Species surveys at defined tides on the exposed rocky shores of Tatoosh Island, Makah Reservation, Washington 2014-2017

Website: https://www.bco-dmo.org/dataset/1003120
Data Type: Other Field Results
Version: 1
Version Date: 2026-07-29

Project
» Eco-Evolutionary Response to the Scale of Temporal Environmental Fluctuation (Eco Evolutionary Response)
» LTREB: Ecological Dynamics in an Experimentally-Tractable Natural Ecosystems (LTREB Ecological Dynamics)

Program
» Long Term Research in Environmental Biology (LTREB)

Contributors	Affiliation	Role
Wootton, Timothy	University of Chicago	Principal Investigator
Miranda, Khashiff	University of Chicago	Student
Rauch, Shannon	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
To quantify spatio-temporal changes in sessile species cover across a strong environmental gradient, we implemented a structured sampling program of quadrats deployed at discrete tidal heights in the rocky intertidal shores of Tatoosh Island, Makah Reservation, Washington, USA. At each of four wave-exposed sites with fairly uniform large rock benches, we placed and digitally photographed 50 x 50 centimeter (cm) quadrats at defined tide heights across the vertical extent of the shoreline during spring low tides using a laser level. At each tide height, we placed 10 quadrats spaced in an approximately uniform pattern to sample the entire benches, while avoiding irregular topographic features such as tide pools and large cracks, thereby establishing 10 sampling paths down the shore. Sampling heights were defined at 0.2-meter (m) intervals, occasionally at 0.1 m intervals and referenced to markers at the sites of known tidal height. Surveys were made annually from 2014-2017 in July-August following the same general methods. Quadrat locations were not identical from year to year, but followed the same general paths from one year to the next, allowing some degree of control over topographical and hydrodynamic differences across the bench from one year to the next. Photographs of the upper and lower halves of each quadrat were analyzed separately by computer in the lab for the percentage of area covered of each visible organism to the lowest taxonomic level identifiable in non-destructive photographs. The resulting data provide a picture of variability in sessile species composition across time and space along a strong gradient of environmental change, including documenting temporal variability of populations, changes in sea level, effects of changes in the abundance of key species via disease and climate variation, and determinants of zonation.

Table of Contents

Coverage

Spatial Extent: **N**:48.39386944 **E**:-124.7327056 **S**:48.39120556 **W**:-124.7409806
Temporal Extent: 2014-07-10 - 2017-07-25

Methods & Sampling

Samples were taken at four sites of relatively uniform rock bench of at least 30 meters (m) in length at Tatoosh Island, Makah Reservation, Washington, USA, known by investigators as: East Strawberry (48.39144N, -124.73839W), The Finger (48.39387N, -124.73841), The Glacier (48.39145N, -124.74098), and Simon's Landing (48.39121N, -124.73271W). Sampling occurred on days with low spring tides to sample the broadest stretch of shoreline exposed at low tide. At each site, once per year, we set a Dewalt rotating, self-leveling laser level on a tripod just above the upper limit of the barnacle zone, set the laser detector to a specified level on the transit and moved along the shore from south to north choosing 10 spots along the bench at the selected transit height spaced as evenly as possible along the entire rock bench while avoiding topographic irregularities such as tide pools or large cracks in the rock bench. This sampling pattern resulted in 10 general sampling bands extending down each rock bench. Within each band, sampling points were selected by moving the transit to a point in the band at a generally appropriate height as assessed by moving the transit upward or angling it sideways until the laser detector on the transit beeped, then slowly moving the base of the transit up or down the shore while holding the transit vertical until the laser beam was detected. At each point, a 50 x 50 centimeter (cm) quadrat, divided into 121 sub-squares defined with monofilament cross lines to aid in estimating percent cover was centered on the identified sample point and oriented to be perpendicular to the slope of the rock, and was photographed from below (seaward side at the bottom), with the quadrat frame spanning nearly the entire vertical (short) frame of the photograph to maximize detail. Upon completion of sampling at one tide height, the detector on the transit would be moved by the selected vertical tidal sampling increment, usually 0.2 m but occasionally 0.1 m at some sites/years, and the process was repeated until the lowest point that could be reached at low tide was surveyed. Sampling was initiated 3-3.5 hours before predicted low tide to follow the tide out to its lowest level.

Data Processing Description

Tide heights were calculated by measuring the height of the transit to the level from markers of known height at the sites, adding the known marker height to the measured transit height for the marker, then subtracting the measured transit height of each quadrat point from the sum of the defined marker height and the transit height of the marker. Data were extracted from the collected photographs on computers using Apple Preview and/or Adobe Photoshop software to allow zooming in to aid identification as necessary. To increase the spatial resolution, data were extracted separately from the top and bottom of each quadrat. The data analyst would go through each photo systematically subsquare by subsquare for each species estimating the fraction of area covered by each species in the image and then summing these areas to obtain a final total number of squares covered. Individuals were identified to the lowest possible taxonomic level possible in the photograph. Sampling was non-destructive, so the transit necessarily rested on the organisms living on the rock, making the measured tide height slightly higher than the height of the underlying rock bench.

BCO-DMO Processing Description

- Imported original file "TideHtQuadrat Variability All BCODMO.csv" into the BCO-DMO data processing system.
- Renamed columns to comply with BCO-DMO naming conventions.
- Converted Sample_Date from M/D/YY format (%m/%d/%y) to ISO 8601 date format (%Y-%m-%d).
- Removed "??" characters from Mazzaella_cornucopiae column values using find/replace (missing data values are empty/blank in the final CSV file).
- Saved the final file as "1003120_v1_tide_height_variability.csv".

Problem Description

Re-surveys do not return to the same quadrat locations each year, so variability across years may reflect both spatial variation in the spots surveyed, including sampling slightly different tide heights depending on how the laser level was set up from year to year, and temporal change. The larger number and spatial scale of sampling made possible by analyzing photographs rather than in-situ censusing of the quadrats limits the ability to identify all individuals to the species level, and precludes censusing individuals in the understory of large sessile organisms. In a few cases, a 10th survey was inadvertently not included in sampling of some tide heights in at the Simon's Landing site in 2014 and 2016. Only the Glacier and Simon's Landing sites were surveyed in 2015.

[table of contents | back to top]

Related Publications

Wootton, J. T., Miranda, K., Henry, A. K., Pfister, C. A. In Review. Field experiments predict ecological response to a large-scale epidemic of an anti-keystone pathogen. Proceedings of the National Academy of Sciences, USA.
Results

[table of contents | back to top]

Parameters

Parameter	Description	Units
Site	General location of sampling on Tatoosh Island	Name used by Tatoosh Island investigators
Sample_Date	Date of Survey	unitless
Transit	Height on transit of laser detector at the sample point	meters
Marker	Measured height of reference marker during survey	meters
Tide_Height	Calculated actual tide height of sample point	meters
Quadrat_number	Quadrat number (S to N) at a given tide height and site. Also referred to as vertical path.	unitless
Upper_Lower_Half	Half of quadrat enumerated.	unitless
Bare_Rock	number of subsquares without observable organisms	number of occupied subsquares
Hedophyllum_sessile	Hedophyllum sessile	number of occupied subsquares
Alaria_marginata	Alaria marginata	number of occupied subsquares

Laminaria_setchellii	Laminaria setchellii	number of occupied subsquares
Costaria_costata	Costaria costata	number of occupied subsquares
PostePostelsia_palmaeformisIsia_palmeaformis	Postelsia palmaeformis	number of occupied subsquares
Fucus_gardneri	Fucus gardneri	number of occupied subsquares
Egregia_menziesii	Egregia menziesii	number of occupied subsquares
Lessoniopsis_littoralis	Lessoniopsis littoralis	number of occupied subsquares
Leathesia_difformis	Leathesia difformis	number of occupied subsquares
Nereocystis_luetkeana	Nereocystis luetkeana	number of occupied subsquares
Pelvetiopsis_limitata	Pelvetiopsis limitata	number of occupied subsquares
Crustose_Coralline_Algae	Crustose Coralline Algae	number of occupied subsquares
Articulated_Coralline_Algae	Articulated Coralline Algae	number of occupied subsquares
Crustose_Red_Algae	Crustose Red Algae	number of occupied subsquares
Foliose_Red_Algae	Foliose Red Algae, not including red algae identified to species	number of occupied subsquares
Filamentous_Red_Algae	Filamentous Red Algae, not including red algae identified to species	number of occupied subsquares
Halosaccion_glandiforme	Halosaccion glandiforme	number of occupied subsquares
Callithamnion_pikeanum	Callithamnion pikeanum	number of occupied subsquares
Mastocarpus_papillatus	Mastocarpus papillatus	number of occupied subsquares

Endocladia_muricata	Endocladia muricata	number of occupied subsquares
Porphyra_spp	Porphyra spp.	number of occupied subsquares
Mazzaella_cornucopiae	Mazzaella cornucopiae	number of occupied subsquares
Ulva_spp	Ulva spp.	number of occupied subsquares
Acrosiphonia_coalita	Acrosiphonia coalita	number of occupied subsquares
Phyllospadix_spp	Phyllospadix spp.	number of occupied subsquares
Allopora_californica	Allopora californica	number of occupied subsquares
Colonial_Hydroid	Colonial Hydroid, not Allopora	number of occupied subsquares
Anthopleura_xanthogrammica	Anthopleura xanthogrammica	number of occupied subsquares
Anthopleura_elegantissima	Anthopleura elegantissima	number of occupied subsquares
Clathria_spp	Clathria spp.	number of occupied subsquares
Halichondria_bowerbanki	Halichondria bowerbanki	number of occupied subsquares
Halichondria_panicea	Halichondria panicea	number of occupied subsquares
Haliclona_cinerea	Haliclona cinerea	number of occupied subsquares
Serpula_columbiana	Serpula columbiana	number of occupied subsquares
Aplidium_californicum	Aplidium californicum	number of occupied subsquares
Mytilus_californianus	Mytilus californianus	number of occupied subsquares

Mytilus_trossulus	Mytilus trossulus	number of occupied subsquares
Pollicipes_polymerus	Pollicipes polymerus	number of occupied subsquares
Balanus_nubilus	Balanus nubilus	number of occupied subsquares
Semibalanus_cariosus	Semibalanus cariosus	number of occupied subsquares
Balanus_glandula	Balanus glandula	number of occupied subsquares
Chthamalus_dalli	Chthamalus dalli	number of occupied subsquares
Inidentified_Barnacles	Inidentified Barnacles	number of occupied subsquares
Others	Unidentified or rare non-target taxa	number of occupied subsquares
SSWD_Zonation_Change_Data	Indicator of data used in study of zonation change following sea star wasting disease. 0=unused, 1=used	unitless
Site_Latitude	Latitude of center of sampling site (positive values = North)	Decimal degrees
Site_Longitude	Longitude of center of sampling site (negative values = West)	Decimal degrees

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	Panasonic Lumix DMC FZ1000 digital camera
Generic Instrument Name	Camera
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

Dataset-specific Instrument Name	Dewalt DW074KD self-leveling rotary laser level
Generic Instrument Name	Levels and staffs
Generic Instrument Description	Optical instruments and graduated poles used in surveying to determine the elevation of a location relative to a datum level.

[table of contents | back to top]

Project Information

Eco-Evolutionary Response to the Scale of Temporal Environmental Fluctuation (Eco Evolutionary Response)

Coverage: Salish Sea, Washington, USA

NSF Award Abstract:
Cyclical variations in environmental conditions, like tides or seasons, comprise a common theme in nature. Living organisms must cope with repetitive arrivals of unfavorable conditions for survival. Therefore species around the world are under evolutionary pressure to schedule their "life cycles" or "life histories" to fit the environmental cycle regimes within which they reside. Recent climate change has shifted historical cyclical patterns in many ecosystems, such as season length, resulting in mismatches between life histories and the ideal environmental conditions of plants and animals, to the detriment of population persistence and ecological stability. Adaptive evolution offers a mechanism that may buffer these mismatches. Accumulating evidence of shifts in life history schedules from around the world shows us that much remains to be done to understand how life histories are "fit" to environmental cycles, and to changes in cycles, despite their everyday familiarity. Testing theoretical ideas with data and experiments is essential. Marine coastal habitats are subject to conspicuous cycles occurring at multiple time scales, such as diel, tidal, lunar, seasonal, and multi-annual fluctuations. Populations of the intertidal crustacean Tigriopus californicus occupy rocky shore across the entire eastern Pacific coastline in upper tidepools that are periodically wave-swept at high tide at varying intervals. This project develops mathematical models to uncover fundamental rules of life history variation and adaptation in regularly varying environments, and tests hypotheses across Tigriopus californicus populations experiencing varying tidal disturbances using efficient and highly replicated field collections and manipulative experiments in the lab. Beyond producing broadly applicable theory and abundant open-access data, the investigators engage with local Makah Tribe students near field sites for sampling and natural history studies to enhance STEM education in an underserved rural community. Furthermore, the project expands the nation's scientific capacity by training undergraduate and graduate students in experimental design, theoretical modelling in population ecology and life history evolution, and data analysis.

How natural populations persist in variable environments has been a long-standing question in ecology and evolution. In particular, cyclical variability is common in nature, and many species show predictable life history strategies that follow cycles in nature (e.g. phenology). However, a general conceptual framework is lacking for how adaptation to cycles occurs and how the scaling of life histories to fluctuations buffers changes in the environment. Marine environments fluctuate predictably across a range of temporal scales, such as tidal and seasonal, and provide unique opportunities to study population persistence and evolution in cyclical environments. A general mathematical framework is developed that explores life history optimization in the context of cyclically varying environments. The marine intertidal copepod Tigriopus californcus is ideal for testing model predictions and motivating extensions. Many isolated populations can be sampled entirely in the field, and the short timescale of tide cycles, short generation times, and ease of frequent sampling will provide a dense dataset of eco-evolutionary patterns in response to natural disturbance regimes. Pilot studies have established experimental populations in the laboratory, and have proven that Tigriopus californcus is amenable to careful manipulations of simulated disturbance frequency (both cyclical and stochastic) that seamlessly translate to the model framework. The combination of modelling, field parameterization, and experimental investigation of life histories in cyclical and stochastic environments is a novel and holistic approach to the question of life history diversity within an environment. Finally, a general understanding of evolutionary mechanisms in cyclical environments can improve predictions of the fate of populations when natural cycles are perturbed, which is expected across many ecosystems due to climate change.

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.

LTREB: Ecological Dynamics in an Experimentally-Tractable Natural Ecosystems (LTREB Ecological Dynamics)

Coverage: Tatoosh Island, Washington, United States of America

NSF Award Abstract for DEB-0919420:

This award is funded under the American Recovery and Reinvestment Act of 2009 (Public Law 111-5).

A core challenge for ecologists is to develop frameworks to predict how complex natural communities and ecosystems will respond to environmental impacts such as species extinction and global change. Because ecological interactions are comprised of complex networks, meeting this challenge requires an integration of mathematical frameworks with empirical data. In this project, the investigator will extend several long-term multi-species data sets for marine rocky intertidal organisms and environmental conditions, and use these data to estimate species interaction strengths in dynamic, multi-species models. These results will then be used to test for general patterns of interaction strength and to generate predictions for different potential environmental impacts. Long-term species manipulation experiments in this intertidal habitat will be used to validate predictions generated by multi-species models.

Results of this study will significantly enhance the ability to address an urgent societal need - the prediction of natural ecosystem responses to global change, including climate change. In the process, the study will increase collaboration and data sharing among university researchers and governmental management agencies (Tribal and NOAA National Marine Sanctuary staff), provide advanced training for Ph. D. students, and facilitate research experience for undergraduate in ecological science. Data associated with the project will be publicly available through the University of Chicago, the Knowledge Network for Biocomplexity, and through the Ecological Society of America's Ecological Archives.

NSF Award Abstract for Continuing Award DEB-1556874:

A central goal for ecology is to document if and how the environment is changing, to determine the causes of these changes, and to predict what the consequences of these changes will be to ecological systems. This is a challenge because of the complex network of connections among the living organisms and the non-living parts of ecosystems. Mathematical models are essential tools to keep track of these ecological interactions and to predict how they will respond to environmental changes. However, models need to be linked to data from nature. Two major challenges in developing predictive models of environmental change are 1) collecting sufficient data on how interactions among a complete set of species and environmental factors change over time, and (2) rigorously testing model predictions with experiments. This study will combine a quarter-century long series of data on 100+ species and relevant environmental variables in the rocky shoreline of Tatoosh Island in Washington state, with a long-term field experiment that mimics the extinction of a key species, the California mussel. The long term data will be applied to several different modeling approaches and predictions from these models will subsequently be tested with the long-term field experiment. The research will identify the most promising modeling approaches for making ecological prediction, and make them available to ecosystem managers and policy makers interested in the consequences of environmental impacts such as species extinction and global change. The comprehensive data series also will be made available to other scientists to be used as a platform for additional studies. This project will also engage undergraduate students in field research, data management, mathematical modeling, and in communicating with the public, managers, and policy makers. Furthermore, because the challenge of understanding networks of species interactions is shared with other scientific disciplines that deal with complex networks, project results will be of general value in other disciplines.

The researcher will conduct annual surveys of replicated permanent plots for plants and animals on the shoreline in two ways: 1) by documenting the species identities under 2,600 fixed points over a 5-year period and generating annual transition probabilities among species, and 2) by generating abundance estimates in permanent 60 x 60 cm census plots. Fifteen experimental plots will be maintained by selectively removing individuals of Mytilus californianus when they appear, leaving all other species undisturbed. Environmental data will be collected every 30 minutes using a submersible data logger and a land-based weather station. Water chemistry, including critical nutrients, will be monitored. These data will be analyzed in several ways, including 1) parameterizing transition-based models (Markov chain models, spatially-explicit cellular automata) with environmental dependencies, 2) parameterizing multi-species population dynamic models from plot counts, 3) applying multi-spatial cross-convergent mapping and testing whether it accurately detects key species known to have strong causal effects from independent experiments, 4) applying neural network models and testing their predictions about the consequences of species extinction, and 5) testing whether there is a relationship between the variability of a species' abundance through time and its importance to the ecosystem as assessed by independent experiments. The community modeling projects enabled by the rich long term data sets have a strong potential to advance our understanding of mechanisms underlying community dynamics and their response to environmental change.

[table of contents | back to top]

Program Information

Long Term Research in Environmental Biology (LTREB)

Website: https://www.nsf.gov/funding/opportunities/ltreb-long-term-research-environmental-biology

Long Term Research in Environmental Biology (LTREB)

Supports research for a period of 10 years or longer to generate an extended time series of data with a focus on evolutionary biology, ecology and ecosystem science.

Synopsis
The Long Term Research in Environmental Biology (LTREB) Program supports the generation of extended time series of data to address important questions in evolutionary biology, ecology, and ecosystem science. Research areas include, but are not limited to, the effects of natural selection or other evolutionary processes on populations, communities, or ecosystems; the effects of interspecific interactions that vary over time and space; population or community dynamics for organisms that have extended life spans and long turnover times; feedbacks between ecological and evolutionary processes; pools of materials such as nutrients in soils that turn over at intermediate to longer time scales; and external forcing functions such as climatic cycles that operate over long return intervals.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1851489
NSF Division of Environmental Biology (NSF DEB)	DEB-1556874

[table of contents | back to top]