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Stress event for "super corals" in Great Barrier Reef mangrove lagoon

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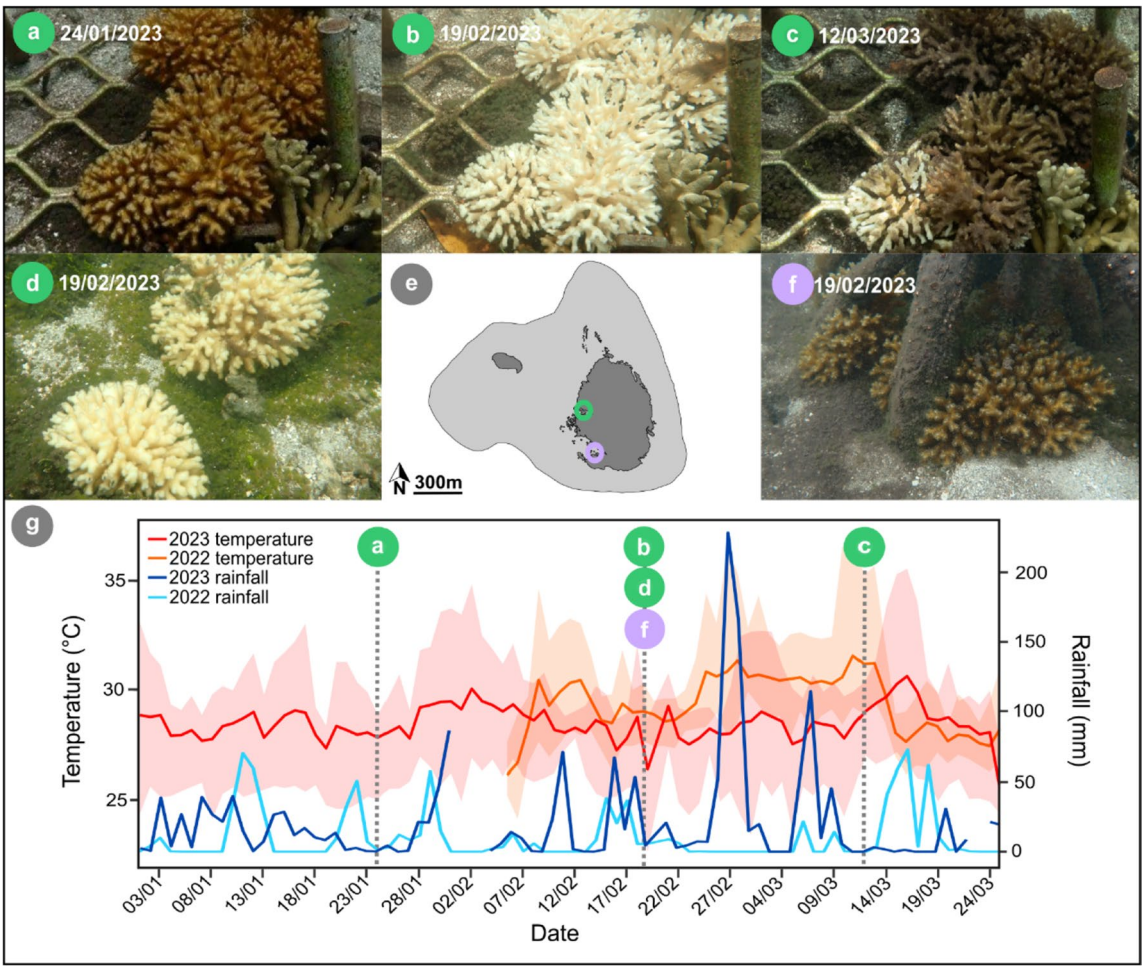

Fig. 1 **a–c** Time series photos of *Pocillopora acuta* colonies depicting pre-bleaching (colour card D5/D6), bleaching (D1/D2), and post-bleaching mortality (not applicable) on 24/01/2023, 19/02/2023, and 12/03/2023, respectively, of a transplantation frame in the northern bay of Woody Isles; **d** Photo of a wild bleached *P. acuta* colony in the northern bay of Woody Isles taken on the 19/02/2023; **e** Map of Woody Isles with the green circle indicating the northern bay, and the purple circle indicating the southern bay; **f** Photo of a wild *P. acuta* colony in the southern bay of Woody Isles taken on 19/02/2023; **g** Daily average temperature (°C; red = 2023, orange = 2022) recorded by loggers deployed in 2022 and again in 2023; temperature data prior to 5/02/2022 is not presented as loggers were not yet deployed. Daily temperature range is represented by the shaded area (°C; red = 2023, orange = 2022). Bureau of Meteorology (BOM 2023) daily rainfall data is also presented (mm; dark blue = 2023, light blue = 2022). Breaks in rainfall data represent periods where no data was reported by the BOM

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Corals persisting within naturally extreme ecosystems are often labelled as "super corals" due to their innate tolerance to withstand stress (Grottoli et al. 2017). Although this descriptor acknowledges their resilience to single or multiple environmental stressors, it does not entirely recognise that even the

most resilient coral species may succumb to other, lesser-studied stressors (Camp et al. 2018), including freshwater bleaching. Environmental conditions in the mangrove lagoons of Woody Isles on the Great Barrier Reef, Australia (16.388° S, 145.566° E), are shown to be more extreme than those of the surrounding Low Isles Reef (16.386° S, 145.558° E) (Camp et al. 2019). Corals within these mangrove lagoons normally withstand large temperature variations (> 7 °C), low oxygen saturation (< 1 mg/L), and high acidity (< 7.6 pH) (Camp et al. 2019). In February 2023, severe bleaching (CoralWatch colour card D1/D2) of all (ca. 50 colonies) *Pocillopora acuta* coral colonies in the shallow (ca. 1 m), low-flow northern mangrove lagoon of Woody Isles was observed (Fig. 1e), including colonies on metal frames involved in an ongoing transplantation study. Other native coral species observed in the northern or southern lagoon (e.g., *Porites lutea*, *Montipora* sp., *Favites* sp.) did not show signs of bleaching. It is noted that a prior die-off of *P. acuta* in 2018 was observed (per obs. E. Camp) at Woody Isles following extreme rainfall (Camp et al. 2019); however, pre-stress, bleaching, and post-stress evidence was not available to document that event.

We hypothesise that the observed species-specific bleaching was likely due to reduced salinity—which fluctuates significantly within this ecosystem following heavy rainfall (Camp et al. 2019)—since *P. acuta* is susceptible to polyp bail-out during extreme changes in salinity (Gösser et al. 2021). Recovery of temperature data from loggers deployed in the mangrove lagoon (attached to the transplantation frames at colony depth), combined with daily rainfall records (BOM 2023; Fig. 1g), supports this hypothesis. From 24th January to 19th February 2023 inclusive, 447 mm of rain fell over Woody Isles, which is almost twofold higher than that of the previous year (~ 245 mm; Fig. 1g), with an average daily minimum temperature within the expected range (25.9 °C). In addition, almost 760 mm of rainfall was recorded from 19th February to 12th March 2023, compared to just 61 mm in 2022 (Fig. 1g). Prior to this, all *P. acuta* colonies within the northern bay of the mangrove lagoon showed no signs of bleaching (e.g., Fig. 1a), and following this heavy rainfall period, both native and transplanted colonies exhibited visible bleaching (Fig. 1b, d), hence suggesting that the transplantation frames did not appear to have an impact on the bleached versus unbleached colonies. By the 12th of March 2023, macroalgae growth was observed over most of the bleached colony skeletons (Fig. 1c), and a second high rainfall event (~ 450 mm between 26th February and 28th February 2023; Fig. 1e) may have contributed to *P. acuta*'s post-bleaching mortality. Contrastingly, *P. acuta* colonies growing in a separate mangrove lagoon ~ 300 m south (Fig. 1e) were not affected (CoralWatch colour card D5/D6; Fig. 1f), possibly due to the greater depth (ca. 2 m) and higher connectivity to the open ocean (see Fig. 1e).

These observations highlight the heterogeneity of stress that can be experienced within a single system, and further work is required to confirm the cause of this bleaching event. Our observations highlight that caution is needed when considering the potential role super corals can play in active reef interventions (Camp et al. 2018; Burt et al. 2020; Schoepf et al. 2023) as they may be susceptible to lesser studied stressors, such as freshwater bleaching. Determining the effects of these lesser studied stressors on corals may be a pertinent next step in uncovering potential trade-offs which have not yet been explored.

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Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval No animal testing was performed during this study.

Sampling and field studies All necessary permits for sampling and observational field studies have been obtained by the authors from the competent authorities and are mentioned in the acknowledgements.

Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Author contribution N.J.D., L.H., and E.F.C. performed observational and preliminary collection of data in the field, and N.B. collected ancillary data and prepared figures. Manuscript was written by N.J.D., N.B., and L.H., and all authors edited and approved the final manuscript.

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