Coral and algae cover, coral richness, and coral diversity from coral reef sites sampled by small boats in the Palauan archipelago from 2011-2013

Website: https://www.bco-dmo.org/dataset/520476
Data Type: Other Field Results
Version: 2
Version Date: 2015-06-23

Project
» An Investigation of the Role of Nutrition in the Coral Calcification Response to Ocean Acidification (OA Nutrition and Coral Calcification)
» 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)
» Science, Engineering and Education for Sustainability NSF-Wide Investment (SEES): Ocean Acidification (formerly CRI-OA) (SEES-OA)
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Abstract
Average coral and algae cover, coral richness, and coral diversity from 8 coral reef sites in Palau.

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Coverage

Spatial Extent: **N**:7.544 **E**:134.557 **S**:7.271 **W**:134.357
Temporal Extent: 2010 - 2012

Dataset Description

Average coral and algae cover, coral richness, and coral diversity from 8 coral reef sites in Palau.

For more information, see main article and supporting information (including figures and tables) from: Barkley et al. (2015), DeCarlo et al. (2015), and Shamberger et al. (2014).

Methods & Sampling

Coral reef community data were collected from eight reef sites. At each site, five 50m transects were laid on the reef at 3m depth and a photograph of a 0.5m x 0.5m quadrat was taken every meter. All transects were conducted in 2010, except for those from Risong Bay, which were conducted in 2012.

Data Processing Description

Photographs of the benthic community were analyzed using Coral Point Count with Excel extensions. Benthic cover of each photograph was evaluated by randomly overlaying five crosses on each image and identifying the type of cover and taxa underneath each cross, with all corals identified to the genus level, for a total of 200 points evaluated per transect and 1000 points evaluated per site. Percent cover (coral, macroalgae, and crustose coralline algae) and community ecological indices (genera richness, Shannon diversity, and Shannon evenness) were calculated for each of the five transects per reef site.

See the supplementary information from Shamberger et al. (2014) for more information.

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Data Files

File
coral_div_richness.csv (Comma Separated Values (.csv), 1.13 KB) MD5:4af9391db9ba2fcd4265a72dac9b28df Primary data file for dataset ID 520476

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Related Publications

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

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

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

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Parameters

Parameter	Description	Units
site_name	Sampling site name.	dimensionless
lat	Latitude of sampling location. North = positive values.	decimal degrees
lon	Longitude of sampling location. East = positive values.	decimal degrees
omega_Ar	Average saturation state of seawater with respect to aragonite.	dimensionless
omega_Ar_err	Standard error of Omega_ar.	dimensionless
coral_cover_pcnt	Average percent coral cover.	percent (%)
coral_cover_err	Standard error of coral cover.	percent (%)
coral_richness	Average coral genera richness (number of genera observed).	genera per transect
coral_richness_err	Standard error of coral richness.	genera per transect
diversity	Average coral genera diversity (Shannon).	dimensionless
diversity_err	Standard error of coral diversity.	dimensionless
evenness	Average coral genera evenness (Shannon).	dimensionless
evenness_err	Standard error of coral evenness.	dimensionless
porites_cover_pcnt	Average Porites coral percent cover.	percent (%)
porites_cover_err	Standard error of Porites cover.	percent (%)
acropora_cover_pcnt	Average Acropora coral percent cover.	percent (%)

acropora_cover_err	Standard error of Acropora percent cover.	percent (%)
macroalgae_cover_pcnt	Average macroalgae percent cover.	percent (%)
macroalgae_cover_err	Standard error of macroalgae percent cover.	percent (%)
cca_cover_pcnt	Average crustose coralline algae (CCA) cover.	percent (%)
cca_cover_err	Standard error of CCA cover.	percent (%)

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Instruments

Dataset-specific Instrument Name	camera
Generic Instrument Name	Camera
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

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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".

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Project Information

An Investigation of the Role of Nutrition in the Coral Calcification Response to Ocean Acidification (OA Nutrition and Coral Calcification)

Coverage: global; experimental

The project description is a modification of the original NSF award abstract.

This research project is part of the larger NSF funded CRI-OA collaborative research initiative and was funded as an Ocean Acidification-Category 1, 2010 award. Over the course of this century, all tropical coral reef ecosystems, whether fringing heavily populated coastlines or lining remote islands and atolls, face unprecedented threat from ocean acidification caused by rising levels of atmospheric CO2. In many laboratory experiments conducted to date, calcium carbonate production (calcification) by scleractinian (stony) corals showed an inverse correlation to seawater saturation state OMEGAar), whether OMEGAar was manipulated by acid or CO2 addition. Based on these data, it is predicted that coral calcification rates could decline by up to 80% of modern values by the end of this century. A growing body of new experimental data however, suggests that the coral calcification response to ocean acidification may be less straightforward and a lot more variable than previously recognized. In at least 10 recent experiments including our own, 8 different tropical and temperate species reared under nutritionally-replete but significantly elevated CO2 conditions (780-1200 ppm, OMEAGar ~1.5-2), continued to calcify at rates comparable to conspecifics reared under ambient CO2. These experimental results are consistent with initial field data collected on reefs in the eastern Pacific and southern Oman, where corals today live and accrete their skeletons under conditions equivalent to 2X and 3X pre-industrial CO2. On these high CO2, high nutrient reefs (where nitrate concentrations typically exceed 2.5 micro-molar), coral growth rates rival, and sometimes even exceed, those of conspecifics in low CO2, oligotrophic reef environments.

The investigators propose that a coral's energetic status, tightly coupled to the availability of inorganic nutrients and/or food, is a key factor in the calcification response to CO2-induced ocean acidification. Their hypothesis, if confirmed by the proposed laboratory investigations, implies that predicted changes in coastal and open ocean nutrient concentrations over the course of this century, driven by both climate impacts on ocean stratification and by increased human activity in coastal regions, could play a critical role in exacerbating and in some areas, modulating the coral reef response to ocean acidification. This research program builds on the investigators initial results and observations. The planned laboratory experiments will test the hypothesis that: (1) The coral calcification response to ocean acidification is linked to the energetic status of the coral host. The relative contribution of symbiont photosynthesis and heterotrophic feeding to a coral's energetic status varies amongst species. Enhancing the energetic status of corals reared under high CO2, either by stimulating photosynthesis with inorganic nutrients or by direct heterotrophic feeding of the host lowers the sensitivity of calcification to decreased seawater OMEGAar; (2) A species-specific threshold CO2 level exists over which enhanced energetic status can no longer compensate for decreased OMEGAar of the external seawater. Similarly, we will test the hypothesis that a nutrient threshold exists over which nutrients become detrimental for calcification even under high CO2 conditions; and (3) Temperature-induced reduction of algal symbionts is one stressor that can reduce the energetic reserve of the coral host and exacerbate the calcification response to ocean acidification.

The investigator's initial findings highlight the critical importance of energetic status in the coral calcification response to ocean acidification. Verification of these findings in the laboratory, and identification of nutrient and CO2 thresholds for a range of species will have immediate, direct impact on predictions of reef resilience in a high CO2 world. The research project brings together a diverse group of expertise in coral biogeochemistry, chemical oceanography, molecular biology and coral reproductive ecology to focus on a problem that has enormous societal, economic and conservation relevance.

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 (Omega) 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 Delta calcium carbonate saturation conforms to the empirical rate equation R=k(Aragonite saturation state -1)n, which also describes the relationship between the rate of net abiogenic CaCO3 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 Delta 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.

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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 $11.4 million in new grants to study effects on marine ecosystems - US National Science Foundation (NSF)

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-1041106
NSF Division of Ocean Sciences (NSF OCE)	OCE-1220529
NSF Division of Ocean Sciences (NSF OCE)	OCE-1031971

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