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Are we forgetting early observations of coral bleaching?

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ABSTRACT: I argue that the first observed mass coral bleaching event on Australia's Great Barrier Reef (GBR) occurred in 1982. This claim should not be controversial given the expert testimonies and data collected at the time. However, the GBR mass bleaching of 1982 has been repeatedly and inexplicably absent from descriptions of the GBR bleaching history in recent peer-reviewed literature, government reports, and popular media. This is leading to a paradigm that severe, widespread coral bleaching began on the GBR in 1998, with that event impacting coral communities that had only been previously impacted by minor, localized bleaching. Here, I show that this paradigm is misleading, that mass bleaching during 1982 is consistent with the levels of heat and light stress that have sparked other GBR bleaching events, and that consideration of the full timeline of observed GBR mass bleaching is important for interpretations of community dynamics and potential changes in sensitivity to heat stress over time.

KEY WORDS: Coral · Mass bleaching · Great Barrier Reef · Climate change

1. INTRODUCTION

As the austral summer of 2024 winds down, leaving in its wake yet another mass coral bleaching event across the iconic Great Barrier Reef (GBR), scientific studies will surely soon arise assessing the extent, severity, and implications of this most recent bout of bleaching. I expect that many of these studies will place the 2024 bleaching event in the context of the observed GBR bleaching history, and — if the entrenched paradigm continues — will likely cast this as the 'seventh' mass bleaching event on the GBR (hopefully at least with the qualifier 'since 1998'). These events are 1998, 2002, 2016, 2017, 2020, 2022, and 2024 (Berkelmans & Oliver 1999, Berkelmans et al. 2004, Hughes & Kerry 2017, Hughes 2024). However, GBR mass bleaching was observed by scientists before 1998, during the austral summer of 1982 (Fisk & Done 1985, Harriott 1985, Oliver 1985). What separates 1982 from the 7 mass bleaching events observed since 1998 is that bleaching in 1982 was observed by a relatively small group of scientists across a relatively small number of reefs, whereas all subsequent mass bleaching events were assessed across large tracts of the GBR by aerial surveys. Yet, despite the sparse observations in 1982, the following excerpts clearly describe a mass coral bleaching event:

> 'Extensive bleaching of at least 25 species of hard coral and 2 species of soft coral was observed on reefs in the central and northern Great Barrier Reef during January to March 1982. Resultant mortality was high and it is estimated that more than 50% of the living coral cover of some reefs died... Records of bleaching extended over [4° latitude or 500 km], and encompassed a wide range of environments, ranging from inshore fringing reefs... to shelf-edge reefs in clear oceanic water.' (Oliver 1985, p. 201)

> 'Although the total number of reefs where bleaching was recorded in 1982 is fairly small (14), it includes almost every reef which was being regularly visited by Townsville scientists at that time.' (Oliver 1985, p. 204)

> 'Mass bleaching of shallow-water corals was observed at Lizard Island and at other locations on the Great Barrier Reef in early 1982.' (Harriott 1985, p. 81)

> 'Zooxanthellae were absent from large areas of tissue in coral colonies at the study site, at nearby reefs, and at reefs near Townsville (own obs.).' (Harriott 1985, p. 83)

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What defines 'mass' coral bleaching? Hughes (2024) defined mass bleaching as 'bleaching that is [1] severe and widespread, [2] affecting reefs at a regional scale or even throughout the tropics [3] triggered by rising global sea temperatures' (numbers in brackets added to facilitate following sentences). (1) Severity usually refers to the percent of corals in a community that bleach at one time, and Hughes et al. (2018) defined 'minor–moderate' bleaching as 1–30% of corals bleached and 'severe' bleaching as >30% of corals bleached. Both Oliver (1985) and Harriott (1985) clearly documented bleaching exceeding 30% on multiple reefs. 'Widespread' could refer to types of environments or numbers of coral taxa. To my knowledge, neither has a clear threshold, but the 1982 bleaching event can certainly be considered widespread because bleaching occurred in at least tens of coral species across nearshore-fringing and oceanic-facing reefs. (2) While 'regional scale' is subjective, 1982 bleaching occurred across at least 500 km of the GBR and this could easily be considered 'regional.' It is important to note that 500 km is the range wherein observations were made; it is entirely possible that bleaching extended beyond these observations. Additionally, bleaching from 1982 to 1983 occurred at other locations across the tropics (Coffroth et al. 1990, DeCarlo 2020a). (3) I suggest that 'mass coral bleaching' need not be 'triggered by rising global sea temperatures' (as opposed to temperature anomalies or even some non-temperature causes), but nevertheless, anthropogenic greenhouse gas-driven warming had created a discernable global warming signal by 1982 (Lough et al. 2018).

2. MATERIALS AND METHODS

I used Optimum Interpolation Sea Surface Temperature (OI-SST) version 2.1 (Banzon et al. 2016) to calculate degree heating weeks (DHW, in °C-wk) following the optimized DHW definition as described by DeCarlo (2020b). Note that this SST product is the most appropriate for assessing the multi-decadal variability of heat stress on the GBR, in part because it is less prone to temporal changes in biases (DeCarlo & Harrison 2019, DeCarlo 2020b), but also because it includes the year 1982, which is not included in the current version of CoralTemps provided by Coral Reef Watch. Each reef was assigned to the closest 0.25° OI-SST gridbox, and bleaching was predicted based on whether the annual maximum DHW exceeded the optimized prediction threshold of 5.4°C-wk from DeCarlo (2020b).

To assess light stress, I used outgoing longwave radiation (OLR) anomalies because they represent cloudiness (positive OLR anomalies indicate relatively low cloud cover or high photosynthetically active radiation; see Reed 1976, Kessler et al. 2000, DeCarlo & Harrison 2019). These data come from Liebmann & Smith (1996). First, a monthly climatology was calculated based on mean monthly OLR from 1979 to 2024, and monthly anomalies calculated as the deviation from this climatology during each month from 1980 to 2024. The monthly anomalies were then averaged for January, February, and March (JFM) to represent austral summer. Finally, all OLR gridboxes within the boundary of the GBR were averaged together to produce a single GBR-wide OLR anomaly for JFM of each year.

I used the World Atlas of Coral Reefs for locations of all reefs of the GBR, which was downloaded from ReefBase (Spalding et al. 2001).

3. RESULTS AND DISCUSSION

Observations of coral bleaching on the GBR during 1982 are sparse. Our ability to precisely characterize the extent and severity of bleaching from *in situ* observations of bleaching presence across just 14 reefs certainly pales in comparison to the aerial surveys conducted for all subsequent mass bleaching events on the GBR. However, we should not consider the scarcity of observations to mean a scarcity of bleaching. The observations that do exist found severe bleaching at most surveyed sites across 500 km of the GBR where bleaching-level heat stress occurred (Fig. 1; Fisk & Done 1985, Harriott 1985, Oliver 1985). Clearly, the reports suggest this was a mass coral bleaching event. Beyond the published reports, corals on some other reefs in the far northern GBR were not observed bleached during February and March 1982 (T. Done pers. comm.; Table 1). These reefs were mostly outside of the area of expected bleaching, except Corbett Reef, where DHW reached 9.8°C-wk (Fig. 1). The absence of bleaching at Corbett Reef — at least as was visible during a 1 h snorkel — is enigmatic because it was noted within 3 d of observing mass bleaching at nearby Lizard Island and surrounding reefs (T. Done pers. comm.).

The occurrence of mass bleaching on the GBR in 1982 is broadly consistent with coral bleaching being a response to anomalously high summer temperatures, and this event in no way casts doubt on anthropogenic warming being the leading driver of more frequent and severe bleaching events. The scientists who ob-

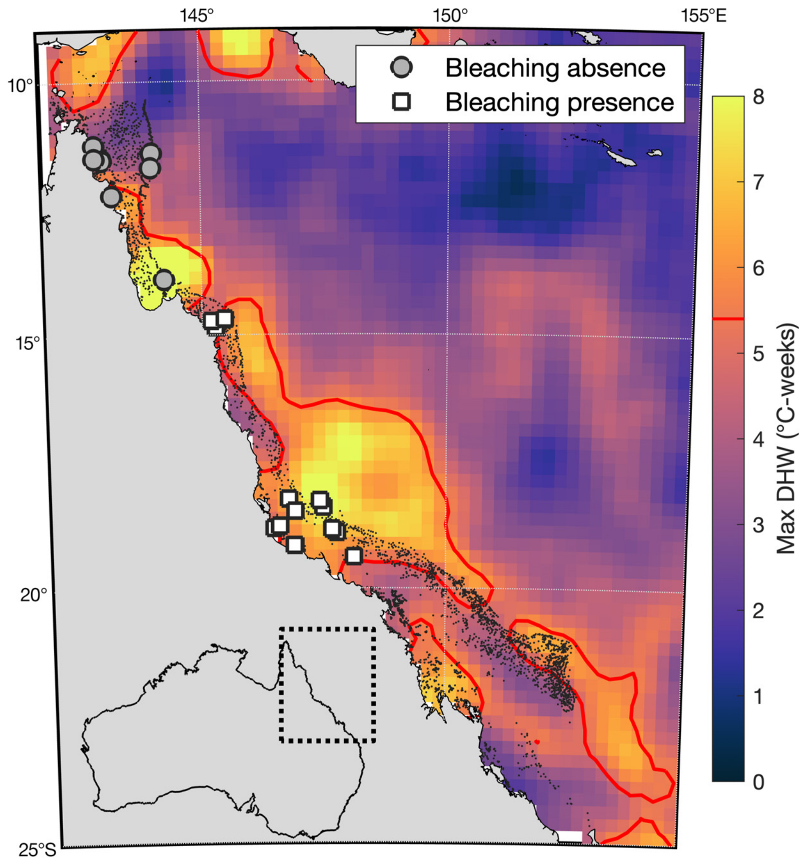

Fig. 1. Spatial distribution of maximum degree heating weeks (DHW; color scale) during 1982 on the Great Barrier Reef (GBR), Australia. Black dots indicate GBR reefs and white squares indicate locations where bleaching was observed during 1982. Red line: areas where DHW crossed the threshold beyond which bleaching is expected (>5.4°C-wk). Bleaching absence points were all observed by Dr. Terry Done and reported in personal communications

Table 1. Bleaching presence/absence observations not previously published, based on personal communications with Dr. Terry Done

Reef	Date observed (in 1982)	Bleaching presence/absence
Moulter Cay (previously Pandora Cay)	22 Feb	Absent
Great Detached Reef	23 Feb	Absent
Baird Reef	25 Feb	Absent
South Denham Reef	25–26 Feb	Absent
Bushy Reef	28 Feb	Absent
Wizard Reef	1 Mar	Absent
Hunter Reef	2 Mar	Absent
Corbett Reef	3 Mar	Absent
Lizard Island	6 Mar	Present
Turtle Islands	7 Mar	Present
Decapolis Reef	8 Mar	Present

served 1982 bleaching were unsure of the cause at the time, but they suggested that high light levels and potentially high temperatures may be involved (Fisk & Done 1985, Harriott 1985). With access to an additional 4 decades of bleaching presence/absence data and satellite-based observations of SST and cloudiness, we can now determine if conditions on the GBR during 1982 were conducive to producing a mass bleaching event. Fig. 2a shows a calculated time series of predicted percent of GBR reefs that experienced bleaching each year from 1982 through 2024. Close to 40% of the GBR experienced bleaching-level heat stress during 1982 (see also Fig. 1). Fig. 2b shows anomalies of outgoing longwave radiation (a proxy for clear skies, or photosynthetically active radiation; DeCarlo & Harrison 2019) during austral summer (JFM) from 1980 through 2024. From these plots, it is apparent that mass bleaching on the GBR is most closely tied with heat stress (Fig. 2a), but also that most bleaching events (including 1982) occurred under positive OLR anomalies (i.e. low cloud cover). Fig. 2c,d more clearly shows that mass bleaching events tend to occur under combinations of high temperature and light, generally requiring DHW exceeding ~5°C-wk and OLR anomaly to exceed −5 W m^{-2}. Oceanographic variability such as upwelling strength can further modulate bleaching (e.g. during the year 2004, see DeCarlo & Harrison 2019).

Oddly, mentions of GBR mass coral bleaching during 1982 are rare in the literature. In reporting the 1998 mass bleaching event, Berkelmans & Oliver (1999, p. 59) stated that 'a subjective comparison of the 1982 and 1998 bleaching events suggests that the intensity of bleaching at inshore sites... was more severe in 1998 than 1982', based on personal observations. Four years later, mass bleaching occurred again in 2002 and the paper describing that event did not mention the 1982 bleaching (Berkelmans et al. 2004). The first description of the 2016 bleaching event also did not mention 1982 bleaching (Hughes et al. 2017). Most surprisingly, Hughes et al. (2018) compiled bleaching histories for 100 reef sites from 1980 through 2016, and they did not report any bleaching (not even minor

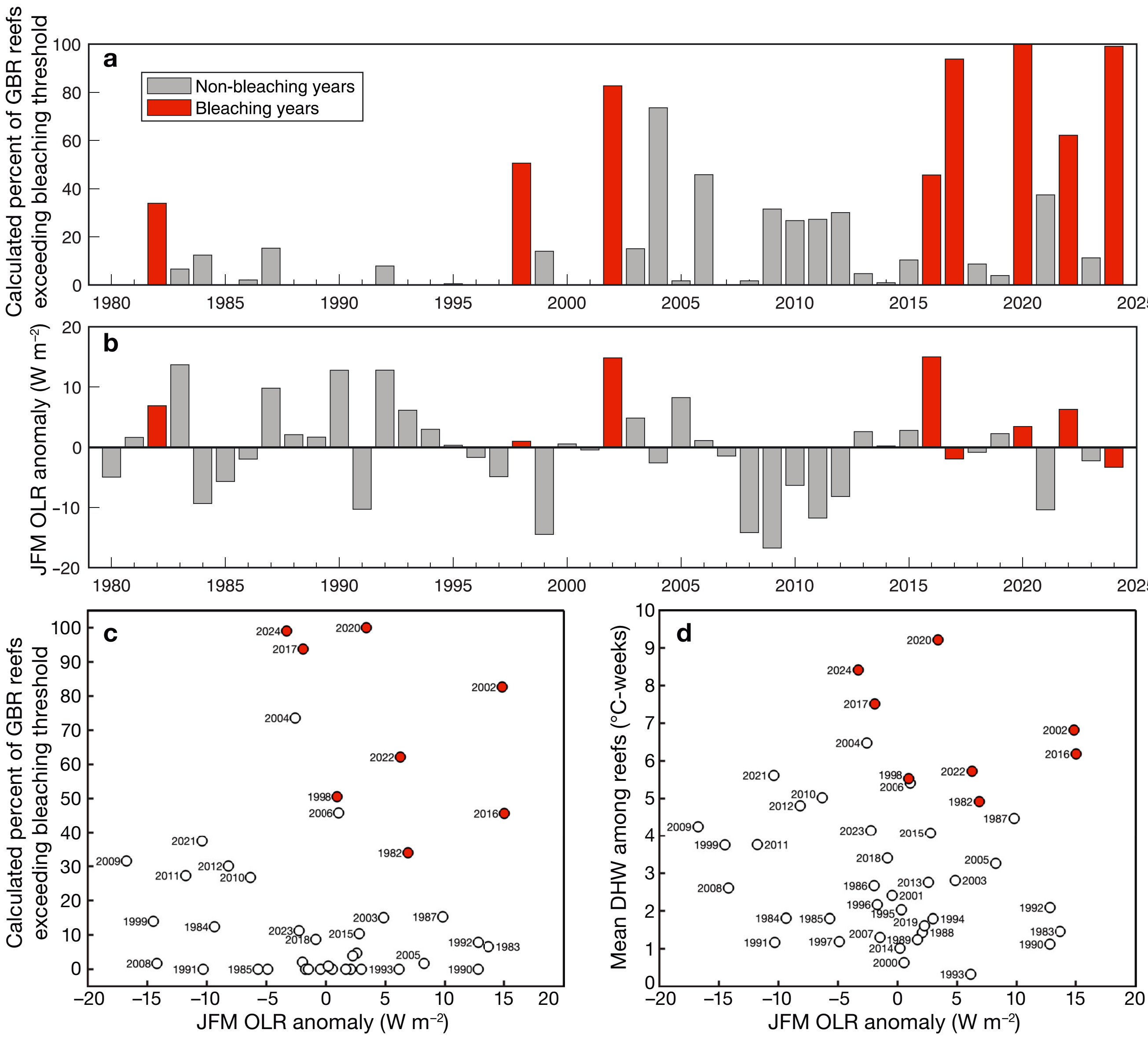

Fig. 2. Summertime heat stress and cloudiness over recent decades on the Great Barrier Reef (GBR). (a) Percent of the 3863 reefs of the GBR predicted to have bleached each year based on whether or not the degree heating weeks (DHW) they were exposed to exceeded 5.4°C-wk. (b) Anomalies of outgoing longwave radiation (OLR) on the GBR during January–March (JFM) of each year. Higher values indicate clearer skies. (c) Predicted bleaching and OLR anomalies. (d) Mean GBR-wide DHW and OLR anomalies. Red circles indicate years of observed mass coral bleaching. See DeCarlo & Harrison (2019) for explanation of the absence of mass bleaching during 2004

bleaching) during 1982 on any of the southern, central, or northern GBR. These authors cited Oliver (1985) correctly for minor bleaching occurring in the central GBR during 1980, but not 1982. As of 2024, bleaching has now struck the GBR during 5 of the past 9 yr, and these dwindling return times deservedly receive great attention. Yet, statements about the GBR bleaching history almost always only go back to 1998 (e.g. Hughes & Kerry 2017, Cantin et al. 2024, Hughes 2024). This unfortunately can lead audiences to interpret that mass bleaching was never observed on the GBR before 1998, a notion reinforced by Hughes (2024) stating, 'Before 1998, coral bleaching on the Great Barrier Reef was infrequent and localized.' Although 'localized' is subjective, I suggest this statement is misleading given what we know about 1982 GBR bleaching.

Consideration of the observations of mass bleaching in 1982 is critical for analyses of long-term bleaching patterns and thresholds on the GBR. Heat stress was lower on the GBR, on average, during 1982 compared to all other mass bleaching years (Fig. 2c,d). There are several possible explanations for this. First, heat stress during 1982 may have just barely crossed the threshold for sparking mass bleaching. This explanation, on its own, seems insufficient because several other years have higher levels of heat stress but without mass bleaching. Second, the heat stress during 1982 could have acted synergistically with other stressors, such as the relatively high light levels and/or elevated levels of nutrients due to anomalously strong upwelling onto the GBR that year (DeCarlo & Harrison 2019). Third, if mass bleaching had not occurred for decades prior to 1982, the coral communities in 1982 may have contained relatively sensitive individuals that died during 1982 and left more heat-tolerant corals that later bleached only under greater heat stress. Coral skeletal cores from the northern GBR and Coral Sea region support this notion in that multiple cores contained 1982 'stress bands' indicative of bleaching, but no other year in the 20th century contained stress bands across multiple cores (DeCarlo et al. 2019). Finally, it is possible that corals acclimated following 1982 so that the heat-stress threshold for initiating bleaching has increased over recent decades. While we may not yet be able to definitively distinguish between these possibilities, I suggest that our ability to test these and other hypotheses regarding bleaching sensitivity on the GBR is limited by the relatively small test set of 8 (including 1982) mass bleaching events that have been observed. Including 1982 in the list of observed mass bleaching events on the GBR is crucial for advancing our understanding of the drivers of coral bleaching and predicting the fate of coral communities under continued anthropogenic warming.

Data and code availability. Data and code are available at https://codeocean.com/capsule/7239149/tree/v1.

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