Pencil urchin respiration rates at different temperatures from four sites in the Galápagos archipelago

Website: https://www.bco-dmo.org/dataset/838816
Data Type: Cruise Results
Version: 2
Version Date: 2021-09-07

Project
» The Role of Temperature in Regulating Herbivory and Algal Biomass in Upwelling Systems (Temperature and Herbivory)

Contributors	Affiliation	Role
Bruno, John	University of North Carolina at Chapel Hill (UNC-Chapel Hill)	Principal Investigator
Rauch, Shannon	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
The responses of ectothermic organisms to changes in temperature can be modified by acclimatization or adaptation to local thermal conditions. Thus, the effect of global warming and the deleterious effects of extreme highs (e.g., heatwaves) on the metabolism and fitness of ectotherms can be population-specific and reduced at warmer sites. We tested the hypothesis that grazer populations at warmer sites in the Galápagos are less thermally sensitive than populations at cooler sites (i.e., potentially due to acclimatization or adaptation). We quantified the acute thermal sensitivity of four populations of the pencil sea urchin, Eucidaris galapagensis, by measuring individual oxygen consumption across a range of temperatures. Thermal performance curves were estimated for each population and compared to the local ocean temperature regime. Results indicated that E. galapagensis populations were adapted and/or acclimatized to local thermal conditions as populations at warm sites had substantially higher thermal tolerance. The acute thermal optimums (Topt) for the warmest and coolest site populations differed by 3°C and the Topt was positively correlated with maximum temperature recorded at each site. Additionally, temperature-normalized respiration rates and activation energy were negatively related to the maximum temperature. Understanding the temperature-dependent performance of the pencil urchin (the most significant mesograzer in this system), including its population-specificity, provides insight into how herbivores and the functions they perform might be affected by further ocean heating.

Table of Contents

Coverage

Spatial Extent: **N**:0.2703 **E**:-90.4226 **S**:-1.2914 **W**:-90.5448
Temporal Extent: 2018-08-11 - 2019-05-23

Acquisition Description

We performed the urchin physiology experiments in August 2018 at four different sites accessed via the R/V Queen Mabel. We recorded the temperature at each site by deploying one temperature logger (HOBO Water Temperature Pro v2 Data Logger- U22 001, Onset corporation, USA) during a previous research cruise in March 2018. Temperature was recorded at each site every 30 min at 7-12 m depth from March to August 2018. Punta Espinosa, located in the northeastern point of Fernandina Island in the western bioregion of the Archipelago, is within a major upwelling zone. La Botella and Punta Cormorant are located in the western and central-northern sides of Floreana, respectively, a southern island in the central-southeastern bioregion. Bartolomé is located in the south-eastern side of Santiago Island, in the central bioregion. Punta Espinosa and La Botella are located in high-upwelling zones; while Bartolomé and Punta Cormorant are located in low upwelling zones.

Site / Lat, Long
La Botella / 1.2914° S, 90.4965° W
Punta Cormorant / 1.2206° S, 90.4226° W
Punta Espinosa / 0.2703° S, 91.4358° W
Bartolomé / 0.2797° S, 90.5448° W

Using SCUBA at rocky reefs of depths of 7-12 m, eight individuals of Eucidaris galapagensis were hand-collected from each of the four sites during the August 2018 cruise aboard the R/V Queen Mabel. Selected sites displayed average urchin densities ranging from 2.5 to 5.0 ind·m-2. After collections, urchins were allowed to stabilize in a bucket on the ship with seawater and an aerator at ambient temperature for 30 min. Sea surface temperature was recorded for each collection site using a calibrated digital thermometer (Traceable High Accuracy ±0.2°C Digital Thermometer S/N 170718701).

The thermal sensitivity of each urchin (n=8 per site) was measured in a closed system of ten 620 ml acrylic respiration chambers with magnetic stir bars. In this respirometry setup, there were eight replicate chambers that contained sea urchins and two chambers with only seawater as controls. Oxygen consumption and temperature were monitored in each individual chamber with a fiber-optic oxygen probe (Presens dipping probes [DP-PSt7-10-L2.5-ST10-YOP], Germany) and a temperature probe (Pt1000), respectively. Measurements were taken using a Presens Oxygen Meter System (OXY-10 SMA (G2) Regensburg, Germany) with temperature correction made for each probe independently. Oxygen concentration in the urchins and control chambers was measured every 1 s during trials, that lasted 6 to 10 minutes for a given temperature. Temperature was controlled [±0.2°C] using a thermostat system (Apex Aquacontroller, Neptune Systems), bucket heaters (King Work Bucket Heater 05-742G 1000W), and a chiller (AquaEuroUSA Max Chill-1/13 HP). At each site, the initial (and lowest) temperature was the local ambient. After each trial, the temperature was increased by 1-3°C, depending on the temperature. We decreased the range between treatment temperatures around the expected respiration peak (based on pilot data) because increased resolution improves curve fitting. We used the following temperatures (in °C) for urchins tested from each of the four sites: Punta Espinosa (19, 23, 26, 28, 30, 31, 32, 33, 34, 36, 38, 42), La Botella (20, 23, 26, 28, 30, 31, 32, 33, 34, 36, 38, 42), Punta Cormorant (22, 26, 28, 30, 31, 32, 33, 34, 36, 38, 42) and Bartolomé (23, 26, 28, 30, 31, 32, 33, 34, 36, 38, 41). It took 10 to 20 minutes to warm the water bath between treatment levels (temperature ramping rates did not differ between sites). Once stabilized at the new temperature treatment level, the water inside the chambers was replaced with new seawater to ensure that it matched the temperature of the water bath, and to reset O2 and CO2 levels. The water volume in each chamber was measured indirectly by measuring urchin volume (as the volume of water displaced from a graduated cylinder) and subtracting that from the known chamber volumes. After all measurements had been made, urchins were frozen on the ship and brought to the Marine Ecology Laboratory of the Galápagos Science Center (GSC) on San Cristóbal Island. Respiration rates were normalized to urchin Ash-Free Dry Weight, which was determined by first drying each sample in a drying oven for 24 hrs at 60°C and then burning it in a muffle furnace (Optic Ivymen System Laboratory Furnace 8.2/1100) for 4 hrs at 500°C.

Processing Description

We used simple linear models to compare the relationship between thermal history and site-level means and variances (n = 4 sites) of three TPC metrics (Topt, E, and b(Tc)). We compared five thermal history metrics from the two months preceding collections using AICs (Akaike Information Criterion), including maximum, mean, minimum, range, and upper 95th percentile temperature. The upper 95th percentile temperature always had the lowest AIC scores and, thus, was used it as the independent variable in all models reported in the results. Normality of residuals was visually inspected using quantile-quantile plots. All data were analyzed using R, and data and code are publicly available at https://github.com/njsilbiger/GalapagosUrchins

BCO-DMO Processing:
- renamed parameters (replaced periods with underscores);
- changed date format to YYYY-MM-DD;
- changed start and stop time columns to ISO8601 format: YYYY-MM-DDThh:mm;
- added start and stop time columns in UTC;
- 2021-09-07 (v2): processed data file received on 2021-09-06 and updated metadata.

[table of contents | back to top]

Related Publications

Silva Romero, I., Bruno, J. F., Silbiger, N. J., & Brandt, M. (2021). Local conditions influence thermal sensitivity of pencil urchin populations (Eucidaris galapagensis) in the Galápagos Archipelago. Marine Biology, 168(3). doi:10.1007/s00227-021-03836-9
Results

[table of contents | back to top]

Parameters

Parameter	Description	Units
File	raw PreSens data file number	unitless
Species_Site	Species name_site name+temp treatment level	unitless
Intercept	intercept of the measured respiration slope	unitless
Respiration_umol_L_sec	Measured respiration rate	umol per L per sec
Temp_C	Temperature	degrees Celsius
Date	Date of collection (time zone = local Galapagos time); format: YYYY-MM-DD	unitless
Chamber_Channel	Respiration number and device channel number	unitless
Species	Species abbreviation (stands for Eucidaris galapagensis)	unitless
Temp_Cat	Temperature	degrees Celsius
Start_Time_Local	Date and time at start of experiment (time zone = local Galapagos time); format: YYYY-MM-DDThh:mm	unitless
Stop_Time_Local	Date and time at end of experiment (time zone = local Galapagos time); format: YYYY-MM-DDThh:mm	unitless
Light_Dark	ambient light present	unitless
Organism_ID	idenification number for the organism	unitless
Location	Location abbreviations (see metadata for site coordinates)	unitless
Species_Fullname	Full name of species	unitless
Initial_Volume_ml	organism volume	milliliters (mL)
Pre_Burn_Dry	organism mass pre-burn	grams (g)
Post_Burn	organism mass post-burn	grams (g)
AFDW	ash free dry weight	grams (g)
Volume	chamber volume	milliliters (mL)
Vol_L	chamber volume	liters (L)
umol_sec	oxygen consumption rate per S	umol per sec
blank_rate	oxygen consumption rate per S in blank (empty) chamber	umol per sec
umol_sec_corr	"corrected" rate, i.e. after correcting for observed drift in blank chambers	umol per sec
Start_Time_UTC	Date and time at start of experiment (time zone = UTC); format: YYYY-MM-DDThh:mmZ	unitless
Stop_Time_UTC	Date and time at end of experiment (time zone = UTC); format: YYYY-MM-DDThh:mmZ	unitless

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	HOBO Water Temperature Pro v2 Data Logger- U22 001
Generic Instrument Name	HOBO Onset Pro v2 temperature logger
Generic Instrument Description	The HOBO Water Temp Pro v2 temperature logger, manufactured by Onset Computer Corporation, has 12-bit resolution and a precision sensor for ±0.2°C accuracy over a wide temperature range. It is designed for extended deployment in fresh or salt water. Operation range: -40° to 70°C (-40° to 158°F) in air; maximum sustained temperature of 50°C (122°F) in water Accuracy: 0.2°C over 0° to 50°C (0.36°F over 32° to 122°F) Resolution: 0.02°C at 25°C (0.04°F at 77°F) Response time: (90%) 5 minutes in water; 12 minutes in air moving 2 m/sec (typical) Stability (drift): 0.1°C (0.18°F) per year Real-time clock: ± 1 minute per month 0° to 50°C (32° to 122°F) Additional information (http://www.onsetcomp.com/) Onset Computer Corporation 470 MacArthur Blvd Bourne, MA 02532

Dataset-specific Instrument Name	bucket
Generic Instrument Name	bucket
Generic Instrument Description	A bucket used to collect surface sea water samples.

Dataset-specific Instrument Name	temperature probe (Pt1000)
Generic Instrument Name	Water Temperature Sensor
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	fiber-optic oxygen probe (Presens dipping probes [DP-PSt7-10-L2.5-ST10-YOP], Germany)
Generic Instrument Name	Dissolved Oxygen Sensor
Generic Instrument Description	An electronic device that measures the proportion of oxygen (O2) in the gas or liquid being analyzed

Dataset-specific Instrument Name	Presens Oxygen Meter System (OXY-10 SMA (G2) Regensburg, Germany)
Generic Instrument Name	Dissolved Oxygen Sensor
Generic Instrument Description	An electronic device that measures the proportion of oxygen (O2) in the gas or liquid being analyzed

Dataset-specific Instrument Name	King Work Bucket Heater 05-742G 1000W
Generic Instrument Name	Immersion heater
Generic Instrument Description	Submersible heating element for water tanks and aquaria.

Dataset-specific Instrument Name	chiller (AquaEuroUSA Max Chill-1/13 HP)
Generic Instrument Name	Aquarium chiller
Generic Instrument Description	Immersible or in-line liquid cooling device, usually with temperature control.

Dataset-specific Instrument Name	drying oven
Generic Instrument Name	Drying Oven
Generic Instrument Description	a heated chamber for drying

Dataset-specific Instrument Name	Traceable High Accuracy ±0.2°C Digital Thermometer S/N 170718701
Generic Instrument Name	digital thermometer
Generic Instrument Description	An instrument that measures temperature digitally.

Dataset-specific Instrument Name	SCUBA
Generic Instrument Name	Self-Contained Underwater Breathing Apparatus
Generic Instrument Description	The self-contained underwater breathing apparatus or scuba diving system is the result of technological developments and innovations that began almost 300 years ago. Scuba diving is the most extensively used system for breathing underwater by recreational divers throughout the world and in various forms is also widely used to perform underwater work for military, scientific, and commercial purposes. Reference: http://oceanexplorer.noaa.gov/technology/diving/diving.html

Dataset-specific Instrument Name	muffle furnace (Optic Ivymen System Laboratory Furnace 8.2/1100)
Generic Instrument Name	muffle furnace
Generic Instrument Description	A muffle furnace or muffle oven (sometimes retort furnace in historical usage) is a furnace in which the subject material is isolated from the fuel and all of the products of combustion, including gases and flying ash. A type of jacketed enclosure that is used to heat a material to significantly high temperatures while keeping it contained and fully isolated from external contaminants, chemicals or substances. Muffle furnaces are usually lined with stainless steel, making them largely corrosion-resistant.

Dataset-specific Instrument Name	thermostat system (Apex Aquacontroller, Neptune Systems)
Generic Instrument Name	thermostat
Generic Instrument Description	A device designed to regulate temperature by controlling the starting and stopping of a heating/cooling system.

[table of contents | back to top]

Deployments

2018-08_Bruno

Website	https://www.bco-dmo.org/deployment/838840
Platform	R/V Queen Mabel
Description	August 2018 research cruise in the Galápagos archipelago aboard the vessel Queen Mabel.

[table of contents | back to top]

Project Information

The Role of Temperature in Regulating Herbivory and Algal Biomass in Upwelling Systems (Temperature and Herbivory)

Website: http://github.com/johnfbruno/Galapagos_NSF.git

NSF Award Abstract:

A well-known pattern in coastal marine systems is a positive association between the biomass of primary producers and the occurrence or intensity of upwelling. This is assumed to be caused by the increase in nutrient concentration associated with upwelling, enabling higher primary production and thus greater standing algal biomass. However, upwelling also causes large, rapid declines in water temperature. Because the metabolism of fish and invertebrate herbivores is temperature-dependent, cooler upwelled water could reduce consumer metabolism and grazing intensity. This could in turn lead to increased standing algal biomass. Thus upwelling could influence both bottom-up and top-down control of populations and communities of primary producers. The purpose of this study is to test the hypothesis that grazing intensity and algal biomass are, in part, regulated by temperature via the temperature-dependence of metabolic rates. Broader impacts include the training and retention of minority students through UNC's Course Based Undergraduate Research program, support of undergraduate research, teacher training, and various outreach activities.

The investigators will take advantage of the uniquely strong spatiotemporal variance in water temperature in the Galápagos Islands to compare grazing intensity and primary production across a natural temperature gradient. They will combine field monitoring, statistical modeling, grazing assays, populations-specific metabolic measurements, and in situ herbivore exclusion and nutrient addition to measure the effects of temperature on pattern and process in shallow subtidal communities. The researchers will also test the hypothesis that grazer populations at warmer sites and/or during warmer seasons are less thermally sensitive, potentially due to acclimatization or adaptation. Finally, the investigators will perform a series of mesocosm experiments to measure the effect of near-future temperatures on herbivores, algae, and herbivory. This work could change the way we view upwelling systems, particularly how primary production is regulated and the temperature-dependence of energy transfer across trophic levels.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1737071

[table of contents | back to top]