Pteropod shell dissolution in natural and high-CO2 environments from samples collected on RRS James Clark Ross cruise JR177 in the Scotia Sea, Southern Ocean from 2007-2008

Website: https://www.bco-dmo.org/dataset/489471
Data Type: Other Field Results
Version: 1
Version Date: 2014-02-03

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
Tarling, Geraint	British Antarctic Survey (BAS)	Lead Principal Investigator
Bakker, Dorothee C.E.	University of East Anglia (UEA)	Co-Principal Investigator
Fielding, Sophie	British Antarctic Survey (BAS)	Co-Principal Investigator
Bednarsek, Nina	National Oceanic and Atmospheric Administration (NOAA-PMEL)	Contact
Rauch, Shannon	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
This dataset contains data from a study of pteropod shell dissolution on individuals exposed to CO2-enriched seawater. The data include the amount of dissolution as well as the physical and chemical parameters on which carbonate chemistry parameters were calculated.

Table of Contents

Dataset Description

This dataset contains data from a study of pteropod shell dissolution on individuals exposed to CO2-enriched seawater. The data include the amount of dissolution as well as the physical and chemical parameters on which carbonate chemistry parameters were calculated.

For more information on the experimental methods and results, see Bednarsek et al., 2012.

This dataset has 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.779926

Methods & Sampling

Sample collection:
Pteropods were collected from upper ocean water down to a maximum depth of 200 m from various locations across the Scotia Sea using a combination of vertically and obliquely towed Bongo nets and MOCNESS nets during the JR177 research cruise. Oblique tows were carried out at speeds of less than 1 knot.

Experimental conditions:
A fraction of the captured specimens was preserved immediately in 70% ethanol to act as controls for comparison with those exposed to raised pCO2 conditions. A further fraction of specimens was incubated at various levels of pCO2 to test the effect on shell dissolution. Two liter bottles containing filtered sea water (0.7 um filters) were bubbled with air/CO2 mixtures of 500 ppm, 750 ppm, and 1200 ppm, until the required xCO2 was reached. An average of 30 live pteropod of *Limacina helicina ant.* were incubated in each experimental container and maintained for 4, 8, and 14 days before extraction and immediate preservation in 70% ethanol. The majority of specimens were juvenile stages of *Limacina helicina ant.*, but the incubations were also carried out on adult stages of both *Limacina helicina ant.* and *Clio pyramidata* f. *ant.*

Omega was assessed from measurements of DIC (dissolved inorganic carbon) and total alkalinity (TA) at the start and end of each incubation experiment. DIC and TA were measured using VINDTA instrument (Versatile INstrument for the Determination of Titration Alkalinity, Marianda, Kiel, Germany) following the Standard Operating Procedures for oceanic CO2 measurements (Dickson et al. 2007) with a Certified Reference Material (CRM) analysed in duplicate at the beginning and end of each sample analysis day. Other carbonate chemistry parameters (total pH and Omega-aragonite) were calculated from all discrete samples using DIC, TA, temperature, salinity, pressure and macronutrient concentrations using the CO2SYS programme (Lewis and Wallace 1998) with thermodynamic dissociation constants for K1 and K2 by Mehrbach et al. (1973) refitted by Dickson & Millero (1987).

Shell dehydration:
Dehydration was undertaken using 2,2-Dimethoxypropane (DMP; chemical formula: (CH3)2C(OCH3)2), and 1,1,1,3,3,3-hexamethyldisilazane (HMDS; chemical formula: (CH3)3SiNHSi(CH3)3). Before starting dehydration with DMP, the shells were transferred to 50% methanol for two 5 min washes then transferred to 85% methanol (10 min). Complete tissue dehydration was accomplished by immersion in DMP: two changes at 15-20 min each. It was important not to let the shells air dry at this stage, so they were transferred to a 1:1 mixture of DMP and HMDS for about 10 min, followed by 100% HMDS for 20–25 min twice. The HMDS was subsequently allowed to evaporate allowing the shells to dry completely (Figure 2 of Bednarsek et al., 2012). The moderate vapor pressure and very low surface tension of HMDS allowed the shells to dry without distortion or loss of shell integrity.

SEM:
Scanning Electron Microscopy (SEM) was done using a JEOL JSM 5900LV fitted with a tungsten filament at an acceleration voltage of 15 kV and a working distance of about 10 mm. Analysis of SEM photos enabled observation of the shell surface and identification of shell dissolution. Refer to Bednarsek et al. (2012) for more information on dissolution types.

Data Processing Description

BCO-DMO Processing Notes:
- Modified parameter names to conform with BCO-DMO naming conventions.
- Added "N" column per Table 1 in Bednarsek et al. 2012.

[table of contents | back to top]

Data Files

File
pteropod_shell_dissolution.csv (Comma Separated Values (.csv), 1.21 KB) MD5:09fbeb93408ecfe2a953fde6fde1de07 Primary data file for dataset ID 489471

[table of contents | back to top]

Related Publications

Bednaršek, N., Tarling, G. A., Bakker, D. C., Fielding, S., Cohen, A., Kuzirian, A., … Montagna, R. (2012). Description and quantification of pteropod shell dissolution: a sensitive bioindicator of ocean acidification. Global Change Biology, 18(7), 2378–2388. doi:10.1111/j.1365-2486.2012.02668.x
Results

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
Methods

[table of contents | back to top]

Parameters

Parameter	Description	Units
treatment	Type of experimental treatment.	dimensionless
incubation_time	Number of days incubated.	days
N	Number of samples in the treatment.	dimensionless
species	Name of the species of study.	dimensionless
sal	Salinity.	dimensionless
temp	Water temperature.	degrees Celsius
phosphate	Phosphate concentration.	micromoles per kilogram (umol/kg)
silicate	Silicate concentration.	micromoles per kilogram (umol/kg)
alk_tot	Total alkalinity.	micromoles per kilogram (umol/kg)
alk_tot_stdev	Standard deviation of alk_tot.	micromoles per kilogram (umol/kg)
DIC	Total dissolved inorganic carbon.	micromoles per kilogram (umol/kg)

DIC_stdev	Standard deviation of C_tot.	micromoles per kilogram (umol/kg)
pH	pH of the water.	dimensionless
pH_stdev	Standard deviation of pH.	dimensionless
pCO2	Partial pressure of carbon dioxide at sea surface temperature.	microatmospheres (uatm)
pCO2_stdev	Standard deviation of pCO2.	microatmospheres (uatm)
bicarbonate	Concentration of bicarbonate ion [HCO3]-.	micromoles per kilogram (umol/kg)
bicarbonate_stdev	Standard deviation of bicarbonate concentration.	micromoles per kilogram (umol/kg)
carbonate	Concentration of carbonate ion [CO3]2-.	micromoles per kilogram (umol/kg)
carbonate_stdev	Standard deviation of carbonate concentration.	micromoles per kilogram (umol/kg)
omega_Arg	Aragonite saturation state.	dimensionless
omega_Arg_stdev	Standard deviation of omega_Arg.	dimensionless
non_diss	Percentage of non-dissolving individuals as determined by SEM.	percentage (%)
non_diss_stdev	Standard deviation of non_diss.	percentage (%)
diss_rate1	Type I dissolution rate as determined by SEM. Bednarsek et al. (2012) describe Type I dissolution as "First indices of slightly increased porosity. Aragonite crystals within the upper-prismatic layer affected by dissolution - ‘cauliflower heads’ present."	percentage (%)
diss_rate1_stdev	Standard deviation of diss_rate1.	percentage (%)
diss_rate2	Type II dissolution rate as determined by SEM. Bednarsek et al. (2012) describe Type II dissolution as "Increased porosity. Dissolved patches more extensive and numerous. Prismatic layer partially or completely dissolved, crossed-lamellar layer exposed."	percentage (%)
diss_rate2_stdev	Standard deviation of diss_rate2.	percentage (%)

diss_rate3	Type III dissolution rate as determined by SEM. Bednarsek et al. (2012) describe Type III dissolution as "Less compact crystal structure with compromised shell integrity and extreme frailness. Dissolution within crossed-lamellar layer with crystals thicker and chunkier."	percentage (%)
diss_rate3_stdev	Standard deviation of diss_rate3.	percentage (%)

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	Bongo Net
Generic Instrument Name	Bongo Net
Dataset-specific Description	Specimens were collected by vertically integrating the upper 200 m using a vertical Bongo (mesh size 200 um with an opening of 0.5 m2) and a towed Bongo net (2 nets, with 300 um and 600 um mesh sizes).
Generic Instrument Description	A Bongo Net consists of paired plankton nets, typically with a 60 cm diameter mouth opening and varying mesh sizes, 10 to 1000 micron. The Bongo Frame was designed by the National Marine Fisheries Service for use in the MARMAP program. It consists of two cylindrical collars connected with a yoke so that replicate samples are collected at the same time. Variations in models are designed for either vertical hauls (OI-2500 = NMFS Pairovet-Style, MARMAP Bongo, CalVET) or both oblique and vertical hauls (Aquatic Research). The OI-1200 has an opening and closing mechanism that allows discrete "known-depth" sampling. This model is large enough to filter water at the rate of 47.5 m3/minute when towing at a speed of two knots. More information: Ocean Instruments, Aquatic Research, Sea-Gear

Dataset-specific Instrument Name	Scanning Electron Microscope
Generic Instrument Name	Electron Microscope
Dataset-specific Description	SEM was done using a JEOL JSM 5900LV fitted with a tungsten filament at an acceleration voltage of 15 kV and a working distance of about 10 mm.
Generic Instrument Description	Instruments that generate enlarged images of samples using the phenomena of reflection and absorption of electrons behaving as waves.

Dataset-specific Instrument Name	inorganic carbon and alkalinity analyser
Generic Instrument Name	MARIANDA VINDTA 3C total inorganic carbon and titration alkalinity analyser
Dataset-specific Description	DIC and TA were measured using VINDTA instrument (Versatile INstrument for the Determination of Titration Alkalinity, Marianda, Kiel, Germany) following the Standard Operating Procedures for oceanic CO2 measurements (Dickson et al. 2007).
Generic Instrument Description	The Versatile INstrument for the Determination of Total inorganic carbon and titration Alkalinity (VINDTA) 3C is a laboratory alkalinity titration system combined with an extraction unit for coulometric titration, which simultaneously determines the alkalinity and dissolved inorganic carbon content of a sample. The sample transport is performed with peristaltic pumps and acid is added to the sample using a membrane pump. No pressurizing system is required and only one gas supply (nitrogen or dry and CO2-free air) is necessary. The system uses a Metrohm Titrino 719S, an ORION-Ross pH electrode and a Metrohm reference electrode. The burette, the pipette and the analysis cell have a water jacket around them. Precision is typically +/- 1 umol/kg for TA and/or DIC in open ocean water.

Dataset-specific Instrument Name	MOCNESS
Generic Instrument Name	MOCNESS
Dataset-specific Description	Pteropods were collected using a combination of vertically and obliquely towed Bongo nets and MOCNESS nets
Generic Instrument Description	The Multiple Opening/Closing Net and Environmental Sensing System or MOCNESS is a family of net systems based on the Tucker Trawl principle. There are currently 8 different sizes of MOCNESS in existence which are designed for capture of different size ranges of zooplankton and micro-nekton Each system is designated according to the size of the net mouth opening and in two cases, the number of nets it carries. The original MOCNESS (Wiebe et al, 1976) was a redesigned and improved version of a system described by Frost and McCrone (1974).(from MOCNESS manual) This designation is used when the specific type of MOCNESS (number and size of nets) was not specified by the contributing investigator.

[table of contents | back to top]

Deployments

JR177

Website	https://www.bco-dmo.org/deployment/489470
Platform	RRS James Clark Ross
Report	http://dmoserv3.whoi.edu/data_docs/OA_Nutrition_Coral_Calc/jr177.pdf
Start Date	2007-12-31
End Date	2008-02-16
Description	Cruise information from the British Oceanographic Data Centre (BODC): "Cruise JR 177 was conducted within the Scotia Sea, Southern Ocean. Three transects were run as follows: 1. from Port Stanley (Falkland Islands) to the ice edge, close to South Orkneys Islands, 2. from the ice edge to the Polar Front, north of South Georgia, and 3. from South Georgia to Port Stanley. There were nine main sampling stations along transect 2. Supplementary sampling was carried out at two further stations, one on transect 1 and one in the vicinity of South Georgia. The time spent at each station varied between 1 and 4 days depending on scheduled activities, which was a mixture of CTD, netting, acoustic surveying and mooring deployments. At each station we took samples and measurements to characterise the oceanography, micro- and macronutrients, phytoplankton, zooplankton, krill and myctophid fish. Observations for higher predators were maintained for the majority of daytime hours throughout the cruise. Moorings were recovered and redeployed at 2 stations and contained oceanographic and acoustic instruments and a sediment trap. Whale acoustic buoys were deployed at a supplementary station in vicinity of South Georgia The sampling was undertaken as part of the DISCOVERY 2010 BAS programme, with its remit to investigate and describe the response of the Southern Ocean ecosystem to climate variability, climate change and commercial exploitation."

[table of contents | back to top]

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.

[table of contents | back to top]

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.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1041106
United Kingdom Natural Environmental Research Council (NERC)	NE/H017267/1
European Commission Marie Curie Actions Program (EC - Marie Curie Actions)	MEST-CT-2004-514159

[table of contents | back to top]