

# Calcification and carbonate chemistry from outdoor flume experiments with corals at locations in Moorea, Okinawa, and Hawaii from 2011 to 2013

Website: <https://www.bco-dmo.org/dataset/754718>

Version: 1

Version Date: 2020-12-02

## Project

» [Moorea Coral Reef Long-Term Ecological Research site](#) (MCR LTER)

» [RUI: Ocean Acidification- Category 1- The effects of ocean acidification on the organismic biology and community ecology of corals, calcified algae, and coral reefs](#) (OA\_Corals)

## Programs

» [Long Term Ecological Research network](#) (LTER)

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

Contributors	Affiliation	Role
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## Abstract

Pacific-wide contrast of reef calcifiers to ocean acidification. Data were published in Comeau et al. (2014). Calcification and carbonate chemistry from outdoor flume experiments with corals at locations in Moorea, Okinawa, and Hawaii from 2011 to 2013.

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## Coverage

**Temporal Extent:** 2011-09 - 2013-06

## Methods & Sampling

See Comeau et al. (2014) for full methodology details.

Locations:

UCB Gump Research Station, Moorea, French Polynesia

Sesoko Station, Tropical Biosphere Research Center, Okinawa, Japan

Hawaii Institute of Marine Biology (HIMB), Coconut Island, Oahu, Hawaii

Methodology:

At the three locations, pH was measured twice daily using a portable pH meter (Orion 3-stars) fitted with a DG 115-SC pH probe (Mettler) calibrated every other day with Tris/HCl buffers (A. Dickson, San Diego, CA, USA). In Moorea and in Hawaii, pH also was measured spectrophotometrically once a week using m-cresol dye. T was calculated using a modified Gran function applied to pH values ranging from 3.5 to 3.0. Parameters of the carbonate system in seawater were calculated from salinity, temperature, AT and pHT using the R package seacarb.

To quantify net calcification, the difference between the initial and final buoyant weight after 14 days of incubation was converted to dry weight using an aragonite density of 2.93 g cm<sup>-3</sup> for corals and Halimeda macroloba, and a calcite density of 2.71 g cm<sup>-3</sup> for Porolithon onkodes. Net calcification was normalized to surface area, obtained using the foil technique for corals, and image analysis (IMAGEJ, US NIH) of aerial photographs for P. onkodes.

Species list:

Halimeda macroloba (macroalga). AphiaID 211524

Pocillopora damicornis (coral). AphiaID 206953

Porolithon onkodes (macroalga). AphiaID 495983

massive Porites (coral). AphiaID 206485

## Data Processing Description

R packages:

Lavigne H, Gattuso J-P. 2011. seacarb: seawater carbonate chemistry with R. R package version 2.4.1. <http://CRAN.Rproject.org/> package=seacarb

BCO-DMO Data Manager Processing Notes:

\* Original file submitted as folder/file "Comeau et al. 2014 - PRSB/comeau et al. 2014\_data.xlsx" sheet "data" extracted to csv.

\* added a conventional header with dataset name, PI name, version date

\* modified parameter names to conform with BCO-DMO naming conventions: only A-Za-z0-9 and underscore allowed. Can not start with a number. (spaces, +, and - changed to underscores).

\* Taxon names checked using the World Register of Marine Species (WoRMS). Species list added to Acquisition Description including the AphiaIDs.

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## Related Publications

Comeau, S., Carpenter, R. C., Nojiri, Y., Putnam, H. M., Sakai, K., & Edmunds, P. J. (2014). Pacific-wide contrast highlights resistance of reef calcifiers to ocean acidification.

Proceedings of the Royal Society B: Biological Sciences, 281(1790), 20141339-20141339. doi:[10.1098/rspb.2014.1339](https://doi.org/10.1098/rspb.2014.1339)

Results

Davies, P.S. (1989). Short-term growth measurements of corals using an accurate buoyant weighing technique. *Marine Biology*, 101(3), 389-395. doi:10.1007/bf00428135 <https://doi.org/10.1007/BF00428135>

*Methods*

Lavigne H, Gattuso J-P. (2011). seacarb: seawater carbonate chemistry with R. R package version 2.4.1. <http://CRAN.Rproject.org/package=seacarb>

*Software*

Nisumaa, A.-M., Pesant, S., Bellerby, R. G. J., Delle, 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

*Methods*

Schneider, C. A., Rasband, W. S., ... (n.d.). ImageJ. US National Institutes of Health, Bethesda, MD, USA. Available from <https://imagej.nih.gov/ij/>

*Software*

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## Parameters

Parameter	Description	Units
Location	Location	unitless
Species	Species. Identification in format Genus species (category or common name)	unitless
pCO2water_SST_wet_1	Partial pressure of carbon dioxide (water) at sea surface temperature (wet air)	uatm
AT	Alkalinity, total. Potentiometric titration.	umol/kg
pH	pH, total scale. Potentiometric.	total hydrogen ion scale (pHT)
Temp	Temperature, water	degrees C
Sal	Salinity	PSU
Calc_rate_CaCO3_surf	Calcification rate of calcium carbonate (CaCO3) normalized by surface. Buoyant weighing technique (Davies, 1989).	mg/cm2/day
Calc_rate_CaCO3_biom	Calcification rate of calcium carbonate (CaCO3) normalized by biomass (tissue dry weight). Buoyant weighing technique (Davies, 1989).	mg/g/day
Date_start	Date and month of experiment start in format yyyy-mm	unitless
Date_end	Date and month of experiment end in format yyyy-mm	unitless
CSC_flag	Carbonate system computation flag. Calculated using seacarb after Nisumaa et al. (2010).	unitless
CO2	Carbon dioxide. Calculated using seacarb after Nisumaa et al. (2010).	umol/kg
pCO2water_SST_wet_2	Partial pressure of carbon dioxide (water) at sea surface temperature (wet air). Calculated using seacarb after Nisumaa et al. (2010).	uatm
fCO2water_SST_wet	Fugacity of carbon dioxide (water) at sea surface temperature (wet air). Calculated using seacarb after Nisumaa et al. (2010).	uatm
Bicarbonate_ion	Bicarbonate ion [HCO3]-. Calculated using seacarb after Nisumaa et al. (2010).	umol/kg
Carbonate_ion	Carbonate ion [CO3]2-. Calculated using seacarb after Nisumaa et al. (2010).	umol/kg
DIC	Carbon, inorganic, dissolved. Calculated using seacarb after Nisumaa et al. (2010).	umol/kg
Omega_Arg	Aragonite saturation state. Calculated using seacarb after Nisumaa et al. (2010).	Omega Arg ( $\Omega_a$ )
Omega_Cal	Calcite saturation state. Calculated using seacarb after Nisumaa et al. (2010).	Omega Cal ( $\Omega_{cal}$ )

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## Instruments

<b>Dataset-specific Instrument Name</b>	4p quantum sensor (LI-193) and a LiCor LI-1400
<b>Generic Instrument Name</b>	Light Meter
<b>Dataset-specific Description</b>	Light: 4p quantum sensor (LI-193) and a LiCor LI-1400 meter
<b>Generic Instrument Description</b>	Light meters are instruments that measure light intensity. Common units of measure for light intensity are $\mu\text{mol}/\text{m}^2/\text{s}$ or $\mu\text{E}/\text{m}^2/\text{s}$ (micromoles per meter squared per second or microEinsteins per meter squared per second). (example: LI-COR 250A)

<b>Dataset-specific Instrument Name</b>	
<b>Generic Instrument Name</b>	pH Sensor
<b>Dataset-specific Description</b>	pH: Orion 3-stars pH Meter fitted with a DG 115-SC pH probe
<b>Generic Instrument Description</b>	An instrument that measures the hydrogen ion activity in solutions. The overall concentration of hydrogen ions is inversely related to its pH. The pH scale ranges from 0 to 14 and indicates whether acidic (more H+) or basic (less H+).

<b>Dataset-specific Instrument Name</b>	YSI 3100
<b>Generic Instrument Name</b>	Salinity Sensor
<b>Generic Instrument Description</b>	Category of instrument that simultaneously measures electrical conductivity and temperature in the water column to provide temperature and salinity data.

<b>Dataset-specific Instrument Name</b>	ThermoFisher Traceable
<b>Generic Instrument Name</b>	Temperature Logger
<b>Generic Instrument Description</b>	Records temperature data over a period of time.

<b>Dataset-specific Instrument Name</b>	Mettler Toledo T50
<b>Generic Instrument Name</b>	Titration
<b>Dataset-specific Description</b>	TA: Mettler Toledo T50
<b>Generic Instrument Description</b>	Titration is an instrument that incrementally adds quantified aliquots of a reagent to a sample until the end-point of a chemical reaction is reached.

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## Project Information

### Moorea Coral Reef Long-Term Ecological Research site (MCR LTER)

**Website:** <http://mcr.lternet.edu/>

**Coverage:** Island of Moorea, French Polynesia

### NSF Award Abstract:

Coral reefs provide important benefits to society, from food to exceptional biodiversity to shoreline protection and recreation, but they are threatened by natural perturbations and human activities, including those causing global-scale changes. These pressures increasingly are causing coral reefs to undergo large, often abrupt, ecological changes where corals are being replaced by seaweeds or other undesirable organisms. Historically, the major agent of disturbance to coral reefs has been powerful storms, but in recent decades, episodes of mass coral bleaching from marine heat waves have become more frequent and severe as the temperature of ocean surface waters continues to rise. Coral reefs are further stressed by local human activities that cause nutrient pollution and deplete herbivorous fishes that control growth of seaweeds. Studying how coral reefs respond to these two types of disturbance under different levels of nutrient pollution and fishing provides essential information on what affects the ability of coral reefs to buffer environmental change and disturbances without collapsing to a persistent, degraded condition. The fundamental goals of the Moorea Coral Reef Long Term Ecological Research program (MCR LTER) are to understand how and why coral reefs change over time, to assess the consequences of these changes, and to contribute scientific knowledge needed to sustain coral reef ecosystems and the important societal services they provide. This research improves understanding and management of coral reefs, which benefits all groups concerned with the welfare of this ecologically, economically and culturally important ecosystem. In addition to academic communities, scientific findings are communicated to interested individuals, non-governmental organizations, island communities and governmental entities. These findings also are integrated into K-12, undergraduate, graduate and public education activities through a multi-pronged program that includes inquiry-based curricula, interactive and media-based public education programs, and internet-based resources. MCR's research, training, education and outreach efforts all emphasize broadening participation in STEM fields and strengthening STEM literacy.

New research activities build on MCR LTER's powerful foundation of long-term observations and broad ecological understanding of oceanic coral reefs to address the following core issues: How is the changing disturbance regime (recurrent heat waves in addition to cyclonic storms) altering the resilience of coral reefs, and what are the ecological consequences of altered resilience? Research activities are organized around a unifying framework that explicitly addresses how reef communities are affected by the nature and history of coral-killing disturbances, and how those responses to disturbance are influenced by the pattern of local human stressors. New studies answer three focal questions: (1) How do different disturbance types, which either remove (storms) or retain (heat waves) dead coral skeletons, affect community dynamics, abrupt changes in ecological state, and resilience? (2) How do local stressors interact with new disturbance regimes to create spatial heterogeneity in community dynamics, ecosystem processes, and spatial resilience? And (3) What attributes of coral and coral reef communities influence their capacity to remain resilient under current and future environmental conditions? These questions provide an unparalleled opportunity to test hypotheses and advance theory regarding ecological resilience and the causes and consequences of abrupt ecological change, which is broadly relevant across aquatic and terrestrial ecosystems.

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.

**From** <http://www.lternet.edu/sites/mcr/> and <http://mcr.lternet.edu/>:

The Moorea Coral Reef LTER site encompasses the coral reef complex that surrounds the island of Moorea, French Polynesia (17°30'S, 149°50'W). Moorea is a small, triangular volcanic island 20 km west of Tahiti in the Society Islands of French Polynesia. An offshore barrier reef forms a system of shallow (mean depth ~ 5-7 m), narrow (~0.8-1.5 km wide) lagoons around the 60 km perimeter of Moorea. All major coral reef types (e.g., fringing reef, lagoon patch reefs, back reef, barrier reef and fore reef) are present and accessible by small boat.

The MCR LTER was established in 2004 by the US National Science Foundation (NSF) and is a partnership between the University of California Santa Barbara and California State University, Northridge. MCR researchers include marine scientists from the UC Santa Barbara, CSU Northridge, UC Davis, UC Santa Cruz, UC San Diego, CSU San Marcos, Duke University and the University of Hawaii. Field operations are conducted from the UC Berkeley Richard B. Gump South Pacific Research Station on the island of Moorea, French Polynesia.

**MCR LTER Data:** The Moorea Coral Reef (MCR) LTER data are managed by and available directly from the MCR project data site URL shown above. The datasets listed below were collected at or near the MCR LTER sampling locations, and funded by NSF OCE as ancillary projects related to the MCR LTER core research themes.

### This project is supported by continuing grants with slight name variations:

- LTER: Long-Term Dynamics of a Coral Reef Ecosystem

- LTER: MCR II - Long-Term Dynamics of a Coral Reef Ecosystem
- LTER: MCR IIB: Long-Term Dynamics of a Coral Reef Ecosystem
- LTER: MCR III: Long-Term Dynamics of a Coral Reef Ecosystem
- LTER: MCR IV: Long-Term Dynamics of a Coral Reef Ecosystem

**RUI: Ocean Acidification- Category 1- The effects of ocean acidification on the organismic biology and community ecology of corals, calcified algae, and coral reefs (OA\_Corals)**

**Coverage:** Moorea, French Polynesia

While coral reefs have undergone unprecedented changes in community structure in the past 50 y, they now may be exposed to their gravest threat since the Triassic. This threat is increasing atmospheric CO<sub>2</sub>, which equilibrates with seawater and causes ocean acidification (OA). In the marine environment, the resulting decline in carbonate saturation state (Omega) makes it energetically less feasible for calcifying taxa to mineralize; this is a major concern for coral reefs. It is possible that the scleractinian architects of reefs will cease to exist as a mineralized taxon within a century, and that calcifying algae will be severely impaired. While there is a rush to understand these effects and make recommendations leading to their mitigation, these efforts are influenced strongly by the notion that the impacts of pCO<sub>2</sub> (which causes Omega to change) on calcifying taxa, and the mechanisms that drive them, are well-known. The investigators believe that many of the key processes of mineralization on reefs that are potentially affected by OA are only poorly known and that current knowledge is inadequate to support the scaling of OA effects to the community level. It is vital to measure organismal-scale calcification of key taxa, elucidate the mechanistic bases of these responses, evaluate community scale calcification, and finally, to conduct focused experiments to describe the functional relationships between these scales of mineralization.

This project is a 4-y effort focused on the effects of Ocean Acidification (OA) on coral reefs at multiple spatial and functional scales. The project focuses on the corals, calcified algae, and coral reefs of Moorea, French Polynesia, establishes baseline community-wide calcification data for the detection of OA effects on a decadal-scale, and builds on the research context and climate change focus of the Moorea Coral Reef LTER.

This project is a hypothesis-driven approach to compare the effects of OA on reef taxa and coral reefs in Moorea. The PIs will utilize microcosms to address the impacts and mechanisms of OA on biological processes, as well as the ecological processes shaping community structure. Additionally, studies of reef-wide metabolism will be used to evaluate the impacts of OA on intact reef ecosystems, to provide a context within which the experimental investigations can be scaled to the real world, and critically, to provide a much needed reference against which future changes can be gauged.

**Datasets listed in the "Dataset Collection" section include references to results journal publications published as part of this project.**

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## **Program Information**

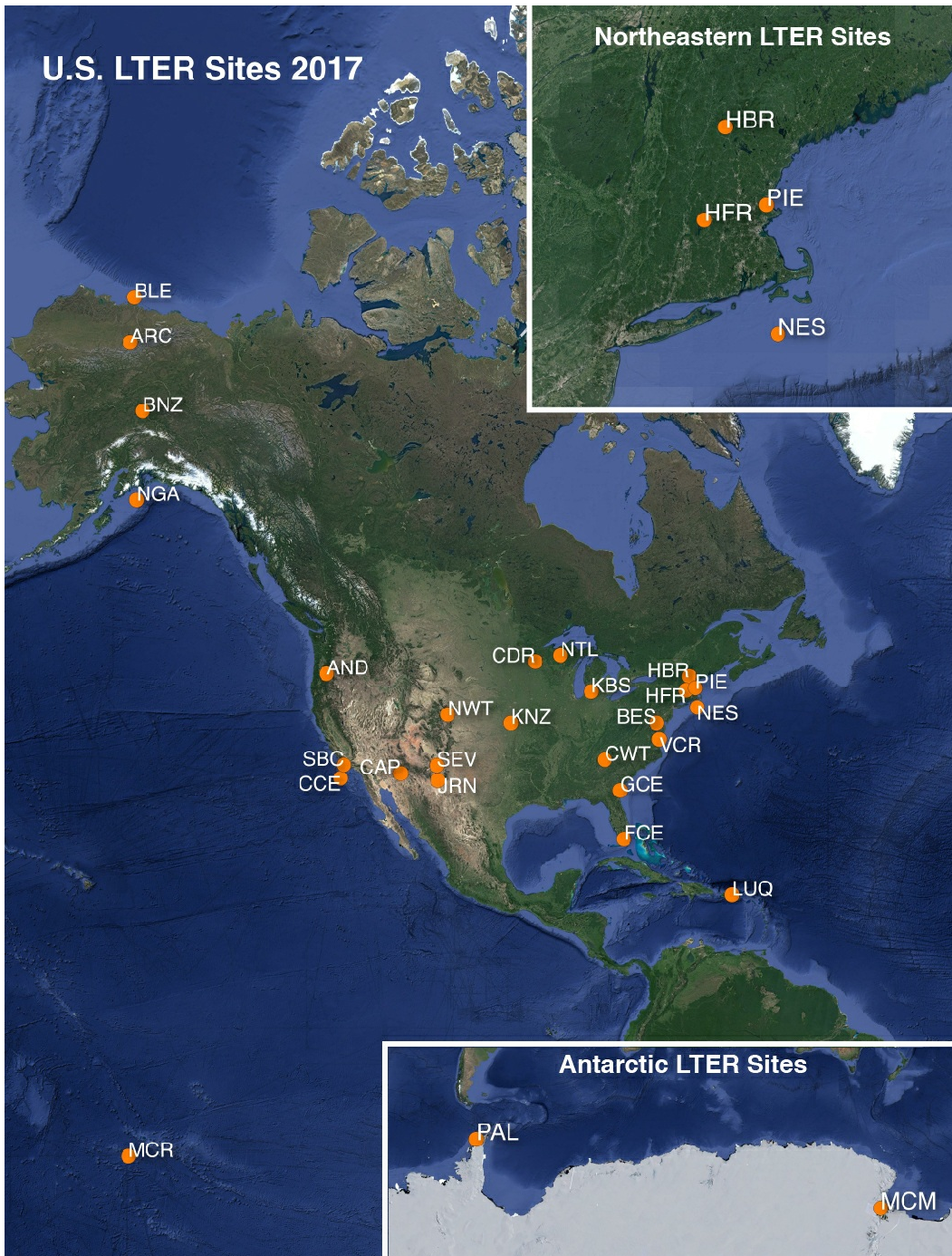
### **Long Term Ecological Research network (LTER)**

**Website:** <http://www.lternet.edu/>

**Coverage:** United States

**adapted from** <http://www.lternet.edu/>

The National Science Foundation established the LTER program in 1980 to support research on long-term ecological phenomena in the United States. The Long Term Ecological Research (LTER) Network is a collaborative effort involving more than 1800 scientists and students investigating ecological processes over long temporal and broad spatial scales. The LTER Network promotes synthesis and comparative research across sites and ecosystems and among other related national and international research programs. The LTER research sites represent diverse ecosystems with emphasis on different research themes, and cross-site communication, network publications, and research-planning activities are coordinated through the LTER Network Office.



### Site Codes

AND	Andrews Forest LTER
ARC	Arctic LTER
BES	Baltimore Ecosystem Stu
BLE	Beaufort Lagoon Ecosystems LTER
BNZ	Bonanza Creek LTER
CCE	California Current Ecosystem LTER
CDR	Cedar Creek Ecosystem Science Reserve
CAP	Central Arizona- Phoenix LTER
CWT	Coweeta LTER
FCE	Florida Coastal Everglades LTER
GCE	Georgia Coastal Ecosystems LTER
HFR	Harvard Forest LTER
HBR	Hubbard Brook LTER
JRN	Jornada Basin LTER
KBS	Kellogg Biological Station LTER
KNZ	Konza Prairie LTER
LUQ	Luquillo LTER
MCM	McMurdo Dry Valleys LT
MCR	Moorea Coral Reef LTER
NWT	Niwot Ridge LTER
NTL	North Temperate Lakes I
NES	Northeast U.S. Shelf LTER
NGA	Northern Gulf of Alaska I
PAL	Palmer Antarctica LTER
PIE	Plum Island Ecosystems LTER
SBC	Santa Barbara Coastal L
SEV	Sevilleta LTER
VCR	Virginia Coast Reserve L

2017 LTER research site map obtained from <https://lternet.edu/site/lter-network/>

### 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](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](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 \(NSF\)](#)

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**Funding**

Funding Source	Award
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-0417412</a>
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-1041270</a>
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-1026851</a>

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