Calcification and linear extension rates for Oculina arbuscula corals grown under different pCO2 levels; from the Cohen lab at WHOI in Woods Hole, MA (OA Nutrition and Coral Calcification project)

Website: https://www.bco-dmo.org/dataset/490464
Data Type: Other Field Results, experimental
Version: 1
Version Date: 2014-02-06

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

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

Contributors	Affiliation	Role
Cohen, Anne L	Woods Hole Oceanographic Institution (WHOI)	Lead Principal Investigator
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Dataset Description

Data from experiments examining the effect of CO2-induced ocean acidification on the scleractinian coral *Oculina arbuscula*.

For more information on the experimental methods and results, see Ries et al., 2010.

These data have also been deposited to PANGAEA where additional carbonate system variables were calculated as described by Nisumaa et al. (2010). See: http://doi.pangaea.de/10.1594/PANGAEA.754790

Acquisition Description

Methodology as described in Ries et al. (2010):
Zooxanthellate colonies of *Oculina arbuscula* were collected offshore of Bogue Banks North Carolina in August 2007. After collection, the organisms were transported to the Marine Calcification Laboratory at Woods Hole Oceanographic Institution. After acclimation to the laboratory conditions, fragments of each colony were harvested and mounted on acrylic slides. Specimens were then transferred to the experimental seawaters for additional acclimation for 14 days prior to the start of the experiment.

The *O. arbuscula* specimens were reared for 60 days from Sept. to Nov. 2007 in four 38-liter glass aquaria filled with filtered seawater. The experimental seawaters were bubbled continuously with air-CO2 mixtures of 409, 606, 903, or 2856 ppm pCO2. Temperature was maintained at 25 +/- 1 degrees Celsius. Aquaria were illuminated 10 hours per day. Seventy-five percent seawater changes were made every 14 days. Coral fragments were fed *Artemia sp.* every other day. The experimental air-CO2 gas mixtures were formulated using Aalborg mass flow controllers, yielding average seawater saturation states of 2.6, 2.3, 1.6, and 0.8 with respect to aragonite. Salinity, temperature, and pH of the seawaters, and pCO2 of the mixed gases were measured weekly. Total alkalinity was measured every 2 weeks. DIC, bicarbonate ion concentration, dissolved CO2, aragonite saturation state, and pCO2 were calculated from the measured parameters. Refer to Table 1 of Ries et al. (2010) for more detail on the measured and calculated carbonate chemistry parameters, including mean, range, and standard deviation.

A buoyant weighing method was used to estimate the corals' calcification rates. Calcification

rates were calculated as the percent change in buoyant weight between the beginning and end of the experiment.

Each aquarium was dosed with 137BaCO3 for 14 days at the beginning of the experiment. After 14 days, the 137Ba-enriched seawaters were replaced with seawaters of natural Ba isotopic composition. This temporary increase in the concentration of Barium-137 in the experimental seawaters resulted in a five-fold spike in the ratio of Ba-137 to Ba-138 in the coral skeletons accreted during the first 14 days of the experiment. This spike provided the baseline from which linear extension of the coral skeletons could be measured. Four coral specimens were randomly selected from each of the treatments and sectioned parallel to the growth axis. 137Ba/138Ba ratios were measured using laser ablation-inductively coupled plasma-mass spectrometry. To determine linear extension, the time elapsed from the detection of the 137Ba/138Ba spike and the outer edge of the coral skeleton was converted to distance by multiplying the elapsed time by the scan rate of the laser.

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Related Publications

Nisumaa, A.-M., Pesant, S., Bellerby, R. G. J., Delille, B., Middelburg, J. J., Orr, J. C., … Gattuso, J.-P. (2010). EPOCA/EUR-OCEANS data compilation on the biological and biogeochemical responses to ocean acidification. Earth System Science Data, 2(2), 167–175. doi:10.5194/essd-2-167-2010

Ries, J. B., Cohen, A. L., & McCorkle, D. C. (2010). A nonlinear calcification response to CO2-induced ocean acidification by the coral Oculina arbuscula. Coral Reefs, 29(3), 661–674. doi:10.1007/s00338-010-0632-3

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Parameters

Parameter	Description	Units
omega_Arg	Saturation state with respect to aragonite.	dimensionless
species	Name of the coral species.	dimensionless
sample	Unique sample indentifier.	dimensionless
buoyant_wt_init	Initial buoyant weight of the coral; measured at the beginning of the experiment.	milligrams (mg)
buoyant_wt_final	Final buoyant weight of the coral; measured at the end of the experiment.	milligrams (mg)
calcification_rate	Calcification rate measured as the percent change in buoyant weight over the course of the experiment (60 days).	percent (%)
linear_ext	Linear extension of the coral skeleton; distance from the 137Ba/138Ba spike to the outer edge of the coral skeleton. Measured on 4 specimens randomly selected from each of the treatments.	micrometers (um)

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Instruments

Dataset-specific Instrument Name	ICP Mass Spec
Generic Instrument Name	Inductively Coupled Plasma Mass Spectrometer
Dataset-specific Description	The ratio of 137Ba to138Ba was measured using laser ablation inductively coupled plasma-mass spectrometry (Thermo-Finnegan Element2 LA-ICP-MS; beam diameter = 5 lm; scan speed = 6 lm/sec; intensity = 35%; frequency 8 Hz).
Generic Instrument Description	An ICP Mass Spec is an instrument that passes nebulized samples into an inductively-coupled gas plasma (8-10000 K) where they are atomized and ionized. Ions of specific mass-to-charge ratios are quantified in a quadrupole mass spectrometer.

Dataset-specific Instrument Name	Autosal conductivity meter
Generic Instrument Name	Autosal salinometer
Dataset-specific Description	Salinity was determined using an Autosal conductivity meter in the WHOI Hydrographic Laboratory and/or using a refractometer.
Generic Instrument Description	The salinometer is an instrument for measuring the salinity of a water sample.

Dataset-specific Instrument Name	Mercury-glass thermometer
Generic Instrument Name	Water Temperature Sensor
Dataset-specific Description	Temperature was measured with a partial-immersion mercury-glass thermometer (precision = +/- 0.3%, accuracy = +/- 0.4%).
Generic Instrument Description	General term for an instrument that measures the temperature of the water with which it is in contact (thermometer).

Dataset-specific Instrument Name	Refractometer
Generic Instrument Name	Refractometer
Dataset-specific Description	Salinity was determined using an Autosal conductivity meter in the WHOI Hydrographic Laboratory and/or using a refractometer calibrated with simultaneous measurements of conductivity (precision = +/- 0.3%; accuracy = +/- 0.4%).
Generic Instrument Description	A refractometer is a laboratory or field device for the measurement of an index of refraction (refractometry). The index of refraction is calculated from Snell's law and can be calculated from the composition of the material using the Gladstone-Dale relation. In optics the refractive index (or index of refraction) n of a substance (optical medium) is a dimensionless number that describes how light, or any other radiation, propagates through that medium.

Dataset-specific Instrument Name	pH Meter
Generic Instrument Name	Benchtop pH Meter
Dataset-specific Description	Seawater pH was determined weekly using an Orion pH electrode/meter (precision = +/- 0.005; accuracy = +/- 0.02).
Generic Instrument Description	An instrument consisting of an electronic voltmeter and pH-responsive electrode that gives a direct conversion of voltage differences to differences of pH at the measurement temperature. (McGraw-Hill Dictionary of Scientific and Technical Terms) This instrument does not map to the NERC instrument vocabulary term for 'pH Sensor' which measures values in the water column. Benchtop models are typically employed for stationary lab applications.

Dataset-specific Instrument Name	Aquarium
Generic Instrument Name	Aquarium
Dataset-specific Description	Specimens of O. arbuscula were reared in each of four 38-liter glass aquaria (76 specimens in total) filled with 0.2 um-filtered seawater.
Generic Instrument Description	Aquarium - a vivarium consisting of at least one transparent side in which water-dwelling plants or animals are kept

Dataset-specific Instrument Name	MFC
Generic Instrument Name	Mass Flow Controller
Dataset-specific Description	The experimental air-CO2 gases were formulated using Aalborg mass flow controllers. See more information from Aalborg.
Generic Instrument Description	Mass Flow Controller (MFC) - A device used to measure and control the flow of fluids and gases

Dataset-specific Instrument Name	Scale
Generic Instrument Name	Scale
Dataset-specific Description	Buoyant weights were determined using an aluminum wire hanging from a Cole Parmer bottom-loading scale.
Generic Instrument Description	An instrument used to measure weight or mass.

Dataset-specific Instrument Name	Qubit S151 infrared analyzer
Generic Instrument Name	Gas Analyzer
Dataset-specific Description	Mixed gas pCO2 was measured with a Qubit S151 infrared analyzer (calibrated using certified air-CO2 gas standards; precision = +/- 2.0%; accuracy = +/- 1.8%). More information from the manufacturer: Q-S151 CO2 Analyzer
Generic Instrument Description	Gas Analyzers - Instruments for determining the qualitative and quantitative composition of gas mixtures.

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Deployments

lab_Cohen_WHOI

Website	https://www.bco-dmo.org/deployment/59089
Platform	WHOI
Description	Experiments and analyses carried out in Anne Cohen's lab at Woods Hole Oceanographic Institution (WHOI) as part of the project "An Investigation of the Role of Nutrition in the Coral Calcification Response to Ocean Acidification". See: Project description from Cohen Lab

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.

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Program Information

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

Website: http://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 (http://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-FY2011NSF 12-500, FY 2012NSF 12-600, FY 2013NSF 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

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