (Mallela and Parkinson 2008; Mallela and Crabbe 2009).

While the 2010 bleaching event was less widespread throughout the Caribbean region compared to 2005, the heat stress experienced in Tobago was more severe and resulted in greater mortality. In 2010, the Institute of Marine Affairs (IMA) conducted its first assessment of coral bleaching across three major reef systems – Buccoo, Culloden and Speyside. In contrast to the 2005 bleaching event, Speyside reefs suffered the highest bleaching and mortality. The 2010 bleaching event accounted for the largest mortality event recorded in Tobago with an estimated loss of ~ 38% coral cover (Alemu I and Clement 2014). IMA's long-term monitoring estimates an average of ~ 50% decline in coral cover across all monitoring sites in the aftermath of this bleaching event (average coral cover in 2010: 29.8%, 2011: 15.2%, 2020: 14.5%) with no significant recovery observed at monitored sites to date (Ganase 2020, Ganase and Lochan 2023 Fig. 1).

Most mass bleaching events were strongly driven by the ENSO (El Niño Southern Oscillation) that resulted in warmer, drier conditions in 1997 - 1998, 2009 – 2010, 2014 – 2016, 2023 -2024, with the exception of 2005 (Eakin *et al.* 2010). Over the last five years, Tobago's reefs have experienced low-level bleaching during the warmer months of the year, even under La Niña conditions (cooler, wetter conditions) from 2020 to 2022, as reported by marine-users and by the IMA through its reef monitoring programme. With impacts from climate change, La Niña events are now warmer than ENSO events occurring 30 years ago (Hughes *et al.* 2018). Trinidad & Tobago and the rest of the world were bracing for the worst as we entered ENSO conditions in 2023.

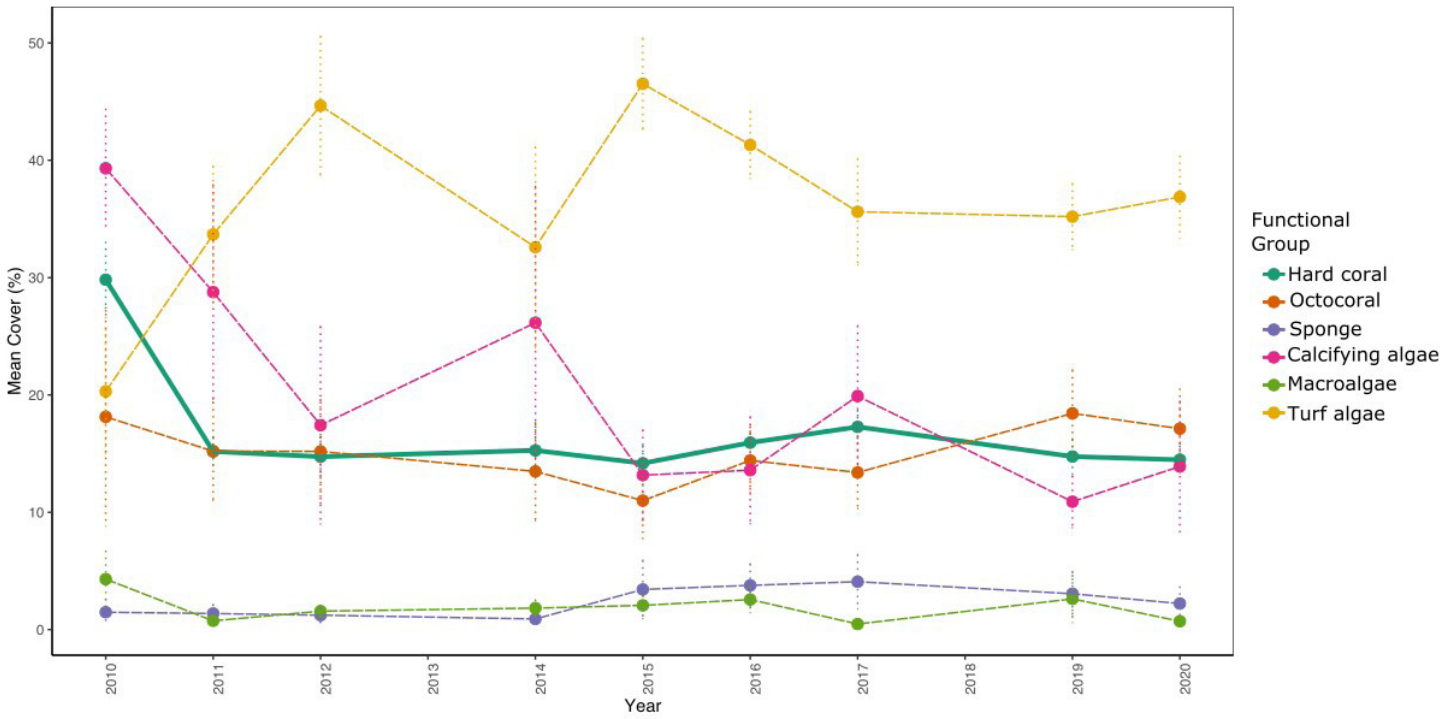

Fig.1. Long-term average change in coral reef benthic compositions from 2010 to 2020 for IMA monitoring sites around Tobago.

The 2023 and 2024 mass coral bleaching event

Summer temperature profiles for Trinidad & Tobago in 2023 revealed 19 Degree Heating Weeks between August and November 2023 (NOAA Coral Reef Watch, 2023). There were several reports of bleaching around Tobago, and a bleaching assessment in November showed between 20% and 60% partial and full bleaching at five sites, with Charlotteville and Mt Irvine faring the worst (Lochan and Ganase, 2024). The most impacted species were the grooved brain, massive starlet, great star and the mountainous star corals, which had over 70% of their colonies bleached at one or more sites.

Critically endangered species, such as the elkhorn corals at Mt Irvine, fared better with 98% of the colonies observed not affected (Lochan and Ganase, 2024). Even though there was some mortality of the massive starlets and the grooved brain corals, we also observed some partial recovery of other species by March 2024. However, by April 2024, NOAA officially declared the fourth global coral bleaching event given extensive bleaching occurring in Australia, north and western Caribbean and the Indo-Pacific with a possible continuation of more marine heat waves during the summer of 2024.

Trinidad & Tobago was placed under Bleaching Alert Level 2 (risk of reef-wide bleaching with mortality of heat-sensitive corals) by August and was then upgraded to Bleaching Alert Level 5 (the highest risk level with a risk of near complete mortality of more than 80 % of corals) by October 2024 with records of sea surface temperatures around 30°C, and as high as 33°C at specific sites (Ganase, pers. obs.). From September to November, IMA received several reports from marine resource users, namely boating and diving tour operators, of coral bleaching across many reef sites and on many species. In November 2024, the IMA conducted a rapid reef assessment at eight sites in southwest and northeast Tobago, with impacts of bleaching being observed at all sites, as well as observations of extensive coral bleaching beyond survey areas (Plate 1). Thermal stress impacted all sites with > 50% of corals displaying impact from heat stress in the form of bleaching, paling and recent mortality at seven out of eight sites (Fig. 2). The most impacted site was the Buccoo Reef Marine Protected Area (MPA) with 78.6% of its corals affected by bleaching (Plate 1B). The corals most severely impacted are the large (> 1m in diameter) colonies of dominant reef-builder species that are critical habitat providers on Tobago's reefs. These species include the mountainous star and boulder brain corals; these large colonies are slow growing and possibly hundreds of years old. Many of these colonies were fully bleached. Mountainous star corals, which contribute more than 50% of hard coral cover to Tobago's forereefs, showed 100% impact from heat stress at Melville Drift and Angel Reef (Plate 1 A&D), and > 75% impact at Castara, Culloden, Buccoo and Booby Island (Fig. 3). Other severely impacted species include the great star coral (> 95% impacted at six sites) and lettuce corals (> 90% impacted at all sites) (Fig. 3).

In 2024, the IMA monitored elkhorn and staghorn patches at Mt Irvine and within the Buccoo Reef Marine Park for bleaching and mortality. At Mt Irvine, partial bleaching was observed in over 500 colonies, with some colonies already

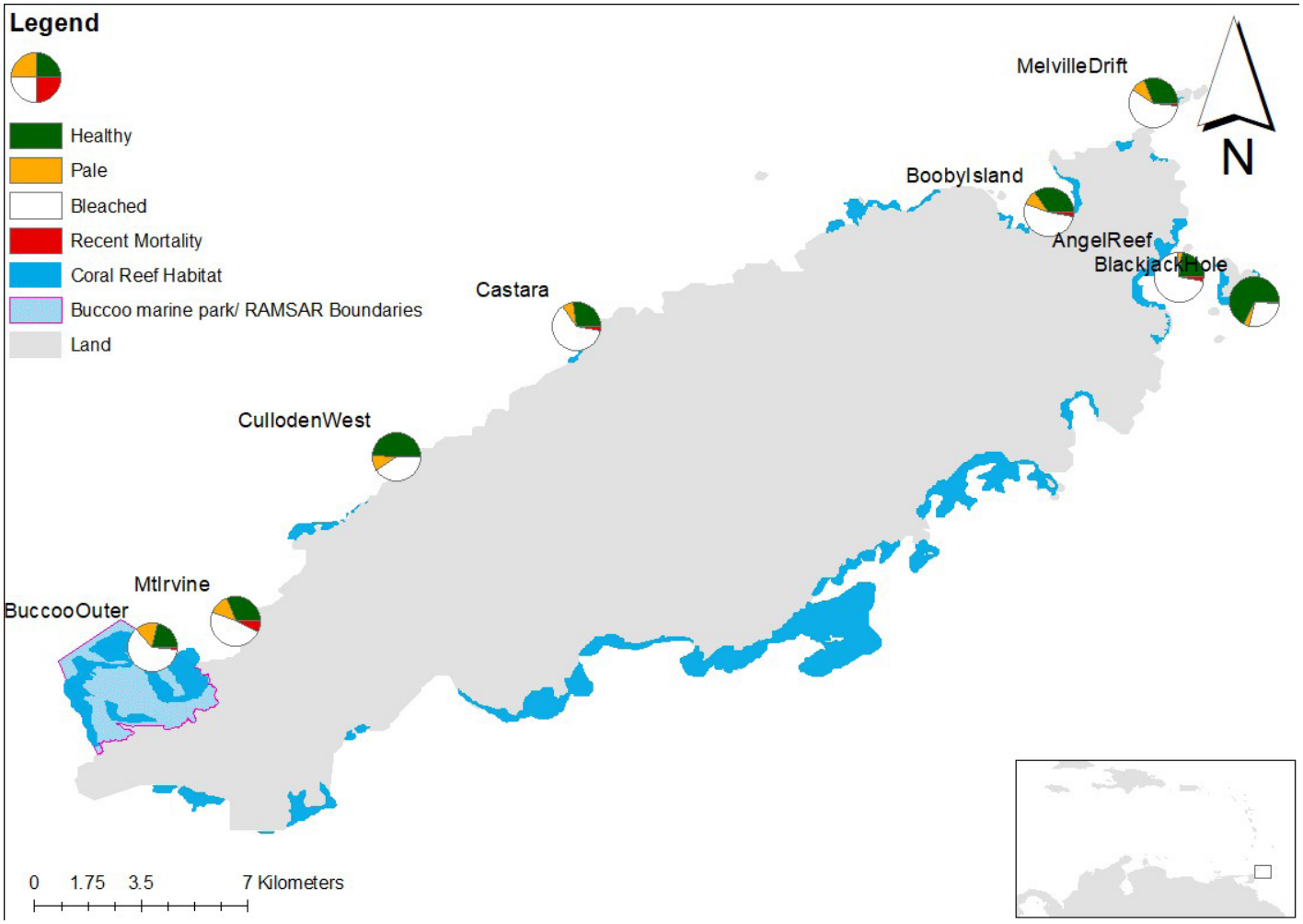

Fig. 2. Coral bleaching assessment showing the percentage bleaching impacts of eight survey sites around Tobago in November 2024

suffering from partial mortality. Within the outer lagoon of Buccoo, there was 100% mortality of a large staghorn patch, likely to result in extinction at that site. As the only sizeable patch in Tobago, there are concerns about wider local extinction (Plate 1 C). There was also 100% mortality of a large elkhorn patch in the eastern side of the Buccoo back reef area. Despite faring well in 2023, these corals have now succumbed to the heat stress.

Of concern is the impact on the recovery potential of the corals that have experienced repeated heat stress and were not fully recovered from the 2023 bleaching along with the severity of the 2024 marine heat wave with over 25-degree heating weeks (NOAA 2024). The heat stress experienced by coral reefs in Tobago and the wider Caribbean is unprecedented and we continue to monitor for disease outbreaks and die off in the aftermath.

Implications for Tobago's coral reefs

According to the IPCC Special Report (1.5°C) on the impacts of global warming, a rise in global temperature of 1.5°C above pre-industrial levels will result in 70-90% decline of coral populations, while a 2°C rise in temperature will result in 99% decline (IPCC 2018). Given the current trajectory of carbon emissions, it is expected that the 1.5°C will be exceeded as early as 2027 (estimated range 2027-2040) (WMO 2024). Globally, the average projected onset of annual severe bleaching (ASB) events is expected to be 2045 for middle of the road emissions scenarios (SSP2-4.5) which are closest to our current trajectory. For these scenarios, a 3.8-4.2°C rise is certain by the end of the century (IPCC, CMIP6 Models; van Hooidonk 2020). The onset of annual severe bleaching for the high emissions scenario (SSP 5-8.5) is 2034 (van Hooidonk 2020).

Under the high emissions scenario for Trinidad & Tobago, it is projected that 80% of our coral reefs are expected to experience ASB by 2025 with the remaining 20% likely to experience ASB between 2030 and 2034 (van Hooidonk 2020). However, for middle of the road scenarios, the delay in onset is still less than 10 years for most reefs (van Hooidonk 2020). If emissions are not curtailed, coral reef management and restoration will not be effective.

Possible interventions

The future of coral reefs around the world and here in

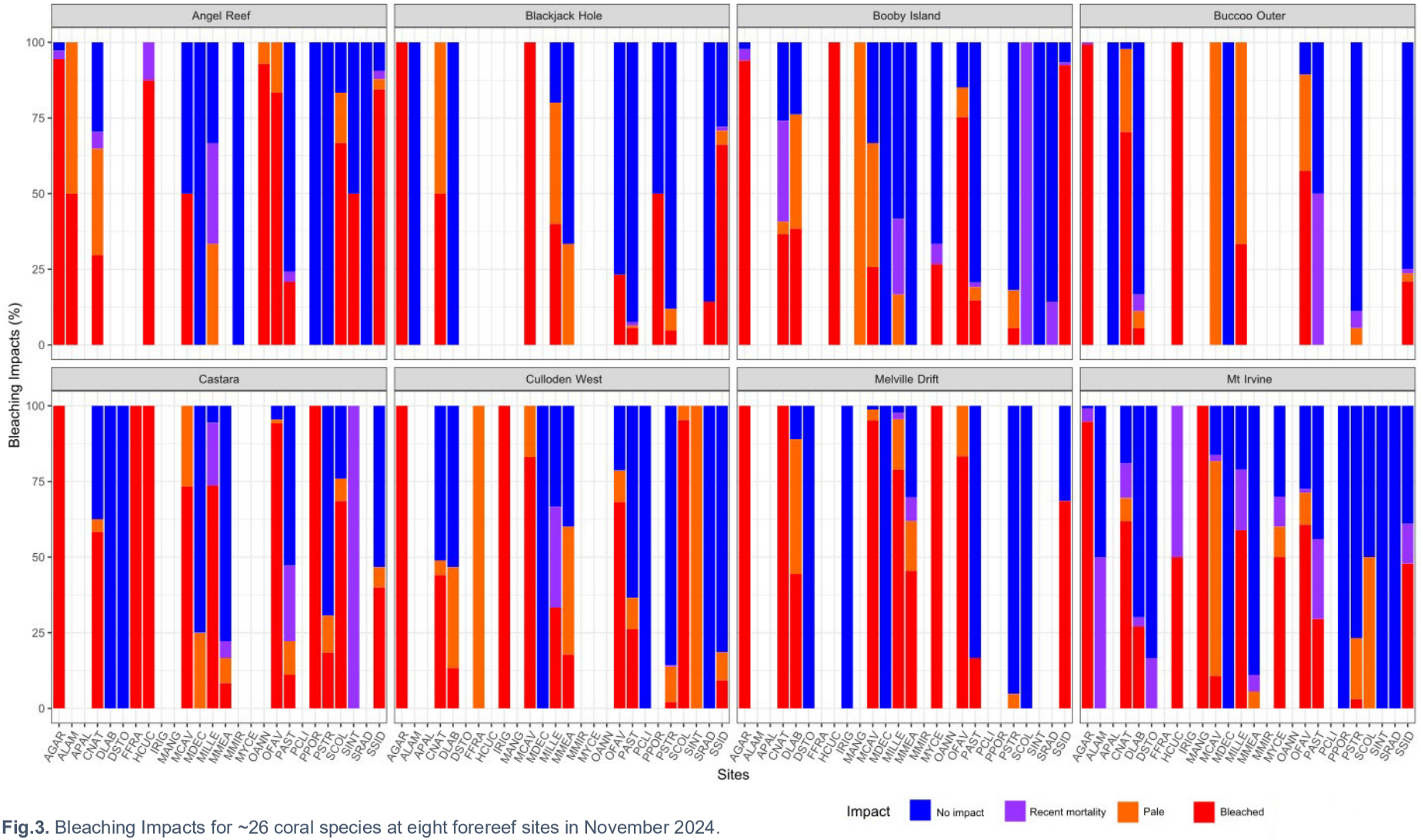

Fig.3. Bleaching Impacts for ~26 coral species at eight forereef sites in November 2024.

Species list: AGAR- *Agaricia spp.; ALAM – Agaricia lamarcki, APAL – Acropora palmata, CNAT – Colpophyllia natans, DLAB – Diploria labyrinthiformis, DSTO – Dichocoenia stokesii, FFRA – Favia fragum, HCUC – Helioseris cucullata, IRIG – Isophyllia rigida, MANG – Mussa angulosa, MCAV – Montastraea cavernosa, MDEC – Madracis decactis, MILLE – Millepora sp., MMIR – Madracis mirabilis (now called M. auretenra), MYCE- Mycetophyllia spp., OANN – Orbicella annularis, OFAV – Orbicella faveolata, PAST – Porites astreoides, PCLI – Pseudodiploria clivosa, PPOR – Porites porites, PSTR – Pseudodiploria strigosa, SCOL – Scolymia spp., SINT – Stephanocoenia intersepta, SRAD – Siderastrea radians, SSID – Siderastrea siderea.*

T&T is bleak. We are likely to suffer significant loss and perhaps local extinction of critical species. Coral reefs are vital to Tobago's fisheries and tourism, as well as provide coastal protection, especially in south-west Tobago. According to Burke *et al.* (2008), the annual value of our coral reefs is estimated between $120 - $164 million USD (2006 estimate). This value is based on fisheries and reef-related tourism products, as well as coastal protection for Tobago. Unfortunately, severe mass bleaching events are expected to reduce the economic value of coral reefs by 50% (Cesar *et al.* 2003). Added to this are the costs to repair coastal erosion and saltwater intrusion from storm surge and sea-level rise as coral reefs degrade and erode.

Recommended interventions include large-scale marine protected areas, coral breeding and restoration programmes, and cryopreservation of coral larvae for posterity. Most of these are already underway in Mexico, Florida, Puerto Rico, and Curaçao. Many Caribbean Islands have also set up land-based facilities to serve as coral sanctuaries and stations for scientific breeding to build thermal tolerance and genetic resilience. Marine spatial models are constructed to identify priority coral reef sites that are most likely to survive climate change with the efforts of management and restoration. Given the importance of tourism and fisheries to many islands, governments are implementing active management of all ocean activities and working to protect marine areas (encouraged by the global effort to protect 30% of the Earth's land and ocean by 2030), while developing coral restoration technologies and sustainable mariculture for food security.

The Institute of Marine Affairs (IMA), through the Marine Resilience Initiative (MARIN) Tobago seeks to build ocean resilience against climate change. The project has three main components (1) implementing strategies of adaptive management and a Marine Resilience Network (MRN) for sustainable ocean resilience, (2) the restoration of sensitive marine ecosystems, coral reefs and seagrasses, that considers population genetics, and (3) building ocean stewardship. The IMA has partnered with SECORE International (secore.org) in conducting coral restoration using larval propagation strategies in Tobago, which started in July 2024. Most bleaching reports by stakeholders were submitted through the Marine Resilience Network, where the IMA regularly communicates on project updates and shares guidelines on responsible use.

Immediate action for coral recovery

Urgent management is necessary to facilitate coral recovery in the aftermath of mass bleaching. Most important is coral disease management as all corals (bleached and non-bleached) are more susceptible to diseases as heat stress severely compromises their immunity. While 8% of Tobago's corals chronically suffer from coral diseases (Ganase and Lochan 2023), Trinidad & Tobago is on the alert for the arrival of the highly virulent and transmissible Stony Coral Tissue Loss Disease (SCTLD), which has decimated coral reefs throughout the Caribbean region. The disease results in rapid tissue loss and death within a few months. Currently, Grenada is the closest island to Tobago where SCTLD is present. Recommended management actions include: avoiding diving, fishing or hunting on severely bleached reefs or reefs with signs of disease. If diving is essential, disinfection of gear between dive sites is recommended.

The second concern is the risk of algal blooms when reefs suffer from high coral mortality. While corals, as reef builders, create new reef structures for other marine life to utilise, under scenarios of high coral mortality, the remaining coral skeletons can quickly become overgrown by algae. High nutrient pollution, grey water outflow from drains, wastewater discharge and fertiliser run off, all encourage opportunistic algal blooms following a mass bleaching event. In the absence of a healthy herbivore population to graze the algae and keep the reef surfaces clean, algal blooms can prevent coral recruitment by smothering and overgrowing juvenile corals. As corals only reproduce once a year between June and October, it is necessary to manage algal blooms by (1) restricting fishing on impacted reefs, especially of algae grazers such as parrotfish, doctorfish, conch, crabs and sea urchins, and (2) controlling water quality and sedimentation by regulating land clearing activities during peak rain and flood periods.

Our Future

Trinidad & Tobago urgently needs to safeguard our marine resources. Effective management of our marine ecosystems is long overdue, and investment into climate adaptation is needed. Coral bleaching is one example of climate disaster that small-island ecosystems face, and the sudden loss of these natural resources will have critical economic and social consequences. The issue of protection is not a scientific one, but a social one. We are a society that has prospered for 100 years from oil and gas. While we are culturally connected to this industry which is intertwined in our carnival, economy and politics, we have disregarded and ignored our other natural resources with little care or understanding about their importance, unless there is profit to be made.

Unfortunately, the economic losses as a result of the decline of coral reefs will be felt by citizens of Trinidad & Tobago. Our leaders need to hold high polluting nations accountable for carbon emissions as our ocean health depends on it. At the same time, we must commit to reducing carbon emissions and protecting our own marine environments. We are responsible for holding our leaders accountable.

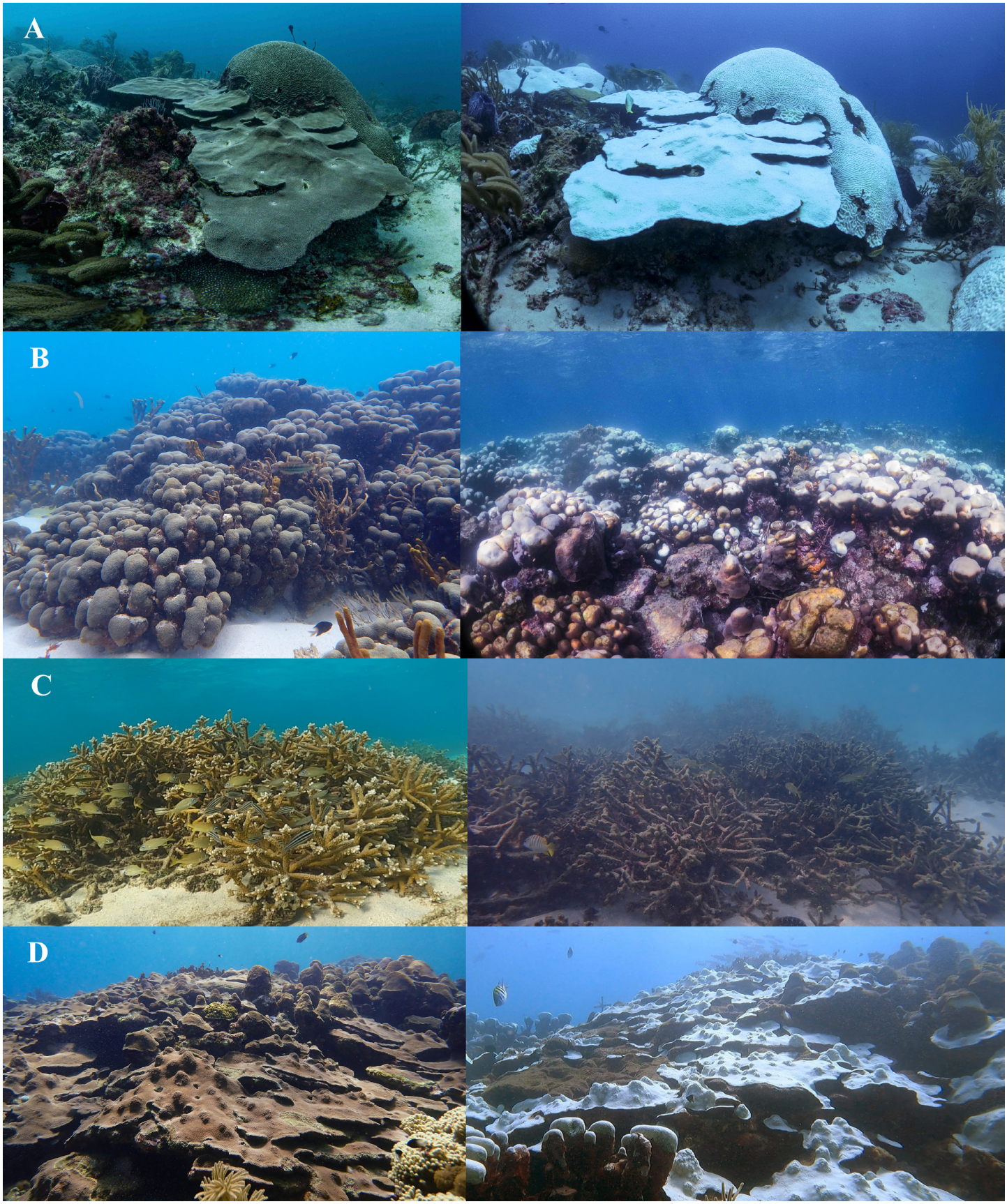

Plate 1. Healthy corals (left) and the same colonies (right) after the 2024 coral bleaching event. A: Mountainous star and boulder brain corals at Melville Drift reef off St Giles Island. B: Boulder star corals at Coral Gardens in the Buccoo Reef Marine Park. C: Vibrant staghorn coral patch in the Buccoo Reef Marine Park taken in February 2024 but completely dead in November 2024. D: Mountainous star corals of Angel Reef in Speyside. All photos courtesy IMA.

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