Experimental sump pCO2 data collected as part of a study of pCO2 variability on the reef-building coral Pocillopora damicornis conducted at Heron Island Research Station, Heron Island, southern Great Barrier Reef in 2021

Website: https://www.bco-dmo.org/dataset/885674
Data Type: Other Field Results
Version: 1
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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)	Principal Investigator
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Abstract
This dataset contains experimental sump pCO2 data. These data were collected as part of a study of pCO2 variability on the reef-building coral Pocillopora damicornis conducted at Heron Island Research Station, Heron Island, southern Great Barrier Reef in 2021 (Brown et al., 2022). Abstract for all data from the study (Brown et al., 2022) including this dataset: Ocean acidification is a growing threat to coral growth and the accretion of coral reef ecosystems. Corals inhabiting environments that already endure extreme diel pCO2 fluctuations, however, may represent acidification resilient populations capable of persisting on future reefs. Here, we examined the impact of pCO2 variability on the reef-building coral Pocillopora damicornis originating from reefs with contrasting environmental histories (variable reef flat vs. stable reef slope) following reciprocal exposure to stable (218 ± 9) or variable (911 ± 31) diel pCO2 amplitude (µtam) in aquaria over eight weeks. This study measured: growth (net calcification, extension, CaCO3 density) and physiology (dark respiration, light-enhanced dark respiration, host soluble protein, mycosporine-like amino acids, net photosynthesis, photosynthetic efficiency, endosymbiont density, chlorophyll a concentration, intracellular pH) of P. damicornis across treatment and origin. See all datasets related to this publication (https://www.bco-dmo.org/related-resource/885684).

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Coverage

Spatial Extent: **Lat**:-23.27 **Lon**:151.55
Temporal Extent: 2021-01-06 - 2021-04-06

Methods & Sampling

This methodology describes this dataset and other datasets from this experiment. See "Related Datasets" section for data access and more details of each related dataset.

Study location and environmental conditions

The experiment was performed during the austral summer from mid-January to late March 2021 at Heron Island Research Station (HIRS), southern Great Barrier Reef (23 27°S, 151 55°E). Heron Reef is composed of five distinct geomorphological habitats characterized by diverse benthic communities and biogeochemical conditions (Phinn et al., 2012; Brown et al., 2018). This study focused on two distinct habitats, the reef flat (North Beach) and reef slope (North Bommie) (Brown et al. 2022 Figure 1). Semidiurnal tidal fluctuations on the reef flat result in higher variability in temperature and CO2 compared to reef slope habitats, and exposes reef flat corals to extreme temperature and CO2 conditions projected for future reefs (Rathbone et al., 2021; Camp et al., 2018; Brown et al., 2018)(Brown et al., 2022 Figure 1 and Figure S1). In-field measurements (temperature, photosynthetically active radiation, and nutrients) were recorded concurrently with the manipulative experiment at the same locations where corals were collected (8 January – 18 March 2021), whereas pCO2 was recorded over the same season, but in 2016 (8 January – 18 March 2016; Supp Methods). Long-term studies show remarkable consistency in pCO2 measurements recorded at the same location between years (Fabricius et al., 2020), suggesting pCO2 variability measured within these identical reef habitats over the same time period may be similar across years.

Seawater temperature (n=2 sensors) and photosynthetically active radiation (PAR) (n=2 sensors) were continuously recorded at 30 min intervals (Brown et al., 2022 Figure S1). PAR sensors were fitted with copper rings to prevent biofouling and were cleaned weekly. Additionally, weekly trips were made to North Beach and North Bommie at both low and high tide to collect seawater samples to determine nutrient concentrations (i.e., ammonium, nitrate, nitrite and phosphate) (Brown et al., 2022 Figure 1 and Figure S2). Seawater was collected at depth directly adjacent to sensors in a 500 mL glass bottle pre-rinsed with 0.1M HCl. Samples were brought to HIRS in the dark on ice after collection and immediately filtered (0.22 µM) into triplicate 20mL glass vials pre-rinsed with 0.1M HCl. Samples were stored at -20°C prior to analysis. Nutrient determination was done by Flow Injection Analysis (Lachat QuikChem 8500 Series 2 Flow Injection Analyser) at the Advanced Water Management Facility, University of Queensland. Seawater pCO2 conditions were determined by use of by use of Conductivity Temperature Depth units (SBE 16plusVS SEA-CAT) fitted with an auxiliary CO2 sensor (Optical CO2 sensor, AMT Analysemesstechnik GmbH) within the reef flat (n=1) and reef slope (n=1) over the same season in 2016 (Brown et al., 2022 Figure 1).

Sample collection, species identification and experimental design

Fragments of the coral *Pocillopora damicornis* were collected from the reef flat and slope locations within the same depth range (1–3 m) on 14 and 15 January 2021 (Brown et al., 2022 Figure 1). Four fragments were collected from each individual colony (genetic clones), totaling 96 fragments from 24 colonies (n = 12 per habitat) (Brown et al., 2022 Figure S2). One additional chip per colony was preserved in 100% ethanol and kept at -80°C for genetic analyses to confirm the collected coral specimens were all *P. damicornis* based on the mitochondrial ORF [cf. Schmidt-Roach et al., 2013] and identify the species of resident intracellular Symbiodiniaceae using the ITS2 rDNA and chloroplast minicircle psbA non coding region [cf. (Sampayo et al, 2009; LaJeunesse et al., 2011); full details in Brown et al., 2022 Supp Methods). All 96 collected coral fragments were standardized to a length of ~5 cm using bone cutters and randomly suspended with nylon fishing line from a bamboo stick (Brown et al., 2022 Figure S2). Six fragments were suspended from each stick and two sticks placed in each experimental treatment tank (33L; n = 12 fragments per tank). To minimize 'tank effects', the eight tanks were randomized across one outdoor table (n = 4 per treatment), with each set of coral fragments rotated into an adjacent tank of the same treatment every third day. Tanks and lids were covered with filters (Old Steel Blue #725, Lee Filters) to mimic the light environment at the collection sites (Brown et al., 2022 Figure 1, Figure S1, Figure S3). Noticeable paling was observed during the first week of the experiment, so light intensities were reduced with an additional shade cloth (Brown et al., 2022 Figure S1). All surfaces including exposed cut coral bases were cleaned every three days to remove any epilithic algae.

After 7 days of recovery from collection and handling, corals were exposed to two distinct treatments for 8 weeks: (1) stable pCO2 and (2) variable pCO2 (Brown et al., 2022 Figure 2), which were maintained following previously described methods (Eyre et al., 2018; Dove et al., 2013)(Brown et al., 2022 Supp Methods, Figure S3). Upstream CO2 was continuously recorded in treatment sumps (Brown et al., 2022 Figure 2) and within experimental tanks, seawater temperature (HOBO pendant logger) and photosynthetically active radiation (Odyssey PAR sensor) were continuously measured at 30 min intervals in each treatment by randomly rotating two probes per treatment between tanks (Brown et al., 2022 Figure S1). Weekly samples (n = 3 per treatment) were collected for total alkalinity (AT) and pHTotal at midday and midnight. AT was determined via the Gran titration method using 0.1 M HCl and pHTotal was determined via a high-precision glass pH electrode (DGi101-SC, Mettler Toledo) across replicated 20 g seawater samples (Kline et al., 2012). Acid concentration

was calibrated at the beginning of each titration session using the certified reference materials from the Dickson Laboratory at Scripps Institute of Oceanography, USA. Salinity was measured via refractometer, and remained constant at 35.0 throughout the experiment. Parameters of the seawater carbonate chemistry, including carbonate, bicarbonate, aragonite saturation state, were calculated from our temperature, salinity, AT and pHTotal measurements using the *seacarb* package in R (Gattuso, 2021)(Brown et al., 2022 Table 1).

CO2 conditions were manipulated using a flow-through acidification simulation system. Seawater was pumped directly from the Heron Island reef flat into two very large treatment sumps (8,000 L). Sumps were maintained in the dark, and in combination with high flow rates, were used to effectively eliminate any interaction between the sump walls and the bulk of the water that passed through them (i.e., differential confinement effects) (Rivest et al., 2017). Conditions in each sump were manipulated using a computer-controlled feedback system that responded to conditions measured in experimental aquaria (SCIWARE Software Solutions). CO2 (Invensys Process Systems and CO2 -Pro CO2 regulators, ProOceanus) was manipulated by injection of air enriched to 30% CO2 or CO2 -free air. Sump, as opposed to tank, CO2 was controlled and monitored to allow organisms and their biology to influence in-tank CO2. Manipulated treatment seawater was then pumped from the sumps into flow-through tanks at an average rate of 4.17 L min-1, with circulation within each tank enhanced by a wave-maker (Nano 900, Hydor).

For more detailed information, please see: Brown et al. (2022).

Data Processing Description

Parameters of the seawater carbonate chemistry, including carbonate, bicarbonate, aragonite saturation state, were calculated from our temperature, salinity, AT and pHTotal measurements using the seacarb package in R (Kline et al, 2012) (Brown et al., 2022 Table 1). Seawater temperature, CO2, PAR and nutrient concentrations were analyzed for differences within and between experimental treatments (treatment: stable, variable) and reef habitats (origin: reef flat, reef slope). The effect of tide (tide: high, low) was also explored on nutrient concentrations. All data met assumptions (homogeneity of variance, normality of distribution) through graphical analyses of residual plots. The significance of fixed effects and their interactions was determined using an analysis of variance with a type III error structure using the Anova function in the car package (Bates et al., 2015). Significant interactive effects were followed by pairwise comparison of estimate marginal means using the emmeans package with Tukey HSD adjusted p values (Lenth et al., 2018).

See results publication Brown et al., 2022 for details of statistical analyses performed using these data. All statistical analyses were done using R version 4.0.0 software (R Core Team, 2021), and graphical representations were produced using the package ggplot2 (Wickham, 2016).

The analysis code package for 'Environmental memory gained from exposure to extreme pCO2 variability promotes coral cellular acid-base homeostasis" published as Brown (2022, doi: 10.5281/zenodo.7373705) which is a publication of github repository https://github.com/imkristenbrown/pCO2-variability-promotes-coral-cellular-acid-base-homeostasis.

The code package includes the following R-markdown files and supplemental files related to this dataset:

- 'Sump pCO2 all.csv"pHi all.csv' = This is the source data file that was imported for this BCO-DMO dataset https://www.bco-dmo.org/dataset/885674
- 'Experimental and in situ temperature all.csv' = This is the source data file that was imported for BCO-DMO dataset https://www.bco-dmo.org/dataset/885654
- 'Nutrient results with sample IDs.csv' = This is the source data file that was imported for BCO-DMO dataset https://www.bco-dmo.org/dataset/885669
- 'In situ and experimental physio-chemical conditions.Rmd' = R markdown file with code for analyses and figures for the physico-chemical conditions
- 'seacarb_R.csv' = Parameters of the seawater carbonate chemistry, including carbonate, bicarbonate, aragonite saturation state, were calculated from our temperature, salinity, total alkalinity and pHTotal measurements using the seacarb package in R
- 'Seacarb_all.csv' = R markdown file with code for analyses and figures for the physico-chemical conditions

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BCO-DMO data manager processing notes:
* Source file 'Sump pCO2 all.csv' imported as a data table into the BCO-DMO data system with values "NA" as missing data identifiers.
* Columns deemed "unnecessary for data analyses or interpretation" by submitter were removed from table (Mean_so_far,Std_Dev_so_far,SWVersion)
* Added description that Date and Time columns are AEST (as stated by submitter).
* Added ISO_DateTime_UTC column

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Data Files

File
infield_pco2.csv (Comma Separated Values (.csv), 729.51 KB) MD5:cd2177d8e923c4f1e819d2a2afc4826b Primary data file for dataset ID 885674

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Related Publications

Brown, K. T. (2022). Barott Lab/Heron pHi [Data set]. Zenodo. https://doi.org/10.5281/ZENODO.7373705 https://doi.org/10.5281/zenodo.7373705
Software

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., Mello-Athayde, M. A., Sampayo, E. M., Chai, A., Dove, S., & Barott, K. L. (2022). Environmental memory gained from exposure to extreme pCO2 variability promotes coral cellular acid–base homeostasis. Proceedings of the Royal Society B: Biological Sciences, 289(1982). https://doi.org/10.1098/rspb.2022.0941
Results

Camp, E. F., Schoepf, V., Mumby, P. J., Hardtke, L. A., Rodolfo-Metalpa, R., Smith, D. J., & Suggett, D. J. (2018). The Future of Coral Reefs Subject to Rapid Climate Change: Lessons from Natural Extreme Environments. Frontiers in Marine Science, 5. https://doi.org/10.3389/fmars.2018.00004
Methods

Dove, S. G., Brown, K. T., Van Den Heuvel, A., Chai, A., & Hoegh-Guldberg, O. (2020). Ocean warming and acidification uncouple calcification from calcifier biomass which accelerates coral reef decline. Communications Earth & Environment, 1(1). https://doi.org/10.1038/s43247-020-00054-x
Methods

Fabricius, K. E., Neill, C., Van Ooijen, E., Smith, J. N., & Tilbrook, B. (2020). Progressive seawater acidification on the Great Barrier Reef continental shelf. Scientific Reports, 10(1). https://doi.org/10.1038/s41598-020-75293-1
Methods

Fox J et al. (2012) Package 'car': Companion to Applied Regression. R package version 2.0. Vienna: R Foundation for Statistical Computing. Available from https://cran.r-project.org/package=car
Software

Gattuso J-P., et al. (2021). seacarb: seawater carbonate chemistry with R. R package version 3.2. http://CRAN.Rproject.org/package=seacarb
Software

LaJeunesse, T. C., & Thornhill, D. J. (2011). Improved Resolution of Reef-Coral Endosymbiont (Symbiodinium) Species Diversity, Ecology, and Evolution through psbA Non-Coding Region Genotyping. PLoS ONE, 6(12), e29013. https://doi.org/10.1371/journal.pone.0029013
Methods

Lenth, R. et al. (2018). emmeans: Estimated Marginal Means, aka Least-Squares Means. Estimated Marginal Means, aka Least-Squares Means.R package version 1.3. Vienna: R Foundation for Statistical Computing. Available from https://cran.r-project.org/package=emmeans
Software

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

R Core Team (2021). R: A language and environment for statistical computing. R v4.0.0. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/
Software

Rathbone, M., Brown, K. T., & Dove, S. (2021). Tolerance to a highly variable environment does not infer resilience to future ocean warming and acidification in a branching coral. Limnology and Oceanography, 67(1), 272–284. Portico. https://doi.org/10.1002/lno.11991
Methods

Rivest, E. B., Comeau, S., & Cornwall, C. E. (2017). The Role of Natural Variability in Shaping the Response of Coral Reef Organisms to Climate Change. Current Climate Change Reports, 3(4), 271–281. https://doi.org/10.1007/s40641-017-0082-x
Methods

SAMPAYO, E. M., DOVE, S., & LAJEUNESSE, T. C. (2009). Cohesive molecular genetic data delineate species diversity in the dinoflagellate genusSymbiodinium. Molecular Ecology, 18(3), 500–519. https://doi.org/10.1111/j.1365-294x.2008.04037.x https://doi.org/10.1111/j.1365-294X.2008.04037.x
Methods

Schmidt-Roach, S., Lundgren, P., Miller, K. J., Gerlach, G., Noreen, A. M. E., & Andreakis, N. (2012). Assessing hidden species diversity in the coral Pocillopora damicornis from Eastern Australia. Coral Reefs, 32(1), 161–172. https://doi.org/10.1007/s00338-012-0959-z
Methods

Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York. ISBN 978-3-319-24277-4, https://ggplot2.tidyverse.org. https://doi.org/10.1007/978-3-319-24277-4
Methods

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Related Datasets

IsRelatedTo

Barott, K., Brown, K. T. (2023) **Experimental and in situ seawater nutrient data collected as part of a study of pCO2 variability on the reef-building coral Pocillopora damicornis conducted at Heron Island Research Station, Heron Island, southern Great Barrier Reef in 2021.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2022-12-20 doi:10.26008/1912/bco-dmo.885669.1 [view at BCO-DMO]
Relationship Description: Data from the same experiment.

Barott, K., Brown, K. T. (2023) **Experimental and in situ seawater temperature data collected as part of a study of pCO2 variability on the reef-building coral Pocillopora damicornis conducted at Heron Island Research Station, Heron Island, southern Great Barrier Reef in 2021.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2022-12-20 doi:10.26008/1912/bco-dmo.885654.1 [view at BCO-DMO]
Relationship Description: Data from the same experiment.

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Parameters

Parameter	Description	Units
Date	Date (local, Time Zone AEST)	unitless
Time	Time (local, Time Zone AEST)	unitless
Name	Name, treatment (Stable | Variable)	unitless
CO2_Measured	CO2 measured (ppm)	parts per million (ppm)
CO2_Setpoint	CO2 setpoint (ppm)	parts per million (ppm)
ISO_DateTime_UTC	Date and time in ISO 8601 format (in UTC time zone).	unitless

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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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