

Reef locations, macrobioerosion rates, and nitrate concentrations in the tropical Pacific from 2011-2012 (Coral Reef Ecosystem OA Impact project, Thermal Thresholds and Projections project)

Website: <https://www.bco-dmo.org/dataset/542290>

Version: 2014-12-10

Project

- » [Toward Predicting the Impact of Ocean Acidification on Net Calcification by a Broad Range of Coral Reef Ecosystems: Identifying Patterns and Underlying Causes](#) (Coral Reef Ecosystem OA Impact)
- » [Constraining Thermal Thresholds and Projections of Temperature Stress on Pacific Coral Reefs Over the 21st Century: Method Refinement and Application](#) (Thermal Thresholds and Projections)

Programs

- » [Science, Engineering and Education for Sustainability NSF-Wide Investment \(SEES\): Ocean Acidification \(formerly CRI-OA\)](#) (SEES-OA)
- » [Ocean Carbon and Biogeochemistry](#) (OCB)

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Coverage

Spatial Extent: N:19.316 E:-80 S:-14.545 W:135

Dataset Description

Using an automated program to quantify macrobioerosion in three-dimensional computerized tomography (CT) scans of coral cores, macrobioerosion rates of live *Porites* colonies in both low-nutrient (oligotrophic) and high-nutrient ($>1 \mu\text{M}$ nitrate) waters were measured across the Pacific basin.

Related Datasets:

[Porites macrobioerosion: seawater chemistry](#)

[Porites macrobioerosion: skeleton density](#): individual core data

Relevant References:

* 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*.

DeCarlo, T. M., Cohen, A. L., Barkley, H. C., Cobban, Q., Young, C., Shamberger, K. E., Brainard, R.E., Golbuu, Y. (2015). [Supplemental information](#) to the above publication associated with DeCarlo et al. (2015) in *Geology*.

D'Croz, L., and O'Dea, A., 2007. Variability in upwelling along the Pacific shelf of Panama and implications for the distribution of nutrients and chlorophyll: *Estuarine, Coastal and Shelf Science*, v. 73, p. 325–340, doi:10.1016/j.ecss.2007.01.013.

Manzello, D.P., Kleypas, J.A., Budd, D.A., Eakin, C.M., Glynn, P.W., and Langdon, C., 2008, Poorly cemented coral reefs of the eastern tropical Pacific: Possible insights into reef development in a high-CO₂ world: *Proceedings of the National Academy of Sciences of the United States of America*, v. 105, p. 10,450–10,455, doi:10.1073/pnas.0712167105.

Shamberger, K.E., Cohen, A.L., Golbuu, Y., McCorkle, D.C., Lentz, S.J., and Barkley, H.C., 2014, Diverse coral communities in naturally acidified waters of a Western Pacific reef: *Geophysical Research Letters*, v. 41, p. 499–504, doi: 10.1002/2013GL058489.

Methods & Sampling

Coral skeleton cores were collected from living *Porites* colonies with underwater pneumatic drills. Core holes in the coral colonies were plugged with cement so that the coral can grow over the plug within one year. The intact cores were CT (computerized tomography) scanned to reveal skeletal density.

Samples for seawater chemistry were collected in Niskin and borosilicate bottles and analyzed for total alkalinity (TA), dissolved inorganic carbon (DIC), and nutrients following standard procedures as indicated in the [supplemental information](#).

Seawater samples from Palauan reefs were collected during daylight hours in September 2011 and March 2012. Samples from Rose Atoll, Palmyra Atoll, Kingman Atoll, and Jarvis Island were collected during NOAA Pacific Reef Assessment and Monitoring Program (RAMP) cruises during daylight hours of March/April of 2006, 2008 2010, 2012, and a September 2012 cruise to Jarvis Island. Panama Ω and nitrate are taken from Manzello et al. (2008) and D'Croz and O'Dea (2007), respectively. Parentheses indicate climatological values from World Ocean Atlas and the Global Data Analysis Project (GLODAP).

Aragonite saturation state was determined from TA and DIC of seawater preserved with HgCl₂ following methods and calculations described in Shamberger et al. (2014). The mean absolute differences in Ω and nitrate between 12 duplicate samples were 0.035 and 0.13 mM, respectively. Nitrates reported from the Panama sites in this dataset are from D'Croz, L., and O'Dea, A. (2007).

Data Processing Description

An automated computer program ("coralCT") was developed to quantify the amount of skeleton removed by bioeroding organisms. Details of the program are described in the [supplemental information](#) file associated with DeCarlo et al. (2015) in *Geology*.

Seawater aragonite saturation state was calculated from TA and DIC as indicated in the supplemental information.

BCO-DMO Processing:

- added conventional header with dataset name, PI name, version date, reference information
- renamed parameters to BCO-DMO standard
- replaced blanks and / with underscores
- removed spaces and special characters
- split erosion rate, numbers of cores used for calcification rate, and macrobioerosion measurements into 3 columns from 1.
- split aragonite state, standard error and climatological value into 3 columns
- split nitrate concentration, standard error and climatological value into 3 columns

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Data Files

File
Porites_erosion.csv (Comma Separated Values (.csv), 1.00 KB) MD5:90ce041295823dacb5663fe165d6893b Primary data file for dataset ID 542290

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Parameters

Parameter	Description	Units
site	sampling location	unitless
lat	latitude; north is positive	decimal degrees
lon	longitude; east is positive	decimal degrees
reef_type	type of reef	unitless
depth_range	depth range of sampling	meters
erosion_rate	macrobioerosion rate	mg/cm ² /yr
cores_calc	number of core used in calcification analysis	cores
cores_erosion	number of core used in macrobioerosion analysis	cores
aragonite_sat_omega	aragonite saturation state; omega	unitless
Om_Ar_stderr	omega standard error	unitless
Om_Ar_Atlas	omega from World Ocean Atlas and the Global Data Analysis Project (GLODAP)	unitless
NO3	nitrate concentration	microMoles
NO3_stderr	nitrate concentration standard error	microMoles
NO3_Atlas	nitrate concentration from World Ocean Atlas and the Global Data Analysis Project (GLODAP)	microMoles

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Deployments

lab_Cohen_deCarlo

Website	https://www.bco-dmo.org/deployment/542436
Platform	WHOI
Start Date	2011-09-01
End Date	2012-03-31
Description	Coral skeleton cores were collected in the Tropical Pacific Ocean and analyzed in the lab. Seawater samples were collected.

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Project Information

Toward Predicting the Impact of Ocean Acidification on Net Calcification by a Broad Range of Coral Reef Ecosystems: Identifying Patterns and Underlying Causes (Coral Reef Ecosystem OA Impact)

Coverage: Republic of Palau, Caroline Islands, Micronesia, western Pacific Ocean; Dongsha Atoll, Pratas Islands, South China Sea; Kingman Reef, US Northern Line Islands, 6 deg. 23 N, 162 deg. 25 W

text copied from the NSF award abstract:

Much of our understanding of the impact of ocean acidification on coral reef calcification comes from laboratory manipulation experiments in which reef organisms are removed from their natural habitat and reared under conditions of calcium carbonate saturation (Ω) predicted for the tropical oceans at the end of this century. By comparison, there is a paucity of in situ data describing the sensitivity of coral reef ecosystems to changes in calcium carbonate saturation. Yet emerging evidence suggests there may be critical differences between the calcification response of organisms in culture and the net calcification response of a coral reef ecosystem, to the same degree of change in calcium carbonate saturation. In the majority of cases, the sensitivity of net reef calcification to changing calcium carbonate saturation is more severe than laboratory manipulation experiments predict. Clearly, accurate predictions of the response of coral reef ecosystems to 21st century ocean acidification will depend on a robust characterization of ecosystem-scale responses and an understanding of the fundamental processes that shape them. Using existing data, the investigators show that the sensitivity of coral reef ecosystem calcification to Δ calcium carbonate saturation conforms to the empirical rate equation $R = k(\text{Aragonite saturation state} - 1)^n$, which also describes the relationship between the rate of net abiogenic CaCO_3 precipitation (R) and the degree of Aragonite supersaturation (Aragonite saturation state - 1). By implication, the net ecosystem calcification (NEC) response to ocean acidification is governed by fundamental laws of physical chemistry and is potentially predictable across space and time. When viewed this way, the existing, albeit sparse, dataset of NEC reveals distinct patterns that, if verified, have important implications for how different coral reef ecosystems will respond to 21st century ocean acidification. The investigators have outlined a research program designed to build on this proposition. The project expands the currently sparse dataset of ecosystem-scale observations at four strategically placed reef sites: 2 sites in the Republic of Palau, Caroline Islands, Micronesia, western Pacific Ocean; a third at Dongsha Atoll, Pratas Islands, South China Sea; and the fourth at Kingman Reef, US Northern Line Islands, 6 deg. 23 N, 162 deg. 25 W. The four selected sites will allow investigators to test the following hypotheses: (1) The sensitivity (" n " in the rate equation) of coral reef ecosystem calcification to Δ Aragonite saturation state decreases with decreasing Aragonite saturation state. By implication, the rate at which reef calcification declines will slow as ocean acidification progresses over the course of this century. (2) The energetic status of the calcifying community is a key determinant of absolute rates of net ecosystem calcification (" k " in the rate equation), which, combined with n , defines the Aragonite saturation state value at which NEC approaches zero. By implication, the shift from net calcification to net dissolution will be delayed in healthy, energetically replete coral reef ecosystems and accelerated in perturbed, energetically depleted ecosystems. and (3) The calcification response of individual colonies of dominant reef calcifiers (corals and algae) is weaker than the measured ecosystem-scale response to the same change in Aragonite saturation state. By implication, processes not adequately captured in laboratory experiments, such as bioerosion and dissolution, will play an important role in the coral reef response to ocean acidification.

Broader Impacts: Ocean acidification threatens the livelihoods of 500 million people worldwide who depend on

coral reefs to provide habitable and agricultural land, food, building materials, coastal protection and income from tourism. Yet data emerging from ocean acidification (OA) studies point to critical gaps in our knowledge of reef ecosystem-scale responses to OA that currently limit our ability to predict the timing and severity of its impact on different reefs in different parts of the world. Using existing data generated by the investigators and others, this project will address a series of related hypotheses, which, if verified by the research, will have an immediate, direct impact on predictions of coral reef resilience in a high CO₂ world. This project brings together expertise in coral reef biogeochemistry, chemical oceanography and physical oceanography to focus on a problem that has enormous societal, economic and conservation relevance. In addition to sharing the resultant data via BCO-DMO, project data will also be contributed to the Ocean Acidification International Coordination Centre (OA-ICC) data collection hosted at the PANGAEA Open Access library (<http://www.pangaea.de>).

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.

Program Information

Science, Engineering and Education for Sustainability NSF-Wide Investment (SEES): Ocean Acidification (formerly CRI-OA) (SEES-OA)

Website: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503477

Coverage: global

NSF Climate Research Investment (CRI) activities that were initiated in 2010 are now included under Science, Engineering and Education for Sustainability NSF-Wide Investment (SEES). SEES is a portfolio of activities that highlights NSF's unique role in helping society address the challenge(s) of achieving sustainability. Detailed information about the SEES program is available from NSF (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504707).

In recognition of the need for basic research concerning the nature, extent and impact of ocean acidification on oceanic environments in the past, present and future, the goal of the SEES: OA program is to understand (a) the chemistry and physical chemistry of ocean acidification; (b) how ocean acidification interacts with processes at the organismal level; and (c) how the earth system history informs our understanding of the effects of ocean acidification on the present day and future ocean.

Solicitations issued under this program:

[NSF 10-530](#), FY 2010-FY2011

[NSF 12-500](#), FY 2012

[NSF 12-600](#), FY 2013

[NSF 13-586](#), FY 2014

NSF 13-586 was the final solicitation that will be released for this program.

PI Meetings:

[1st U.S. Ocean Acidification PI Meeting](#) (March 22-24, 2011, Woods Hole, MA)

[2nd U.S. Ocean Acidification PI Meeting](#) (Sept. 18-20, 2013, Washington, DC)

3rd U.S. Ocean Acidification PI Meeting (June 9-11, 2015, Woods Hole, MA – Tentative)

NSF media releases for the Ocean Acidification Program:

[Press Release 10-186 NSF Awards Grants to Study Effects of Ocean Acidification](#)

[Discovery Blue Mussels "Hang On" Along Rocky Shores: For How Long?](#)

[Discovery nsf.gov - National Science Foundation \(NSF\) Discoveries - Trouble in Paradise: Ocean Acidification This Way Comes - US National Science Foundation \(NSF\)](#)

[Press Release 12-179 nsf.gov - National Science Foundation \(NSF\) News - Ocean Acidification: Finding New Answers Through National Science Foundation Research Grants - US National Science Foundation \(NSF\)](#)

[Press Release 13-102 World Oceans Month Brings Mixed News for Oysters](#)

[Press Release 13-108 nsf.gov - National Science Foundation \(NSF\) News - Natural Underwater Springs Show How Coral Reefs Respond to Ocean Acidification - US National Science Foundation \(NSF\)](#)

[Press Release 13-148 Ocean acidification: Making new discoveries through National Science Foundation research grants](#)

[Press Release 13-148 - Video nsf.gov - News - Video - NSF Ocean Sciences Division Director David Conover answers questions about ocean acidification. - US National Science Foundation \(NSF\)](#)

[Press Release 14-010 nsf.gov - National Science Foundation \(NSF\) News - Palau's coral reefs surprisingly resistant to ocean acidification - US National Science Foundation \(NSF\)](#)

[Press Release 14-116 nsf.gov - National Science Foundation \(NSF\) News - Ocean Acidification: NSF awards](#)

Ocean Carbon and Biogeochemistry (OCB)

Website: <http://us-ocb.org/>

Coverage: Global

The Ocean Carbon and Biogeochemistry (OCB) program focuses on the ocean's role as a component of the global Earth system, bringing together research in geochemistry, ocean physics, and ecology that inform on and advance our understanding of ocean biogeochemistry. The overall program goals are to promote, plan, and coordinate collaborative, multidisciplinary research opportunities within the U.S. research community and with international partners. Important OCB-related activities currently include: the Ocean Carbon and Climate Change (OCCC) and the North American Carbon Program (NACP); U.S. contributions to IMBER, SOLAS, CARBOOCEAN; and numerous U.S. single-investigator and medium-size research projects funded by U.S. federal agencies including NASA, NOAA, and NSF.

The scientific mission of OCB is to study the evolving role of the ocean in the global carbon cycle, in the face of environmental variability and change through studies of marine biogeochemical cycles and associated ecosystems.

The overarching OCB science themes include improved understanding and prediction of: 1) oceanic uptake and release of atmospheric CO₂ and other greenhouse gases and 2) environmental sensitivities of biogeochemical cycles, marine ecosystems, and interactions between the two.

The OCB Research Priorities (updated January 2012) include: ocean acidification; terrestrial/coastal carbon fluxes and exchanges; climate sensitivities of and change in ecosystem structure and associated impacts on biogeochemical cycles; mesopelagic ecological and biogeochemical interactions; benthic-pelagic feedbacks on biogeochemical cycles; ocean carbon uptake and storage; and expanding low-oxygen conditions in the coastal and open oceans.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1220529
NSF Division of Ocean Sciences (NSF OCE)	OCE-1031971

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