Climate change-related disturbances in 2024 drive the largest known population of elkhorn coral (Acropora palmata) in Barbados to the brink of extirpation

Henri Vallès
`henri.valles@cavehill.uwi.edu`

University of the West Indies

Kristen Clarke
University of the West Indies

Annabel J. Cox
University of the West Indies

Robert Bourne
University of the West Indies

Julian Walcott
University of the West Indies

Hazel A. Oxenford
University of the West Indies

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Abstract

Climate change is leading to global increases in frequency and severity of marine heatwaves, increasingly contributing to coral reef degradation. In 2024, Barbados was impacted by the passage of Hurricane Beryl and the most severe marine heatwave to date. Here, we report on the fate of the largest known population of the foundational Caribbean reef building coral, *Acropora palmata*, in Barbados in the face of such disturbances. Between June 2024 and March 2025, we tagged, measured and monitored (biweekly to monthly) the health status of 33–41 *A. palmata* colonies at Mullins Reef on Barbados' west coast. On July 1, Hurricane Beryl passed south of Barbados, causing the loss of 36.4% of tagged colonies. On August 4 and September 2 2024, average daily cumulative heat stress reached four and eight Degree Heating Weeks (DHW), respectively, peaking on November 12 at an unprecedented 24.2 DHW. After Beryl, tagged colonies that were not destroyed remained healthy until September 16, when some started to show bleaching signs. By October 29, all colonies were fully bleached and by December 18 most colonies had died. By February 14 2025, only one colony remained alive; it had regained full coloration, but lost > 50% of its live tissue. The collapse of the most important *A. palmata* population on the west coast, coupled with the devastating impact of Hurricane Beryl on the south coast, provide a stark warning that *A. palmata* might have now reached functional extinction in Barbados, abruptly ending two decades of slow *A. palmata* recovery.

Introduction

Climate change is resulting in a global increase in the frequency and/or severity of marine heatwaves (Smith et al. 2025) and tropical hurricanes (Knutson et al. 2020; Knutson et al. 2021). Since the 1980s, marine heatwaves and hurricanes have played an increasingly important role in the degradation of coral reefs in the wider Caribbean (Gardner et al. 2005; Wilkinson and Souter 2008; Eakin et al. 2010; Cetina-Heredia and Allende-Arandía 2023; Gonzalez-Barrios et al. 2023; Lenton et al. 2025).

Corals differ markedly in life-history traits (Darling et al. 2012) that are linked to differences in their vulnerability to thermal-induced bleaching mortality (Loya et al. 2001; Mizerek et al. 2018) and/or storm-induced mortality due to colony dislodgement (Madin et al. 2014). These differences have strongly contributed to driving shifts in the composition of the surviving coral assemblages over time that undermine the structure and function of these systems (Hughes et al. 2018; Estrada-Saldívar et al. 2019) and their ability to provide a wide range of critical ecosystem services (Eddy et al. 2021; Smith et al. 2025). The increasing frequency and severity of such episodic disturbances is now impacting even the more resilient coral species (Byrne et al. 2025; Doherty et al. 2025). In the Caribbean, which already suffers from relatively low functional and taxonomic coral diversity (Bellwood et al. 2004), and where such climate-related stressors often interact with chronic local stressors such as poor water quality and overfishing, this is driving coral reefs ever closer to a long-term regime shift to an algal-dominated or degraded state (Lenton et al. 2025).

Elkhorn coral, *Acropora palmata* (Lamarck, 1816), is one of the foundational reef building corals of Caribbean reefs, historically being the main reef framework constructor and inhabitant of the shallow reef crest zone of many of the region's fringing reefs (Goreau 1959; Gladfelter 1982; Cramer et al. 2021). As such it played a crucial ecological role through the provision of complex three dimensional physical structure that benefits other reef organisms (Lirman 1999), and was responsible for mediating the wave energy attenuation effect of reefs that protects coastlines (Toth et al. 2023). More recent paleoecological evidence supports that the abundance of *A. palmata* (and that of the only other Caribbean acroporid species, *A. cervicornis*, Lamarck, 1816) across the region dropped considerably around the mid 1950s and 1960s, likely due to human-induced local stressors such as coastal run off affecting water quality (Cramer et al. 2020). *A. palmata* populations underwent further rapid declines primarily due to a Caribbean-wide episode of White Band Disease in the late 1970s and early 1980s, with hurricanes also playing an important, but more localized role, in this decline (Aronson and Precht 2001). Subsequently, *A. palmata* has demonstrated high vulnerability to both thermal-induced bleaching mortality and storm-induced mortality in the region (Wilkinson and Souter 2008). Although there have been some reports of *A. palmata* population recovery across the Caribbean in recent decades (Macintyre and Toscano 2007; Zubillaga et al. 2007; Muller et al. 2013; Larson et al. 2014; Croquer et al. 2016), Caribbean acroporids are still considered critically endangered (Gutierrez et al. 2024).

In Barbados, like other countries across the Caribbean, *A. palmata* has historically been a dominant reef framework constructor (Lewis 1984; Macintyre et al. 2007). Its last remnant shallow water populations on the west coast of the island declined sometime during the 1900's, likely primarily due to sedimentation driven by island-scale deforestation and tropical storms (Lewis 1984), in a time line consistent with Cramer et al. (2020)'s paleoecological region-wide study. By the time regular monitoring of Barbados reefs began in the early 1980s, *A. palmata* (and *A. cervicornis*) were relatively rare.

However, MacLean and Oxenford (2016) provided strong evidence that *A. palmata* populations were recovering in 2015 in Barbados. MacLean and Oxenford (2016) exhaustively surveyed 46 shallow fringing reefs along the entire west coast of Barbados in 2015 and recorded a total of 707 *A. palmata* colonies, present in 57% of the reefs surveyed. Importantly, one reef located towards the northern end of the west coast, the Mullins Reef, accounted for 68% of all the *A. palmata* colonies found (482 colonies) and exhibited the highest colony density (137 colonies per hectare). More detailed subsequent surveys at Mullins Reef in 2016 by Oxenford et al. (2024) yielded a revised total abundance estimate of 599 *A. palmata* colonies, i.e. 72% of all reported colonies on the west coast's fringing reefs between 2015 and 2016. Moreover, this *A. palmata* population included many large mature colonies, with *in situ* confirmation of active spawning taking place in 2017 (Oxenford et al. 2024). Finally, genetic analyses confirmed the presence of at least eight different *A. palmata* genets at Mullins Reef, which largely exceeded the genotypic diversity found in a few other shallow reefs surveyed in the south and west coasts of Barbados in 2016 (Oxenford et al. 2024). These different lines of evidence jointly support that the thriving *A. palmata* population at Mullins Reef in 2015 and 2016 likely played a particularly important role as a source population in the recovery of this species in Barbados at that time.

The above characteristics motivated the use of *A. palmata* colonies from the Mullins Reef as donor material in the context of an *A. palmata* coral restoration project in Barbados in 2024. This effort also led to the frequent monitoring of a representative fraction of this population from June 2024 onward, for the first time since 2016.

However, 2024 was a year with a relatively high number of major hurricanes in the Caribbean (five in total; NOAA's National Hurricane Center at https://www.nhc.noaa.gov/) of which one, Hurricane Beryl, made history as the earliest Category 5 hurricane on record in the Atlantic Basin (Beven II et al. 2025). Hurricane Beryl cut through the Windward Islands on July 1st 2024, passing approximately 200 km south of Barbados as a Category 4 hurricane, making landfall on the Grenadian island of Carriacou, and becoming a Category 5 hurricance on July 2nd 2024 (Fig. 1A) (Beven II et al. 2025). Although Barbados was not in the direct path of the hurricane, the south and west coastal and nearshore environments of the island were heavily affected by storm surge, which breached the Bridgetown fishing harbour wall, severely damaging hundreds of fishing vessels as well as the Bridgetown harbour cruise ship terminal (Beven II et al. 2025).

Moreover, between 2023 and 2024 the world experienced the hottest marine heatwave on record, amplified by El Niño conditions (Jiang et al. 2024; Smith et al. 2025), which translated into the highest cumulative temperature stress (as degree heating weeks (DHW)) on record for the Windward Islands, peaking in November 2024 for this subregion (Fig. 1B). The 2023–2024 marine heatwave resulted in the 4th global mass coral bleaching event (Goreau and Hayes 2024; Reimer et al. 2024), with multiple reports confirming mass coral bleaching and mortality throughout the wider Caribbean (Mejias-Rivera and Courtney 2024; Muniz-Castillo et al. 2024; Neely et al. 2024; Prato-Valderrama et al. 2024; Doherty et al. 2025), including a report from the Windward Island of Martinique during this period (Bon et al. 2025). The few recently published reports support that most remaining populations of *A. palmata* have suffered extensive bleaching-induced mortality across the region, further threatening the long-term persistence of this critically endangered species (Neely et al. 2024; Birkart and Alvarez-Filip 2025; Manzello et al. 2025), although some locations were not as severely affected (Neely et al. 2024). In Barbados, *A. palmata* populations at Mullins and several other reefs did suffer bleaching in 2023, but they recovered well thereafter (pers obs), likely because the heatwave did not reach its peak in the Windward Islands until 2024 (Fig. 1B).

Here, we report on the fate of the *A. palmata* population at Mullins Reef in the face of the passage of Hurricane Beryl and the 2023–2024 heatwave in 2024, when it was most severe in the subregion, and provide some notes on impacts on other *A. palmata* populations in Barbados around the same time. Because Barbados is located in the most southeastern range of the wider Caribbean, east of the Lesser Antilles Island chain, we hope that our data will contribute to filling a geographic gap on the direct and most recent impact of climate change-related events on *A. palmata* populations across the entire range of this species.

Methods

On June 19 2024, 33 haphazardly selected *A. palmata* colonies of the population at Mullins Reef were tagged for monitoring (Fig. 2). These colonies were located at depths of 1.0 m to 2.5 m, the depth range that hosted the majority of the *A. palmata* population (Fig. 2). On July 21 2024, an additional 20 colonies were tagged after the passage of Hurricane Beryl (Fig. 2).

The depth of each colony was estimated using a SCUBA depth gauge to the nearest 0.1 m and the maximum height of each colony from the benthic substrate was estimated to the nearest cm using a marked rod. The tagged colonies were surveyed approximately biweekly via SCUBA until January 2025, and at least monthly thereafter until March 2025. During each survey, top-down photographs of every colony were taken. A one-metre reference rod marked at 10 cm intervals was included in each photograph as a reference scale. These images were later analysed in ImageJ (Abramoff et al. 2004) to calculate additional colony size metrics and colony health status. Additional colony size metrics included colony length (longest planar dimension), colony width (longest planar dimension perpendicular to length) and colony total planar area. Colony health status included percent area that is dead out of the colony's total planar area (i.e. % dead surface) and the pigmentation status of the live tissue. The latter was categorized as fully pigmented, bleached, or dead. Fully pigmented implied that the colony had live tissue and that such live tissue exhibited conspicuous and bright brownish colouration. Bleached implied that the colony had live tissue, but such tissue had either lost some pigmentation (relative to the initial baseline colouration photographs of June 2024) or completely lacked any pigmentation (fully bleached). Dead colonies exhibited no live tissue, which was evidenced by turf algae overgrowth of the coral skeleton.

In situ sea surface temperature readings were obtained from a HOBO Water Temp Pro v2 Logger (U22-001) deployed at a depth of 4 m on a fringing reef site located midway along the west coast of Barbados. Shallow sea surface temperature profiles are very similar along the west coast of Barbados, so the data generated at this central site will be sufficiently representative of the temperature experienced at Mullins Reef. Degree Heating Weeks (DHW), a measure of cumulative heat stress, were derived from NOAA's Coral Reef Watch Windward Caribbean Islands Time Series, accessed via the National Environmental Satellite, Data, and Information Service (NESDIS; https://www.nesdis.noaa.gov/). Daily *in situ* sea surface temperature readings and DHW estimates were averaged over each biweekly period preceding a colony survey and these averages were displayed graphically.

Colony size metrics and colony depth were described graphically as size frequency distributions. Potential differences in colony size dimensions among different sets of tagged colonies were assessed using Mann-Whitney tests. Potential associations between colony size metrics and depth were assessed using Spearman's rank correlation tests. Changes in colony health metrics over time were summarized and displayed graphically as percentage of colonies under each pigmentation status and as boxplots of dead surface area estimates across colonies over time. Analyses were conducted in R (R Core Team 2025) and plots were generated using ggplot (Wickham 2016) and MS Excel.

Results and Discussion

Impact of Hurricane Beryl

The initial 33 *A. palmata* colonies tagged before the passage of Hurricane Beryl had an average length of 89.7 cm ± 9.4 (standard error), an average width of 70.3 cm ± 5.8 (Fig. 3B), an average height of 34.0 cm ± 4.0 (Fig. 3C), and were found at an average depth of 1.8 m ± 0.1 (Fig. 3D). These dimensions align well with the large size category (longest top-down planar dimension of 50–100 cm) of Oxenford et al. (2024), which accounted for 25% of the 586 colonies measured in 2016 at Mullins Reef, with only 12.5% of the colonies being larger (> 100 cm) at that time. It also suggests that *A. palmata* colonies had increased considerably in size since 2016, when the population was dominated (63%) by considerably smaller colonies (< 50 cm) (Oxenford et al. 2024). Satellite imagery data from 2016 and 2023 also supports that the population in 2023 was at least as abundant as, and likely more abundant than, in 2016 (Fig S1). However, unlike Oxenford et al. (2024)'s study, our colony sampling was not specifically designed to fully characterize the colony abundance and size class distribution of the entire population at Mullins Reef, so this temporal comparison warrants caution.

Colony height was significantly positively correlated with depth (Spearman rank correlation test: r_s=0.30, p = 0.032), but this was not the case for colony width (r_s=0.17, p = 0.211) nor length (r_s=0.18, p = 0.192). A positive correlation between colony height and depth is expected given the shallow depth range of the reef crest that was surveyed in this study (1.0-2.5 m), which will necessarily limit colony height growth in this fast growing species (Gladfelter et al. 1978).

The swells generated by the storm surge of Hurricane Beryl led to the complete dislodgement and loss of 12 (36.4%) of the initial 33 colonies on July 1st 2024. The tagged colonies lost to Beryl did not differ significantly in height, width, or length from the tagged colonies that survived (Mann-Whitney tests: X^2 ≤0.48, df = 1, p ≥ 0.487) (Fig. 3A-C). However, they were significantly shallower (average: 1.3 m ± 0.1, n = 12) than the survivor ones (2.1 m ± 0.1, n = 21) (Mann-Whitney test: X^2 =14.81, df = 1, p ≤ 0.001; Fig. 3D) and located on the reef crest zone closer to shore (Fig. 2). Subsequent surveys confirmed the disappearence of most (tagged and non-tagged) colonies at this depth (Clarke 2025). Fringing reefs significantly reduce wave energy and height, with the reef crest playing a dominant role in wave energy dissipation (Ferrario et al. 2014), which helps explain why the shallower colonies were much more heavily impacted by the wave-breaking energy derived from the storm surge than their deeper counterparts.

The survival of a relatively large fraction of the *A. palmata* population at Mullins Reef through Hurricane Beryl was facilitated by the location of the reef, which lies in the northern section of the west coast (Fig. 2). Because Hurricane Beryl travelled south of Barbados (Fig. 1A), it had a much stronger impact on the south coast than on the west coast, resulting in substantial infrastructure damage and vessel losses in the south (Beven II et al. 2025). In that regard, the second largest known population of *A. palmata* at the time, located at greater average depths (> 2.5 m) near a popular surfing area of the south coast (Drill Hall), approximately 3 km south of the Bridgetown Harbour, was completely eradicated by the passage of Beryl (Clarke 2025). It is thus likely that any remaining patches of *A. palmata* colonies that had survived Beryl's passage were primarily confined to the west and north coasts of Barbados, with the Mullins Reef continuing to host one of the most important populations right after Beryl.

A. palmata has historically dominated shallow high wave energy reef environments in the Caribbean (Cramer et al. 2020; Cramer et al. 2021), and its fast growth rates and branching shape are well adapted to undergo wave-induced fragmentation (Gladfelter et al. 1978; Lirman 2000). However, these life traits also make it particularly susceptible to impacts by tropical storms and so increases in storm frequency and/or intensity have been repeatedly identifed as important contributing factors to its long-term demise across the region (Woodley et al. 1981; Gardner et al. 2005; Macintyre et al. 2007; Wilkinson and Souter 2008; Hernández-Delgado et al. 2024), even though individual storms will impact reefs at more localized spatial scales than other regional disturbances such as marine heatwaves and disease outbreaks. In line with this, our study highlights that Hurricane Beryl had already drastically reduced standing *A. palmata* populations in Barbados before the 2023–2024 regional marine heatwave reached its peak severity in 2024.

Impact of the 2024 heatwave

The additional 20 colonies that were tagged at Mullins Reef post-Beryl to replace and supplement the ones lost to Beryl did not differ from the initially tagged colonies that survived Beryl in either height, width, or length (Mann-Whitney tests: $X^2 \leq 0.08$, df = 1, $p \geq 0.784$) (Fig. 3A-C). However, they were minimally but significantly shallower (average: 1.9 m ± 0.1) than the initially tagged survivors (average: 2.1 m ± 0.1) (Mann-Whitney test: $X^2 = 14.81$, df = 1, $p \leq 0.001$) (Fig. 3D) and were also closer to shore (Fig. 2).

In situ daily sea surface water temperature on the west coast of Barbados during 2024 were the highest on record, exceeding that of 2005, 2010 and 2023, which were years that also showed unsually high temperatures over the last two decades (Fig S2) and during which mass coral bleaching events were reported in Barbados (Oxenford et al. 2008; Oxenford and Vallès 2016; Irvine et al. 2025). The 2024 *in situ* temperature measurements for Barbados were generally within the range of minimum and maximum values estimated by NOAA Coral Reef Watch for the Windward Caribbean Islands (Fig S2), supporting that such satellite temperature data adequately inform on the nearshore marine environment of Barbados, which is not always the case across Caribbean reefs (Margaritis et al. 2025).

During the biweekly period up to July 8, average *in situ* daily sea surface temperature was 29.3 degrees Celsius and continued to gradually increase thereafter, reaching peak values in the October 15 biweekly period of 30.8 degrees Celsius (Fig. 4A). It gradually dropped thereafter, reaching 29.5 degrees Celsius during the December 4 period and 28.1 degrees Celsius during the January 31 period (Fig. 4A). Cumulative heat stress, expressed as average daily degree heating weeks, exceeded the four-week bleaching threshold and eight-week bleaching-induced mortality theshold during the August 6 and September 2 biweekly periods, respectively, reaching a peak of 24.2 DHW during the November 12 biweekly period and gradually decreasing thereafter (Fig. 4A).

On July 8, a week after the passage of Beryl, all the tagged colonies were fully pigmented and had very low levels of tissue mortality (average: <2% of dead surface area); these health metrics remained relatively similar through September 2 (Fig. 4B-C; Fig. 5A). By September 16 some colonies (17%) started to show signs of bleaching (partial loss of original pigmentation) and by October 1 all colonies showed signs of bleaching in varying degrees. By October 29 all colonies were fully bleached (complete loss of pigmentation; Fig. 4B; Fig. 5B-D), which coincided with the first record of increases in tissue mortality (Fig. 3B; Fig. 5B-D). By November 12 some colonies (15%) had fully died (Fig. 3B; Fig. 5B-D). By December 4, a period of unusually high wave energy led to the dislodgement and loss of a further four of the tagged colonies (10%) (Fig. 3B). December 4 coincided with a dramatic increase in tissue mortality that led to more than one third (38%) of colonies fully dying (Fig. 3B-D; Fig. 5B-F). By December 18, the majority of the tagged colonies (70%) had completely died after bleaching, with just three bleached tagged colonies surviving but showing varied levels of tissue mortality (Fig. 3B-C). On January 3, only two bleached tagged colonies were still alive with high levels of tissue mortality (average: >50% of dead surface area) (Fig. 3B-C). On January 31, one of the two colonies had regained full pigmentation while the other one remained bleached (Fig. 3B-C). By February 14, only the colony that had regained full pigmentation during the preceding period remained alive (Fig. 3B-C).

Overall, out of the 41 tagged healthy colonies monitored post-Beryl (July 8, 2024 - March 12, 2025), 36 (88%) died due to thermal-induced bleaching, four (10%) were lost to high wave action, and one (2%) survived, but suffered high tissue mortality. Photographic evidence of the wider Mullins Reef population mirrored the fate of the tagged colonies and confirmed the near complete extirpation of its entire *A. palmata* population (Fig S3).

The unprecedented cumulative heat stress experienced in the last half of 2024 (reaching as high as 24.2 DHW) led to the final collapse of the *A. palmata* population at Mullins Reef. This was the case even though this population undoubtedly exhibited a substantial degree of thermal tolerance, having survived previous heatwaves, including those of 2005, 2010 and 2023, which exceeded the 14 DHW (Fig. 1B) that has been suggested as the general upper thermal threshold of *A. palmata* (Birkart and Alvarez-Filip 2025). Our findings support Williams et al. (2017), who suggested that thermal tolerance thresholds for *A. palmata* likely vary geographically. They also suggested that *A. palmata* populations, at least in the upper Florida Keys, do not become increasingly thermally tolerant following repeated severe thermal stress exposures, findings that concord with our own observations in Barbados, despite the previously documented relatively high genotypic diversity at our site in 2016 (Oxenford et al. 2024). Although such genetic diversity was not reassessed in 2024, conspicous differences in colony morphology (pers obs) suggested that much of it remained at the site. Our findings also echo those reported by others across the region as a result of the extreme heatwave experienced over 2023–2024. For example Thompson et al. (2025) witnessed the extirpation of *A. palmata* populations in the Dry Tortugas (Florida Keys), and Manzello et al. (2025) report the functional extinction of *A. palmata* (and *A. cervicornis*) throughout the Florida Keys. Likewise, Birkart and Alvarez-Filip (2025) report that *A. palmata* vanished from the Puerto Morelos reefscape and concluded that this species suffered catastrophic mass mortality across its entire shallow water distribution range in the Greater Caribbean. The observation by Williams et al.

(2017) supported by our own observations that *A. palmata* does not improve heat tolerance with successive exposure to heatwaves contrasts with adaptive responses (acclimitization) observed in some other coral species (e.g. Guest et al. 2012), including an Indo-Pacific acroporid (*A. digitifera*) (e.g. Humanes et al. 2022).

Of note, several rapid surveys on other shallow reefs on the west coast of Barbados in November 2024 identified a few small patches of surviving *A. palmata* colonies that were not bleached (unpublished data), highlighting the existence of some uniquely heat-resistant phenotypes and providing a glimmer of hope. Whether such heat-resistance is driven by the coral host genotype, the symbiont identity and/or reef-scale environmental factors remains to be determined (e.g. Karp et al. 2025).

Conclusion

The likely extirpation of *A. palmata* populations on the south coast due to Hurricane Beryl, coupled with the subsequent bleaching-induced loss of the *A. palmata* population at Mullins Reef, a population that exhibited the highest abundance and density on the west coast and included many sexually reproductive individuals, suggest that *A. palmata* might now be functionally extinct in Barbados, an island that is primarily self-recruiting (Cowen et al. 2006). Overall, this mirrors other reports of extirpation and functional extinction of *A. palmata* from across the Caribbean suggesting that the slow recovery of this now endangered species over recent decades has endured a major setback. This underscores the urgent need to biopreserve the few and uniquely heat-resistant phenotypes left in Barbados and other islands and engage in their assisted recovery to prevent loss of this valuable foundational species (Muller et al. 2025).

Declarations

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Authors contributions

Conceptualization and Methodology: HV; Supervision: AJC; Investigation: KC, AJC, RB, HAO; Data curation: AJC, KC, HV; Formal analysis: HV, KC; Visualization: HV, AJC, KC; Writing-original draft preparation: HV, KC; Writing-review and editing: HV, HAO, JW, KC, AJC, RB; Funding acquisition: HV, JW, HAO.

Competing interests

The authors have no competing interests to declare that are relevant to the content of this article

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Figures

Figure 1

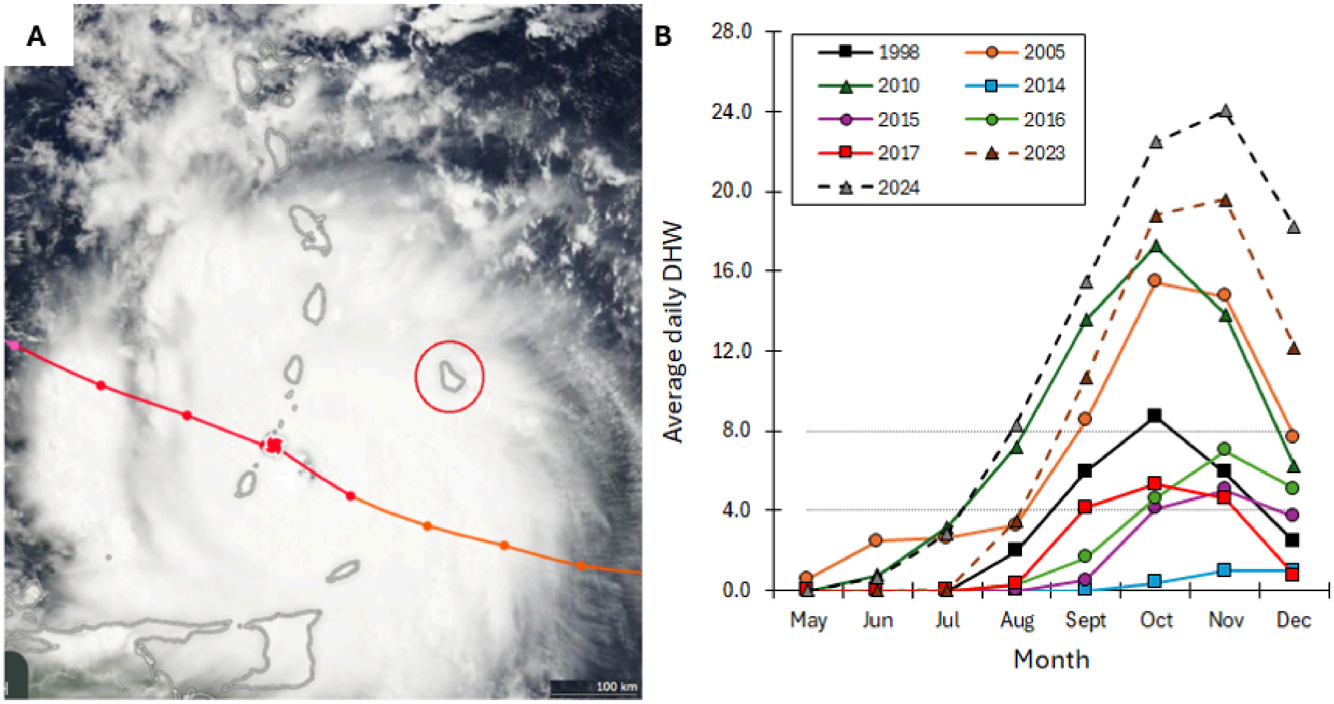

Figure 1

Climate-change related disturbances affecting Barbados. A) Modified satellite imagery of the Windward Islands including Barbados (red circle) showing the trajectory of Hurricane Beryl (red/orange dotted line) and its location (red start) and associated water vapor cover on July 1^{st} 2024; original image source:

Zoom Earth (https://zoom.earth); B) Average daily Degree Heating Weeks (DHW) for the Windward Islands for the months of May to December for the years corresponding to global (1998; 2010; 2014-2017; 2023-2024) and regional (2005) mass coral bleaching events; dotted vertical black lines indicate four and eight DHWs; data source: NOAA Coral Reef Watch accessed via the National Environmental Satellite, Data and Information Service (NESDIS; https://www.nesdis.noaa.gov/).

Figure 2.

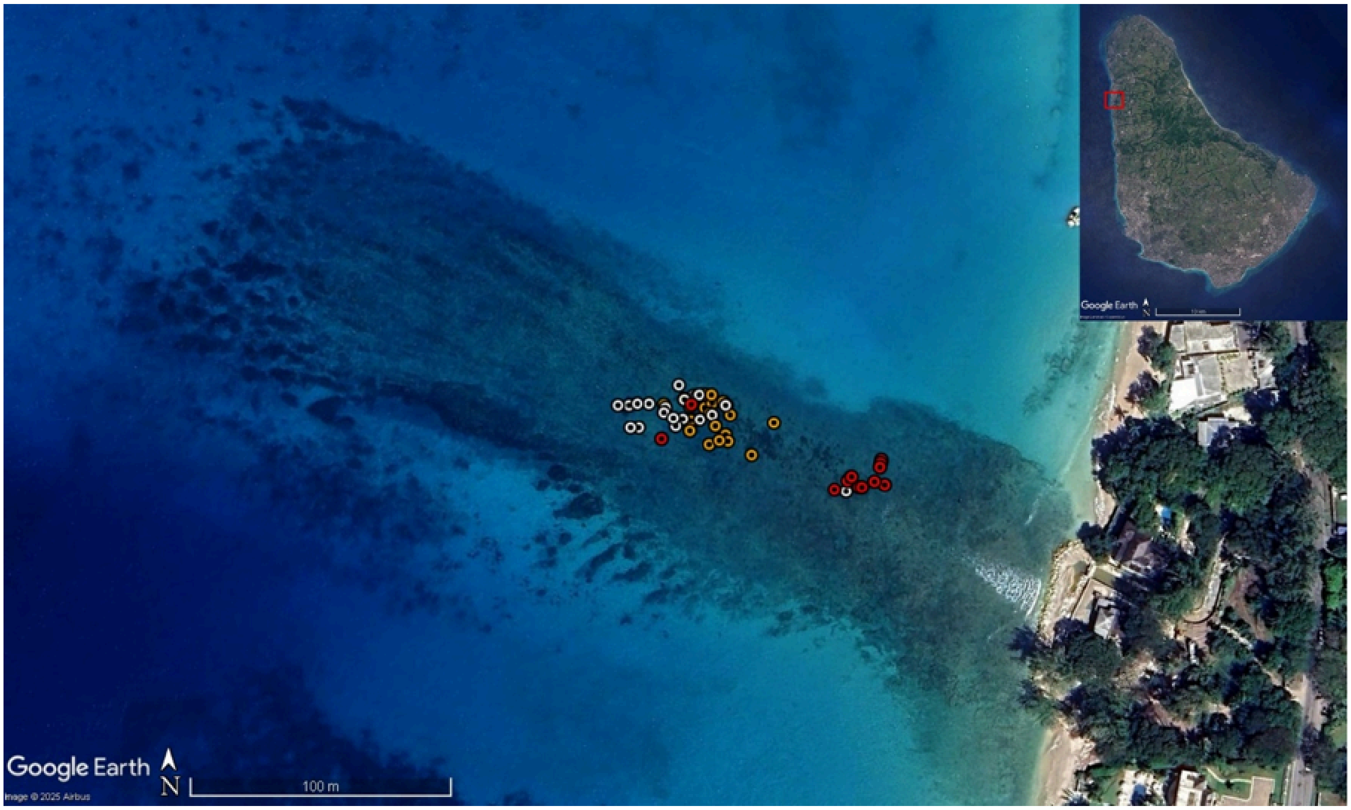

Figure 2

Location of 53 *A. palmata* colonies at Mullins Reef in Barbados that were tagged before (white and red circles) and after (orange circles) the passage of Hurricane Beryl, identifying those that were lost to Hurricane Beryl (red circles). The location of Mullins Reef on the west coast of Barbados is shown in the inset. Original image source: Google EarthPro.

Figure 3.

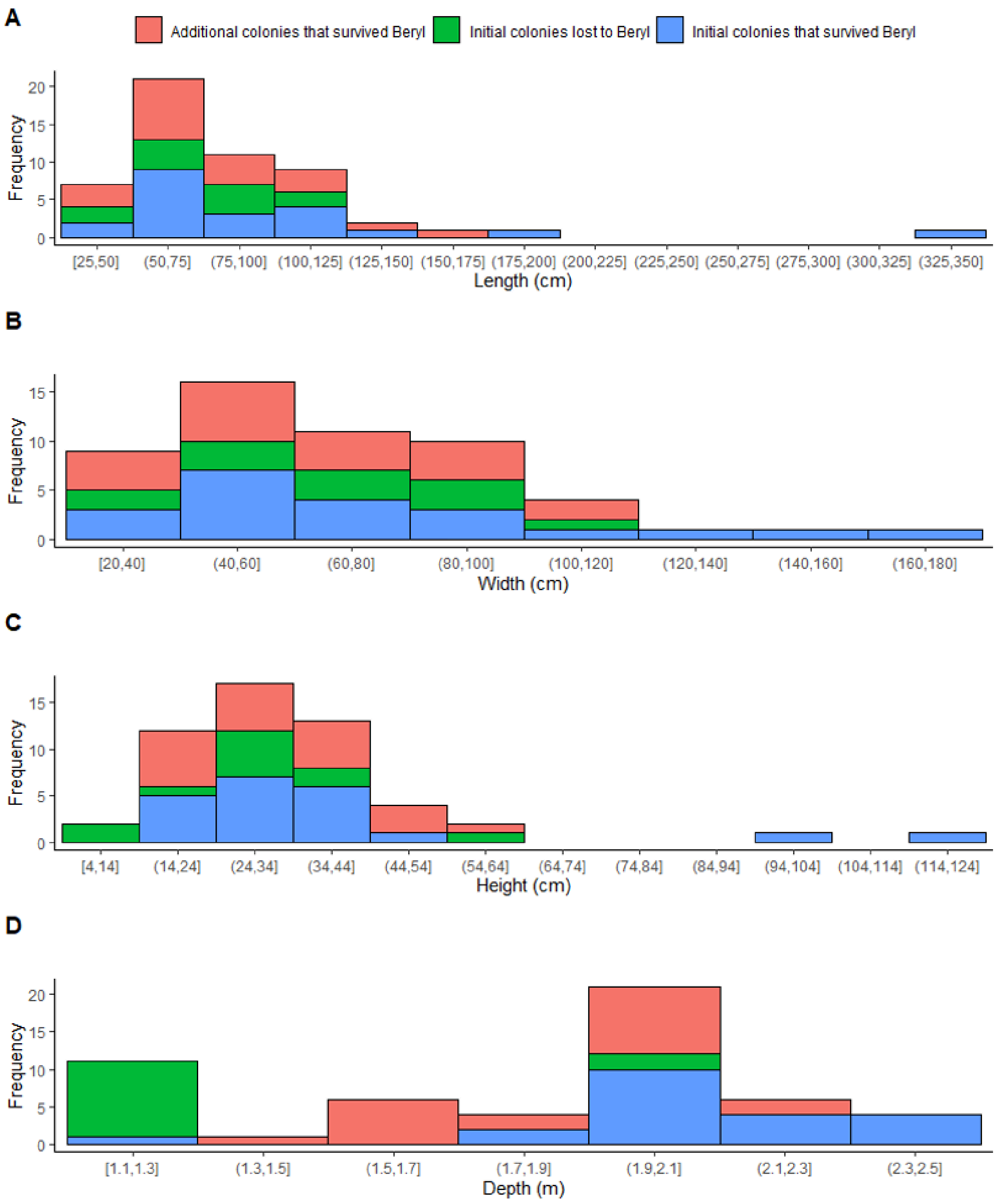

Figure 3

Frequency distributions of 53 *A. palmata*colonies at Mullins Reef that were tagged before and after the passage of Hurricane Beryl, identifying those that were lost to Hurricane Beryl, for A) colony maximum length; B) colony maximum width; C) colony maximum height, and D) colony depth.

Figure 4.

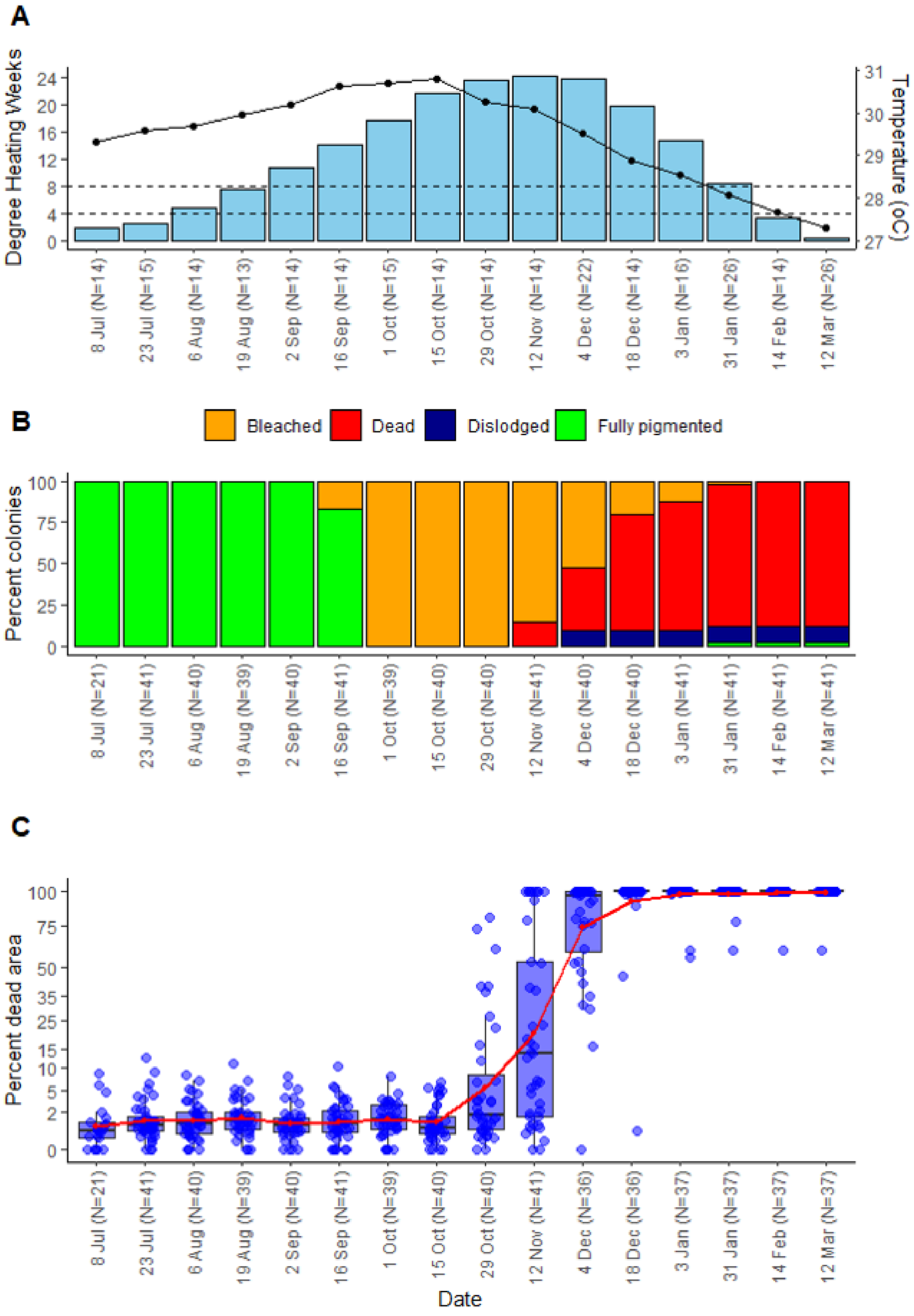

Figure 4

Time series of sea surface temperature metrics and coral health metrics from the tagged *A. palmata* colonies at Mullins Reef that survived the passage of Hurricane Beryl between July 8 2024 and March 2025. A) Biweekly average daily sea surface temperature (derived *in situ* from a central site on Barbados' west coast; black line) and associated average daily Degree Heating Weeks for the Windward Islands (blue bars); B) Percent of tagged *A. palmata* colonies allocated to four different health status categories over time; C) Boxplots of dead surface area estimates for the tagged *A. palmata* colonies and corresponding mean dead surface area (across tagged colonies) (red line) over time. Dashed vertical black lines in A) indicate four and eight DHWs.

Figure 5.

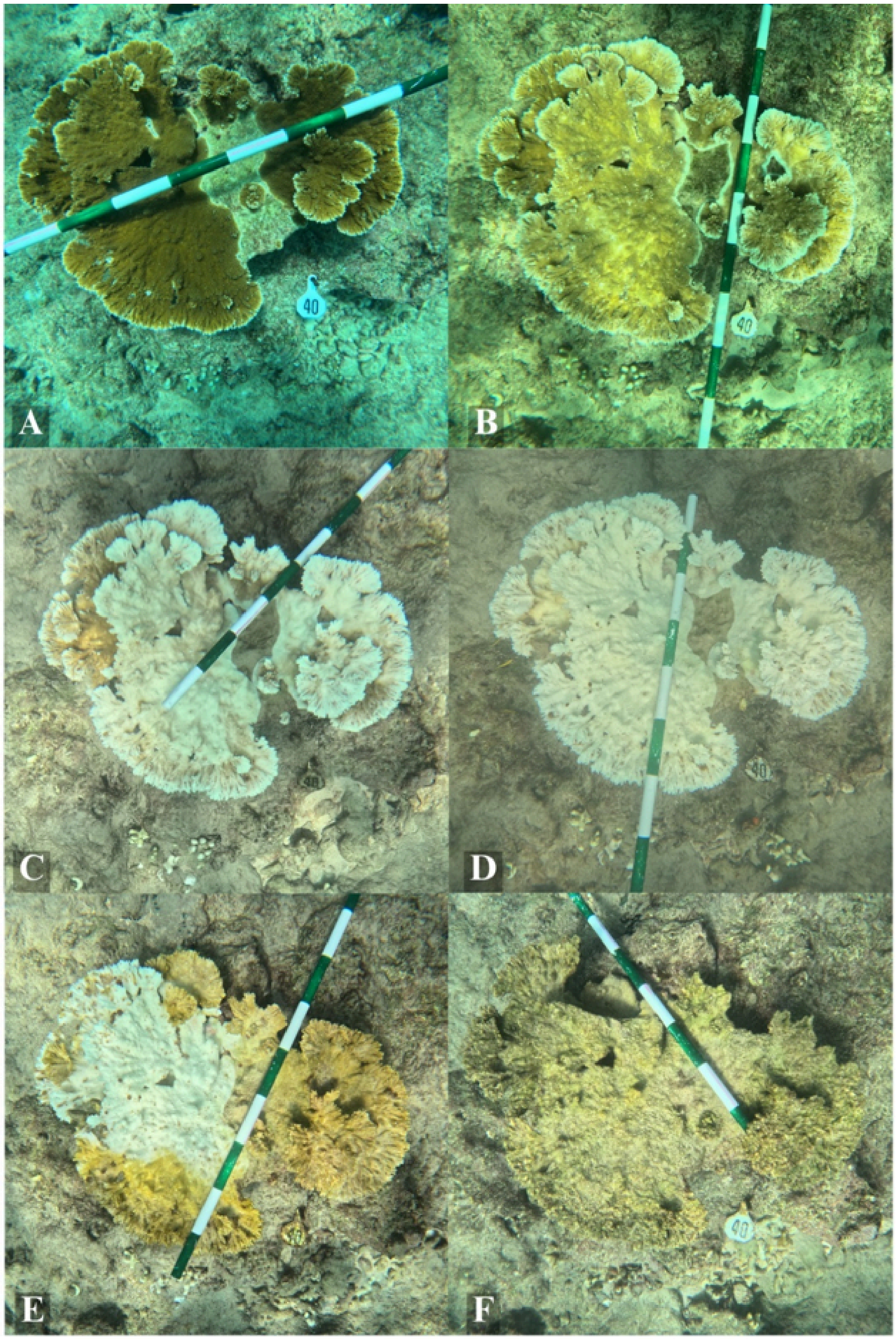

Figure 5

Progression of a selected tagged *A. palmata* colony from the Mullins Reef population, as it transitions from alive and fully pigmented to completely dead between July 8 and November 11, 2024. A) fully pigmented (July 8); B) early signs of bleaching, with partial discolouration visible (September 16); C) partially bleached with significant loss of pigment (October 1); D) fully bleached with small spots of algal growth; E) increased mortality and widespread algal growth (October 29); F) fully dead with extensive algal growth covering the colony (November 11).

Supplementary Files

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