Coral carbon, oxygen, and boron isotopes; coral Sr/Ca, Mg/Ca, U/Ca, and Ba/Ca; coral chlorophyll-a from samples from reef field sites in Puerto Morelos, Mexico & Kaneohe Bay, Hawaii

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Project
» Physiology and Biogeochemistry of Repeatedly Bleached and Recovering Caribbean Corals (repeat coral bleaching)

Contributors	Affiliation	Role
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Dataset Description

Coral carbon, oxygen and boron isotopes; coral Sr/Ca, Mg/Ca, U/Ca and Ba/Ca; coral chlorophyll-a. Coral samples collected at Puerto Morelos, Mexico (20°50'N, 86°52'W) in August and September 2010.

Methods & Sampling

Full details of the experimental design and analytical methods are in:
Schoepf V, McCulloch MT, Warner ME, Levas SJ, Matsui Y, Aschaffenburg MD, Grottoli AG. 2014. Short-term coral bleaching is not recorded by skeletal boron isotopes. PLOS ONE 9(11): e112011. doi:10.1371/journal.pone.0112011

A brief description of the methods follows:

Coral Bleaching Experiment
The corals used for this study were taken from an experiment where three species of Caribbean corals were experimentally bleached in two consecutive summers. These corals were physiologically fully recovered (i.e., there were no significant differences between treatment and control corals in any of the measured variables) after a year on the reef prior to exposure to the elevated temperature stress for a second time. The coral fragments were collected from 9 healthy colonies of *Porites divaricata* (branching morphology), *Porites astreoides* (mounding/encrusting morphology), and mounding *Orbicella faveolata* (formerly *Montastraea faveolata*) (large mounding morphology) in July 2009 from reefs near Puerto Morelos, Yucatan Peninsula, Mexico (20 deg 50' N, 86 deg 52' W). Half of the coral fragments from each parent colony were randomly assigned to each treatment: (1) ambient control fragments were maintained in tanks with ambient seawater

temperature (30.66 +/- 0.24 degrees C), and (2) treatment fragments were placed in tanks with elevated seawater temperature (31.48 +/- 0.20 degrees C). Seawater temperature in the treatment tanks was gradually elevated over the course of a week. Corals were not fed but had access to unfiltered seawater. After a total of 15 days, temperature in all tanks was returned to ambient levels, and all coral fragments were placed back in situ on the reef for one year.

The experiment was repeated in July 2010. All corals that had served as ambient control fragments the previous summer were placed in tanks with ambient seawater, whereas all corals that had been used as treatment fragments were maintained in tanks with elevated temperature. After 17 days, all tanks were returned to ambient temperature levels and one control and one treatment fragment per colony of each species were then frozen for geochemical analyses (0 weeks on the reef). All remaining fragments were placed on the back reef. All remaining corals were recollected from the reef after 6 weeks and frozen for geochemical analyses.

Chlorophyll a
Coral tissue was removed from the skeleton of a portion of each fragment with a WaterPik, homogenized and centrifuged. Chlorophyll a was determined using a Shimadzu UV-VIS spectrophotometer and the equations of Jeffrey and Humphrey. Chlorophyll a content was standardized to surface area, which was determined using the aluminium foil method.

Calcification
Published calcification rates determined using the buoyant weight technique were reproduced from Grottoli et al.

Isotopic Analyses
Coral tissue was removed from the skeleton using a dental hygiene tool. The uppermost layer of the dried skeleton was then gently shaved with a diamond-tipped Dremel tool and ground to fine powder using agate mortar and pestles.

Boron isotopes: Refer to Schoepf et al. 2014 PLOS ONE for the boron extraction methods. The extracted boron was analysed at the University of Western Australia using either a Neptune Plus Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS; Thermo Fisher Scientific) fitted with a PFA nebulizer and a cyclonic quartz spray chamber or a NU Plasma II MC-ICP-MS (NU Instruments). The boron isotopic composition of the skeleton (delta 11B) was reported as the per mil deviation of the stable isotopes 11B:10B relative to SRM-951.

Carbon and oxygen isotopes: An aliquot of the dried and ground skeletal powder was analysed for d13C and d18O using an automated Kiel Carbonate Device coupled to a Stable Isotope Ratio Mass Spectrometer (SIRMS; Finnigan Delta IV) at The Ohio State University. Samples were not pre-treated. Samples were acidified under vacuum with 100% ortho-phosphoric acid. The carbon isotopic composition of the skeleton (d13C) was reported as the per mil deviation of the stable isotopes 13C:12C relative to Vienna-Peedee Belemnite Limestone standard (v-PDB). Skeletal oxygen isotopes (d18O) were reported as the per mil deviation of the stable isotopes 18O:16O relative to v-PDB.

Trace Element Analyses
From the solution used for d11B analysis, a 2-7 uL aliquot was diluted to a final concentration of 10 ppm Ca in 2% HNO3 spiked with ~19 ppb Sc, 19 ppb Y, 0.19 ppb Pr, 0.095 ppb Bi, and 19 ppb V. Samples were then analysed for Sr/Ca, Mg/Ca, U/Ca, and Ba/Ca on an X-Series 2 Quadrupole Inductively Coupled Plasma Mass Spectrometer (Q-ICPMS; Thermo Fisher Scientific) at the University of Western Australia using the standard Xt interface and the plasma screen fitted.

Data Processing Description

Details of the statistical analysis methods are in Schoepf et al. 2014 PLOS ONE (doi:10.1371/journal.pone.0112011).

BCO-DMO edits:
- Modified parameter names to conform with BCO-DMO naming conventions.
- Replaced spaces with underscores in the species column.
- Replaced '.' with 'nd' to indicate 'no data'.
- Added lat/lon of collection site from the metadata form.
- 26 Feb 2015: corrected time_on_reef values. Values of 2 to were changed to 1.5. (rounding error in original

spreadsheet).

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Data Files

File
coral_isotopes.csv (Comma Separated Values (.csv), 13.49 KB) MD5:a650d18f6709a759645bb66fd997b11e Primary data file for dataset ID 550834

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Parameters

Parameter	Description	Units
collection_site	Name of the place where the coral samples were collected.	unitless
lat	Latitude of the collection site. Positive values = North.	decimal degrees
lon	Longitude of the collection site. Positive values = East.	decimal degrees
species	Name of the coral species.	unitless
time_on_reef	Number of weeks on the reef.	weeks
treatment_type	Treatment type: Control = nonbleached; treatment = bleached.	unitless
coral_ID	Coral identification number.	unitless
genotype	Genotype (parent colony). mix = skeletal powder from different genotypes was combined because individual samples did nothave enough material for d11B and trace elements.	unitless
chl_a	The chlorophyll a content of the endosymbiont fraction standardized to surface area of the fragment.	micrograms per square centimeter (ug/cm2)
delta_11B	The coral skeletal boron isotope composition relative to the standard SRM951 in per mil.	per mil (‰)
delta_13C	The coral skeletal carbon isotope composition relative to the standard v-PDB in per mil.	per mil (‰)
delta_18O	The coral skeletal oxygen isotope composition relative to the standard v-PDB in per mil.	per mil (‰)
Sr_to_Ca	The coral skeletal Sr concentration normalized to coral skeletal Ca concentration.	millimole per mole (mmol/mol)
Mg_to_Ca	The coral skeletal Mg concentration normalized to coral skeletal Ca concentration.	millimole per mole (mmol/mol)
U_to_Ca	The coral skeletal U concentration normalized to coral skeletal Ca concentration.	micromole per mole (umol/mol)
Ba_to_Ca	The coral skeletal Ba concentration normalized to coral skeletal Ca concentration.	micromole per mole (umol/mol)

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Instruments

Dataset-specific Instrument Name	Inductively Coupled Plasma Mass Spectrometer
Generic Instrument Name	Inductively Coupled Plasma Mass Spectrometer
Dataset-specific Description	The extracted boron was analysed at the University of Western Australia using either a Neptune Plus Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS; Thermo Fisher Scientific) fitted with a PFA nebulizer and a cyclonic quartz spray chamber or a NU Plasma II MC-ICP-MS (NU Instruments). An aliquot of the dried and ground skeletal powder was analysed for d13C and d18O using an automated Kiel Carbonate Device coupled to a Stable Isotope Ratio Mass Spectrometer (SIRMS; Finnigan Delta IV) at The Ohio State University. Samples were then analysed for Sr/Ca, Mg/Ca, U/Ca, and Ba/Ca on an X-Series 2 Quadrupole Inductively Coupled Plasma Mass Spectrometer (Q-ICPMS; Thermo Fisher Scientific) at the University of Western Australia using the standard Xt interface and the plasma screen fitted.
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	Shimadzu UV-VIS spectrophotometer
Generic Instrument Name	Spectrophotometer
Dataset-specific Description	Chlorophyll a was determined using a Shimadzu UV-VIS spectrophotometer and the equations of Jeffrey and Humphrey.
Generic Instrument Description	An instrument used to measure the relative absorption of electromagnetic radiation of different wavelengths in the near infra-red, visible and ultraviolet wavebands by samples.

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Deployments

Coral_physiology_field_exper

Website	https://www.bco-dmo.org/deployment/517699
Platform	Reef Field Sites

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Project Information

Physiology and Biogeochemistry of Repeatedly Bleached and Recovering Caribbean Corals (repeat coral bleaching)

Coverage: Puerto Morelos, Mexico

(Extracted from the NSF award abstract)

The overall stability and health of coral reefs is declining world-wide at an unprecedented rate. Mass coral bleaching, wherein exposure to elevated temperature leads to the loss of significant numbers of endosymbiotic

dinoflagellates (Symbiodinium spp., commonly called zooxanthellae) and/or photosynthetic pigments, serves as a primary global example of how fragile this symbiosis is. While we have begun to understand the ecological and physiological impacts of bleaching, there remain key fundamental gaps in knowledge. In particular, it is becoming increasingly clear that a) not all corals either respond to, or recover from, bleaching events the same way, and that b) the impact of annual or repeated bleaching events on corals has not been examined in sufficient detail. Several non-mutually exclusive ecological and physiological pathways could impact how a particular coral species succumbs to or recovers from bleaching. Recent evidence suggests that the following features may play key roles for coral survival in the face of future seawater warming and mass bleaching events: 1) shifts in trophic partitioning (e.g., proportional reliance on autotrophy and heterotrophy) and energy reserve utilization, 2) enhanced thermal tolerance through host and algal-mediated physiological responses, and 3) harboring of different Symbiodinium phylotypes. However, these mechanisms have yet to be investigated in a unified approach that covers the entire coral holobiont system (algae, host tissue, and skeleton), or under scenarios of repeated bleaching.

The overall objectives of this study are as follows: 1) to determine the effect of single and repeated bleaching on the physiology, biogeochemistry, and recovery of some Caribbean coral species, and 2) to determine which Symbiodinium-type and host-species combinations are more resilient to single and repeated bleaching, what aspects of their physiology and biogeochemistry render them resilient, and to use this information to evaluate the long-term persistence of Caribbean coral reefs. To address these objectives, the following physiological variables will be measured: 1) Symbiodinium type, photochemical function and algal stress physiology, and 2) animal host energy reserves, defense enzyme concentration, skeletal growth, and feeding capacity in the corals Porites porites, Porites astreoides, and Montastraea faveolata. Corals will be examined immediately following thermal stress designed to approximate natural bleaching, and recovery will be monitored over short and long-term time scales. Next, the impact of repeated bleaching will be examined in the subsequent year, followed by examination over the next recovery period. This research is designed to simultaneously evaluate the symbiotic algae, coral host, and skeleton, and to identify patterns of physiological responses and recovery of each Symbiodinium-type and host-species combination that would be indicative of the resilience capacity of Caribbean corals to future more frequent thermal perturbations.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-0825413

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