Supplementary Information for:

Acclimatization of massive reef-building corals to consecutive heatwaves

Thomas M. DeCarlo*, Hugo B. Harrison, Laura Gajdzik, Diego Alaguarda, Riccardo Rodolfo-Metalpa, Juan D’Olivo, Gang Liu, Diana Patalwala, and Malcolm T. McCulloch

*Correspondence to: thomas.decarlo@uwa.edu.au

Supplementary Figures S1-S5

Supplementary Tables S1-S5
Supplementary Figure S1. Marine heatwaves on the northern GBR in the 21st century. Solid black line shows the weekly NOAA Optimum interpolation SST (1° spatial resolution) data for our northern GBR sites from 2000-2017. The dashed and dot-dashed lines show thresholds for Category 1 (orange) and Category II (red) marine heat waves [37]. The x-axis shows months of the year. Summertime Category II heatwaves were reached in 2004, 2010, 2015, 2016, and 2017.
Supplementary Figure S2. Validation of satellite SST with *in-situ* loggers. Each panel compares daily mean SST from *in situ* temperature loggers [21,22] (x-axis) with NOAA CRW satellite SST (y-axis). Blue and red colours indicate all and warm (>28 °C, except for Nouméa >27 °C) time points, respectively. Regression lines show reduced major axis (RMA) fits to all data (blue) and warm data (red), and dashed black lines show 1:1 relationships.
Supplementary Figure S3. Compiling coral core CT scans to develop centuries-long chronologies. Multiple µCT scans (dark/light shading = low/high density) of pieces of the same core are connected to develop a full chronology for core CS19. Yellow tick marks indicate annual low-density bands, with each decade is labelled in yellow text. The first evidence of heat stress is a partial mortality scar dated to 2002 (inset image). Note that the inset image was acquired after slight 3D rotation and tilting to obtain the clearest view of the partial mortality scar.
Supplementary Figure S4. Validation of μCT chronologies with luminescence banding visible under UV light. A μCT scan (left) of core LIZ17-01 with clear density banding is matched to the bright luminescence band (right) visible in the same core, indicating that the bright luminescence band formed between 2010 and 2011. The year labels on the μCT image are placed on the low-density band, with the partial development of a high/low density band pair above 2016 interpreted as 2017 since the core was collected in early October 2017.
Supplementary Figure. S5. Validation of coral chronologies by comparing linear extension estimates from $\mu$CT, luminescent bands, and dissepiment spacing. Each point represents the comparison of annual extension rate measured via two techniques on the same colony, solid blue line indicates RMA regression, and dashed black line indicates a 1:1 relationship.
Supplementary Table S1. Satellite-logger calibration slopes. “Warm” is defined as >28 °C for all locations except Nouméa, where it is >27 °C. Slopes were derived from reduced major axis (RMA) regressions. CI = “confidence interval”.

| Site             | RMA slope | RMA slope 95% CI | RMA slope warm | RMA slope warm 95% CI |
|------------------|-----------|------------------|----------------|-----------------------|
| Lizard Island    | 0.91      | 0.90-0.92        | 0.98           | 0.91-1.06             |
| Yonge Reef       | 1.16      | 1.13-1.18        | 1.69           | 1.01-2.84             |
| Bougainville Reef| 1.02      | 1.01-1.04        | 1.04           | 0.98-1.10             |
| Willis Island    | 1.05      | 1.03-1.08        | 1.07           | 0.94-1.20             |
| Flinders Reef    | 1.03      | 1.01-1.04        | 1.04           | 0.85-1.26             |
| Nouméa           | 0.95      | 0.94-0.96        | 0.90           | 0.84-0.96             |
Supplementary Table S2. Northern Great Barrier Reef coral coring locations, depths, colony ages (earliest dated growth band), and stress band years.

| Core ID  | Reef location    | Latitude  | Longitude  | Depth (m) | Age | Stress band years |
|----------|------------------|-----------|------------|-----------|-----|------------------|
| LIZ17-01 | Lizard Island    | -14.68683 | 145.44128  | 2         | 1912| 1968             |
| LIZ17-02 | Lizard Island    | -14.68683 | 145.44128  | 4         | 1994| 2010             |
| LIZ17-03 | Lizard Island    | -14.68683 | 145.44128  | 4         | 1999| 2002, 2015       |
| LIZ17-04 | Lizard Island    | -14.68756 | 145.46576  | 7         | 1916| 1982             |
| LIZ17-05 | Lizard Island    | -14.68726 | 145.46509  | 2.5       | 1935| 1976             |
| LIZ17-06 | Lizard Island    | -14.68726 | 145.46509  | 2.5       | 1972| 1982, 1995, 2015 |
| LIZ17-07 | Lizard Island    | -14.68934 | 145.46725  | 2.5       | 2002| 2002, 2006, 2010, 2016 |
| LIZ17-08 | Lizard Island    | -14.68933 | 145.46748  | 2.5       | 1932| 1998, 2002, 2011 |
| LIZ17-09 | Lizard Island    | -14.68577 | 145.44197  | 1         | 1993| 2010, 2015       |
| LIZ17-10 | Lizard Island    | -14.68577 | 145.44197  | 1         | 1990| 2002, 2010       |
| YON17-01 | Yonge Reef       | -14.57188 | 145.61493  | 9.5       | 1902| 1910, 1949, 1982, 1998, 2015 |
| YON17-02 | Yonge Reef       | -14.57803 | 145.61040  | 7.5       | 1969| 2004, 2010, 2016 |
| YON17-03 | Yonge Reef       | -14.57803 | 145.61040  | 8         | 1939| 1995, 2002       |
| YON17-04 | Yonge Reef       | -14.57078 | 145.61623  | 3         | 1855| 1877, 2011, 2016 |
| YON17-05 | Yonge Reef       | -14.57624 | 145.61122  | 7.5       | 2008| N/A              |
| YON17-06 | Yonge Reef       | -14.57624 | 145.61122  | 8         | 1970| 1982, 2015       |
| YON17-07 | Yonge Reef       | -14.57624 | 145.61122  | 8         | 1976| 1982, 1994, 2002, 2009 |
| YON17-08 | Yonge Reef       | -14.57624 | 145.61122  | 7         | 1989| 1989, 2002, 2010, 2012 |
| YON17-09 | Yonge Reef       | -14.57624 | 145.61122  | 7         | 1991| 2002, 2010       |
| YON17-10 | Yonge Reef       | -14.57624 | 145.61122  | 9         | 1988| 1990, 2002, 2010, 2015 |
| MAC17-01 | MacGillivray Reef| -14.64767 | 145.48752  | 5.5       | 1986| 2002, 2004, 2014 |
| MAC17-02 | MacGillivray Reef| -14.64767 | 145.48752  | 5         | 1997| 2002             |
| MAC17-03 | MacGillivray Reef| -14.64767 | 145.48752  | 6.5       | 1997| N/A              |
| MAC17-04 | MacGillivray Reef| -14.64767 | 145.48752  | 5         | 2008| N/A              |
| MAC17-05 | MacGillivray Reef| -14.64767 | 145.48752  | 5         | 1998| 2001, 2006, 2013 |
| MAC17-06 | MacGillivray Reef| -14.65400 | 145.48985  | 3         | 1921| 1924, 2010       |
Supplementary Table S3. Coral Sea coral coring locations, depths, colony ages (earliest dated growth band), and stress band years.

| Core ID | Reef location     | Latitude  | Longitude  | Depth (m) | Age  | Stress band years          |
|---------|-------------------|-----------|------------|-----------|------|---------------------------|
| CS01    | Bougainville      | -15.48429 | 147.10564  | 1         | 1949 | 1982, 2002, 2008, 2013, 2016 |
| CS02    | Bougainville      | -15.48384 | 147.10576  | 2         | 2000 | N/A                       |
| CS03    | Bougainville      | -15.48378 | 147.10583  | 2         | 1990 | N/A                       |
| CS04    | Bougainville      | -15.48185 | 147.105   | 4         | 1925 | 1940, 1996, 2002, 2016    |
| CS05    | Bougainville      | -15.48341 | 147.11203  | 2         | 1979 | 1980, 2002                |
| CS06    | Bougainville      | -15.48341 | 147.11203  | 2         | 2001 | N/A                       |
| CS07    | Bougainville      | -15.51208 | 147.13206  | 9         | N/A  | N/A                       |
| CS08    | Bougainville      | -15.51208 | 147.13206  | 12        | N/A  | N/A                       |
| CS09    | Bougainville      | -15.51208 | 147.13206  | 14        | 2008 | 2010                      |
| CS10    | Moore Northwest   | -15.8837  | 149.15414  | 5         | 1986 | N/A                       |
| CS11    | Moore Northwest   | -15.87988 | 149.15758  | 8         | 1981 | 1998                      |
| CS12    | Moore Northwest   | -15.87988 | 149.15758  | 8         | 1995 | N/A                       |
| CS13    | Moore Northwest   | -15.89456 | 149.16384  | 16        | 2008 | N/A                       |
| CS14    | Moore Southeast   | -15.96871 | 149.1927   | 2         | 1815 | N/A                       |
| CS15    | Diane Bank        | -15.72173 | 149.61452  | 7         | 2006 | 2010                      |
| CS16    | Diane Bank        | -15.72331 | 149.61786  | 20        | 2006 | 2010                      |
| CS17    | Diane Bank        | -15.72095 | 149.61618  | 10        | 1998 | N/A                       |
| CS18    | Willis North Cay  | -16.13444 | 149.97911  | 10        | 2012 | N/A                       |
| CS19    | Willis Middle Cay | -16.21289 | 149.98933  | 11        | 1818 | 2002, 2003                |
| CS20    | Willis South Cay  | -16.29156 | 149.96413  | 8         | N/A  | N/A                       |
| CS21    | Magdalene North   | -16.52323 | 150.27562  | 14        | 2008 | N/A                       |
| CS22    | Magdalene North   | -16.52425 | 150.27684  | 13        | 1964 | N/A                       |
| CS23    | Magdalene North   | -16.5242  | 150.27827  | 14        | 1922 | N/A                       |
| CS24    | Magdalene South   | -16.59631 | 150.33476  | 10        | 2006 | N/A                       |
| CS25    | Magdalene South   | -16.59631 | 150.33476  | 10        | 2009 | N/A                       |
| CS26    | Magdalene South   | -16.59955 | 150.32698  | 17        | 1997 | 1998, 2002, 2010, 2016    |
| CS27    | Magdalene South   | -16.59955 | 150.32698  | 13        | 2001 | 2007, 2010, 2012, 2015    |
| CS28    | Flinders Reef     | -17.70472 | 148.46541  | 4         | 1835 | N/A                       |
| CS29    | Flinders Reef     | -17.70472 | 148.46541  | 5         | N/A  | N/A                       |
| CS30    | Flinders Reef     | -17.71715 | 148.44731  | 6         | 1990 | N/A                       |
Supplementary Table S4. Nouméa coral coring locations, depths, colony ages (earliest dated growth band), and stress band years.

| Core ID | Reef location | Latitude  | Longitude | Depth (m) | Age  | Stress band years |
|---------|---------------|-----------|-----------|-----------|------|-------------------|
| NOU Z9A | Nouméa        | -22.29577 | 166.43535 | 3         | 2012 | 2015              |
| NOU Z8A | Nouméa        | -22.29577 | 166.43535 | 3         | 2012 | 2015              |
| NOU Z6A | Nouméa        | -22.29577 | 166.43535 | 3         | 2008 | N/A               |
| NOU Z6A | Nouméa        | -22.29577 | 166.43535 | 3         | 2012 | N/A               |
| NOU B1A | Nouméa        | -22.29577 | 166.43535 | 3         | 2015 | 2015              |
| NOU B8A | Nouméa        | -22.29577 | 166.43535 | 3         | 2007 | 2015              |
| NOU B9A | Nouméa        | -22.29577 | 166.43535 | 3         | 2013 | N/A               |
| NOU B12A| Nouméa        | -22.29577 | 166.43535 | 3         | 2007 | 2009, 2016        |
Supplementary Table S5. Statistical results.

| Model                                      | Slope         | p value | n   | factor(s)                  | $r^2$ | F     |
|--------------------------------------------|---------------|---------|-----|----------------------------|-------|-------|
| Stress band occurrence vs. time (yrs)     | 0.030 ± 0.006 | 1x10^{-6} | 2644 years | depth (p = 0.34) depth (p = 0.02) |       |       |
|                                            |               |         | 65 cores | Noumea (p = 0.02) Yonge (p = 0.006) |       |       |
|                                            |               |         |         | Cores as random factors     |       |       |
| Sensitivity vs. time (yrs)                 | -0.05 ± 0.02  | 0.013   | 13   | -                          | 0.44  | $F_{1,11} = 8.74$ |
| Sensitivity vs. stress band occurrence vs. DHW | -0.13 ± 0.05  | 0.007   | 276  | No sites were significant factors |       |       |
|                                            |               |         |         | Cores as random factors     |       |       |

Notes: ± indicates standard error. Sensitivity vs. time was performed with simple linear regression and has $r^2$ and F statistics, whereas Stress band occurrence vs. time and stress band occurrence vs. DHW were tested with generalized linear mixed effects models.