Coral physiological and biological data collected during diel sampling in outdoor mesocosms in Hawaii from June 2022 to March 2024

Website: https://www.bco-dmo.org/dataset/995155
Data Type: experimental
Version: 1
Version Date: 2026-03-18

Project
» Collaborative Research: Reevaluating calcification response to changes in seawater chemistry by testing the Proton Flux Hypothesis and the Coral Metabolism Model (Proton Flux Hypothesis)

Contributors	Affiliation	Role
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Abstract
This dataset contains high-frequency environmental and experimental measurements collected from a long-term mesocosm experiment conducted at the Hawaii Institute of Marine Biology. Data were recorded every hour on the hour from 12 continuous flow-through mesocosms, each approximately 500 liters in volume and stocked with two species of Hawaiian corals (20 colonies per species per mesocosm). The experiment was designed to quantify the effects of multiple seasonal and environmental treatments on coral physiological responses under controlled, yet ecologically realistic, conditions. For each mesocosm, the dataset includes time-stamped observations of experimental identifiers (experiment, treatment, type, season), mesocosm descriptors (tank area, tank depth, time of day, flow rate), and a suite of environmental parameters measured in situ, including total alkalinity (ta), temperature (temp), salinity (sal), dissolved oxygen (o2), and pH on the NBS scale (ph_nbs). Together, these measurements provide an integrated record of physical and biogeochemical dynamics within the mesocosms and enable detailed assessment of coral environmental exposure throughout the experiment. This dataset supports investigations into coral reef resilience, carbonate chemistry variability, and environmental drivers of coral physiological performance under future ocean conditions.

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Coverage

Location: Hawaii Institute of Marine Biology, Kaneohe Bay, Oahu, Hawaii
Spatial Extent: **Lat**:21.4327 **Lon**:-157.7877
Temporal Extent: 2022-06-07 - 2024-03-15

Methods & Sampling

Overview

Seasonal mesocosm incubations of Montipora capitata and Pocillopora acuta were conducted at the Hawai'i Institute of Marine Biology (HIMB) from June 2022 through March 2024. Experiments were run during two seasonal windows each year: winter (January 10–March 17) and summer (June 10–August 17). Due to facility limitations, all treatments could not run simultaneously. Therefore, each seasonal experiment consisted of two sequential 30-day exposures, each using newly collected coral colonies. At the beginning (Day 0) and end (Day 30) of each experiment, a 26-hour diel sampling was conducted to characterize variability in total alkalinity (TA) and carbonate system parameters under each treatment. All methods were standardized across replicates, with only TA and pH manipulations differing among treatments.

Coral Collection and Pre-Experiment Holding

Coral colonies of M. capitata and P. acuta were collected by hand while snorkeling from shallow (1 m) fringing reef habitat surrounding HIMB in Kāne'ohe Bay, Hawai'i. Colonies were transported immediately to the HIMB mesocosm facility and held for one week in flow-through tanks identical to the experimental mesocosms. One day before each 30-day experiment, colonies were stained with alizarin red for eight hours to mark the starting skeletal growth band (Jokiel and Morrissey 1986). At the start of each experiment, colonies were buoyant weighed following Jokiel (1978) and randomly assigned to mesocosms. Each mesocosm contained 20 colonies of each species arranged in a standardized alternating layout to avoid species-level clustering.

Mesocosm Facility Design

Experiments were conducted in a flow-through mesocosm facility described by Jokiel et al. (2014). The system consisted of twelve 450 L fiberglass tanks arranged in four rows of three mesocosms, each row supplied by a dedicated header tank. Natural seawater was pumped from Kāne'ohe Bay at ~3 m depth and delivered unfiltered to preserve natural diel and seasonal environmental variability. Each header tank fed seawater into a 100 L mixing reservoir where TA and pH manipulations were applied before seawater entered the mesocosms. Residence time in each mesocosm was greater than one hour. Each tank contained two submersible circulation pumps and a continuously running airstone to maintain internal water movement and oxygenation.

Treatment Conditions and Carbonate Chemistry Manipulation

Four carbonate chemistry treatments were created across each pair of 30-day experiments through controlled manipulation of total alkalinity (TA), dissolved inorganic carbon (DIC), and pH:

Ambient control

Low pH (target ΔpH approximately −0.3 from ambient)

High or low TA (±100 µmol kg−1 from ambient)

Combined low pH and altered TA

TA manipulations were accomplished in header mixing tanks using peristaltic pumps delivering either 1.0 M HCl (for low TA; ~3 mL min−1) or 1.0 M Na2CO3 (for high TA; ~2 mL min−1). pH reductions were achieved by bubbling pure CO2 or a CO2-air mixture directly into mesocosms using a Maxi-Jet 1600 pump-driven venturi injector. Because each row was supplied by a single header tank, only one direction of TA manipulation (increase or decrease) could be performed within a given 30-day period. The second 30-day experiment used the opposite TA manipulation to ensure all treatments were completed each season.

Seawater Sampling and Measurements

Daily Measurements

Temperature, salinity, dissolved oxygen, and pHNBS were measured daily at mid-day in each mesocosm and header tank. During diel sampling, these parameters were measured every hour on the hour for 26 consecutive hours. Measurements were collected using a YSI ProDSS or YSI 556 MPS multiparameter meter.

pH electrodes were calibrated daily using NIST-traceable pH 4, 7, and 10 buffers and corrected to the total scale using Tris buffer from the A. Dickson laboratory (Scripps Institution of Oceanography). Dissolved oxygen probe calibrations followed manufacturer air-saturation protocols.

Total Alkalinity Sampling and Storage

Seawater samples for TA analysis were collected hourly during each 26-hour diel cycle. Bottles were rinsed three times with sample water and filled in acid-cleaned 100 mL borosilicate bottles with no headspace to prevent gas exchange. Samples were stored in the dark at ambient temperature and analyzed within 12 hours of collection. Sampling followed best practices described in Dickson et al. (2007).

TA Determination and Derived Carbonate Chemistry

Total alkalinity was measured by open-cell potentiometric titration on a Metrohm 877 Titrino Plus with a Metrohm 9101 Herisau glass pH electrode. All titrations were standardized using certified reference materials (CRMs) from the Dickson laboratory. Electrode slope, offset, and drift were checked daily to ensure analytical consistency. Carbonate system parameters, including DIC, pCO2, bicarbonate, carbonate ion concentration, and omega aragonite, were calculated using the R package seacarb.

Data Processing Description

Overview

Data processing included organization of raw seawater chemistry measurements, conversion of pH values to the total scale, calculation of carbonate system parameters, buoyant-weight-based calcification calculations, and post-hoc biochemical and skeletal data extraction. All steps described below represent the procedures used to generate the submitted dataset. No statistical analysis, modeling, or graphing is included here.

Seawater Chemistry Data Processing

pH Conversion

Daily pHNBS measurements from the YSI multiparameter meter were converted to total scale (pHT) using Tris buffer reference standards prepared and certified by the Dickson Laboratory. Temperature-dependent conversion equations followed Dickson et al. (2007).
All pH values were standardized across seasons using:

pHT = pHNBS + (Δbuffer offset)

where Δbuffer offset was determined daily from Tris-buffer calibration measurements.

Total Alkalinity (TA)

Raw potentiometric titration files from the Metrohm 877 Titrino Plus were exported using Metrohm tiamo software (version 2.5).
Processing included:

Drift correction and electrode slope verification.

CRM standardization using certified values for TA (Dickson Laboratory, batch number provided in metadata).

Extraction of equivalence point and TA value using open-cell titration algorithms embedded in tiamo.

TA values were reported in µmol kg-1.
If sample density was required, seawater density was calculated using temperature and salinity data following Fofonoff and Millard (1983).

BCO-DMO Curation Notes

Curation Actions Performed on Data

- Loaded ecosys_dat.csv as resource "995155_v1_diel-sampling" in CSV format, treating empty strings and "NA" as missing values, with headers on row 1
- Converted date field from M/D/YYYY format to ISO 8601 YYYY-MM-DD date format
- Renamed five fields to valid identifiers: "tank area (m2)" to tank_area, "tank depth (m)" to tank_depth, "flow rate (L sec-1)" to flow_rate, "ta (umol kg -1)" to ta, and "o2 (mg/L)" to o2
- Set data types for all 16 fields: date as date (%Y-%m-%d), experiment and mesocosm and tp as integer, flow_rate, o2, ph_nbs, sal, ta, tank_area, tank_depth, and temp as number, and season, tod, treatment, and type as string
- Output written to 995155_v1_diel-sampling.csv

Curation Actions Performed on Metadata

* Standard metadata entry and formatting of provided metadata.
* Title of dataset updated to include the time range in the data starting in June 2022 not January 2022

Known Issues [Potentially Impacting Reuse]

* units of salinity described as ppt with uncertainty indicated by a question mark

Problem Description

N/A

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Data Files

File
995155_v1_diel-sampling.csv (Comma Separated Values (.csv), 512.45 KB) MD5:01a01ecf48b83e035b823b5b7a920f8d Primary data file for dataset ID 995155, version 1

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Related Publications

Dickson, A.G.; Sabine, C.L. and Christian, J.R. (eds) (2007) Guide to best practices for ocean CO2 measurement. Sidney, British Columbia, North Pacific Marine Science Organization, 191pp. (PICES Special Publication 3; IOCCP Report 8). DOI: https://doi.org/10.25607/OBP-1342
Methods

Fofonoff, N. P., & Millard Jr, R. C. (1983). Algorithms for Computation of Fundamental Properties of Seawater. Endorsed by Unesco/SCOR/ICES/IAPSO Joint Panel on Oceanographic Tables and Standards and SCOR Working Group 51. Unesco Technical Papers in Marine Science, No. 44.
Methods

Jokiel, P. L., & Morrissey, J. I. (1986). Influence of size on primary production in the reef coral Pocillopora damicornis and the macroalga Acanthophora spicifera. Marine Biology, 91(1), 15–26. https://doi.org/10.1007/bf00397566 https://doi.org/10.1007/BF00397566
Methods

Jokiel, P. L., Bahr, K. D., & Rodgers, K. S. (2014). Low-cost, high-flow mesocosm system for simulating ocean acidification with CO2 gas. Limnology and Oceanography: Methods, 12(5), 313–322. Portico. https://doi.org/10.4319/lom.2014.12.313
Methods

Jokiel, P. L., Maragos, J. E., & Franzisket, L. (1978). Coral growth: buoyant weight technique. In D. R. Stoddart & R. E. Johannes (Eds.), Coral reefs: research methods (pp. 529–541). Paris: UNESCO. ISBN 9789231014918. Available from https://www.researchgate.net/publication/285472773_Coral_growth_buoyant_weight_technique_In_Stoddart_DR_Johannes_RE_eds_Coral_reefs_research_methods
Methods

Lavigne H, Gattuso JP (2016) Seacarb: seawater carbonate chemistry with R, R package version 3.3.0. http://CRAN.R-project.org/package=seacarb
Software

Metrohm AG (2015). Tiamo version 2.5.0 [software]. Available from https://activation.metrohm.com/software/tiamo/v/2.5.0
Software

Page, H. N., Andersson, A. J., Jokiel, P. L., Rodgers, K. S., Lebrato, M., Yeakel, K., … Bahr, K. D. (2016). Differential modification of seawater carbonate chemistry by major coral reef benthic communities. Coral Reefs, 35(4), 1311–1325. doi:10.1007/s00338-016-1490-4
Results

RStudio Team (2022) RStudio: Integrated Development for R. Version 4.2.0,. RStudio, Inc., Boston, MA. http://www.rstudio.com/
Software

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Parameters

Parameter	Description	Units
date	Date	units
experiment	Identifier for each mesocosm experiment conducted between 2022 and 2024	unitless
tp	Timepoint indicator describing sampling day within the experiment (e.g., Day 0 or Day 30)	unitless
season	Season during which the experiment was conducted (e.g., summer, winter)	unitless
treatment	Carbonate chemistry treatment applied (ambient control or elevated pCO2)	unitless
type	Sampling type indicating diurnal sampling effort	unitless
mesocosm	Identifier of the mesocosm unit from which measurements were taken	unitless
tank_area	Surface area of the mesocosm tank	square meters (m2)
tank_depth	Depth of the mesocosm tank	meters (m)
tod	Time of day of measurement (e.g., morning, midday, evening)	unitless
flow_rate	Flow rate of seawater entering the mesocosm	liters per second (L sec-1)
ta	Total alkalinity of seawater	micromoles per kilogram (umol kg -1)
temp	Seawater temperature	degrees Celsius
sal	Seawater salinity	parts per thousand (ppt)
o2	Dissolved oxygen concentration	miligrams per liter (mg/L)
ph_nbs	pH measured on the NBS scale	NBS scale

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Instruments

Dataset-specific Instrument Name	Snorkel-based Coral Collection Gear
Generic Instrument Name	Diving Mask and Snorkel
Dataset-specific Description	Use: Hand-collection of coral colonies at 1 m depth surrounding HIMB. Notes: Standard snorkeling gear (mask, snorkel, fins) and hand tools (bone cutters, chisels) were used; no specialized electronic instrumentation.
Generic Instrument Description	A diving mask (also half mask, dive mask or scuba mask) is an item of diving equipment that allows underwater divers, including, scuba divers, free-divers, and snorkelers to see clearly underwater. Snorkel: A breathing apparatus for swimmers and surface divers that allows swimming or continuous use of a face mask without lifting the head to breathe, consisting of a tube that curves out of the mouth and extends above the surface of the water.

Dataset-specific Instrument Name	Flow-through Mesocosm System
Generic Instrument Name	no_bcodmo_term
Dataset-specific Description	Flow-through Mesocosm System Reference: Jokiel et al. 2014 Description: Outdoor continuous-flow mesocosm facility at HIMB consisting of twelve 450 L fiberglass tanks (1 m x 1 m x 0.5 m) supplied by seawater pumped from ~3 m depth in Kāneʻohe Bay. Flow: Adjustable head box delivering ~50 min-1 seawater residence time. Notes: All mesocosms contained two submersible pumps and an airstone for continuous mixing.
Generic Instrument Description	No relevant match in BCO-DMO instrument vocabulary.

Dataset-specific Instrument Name	CO2 Gas Delivery System
Generic Instrument Name	no_bcodmo_term
Dataset-specific Description	Components: CO2 cylinder, regulator, and gas injection line. Use: Manipulation of mesocosm pH by bubbling pure CO2 or CO2-air mixtures directly into individual mesocosms. Calibration: Flow checked daily using bubble-rate timing; regulator pressures recorded each morning.
Generic Instrument Description	No relevant match in BCO-DMO instrument vocabulary.

Dataset-specific Instrument Name	Submersible Pumps
Generic Instrument Name	Pump
Dataset-specific Description	Manufacturer: Maxi-Jet Model: Maxi-Jet 1600 Use: Internal water circulation and CO2 injection mixing inside mesocosms. Calibration: Flow rate verified twice per season using volumetric bucket timing.
Generic Instrument Description	A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps

Dataset-specific Instrument Name	Peristaltic Pumps for TA Manipulation
Generic Instrument Name	Pump
Dataset-specific Description	Manufacturer: To be filled by user (brand not provided) Flow Rate: 2–3 mL min-1 Use: Delivery of 1.0 M HCl or 1.0 M Na2CO3 to achieve target alkalinity offsets. Calibration: Flow rate calibrated at the start of each 30-day experiment by measuring timed output volumes.
Generic Instrument Description	A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps

Dataset-specific Instrument Name	Buoyant Weighing Apparatus
Generic Instrument Name	scale or balance
Dataset-specific Description	Use: Measurement of initial and final coral colony mass for calcification estimates. Components: Electronic balance Custom platform submerged in seawater for buoyant weight readings Calibration: Balance calibrated daily using known-weight standards. System checked for drift by repeated weighing of a reference coral fragment.
Generic Instrument Description	Devices that determine the mass or weight of a sample.

Dataset-specific Instrument Name	Open-cell Potentiometric Titrator for Total Alkalinity
Generic Instrument Name	Titrator
Dataset-specific Description	Manufacturer: Metrohm Model: 877 Titrino Plus with 9101 Herisau glass pH electrode Use: Measurement of TA from discrete 100 mL seawater samples twice weekly. Calibration: Daily electrode slope and offset verification. Weekly CRM calibration using certified reference materials from A. Dickson (batch number supplied by user). Notes: All titrations performed at constant temperature.
Generic Instrument Description	Titrators are instruments that incrementally add quantified aliquots of a reagent to a sample until the end-point of a chemical reaction is reached.

Dataset-specific Instrument Name	YSI Multiparameter Water Quality Meters
Generic Instrument Name	Water Quality Multiprobe
Dataset-specific Description	YSI ProDSS YSI 556 MPS Manufacturer: YSI Inc. Parameters Measured: Temperature, salinity, dissolved oxygen, and pHNBS. Calibration: DO probe calibrated daily using water-saturated air. pH electrode calibrated daily using pH 4, 7, and 10 NIST buffers; corrected to total scale using Tris buffer from Dickson Laboratory. Conductivity and temperature routinely checked using certified standards.
Generic Instrument Description	An instrument which measures multiple water quality parameters based on the sensor configuration.

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Project Information

Collaborative Research: Reevaluating calcification response to changes in seawater chemistry by testing the Proton Flux Hypothesis and the Coral Metabolism Model (Proton Flux Hypothesis)

Coverage: Kaneohe, Hawaii

NSF Award Abstract:
Corals build calcium carbonate skeletons to maintain the three-dimensional structure of a coral reef, which provides habitat for many organisms and protects shorelines from bioerosion and storm damage. However, changes in ocean chemistry threaten the ability of corals to build and sustain these ecological important structures. To further the understanding of how climate change impacts coral reefs, this project investigates how changes in ocean carbonate chemistry directly influence coral calcification. The researchers are conducting a series of experiments on corals grown in seawater tanks to study corals responses to seawater chemistry in a changing ocean. Broader impacts of the project include student research opportunities, science-inquiry labs, and virtual learning. This project supports the training of several early career researchers, Ph.D. students, undergraduates, and high school students in the disciplines of chemistry, engineering, and marine ecology. Researchers partner with the Texas State Aquarium to communicate with the general public through a virtual research expedition series that will focus on coral reef health. This series includes interviews, behind the scene tours, and virtual dives on coral reefs in Hawaii.

This project examines the fundamental connections between seawater chemistry and coral physiology by investigating the modulation of seawater chemistry in the microenvironment surrounding corals. Specifically, this project 1) examines the response of corals to differing carbonate chemistry and 2) characterizes the proton gradient across the corals' boundary layers under differing ocean acidification conditions. Results of this work isolate whether carbonate ions or hydrogen ions have a stronger influence on calcification rates. This work utilizes a state-of-the-art experimental mesocosm facility that combines an automated systems to simultaneously and independently control both total alkalinity and carbon dioxide in the tanks to examine coral response under different carbon chemistry scenarios. Small-scale gradients in carbon chemistry surrounding the corals are being characterized using an innovative solid-state, reagentless sensor capable of making simultaneous measurements of two critical carbon system parameters. Coral biological response variables are quantified during short-term incubations and long-term mesocosm manipulations to understand physiological implications across multiple scales (i.e., individual and community scales) and across boundary layers.

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.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2049406
NSF Division of Ocean Sciences (NSF OCE)	OCE-2049407

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