Histological gonad reproductive scores for purple sea urchins from experiments at the Quadra Island Ecological Observatory from Sep to Dec 2021

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Data Type: experimental
Version: 1
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Project
» Collaborative Research: The effects of marine heatwaves on reproduction, larval transport and recruitment in sea urchin metapopulations (Urchin metapopulations)

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Abstract
These data include histological scores of individual purple sea urchins, Strongylocentrotus purpuratus (urn:lsid:marinespecies.org:taxname:240747), involved in a multifactorial laboratory experiment at the Hakai Institute Quadra Island Ecological Observatory between 2021-09-20 and 2021-12-06. These data include histological analysis associated with animals in the related dataset (Okamoto et al. 2026), which contains associated data for each animal and which is linked via the HISTO_CASETTE_NO parameter in each dataset. The experiment investigated impacts of contemporary high pCO2 and imposed dynamic historical temperature trends (21-18 °C mimicking a historical El Nino and 18-14 °C mimicking a historical La Nina) on multiple aspects of individual thermal performance as well as constant temperatures (10, 13, 16, 17, 18 , and 20 °C). All animals were simultaneously collected from Ucluelet, British Columbia, Canada (48° 56.604N, 125° 34.699W) from a depth of 7-8 m relative to mean low tide on 3 September 2021 using SCUBA and immediately transported to the Marna Laboratory flow through seawater system. Animals were haphazardly selected and assigned to the "Wild" group or "Experimental" group (and thereafter treatments) from this pool.

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Coverage

Location: Hakai Institute Quadra Island Ecological Observatory, Quadra Island, British Columbia, Canada with animals collected from Ucluelet, British Columbia, Canada (48° 56.604N, 125° 34.699W)
Spatial Extent: **Lat**:48.9434 **Lon**:-125.5783
Temporal Extent: 2021-08-01 - 2021-12-20

Methods & Sampling

To quantify how different thermal regimes affect investment in gonads and development of gametes in male and female urchins, we first conducted a 10-week experiment in which 300 animals were incubated in replicate 350L mesocosms that simulated El Niño (N = 4 mesocosms, 60 animals per treatment) or La Niña (N = 4 mesocosms, 60 animals) conditions based on historical, empirical benthic temperature time series from Scripps Pier in La Jolla, Californiathat coincide with historical collapses in larval supply in Southern California.

We paired these treatments with a range of fixed temperature incubations (10, 13, 16, 17, 18, 20 °C, N = 2 mesocosms, 30 animals per treatment), two of which matched the mean temperature of the El Niño (20 °C) and La Niña (16 °C). Experiments were conducted at the Marna Lab at the Hakai Institute's Quadra Island Ecological Observatory in Heriot Bay, British Columbia due to availability of sophisticated seawater systems for careful, replicated temperature manipulations.

Field Collections and Acclimation

We collected sea urchins by hand on SCUBA in the vicinity of Ucluelet, British Columbia, Canada (48.94°N, 125.56° W) from a depth of 7-8 m relative to mean low tide in September 2021 and transported them to the Marna Lab via truck in seawater filled coolers with bubblers in less than 24 hours. We transferred sea urchins to flow-through sea tables and allowed them to recover for a period of one week before placing animals into the mesocosm system. Animals were haphazardly selected and assigned to the "Wild" group or "Experimental" group (and thereafter treatments) from this pool.

For the "Experimental" group, we selected healthy individuals within a constrained size range for incubations (n = 300, mean test diameter = 56.09 mm, range test diameter = 42.12 – 69.46 mm). Finally, we assigned animals to mesocosms at random at ambient temperature and exposed each assigned mesocosm to a temperature ramp, where the ramp reached target temperatures after two weeks from the initial incoming, ambient temperature (mean across all tanks of 13.3°C, SD = 0.3°C) to avoid thermal shock. Once initial target temperatures were reached, they were maintained or, for the variable treatments, were manually adjusted daily in the AM (~8am each day) as needed by 0.5 °C increments in a scheduled manner to match historical mean El Niño and La Niña daily temperature trends.

Mesocosm System

We placed urchins in a custom-built array of twenty replicated 214 L [90(L) x 59.5(W) x 40(H) cm] acrylic mesocosms supplied with flow-through UV sterilized and filtered seawater. Each mesocosm was capable of independent control of temperature and animals were provided a lighting regime for all mesocosms using LED fixtures (Aquamaxx, CA, USA) programmed to provide 10L:14D with two-hour linear light intensity transition periods for dawn and dusk (0-100% from 07:00 to 09:00 "dawn", and 100-0% from 17:00 to 19:00 "dusk"). Each mesocosm independently maintained temperature treatments using a heat exchanger fitted with a titanium coil regulated by a dual stage digital temperature controller (Resolution = 0.1°C, Dwyer Instruments, LLC.©, Michigan City, IN, USA). The mesocosm system employed central cooling (Aermec Mits Airconditioning Inc., Mississauga, ON, Canada) and heating (boiler array, Viessmann Manufacturing Company Inc., Warwick, RI, USA) to supply independent heat exchangers with on-demand cold and warm glycol loops for down- and up-regulation of water temperature, respectively. We manually checked and re-calibrated sensors, as needed, using digital traceable thermometers twice daily to control potential temperature sensor drift. We randomly assigned mesocosms to the specified treatments.

Animal husbandry

We fed individuals uniform dry pellets combining several macroalgal species formulated for the aquaculture

of S. purpuratus (Urchinomics Canada Inc., Halifax, NS, Canada). Animals in mesocosms were fed twice per week and we removed uneaten food and refuse every 72 h. More detail available in the results publication (Okamoto et al. 2023).

Histological and gonad assays

Animals were measured and sacrificed and gonads were carefully excised from the opened test. Using a clean, sterile scalpel we excised an approximately 2 mm cross section from the first gonad, placed in a histological cassette, soaked in Davidson's solution for 24 hours, and placed in 95% EtOH for long term storage. Preserved gonads were then sent to Histology Consultants, Inc. for sectioning, staining with Eosin and Myosin, and mounting on slides. Mounted slides were then analyzed for gametogenic stage. We scored gametogenesis using a standard staging scale of I to IV where IV is fully mature and I is immature (Byrne 1990).

For full methods, see results publication (Okamoto et al. 2023).

BCO-DMO Curation Notes

This section documents curation actions performed prior to publication review with the submitter, and additional information relevant to understanding and reusing this dataset. It distinguishes changes made to the submitted (meta)data from unresolved issues and/or enhancements that improve future reuse and interoperability.

CURATION ACTIONS PERFORMED ON DATA

- Imported "Marna_histology_2021.csv" into BCO-DMO system
- Replaced periods with underscores to comply with BCO-DMO guidelines
- Replaced "l" with "Low" and "h" with "High" in the "pco2_h_l" parameter values
- Removed extra unlabelled column with row numbers
- Exported file as "968848_v1_urchin_hist_marna_lab.csv"

CURATION ACTIONS PERFORMED ON METADATA

- Species name Strongylocentrotus purpuratus (urn:lsid:marinespecies.org:taxname:240747) verified as current accepted form on 2025-07-08, using the WoRMs World Registery of Marine Species database.
- Standard metadata entry and text formatting steps were performed.
- Parameter definitions adjusted to reflect values presented (Mean and range of temperature)

ISSUES POTENTIALLY IMPACTING REUSE

- N/A

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Data Files

File	
968848_v1_urchin_hist_marna_lab.csv	(Comma Separated Values (.csv), 11.07 KB) MD5:835ca5a5ef5c9d567364dd9028cbd59d
Primary data file for dataset ID 968848, version 1	

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Related Publications

Byrne, M. (1990). Annual reproductive cycles of the commercial sea urchinParacentrotus lividus from an exposed intertidal and a sheltered subtidal habitat on the west coast of Ireland. Marine Biology, 104(2), 275–289. https://doi.org/10.1007/bf01313269 https://doi.org/10.1007/BF01313269
Methods

Okamoto, D. K., Spindel, N. B., Collicutt, B., Mustermann, M. J., Karelitz, S., Gimenez, I., Rolheiser, K., Cronmiller, E., Foss, M., Mahara, N., Swezey, D., Ferraro, R., Rogers-Bennett, L., & Schroeter, S. (2023). Thermal suppression of gametogenesis explains historical collapses in larval recruitment. https://doi.org/10.1101/2023.09.28.559919
Results

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Related Datasets

IsRelatedTo

Munstermann, M. J., Karelitz, S. E., Swezey, D., Ward-Diorio, R., Okamoto, D. K. (2026) **Histological gonad reproductive scores for purple sea urchins from experiments at the Bodega Marine Laboratory from Sep to Dec 2023.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-03-18 doi:10.26008/1912/bco-dmo.968787.1 [view at BCO-DMO]
Relationship Description: Histological gonad reproductive scores for population collected in Sonoma, Santa Barbara, San Diego Counties

Okamoto, D. K., Spindel, N., Karelitz, S. E., Munstermann, M. J., Swezey, D., Collicutt, B., Mahara, N., Cronmiller, E., Rolheiser, K., Foss, M., Gimenez, I., Ward-Diorio, R. (2026) **Purple sea urchin morphometrics from Marna Laboratory Experiments at the Quadra Island Ecological Observatory from Sep to Dec 2021.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-03-18 doi:10.26008/1912/bco-dmo.963419.1 [view at BCO-DMO]
Relationship Description: Morphometrics data from the same experiment.

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Parameters

Parameter	Description	Units
HISTO_CASETTE_NO	Unique identifier for the histological sample that relates to the organismal data file	unitless
sex	Sex of the organism	unitless
cat	Histological stage category; standard staging scale of 1 to 4 where 4 is fully mature and 1 is immature	unitless
pco2_h_l	High or low pCO2 treatment where "Low" is 600 ppm and "High" is 1200 ppm	Parts per million (ppm)
treatment	Temperature treatment consisting of constant temperatures at 10, 13, 16, 17, 18, or 20 degrees, an El Niño treatment dropping from 21 to 18 degrees or a La Niña treatment dropping from 18 to 16 degrees	unitless
tank_id	Identifier for experimental mesocosm	unitless
temp_deg_c	Mean temperature of the treatment (e.g., 20 degrees was the mean temperature for the El Niño treatment) or temperature range	degrees Celsius

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Instruments

Dataset-specific Instrument Name	
Generic Instrument Name	Microscope - Optical
Dataset-specific Description	Preserved gonads were then sent to Histology Consultants, Inc. for sectioning, staining with Eosin and Myosin, and mounting on slides. Mounted slides were then analyzed for gametogenic stage.
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".

Dataset-specific Instrument Name	SCUBA
Generic Instrument Name	Self-Contained Underwater Breathing Apparatus
Dataset-specific Description	All animals were simultaneously collected from Ucluelet, British Columbia, Canada (48° 56.604N, 125° 34.699W) from a depth of 7-8 m relative to mean low tide on 3 September 2021 using SCUBA and immediately transported to the Marna Laboratory flow through seawater system.
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: https://oceanexplorer.noaa.gov/technology/technical/technical.html

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Project Information

Collaborative Research: The effects of marine heatwaves on reproduction, larval transport and recruitment in sea urchin metapopulations (Urchin metapopulations)

Coverage: Coastal California Waters from San Diego through Mendocino Counties

NSF Award Abstract:
Rapid and extreme warming events such as El Niño and marine heatwaves have had ecological and economic impacts on nearshore marine ecosystems. These impacts include reductions in biomass and collapses in commercial fisheries. For many species, population booms and busts are controlled by shifts in reproduction and juvenile dispersal related to warmer temperatures and ocean circulation. However, how population fluctuations are shaped by interacting processes that control adult reproduction and larval survival remains unclear. Marine heatwaves often accompany major disruptions in ocean circulation, which can affect survival and the distribution of species that produce free-floating, planktonic larvae. As a result, species can be impacted directly by temperature effects on organismal reproduction and survival, and indirectly by shifts in

ocean circulation that affect larval success. This project is examining how the joint effects of temperature and ocean circulation are controlling populations of purple sea urchins (Strongylocentrotus purpuratus). To address project objectives, the team is developing oceanographic models to predict dispersal of planktonic larvae in combination with controlled experiments on adult reproductive success. This project is advancing the understanding of how ecologically important species respond to ocean temperature and circulation, which are forecast to shift under future climate change scenarios. Broader impacts of the project include training of students and post-docs in STEM and educational outreach. Curriculum development and implementation is occurring in collaboration with existing K-12 outreach programs that focus on underserved communities and under-represented groups. The goal is to empower the next generation of scientists to use integrative approaches to predict ecological consequences of climate change.

Purple sea urchins are an ideal species for studying the coupled impacts of warming and ocean circulation on recruitment and survival given a wealth of ecological and organismal data. The species has a mapped genome, can be transported large distances as larvae by ocean currents, and larval abundances in California exhibit orders of magnitude variation with heatwaves and El Niño fluctuations. To quantify the processes that shape spatial and temporal variability in larval supply, researchers are applying a novel combination of biophysical modeling, experiments and statistical modeling of long-term, high-resolution data on larval settlement across the Southern California Bight (SCB). Research module 1 is quantifying spatial and temporal patterns of larval transport using a 3D-biophysical model of the SCB. The model is testing how interactions among historical changes in ocean circulation and temperature, larval life history, and larval behavioral traits affect variation in larval supply in space and time. Research module 2 is focused on how temperature could affect spatial and temporal variation in egg production. Experiments are characterizing reproductive thermal performance curves and quantifying how these vary among populations and organismal history. A novel assay is assessing epigenetic regulation of gene expression associated with performance curves. Finally, Module 3 will integrate mechanistic models from Modules 1 and 2 to statistically assess their ability to explain spatial and temporal trends in a nearly three-decade dataset of larval settlement from six sites in the SCB. This is one of the first studies that integrates models of larval transport, reproductive performance and settlement data to empirically test how physical and biological processes affect local recruitment patterns in complex marine meta-populations.

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-2023693
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023664
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023649

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