Annual calcification histories for corals from ten Palau reef sites representing lagoon and barrier reef environments

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Project
» Constraining Thermal Thresholds and Projections of Temperature Stress on Pacific Coral Reefs Over the 21st Century: Method Refinement and Application (Thermal Thresholds and Projections)

Contributors	Affiliation	Role
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Abstract
Annual calcification histories for corals from ten Palau reef sites representing lagoon and barrier reef environments.

Table of Contents

Coverage

Spatial Extent: **N**:7.822 **E**:134.562 **S**:7.16 **W**:134.22
Temporal Extent: 1990-01-01 - 2013-12-31

Dataset Description

Annual calcification histories for corals from ten reef sites representing lagoon and barrier reef environments.

These data were originally published in figure 5 of:
H.C. Barkley, A.L. Cohen. Skeletal stress markers in *Porites* corals estimate coral reef community bleaching. Coral Reefs, 35, 1407-1417 (2016). doi:10.1007/s00338-016-1483-3

Methods & Sampling

Coral skeletal core collection: We collected 101 skeletal cores from massive *Porites* coral colonies at ten reef sites representing two major reef environments, barrier reef and lagoon, the latter including fringing reefs around the uplifted karst Rock Islands. The two environments are broadly distinguishable in both physical (flow, temperature, and light regimes) and chemical (carbon system parameters, salinity) characteristics with generally higher flow, light, pH, and salinity and lower SST on the barrier reefs (Shamberger et al. 2014; Barkley et al. 2015).

Skeletal cores (20-40 cm in length) were collected in April 2011, September 2011, April 2012, August 2014, and January 2015 vertically from live coral colonies at 1-6 m depth using pneumatic drills with 3.8 cm diameter diamond drill bits. Core holes were filled with cement plugs hammered flush with the colony surface and sealed with underwater epoxy. Visual inspections of colonies 6-12 months after coring revealed significant overgrowth of plugs and no long-term impacts to the corals. Coral cores were oven-dried and scanned with a Siemens Volume Zoom Helical Computerized Tomography (CT) Scanner at Woods Hole Oceanographic Institution. 3-D CT scans of coral cores were analyzed using OsiriX freeware to visualize the 3-D image (Cantin et al. 2010; Crook et al. 2013) and an automated MATLAB code to quantify skeletal growth parameters and stress banding (DeCarlo et al. 2015).

Coral calcification histories: Annual calcification rates were calculated as the product of annual linear extension and density following the automated procedure described in DeCarlo et al. (2015), which traces density variations along individual corallites identified within the entire 3-D core. Extension rates (upward linear growth) were measured between the successive low-density bands of annual high-low density couplets. Annual density banding was clearly represented in all cores, with low density bands formed at the beginning of each year (c. February) and high-density bands accreted toward the mid-to-late months of the year (c. September). Band identifications were verified using cross-dating, a dendrochronology technique in which shared years of lower growth rates are identified and matched across core records (Fritts 1976; Yamaguchi 1991). Annual skeletal densities were calculated from CT scan intensities converted to calcium carbonate density values using nine coral standards (0.81-1.54 g cm-3), where independent measurements of weight and volume for each standard were used to derive a linear relationship between CT scan intensity values (in Hounsfield units) and calcium carbonate density (in g cm-3) (DeCarlo et al. 2015).

Data Processing Description

BCO-DMO Processing:
- modified parameter names to comply with BCO-DMO naming conventions;
- replaced spaces with underscores;
- added site lats and lons obtained from the Supplmentary Material to Barkley and Cohen (2016).

[table of contents | back to top]

Data Files

File
coral_calc_rates.csv (Comma Separated Values (.csv), 105.27 KB) MD5:5695b5fa3fb1f29a5495e654daec92ab Primary data file for dataset ID 707106

[table of contents | back to top]

Related Publications

Barkley, H. C., & Cohen, A. L. (2016). Skeletal records of community-level bleaching in Porites corals from Palau. Coral Reefs, 35(4), 1407–1417. doi:10.1007/s00338-016-1483-3
Results
,
Methods

Barkley, H. C., Cohen, A. L., Golbuu, Y., Starczak, V. R., DeCarlo, T. M., & Shamberger, K. E. F. (2015). Changes in coral reef communities across a natural gradient in seawater pH. Science Advances, 1(5), e1500328–e1500328. doi:10.1126/sciadv.1500328
Methods

Barkley, H. C., Cohen, A. L., McCorkle, D. C., & Golbuu, Y. (2017). Mechanisms and thresholds for pH tolerance in Palau corals. Journal of Experimental Marine Biology and Ecology, 489, 7–14. doi:10.1016/j.jembe.2017.01.003
General

Cantin, N. E., Cohen, A. L., Karnauskas, K. B., Tarrant, A. M., & McCorkle, D. C. (2010). Ocean Warming Slows Coral Growth in the Central Red Sea. Science, 329(5989), 322–325. doi:10.1126/science.1190182
Methods

Crook, E. D., Cohen, A. L., Rebolledo-Vieyra, M., Hernandez, L., & Paytan, A. (2013). Reduced calcification and lack of acclimatization by coral colonies growing in areas of persistent natural acidification. Proceedings of the National Academy of Sciences, 110(27), 11044–11049. doi:10.1073/pnas.1301589110
Methods

DeCarlo, T. M., Cohen, A. L., Barkley, H. C., Cobban, Q., Young, C., Shamberger, K. E., Brainard R.E., Golbuu, Y. (2015). Coral macrobioerosion is accelerated by ocean acidification and nutrients. Geology, 43(1), 7–10. doi:10.1130/g36147.1 https://doi.org/10.1130/G36147.1
Methods

Fritts H (1976) Tree rings and climate. Academic Press, New York https://isbnsearch.org/isbn/0-12-268450-8
Methods

Shamberger, K. E. F., Cohen, A. L., Golbuu, Y., McCorkle, D. C., Lentz, S. J., & Barkley, H. C. (2014). Diverse coral communities in naturally acidified waters of a Western Pacific reef. Geophysical Research Letters, 41(2), 499–504. doi:10.1002/2013gl058489 https://doi.org/10.1002/2013GL058489
Methods

Yamaguchi, D. K. (1991). A simple method for cross-dating increment cores from living trees. Canadian Journal of Forest Research, 21(3), 414–416. doi:10.1139/x91-053
Methods

[table of contents | back to top]

Parameters

Parameter	Description	Units
site	Name of reef site where cores were collected	unitless
reef_type	Reef environment at core collection site (Barrier or Lagoon)	unitless
lat	Latitude of the reef site; North = positive	decimal degrees
lon	Longitude of the reef site; East = positive	decimal degrees
coral_id	Unique coral identification number	unitless
year	Year of growth rate measured	unitless
density	Coral skeletal density	grams per square centimeter (g/cm2)
extension	Coral annual linear extension rate	centimeters per year (cm/yr)
calcification	Coral annual calcification rate	grams per square centimeter per year (g/cm2/yr)

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	Siemens Volume Zoom Helical Computerized Tomography (CT) Scanner
Generic Instrument Name	Computerized Tomography (CT) Scanner
Dataset-specific Description	Siemens Volume Zoom Helical Computerized Tomography (CT) Scanner
Generic Instrument Description	A CT scan makes use of computer-processed combinations of many X-ray measurements taken from different angles to produce cross-sectional (tomographic) images (virtual "slices") of specific areas of a scanned object.

[table of contents | back to top]

Deployments

Palau_reefs_2011-13

Website	https://www.bco-dmo.org/deployment/489112
Platform	PICRC Small Boats
Start Date	2011-09-19
End Date	2013-11-12
Description	Between September 2011 and November 2013, samples were collected from sites throughout the Palauan archipelago. Sampling was performed from small boats taken out daily from the Palau International Coral Reef Center (PICRC). Sampling was done as part of the project, "An Investigation of the Role of Nutrition in the Coral Calcification Response to Ocean Acidification".

[table of contents | back to top]

Project Information

Constraining Thermal Thresholds and Projections of Temperature Stress on Pacific Coral Reefs Over the 21st Century: Method Refinement and Application (Thermal Thresholds and Projections)

Description from NSF award abstract:
Sea surface temperature (SST) across much of the global tropics has increased by 0.5-1 degrees C in the past 4 decades and, with it, the frequency and geographic extent of coral bleaching events and reef mortality. As levels of atmospheric CO2 continue to rise, there is mounting concern that CO2-induced climate change will pose the single greatest threat to the survival of coral reefs. Averaged output of 21 IPCC climate models for a mid-range CO2 emissions scenario predicts that tropical SSTs will increase another 1.5-3 degrees C by the end of this century. Combined with current estimates of thermal thresholds for coral bleaching, the outlook for the future of coral-reef ecosystems, worldwide, appears bleak. There are several key issues that limit accurate predictions of the full and lasting impact of rising SSTs. These include (1) level of confidence in the spatial and temporal patterns of the predicted warming, (2) knowledge of thermal thresholds of different reef-building coral species, and (3) the potential for corals to increase resistance to thermal stress through repeated exposure to high temperature events.

New skeletal markers have been developed that constrain the thermal thresholds and adaptive potential of multiple, individual coral colonies across 3-D space and through time. The method, based on 3-D CAT scan reconstructions of coral skeletons, has generated initial data from two coral species in the Red Sea, Great

Barrier Reef and Phoenix Islands. Results showed that large, abrupt declines in skeletal growth occur at thresholds of accumulated heat stress defined by NOAA's Degree Heating Weeks Index (DHWs). In addition, there was a significant correlation between host lipid reserve, an independent measure of stress and mortality risk, and rates of skeletal growth. Because the coral skeleton archives the history of each coral's response to and recovery from successive, documented thermal anomalies, this approach pinpoints the thermal thresholds for sub-lethal impacts, the recovery time (if any) following a return to normal oceanographic conditions, and tests for a dampened response following successive events, indicative of acclimation.

This research program builds on initial work, focusing on method refinement and application to corals on two central Pacific reefs. With contrasting thermal histories, these reefs are considered at greatest risk from future ocean warming. In parallel, new experiments will be run on an ocean general-circulation model (OGCM) that is well suited to the tropical Pacific and of sufficiently high resolution, both horizontal and vertical, to maximize projections of thermal stress on specific central Pacific Reef sites over the next few decades. The OGCM output will also be of sufficient temporal resolution to compute DHWs, thus addressing a major limitation of the direct application of global climate model output (as archived for the IPCC AR4) toward coral-reef studies. Specifically, this study will: (1) collect multiple new, medium-length (15-30 yrs) cores and branches from two dominant reef-building species at 1-30m depth in the Gilbert and Jarvis Islands, central tropical Pacific; (2) apply 3-D CAT scanning and image analysis techniques to quantify systematically thermal thresholds, rates of recovery and resilience for each species, at each reef site and with depth; (3) quantify energetic reserve and symbiont genotype amongst thermally more- and less- resilient colonies, establishing a quantitative link between calcification stress and mortality risk, and determining the physiological basis for calcification responses to thermal stress; (4) use an OGCM specifically tailored to the tropical Pacific to produce a dynamically consistent set of forecasts for near-term climate change at the target reef sites; and (5) combine coral data with model output and refine the projected thermal stress forecast, in degree heating weeks, for corals in this central Pacific Island group over the 21st century.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1031971

[table of contents | back to top]