Kelp responses to temperature at 5-10 meters depth at three locations along the California coast from September to December 2016

Website: https://www.bco-dmo.org/dataset/878555
Data Type: Other Field Results
Version: 1
Version Date: 2022-10-15

Project
» RUI: Collaborative Research: Genetic variation as a driver of host and symbiont response to increased temperature on coral reefs (Host Symbiont Temp Response)

Contributors	Affiliation	Role
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Abstract
Giant kelp (Macrocystis pyrifera) is a globally distributed foundation species with seasonal fluctuations in abundance in response to local nutrient levels, storm intensity, and ocean temperatures. In this study, we examined individual and population level responses of early life history stages (zoospore settlement, survival, and gametogenesis) to increased temperatures to determine the capacity for temperature-tolerant individuals to allow adaptation in a changing climate. We collected fertile M. pyrifera sporophyll blades from three sites along the California coast (Los Angeles, Santa Barbara, Monterey Bay) and induced zoospore release in the lab. Spores settled on microscope slides at three treatment temperatures (16º, 20º, 22º C), matured for 21 days, and were imaged weekly to determine settlement, survival, and maturation success. On average, individuals from all sites showed lower rates of settlement and maturation in response to increasing temperature.

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Coverage

Spatial Extent: **N**:36.6269 **E**:-118.283 **S**:33.711 **W**:-121.917
Temporal Extent: 2016-09-01 - 2016-12-31

Methods & Sampling

Giant kelp (*Macrocystis pyrifera*) is a foundation species in the California ecosystem that creates habitats for numerous other organisms and adjusts seasonally to fluctuations in nutrients, storm intensity, and ocean temperature. This study examined whether early life history stages of the population could similarly adjust to

increased temperatures due to changing climate.

Fertile *M. pyrifera* sporophyll blades were collected from kelp forests at 5 to 10 meters depth from three sites along the California coast followed by induced zoospore release in the lab.

1. Cabrillo Beach in Los Angeles, California (33.7110° N, 118.2833° W)
2. Arroyo Burro Beach in Santa Barbara, California (34.4028° N, 119.7432° W), and
3. Lover's Point, Monterey Bay, California (36.6269° N, 121.9170° W).

Multiple fertile sporophyll blades were collected from the base of *M. pyrifera* individuals at each site (Los Angeles [LA] n=16, Santa Barbara [SB] n=20, Monterey [MB] n=20] in September and October 2016. All blades were collected between 5 meters and 10 meters depth and we chose individuals haphazardly, but assured they were never nearest neighbors to one another (~2 to 5 meters apart) and that the adults were similar heights. We collected individuals from a site on the same day using SCUBA. We separated the blades from the stipe by hand, taking care not to tear the blades. We immediately placed up to ten fertile sporophyll blades from each individual in a sealed plastic bag underwater to maintain both the separation and survival of individuals. We then placed the collections in a cooler on a thin layer of ice to keep cool during transport immediately to California State University, Northridge.

We induced zoospore release in the laboratory following previously established methods (Deysher & Dean 1984). We rinsed all individuals with filtered seawater to reduce potential bacteria and mucus released in transit. We wrapped the rinsed sporophylls in damp towels and placed them back into the sealed plastic bag and stored them overnight at 15° C in a temperature-controlled room. Such desiccation promotes the release of spores from sporophylls. The next morning, we removed the sporophylls from storage and placed four sporophylls from each individual into 1-liter containers of 15°C filtered seawater. We completed this procedure for all collections and kept sporophylls from different individuals separate at all times to prevent cross-contamination. We removed sporophylls from the seawater after 30 minutes and discarded them. After removing the sporophylls, we took a 1.5 milliliter (mL) sample from each well-mixed spore solution. We quantified the spore density in each sample using a hemocytometer.

We established three target temperature treatments in this experiment: 16°, 20°, and 22° C. The lowest temperature represents the average high temperature among the three sites (Table 1: "Temperature_at_Collection_Sites_Table1.pdf" in Supplemental Files section), while 20 and 22°C fall within the Intergovernmental Panel on Climate Change (IPCC) predictions for the end of the century temperature increase (IPCC, 2021). The highest treatment is beyond at least 1 standard deviation unit of the average upper temperature currently experienced by the sites. Although the SB and MB sites do not currently experience 20 or 22°C, they likely will experience these temperatures within this century. We performed all work in a temperature-controlled room maintained at 15.4 °C ± 1.05 °C (mean ± standard deviation), and used heating pads placed below Petri dishes to establish the target treatment temperatures (RootRadiance, DL Wholesale, Livermore, CA, USA). Lights were set to a 12:12 hour day: night cycle, with 8.56 ± 0.266 µmol photons m−2 s−1 during the day cycle.

We placed three glass microscope slides in a square 10x10 cm plastic petri dish to cover the bottom of the dish and added 50 mL of the spore solution to each dish. We established three replicate dishes per individual at each temperature (3 temperatures x 56 individuals x 3 replicates = 504 dishes). Spores were allowed to settle on microscope slides at treatment temperatures for 24–36 hours in the dark. Preliminary work showed uniform settlement both within and among slides in the same petri dish, so we haphazardly chose one of the three slides in each petri dish to quantify settlement. We took digital images of one randomly selected field of view at 400x total magnification on each slide. We used ImageJ (NIH version 1.50i) with the Cell Counter plugin to count the number of successfully settled spores in each image, identified by an extended germ tube.

After imaging, we returned the slides to the Petri dishes and replaced the spore solution with 50 milliliters (mL) of Provasoli-enriched seawater (NCMA/Bigelow Laboratory for Ocean Sciences; East Boothbay, ME). We imaged slides at the same location on the slide weekly for 21 days to monitor gametogenesis and/or spore death. We replenished the media at least once each week and disposed of slides that no longer contained spores. To evaluate successful gametogenesis, we analyzed the last image of each individual (21 days, or day of disposal) and classified spores as mature, immature, or dead. We identified mature gametophytes by their distinct shapes. Immature gametophytes were identified by stunted maturation; for example, if the settled spores never matured further than their initial state, but still contained visible pigment (Roleda et al. 2004). We calculated the total number of dead spores by subtracting the sum of the mature and immature spores from the initial number of settled spores.

Known Issues:
Early in the experiment, we lost one replicate of every individual from Monterey Bay at 22 degrees due to a malfunction in the heating pads and those individuals were excluded from the analysis.

Data Processing Description

An R script (see supplemental file) was used to fit linear models to each of the dependent variables in the dataset (Proportion Settled, Survival, and Proportion Mature). Each linear model tested the fixed effects of site and temperature, with individuals nested within sites. This script was also used to generate summary plots of the data.

BCO-DMO Processing Description:
- Adjusted field/parameter names to comply with BCO-DMO naming conventions
- Added a conventional header with dataset name, PI names, version date
- Added columns for latitude and longitude to the dataset
- Rounded columns: "Prop_Alive" and "Prop_Mature" to 3 decimal places and column "Prop_Settled" to 5 decimal places

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Data Files

File
data_for_r.csv (Comma Separated Values (.csv), 31.33 KB) MD5:ad063e45e81fd42007a5e67f9480064a Primary data file for dataset ID 878555

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Supplemental Files

File
R script for Kelp linear models for C. terHorst filename: kelp_script.R (Octet Stream, 23.92 KB) MD5:41d140d5b402b0dca833d025230808ed This R script was used to fit linear models to each of the dependent variables in the dataset (Proportion Settled, Survival, and Proportion Mature). Each linear model tested the fixed effects of site and temperature, with individuals nested within sites. This script was also used to generate summary plots of the data.
Temperature at Collection Sites filename: Temperature_at_Collection_Sites_Table1.pdf (Portable Document Format (.pdf), 47.52 KB) MD5:4ae681b19252684e2521e94da1fc6b9d Table 1 referenced in "Kelp responses to temperature" dataset (878555) referring to water temperatures at each collection site.

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Related Publications

Deysher, L. E., & Dean, T. A. (1984). CRITICAL IRRADIANCE LEVELS AND THE INTERACTIVE EFFECTS OF QUANTUM IRRADIANCE AND DOSE ON GAMETOGENESIS IN THE GIANT KELP, MACROCYSTIS PYRIFERA1. Journal of Phycology, 20(4), 520–524. https://doi.org/10.1111/j.0022-3646.1984.00520.x
Methods

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change[Masson-Delmotte, V., P. Zhai, A. Pirani,

S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.
Methods

Kurman, M. D., & terHorst, C. (2023). Individual and population-level variation in susceptibility to temperature in early life history stages of giant kelp. Marine Ecology. Portico. https://doi.org/10.1111/maec.12770
Results

Roleda, M., van de Poll, W., Hanelt, D., & Wiencke, C. (2004). PAR and UVBR effects on photosynthesis, viability, growth and DNA in different life stages of coexisting Gigartinales: implications for recruitment and zonation pattern. Marine Ecology Progress Series, 281, 37–50. https://doi.org/10.3354/meps281037
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
Site	One of three sites (LA = Los Angeles, SB = Santa Barbara, MB = Monterey Bay)	unitless
Latitude	Latitude North of the three sample sites	decimal degrees
Longitude	Longitude East (West is negative) of the three sample sites	decimal degrees
Indiv	Individual within a site. Same numbered individuals from different sites are not the same	unitless
Temp	Temperature at which individuals were grown (16, 20, or 22 degrees C)	degrees celsius
Rep	Replicate of each individual from each site at each temperature	unitless
Starting_Density	the number of spores initially added to each replicate	unitless
Settlement	the number of settled spores	unitless
Prop_settled	the proportion of the starting number of spores that settled successfully	unitless
Prop_Alive	the number of settled spores that survived until the end of the experiment	unitless
Prop_Mature	the proportion of the settled spores that matured into gametophytes	unitless
Dead	the number of settled spores that died before the end of the experiment	unitless
Immature	the number of settled spores that survived, but did not completely mature into gametophytes	unitless
Mature	the number of settled spores that matures into gametophytes	unitless

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Instruments

Dataset-specific Instrument Name	
Generic Instrument Name	Hemocytometer
Generic Instrument Description	A hemocytometer is a small glass chamber, resembling a thick microscope slide, used for determining the number of cells per unit volume of a suspension. Originally used for performing blood cell counts, a hemocytometer can be used to count a variety of cell types in the laboratory. Also spelled as "haemocytometer". Description from: http://hlsweb.dmu.ac.uk/ahs/elearning/RITA/Haem1/Haem1.html.

Dataset-specific Instrument Name	Leica dissection microscope
Generic Instrument Name	Microscope - Optical
Generic Instrument Description	Instruments that generate enlarged images of samples using the phenomena of reflection and absorption of visible light. Includes conventional and inverted instruments. Also called a "light microscope".

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Project Information

RUI: Collaborative Research: Genetic variation as a driver of host and symbiont response to increased temperature on coral reefs (Host Symbiont Temp Response)

Coverage: Florida Keys, Caribbean

Description from NSF award abstract:
On coral reefs, mutualisms with single celled algae (Symbiodinium) and reef species literally and figuratively form the foundation of reef ecosystems. Coral reefs are among the most threatened ecosystems under a changing climate and are rapidly declining due to increasing levels of environmental stress, namely increased temperatures. Climate change is resulting in even warmer ocean temperatures that threaten associations between Symbiodinium and their hosts. In this project the investigators examine the genetic diversity of Symbiodinium and the potential for this important species to evolve in response to temperature. The project will also address whether the ecological and evolutionary dynamics of the Symbiodinium population affect the performance of their host. If so, this suggests that the evolution of microscopic organisms with short generation times could confer adaptation to longer-lived host species on ecologically and economically vital coral reefs. Given that diversity is already being lost on many reefs, considering how evolutionary changes in Symbiodinium will affect reef species is crucial for predicting the responses of reefs to future climate change. This project provides training for two graduate students and several undergraduates at a Hispanic-serving institution. This work includes outreach to the students and the general public through the Aquarium of Niagara, local K-12 schools, and web-based education modules.

The effects of evolution on contemporary ecological processes are at the forefront of research in evolutionary ecology. This project will answer the call for experiments elucidating the effects of genetic variation in Symbiodinium performance and the effect on the response of the holobiont (host and symbiont) to increased temperature. These experiments examine the effects of temperature through both ecological and evolutionary mechanisms and will determine the relative importance of adaptation and acclimatization in replicated experimental populations. The investigators will examine how genetic variation within a species (Symbiodinium antillogorgium) affects symbiont performance in culture and in the host and how this affects the response of the holobiont to increased temperature. Further, the project examines whether holobiont response to

increased temperature associated with climate change depends on particular GxG host-symbiont combinations. Moreover, the investigators will examine the effects of symbiont history on mutualist hosts, which have been largely ignored in eco-evolutionary studies. These experiments provide a first step in predicting whether invertebrate hosts on coral reefs will respond to global change via adaptation of their symbionts.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1559105

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