Measurements of seawater temperature, depth, and photosynthetically active radiation (PAR) across seven sites at Heron Island, southern Great Barrier Reef from 2015 to 2020

Website: https://www.bco-dmo.org/dataset/918182
Data Type: Other Field Results
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Project
» Influence of environmental pH variability and thermal sensitivity on the resilience of reef-building corals to acidification stress (Coral Resilience)

Contributors	Affiliation	Role
Barott, Katie	University of Pennsylvania (Penn)	Co-Principal Investigator
Brown, Kristen	University of Pennsylvania (Penn)	Co-Principal Investigator
Rauch, Shannon	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
Increasing ocean temperatures threaten coral reefs globally, but corals residing in habitats that experience high thermal variability are thought to be better adapted to survive climate-induced heat stress. Here, we used long-term ecological observations and in situ temperature data from Heron Island, southern Great Barrier Reef to investigate how temperature dynamics within various thermally variable vs. thermally stable reef habitats change during a marine heatwave and the resulting consequences for coral community survival. This data set includes the in-field measurements of seawater temperature, depth, and photosynthetically active radiation (PAR) across seven sites at Heron Island, southern Great Barrier Reef.

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Coverage

Location: Heron Island Research Station, Heron Island, southern Great Barrier Reef
Spatial Extent: **N**:-23.4395 **E**:151.9802 **S**:-23.45977 **W**:151.9292
Temporal Extent: 2015-07-24 - 2020-08-16

Methods & Sampling

Study location:
This study was conducted across eight sites at Heron Island, southern Great Barrier Reef (23°27’ S 151°55’ E), previously characterized in detail (Brown et al. 2018, 2020). Briefly, sites included each geomorphological habitat of Heron Reef: reef slope, reef crest, reef flat, shallow lagoon, and deep lagoon (Phinn et al. 2012) (Fig. 1 of Brown et al. 2023). The geomorphological habitats of Heron Reef are distinguished by diverse benthic communities, with hard coral cover higher within the reef slope and macroalgae cover greater within the

lagoonal habitats (Brown et al. 2018; Roelfsema et al. 2021). Reef-wide coral cover in 2015 and 2016 was amongst the highest observations in the past 60 years (Connell et al. 1997; Brown et al. 2018; Roelfsema et al. 2021) (e.g., ~75% within the south-west reef slope and ~20% within lagoon), making these years optimal as a recent baseline record.

Within the reef slope habitat, four sites were established: two within the north-east section of the reef (Fourth Point, 4.2 meters (m) and 8 m) and two within the south-west (Harry's Bommie, 6.1 m and 8.2 m) (Fig. 1 of Brown et al. 2023). The northeast of Heron Reef is the exposed side, subject to extreme wave forces during cyclones, whereas the south-west is sheltered from waves generated by both the south-east trade winds and extreme wave action of cyclones (Connell et al. 1997). One site was established in each other geomorphological habitat, with each site sharing its name: Reef Crest (RC; 0.9 m), Reef Flat (RF; 0.7 m), Shallow Lagoon (SL; 1.3 m) and Deep Lagoon (DL; 2.6 m) (Fig. 1 of Brown et al. 2023). Inside the lagoon, semidiurnal tidal fluctuations result in higher variability in temperature and pH than reef slope sites (Brown et al. 2018; Cyronak et al. 2020) (Fig. 2, Fig. S1 of Brown et al. 2023). Photosynthetically active radiation (PAR; µmol quanta $m^{-2}s^{-1}$) is lower within reef slope habitats (HB5: 75.9, HB8: 72.8, FP5: 179.4, FP8: 58.9) than within the lagoon habitats (RC: 199.2, RF: 371.7, SL: 201.8, DL: 198.8), due to differences in depth (Brown et al. 2018; Cyronak et al. 2020). Mean depth and PAR were determined by use of Conductivity Temperature Depth (CTD) units that continuously recorded between July 2015 and November 2016 (SBE 16plus V2 SEACAT fitted with an auxiliary PAR sensor, Satlantic/ECO-PAR sensor) (see Brown et al. 2018 for more detailed methodology).

Evaluation of thermal stress:
Seawater temperatures were recorded at hourly intervals using cross-calibrated HOBO Pendant loggers (UA-001-64; ± 0.552 degrees Celsius (°C) accuracy) between September 2019 and August 2020. Logger accuracy was assessed at the end of the deployment period using a water bath (Thermo Scientific Precision TSGP20). Due to logger failures, only a partial temperature record was obtained at HB8 (from December 2019), RC (from February 2020), and DL (from February 2020) and there is no temperature record at FP5 (Table 1, Fig. S1 of Brown et al. 2023). No loggers were deployed at FP8 during 2019-2020.

Seawater temperatures recorded in 2019-2020 were compared to temperatures recorded at the same locations in 2015-2016 (see Brown et al. 2018 for detailed methodology). The mean, maximum, minimum, and mean daily amplitude were calculated at each site for the two periods September 2015 to August 2016 and September 2019 to August 2020 (Table 1 of Brown et al. 2023). Daily (24-hour) mean temperatures (T) were extracted from the logger data. The climatological maximum monthly mean (MMM) of Heron Reef is 27.3°C (Weeks et al. 2008). Temperature anomalies, or 'hotspots' (HS), were calculated from the logger data using U.S. National Oceanic and Atmospheric Administration (NOAA) Coral Reef Watch (CRW) methodology (Eakin et al. 2010). If T, representing the daily mean temperature, exceeded the region's coral bleaching threshold (MMM + 1°C; 28.3°C), then the MMM was subtracted from T. Importantly, we did not use nighttime-only temperatures, as is done with NOAA CRW, instead choosing to use 24-hour mean temperatures due to the diel variability across sites. Thermal anomalies were then summed across a rolling 12-week (90-day) period to determine the extent of thermal stress in degree heating weeks (DHW; °C per week).

For more detailed information, please see:
Brown, K.T., Eyal, G., Dove, S.G. et al. (2023) Fine-scale heterogeneity reveals disproportionate thermal stress and coral mortality in thermally variable reef habitats during a marine heatwave. Coral Reefs 42, 131-142.
https://doi.org/10.1007/s00338-022-02328-6

Data Processing Description

The attached Supplemental File "Coral-resilience-to-marine-heatwaves-1.0.zip" contains R notebooks with the code and analyses presented in Brown et al., 2023 (DOI: 10.1007/s00338-022-02328-6). It contains the following files:

"Heron temp data from 2015-2020.Rmd " is an R notebook that compiles all of the environmental data from 2015-2020 and plots it. The temperature data are part of this dataset.

"Brown et al. Temperature variability does not promote coral resilience to marine heatwaves.Rmd" is an R notebook that analyzes and creates the figures for the benthic community composition data in Brown et al., 2023.

The original GitHub repo for these files can be found at https://github.com/imkristenbrown/Coral-resilience-to-marine-heatwaves

BCO-DMO Processing Description

- Imported the original file "All in situ temperature PAR and depth from 2015-2020 at Heron Island.xlsx" into the BCO-DMO system.
- Flagged 'NA' as a missing data value (missing data are empty/blank in the final CSV file).
- Removed the first column (row count).
- Created a column for ISO 8601 date-time in UTC.
- Converted the AEST date-time column to ISO 8601 format.
- Created columns for Latitude and Longitude using the site locations provided as part of the metadata.
- Saved the final file as "918182_v1_heron_isl_temp_2015-2020.csv".

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Data Files

File
918182_v1_heron_isl_temp_2015-2020.csv (Comma Separated Values (.csv), 14.14 MB) MD5:b3ccdf9ed9292519c98f93536ce0f88a Primary data file for dataset ID 918182, version 1

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Supplemental Files

File
Coral-resilience-to-marine-heatwaves-1.0.zip (ZIP Archive (ZIP), 12.00 KB) MD5:7f348828a4cda1be2e6cc2323c5c8d42 Supplemental file for BCO-DMO dataset 918182. The original GitHub repository https://github.com/imkristenbrown/Coral-resilience-to-marine-heatwaves was forked to https://github.com/BCODMO/Coral-resilience-to-marine-heatwaves/ for curation purposes and tagged with release v1.0, which corresponds to this dataset. The original repository may have continued updates.

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Related Publications

Brown, K. T., Bender-Champ, D., Kubicek, A., van der Zande, R., Achlatis, M., Hoegh-Guldberg, O., & Dove, S. G. (2018). The Dynamics of Coral-Algal Interactions in Space and Time on the Southern Great Barrier Reef. Frontiers in Marine Science, 5. https://doi.org/10.3389/fmars.2018.00181
Methods

Brown, K. T., Bender-Champ, D., Achlatis, M., Zande, R. M., Kubicek, A., Martin, S. B., Castro-Sanguino, C., Dove, S. G., & Hoegh-Guldberg, O. (2020). Habitat-specific biogenic production and erosion influences net framework and sediment coral reef carbonate budgets. Limnology and Oceanography, 66(2), 349–365. Portico. https://doi.org/10.1002/lno.11609
Methods

Brown, K. T., Eyal, G., Dove, S. G., & Barott, K. L. (2023). Fine-scale heterogeneity reveals disproportionate thermal stress and coral mortality in thermally variable reef habitats during a marine heatwave. Coral Reefs, 42(1), 131–142. https://doi.org/10.1007/s00338-022-02328-6
Results

Connell, J. H., Hughes, T. P., & Wallace, C. C. (1997). A 30-year study of coral abundance, recruitment, and disturbance at several scales in space and time. Ecological Monographs, 67(4), 461–488. https://doi.org/10.1890/0012-9615(1997)067[0461:aysoca]2.0.co;2 https://doi.org/10.2307/2963466

Methods

Cyronak, T., Takeshita, Y., Courtney, T. A., DeCarlo, E. H., Eyre, B. D., Kline, D. I., Martz, T., Page, H., Price, N. N., Smith, J., Stoltenberg, L., Tresguerres, M., & Andersson, A. J. (2019). Diel temperature and pH variability scale with depth across diverse coral reef habitats. Limnology and Oceanography Letters, 5(2), 193–203. Portico. https://doi.org/10.1002/lol2.10129
Methods

Eakin, C. M., Morgan, J. A., Heron, S. F., Smith, T. B., Liu, G., Alvarez-Filip, L., Baca, B., Bartels, E., Bastidas, C., Bouchon, C., Brandt, M., Bruckner, A. W., Bunkley-Williams, L., Cameron, A., Causey, B. D., Chiappone, M., Christensen, T. R. L., Crabbe, M. J. C., Day, O., … Yusuf, Y. (2010). Caribbean Corals in Crisis: Record Thermal Stress, Bleaching, and Mortality in 2005. PLoS ONE, 5(11), e13969. https://doi.org/10.1371/journal.pone.0013969
Methods

Phinn, S. R., Roelfsema, C. M., & Mumby, P. J. (2012). Multi-scale, object-based image analysis for mapping geomorphic and ecological zones on coral reefs. International Journal of Remote Sensing, 33(12), 3768–3797. https://doi.org/10.1080/01431161.2011.633122
Methods

Roelfsema, C., Kovacs, E. M., Vercelloni, J., Markey, K., Rodriguez-Ramirez, A., Lopez-Marcano, S., Gonzalez-Rivero, M., Hoegh-Guldberg, O., & Phinn, S. R. (2021). Fine-scale time series surveys reveal new insights into spatio-temporal trends in coral cover (2002–2018), of a coral reef on the Southern Great Barrier Reef. Coral Reefs, 40(4), 1055–1067. https://doi.org/10.1007/s00338-021-02104-y
Methods

Weeks, S. J., Anthony, K. R. N., Bakun, A., Feldman, G. C., & Guldberg, O. H.-. (2008). Improved predictions of coral bleaching using seasonal baselines and higher spatial resolution. Limnology and Oceanography, 53(4), 1369–1375. Portico. https://doi.org/10.4319/lo.2008.53.4.1369
Methods

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Parameters

Parameter	Description	Units
ISO_DateTime_AEST	Date and time of measurement in AEST time zone (ISO 8601 format)	unitless
ISO_DateTime_UTC	Date and time of measurement in UTC (ISO 8601 format)	unitless
Site	Site code. Harry's Bommie 8m (HB8), Harry's Bommie 5m (HB5), Reef Crest (RC), Reef Flat (RF), Shallow Lagoon (SL), Deep Lagoon (DL), Fourth Point 5m (FP5)	unitless
Latitude	Latitude of site; negative values = South	decimal degrees
Longitude	Longitude of site; positive values = East	decimal degrees
Date_AEST	Date of measurement	unitless
Depth	Depth	meters (m)
PAR	Photosynthetically active radiation	micromoles quanta per square meter per second (umol quanta m-2 s-1)
Temperature	Water temperature	degrees Celsius

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Instruments

Dataset-specific Instrument Name	HOBO Pendant loggers (UA-001-64)
Generic Instrument Name	Onset HOBO Pendant Temperature/Light Data Logger
Dataset-specific Description	Seawater temperature (2019-2020): HOBO pendant logger
Generic Instrument Description	The Onset HOBO (model numbers UA-002-64 or UA-001-64) is an in-situ instrument for wet or underwater applications. It supports light intensity, soil temperature, temperature, and water temperature. A two-channel logger with 10-bit resolution can record up to approximately 28,000 combined temperature and light measurements with 64K bytes memory. It has a polypropylene housing case. Uses an optical USB to transmit data. A solar radiation shield is used for measurement in sunlight. Temperature measurement range: -20 deg C to 70 deg C (temperature). Light measurement range: 0 to 320,000 lux. Temperature accuracy: +/- 0.53 deg C from 0 deg C to 50 deg C. Light accuracy: Designed for measurement of relative light levels. Water depth rating: 30 m.

Dataset-specific Instrument Name	PAR sensor; Satlantic/ECO-PAR sensor
Generic Instrument Name	Photosynthetically Available Radiation Sensor
Dataset-specific Description	Seawater temperature, photosynthetically active radiation (PAR) and depth (2015-2016): Conductivity Temperature Depth units (SBE 16plusVS SEA-CAT) fitted with an auxiliary PAR sensor, Satlantic/ECO-PAR sensor)
Generic Instrument Description	A PAR sensor measures photosynthetically available (or active) radiation. The sensor measures photon flux density (photons per second per square meter) within the visible wavelength range (typically 400 to 700 nanometers). PAR gives an indication of the total energy available to plants for photosynthesis. This instrument name is used when specific type, make and model are not known.

Dataset-specific Instrument Name	SBE 16plus V2 SEACAT
Generic Instrument Name	Sea-Bird SBE 16Plus V2 SEACAT
Dataset-specific Description	Seawater temperature, photosynthetically active radiation (PAR) and depth (2015-2016): Conductivity Temperature Depth units (SBE 16plusVS SEA-CAT) fitted with an auxiliary PAR sensor, Satlantic/ECO-PAR sensor)
Generic Instrument Description	The SBE 16plus V2 is a high accuracy conductivity and temperature recorder (pressure optional) with RS232 or RS485 interfaces. It is designed for moorings and other long-duration, fixed-site deployments. It has 6 amplified A/D input channels and conditioned power of 500 ma is available for auxiliary sensors, dissolved oxygen, turbidity, fluorescence, PAR etc. Compared to the previous 16plus, the V2 incorporates an electronics upgrade and additional features, with six differentially amplified A/D input channels, one RS-232 data input channel, and 64 MB FLASH memory. Data can be output in XML as well as ASCII and HEX formats. Firmware upgrades can be downloaded through the communications port, without opening the instrument.

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Project Information

Influence of environmental pH variability and thermal sensitivity on the resilience of reef-building corals to acidification stress (Coral Resilience)

Coverage: Kaneohe Bay, Oahu, HI; Heron Island, Queensland, Australia

NSF Award Abstract:
Coral reefs are incredibly diverse ecosystems that provide food, tourism revenue, and shoreline protection for coastal communities. The ability of coral reefs to continue providing these services to society is currently threatened by climate change, which has led to increasing ocean temperatures and acidity that can lead to the death of corals, the animals that build the reef framework upon which so many species depend. This project examines how temperature and acidification stress work together to influence the future health and survival of corals. The scientists are carrying out the project in Hawaii where they have found individual corals with different sensitivities to temperature stress that are living on reefs with different environmental pH conditions. This project improves understanding of how an individual coral's history influences its response to multiple stressors and helps identify the conditions that are most likely to support resilient coral communities. The project will generate extensive biological and physicochemical data that will be made freely available. Furthermore, this project supports the education and training of undergraduate and high school students and one postdoctoral researcher in marine science and coral reef ecology. Hands-on activities for high school students are being developed into a free online educational resource.

This project compares coral responses to acidification stress in populations experiencing distinct pH dynamics (high diel variability vs. low diel variability) and with distinct thermal tolerances (historically bleaching sensitive vs. tolerant) to learn about how coral responses to these two factors differ between coral species and within populations. Experiments focus on the two dominant reef builders found at these stable and variable pH reefs: Montipora capitata and Porites compressa. Individuals of each species exhibiting different thermal sensitivities (i.e., bleached vs. pigmented) were tagged during the 2015 global coral bleaching event. This system tests the hypotheses that 1) corals living on reefs with larger diel pH fluctuations have greater resilience to acidification stress, 2) coral resilience to acidification is a plastic trait that can be promoted via acclimatization, and 3) thermally sensitive corals have reduced capacity to cope with pH stress, which is exacerbated at elevated temperatures. Coral cells isolated from colonies from each environmental and bleaching history are exposed to acute pH stress and examined for their ability to recover intracellular pH in vivo using confocal microscopy, and the expression level of proteins predicted to be involved in this recovery (e.g., proton transporters) is examined via Western blot and immunolocalization. Corals from each pH history are exposed to stable and variable seawater pH in a controlled aquarium setting to determine the level of plasticity of acidification resilience and to test for pH acclimatization in this system. Finally, corals with different levels of thermal sensitivity are exposed to thermal stress and recovery, and their ability to regulate pH is examined over time. The results of these experiments help identify reef conditions that promote coral resilience to ocean acidification against the background of increasingly common thermal stress events, while advancing mechanistic understanding of coral physiology and symbiosis.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1923743

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